ALTERNATIVE FUELS IN THE TRANSPORT SECTOR

FOCUS ON THE ATLANTIC AREA
**BATTERIE Introduction**

*BATTERIE is an EU Atlantic Area project established in January 2012. Its purpose is to improve the cooperation and links between various transport services within the Atlantic Area region and to promote the application of smart technologies and usage of alternative fuels.*

The BATTERIE (Better Accessible Transport to Encourage Robust Intermodal Enterprise) project was created as a response to the EU Atlantic Area priorities. As part of the priority 3.1 “Improve accessibility and internal links – Promote interoperability and continuity of existing transport networks, and sea/road/rail/air intermodality” it focuses on transportation and aims to improve the coordination of and interconnectivity between transport services supplied by various operators. It also recognises and gives due regard to National and EU transport, energy and related economic policies, with particular reference to the objectives set out in the Lisbon and Gothenburg Agendas.

The BATTERIE project started on 1st January 2012 and will run for three years. It is held in cooperation with eleven full partners and two associate partners of the Atlantic Area Region, i.e. the UK, Ireland, Scotland, France, Spain and Portugal.

The main objective of BATTERIE is to establish the impact of applied smart technologies (e.g. E-Journey Planning) and alternative fuels and to design scenarios and models of changes to policy, behaviour and transnational strategies in order to help optimise transnational trips for passengers.

Other activities include screening and modelling the availability, future development, costs and environmental impact of using smart technologies and alternative fuels and establishing pilot networks and demonstration of best practice in this sector.
Executive Summary

Alternative fuels are part of the energy policy of the European Union. Their use in the transport sector allows a reduction in the need for conventional energy sources, mainly products derived from petroleum. They create economic and environmental benefits as well as reducing dependence on foreign energy.

However, before their wide introduction into the market place, one should take into account the following requirements: (a) how to produce alternative fuels; (b) the infrastructure necessary for using them; and (c) the development of vehicles that can use them. It is important to note that in order to increase the viability of each of the alternative fuels (biofuels, electricity, hydrogen, natural gas, LPG), it is necessary to analyse and understand these three requirements. The aim is to improve their technical and economic feasibility.

This report investigates the requirements for increasing the viability of alternative fuels. Some policies aimed at the wide introduction of alternative fuels across Europe are also discussed.

The main general conclusions from this report are:

- Technology for the production and use of alternative fuels is available and ready for wider deployment.
- Public and private institutions are working to improve the incorporation of alternative fuels into the current publicly accepted fuelling system.
- Continued support is required by public and private institutions to create the necessary infrastructures and vehicles that use alternative fuels.
- There is a lack of public knowledge for alternative fuels and their use.
- There is a real urgency for further influencing decision makers and making information widely available through awareness-raising work and demonstration projects.

The main conclusions regarding each alternative fuel are the following:

- **Electricity**:
  - Electric vehicle technology contributes to a multi-modal shift in the transport sector, in line with recent EU policy goals. There are some significant challenges (driving range limitations, cost/weight/volume of batteries, disposal of used batteries and availability of rare earth metals commonly used in advanced battery technology) that still need to be resolved.
  - The work of the European standardization bodies is still on-going. For example a single interface solution should be adopted by all industry players for charging infrastructure, vehicle manufacturers, electricity providers and electricity distribution network operators, to ensure interoperability and connectivity between the electricity supply point and the vehicle.
  - Communication between consumers and the charging infrastructure will be crucial for public charging.
  - Slow charging from existing sockets is already possible.
- Strict safety requirements have been put in place by legislation, but they may differ across EU Member States, as electrical grid characteristics change.

- It is expected that ‘second generation’ electric vehicle technologies will provide an increase in energy efficiency and the integration of more advanced energy storage systems.

- **Hydrogen:**
  - Hydrogen is currently mainly produced and distributed in large quantities in petrochemical plants. Its infrastructure for vehicular use is at an early phase of development with some 200 filling stations across Europe expected by 2015.
  - Hydrogen and fuel cell standards are well advanced for the transport sector with ISO and SAE standards, already providing globally harmonized requirements such as the hydrogen refuelling interface, hydrogen fuel quality, and hydrogen refuelling station safety.
  - In the absence of economic viability, an appropriate regulatory framework and public financial support, as well as neutral public budget incentives, will be required to introduce Hydrogen to the market.

- **Biofuels:**
  - Biofuel represents an alternative to fossil based fuels. Biofuel is more environmentally friendly compared to traditional fuel with fewer greenhouse gases emissions, and can be produced locally.
  - The main challenges to promote biofuels are sustainable practices in energy crops and the development of advanced bio-crop processing.
  - The European Commission is committed to promote the production and use of biofuels, proposing a binding minimum target for biofuel use as vehicle fuel for 2020.
  - It is therefore necessary to develop new more productive crops, with lower production costs that are not intended for the food market.

- **Others (Methane, Liquefied Gas):**
  - Production of synthetic fuels is based on synthesis gas (H₂, CO) and a liquefaction step. This applies for all main synthetic pathways: Hydrotreated Vegetable Oil (HVO), Gas To Liquid (GTL), Biomass To Liquid (BTL) and Coal To Liquid (CTL). New pathways include the production of synthetic natural gas from renewable sourced electricity used to generate hydrogen from the electrolysis of water and CO₂.
  - Autogas (Liquefied Petroleum Gas) already powers over 7 million vehicles across Europe. The use of a single standardised connector across Europe would certainly enable the autogas market to grow further.
The disparities in the level of development for using methane in transport in Europe are due to specific national investment strategies. More than €4 billion would be needed to provide adequate refuelling conditions (Report of European Expert Group on Future Transport Fuels).

The general recommendations from this report are:

- Increasing the visibility of the use of alternative fuels is necessary if they are to make a difference in tomorrow’s transport sector.
- Demonstration projects must be introduced to democratize alternative fuels.
- It is imperative to improve the coordination among States in terms of transport policy support and work towards the setting of targets.
- It is critical to develop single EU wide standards for each alternative fuel, for example with the standardization of electric vehicle charging plugs and other infrastructure.
Glossary

AC: Alternating Current
BEV: Battery Electric Vehicle
BTL: Biomass To Liquid
CHADEMO: CHArge de MOve
CTL: Coal To Liquid
DC: Direct Current
EU: Europe
EV: Electric Vehicle
FCV: Fuel Cell Vehicle
GHG: GreenHouse Gas
GTL: Gas To Liquid
HVO: Hydrotreated Vegetable Oil
ICE: Internal Combustion Engine
Intermodality: integrates two or more transport modes on the same journey.
Interoperability: ability of a system to work with or use the parts of another system by exchanging or making use of information.
LNG: Liquefied Natural Gas
LPG: Liquefied Petroleum Gas
toe: Tone of Oil Equivalent

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1. Introduction

The transport sector in the European Union has a vital role to play for the EU economy by providing the means for transferring foods, goods, travellers, workers, mail and others, and is of critical importance to all EU citizens. European transport policies deal with specific common problems that affect all EU Member States. Some examples are finding solutions and regulating air traffic congestion, providing common road policies, reduction in oil dependence and developing effective policies to the issue of greenhouse gas emissions. The transport sector is where most of the EU’s energy is consumed, and therefore it is essential that transport policy is developed with a view to a more sustainable model, a model that allows for the wide deployment of alternative green fuels.

The dependence within the EU on imported hydrocarbon oil for transporting goods and passengers is extremely high. Increasing the efficiency of the transport sector at all levels will have only a small impact on our oil consumption and the EU will remain highly dependent on imported oil to meet up to 96% of its energy needs.

Oil extraction is becoming increasingly difficult and the majority of reserves are situated in unstable regions of the world. Predictions are illustrating that there will be a shortage of supply to meet demand in the coming decade. According to forecasts, by 2050 the price of oil will more than double the 2005 price. This is almost unsustainable and provides a clear argument for the development of new alternative fuels.
In addition to the above, the objective of the EU is to reduce the Greenhouse Gas emissions (GHG) of the transport sector. In fact it is envisaged that the GHG emissions from the transport sector by 2050 should be at 60% of the level compared with 1990 levels, and this is only through improved efficiency and the use of alternative fuels.

The Transport White Paper “Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system” indicates that, among its objectives, the EU will reduce the use of "conventional propulsion" vehicles in urban transport by half by 2030. It also discusses that urban logistics free from CO2 emissions will be created and that the EU will reach a target of 40% of sustainable fuels in aviation by 2050.

The European Directive 2009/28/CE mandated that each Member State shall ensure that the share of energy from renewable sources in all types of transport in 2020 is at least equivalent to 10% of final consumption of energy in transport.

It is therefore evident that the use of alternative fuels is not only a possibility but an obligation within the EU. However, even if the EU is aiming at increasing its green fuels credentials, it is clear that it has a long way to go as per the below figure, where biofuels and the other ‘green alternative’ fuels represent just a minority share out of the overall fuel used in the transport sector within the EU.
From the above, it is clear that there is a need to identify what is the state of play, the real potential and the probability for the use of alternative fuels. Therefore, this report seeks to define the state-of-the-art for the most common alternative fuels. It also aims at defining some of the aspects related to the production of alternative fuels, the required infrastructure and types of vehicles that can use the specific type of ‘green fuel’.

![Chart showing fuel consumption in EU-27](image-url)
2. Electricity

In this section, information regarding the current state of use of electricity as an alternative fuel is described. Of importance, the current coverage, the different demonstration projects and other related electricity projects that are developed in the regions involved in Batterie are highlighted.

2.1 General aspects

The integration of electric mobility onto the electrical network must be performed and planned carefully in order to avoid technical bottlenecks and unnecessary investments. Luckily, such integration has been made possible through the world’s state of the art existing European electricity network system. This system already provides end-users with a very efficient infrastructure for the generation, transmission, distribution and commercialisation of electricity and was therefore easily adapted to accommodate electrical mobility across the Member States.

Probably the main challenge, as seen from the point of view of the users of electric vehicles, is to create a reliable, accessible and convenient electric vehicle charging infrastructure for citizens. This necessitates an EU wide ‘standardised’ grid-to-vehicle connection system. Such standardised connection must feature a common socket, connector and charging point, to allow users to plug a car to the electricity supply at any publicly accessible charging station across Europe.

From the above, it is clear that any additional infrastructure should aim at standardising the charging point.
In the future, the electric transport sector will also benefit from extra infrastructure that will be used in the electrification of railways. As there is a lot of technological and operational experience with transport infrastructure providing electric energy for railways, there are no technical obstacles to this future expansion and the electric vehicle will surely benefit from such an extension. It’s important to take into account that transport by rail is a key activity that should contribute significantly to the development of an efficient economy and low carbon emissions.

The field of information technology and communication are strongly linked to the development of electric vehicles. The expected next step will be the creation of a standard communication protocol network for recharging infrastructure, enabling identification and communication between the energy supplier and the customer, which should be suitable to match the needs of the various sizes of the car’s battery packs and the charging characteristics of the vehicle.

If there is two-way communication between the vehicle and the network, the battery may act as “buffer” or electrical storage system, in case of excess demand or excess generation.

Recharging

There are plenty of devices for recharging electric vehicles which can differ from each other in:

- The output power, and therefore, the recharging time.
- Type of information exchanges with the vehicle recharging point.
- Physical connector that must fit into the electric vehicle.

Five types of charging are defined according to how long it takes to recharge the batteries, which depends directly on the available power. Often these are grouped together as slow charging and fast charging.

- Very slow charging, when the current is limited to 10A or less, to protect from not having a dock with specific protection and proper electrical installation. Recharging full battery of an electric car with 22 to 24 kWh of capacity, can take up to ten or twelve hours.

- Slow recharging, or normal/conventional recharge. This is a normal charge at 16A, with an output power of 3.6 kW. A complete battery recharge, can take between six and eight hours.

- Semi-fast charging, or quick-charge, not as fast as the fast-charge. It has a power of 22 kW. Renault is quite committed to this type of charging, for example with its low cost Chameleon, Renault ZOE-compatible charger. Recharging can take an hour or hour and a half.
Fast charge, the power that is demanded is very high, between 44 and 50 kW. Those 22 to 24 kWh of battery recharging can take half an hour. It is more effective to make a recharge of not more than 80 or 90%.

Ultra-fast recharge, hardly used, and should be considered something still experimental, in electric vehicles to the test with batteries of type supercapacitors (for example, some electric buses). Recharge power is very high, and in about five or ten minutes, the batteries may be charged. Lithium-ion batteries do not support such high temperature that causes this type of charging because it severely impairs its useful life.

The charge modes have to do with the level of communication between electric vehicles and recharging infrastructure, and the grade of control that you can have of the charging process, in order to program it, view status, stop it and resume it, or even tip over electricity network.

- Mode 1, without communication with the network. The one is applied to a conventional socket schuko connector.

- Mode 2, low degree of communication with the network. The cable has an intermediate control device pilot which serves to check the correct connection of the vehicle charging cord. It works with a schuko.

- Mode 3, high degree of communication with the network. Control and protection devices are located within the point of recharge, and cord includes built-in communication pilot wire (e.g. SAE J1772 connectors, Mennekes, combined or Scame).

- Mode 4, high degree of communication with the network. There is a converter to DC and only applies to rapid charging (e.g. CHAdeMO connector).

The future of electric charging stations must also be equipped with a same plug, known as “Type 2”, as it has been established by Brussels as the universals connectors in the EU.

