ALTERNATIVE FUELS FOR A SUSTAINABLE TRANSPORT INDUSTRY

AN ATLANTIC AREA PROJECT

- REPORT 1 -

BATTERIE towards intermodal, sustainable, clean and energetic innovative transport solutions in the Atlantic Area Region

ACKNOWLEDGEMENT

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GLOSSARY

CO_2	Carbon Dioxide Gas	**AATP**	Atlantic Area Transnational Programme
AATP	Atlantic Area Transnational Programme	**AA**	Atlantic Area
EV	Electric Vehicles	**USA**	United States of America
HEV	Hybrid Electric Vehicles	**ICE**	Internal Combustion Engine
PHEV	Plug in Hybrid Vehicles	**H2O**	Water
km	kilometre	**H2**	Hydrogen
NH3	Ammonia	**O2**	Oxygen
BATTERIE	Better accessible transport to encourage robust intermodal enterprise	**CNG**	Compressed Natural Gas
		NG	Natural Gas
EV	Electric Vehicle	**CNG-fW**	Compressed Natural Gas from Waste
GAF	Green Alternative Fuel		

EXECUTIVE SUMMARY

This report has been carried out as part of a pan European project called **BATTERIE**, awarded by the Atlantic Area Transnational Programme (AATP).

In this report, an overview of the different alternative fuels is presented. As such a description of the difference between fuels, alternative fuels and green alternative fuels is provided. This is followed by the most common alternative fuels available today with some of their advantages and disadvantages.

It should be noted that the report is not aimed at providing a summary of all the available alternative fuels that can be used in the Atlantic Area Transnational Programme. This document focuses on (a) describing some of the most important and ready to be used fuels (or almost ready for commercialisation); (b) illustrating what is missing on the ground to allow the uptake of different alternative fuels which are anticipated to play a key role in future AATP transport systems. It takes into account that the use of alternative fuel can lead to a potential unbalancing effect with the food chain (when using biofuels), the supply of electricity to consumers (when using electric vehicles) and the issues associated with the distribution of alternative fuels across the current system (bio-alcohol fuels). This document, therefore, introduces the different concept of alternative fuels that can meet the fuel demand without interruption of the other supply chains (such as food, electricity, etc), and the need to introduce ongrid and offgrid alternative fuel systems that can lead to an effective, efficient, fair and clean balancing of worldwide resources as used for transport.

In summary, the BATTERIE project is highly committed to increasing the uptake of green alternative fuels in the AATP area, by providing innovative green fuel solutions, therefore supporting government policymakers to reach local and regional environmental targets.

KEY FINDINGS

- There are three main categories of fuels: the first category is fuels, the second is alternative fuels and the third is green alternative fuels – note that fuels cover alternative fuels in the same way that alternative fuels include green alternative fuels.
- Hydrocarbon based transport sector economy threatens the actual functioning of the Atlantic Area Region.
- Alternative fuelling methods must be adopted quickly to reduce dependence on current hydrocarbon fuels.
- Locally produced green fuel provides the best alternative to importing hydrocarbon fuel.
- Ethanol fuel is mainly produced in the USA and Brazil.
- Alternative Ethanol fuel is highly criticised as it compete for resources that could be used for producing eatable food and to exterminate hunger globally.
- Methanol alternative fuel is mainly produced from natural gas and overall not deemed to be an alternative fuel.
- Butanol alternative fuel is highly regarded as it is a fuel that can be transported and distributed using our current infrastructure.

- Both Ethanol and Butanol can be produced using biomass. In this case they are quantified as Green Alternative Fuels.
- Biodiesel can be produced from algae, it is biodegradable and in most cases non toxic.
- Battery based vehicles are not noisy and have no emissions at the point of use.
- There are three types of battery vehicles, Standard Electric Vehicles (EV), Hybrid Electric Vehicles (HEV), Plug in Hybrid Vehicles (PHEV).
- Electric vehicles can only be considered as green if the batteries are charged using renewable energy.
- Both HEV and PHEV can only be considered as green if they use biofuel.
- Hydrogen can be produced in large quantities for fuelling vehicles and for balancing the grid at large scale.
- Sustainably produced hydrogen can be used in petrol internal combustion engines and as a top up fuel for ferries, reducing naval and on land emissions.
- It is very simple to convert an internal combustion engine to run on ammonia such as tractors, cars, boats, train, plane, inter-island ferries, etc.
- Only electricity, water and air is required to produce ammonia
- Farmers in the Atlantic Area region can become fuel independent by using hydrogen and ammonia
- Gas Fracking has provided a well deserved resurgence of CNG vehicles, especially buses. However, there is no clarity as to what is the environmental impact of Gas Fracking.
- Many of the Atlantic Area Regions have agricultural waste and fish waste that can be converted to biogas for use as an alternative fuel.
- A vegetable oil fuelled car industry could lead to a vegetable oil crisis.
- Compressed air vehicles are not yet widely commercialised and need green electricity to qualify as being green.

