Institut Thomas More

TRIBUNE

N° 30/Eng – Energy, climate & environment Study Programm – April 2011

Alternative fuels and vehicles: do the european policies make sense?

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Oil reserve depletion, security of supply, energy saving, energy independency, pollution and GHG emissions lead to the basic question: are there realistic alternatives to gasoline and diesel oil, the conventional fuels used for transport?

A holistic approach involving all stakeholders like technology, business, consumers, governments, infrastructure and at last but not least environment, is the more efficient and realistic way to discuss this issue.

The solutions will be sustainable only if they meet the accessibility, availability and acceptability criteria.

The European Commission sets a 10% target share of renewable energy in the transport sector by 2020. But under which conditions renewable energy is sustainable? To properly address the sustainability issue, energy consumption and GHG emissions must be computed globally i.e. over the alternative energy lifecycle: raw material growing and/or power generation, land use changes, industrial production, transport and so on.

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Currently, transportation accounts for more than 50% of the world consumption of liquid fuels. According to ExxonMobil, global transportation fuel demand will further increase in the coming two decades, mainly from heavy duty vehicles.

The EU-27 is also facing an important growth of transportation fuel consumption but with a major supply/demand imbalance, the ratio diesel/gasoline in 2010 being 2.1 (the so-called dieselisation of cars). According to Europia, in 2030 the transport mix in EU-27 is expected to be about 70% for diesel and about 20% for gasoline, the balance for biofuel.

"In 2007, about two thirds of transportation energy use in OECD countries was for passenger travels" (1). This share is expected to slightly decline through 2035.

Energy consumption in EU-27 transport sector accounted for 31% of the total final energy consumption in 2005, up from 26% in 1990. "The transport sector is the largest consumer of oil products in the EU energy system, consuming almost 60% of total oil products. This share was 52.7% in 1990 and is projected to attain 64.4% in 2030…The share of biofuels in liquid fuels consumed for road transportation accounted for only 0.2% in 2000, but increased to 1.1% in 2005 and is projected to reach 9.5% in 2030 (7.4% in 2020)… In EU-27 transport sector, the share of road transport energy consumption in 2007 amounted to 82% and air transport to 14%" (2). By 2030, still 80% of transport fuel will come from fossil fuels.

According to IEA (*World energy outlook 2010*), oil demand (excluding biofuels) continues to grow steadily, reaching about 99 million bbl/day by 2035, 15 Mbbl/d up on 2009.

All of the net growth comes from non-OECD countries, almost half from China alone.

Unconventional oil is set to play an increasingly important role in world oil supply through 2035. It will meet about 10% of world oil demand compared with less than 3% today.

1. Alternative fuels for transport

A global approach is the more efficient and realistic way to compare the different types of alternative fuels. The choice of fuels and vehicles of the future should take into account all stakeholders and, in particular, costs, consumers' acceptance, technology, infrastructure, geopolitics and at last but not least environment.

1.1. Biothanol

Bioethanol is an alcohol made by fermenting and distilling sugars. "For historical, economic and practical reasons, the main crops used for the industrial production of ethanol are sugar cane, corn, wheat and sugar beet. The last two are currently and for the foreseeable future the main sources of bioethanol in Europe… The fermentation process produces alcohol at a fairly low concentration in the water substrate. Purification of the ethanol by distillation is fundamentally energy intensive... There are two options for utilizing the pulp leftover after filtration of the diluted ethanol liquid: animal feed or fuel for the ethanol production process… The possibility of extending the range of feedstocks available for ethanol production from sugars and starch to cellulose is very attractive and a lot of research is being devoted to developing such routes" (3).

> GHG emissions and environment

According to Concawe (4), ethanol from sugar beet well-to-wheel (WTW) GHG emission amounts to 110g CO_2/km (with pulp to animal feed) whereas pure gasoline WTW (5) emission is 160 gCO_2/km (2010). Instead sugar cane and wheat straw ethanol WTW emission is much lower, 20/25 g CO_2/km.