- Type 2: Connector Mennekes, is a German industrial connector, VDE-AR-E 2623-2-2, mainly specific for electric vehicles. It measures 55 mm in diameter. It has seven terminals, four for (three-phase), the land and two for communications.
“Type 2” is both AC and DC, accepts both currents, and its rated with a max of 43.5 kW with AC and 38 kW with DC. It is also 1-phase and 3-phase, up to 63A. So it works on garages wallbox (AC, 1-phase) and public fast charging station (AC, 3-phase) with the same plug.

- single phase, up to 16 A, slow reloading.
- three-phase, up to 63 (43.8 kW) for rapid charging.

Although “Type 2” is the only one accepted by European Commission, for a transitional period that will end January 1, 2019, quick charging points can also be fitted with CHADEMO connectors. Anyway the CHADEMO charging points installed within three years prior to the entry of the directive, may remain in service after 2020.

- CHADEMO, is the standard of the Japanese manufacturers (Mitsubishi, Nissan, Toyota and Fuji, who depends on Subaru). It is specifically designed for rapid charging in DC. It has ten terminals, taking land and communication with the network. It supports up to 200 A current (for ultra-rapidas refills). It is the largest diameter, both the connector and the cable.

There are also other existing connectors, with different size and properties:

- Combo2: Combined unique connector; It has five terminals, power, protection of land and communication with the network. It supports both slow and fast recharge.

- Household connector schuko type, responds to the EEC 74 type F standard and is compatible with European outlets. It has two terminals and ground and supports currents up to 16 a, only to slowly recharges and integrated communication. We can be found in many household appliances.

- Connector SAE J1772, sometimes also known as Yazaki. It is a North American standard, and is designed specifically for electric vehicles. Measures 43 mm in diameter. It has five terminals, the two current, the Earth, and two complementary proximity detection (the car cannot move while it is plugged in) and control (communication with the
network).
- Level 1: up to 16 A, slow recharging.
- Level 2: up to 80 A, for rapid charging.

- Scame connector, also known as EV Plug-in Alliance, mainly supported by French manufacturers. It has five or seven terminals, either single-phase or three-phase, power ground and communication with the network. Supports up to 32 A (for semi-fast charging).

**Vehicle-to-Grid (V2G)**

V2G is the acronym for Vehicle-to-Grid. It is the technology that allows the storage from the batteries of electric vehicles to the grid at valley hours and recovery of electricity at peak times. This technology requires a specific infrastructure that doesn’t exist today.

Electricity is one of the few sources of energy that cannot be stored on a large scale. The power is either consumed or lost. As there is so much energy produced by wind energy at night, all this power could be used to recharge electric cars at night, making the system much more efficient. The possibility of vehicles to return power to the grid when necessary -the vehicles are parked most of the time- would help improve the balance between output and consumption.

Grid electricity is supplied to the vehicle by AC power. Normally, the charger converts it into DC power and supplies it in the proper voltage to the battery, from which it is supplied to the engine and the wheels. Some engines operate on AC power, so an investor must convert the direct current of the battery.

In Spain, as in most countries, the night rate or valley is below normal, ideally, batteries would be recharged at night. An intelligent network, with tens of thousands of charging points in streets and car parks, and appropriate software would warn the vehicle when it needs to reload, stop and even pour the electricity into the grid. This is the reason why electric vehicles can play a key role to start managing the grid better, flattening the load curve, taking the missed active reserve and allowing an increase in the contribution of wind power and other renewable energies.
**EV Typology**

**Hybrid (HEV),** has both internal combustion engine (ICE) and an electric motor for increase fuel economy. There are three types of hybrid vehicles, and all of them are driven exactly like a traditional car.

Hybrids may be classified as the following:

- **Mild hybrid** – uses the electric motor and battery as an assist to the internal combustion engine
- **Full hybrid** – the two propulsion systems (electric motor and internal combustion engine) can work independently or in conjunction with each other
- **Plug-in hybrid** – it’s the same as full hybrid, but has a larger battery and more electric range, as it can be recharged by connecting a plug to an external electric power source.

All of them have limited electric range, but no limit range when the combustion engine is working.

**Battery Electric Vehicle (BEV).** This type of car is powered exclusively by electricity. This electricity is usually provided by a battery, but it can also come from a Hydrogen Fuel Cell. This type of car usually has very limited range, between 100-200km. Batteries are recharged by an external electric power source, recharging points. Standardised plug is Type 2 from Mennekes.

**Extended Range Electric Vehicle (EREV).** This type of car has exclusively electric drivetrain, powered by a battery. It also includes a petrol internal combustion engine that generates electricity to recharge the battery before it ends up. Batteries can also be recharged by VE electric recharging points. These cars would also use Type2 connector.

Examples:

- **HEV Mild hybrid:** Honda Civic IMA
- **HEV Full hybrid:** Toyota Prius/Auris, Lexus CT200h
- **HEV Plug-in hybrid:** Toyota Prius
- **BEV:** Nissan Leaf, Mitsubishi i-MiEV, Peugeot iON, BMW i3
- **EREV:** Opel Ampera, Chevrolet Volt

**Honda Civic IMA**  **Toyota Prius**  **Opel Ampera**
Legislation

The European Commission has proposed a directive that includes objectives for infrastructure development in each Member State, as a minimum number of charging points for electric vehicles, natural gas and hydrogen refuelling points. The proposal also establishes requirements for common technical standards across the EU, as a common standard plug for electric vehicles.

The goal of the initiative is to break the oil dependence of transport and reduce greenhouse gas emissions from transport by accelerating the market uptake of alternative fuels and vehicles adapted to their use. The initiative, which was published at the end of January, consists of a communication on a European alternative fuels strategy (5736/13) and a related proposal for a directive on the deployment of alternative fuels infrastructure (5899/13).

European alternative fuels strategy (5736/13). A consistent long-term strategy on alternative fuels has to meet the energy needs of all transport modes and be consistent with the EU 2020 strategy, including decarbonisation. The benefits of alternative fuels are initially larger in urban areas where pollutant emissions are of great concern and in freight transport where alternatives have reached a sufficient level of maturity. There is no single fuel solution for the future of mobility and all main alternative fuel options must be pursued, with a focus on the needs of each transport mode.

A strategic approach for the Union to meet the long-term needs of all transport modes must therefore build on a comprehensive mix of alternative fuels.

Alternative fuels infrastructure (5899/13). The proposal for a "Directive on the deployment of alternative fuels infrastructure" is a major step to solve the "chicken and egg" problem where alternative fuel infrastructure is not built as there is an insufficient number of vehicles and vessels, the manufacturing industry does not produce them at competitive prices as there is insufficient consumer demand, and consumers in consequence do not purchase them. This proposal provides for sufficient infrastructure coverage to ensure economies of scale on the supply side and network effects on the demand side. It focuses on the fuels where failures of market coordination are particularly relevant, that is electricity, hydrogen and natural gas (LNG and CNG). Without such an action all other efforts to promote alternative fuels risk remaining ineffective.
2.2 Projects

- The **MOVELE Project** in Spain worked in urban environments is set to introduce 2,000 electric vehicles of various categories, features and technologies to a broad group of companies, institutions and individuals, as well as oversee installation of 500 charging points for these vehicles, with the following objectives:
  - Demonstrate the technical feasibility of electric mobility in urban environments, placing Spain among the few to demonstrate real experience in mobility technologies with electricity.
  - Promote measures to encourage use of electric: public infrastructure charging, reserve parking spaces, traffic lanes bus-taxi, etc...
  - Involve private sector companies in the introduction of electric vehicles: electric utilities, insurance and financing (leasing), etc...
  - Serve the identification and promotion of policy measures that favour this technology: tax measures on the purchase or use of vehicles, supply rates, modification of rules that might prevent its development (access to charging points in community housing), etc...
  - The project will take place in three cities, Madrid, Barcelona and Seville. The total investment cost associated with the infrastructure in these cities will amount to € 2,032,500.

- The **LIVE PROJECT**, (Logistics for the Implementation of the Electric Vehicle) is a public-private platform created with the aim of supporting and promoting the development of electric mobility in the city and the Metropolitan area of Barcelona. LIVE is the platform that empowers the electric vehicle in the city, providing an opportunity to position Barcelona as the core of innovation in electric mobility worldwide.
  The LIVE Project is a comprehensive plan for unified strategic deployment of electric vehicles to support the industry, sustainable mobility and the environment around the following axis:
  - Provide support in the development and promotion of electric mobility demonstration projects (Living Labs).
  - Providing the tools and resources necessary to generate a network of innovative assets, economy and industry, for supporting R & D.
  - Promote the organisation and hosting of events and activities that promote electric mobility in Barcelona.
Promote the deployment of public and private networks to cover the entire metropolitan area of Barcelona.

Become the reference point for citizens and companies in Barcelona, for anything related to electric mobility.

- The **MERGE project**, which stands for Mobile Energy Resources of Electricity, develops studies to predict the potential impact involving the integration of electric vehicles on distribution networks in the future. The work is divided into six areas, where Iberdrola will evaluate the technical, economic and environmental impacts associated with the connection of electric vehicles to the network. It will also investigate different options for car smart charging, defining the characteristics of distribution networks.

- **ELVIRE PROJECT** is a European initiative which aims to overcome the user’s uncertainty of electric vehicles with regard to them running out of electric charge before they reach their destination. The aim of the project is to design and implement the necessary systems so as to enable the user to know about the current status of their battery; how many miles can travel, where the nearest charging points are, which of these points are available, how much charging time is needed to reach your destination, which points have a better price, etc...

- **DOMOCCELL** is an innovative system to allow smart charge of Electrical Vehicles. It involves users, and Smart Grid operators; using an M2M platform, a BackOffice, and integration mechanisms; DOMOCCELL will ask the users for his preferences, calculate the status and possibilities of the Grid, and program the charging phase to optimise user preference and network behaviour. DOMOCCELL is a Spanish R&D project financed by the Avanza Plan, with several partners of ICT and Energy organisations.

  The project objectives are to:

  - Develop a comprehensive platform for recharging electric vehicles, which allows them to be easily installed in car parks and encourages community users to swap their conventional combustion vehicles for an electric one.

  - Study the impact of electric vehicles on the electricity network to discover if the architecture design and communications of the system will be adequate for the load from the residential environment in a large city.

  - Study profitable business in the world of car loading.
- Allow energy traders to analyse and anticipate the increases in demand that the emergence of electric vehicles can cause.
- Coordinate and combine the knowledge of IT and energy companies, to obtain an optimal solution to this problem.

About the technology used:

- Development of devices with PLC PRIME, GPRS, and ZigBee communications.
- Embedded distributed systems and centralised systems for managing electric vehicle (EV) charging.
- Behaviour tests on the different lithium-ion batteries technology in cases of thermal or electrical disturbances.
- Technology tests for measuring charging posts and impact on grid service quality.

- **ZEM4ALL Project**: (Zero Emissions Mobility for All) is to prove massively the advantages of electric mobility by deploying a fleet of 200 electric cars, 220 normal charging points and 16 fast charging. This project is run through the partnership program JSIP Hispano-Japanese (Japan Spain Innovation Program) that develops the CDTI in Spain. Endesa and Mitsubishi will lead the consortium that will develop the project in Malaga, although this will also involve other Spanish companies such as Telefonica and Sadiel. The budget will be €60 million and the project, which will last four years, is expected to finish in 2015.

- **SURTIDOR Project**: The goal of the SURTIDOR Project is to develop an experimental, super-fast charging station for electric vehicle batteries, allowing the storage battery of a 20 kWh vehicle to recharge 80% of its useful capacity in less than 30 minutes.
The program has been developed through a consortium of businesses led by GH Electrotermia, and also including Saft Baterías, Iberdrola Generación, Endesa Ingeniería, Talleres Herga, Desarrollo Automovilidad, the Institute of Electric Technology, the University of Oviedo and the Center of Technological Research from the Universitat Politècnica de Catalunya (CITCEA UPC).

The first phase has been completed successfully; this was the development and experimental validation of a DC 50 kW charging station according to Japanese CHADEMO connection protocol.

- **CITYELEC** is a Singular Strategic Project (PSE) funded by the Spanish Ministry of Science and Innovation under the National Program of Public-Private Partnerships National Plan for Scientific Research, Development and Innovation 2008-2011. The main challenge of the project is the definition of a suitable system to meet the needs of current and future urban transport, enabling personal mobility with a minimal carbon footprint through the development of a fleet of light electric vehicles (scooters, cars and city minibuses), development of infrastructure (urban transformation stations with energy storage capacity, local generators of photovoltaic, wind, etc...) and new approaches to the management of electrical energy from renewable sources in the network, focused on maximum storage of renewable energy for mobility.

- **TECMUSA** is a Spanish project. The goal is to develop large electric and hybrid vehicles in order to transport people and goods. During the project the design of two types of vehicle platforms will take place: one for heavy vehicles such as buses and the other for light vehicles intended mainly for logistics activities. In both cases it seeks to develop;

  - Advanced configurations and hybrid electric propulsion
  - Communication and information systems into the vehicle's interior and exterior
  - New materials and storage devices
  - Energy management.
• **CENIT** is a Green Project dedicated to research and the generation of knowledge which is necessary for future manufacture and marketing of environmentally friendly vehicles to Spain; basically plug-in hybrid (PHEV) and electric (EV). This project, which is divided into six areas of work, aims to develop the technologies and key components for hybrid and electric cars, which are a reality in Spain; batteries and electric motors and also charging systems.