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INTRODUCTION

Nowadays there are many different types of alternative fuels that can be used in the transport sector. The wide number of alternative fuels available is making it more difficult for the transport community to understand what alternative can be used and implemented in region.

This report aims to support the transport community to increase its awareness of alternative fuel technologies. It provides and disseminates an overview of the different alternative fuels that can be employed to reduce the dependence of the transport sector on the current hydrocarbon based supply chain.

Through this report, transport sector decision makers, owners, policy makers and business organisations will be able to learn and apply effective fuel, e-mobility, renewable and green alternative fuels. This will support them to identify how to reduce their imported fuel energy consumption and target with great effectiveness their emissions through the different green sustainable fuel solutions provided in this document.

This report is therefore divided into three (03) mains sections. The first sections deal with the introduction, aims and objectives of the report. The second section, the body of the document, describes the different alternative fuels and is divided into nine (09) sub-sections. The first subsection provides a quick recap on the reasons for alternative fuels. This is then followed by eight (08) subsections describing each alternative fuels that are currently the most advanced ones and near commercialisation (if not already commercialised). The final section, section three (03), describes what is the Batterie project.

AIMS

The BATTERIE Project as a whole aims to create a lasting change towards sustainable transport for the Atlantic Area Transnational Programme (AATP) regions. It aims at improving 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.

- This report intends to increase the understanding of alternative fuels that can be used in most of the AATP region. Specifically, this report provides some descriptions on the different commercialised and near commercialisation alternative fuels. This includes alcohol fuels, battery based vehicles, biofuels, hydrogen and ammonia fuels, synthetic fuels, vegetable oil, biomass, compressed air, and finally other less know fuels.

The information described can be used by decision makers in any AATP Region and beyond, to shape the future of transport by the use of the most appropriate alternative fuel.

Of key significance, the fuels described in this document have been selected as they can support an effective implementation of a green, sustainable and sound region.

OBJECTIVES

After reading this report, the reader should be able to:

1. Have a clearer understanding of the different types of alternative fuels available for use in the Atlantic Area Programme and beyond.

2. Understand the difference between the different fuel usage and what are their advantages and disadvantages.

3. Have a better understanding of the different means to produce Green Alternative Fuel (GAF).

4. Understand how apply some of the technologies described in this document to local communities, organisations, etc.

5. Understand how to store excess green energy generated by renewable sources as alternative fuels.

ALTERNATIVE FUELS OTHER THAN DIESEL AND GASOLINE

The sections below summarise some of the alternative fuels that are available to you to reduce your dependence on the well spread diesel, petrol, or in a more general term gasoline. The alternative fuels that are described are as follows:

- Bio-alcohol
- Biodiesel
- Batteries
- Hydrogen
- Ammonia
- Natural Gas
- Vegetable oil
- Compressed air

WHY GREEN ALTERNATIVE FUELS? - QUICK RECAP -

Alternative Fuels and **Green Alternative Fuels** are completely different and it is important to understand the difference between these two concepts before discussing the reasons behind green alternative fuels. Alternative fuels encompass all of the new type of fuels. To better understand alternative fuels, it is easier to list what are the fuels that are considered not to be alternative ones. These are the fuels that we use on a daily basis such as petrol, kerosene, gasoline and diesel. Basically alternative fuels are the fuels that are not currently mainstream.

Therefore, alternative fuels comprise all of the fuels listed above with a few more that are not market ready. In essence, alternative fuels include hydrocarbon based fuels (without the most common ones such as diesel, petrol, etc.) and green fuels.