• **Project FREVUE**, with a budget of €926,000 aims to replace the distribution of goods via diesel engine vehicles in the most sensitive areas of cities; such as London, Stockholm, Milan, Lisbon, Oslo, Amsterdam, Rotterdam and Madrid; and embrace a more sustainable model.

Logistics, transport, shipping and manufacturing and food distribution companies, as SEUR, TNT and Pascual, are participating in the project FREVUE, within the seventh framework programme of the European Commission. An example is found in Madrid, where a distribution centre located in Legazpi has been prepared where traditional trucks arrive to deposit their load, and where to take over electric vans that make deliveries within special population density areas and pedestrian areas, avoiding a significant amount of emissions and noise in these areas.

At the moment this is a pilot project to examine if it is possible to reduce and even eliminate diesel engines of the inner cities when it comes to the distribution of goods, a project that will feature its own application that will tell drivers both routes to follow, the availability of charging
points, and an application that also allows improvement of the situation of the discharge points which will generate reports on the performance of vehicles.

- **Project REVE** consists of a study assessing in detail technical challenges and most important economic aspects to the creation of a network infrastructure so that electric cars can act as energy stores, from the mains while they are not circulating and, therefore, contribute to the improvement of the load factor of the power as a whole system.
  
  The project will analyse how the proposed infrastructure will affect the evacuation of wind energy. For this purpose it shall take into account the growth of the installed wind power, and the foreseeable evolution of its generation.
  
  The starting point of the project is the storage of electricity during periods of low demand, where there are potential reductions for production on wind farms.
  
  Electric cars would act as electrical stores when they are not actually moving. A single battery of this type would not alter the energy supply system, but if hundreds or thousands of vehicle owners adopt this system, the efficiency of the electrical distribution could be improved significantly. All electric cars could act as network storage systems while inactive.

- **E-Car Project, Northern Ireland**

  E-Car is part of the UK-wide scheme known as ‘Plugged in Places’ (PIP) which provides government funding to regions that want to bring charging points to their area. The project has so far achieved excellent coverage with some 400 public charge points (including 14 rapid chargers) and well over 200 private charge points.
**V2G Featured projects.** Some electric companies have launched interesting V2G projects:

- *The Pacific Gas and Electric Company* (PGE), based in San Francisco (USA) is using several Toyota Prius’ owned in a V2G system on the campus of Google, in Mountain View, California.
- *Xcel Energy*, based in Minneapolis (USA), is also experimenting with six Ford Escape hybrids.
- *Endesa* develops a charger enabling electric car to return power to the grid. This technology could be a reality in 2020, and would allow electric vehicle users to sell surplus energy.

  Developed by Endesa in conjunction with the CITCEA centre of the Polytechnic University of Catalonia (UPC) and the Catalonia Institute for Energy Research (IREC), this innovative system is currently being validated in a lab before being rolled out to Endesa’s Smartcity in Malaga for testing in a real environment with real users. They hope the charger will become a reality in 2020.

  Endesa will use one of the first electric vehicles of this kind, the Mitsubishi i-MiEV, to carry out the trials with the V2G charger. After a year of research, this technology now offers many advantages:

  ✓ With just a few small adjustments, users will be able to use the electricity from their vehicles to power their homes.
  ✓ In the future, users will be able to sell the power to the electricity market.
  ✓ This technology will allow complementary services to be offered to the system.

*The Danish island of Bornholm*, with 40,000 inhabitants, will be test subject of a large scale system of V2G. This is a European project, called **EDISON** (Electric Vehicles in a Distributed and Integrated Market using Sustainable Energy and Open Networks), which aims to use the batteries of vehicles on the island (it is planned that all cars are electric) to take advantage of wind power.

It is estimated that currently 20% of Bornholm’s power comes from the wind. Thanks to this system of V2G, the use of this energy source could reach 50%.

In the field of academic research, a team from the *University of Delaware*, in the United States, has worked for more than a decade in the development of this concept, both in its technological side as well as the economic aspect. These scientists are also working with the Californian Company AC Propulsion, creator of the term V2G, to improve both cars and charging systems, and storage systems.
2.3 Regions or Countries in the Batterie Project

Portugal

Public EV charging infrastructure with 1,350 normal charging stations and 50 fast charging stations covers most of the cities and the main highways in the country. With a single smart card, users can charge their EVs at any of these stations. Settlement of payments between the different operators in the system are done automatically without any intervention by the end user.

Asturias (Spain)

Related to the EV there are some recharging points in the centre of the region (some of them public points) where it is possible to recharge electric vehicles but the number of this kind of vehicles is very low.

In terms of the state of development in the infrastructure associated with electric vehicle charging points is something to be improved because there are only about 10 public charging points. However it is linked to the existence of vehicles of that nature. The utility most important in the region is trying to install private charging points mainly in houses (not apartments) but currently it is not possible to charge electricity except in the centre of the region.

Source: Electromaps www.electromaps.com

Some actions by private and public sector are:

Fundación Alimerka. The Alimerka group (supermarkets) has presented its new fleet of electric vans, with which they carry out the distribution of orders in the city of Oviedo.
Nine new vehicles have involved an investment of close to 200,000 euros, as new electrical Chargers are also needed. The cost for each electrical charge is about 3,000 euros. This company delivers around 40,000 orders a year.

These vans have a range of 140 miles and require six hours for a full charge. For this reason, seven conventional vans have been substituted for nine electric units. Alimerka has a fleet of 40 vehicles, and between 25 and 30 would be liable to be replaced.

**Electric cars of the city council of Gijón**

The Town Hall of the Asturian city of Gijon has 8 electric cars, which are shared by employees. These 8 units avoid the emission of one ton of CO₂ in more than 300 tours, covering a total of 2,426 km.

The project is a great success, and is planned to make it extensible to other municipal companies and the possibility that citizens could access the service of car-sharing of the Town Hall. This would help promote the alternative mobility. These public initiatives demonstrate the viability of electric vehicles in urban environments, as well as the advantages of car-sharing services. There are three public access electric vehicle recharging points. These three points are managed by a specific agreement with EDP and for 2013 data collected:

- Active user cards: 14 units.
- Recharges made: 71 units.
- Average completed charging time: 2 hours.
- Average power recharged: 3,92 kWhrecarga.
- Total energy charged: 278,5 kWh.

EMULSA, which is the local urban environmental services corporate, incorporates three electric vehicles and a mower to the parks and gardens service. The investment is around 110,000 euros and joined 10 other vehicles of this type, carried out cleaning work. They will also attend emergency cleaning in green areas for accidents or unforeseen activities.
Basque Country (Spain)

The infrastructure of recharging electrical stations for cars is still very scarce and promoted mainly by public funds.

There are two main initiatives currently in place in the Basque Country to promote electric vehicles and recharging infrastructure. The MOVELE initiative is public and is boosted by the Spanish Government to subsidise and promote the use of urban electrical vehicles and to implement the required infrastructure to support it. This plan also includes funds to enable local and regional governments to purchase cars for their public fleets.

The other initiative in particular from the Basque Country is called ‘IBILEK’. It is a private-public joint venture between EVE - Basque Entity for Energy and Repsol Oil Company. Through the IBILEK initiative there are already 5 car sharing stations spread all over the Basque country (3 parking in Bilbao, 1 in San Sebastian and 1 in Vitoria) and a fleet of 12 electric vehicles. Upon subscription, users can pick up a (2 or 4 seater) electrical vehicle at any of the 5 existing stations that they will have to drop off again at any of the 5 established stations. In the picture above it can be seen the recharging infrastructures managed by IBILEK.

Besides the IBILEK electrical fleet in the Basque Country there are 150 Full Electrical Vehicles registered, very far away from the 50,000 electric vehicles by 2012 in the whole of Spain predicted by President Jose Luis Rodríguez Zapatero in April 2012.

Referring the recharging infrastructure existing in the Basque Country there are now about 50 recharging electrical stations with more than 74 plugs for Electrical Vehicles.

Finally, the MIT-Media Lab “Smart Cities” team reached an agreement with AFYPAIDA (the Association for the Promotion of Automotive Industrial and Sport Activities) for the development of a “city car” prototype called HIRIKO in
collaboration with several automotive sector companies in the Basque Country and the Centre for Innovation and New Business Development – DenokInn.

The HIRIKO prototype was presented in January 2012 in Brussels with the presence of President Jose M. Durao Barroso. The project now is looking for investors to launch mass production of the vehicle and has helped to raise the skills of electric automotive sector in the Basque Country.

**Navarra (Spain)**

Regarding EV, in Navarra there are some companies working on Electric Vehicles such as JOFEMAR and ZEVNA and the company “Car Sharing Navarra for EV rent.”

**JOFEMAR – HIDRONEW XXII.** The HIDRONG system of electric motor is based on the transformation of vehicles already on the market with a combustion engine, which replaces the entire block by an efficient electric motor. A clean system, practical, with no polluting emissions, and much more economical in both pacekeeping and consumption.

In Navarra there is the VEN Plan to promote EV in Navarra with subsidies for EV purchases and research and development projects. The objectives are to have 1,200 EV by 2015, 48 charging points in malls and public parking zones, 24 points on the street, 240 private charging points and 960 for fleets. There are about 50 electric vehicles in Navarra and one urban electric bus has been operating for one year. The Car Sharing Service is based on 8 electric vehicles distributed in at least 4 parking lots.

In order to assess the environmental impacts and safety issues of alternative fuels CENER developed a study of the electric vehicle’s impact in the regional grid. The study demonstrated that proper management of the EV charge could increase the renewables share into the grid. At a national level,
CENER participated in the REVE project to analyse the impact of using EV in Spain from an economic and technical point of view.

**France**

In France, most electric cars are owned by companies or by local authorities. French environmental legislation requires from some actors: local authorities, and public enterprises a renewal rate of 20% in vehicles powered by electricity or CNG or LPG. The main user of electric cars is La Poste (The French Post Office). Mail delivery is particularly demanding for vehicles: they undergo intensive urban use and continually alternate starts and stops. Fuel consumption is therefore commonly twice that of a vehicle used "normally".

The French Post Office wishes to operate by 2015, a fleet of about 10 000 vehicles and could eventually use only Electrical vehicles. The French electrical vehicle market is less than 1% per year. In this table, we represent a projection of number of vehicle registered by French government in 2013.

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Table 1: Vehicle market in France in 2013 (source ADEME)

In France there are 3,449 charging points and 16,153 plugs. In this figure we present the evolution of the number of charging points and plugs in the last months.
The plugs are classified according to their charge speed. This graph shows the distribution between fast charge and standard charge points. Fast charge points allow charging of 80% of an electric car’s battery in less than an hour.

Figure 2: Classification of charging point vs. charge speed

Some charge points are private and some are public. This graph shows the distribution of charge points for each location listed and classified before.

Figure 3: Charging points and type of location
Northern Ireland

Northern Ireland is very much a world-leader in terms of electric infrastructure. It now has some of the most impressive coverage of electric charge points in the world, due to the success of the E-car project and the ongoing “TEN-T” EU project. The infrastructure currently has around 400 public charge points (including at least 14 rapid chargers) and well over 200 private charge points meaning that the next stage is simply the addition of charge points to public sector owned sites. Currently no household lives further than 30 miles from a rapid charger or 10 miles from a fast charger.

The purchase of all new cars is decreasing in Northern Ireland meaning that the purchase of electric cars is on the lower side of predicted estimates. However since the E-car project has provided such good coverage of electric infrastructure and given that cheaper cars are being produced every year, there is a stronger incentive for Northern Irish businesses and the public to purchase electric cars than in most other parts of Europe.

One further hindrance to the uptake of electric cars in Northern Ireland is the perception that, while they may be useful for shorter journeys, a household would need to maintain another fossil fuelled car for longer journeys. Since many inhabitants in Northern Ireland live in rural areas, the idea of a different car for long and short trips is unappealing, compared to a car of equal or lesser price which can do both.

However, the government has taken action in order to entice buyers in the next few years. One of their campaigns was the ‘The Small Business Research Initiative (SBRI) Competition’ in 2014, which encouraged the public to design a series of apps which would be designed to increase the uptake of EV’s. The UK government also runs the ‘Plug-in Car and Van grant’ which offers a £5,000 grant for an electric car buyer and £8,000 for an electric van. In addition, with fuel prices expected to rise to around $200 a barrel by 2030, customer demand for fossil fuel cars is likely to decrease. In Northern Ireland, electric vehicles will be one of the most readily available alternatives because of the high coverage put in place to prepare for the shift to alternative fuels.
South West Region of Ireland

The wind resources for the South West are substantial and this energy may be used in turn to power an Electric Vehicle (EV) for transport. EVs and their infrastructure are rapidly reaching maturity. Ireland has embarked on an effort to install nationwide charging infrastructure for these vehicles. In particular, passenger vehicles are attractive for an island nation with a distance of 250km between Dublin and Cork. Most major towns in the South West region of Ireland have been equipped with public charging infrastructure. Additionally, for longer journeys, intercity fast charging stations will be available to allow vehicles to achieve a near full charge within 20 minutes. Electric vehicles allow increasing amounts of renewable energy to be produced and consumed in the region, thereby increasing the security of energy supply locally. The vehicles may be powered directly from wind or hydro in which case zero CO2 emissions will result.
Scotland

Scotland has a very large potential for Renewable Energy. Thanks to the large resources of free land available with high wind resources, electric vehicles represent a valid alternative to the conventional transport system for reducing the environmental impact and increasing the use of local clean energy.

In the last few years, Scotland has been seen an extremely rapid increase of Renewable Energy generation sites, however due to the unpredictability of the renewable source and the public grid constraint, there has been events of turbines shutting down because the Public Grid was unable to cope with the extra power produced during high winds, or during periods of low demand.

In this scenario Electric Vehicles fit perfectly for solving the unbalancing of the network, by absorbing the excess energy produced by renewables. For this reason, Scotland has already begun to make progress in encouraging the adoption of plug-in vehicles, supporting the early market through purchase incentives and deployment of recharging infrastructure.

The aim in Scotland is to install 375 standard and 6 rapid charging points across the central belt of Scotland. All charging points will each be able to charge two cars simultaneously. Charging points will be installed in 2014.
Scotland case studies:

Fetlar Island Project: The Island of Fetlar is one of the more remote Shetland Islands which, in common with other small islands shares similar issues. These range from severe depopulation and high cost of living to concerns over the future provision of transport for locals.

Unfortunately, the island does not have a fuel station and therefore islanders have to travel off the island for fuel, with the exception of a few crofters who have private diesel tanks. As most islanders have to travel some distance to get fuel, this inevitably significantly increases both their costs and associated CO2 emissions.

When the Post Office announced the withdrawal of their “Postbus” service it prompted the community to look at other options for local community transport. In particular those which minimised emissions. After careful consideration of the options available at the time, a commercially available electric minibus was selected. The idea was simple, the island has a readily available supply of fuel – electricity, hence potential to recharge an electric vehicle. This meant that the vehicle did not have to leave the island to re-fuel. As electrical power is cheaper than petrol or diesel, the operating cost reductions would help offset the higher capital costs as well as lowering CO2 emissions.
Based on operational experience and local energy prices, the cost of energy to run the minibus equates to approximately one third of the cost of an equivalent diesel vehicle. Following the acquisition of the vehicle, the Fetlar Museum Trust has looked to support the further use of electric vehicles by installing fast charging points.

**The Hydrogen Office:** The Hydrogen Office project has been set up by the Business Partnership Ltd to support the accelerated development of the renewable, hydrogen, fuel cell, electric vehicle and energy storage industries. The goal is to inspire people; promote the opportunity; improve access to and understanding of the technology; promote sector development; facilitate research and development; and enhance educational opportunities.

The main project aim of the Hydrogen Office was to design, develop and construct a completely green commercial office using state of the art renewable and hydrogen storage technologies. Today the Hydrogen Office is operational and provides a key location for promoting green hydrogen technology and buildings.
The offices within the Hydrogen Office building are powered by a novel renewable, hydrogen and fuel cell energy system. A wind turbine generates electricity. The wind electricity is used to power all lighting, computers and make coffee and tea as needed in the Hydrogen Office building. Any surplus wind electricity is then used to produce hydrogen from water.

Recently a charging point for an electric vehicle has been set up in the Hydrogen Office complex. Electricity is supplied directly from the Wind Turbine. An electric van is used by the local community for supporting transportation for elderly people.

Fife Shopping and Support Services, (FS&SS), now delivers groceries and pensions to the local elderly and disabled by using the Electric Van charged at The Hydrogen Office. It has become the latest example in the United Kingdom to adopt renewable technology.

At the Hydrogen Office, hydrogen is stored in a large tank on site and can be fed back through a fuel cell to provide power for the Hydrogen Office for up to two weeks without any wind. This means that the electric van will be charged directly from 100% wind power, regardless of the weather, and is believed to be the first in the UK to do so. The charging point was kindly donated by Zero Carbon World, and was installed free of charge by PURE, who were involved in the construction of the Hydrogen Office.
2.4 Recommendations and opportunities

- Electric vehicle technology offers a technological and industrial opportunity:
  - Technological development of industrial components
  - Development of new information and communication technologies (ICT) adapted to smart grids
  - Positioning of the Spanish industry

- Energy Opportunity to promote renewable energies:
  - Contributing to energy efficiency and reducing energy dependence
  - Introduction of renewable energy into the electricity system
  - Improves the use of electricity infrastructure

- Environmental Opportunity:
  - Contributes to reduced CO2 emissions
  - Incorporates transport sector to emissions trading scheme
  - Helps reduce the emission of pollutants

- Given the technology and infrastructure levels currently in place, grid-connected road vehicles can become a reality and are already a reality for rail. Electric vehicle technology contributes to a multi-modal shift in the transport sector, in line with the more recent EU policy goals. Innovative mobility concepts are possible when combining electric vehicles with public transport. There are some significant challenges (driving range limits, cost/weight/volume of batteries, and disposal of used batteries and availability of lithium) that still need to be resolved. There is also the need for an assessment of which possibilities are economically viable for electrifying the public bus fleet: further hybridisation of the bus fleet, battery swapping or quick recharge at each bus stop.

- The work of the European standardisation bodies is still on-going; a single interface solution should be adopted by all industry players, vehicle manufacturers, electricity providers and electricity distribution network operators, to ensure interoperability and connectivity between the electricity supply point and the vehicle.

- The decision on a standardised plug for both AC and DC has to be taken immediately because any delay in these decisions may hamper the market up-take. Work on standardising communication protocols, enabling data communication, safety, payments and supplying information to users need to be continued and intensified in order to reach a consensus as soon as possible.
• This communication between consumers and the charging infrastructure will be crucial for public charging.

• Slow charging from existing electric sockets is already possible. This type of charging will be mainly installed in private homes, commercial buildings and companies.

• Fast vehicle charging points with higher voltages for public access may also be needed to facilitate and extend electro-mobility. Fast charging solutions using the given infrastructure is already possible.

• Strict safety requirements have been put in place by legislation, but they may differ across EU Member States, as the grid characteristics change. This complicates the decision on a dedicated e-mobility plug for AC charging infrastructure. With regard to the charging mode, the electricity industry believes, in line with car manufacturers and equipment manufacturers, that Mode 3, in combination with type 2 plug, is a safer and more reliable option to charge an EV in public locations and should be the preferred long-term infrastructure solution. Public High Power points are more expensive; high power infrastructure will be installed in conventional filling stations and other publicly accessible facilities by electricity and fuel providers, network operators or commercial retailers.

• It is expected that ‘second generation’ electric vehicle technologies will provide an increase in energy efficiency and the integration of more advanced storage systems. At the same time, a wider charging infrastructure will develop, which will allow the dissemination of electric transport throughout various cities and regions.

• It is expected that in ten years or so, the production of electric vehicles and hybrid vehicles will be fully established in Europe. In particular, the batteries, which are the most important component, will be able to provide triple energy density and life, but at a cost 30% below the current level. The infrastructure, in general, will be ready for quick recharge, and the use and integration of smart grids will enable bi-directional communication for transportation.
3. Hydrogen

In this chapter, information is provided regarding the current state of play for the use of hydrogen. This section also looks at what are the most important technology developments in H₂ technologies. It discusses some general aspects of fuel cells, the present coverage, the different demonstration projects and other schemes that are developed in the regions involved in the Batterie project.

3.1 General Aspects

The development of hydrogen and fuel cell technologies for transport will offer:

- A zero tail-pipe pollutant emissions at the point of consumption
- A strong reduction of noise as fuel cells are silent
- Comfort and a vehicle distance range that is potentially similar to ICE (Internal combustion engine) vehicles.

Hydrogen is currently mainly produced and distributed in large quantities in petrochemical plants. It is widely used in industry, which can be leveraged for a public infrastructure. Hydrogen infrastructure is at an early phase of development with some 200 filling stations expected to be installed across Europe by 2015.

Concerning hydrogen and fuel cell standards, they are well advanced for the transport sector with ISO and SAE standards, already providing globally harmonised requirements such as the hydrogen refuelling interface, hydrogen fuel quality, and hydrogen refuelling station safety.

Some advantages:

- **EFFICIENCY**: In a normal driving cycle, hydrogen fuel cells, doubles internal combustion engine efficiency.
- **POWER CONSUMPTION**: Analysing traction chains based on H₂ and fuel cells have lower energy consumption than conventional traction chains.
- **EMISSIONS**: The impact in terms of emissions depends on the technology used to produce hydrogen and the technical efficiency achieved by this kind of vehicles. At the present technology level fuel cell vehicles tank-to-wheel efficiency of about 50% and where hydrogen can be produced from natural gas at 60% efficiency, well-to-wheel (WTW) CO₂ emissions can
be reduced by 50–60% compared to current conventional gasoline vehicles. If hydrogen is derived from water by electrolysis using electricity produced using renewable energy such as solar and wind, or nuclear energy, the entire system from fuel production to end-use in the vehicle has the potential to be a real ‘zero emissions’.

✓ PRODUCTION CAPACITY: There is a superior capacity of H2 production than other alternative fuels (biogas, methanol, biofuels, ethanol, ...)

Another important point is that hydrogen facilitates make use of renewable energy sources: As a fuel for transport or as a fuel for stationary systems such as co-generation of electric power and heat. Generally, three main areas of hydrogen use can be differentiated: Stationary, mobile and portable applications.

Mobile Hydrogen Applications

In principle, almost all means of transport could be powered by hydrogen. There are two ways that hydrogen can power vehicles: Hydrogen is used as fuel in conventional engines instead of gasoline and the other option is the use of fuel cells which generates electric power that supplies an electric motor providing vehicle’s propulsion.

Hydrogen has a high specific energy, high flame speed, wide range of flammability, and clean burning characteristics which suggest a possibility of high performance in internal combustion engines (ICE). These attributes have been realised for more than half a century since the onset of hydrogen engine development. Today, automobile manufacturers continue to work on hydrogen-powered ICEs and many have successfully done so. Below is a picture of an internal combustion engine converted to run on hydrogen (picture courtesy by Pure Energy Centre).

An Internal combustion engine (ICE) converted to run on hydrogen fuel (see http://pureenergycentre.com/hydrogen-engine/)
Hydrogen can also be used advantageously in internal combustion engines as an additive to a hydrocarbon fuel. Hydrogen is most commonly mixed with high pressure natural gas for this purpose since both gases can be stored in the same tank. If hydrogen is blended with other fuels, it usually has to be stored separately and mixed in the gaseous state immediately before ignition. In general, it is impractical to use hydrogen in conjunction with other fuels that also require bulky storage systems, such as propane.

Gaseous hydrogen cannot be stored in the same vessel as a liquid fuel. Hydrogen's low density will cause it to remain on top of the liquid and not mix and liquid hydrogen cannot be stored in the same vessel as other fuels. Hydrogen's low boiling point will freeze other fuels resulting in fuel "ice".

Hydrogen can be used in conjunction with compact liquid fuels such as gasoline, alcohol or diesel provided each are stored separately. In these applications, the fuel tanks can be formed to fit into unused spaces on the vehicle. Existing vehicles of this type tend to operate using one fuel or the other but not both at the same time. One advantage of this strategy is that the vehicle can continue to operate if hydrogen is unavailable.

Hydrogen cannot be used directly in a diesel engine since hydrogen's autoignition temperature is too high. Thus, diesel engines must be outfitted with spark plugs or use a small amount of diesel fuel to ignite the gas (known as pilot ignition). Although pilot ignition techniques have been developed for use with natural gas, no one is currently doing this with hydrogen.

One commercially available gas mixture known as Hythane contains 20% hydrogen and 80% natural gas. At this ratio, no modifications are required to a natural gas engine, and studies have shown that emissions are reduced by more than 20%. Mixtures of more than 20% hydrogen with natural gas can reduce emissions further but some engine modifications are required.

Lean operation of any internal combustion engine is advantageous in terms of nitrogen oxide emissions and fuel economy. For hydrocarbon engines, lean operation also leads to lower emissions of carbon monoxide and unburned hydrocarbons. As more oxygen is available than required to combust the fuel, the excess oxygen oxidizes more carbon monoxide into carbon dioxide, a less harmful emission. The excess oxygen also helps to complete the combustion, decreasing the amount of unburned hydrocarbons, but there is a reduction in the power output. Moreover, lean mixtures are hard to ignite, and results in misfire, which increases un-burned hydrocarbon emissions, reduces performance and wastes fuel, but mixing hydrogen with other hydrocarbon fuels reduces all of these drawbacks.

Using fuel cells in road transport applications has some decisive advantages: There is only water emitting from the exhaust, fuel cells operate without noise and without vibrations and they are more
efficient than combustion engines. Hydrogen, as an alternative fuel for transport and similarly to any other alternative fuel, needs to build up the necessary refuelling infrastructure, in order to reach sufficient network coverage to enable a wider fuel cell vehicles' market entry.

**Passenger cars with fuel cells**

Battery cars are better suited for the small size segment and shorter range, whereas fuel cell cars can also serve larger cars and longer distance range. It may not be wise to pick one or the other since they both are complementary, as they serve different car segments. At global level, major car companies are developing cars with fuel cell drive systems. In Germany mainly Daimler, GM/Opel and Ford are the first to do so. BMW has presented hydrogen powered cars very early but they are still concentrating on combustion engines. As the infrastructure is still missing, customers are limited to fleet operators. It is planned to offer hydrogen cars to all groups of customers by 2018, and the essential parts of the hydrogen infrastructure should exist by then. All in all, and throughout the world, several hundred vehicles are being tested. The most important issue is the building of an appropriate infrastructure. It is believed that 10,000 filling stations should be enough to provide the basic supply all over Europe. Below is a picture showing a hydrogen fuel cell van that is currently available on the market and has a very low price tag (picture supplied by Pure Energy Centre). It is targeted at the fleet market. Another picture illustrates a hybrid hydrogen fuel cell vehicle that has operated at the Pure Project for over 5 years and was the first low cost hydrogen fuel cell vehicle of its type and the UK’s first road licensed hydrogen vehicle.