For a fuel to be green, it must be produced from renewables (wind, solar, waste food, and others). As such, very few fuels correspond to alternative green fuels.

Error! Reference source not found. Figure 1 illustrates the different categories of fuels. It shows that green alternative fuels are included in alternative fuels. It also shows that alternative fuels are included in fuels.

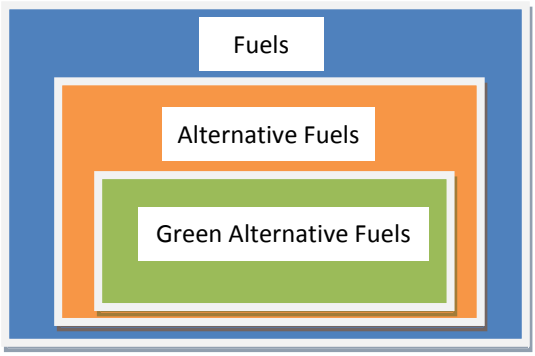

Figure 1 – The different categories of fuels

Now that one can differentiate between the three different categories of fuels, it is possible to define why there is a need for green alternative fuels. The reason is simple. Currently, the worldwide emissions have reached an unprecedented and unattainable level. Several severe weather conditions and catastrophes are now being linked with the high level of emissions, all of which have led to the too well known climate change.

In fact several islands in the pacific are being threatened to sink due to the sea water level

rising to an unprecedented height. Therefore, there is an urgent need to make a drastic change in the way we do things.

In addition to the above, it is important to note that the transport sector is responsible for about 30% of worldwide emissions. Therefore, if the transport sector is supplied with green alternative fuels, fuel being produced from a renewable resource, then this could see the start in reduction of emissions.

Furthermore, producing green alternative fuels could see the development of a complete new sector and support job creations at local levels.

The above clearly highlights that there is a strong argument for the development, deployment and production of green alternative fuels. The basic idea for such development is to use Green Energy from ***local, natural, endless green resources.*** This green energy would then be converted into green fuel, thereby allowing the reduction of emissions from hydrocarbon based fuels. Doing this would also provide great economical, environmental and operational benefits for any Atlantic Area located business and organisation. It would finally provide great benefits for every member of the public, where cities would not be subjected to hydrocarbon type fogs, the number of lung cancers from vehicle particles would reduce and many other health benefits attained.

Green alternative fuels will also find a great application when it comes to the supply of fuel in remote communities. It is clear to the Atlantic Area Programme that many localities and communities are suffering from fuel poverty. Such fuel poverty affects people's life to the extend that many are not able to afford to fill their car tanks full of petrol. In addition, the majority of remote community face fuel insecurity as they rely heavily on imported hydrocarbon based energy. This problem is particularly evident and accentuated in remote areas, where the fuel used is 100% based on hydrocarbon. Unfortunately, as the hydrocarbon is 100% imported, it makes it more difficult to access for the member of the public, as it is expensive and completely out with the control of the local users.

The above highlighted issue with importation of hydrocarbon fuel leads to the high cost of fuel prices and the consequential environmental pollution for using oil based energy sources. Consequently, it is clear that a hydrocarbon-fuel based economy in the based Atlantic Area (AA) creates further pressures onto organisations and anyone living in the AA. In the short to medium terms, such pressures threaten the actual functioning of the AA region as a whole and the member of the public in particular. Therefore, it is crucial and urgent to action the sourcing and uses of green alternative fuel methods based on local, clean and reliable resources.

A hydrocarbon based transport sector economy threatens the actual functioning of the Atlantic Area Region

It is critical that AA regions adopt alternative methods based on local green fuel and better transport intermodality means

BIO-ALCOHOL ALTERNATIVE FUEL

There are many different definitions available to describe bioalcohol alternative fuels. In essence, and for the purpose of the BATTERI project, a bioalcohol alternative fuel is simply a fuel that is based of alcohol. The most common alcohol fuels are:

- Ethanol
- Methanol
- Butanol

Basically, Ethanol fuel is an alcoholic fuel that is similar to the alcoholic beverages as found in supermarkets. Metaphorically, and if you think of it, your car could run from alcohol purchased from your local store. Regrettably, if you try to do this, you would not get the highest efficiency from your engine as Ethanol has some properties that makes is better than the usual store type alcohol.

Ethanol fuel is mainly used and produced in both the USA and Brazil (almost 90% of the worldwide ethanol production is from the USA/Brazil). The reason for this is that to produce ethanol you need substantial agricultural feedstock. As both USA and Brazil are high producers of agricultural feedstock, then this solution was seen as highly appropriate.

However, as ethanol uses substantial natural crops such as sugar cane, corn, potatoes, manioc and others, there is a still today long debates as to why one would use substantial resources such as land, water, fertilisers, etc. to produce fuel. This argument is supported by the fact that the land and other resources could be used to provide feedstock for millions of people who are dying from hunger. Therefore, though bioethanol is seen by many as a renewable fuel, it is clearly being criticised for using resources that could be directed for food crops.

Methanol is a fuel that can be produced from biomass, coal and natural gas. It is sometimes called wood alcohol because it can be produced from wood. However, though methanol can be produced from renewable resources (biomass), it is nowadays produced in its vast majority from natural gas. The reason is simple; natural gas methanol is cheaper to produce than with other resources.

One must be very careful with methanol (as with any other fuel). Methanol is a toxic fuel and therefore highly poisonous if swallowed. When both ethanol and methanol are compared, it is clear that methanol win in pricing and cost of production terms. However, ethanol wins in terms higher energy density and lower toxicity. Of importance, methanol can be produced from combining both CO2 and hydrogen.

On the other hand, Butanol can be produced using two different ways; it can be produced from biomass and in this case it will be called biobutanol. It can also be produced from fossil fuels and in this case it will be called petro-butanol. The main advantage of Butanol when compared to the other alcohol based fuels is that it can be transported using current

hydrocarbon (petroleum) pipelines, while both Ethanol and Methanol cannot use such mechanisms.

Ethanol fuel is mainly produced in the USA and Brazil

Alternative Ethanol fuel is highly criticised as it compete for resources that could be used for producing eatable food and to exterminate hunger globally

Methanol alternative fuel is mainly produced from natural gas and therefore it is sometimes not deemed to be an alternative fuel

Butanol alternative fuel is highly regarded as it is a fuel that can be transported and distributed using our current infrastructure. Hence, there is no need for further infrastructure investments

Both Ethanol and Butanol can be produced using biomass. In this case they are quantified as Green Alternative Fuels.

BIODIESEL

Biodiesel is simply diesel produced from living organisms rather than hydrocarbons. **The Atlantic Area is an ideal candidate for the development of biodiesel because it has most of its 'borders' as coastlines**. Those coastlines are perfect for algaculture. Algaculture is simply a method of breeding algae. Algae can then be turned into biodiesel, creating a unique

opportunity to produce fuel locally all around the AA coastline. As a fuel source, **algae can transformed into fuel and thereafter used directly as biomass to produce electricity as biodiesel for transportation. The figure below illustrates an algae that can be used for producing biofuel.**

The good news with biodiesel is that it is safe and can be easily transported from one location to another. As biodiesel is biodegradable, then it has a low associated toxicity. This means that even if there are spills, the level of pollution will be lower than the current diesel as found at the pump. In addition, biodiesel can be used in any diesel engine as long as it is mixed with mineral diesel.

Regrettably, fuel produced from algae is still a technology under development. The main issue is that it takes a long time to get a mature algae that can be processed quickly to produce fuel. As such substantial research is still undergoing to reduce the time it takes to grow algae and shorten the period from algaculture to biodiesel.

Figure XX – Algae used for producing biofuel[1].

Biodiesel can be produced from algae, it is biodegradable and in most cases non toxic

[1] http://inhabitat.com - *Ford Developing Biofuel From Algae for Use in Vehicles*

Electricity can be used to power electric vehicles. In its most common form, an electric vehicle received electricity from the mains electrical network (through a plug). This electricity is then stored into batteries. When the batteries are charged, the vehicle is then disconnected from the grid and ready for use.

Of high importance, electric vehicles can support energy security (by removing the need for importing fuel). They can also reduce emissions at the point of charge and use of the car (as they do not emit any CO2 when charging and when they vehicles are used). It should be noted that there is a category of vehicles that are called hybrid electric vehicles. These vehicles use electricity to boost fuel efficiency and therefore cannot be fully qualified as alternative fuelled vehicles (unless if they use biodiesel or other form of alternative fuel). In summary, state of the art electric vehicle come in three main types:

- **Standard Electric Vehicles (EV)**: Simply put, any standard electric vehicle is a vehicle that is fully powered by mains electricity. In other words, the mechanical motion/movement of the car is achieved through the sole use of the electrical power stored in batteries available inside the vehicle.