![A hydrogen fuel cell van tailored to the fleet market](http://pureenergycentre.com/hydrogen-cars)
Hydrogen powered city buses

Similarly to the hydrogen cars, there are two different concepts of hydrogen buses: the internal combustion engine one and the fuel cell one. Compared with diesel buses, both hydrogen bus concepts have the advantage of greatly reducing pollutant emissions. In the framework of different European projects hydrogen busses are operating as public service vehicles. One of the most important project for Europe was called “HyFLEET:CUTE” 47 busses were tested at 12 locations.

In the same field is CHIC, the Clean Hydrogen In European Cities Project. This project is the essential next step leading to the full market commercialisation of Fuel Cell Hydrogen (FCH) powered buses. The project involves integrating 26 FCH buses in daily public transport operations and bus routes in five locations across Europe – Aargau (Switzerland), Bolzano/Bozen (Italy), London (UK), Milan (Italy), and Oslo (Norway).

Currently, the largest hydrogen bus project is being developed in Aberdeen, Scotland. Eight buses will be used to transport passengers in 2014 and there will be an extra 5 buses delivered at a later date.

Trucks, trams, railway engines and ships

The usage in trams or railway engines is discussed for all applications especially in places where no overhead lines exist or would be disturbing. Hydrogen fuel cells in trucks is currently being developed and has a wide application. These trucks will be able to deliver goods in the cities at night while many delivery companies were not allowed to operate in the centre of cities due to truck’s noise and high emissions. Below is a hydrogen fuel cell truck (16/18 tons) that will be widely launched in 2015. A 44 ton version is also being developed in parallel.
A hydrogen fuel cell truck (see http://pureenergycentre.com/hydrogen-cars)

The use of fuel cells in delivery vehicles in cities, however, is very interesting as these vehicles are usually part of a fleet and their daily mileage is limited. Emissions of ships which are used in urban areas, could be considerably lowered.

Although the big European aviation industry like Dornier and Airbus have considered and tested hydrogen aircrafts, there are no serious efforts in this field at present. There are concepts, however, to use fuel cells for the power supply on board and use the emitting water on board to reduce flight weight.

Note that they are other applications for hydrogen fuel cell transport such as forklift, special lifting gears, two wheelers etc. The below picture illustrates a hydrogen fuel cell forklift.
A hydrogen fuel cell forklift (see http://pureenergycentre.com/hydrogen-cars/)

3.2 Projects

Clean Energy Partnership (2004-2016) Berlin and Hamburg ¹

The project by the Clean Energy Partnership (CEP) is one of the largest and most innovative hydrogen projects in Europe. It is intended to show that running on hydrogen and building a hydrogen infrastructure will be trouble-free. There are 17 cars running on hydrogen in the two cities at the moment, a number that should increase slowly to 40 in the next few years. In addition, there will be 14 buses with fuel cells running in Berlin.


Clean Urban Transport for Europe – CUTE for short – ran 27 urban buses on hydrogen in nine European towns from 2003 to 2006. The purpose of the project was to demonstrate the practical possibilities of running on hydrogen and to stimulate public acceptance of hydrogen. Hydrogen filling stations where the bus drivers themselves could refuel were situated in the towns. The buses were equipped with a fuel cell system that drove the electric motors.

¹ http://www.cleanenergypartnership.de
² http://www.transport-research.info/web/projects/project_details.cfm?id=14893
HydroGEM (2006–heden) Petten

The HydroGEM was built by ECN in Petten in order to gain practical experience with the fuel technology developed by ECN itself. It was based on DaimlerChrysler’s GEM electric car. The batteries were replaced by a fuel cell and a hydrogen system, which increased the car’s range to 200 kilometers. Instead of taking eight hours to charge the batteries, the HydroGEM can now be fuelled with hydrogen in about ten minutes.

Hydrogen Highway (2005–heden) California (USA)

The project in California, which started in 2005 in order to combat air pollution, is the biggest hydrogen project in the world. The aim was to build fifty to a hundred hydrogen filling stations on the West Coast by 2010, so that driving hydrogen cars would become more attractive. The CO2 emissions from road traffic would be reduced by 30% as a result. Some thirty hydrogen filling stations have become operational to date and there are several under development. The original schedule was not entirely achieved, because the production of hydrogen cars is lagging behind. There are about 250 hydrogen cars on the road in California at the moment. Some have been withdrawn from use because their technology is obsolete.

HyTruck (from 2007) Beverwijk

HyTruck is a collaborative venture in the transport sector that is intended to develop innovative, economically-viable and above all sustainable and environmentally-neutral transport solutions, and in so doing strengthen the position of the Netherlands as a distribution country. The HyTruck has been developed primarily as a distribution vehicle for intense urban and distribution transport. Town centres will impose increasingly strict requirements on the emissions by trucks that serve businesses in them.

The HyTruck has been built on a standard Mitsubishi chassis. Its mechanical drive line has been replaced with a drive system with two electric wheel hub motors of 30 kW each, developed by e-Traction (the same motors as used in the HyMove bus) and a fuel cell stack from NedStack, which provides 16 kW of power. It also has a tank holding 227 litres of hydrogen, and a battery pack. The energy released during braking is recovered and stored, giving additional power for acceleration.

3 https://www.ecn.nl/nl/nieuws/item/ecn-build-first-dutch-hydrogen-car
4 http://www.arb.ca.gov/msprog/zevprog/hydrogen/hydrogen.htm
5 http://www.hytruck.nl/over-hytruck/
HyNOR (2003 – heden) Norway (Denmark and Sweden)  

The HyNOR hydrogen project has been running since 2003. Building a series of hydrogen filling stations along the E39 and the E18 is intended to make it possible to drive a hydrogen-powered car from Stavanger to Oslo. The first hydrogen filling stations are in Stavanger, Porsgrunn, Drammen and Oslo. There will eventually be another three to five filling stations, making it possible to drive entirely on hydrogen all the way along the 580-kilometre long hydrogen motorway. Cars with fuel cells as well as cars with internal combustion engines will be used in the project. There are fifteen examples of the Toyota Prius in Norway that have been converted to run on hydrogen. Mazda is going to supply a total of thirty 5 Hydrogen RE and RX-8 Hydrogen RE cars in Norway, and eight urban buses will also be brought into service this year. Denmark has also built a number of hydrogen filling stations and Sweden wants to do the same, so it will be possible in the long term to drive from Norway to Denmark via Sweden.

Nemo H2 (2010 - date) Amsterdam  

The first green tour boat operated by the Lovers boat company was launched on 9 December 2009. The Nemo H2 has a fuel cell from Nedstack, which provides power to the electric motor that drives the boat’s propeller. Using hydrogen makes the boat not only emission-free but also silent.

Winter Olympics (2010 – 2014) in Vancouver (Canada)  

The winter sport resort of Whistler used twenty fuel cell buses during the Vancouver Winter Olympics in 2010 to bring the public to the stadiums and events. The theme of the 2010 Winter Olympics was sustainability and green energy. Many of the materials used during the games were made from recycled items. Visitor transport also fitted in with that image by using emission-free fuel cell buses. A single fuel cell bus results in a reduction of some 1800 tonnes of CO2 per annum. The buses will continue to be used for another four years after the Olympics. A budget of 89 million Canadian dollars was allocated, coming from the Canadian government and the province of British Columbia.


After the successful conclusion of the CUTE project there, Transport for London, the public transport company, developed a plan for using hydrogen-powered buses in public transport in London again.

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6 http://hynor.no/en/stations  
7 http://www.fuelcellboat.nl  
8 http://www.transitbc.com/fuelcell/fleet.cfm  
Five buses with a fuel cell were brought into service, starting in 2010. It is hoped to increase this number to eight with an additional contribution from the European Union.

The bus project is part of the London Hydrogen Transport programme, which started in 2006 and whose objective is to reduce traffic emissions. It is crucial for public transport to participate, because it is responsible for 22 percent of all the traffic emissions in London. The experience gained during the CUTE project was elaborated upon for the operational implementation and the safety precautions. The project has a Dutch flavour in that the liquid hydrogen is brought by road tanker from the Air Products hydrogen production plant in the Botlek.

**WaterstofNet (2008 - 2030) Southern Netherlands and Flanders**  

The WaterstofNet (Hydrogen Network) is a collaborative venture by the regions of Flanders and the southern Netherlands. Participants in the project include the ECN, a number of regional development agencies, various colleges and regional businesses. The initiative, which has a budget of 14 million euros, has been set up to stimulate the use of hydrogen applications in the region. One of its objectives is to make operational a hydrogen infrastructure that is connected to the network of hydrogen pipelines that lies in the region and connects northern France with Rotterdam. In addition, a hydrogen production plant will be built in the port of Antwerp. An important part of the project is the educational aspect. The colleges involved are jointly developing teaching programmes about hydrogen for use in education.

**CHIC, the Clean Hydrogen In European Cities Project**, is the essential next step leading to the full market commercialization of Fuel Cell Hydrogen powered (FCH) buses.  

The project involves integrating 26 FCH buses in daily public transport operations and bus routes in five locations across Europe – Aargau (Switzerland), Bolzano/Bozen (Italy), London (UK), Milan (Italy), and Oslo (Norway). The CHIC project is supported by the European Union Joint Undertaking for Fuel Cells and Hydrogen (FCH JU) with funding of 26 million euros, and has 25 partners from across Europe, which includes industrial partners for vehicle supply and refuelling infrastructure.

The project is based on a staged introduction and build-up of FCH bus fleets, the supporting hydrogen refuelling stations and infrastructure in order to facilitate the smooth integration of the FCH buses in Europe’s public transport system.

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**References**

10 [http://www.waterstofnet.eu/](http://www.waterstofnet.eu/)

11 [http://chic-project.eu](http://chic-project.eu)
Hydrogen can be produced by different methods, including using renewable energy. Fuel cells use hydrogen to produce electricity while emitting only water vapour. Hydrogen and fuel cells can therefore play an important role in the reduction of local air pollutants, as well as in the decarbonisation of Europe’s transport system. Hydrogen powered transport is currently able to meet the normal operational requirements of buses and light passenger and commercial vehicles. The objective of CHIC is to move these demonstration vehicles towards full commercialisation starting in 2015.

The buses in the CHIC project will be supplied by three different manufacturers and the hydrogen refuelling infrastructure will involve the main industrial players active in hydrogen infrastructure development around the world. CHIC sees the deployment of the latest generation of fuel cell hybrid (FCH) buses, building on the successful field-tests of first and second generation FCH buses within the CUTE and HyFLEET CUTE projects.

**HyTransit & High V.LO City: Aberdeen, Scotland**

Aberdeen Scotland is developing Europe’s largest hydrogen bus fleet (14 buses). The city of Aberdeen is participating in two projects: HyTransit and High V. LO City, both supported through the EU’s JTI program. The HyTransit project was announced by Scotland’s First Minister, Alex Salmond, in August 2012 and will include the rollout of 10 fuel cell buses by early 2014. The 10 buses will be part of a “whole hydrogen” solution with wind energy supplying power for hydrogen generation from electrolysis.

Additionally, Scotland is a partner in the High V.LO City program which includes deployment of 14 buses in three European countries: Italy, Belgium and Scotland. The program aims to create a network of successful fuel cell bus operation sites, which are called Clean Hydrogen Bus Centres of Excellence (CHBCE), linking High V.LO-City sites with similar fuel cell bus demonstrations in Europe. 4 buses will be demonstrated in Aberdeen, Scotland.

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3.3 Regions or Countries in the Batterie Project

**Asturias (Spain)**

In Asturias there was a project directed by FAEN and CTA (the Asturias Transport Consortium) working on the design of a fuel cell car concept by a regional Institute. The aim of this project was to design and manufacture a concept car using this technology in order to analyse results and problems detected.

The second part of this project will be use a conventional car and convert it into a fuel cell car working with hydrogen.

**Basque Country**

No commercial initiatives in Basque Country related to this hydrogen technology.

**Navarre (Spain)**

In 2010, a research group from the Universidad Pública de Navarra (UPNA) adapted a gasoline VW Polo to also run with hydrogen. The team has not only modified the engine but also the electronic control in order to integrate it with the rest of signals and control of the on board computer. Now, the user can choose from the control panel whether to consume hydrogen or gasoline just by activating a switch.
Northern Ireland

The government in Northern Ireland currently has no initiatives in place to promote the creation of a hydrogen infrastructure in the country. This may be because the focus in Northern Ireland has been on electric cars and getting the infrastructure ready for them or it may be because hydrogen technology is only just beginning to make small in-roads to the global market. In terms of even beginning to create a hydrogen strategy for the country there is no current work. One or two university courses offer modules on hydrogen transport and safety and the largest bus producer Wrightbus, sells hydrogen buses. Yet despite this, no action has been taken and the potential to harness the wealth of natural energy in the country is not being taken.

Scotland

Many hydrogen projects have been developed in Scotland starting from the first ever hydrogen road licensed car to the latest hydrogen bus fleets. Below provide a picture of a hydrogen fuel cell royal mail vehicle being fuelled by green hydrogen in the Western Isles.