Obviously, and in this setup, batteries are charged using a standard electrical plug (e.g., your home wall plug). This means that your car's batteries are charged from the mains network grid (in most cases). Note that for safety purposes, all of the EVs come with a strange end plug. The most common of these type of plugs used for charging an electric vehicle is shown in Figure 1.

As aforementioned, it is important to be aware that EVs cannot really be associated with emissions. This is only true at the point of charge and use of the vehicle. Therefore, in terms of the *'fuel tank to wheel'* energy use, they are cleaner and produce much lower carbon emissions than any internal combustion engines (at point of use).

The aforementioned is true, but the facts about EVs are sometimes a little bit overstated. Though electric vehicles do not produce (or produce limited) emissions at the point of use, they regrettably are associated with emissions when being charged from the grid. The reason is that most of the electricity is generated from hydrocarbon fuels. Therefore, no organisation or individual can justify that by using an electric vehicle, it reduces its emissions. Hence, if you ever use an electric vehicle, you only shift the emissions to a different location: at the generating power station.

Nevertheless, there are times where an electric vehicle can be almost completely disassociated from emissions (apart from tires emissions). This particular case occurs when a car is charged directly from a renewable source. As such, and only in this instance, a vehicle can be said to be fully powered by Green Alternative Fuels (GAF).

Figure 1 – Common plug used for charging an electric vehicle[2]

- **Hybrid Electric Vehicles (HEV)**: Three main technologies are usually used to make an HEV:

1. A conventional petrol based Internal Combustion Engine (ICE).
2. A battery bank.
3. An electric motor.

An HEV ICE works in the same way a standard engine operates. It produces heat, which then produces motion. The difference between the two types of engines is found in that in the standard engine, the motion is directly transmitted to the wheels (mechanically) while in the hybrid version the engine motion is converted into electricity. It is this electricity that is then used to supply electric power to an electric motor. The motor turns, which then turns the wheels, hence providing motion to the vehicle. At the same time, the generated electrical power is used to charge the inboard vehicle's batteries (if need be).

It is important to note that the inboard batteries can be recharged in three main different ways. When the vehicle is in braking mode (the user applies pressure on the brake pedal). In this mode, the energy generated when the car brake is reclaimed and transferred to the batteries. This energy is also reclaimed during freewheeling of the vehicle (not all HEV do perform this), or as mentioned above, by receiving the electricity from the petrol based internal combustion engine.

Finally, the only way that an HEV could be considered as a green alternative fuelled vehicle is when it is fuelled using biodiesel (or other green fuel).

- **Plug in Hybrid Vehicles (PHEV):** A PHEV has the qualities and some of the disadvantages of hybrids and EVs. In essence, it is a hybrid vehicle, which has a petrol engine and an electric motor. It also has a larger battery pack (when compared to the HEV). In this instance, the battery can be recharged via a standard household electric socket.

As per the HEVs, any PHEV can only be considered as an alternative fuelled vehicle if the onboard battery bank is charged using 'green' fuel or green alternative energy. This can only happen if renewable electricity is used to charge the batteries and that biofuel (or other green fuel) is used to fuel the vehicle.

Having discussed the different types of vehicles, one should explain the advantages of electric vehicles against incumbent technologies? Using electric vehicles in any set up can have many benefits. **First, if and when a conventional combustion engine vehicle is substituted by an electric vehicle, it is possible to gain in air quality in the vicinity of the vehicle in question. Say that a city would run 90% of their vehicles as electric vehicles, then the city should be almost free from carcinogenic fog related to car emissions.**

Second, many are now complaining about the noise levels that vehicles are producing. Fortunately, electric vehicles are noiseless. Hence, considering the above example of a city running 90% of their vehicles as electric, the noise related to the transport sector would diminish dramatically. Third, there are many electrical grid network related issues with surges in demand that can cause the grid network to go in blackout modes (a black out mode occurs when the electrical grid network cannot cope with the demand and fails. When it fails, it shuts down the network or a part of the grid network, meaning that many consumers will not have electricity). EVs can be used to reduce such problems by taking power off the grid at times where there is excess power onto the grid. The power would be stored into the EVs batteries. The stored power would then be called upon when there is high

[2] http://www.renewableenergyworld.com - *Top Five Electric Vehicle Developments*

grid power demand. Such a system would work in conjunction with Smart Grids. To make the whole system green, there would only be a need to install renewable power and use electric vehicles as a dumping load.

Battery based vehicles are not noisy and have no emissions at the point of use

There are three types of battery vehicles, Standard Electric Vehicles (EV), Hybrid Electric Vehicles (HEV), Plug in Hybrid Vehicles (PHEV)

Electric vehicles can only be considered as green if the batteries are charged using renewable energy

Both HEV and PHEV can only be considered as green if they use biofuel

ALTERNATIVE HYDROGEN FUEL

Hydrogen is everywhere. We even find it in the human body and that in large quantity. If ones think of it, hydrogen is found in water as H2O where H2 is hydrogen and O is oxygen. As such, if we look at our blood structure, it is made of hydrogen, oxygen and other bits and pieces.

There are many different existing methods for producing hydrogen. The most notorious are reformation and electrolysis. In reformation, natural gas is reformed (meaning decomposed) to produce hydrogen. Hydrogen is stored and CO2 available in the natural gas flared away. Obviously, this is not the best method for producing hydrogen as it is associated with high CO2 emissions. Though it is not the best method for producing hydrogen, it is the method that is

currently widely used by the industry. In fact well over 90% of hydrogen produced worldwide uses the reformation method.

The other main hydrogen production method is electrolysis. To produce hydrogen with this method, you only need two things. These are water and electricity. In essence, electricity is used to split water into its two constituents; that is taking H_2O (water), and splitting it into H_2 (hydrogen) gas and O_2 (oxygen) gas. Both gases, H2 and O2, can then be stored for later use. Hydrogen can be used as fuel for vehicles, while O2 can be sold for other purposes such as welding, breeding fish, diving, etc.

In terms of hydrogen fuel, there are two sources of electrical power. One is a hydrocarbon based electrical power generation (from diesel power station). In this case, one would call hydrogen produced using hydrocarbon based electrical power as brown hydrogen. On the other hand, hydrogen produced using clean renewable power is known as green hydrogen or pure hydrogen.

When green pure hydrogen is used for fuel, then a hydrogen vehicle is said to have no emission. If brown hydrogen is used, then the vehicle is said to be associated with emission at the fuel production time and no emissions at time of hydrogen use in the vehicle. Therefore, though hydrogen is an alternative fuel, it can only be called green alternative fuel if it is produced using a green sustainable method such as electrolysis coupled with renewables.

Hydrogen alternative fuel has been for many seen as a perfect solution for the transport sector. The rational is that hydrogen can be used in our current standard Internal Combustion Engines (ICE). These engines require to be modified before running on hydrogen, which is the same for all alternative fuels (biomass, alcohol, biofuel, etc).

Alternatively, one can use hydrogen in a fuel cell vehicle. A fuel cell vehicle uses a fuel cell to produce electricity. This electricity is then transferred to an electric motor. The electricity allows the motor to turn and providing that there is enough torque generated, the vehicle shall move (forward or backward) as in any standard existing vehicle.

The main reason for developing hydrogen fuel cell vehicle is that they are highly efficient, do not have noise associated with them and do not emit pollutants, hence addressing many of our commonly acknowledged current issues with the transport sector.

However, even if hydrogen fuel cell vehicles look great from the outside, there is an issue with them. They are still quite expensive and not accessible to the member of the public.

Currently, as there is no mass manufacture of such vehicles, they are associated with high costs. Nevertheless, it is anticipated that the more demand there will be for hydrogen fuel cell vehicles, the cheaper the vehicles will become, thereby allowing more accessibility to the member of the public.

On a more positive side, hydrogen vehicles do not have the associated problems that battery cars are notorious for. First, battery based vehicles require a long charging time (between 6 to 8 hours), though some fast charging mechanism are available. Often these mechanisms do not take care of the short lifetime of batteries, hence providing a downside for fast charging. Second, battery vehicles have a distance issue. Very few battery vehicles can run for distances longer than 100 miles, which led to them being unpopular with the wider member of the public. Another major issue is found in that there is a lack of charging point and that the cost of battery recycling is quite high.