A hydrogen internal combustion engine Royal Mail van being refuelled with green hydrogen (top picture) and a hydrogen complete infrastructure (bottom picture) (for more information and a complete report, see http://pureenergycentre.com/h2seed-case-study/)

Hydrogen fuel cell vehicles have also been developed such as the hydrogen eco-marathon cars amongst many others.
Hydrogen fuel cell eco-marathon competing at the French event (see http://pureenergycentre.com/hydrogen-cars/)
3.4 Recommendations

- In the absence of economic viability, an appropriate regulatory framework and financial public support, as well as public budget neutral incentives, will be required to introduce clean alternatives to the market and provide the European citizen with a clean choice of transport.
- The 4 types of vehicles; ICE, BEV, PHEV and FCV; are complementary and necessary for a long-term sustainable transport.
- H2 Technology vehicles with fuel cells and are ready to offer greater potential for reducing GHG emissions.
- The cost for hydrogen infrastructure is comparable to recharge battery electric vehicles.
- The biggest barrier to the deployment of the current market for these vehicles is not technical but economic, though hydrogen vans cost now compete with the cost of a hydrogen battery vans.
- To establish a European hydrogen refuelling network, the most effective approach will be to combine measures developed at the European level, defining particular targets and obligations for Member States, with measures adopted by Member States and at the regional level to achieve these targets.
- The “early markets” are helping companies in USA, Germany, Canada, Japan generate R & D and employment. Atlantic Area regions can still “jump on the bandwagon” and create jobs. The following necessary:
  - Public Support “administrative”
  - Financing
  - Infrastructure
  - New legislation where large fleet owners are requested to use hydrogen fuel cell vehicles
- Mass markets (such as automotive) would make the equipment cheaper, opening the door to other markets of great interest for the EU and hydrogen production from renewable.
- A timeline for hydrogen refuelling build-up would be:
  By 2015 around 200 to 300 refuelling units should be in place in various urban regions across Europe, accommodating passenger and light duty mobility leaving the framework in place for commercialisation. By 2020 hydrogen will achieve market penetration by linking existing pre-commercial hydrogen infrastructure networks to build up a European network of; up to 2000 (minimum 1000) fuelling stations, 500,000 FCEV passenger cars and 1000 FC buses. By 2025, sufficient scale and coverage in this network should allow hydrogen to be market-competitive with traditional combustion engines.
- The development of standards is well advanced in the area of hydrogen and fuel cells for the transport sector. SAE and ISO draft standards are already providing globally harmonised requirements with regard to key items such as the hydrogen refuelling interface, the hydrogen
fuel quality, and hydrogen refuelling station safety. European industry-led coordination is required to ensure that the needs of European stakeholders are addressed by international standards and to support the establishment of an efficient regulatory framework encompassing these standards.
4. Biofuels

In this chapter there has been included information regarding the actual situation of the use of biofuels, the present coverage, demonstration projects and other projects that are developed in the regions involved in Batterie.

4.1 General aspects

Biofuels are usually classified as follows:

- **First-generation biofuels** are directly related to a biomass that is generally edible.
- **Second-generation biofuels** are defined as fuels produced from a wide array of different feedstock, ranging from lignocellulosic feedstocks to municipal solid wastes.
- **Third-generation biofuels** are, at this point, related to algal biomass but could to a certain extent be linked to utilisation of CO2 as feedstock.

**First-generation biofuels** include ethanol and biodiesel and are directly related to a biomass that is more than often edible. Ethanol is generally produced from the fermentation of sugars (mostly glucose) using classical or GMO yeast strains such as Saccharomyces cerevisiae.

Only a few different feedstocks, mostly sugarcane or corn, are actually used for the production of first-generation bioethanol. Although very advantageous for the producers, increases in the sugar price are a problem for the bioethanol business. In August 2012, the price of raw sugar was close to US$0.20 per pound while the price for ethanol was US$2.59 per gallon (US$0.68/L). Production of 1 L of ethanol out of raw sugar should cost around US$0.30 to US$0.35, and therefore, the market favoured production of raw sugar instead of ethanol.

Corn is the other major source of carbohydrates for production of ethanol, and requires a preliminary hydrolysis of starch to liberate the sugars that can then be fermented to ethanol.

**Biodiesel** is the only other biofuel produced on an industrial scale. The production process of this biofuel is very different from ethanol because it could be considered as a chemical process. Of course, it uses biomass (oily plants and seeds), but the process itself relies on extracting the oils and converting them into biodiesel by breaking the bonds linking the long chain fatty acids to glycerol, replacing it with methanol in a process called transesterification.

The price for feedstock is the most crucial factor affecting biodiesel production. Therefore, use of other less expensive sources such as used oils and oil from non-edible plants like jatropha is gaining interest.
Algal biomass is also considered as a source of lipids for production of biodiesel, although it is generally related to third-generation biofuels. Production of ethanol from sugarcane or corn and biodiesel from edible oils depends on the prices dictated by the international market, whereas the prices of used cooking oil and jatropha are presently not influenced by such market, which is a good incentive for their use for biodiesel production.

**Second-generation biofuels** are defined as fuels produced from a wide array of different feedstocks, especially but not limited to non-edible lignocellulosic biomass.

For the production of second generation biofuels can choose from three options. The first is biochemistry and consists of extracting the sugars from cellulose with the aid of highly active enzymes for later ethanol by fermenting yeast etanologenic. The second option involves the gasification of the raw material with a mixture of hydrogen and carbon monoxide, then this mixture is transformed into a liquid fuel through a series of intermediate steps. The third option is to obtain a liquid fuel by pyrolysis or liquefaction process. Although presented different development stages, none of these technologies have reached commercial status would be needed to support research in this field and make second generation biofuels are efficient in terms of trade.

The main challenges to promote biofuels are sustainable practices in energy crops and the development of advanced processing.

Biomass used for production of second-generation biofuels is usually separated in three main categories:

- **Homogeneous**, such as white wood chips
- **Quasi-homogeneous**, such as agricultural and forest residues
- **Non-homogeneous**, including low value feedstock as municipal solid wastes

The conversion process for production of second-generation biofuels is usually done according to two different approaches, generally referred to as “thermo” or “bio” pathways.

- The “thermo” approach covers specific processes where biomass is heated with a minimal amount of oxidizing agent, if any. All processes in that category lead to conversion of biomass into three fractions: one solid known as biochar, one liquid currently referred to as pyrolytic oil or bio oil, and one gas known as syngas, which is usually composed of carbon monoxide, hydrogen, short chain alkanes, and carbon dioxide. Thermal processes are to a certain extent self-sufficient in terms of energy because the energy required to heat the biomass up to the requested temperatures can be supplied by the partial or total oxidation of carbon from the biomass, reactions that are usually very exothermic. Biochar, considered
as a solid biofuel, is gaining a lot of attention in the pelletising business, especially in parts of the world where lignocellulosic biomass is rather inexpensive. To produce transportation fuel from this intermediary, a second transformation must be made, which is a rather difficult task because of the high water content as well as the corrosive nature of bio oil. Processes for this transformation:

- hydrodeoxygenation (reducing the amount of oxygen produces a mixture of alkanes similar to petroleum),
- catalytic cracking,
- steam reforming,
- creation of an emulsion with diesel.

Gasification, in contrast to pyrolysis, produces syngas, mostly composed of single carbon compounds and hydrogen. One of the simplest approaches for the industrial production of synfuels out of syngas is to produce methanol. Methanol can be produced from carbon monoxide and hydrogen directly under the action of a reducing catalyst. Methanol cannot be used as additive for fuel at this point, so further transformation is required. Methanol is also investigated for the production of a new generation of fuels such as bioDME, produced through etherification of two methanol molecules. It has been reported as an additive to diesel and has the distinctive advantage of being simple to produce under the action of an acid catalyst.

The “bio” pathway is somewhat comparable with a pulping process because, in most cases, cellulose is first isolated from the lignocellulosic biomass. This is a technological challenge because it has to produce the highest purity of cellulose to remove most inhibitors without consuming too much energy or too many chemicals. Once isolated, the macromolecule requires hydrolysis to be fermented by yeasts.

Usually, the ratio between xylans and glucans in hemicelluloses varies from 50 to 75% of the total carbohydrate content. The main advantage of hemicelluloses is that, due to their highly ramified structure, they can be hydrolyzed easily using water at high temperatures or a very dilut ed aqueous mixture of acids.

Lignin, the second most abundant natural polymer found in lignocellulosic biomass is mostly composed of phenyl propane units. The macromolecule is highly energetic and has been used for cogeneration or as a fuel by the pulp and paper industry. The aromatic monomers
from lignin could also be a very abundant source of high value chemical compounds that could be used in the plastic industry, as well as adhesives. Consequently, the use of biomass to produce such monomers would lead to an interesting new market for bioadhesives and second-generation bioplastics.

The Third Generation of biofuels is based on improvements in the production of biomass. It takes advantage of specially engineered energy crops such as algae as its energy source. The algae are cultured to act as a low-cost, high-energy and entirely renewable feedstock. It is predicted that algae will have the potential to produce more energy per acre than conventional crops. Algae can also be grown using land and water unsuitable for food production, therefore reducing the strain on already depleted water sources. A further benefit of algae based biofuels is that the fuel can be manufactured into a wide range of fuels such as diesel, petrol and jet fuel.

Fourth Generation Bio-fuels are aimed at not only producing sustainable energy but also a way of capturing and storing CO₂. Biomass materials, which have absorbed CO₂ while growing, are converted into fuel using the same processes as second generation biofuels. This process differs from second and third generation production as at all stages of production the carbon dioxide is captured using processes such as oxy-fuel combustion. The carbon dioxide can then be geosequestered by storing it in old oil and gas fields or saline aquifers. This carbon capture makes fourth generation biofuel production carbon negative rather than simply carbon neutral, as it is ‘locks’ away more carbon than it produces. This system not only captures and stores carbon dioxide from the atmosphere but it also reduces co2 emissions by replacing fossil fuels.

The European Commission, as part of its energy policy is committed to promote the production and use of biofuels, proposing a binding minimum target for biofuels use as fuel for vehicles by 10% by 2020. This will promote "second generation" biofuels derived from plants or plant residues that are not in direct competition with food uses. It is therefore necessary to develop new crops more productive, with lower production costs and are not intended for food market. The species involved in producing biomass for energy can be
herbaceous or woody type. The ideal characteristics for these crops are able to obtain high biomass productivity with low production costs, and achieve a positive energy balance, meaning that the net energy contained in the biofuel produced exceeds the worn in culture and in obtaining biofuels and the possibility to easily recover land after the end of the energy crop for other crops.

Crops such, rapeseed Ethiopian (Brassica carinata), thistle (Cynaracardunculus L.), and the use of vegetable oils are examples of materials for the production of biodiesel.

For the production of ethanol fuel are investigating other species such as artichoke (Helianthus tuberosus L.) and sweet sorghum (Sorghum bicolor L.). These crops, in addition to its lower production cost, would be more profitable for the production of ethanol could be used as dry stalks (artichoke) or bagasse (sorghum) for the production of steam and electricity required in the process of obtaining ethanol improving overall emissions balance their life cycle.

Most scientific studies agree that biofuels account for lower emissions of greenhouse gases (between 35 and 50%), bioethanol produced using second generation technologies (which should begin to be marketed between 2010 and 2015) could diminish one hundred percent.
4.2 Projects

TUSSAM, BIOFUELS IN PUBLIC TRANSPORT IN SEVILLA

TUSSAM is carrying out the progressive incorporation of the use of biofuels in their buses from diesel traction. This project is part of the commitment of the reduction of contamination emissions of buses using renewable energy like biodiesel, one of biofuels with greater future.

Four buses were tested in a first phase during 2005 for a period of one year. The used fuel was B15 Biodiesel from waste oils, and the findings of this test were that the use of biodiesel increases fuel consumption very slightly below the 3, and with respect to their impact on the maintenance of the vehicle, seems to be beneficial for the motor, to reduce its consumption of oil. The rate of breakdowns of the four vehicles was similar to the rest of the fleet.

March 2006 began a Biodiesel test on a larger scale, with the use of 30 buses which have been online service since that date and analysed the results obtained in March 2007. The conclusions of the study were the same as those obtained with the previous pilot.

The third phase of implementation began in May 2007, in which were 30 additional vehicles with Euro 3 type engine together with 30 Euro 2 engine vehicles, a total of 60 buses were incorporated. This third phase lasted with 60 vehicles until February 2009. The results of this stage were on the large scale positive, confirming the same conclusions that had been obtained in previous studies. For this reason it was decided that beginning in March 2009, the entire fleet of buses with diesel engines will use interchangeably biodiesel B15 or diesel, based on a criterion of optimisation in the price of the purchase of fuel, so that if the price of biodiesel B15 is superior to the conventional diesel fuel it opts for buy the latter.

390 buses, 4 trams, 15 Mkms/year, 83 million passengers per year.

New technologies: new SAE way GPS, information points in bus stop and in the mobile phone, introduction of gas vehicle, introduction of biofuels.

New vehicles agree with EURO II, IV and EEV normative.
GREEN EMOTION PROJECT,
The Green eMotion project is part of the European Green Cars Initiative (EGCI) that was launched within the context of the European Recovery Plan. It supports the achievement of the EU’s ambitious climate goals, such as the reduction of CO2 emissions by 60 percent by the year 2050. EGCI supports the research and development of road transport solutions that have the potential to achieve sustainable as well as ground-breaking results in the use of renewable and non-polluting energy sources.

The Green eMotion project was launched in Bruxelles on 31 March 2011. Within four years, it will be working to prepare the foundation for the mass deployment of Europe-wide electromobility. The project has a total budget of €42 million and will be funded by the European Commission with €24 million.


BioMara (Northern Ireland, Republic of Ireland, Scotland):
This €6M project, funded by INTERREG IVA with match funding from Highlands and Islands Enterprise and The Crown Estate, has enabled six research institutes from Western Scotland, Northern Ireland and the border region of Ireland to investigate the feasibility and viability of using marine biomass as a source for biofuels (third generation biofuels).

Under the leadership of SAMS, the project has addressed four research themes:
1. Identifying the most appropriate seaweeds for biofuel generation
2. Identifying high oil producing microalgae
3. Evaluating the environmental impacts of algal cultivation and extraction
4. Examining the technological and socio-economic practicalities of producing competitive and sustainable biofuels from marine biomass.
Also there are some important R&D projects:

**S2BIOM (2013-2016)**  
**Project Title:** Delivery of sustainable supply of non-food biomass to support a “resource-efficient” Bioeconomy in Europe  
**Program:** FP7 EU-KBBE work program.  
The main aim of this project is to support the sustainable delivery of non-food biomass feedstock at local, regional and pan European level through developing strategies, and roadmaps that will be informed by a “computerised and easy to use” toolset (and respective databases) with updated harmonised datasets at local, regional, national and pan European level for EU28, western Balkans, Turkey and Ukraine.

**LOGISTEC (2012—2016)**  
**Project Title:** “Logistics for Energy Crops”.  
**Program:** FP7 EU-KBBE work program.  
The LogistEC project aims to develop new or improved technologies of the biomass logistics chains. Cost-efficient, environmental-friendly and socially sustainable biomass supply chains are needed to achieve the 2020 EU RES targets that might be impeded by the potential scarcity of lignocellulosic biomass from agriculture.

**ENERGREEN (2012-2014)**  
**Project Title:** Overcoming barriers to the development of microalgae cultivation for bioenergy  
**Program:** Interreg IVa Poctefa  
ENERGREEN is a project aimed at readapting conventional micro-algae cultures to obtain microorganisms with higher productive potential – compared to the equivalent amount of oil – and suitable for producing bio-diesel in a more cost-effective and environmentally sustainable way.
The project addresses the current R&D needs for the use of micro-algae as a renewable energy source and will deal with all the production process stages – from cultivation to processing into biodiesel – including the exploitation of waste material obtained from oil extraction, as biogas.

**VALUE (2011-2013)**  
**Project Title:** Exchange and technology transfer for agro-industry residue valorisation in SUDOE region  
**Program:** Interreg IVb SUDOE  
The aim of the project “Exchange and technology transfer for agro-industry residue valorisation” is to identify research, validate and disseminate technologies for the treatment and valorisation of residues for its application in companies of vegetable transformation of the SUDOE region. The production of alcohols able to be used as biofuels is one of these valorisations.

CENER participates developing energy based valuating processes from transformed vegetables industry wastes, mainly by means of ethanol production.

**ECODIESEL (2008-2011)**  
**Project title:** High efficiency biodiesel plant with minimum GHG emissions for improved FAME production from various raw materials”.  
**Program:** FP7 EU Energy work program.

The general objective of this project is to get the highest process efficiency with the highest GHG saves in the process of manufacturing biodiesel at industrial scale (200,000 t/y production capacity). Translated into figures, our objective is 40 % of CO₂ saved, keeping CO₂ cost per ton similar to conventional plants (approximately 30 €/t) and not higher. This will be demonstrated through an industrial plant producing cheaper 1st generation biofuels with an improved environmental performance equivalent to those foreseen for 2nd generation biofuels.

4.3 Regions or Countries in the Batterie Project  

**Portugal**

Biofuels are mixed in small percentages into normal diesel and petrol. Only 1 station offers 15% (B15) biodiesel mix while 6 offer a 10% (B10) biodiesel mix.

About the state of development, the mandatory goals for biofuels are the following: 5% from biofuels in 2011 and 2012; 5.5% in 2013 and 2014; 7.5% in 2015 and 2016; 10% in 2020. Until now, the objectives are being met by biodiesel. As such, diesel is now a 6.99% biodiesel.

There are five biodiesel producers:

- Iberol
- Biovegetal
- Fábrica Torrejana
- PrioBiocombustíveis
- Sovena
Asturias (Spain)

Bionorte, which was founded in 2001 to construct a plant in Asturias for production of biodiesel from used cooking oils recycling. Several companies involved in Bionorte are environmental managers and managed the collection of most vegetable oils of waste from nearest regions, Galicia, Castilla León and also Canary islands. The plant has two production lines with a capacity of 4,000 tons per year, expandable to double or triple. These two lines can process all types of used vegetable oils regardless of its composition.

In 2012, sales of Bionorte fell significantly as a result of competition of biofuels from countries such as Argentina, Indonesia and Malaysia, where the production is strongly encouraged by Government subsidies. Moreover, the new tax added to biofuel by the Spanish Government makes the future of biodiesel plants more uncertain.

In the first months of the 2012, the plant generated 600 tons of biodiesel from recycled oils. Since the summer, the number fell to 100 tons.

About biofuels consumption, there are some bus companies where biodiesel is used.

- **Autobuses de Langreo**: Since April, 2006, by the signing of an agreement with the Transport Consortium of Asturias, the company use BIODIESEL, supplied by Bionorte, installed in San Martín del Rey Aurelio, Asturias.
- **EMTUSA**: Public transport buses in Gijón use biodiesel. This change will help save money and CO₂ emissions.
- **Autos Sama**: Since 2002 the entire fleet of buses of Autos Sama has used biofuels.

Apart from this, the normal diesel is mixed with a small percentage of biodiesel.

Basque Country (Spain)

Talking about biodiesel, only some buses (called ecologic) on the public transport system of the main three cities use this source of energy. The total number of ecologic buses represents less than 1% of the total fleet and are being used as a consciousness-raising example more than as a real alternative platform.
As in the rest of Spain, there exists in the petrol stations the so-called “biodiesel” that is a mixture of diesel with small percentage of biofuel. Most modern commercial cars in Spain are fitted to uptake both “sole diesel” and biodiesel.

**Navarra (Spain)**

In Navarra there are 3 biodiesel generation plants: M+W Zander Olite, Biodiesel Caparroso EHN (Acciona Energía) and Abencis Tudela but the second one is not working.

There some companies working on biofuels like Acciona Energía and Ingeteam.

Biofuels are analysed and studied in the Cátedra de Energías Renovables [Public University of Navarra].

It is also important to remark upon the existence of The Second Generation Biofuel Centre. This Centre is a semi-industrial pilot scale test facility to develop 2nd generation biofuel production processes based on raw materials that are not competitive with the food industry (especially lignocellulosic materials such as forest and grass waste) and the production of biofuels via different production means (thermochemical, biochemical and/or enzymatic) and the application of biorefinery concepts. It belongs to CENER’s facilities and is considered as a Singular Scientific and Technical Infrastructure (ICTS) by the Government of Spain.

**France**

EU Member States are mandated to reach a minimum of 10 percent for renewable energy consumed in transport by 2020. Biofuels must meet sustainability requirements established in the Renewable Energy Directive (RED). With 20 percent of the European Union’s (EU) production and consumption of biofuels in transportation, France continues to play a major role in the European biofuels industry and policy. In the March 27, 2013 renewable energy progress report prepared by the European Commission, France is identified as one of the five Member States dominating biofuels production and consumption. The biofuels’ blending rate into transportation fuels in France is higher than the average blending in the EU, and amounted to 7.2 percent in 2011 (source GAIN report FR9118, dated October 5, 2012).

However, in France, there are two categories of stakeholders: those who would like to slow down the first-generation biofuels industry, questioning their environmental impact, and favoring the development of advanced biofuels, and those who argue that the first-generation biofuels industry is competitive. There is also the argument that Biofuels increased use in transport may result in negative impacts on food prices. As a result, with regard to sustainable biofuels expansion many
French associations propose the reduction from 10 to 5 percent of first-generation biofuels in transportation.

The environmental objective of biofuels is to reduce greenhouse gas emissions and reduce fossil fuel consumption. Due to the current economic situation, the project of imposing a carbon tax on stakeholders proportionate to their CO₂ emission was abandoned. However the French Ministry of Ecology and Sustainable Development estimates that the use of biofuels in France generates savings of 5.4 million MT CO₂ emissions.

Bio-fuel agriculture in Normandy involves about 22,000 hectares in 2004, it represents 6.71% of the area of metropolitan France dedicated to energy crops. The agriculture is well developed in this region and could be in progress depending on the market.

Northern Ireland

In Northern Ireland much of the diesel, and some petrol, now contains biofuel. This is up to a maximum of five per cent in petrol and seven per cent in diesel. However traditional biofuels have come under scrutiny for interfering with food production.

The Renewable Transport Fuel Obligation requires UK fuel suppliers to include a certain amount of biofuel in the fuel that they supply. However the government has said that no more than five per cent of fuel in the UK will be biofuel until it can be sure that it is supplied in a way that avoids negative side effects.
A 2004 AFBI (Agri-Food and Biosciences Institute) report on growing biofuels in Northern Ireland noted that “Growing biofuel crops on the 3,500 ha of ‘set-aside’ in Northern Ireland would provide a way of initiating the adoption of biofuel cropping without significantly changing the current arable cropping pattern.” However increasing the scale required to meet the demand of the biofuels market would “represent a more significant change” and would also be hindered by EU rules on ploughing more than 10% of permanent grassland.

The Biomara research programme is one example of some of the work which has been done on biofuels in Northern Ireland. It focused on third-generation fuels from Algae.

**South West of Ireland**

- **Biogas** – this can be produced from waste organic materials produced from the dairy industry, agricultural slurries and municipal organic waste. Biogas requires investment in compression equipment and modified vehicles in order to operate. Generally this additional cost means that companies with high fuel costs and access to an organic waste stream are those most likely to benefit from this technology. Biogas fuel is exempt from carbon tax and fuel duties which could make the fuel an attractive option for fleet operators. Buses, refuse vehicles and other local use heavy duty vehicles would be suitable. Barriers therefore include; access to sustainable waste materials, cost and a lack of demonstrated experience.

- **Liquid Biofuel** – the simplest of these biofuels is produced by pressing and filtering rapeseed oil for use in a special diesel engine. The waste product produces a cake material which is ideal food for dairy animals of which Ireland has a substantial quantity. Biodiesel requires refining of the fuel to remove glycerine from the rapeseed oil. This requires substantial investment in a refining facility and therefore a substantial and reliable supply of rapeseed is required at a reliable price to keep the business viable. The price difference between fuel and food could therefore cause undesired competition for the farmer’s crop from the biofuel refinery. Bioethanol is another biofuel which is produced from wheat or sugar beet. Sugar beet production has ceased in Ireland following the withdrawal of subsidies for the crop. The requirements for this type of facility are similar to those for a Biodiesel facility. These fuels do not offer 100% reductions in CO2 emissions as a certain amount of energy will be required to manufacture the fuel.

Ireland has a biofuel obligation which requires all oil suppliers to ensure that 4% by volume of their petrol/diesel fuel sales contain biofuels. At the moment biofuels are produced from rapeseed
resulting in Pure Plant Oil. Much of this is refined further into Biodiesel in Wexford, at Ireland’s first biodiesel facility. Biofuels are then mixed in with diesel to produce EN590 standard diesel fuel and much of this blending occurs in the Conoco-Philips refinery in the South West region.

It is considered that the next generation of biofuels will be produced more efficiently and economically using improved Biorefinery technology. This is a process whereby multiple revenue streams are produced during the chemical transformation of the raw vegetable material into biofuels.

**Scotland**

Although most of the transport methods in Scotland are petrol and diesel based, the Scottish Government has set a target of 10% by 2010 of Biofuel used in Scotland. This is in line with the European Union targets.

In order to achieve these targets, thanks the EU, the Scottish Government has granted funding for a scheme to increase the uptake of Biogas generation plant and use. It is expected about £1.6 million investment in 2014.

The most important feature of bio fuel is that it is a renewable energy source, unlike coal and petroleum. It can be produced from agricultural products such as sugar cane and wheat that can be grown especially for bio fuel production. In addition agricultural waste, seaweed and paper or other domestic waste could be used to produce Bio fuel and power businesses across Scotland.

Various Biofuel schemes exist at present in Scotland, among them:

- **Westray Biodiesel plant:** Westray Development Trust in Orkney operates a biodiesel vehicle fuelled by the residual vegetable oils from fish and chip outlets. In 2003 the Westray Development Trust was looking at ways to generate operating income, and the Energy sub group of the Trust developed a plan to work towards self-sufficiency in energy produced from renewable resources. The latest growing worldwide interest in alternative fuels and specifically on Biofuel set out the aim to build a biofuel project were to:

  - Collect the local waste (the used cooking oil) for the production of diesel fuel. It then could be used in any ordinary diesel car, truck, tractor without any engine modification required.
  - Make fuel that was environmentally greener in production and would bring environmental benefits in use
Make fuel that would be cheaper at the point of sale to the ordinary retail customer.

Create local employment

Contribute to making Westray self-sufficient in energy

The initial trials have proved promising and several vehicles are now running successfully on the fuel produced with local waste. However to supply bio diesel commercially will require more than waste alone. It is for this reason The Westray Development Trust has entered into partnership with the Agronomy Institute and the Scottish Agriculture College to investigate potential bio-fuel crops and their sustainability in Orkney.