The above issues related to battery vehicles and the cost of fuel cell cars have led to the development of hybrid fuel cell battery vehicles. The hybrid configuration allows to take advantage of both technologies strengths. A battery is commonly agreed to be a highly

effective solution for supplying short burst of high electrical power requirement to the electric motor. A good example of such requirement is when a vehicle is at a red traffic light. In this case, and as soon as the light becomes green, the vehicle driver will accelerate. Such acceleration requirement needs a high level of electrical power. The power must be delivered quickly to the electrical motor in order for the vehicle to move forward, if not it may stay at the traffic light for a couple of seconds. Batteries are excellent in delivering power quickly and that in high demand. Therefore they are perfect to be used in vehicles for high burst demand.

Fuel cells are also good at producing electrical power quickly and in high demand. However, a fuel cell will be quickly damaged if it has to supply high power surges. Therefore, a fuel cell needs a buffer system so that it is protected from surges demands. Such buffer can be a battery. In addition fuel cells are quite good for long distance operation (about 300km with a 350 bar onboard hydrogen storage tank).

As batteries are good for surges, bad for long distances, and fuel cells are bad for surges and good for long distances, then both technologies can be used together to form a winning combination.

Finally, hydrogen can be used as fuel for boats/ferries, vehicles, heat, cooling and in any other application where an alternative fuel is currently being used.

Sustainably produced hydrogen can be used in petrol internal combustion engines and as a top up fuel for ferries, reducing naval and on land emissions

ALTERNATIVE AMMONIA FUEL

The process used for producing ammonia (NH3) is very well known and understood. Simply put, you only need three main elements to produce NH3. First you need electrical power. Second you need hydrogen. Third you need nitrogen which can be extracted from the air. All of these elements are plentiful in the Atlantic Area Region. When you have hydrogen and nitrogen, you just need to combine them together using the harber-bosh process to produce ammonia.

As such the electrical power is used for three main tasks. First it is used to produce hydrogen by either the reformation process or water splitting using an electrolyser. Second it is used to extract nitrogen from our ambient surrounding air. When these two components (H2 and N2) have been produced, they are combined to obtain NH3. This is where electricity is used for the third time.

Ammonia is an important potential alternative fuel. Its production can be completely green (it can also be brown when using brown electrical power and brown hydrogen from reformation).

The reason why ammonia is very important is that it is a dense fuel. Its density is about half the density of current petrol fuel. Therefore, one can think of an ammonia tank as just double the tank of our current vehicle to cover the same distance. For instance, if you have a 60 litre tank in your vehicle, then a 120 litres ammonia tank would be needed to cover the same distance.

What is important to remember is that it is fairly easy to convert an internal combustion engine to operate on ammonia. As it is simple to convert an engine, ammonia would be highly suitable for many applications such as fuelling ferries and other boat transport applications. It is also highly suitable for trains and could be used as a fuel for stationary electrical generation. The key point is that such a fuel can be produced in large quantities as long as there is water and electrical power. Therefore this fuel would be suitable as a dumping load when excess energy is available onto the electrical grid, but also in conjunction with renewable. Finally, this fuel has the potential to reduce the emissions and can be produced locally for local consumption, thereby reducing hydrocarbon dependence.

Further to the aforementioned, there is already a global market for ammonia. NH3 is used worldwide as a fertiliser and therefore can be a solution not only for transport, but also to support farmers in the Atlantic Area. The idea would be to develop small ammonia plants on farmer's land. Then, tractors and heavy duty plants could be converted to run on NH3. Thereafter, farmers would be trained to produce their own ammonia fertiliser. Finally, and when the above stages are finalised, the region could support farmers in exporting their locally produced fertiliser to other countries.

Using the aforementioned strategy, the NH3 plants will become an economical asset for farmers in the Atlantic area. In fact, farmer will be able to sell their locally produced fuel, fertiliser, oxygen (produced via electrolysis) and hydrogen. These are five products which would greatly help farmers facing financial issues to construct a brighter future.