- The Creed Waste management facility, Isle of Lewis: The Creed Anaerobic Digestor Plant on the Isle of Lewis is owned and run by Comhairle nan Eilean Siar (Western Isles Council), providing an integrated waste management facility for the islands chain. The waste management facility acts as the hub for the Council’s municipal waste management service delivery, allowing it to not only meet but exceed the challenging targets for recycling and landfill diversion that have been set by the Scottish Government. At present the Integrated Waste Management Facility processes waste from the northern isles (Lewis & Harris) and the southern isles (the Uists, Benbecula & Barra).

Residual waste is mechanically screened, firstly to separate out metals for recycling, but primarily to produce an organic-rich fraction. The main waste treatment facility was the first plant in the UK to incorporate anaerobic digestion of source-separated biowaste (food, paper and garden waste) on a commercial scale. The biogas produced is used to generate up to substantial electrical power annually for export to the local network, whilst the solid digestate is matured to produce high-quality compost for local use. The facility also houses the recycling of glass and baling of plastics and crushing of cans.

The biogas powered CHP unit provides electrical power and heat for the whole facility yielding a net surplus of electricity. A complementary Hydrogen Project, H2SEED, sits alongside this utilising the space capacity and providing the initial infrastructure for the Hydrogen developments. There
are also plan to install three wind turbines to be co-located at the Creed facility, the power from which could also be utilised to generate Hydrogen.

The H2SEED project has been set up to support the accelerated development of the renewable, hydrogen, fuel cell and energy storage industries in the Outer Hebrides. The H2SEED project implements a hydrogen production system from a Biogas Plant Gas Internal Combustion Engine. It shows high pressure storage at 450bar and a hydrogen refuelling station at 350 bar fuelling a hydrogen internal combustion engine Royal Mail vehicle.

H2SEED project at Creed Facility (see http://pureenergycentre.com/h2seed-case-study/)
4.4 Recommendations

The lines of work to promote biofuels should combat the abusive business practices, expand marketing channels, research and develop new products and new markets, such as aviation. Always compliant under safety standards of quality and sustainability.

Documents like the Transport White Paper 2011, indicate a series of targets for biofuels in a time horizon to 2050. These fall into several categories:

- Reducing conventional vehicles in urban areas (50% in 2030), reducing intercity road transport (50% in 2050), reducing shipping CO2 emissions (50% in 2050), improving aviation alternative fuels (40% in 2050), improving high-speed rail, improving connection stations airports, improving common system information / payment multimodal, improving full development multimodal TEN-T and reducing CO2 emissions (60% in 2050).

The Actions outlined to achieve these goals go through a number of approval vehicles; developing standards in electrical safety, recharging, funding and improving infrastructure, reinforcing RTD engines, fuel and battery enhancements, CO₂ review regulations (130-95 g/km), ITS Promotion, the access to limited supply materials, impact networks and environmental footprint, reuse and recycling of batteries, supervision incentives EM.
5. Other Alternative Fuels

In this chapter there has been included information regarding the actual situation of the use of other alternative fuels less known like Methane, Liquefied Natural Gas and Liquefied Petroleum Gas and synthetic fuels.

5.1 Synthetic Fuels

Production of synthetic fuels is based on synthesis gas (H₂, CO) and a liquefaction step. This applies for all main synthetic pathways: HVO, GTL, BTL and CTL. New pathways include synthetic natural gas produced from temporary surplus of renewable electric power using hydrogen from electrolysis of water, and CO₂.

Reforming (methane or light oil) and gasification (e.g., coal, biomass, and heavy oils) are two ways to produce synthesis gas. Basically any hydrocarbon-containing material can be used as feedstock. There are several types of fuels that can be made from synthesis gas. Alternative liquefaction steps are synthesis into methanol or DME, both of which are more selective than the Fischer-Tropsch process. The output of the Fischer-Tropsch process is typically 50% high-quality, sulphur-free high cetane synthetic diesel, 30% naphtha and 20% other products.

The biomass-to-liquid processes (BTL) are still under development as it is more difficult to apply gasification and liquefaction to biomass than to coal. Shell operates a GTL plant, and is marketing GTL as a diesel component in Thailand, Germany, Austria, Italy, the Netherlands, Greece and Switzerland.

Synthetic FT diesel doesn’t need infrastructure changes, so overall costs might be lower, although cost of producing synthetic FT diesel is slightly higher than costs for e.g., DME.

GTL from stranded natural gas becomes increasingly competitive with soaring crude oil prices. Increased requirements on fuel quality may also drive the development towards synthetic fuels.

CTL production could well be competitive with current and anticipated crude and natural gas prices, and promising figures have been given also for DME from coal. CTL production is most favourable in cogeneration of electricity. High capital costs of plants as well as environmental concerns may retard CTL development. CTL will increase wheel-to-wheel GHG emissions significantly compared with oil based transportation fuels. Even if carbon capture and storage (CCS) were used for the flue gases of the processing plant, the fuel itself would still contain carbon.

Summary of the GTL, BTL and CTL technologies (ASFE):
### 5.2 Methane, Liquefied Natural Gas and Liquefied Petroleum Gas

Advantages of gaseous fuels:
- Reduction of CO2 emissions compared to gasoline.
- Reduction of local emissions versus diesel emissions.
- Diversity of energy sources.
- Low cost.

Natural gas and biomethane are considered as a single fuel, since their molecular composition is the same —CH4, methane—. Liquefied Petroleum Gas (LPG) is a blanket denomination covering propane and butane, two gases which are easily converted to liquid. Biomethane can be derived from different production processes - upgrading of landfill gas or AD biogas. Synthetic biomethane can be produced via gasification of lignocellulosic materials and reforming of produced synthesis gas, or produced from hydrogen and CO2.

LPG is primarily derived during the exploitation of natural gas/oil fields, and is also produced in refineries. LPG can also be obtained as a by-product from the production of synthetic fuels. Autogas, the commonly used term to describe Liquefied Petroleum Gas (LPG) used as an automotive fuel, is poised to play a larger role in the European road transport fuel mix, particularly as regards use in passenger cars. Autogas, already Europe’s most widely used alternative fuel, offers a series of specific advantages. Autogas already powers over 7 million vehicles across Europe, representing roughly 3% of the overall European passenger car fleet and playing a substantial role in numerous countries.
With regard to other tail pipe emissions, methane vehicles have practically zero particle emissions and very low NOx emissions, but their CO2 emissions are comparable to those of conventional oil. A methane infrastructure largely exists, since most of Europe is covered with an extensive natural gas distribution grid for residential, industrial and power plant applications. The gas grid could also be made available for biomethane feed-in to allow for a smooth change-over from fossil to renewable methane gas sources.

In some countries, like France and Spain, there is practically no public network of methane filling stations. Both countries have pushed the use of this fuel in urban trucks and buses, with infrastructure accessible only to these fleets.

High investment costs are required for the build-up of a methane infrastructure. The disparities in the level of development for using methane in transport in Europe are due to specific national investment strategies. The expansion of private refuelling facilities for commercial fleets and public transport companies mainly results from local initiatives between public authorities and industry. More than €4 billion would be needed to provide adequate refuelling conditions.

There are around 3,000 refuelling points (public and private) in the EU and EFTA countries, of which 2,300 are public. Of these, 2,000 public refuelling stations are based in Austria, Germany, Italy, Sweden and Switzerland alone.

The application of Euro VI in 2014 reinforces the relevance of environmental and economic benefits via CNG and LNG, as the natural gas combustion engine technology meets the Euro VI standard.

The use of Natural Gas as an automotive fuel has no presence on Spanish roads despite the more than 13 million CNG-powered vehicles in the world. Its economic and environmental advantages suggest that there is a great potential in the development of this technology.

Natural gas is a gaseous mixture odourless and non-toxic hydrocarbon, composed primarily by methane (CH4) with an approximate ratio of 90. The compressed natural gas (CNG) consists of stored natural gas at a pressure of between 200 and 250 kg/cm2 reducing its volume to less than 1 of which would be at atmospheric pressure. Natural gas vehicle (NGV), is called after the natural gas used by vehicles as fuel. Many times the term Natural Gas vehicles was used as a synonym for Compressed Natural Gas. However, the NGV can also use Liquefied Natural Gas (LNG), which is stored in the liquid phase at -162 °C and, although it is also used as fuel vehicle, its use is marginal.

Use of CNG vehicles in Spain has a rather testimonial presence being reduced to large fleets of vehicles such as urban metropolitan buses or refuse collection services. It should be noted, for example, by The local public transport company (EMT) of Madrid in which 411 from their 2,092 buses, work with CNG.
CNG service stations have a maintenance and operation cost from the point of view of the user, similar to conventional service stations. As main differences it’s desirable to have a connection with the network of gas supply and the need for gas compressors that allow 250 bar pressure.

CNG service stations are more secure and less polluting that conventional stations, since CNG weighs less than the air, and in case of leaks it dissipates quickly in the atmosphere. There is no change to soil contamination or potentially explosive atmospheres for gas accumulation from occurring.

CNG is cheaper compared to other fuels. Based on an estimated price of €0.9 kg of CNG, savings against traditional fuels are 55% with respect to gasoline and 39% with respect to diesel oil. Additional investment must be taken into account to opt for fuels such as diesel oil are similar to the required additional investment to CNG.

The use of a single standardised connector across Europe would certainly enable the autogas market to grow further. Including the Euro connector (EN 13760) which was created in 2003 with four types of filling nozzle are used across Europe. The types of nozzle and their respective geographical distribution are as follows:

- Euro connector: Spain
- ACME filling unit: Ireland, Belgium, and Germany
- Dish filling unit: Portugal, France, Sweden, Poland, Italy, Greece, Austria, Hungary, and Romania
- Bayonet filling unit: UK, Norway, Denmark, and Netherlands
6. Conclusions and recommendations

Conclusions

Alternative fuel usage can be divided into three different sections: electric vehicles, biofuels and those vehicles using gas in any form. Aside from the work on the common policy by the EU members, different countries are working in this field in different ways; however legislative obligations and economic subsidies are the most common strategies to improve the use of alternative fuels.

The main efforts in this field are in regard to electrical vehicles. Some countries like Spain give money to private users to buy EV and also to install charging points. The administration then uses this incentive to create a positive profile of the government’s work on reducing the impact on fuel costs and environmental aspects. However, across Europe there is a real need to standardise the electrical connections because it will otherwise remain a large barrier to EV use in different countries.

Recommendations

Some of the priority actions that will need to be taken are:

For National Government:

- Coordinate the launch and ramp-up of EV and PHEV sales, provision of recharging infrastructure, and electricity supply among national governments.
- Improve the interoperability and standardisation for recharging infrastructure and EV connectors.
- Establish standards for battery construction and disposal, with emphasis on recycling.
- Achieve standardised safety and performance regimes.
- Clearly define the roles and responsibilities of different actors, between governments, regulators and utilities, vehicle OEMs and consumers;
- Incentivise battery manufacturers, to achieve large scale production and reduce production costs.

For local and regional Administrations:

- Encourage and promote the use of alternative fuels within their land use plans and strategies. It is essential that planners, engineers and all relevant staff within these authorities have an appreciation of the role they can play in assisting the role out of alternative fuel infrastructure within their function areas.
- Provision of recharging infrastructure, and electricity supply among national governments.
- Identify regions that are candidates to become early adopters, and help to get them involved.
Publish periodical reports and “scorecards” on progress; report on best practices and issues arising.

Develop good outreach and information programmes to help consumers to understand the benefits of EVs and PHEVs and increase their interest in adopting them.

Explore the viability of fast-charge systems.

For manufacturers, suppliers and University:

- Improve and refine regional and national market potential estimates.
- Ensure that all national targets can be matched to auto company production planning.
- Ensure adequate recharging infrastructures are in place at the time of, or slightly before, vehicles enter service.
- Optimise the supply chain and ensure sufficient battery and hybrid electric system supply through incremental production capacity expansion aligned with EV/PHEV vehicle volume.
- Reduce battery costs for EVs
- Continue strong energy storage research.
- Conduct research, testing and benchmarking to establish appropriate codes and standards for recharging, electricity supply, smart metering, etc.

Others:

- Biofuels are mixed in small percentages into normal diesel and petrol vehicles. However some bus companies use 100% biofuels in different lines. The 2nd generation of biofuels will help to mitigate some problems. First generation biofuel processes are useful but limited: there is a threshold above which they cannot produce enough biofuel without threatening food supplies and biodiversity. Some first generation biofuels produce only limited greenhouse gas emissions savings. Some of the raw materials are required for food, so, if too much biofuel is made from them, food prices could rise.
- Probably the most important barrier is that there isn’t a common strategy in the alternative fuel infrastructure in the different countries. It happens especially with EV but also with others alternative fuels like biodiesel.
- Transport develops slowly, it is therefore important to start investing and supporting the build-up of alternative, sustainable low carbon refuelling wherever possible, also in order to reach the 2020 targets.
- Public transport operators should take the first steps to enter low-polluting vehicles in the cities and serve as a model to other vehicles. The technology exists, it only requires the willingness to invest in sustainable transport and there is a need for more awareness on the subject.
Some alternative fuel options need more time before entering the market. A coherent and sustainable investment policy is important, in order to avoid investments into technologies where the vehicles are not yet commercially available for the end users.

Improving local air quality in urban areas should be supported by promoting viable alternative fuels and the refuelling infrastructure needed for captive fleets (e.g. taxis, municipal fleets) and heavy duty vehicles.

An appropriate EU regulatory framework and financial instruments will be required to introduce clean alternatives to the market and provide the European citizen with a clean choice of transport, in the same way that it has been essential to bring renewable energy production to where it is today.
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