It is very simple to convert an internal combustion engine to run on ammonia such as tractors, cars, etc

Only electricity, water and air is required to produce ammonia

Ammonia can be used in boats, train and inter-islands ferries

Farmers in the Atlantic Area region can become fuel independent by using hydrogen and ammonia

ALTERNATIVE NATURAL GAS FUEL

Alternative natural gas used as fuel for the transport sector has been available for a long time. It was not very popular in its early days because diesel and petrol fuels were so cheap. As the price of diesel and petrol became almost unsustainable, it was clear that another alternative fuel was to be looked at. Natural Gas (NG) was the natural choice made by many as there was an existing infrastructure for transportation and distribution of this gas.

In addition to the above, NG is already widely available at a domestic level. In many houses, in and around the different regions of the Atlantic Area, NG is connected to houses for cooking and heating requirements. It is provide to the customers in its gaseous form, readily usable through the utility infrastructure.

As such, this alternative fuel can nowadays be used by any fleets such as buses, taxis, trucks and many more. These are usually called CNG (Compressed Natural Gas) vehicles. The only requirement would be to add a CNG compressor and a CNG refuelling station.

The main benefit of natural gas is that it is a cleaner fuel than petrol and diesel. Usually, NG is used in vehicles as either compressed natural gas (CNG) or liquefied natural gas (LNG). Though LNG was widely available in the 90s, nowadays, it is the CNG that has taken off. This is especially true in Asia and USA, while in Europe a number of countries are starting to wake up to such technology such as Italy, Netherlands and Germany.

With the uptake of natural gas Fracking, the cost of natural gas has reduced dramatically and this has led to a large investment by bus manufacturers and users in the use of CNG buses. In turn, this has led to a new industry taking up around the world and provided a much deserved break from the ever increase in fuel costs. Though the low pricings of NG is good for the industry and the end customers, questions are still being asked as to the environmental damage gas fracking could cause.

Gas Fracking has provided a well deserved resurgence of CNG vehicles, especially buses. However, there is no clarity as to what is the environmental impact of Gas Fracking.

CNG alternative fuel can be produced from Waste (CNG-fW). Such technology is well understood and has been widely developed. Simply put, NG is extracted from waste, which would otherwise been dumped in fields.

In general, all food type waste is taken to a depot and converted of the biodegradable waste into useful biogas. The process to do this is called anaerobic digestion and such a biogas storage system is shown in Figure 10.

To produce biogas, there is need for a large amount of biodegradable waste. The rational is that in biogas does not make financial sense in a small scale. **The Atlantic Area has many agricultural and fish regions which could convert their agricultural and fish waste into biogas.**

Figure 2 – Example of Biogas storage system

Many of the Atlantic Area Regions have agricultural waste and fish waste that can be converted to biogas for use as an alternative fuel.

ALTERNATIVE VEGETABLE OIL FUEL

Waste vegetable oil can be used to produce alternative fuel. This has long existed but is still today forbidden by law in many countries. The reason is mainly taxation issues. Fuel taxation and oil taxation are in two different taxation categories. Also, if cars would run on vegetable oil, then this could create a vegetable oil crisis. Hence, more fields would need to be planted with sunflowers to produce lucrative vegetable oil fuel, hence potentially creating a food crisis at global level.

However, many car manufacturers have worked on the idea that vegetable oil could be the fuel of vehicles. For instance, Volkswagen has developed a car that can run from a clean fuel, that is recycled vegetable oil, though there is a need for a special permit to run these vegetable oil cars.

A vegetable oil fuelled car industry could lead to a vegetable oil crisis

COMPRESSED AIR FUEL

A compressed air fuelled vehicle is simply a vehicle that uses air as a fuel to provide motion. In essence, air is compressed in a car inboard's tanks. When the tanks are full, then vehicle is ready for operation. The air is therefore released. When it is released, the compressed air expands and pushes the pistons. As the pistons moves, the car is then propelled forward (or backward).

Compressed air vehicles are green at the point of use (they do not emit CO2). In order for an air compressed car to be completely green, there is a need for green electricity to be used to compress the air. Currently, there are no wide manufacturing of such vehicles.

Compressed air vehicles are not yet widely commercialised and need green electricity to qualify as being green

WHAT IS BATTERIE ATLANTIC AREA PROJECT?

BATTERIE is an EU Atlantic Area Programme 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 other twelve 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.

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