Cellulose ethanol reduces GHG emissions much more than sugar beet. Therefore the US Renewable Fuel Standard (RFS) requires from 2010 that a growing portion of the RFS be met using cellulosic biofuels with lifecycle greenhouse gas emissions 60% less than the baseline lifecycle GHG emissions (gasoline or diesel).

However, if several full life cycle studies concluded that corn, cellulosic and Brazilian sugar cane ethanol reduce GHG emissions as compared to gasoline, none of these studies considered the effects of indirect land-use changes (ILUC).

This is a controversy about the real saving of carbon debt. This controversy was intensified in the US when the California Air Resources Board (CARB) included ILUC impacts to establish the California low-carbon fuel standard to be enforced in 2011. When such effects are included, "the lifecycle GHG emissions for US corn ethanol may increase from 135 gCO_2eq/MJ to 177 gCO_2/MJ" (6) which is above that of gasoline. "There is a variety of uncertainties around these net impacts related to economic models, vulnerability of ecosystems, natural disturbance regimes and effects of climate change".

The UK renewable transport fuel obligation program had a similar approach when requiring the Renewable Fuel Agency (RFA) to report any potential impacts of biofuel production, including land use changes, food and other commodity prices. The EU is also concerned with this problem. It issued a directive approved with amendments by the European Parliament, calling for more stringent sustainability criteria for biofuels and other renewable fuels for transport, including indirect land use changes although non specific ILUC penalties have been adopted.

However integrated production of ethanol (e.g. sugar beet by-products like beet pulp which can be sold for animal feed, and molasses which is also sold for animal feed or further processed to extract more sugar) could rescue, to some extent, the battered environmental image of 1st generation vegetable oil fuels. But those processes could be very energy intensive.

To overcome that obstacle, the concept of biorefinery exploiting both the materials and the energy in organic matters is being implemented. A major part of the raw materials used is to be converted into energy, reducing simultaneously both its energy requirements and its consumption of resources.

According to a study by the German IFEU (7), 1st generation ethanol obtained from integrated processes, cannot save, in the best case, more than 50% of the GHG emitted by fossil fuels.

In addition to CO2, emissions from corn ethanol plants include SO_x, NO_x and CO, mercury, particulates. A study published by " Science" in February 2008, shows that ethanol from corn is producing more CO_2 than it spares.

> Prices

The evolution of wheat, corn, vegetal oil or rapeseed prices has an important impact on the competitivity of alternative fuels with respect to petroleum fuels. 20% of the corn production in the US are burned as ethanol and 50% of the European rapeseed production is transformed in biodiesel.

In 2009, the cost of Brazilian ethanol was 0.2 USD/l or 11 USD/GJ, US ethanol price was 0.3 USD/l or 14 USD/GJ and European ethanol, 0.4-0.6 EUR/l or 19-20 EUR/GJ compared to gasoline (50 USD/bbl) price of USD 12/GJ or USD 22/GJ for USD 100/bbl (8).

On the other hand, promoting bioethanol in Europe contributes to increasing refineries production imbalance between gasoline and diesel.

> Performance

Because of its lower energy content per unit volume, bioethanol performance is lower than conventional gasoline. Fuel economy is reduced by approximately 30%. Ethanol however has a higher octane rating than gasoline (113 for bioethanol compared to 87 for regular gasoline). In cold weather, an ethanol powered vehicle may be difficult to start. Indeed because of its lower vapour pressure, engine ignition is more difficult at low temperatures for vehicles running on fuels with high ethanol content.

In terms of energy density, bioethanol (24 MJ/l) is much less performing than gasoline about (34 MJ/l) and diesel (about 36 MJ/l) and even biodiesel (32 MJ/l) (9).

Professor Pimentel, who has been investigating the energetics, economics and environmental aspects of ethanol production (the holistic approach), asserts that "it takes more energy to make ethanol from grain than the combustion of ethanol produces" (10).

The calorific value of bioethanol is 21.3 MJ/l, less than that of biodiesel (see point 1.2, "performance").

> Infrastructure

Investments are required in Europe for providing adequate infrastructure (refuelling stations, pipelines), production facilities for needed volumes at reasonable costs and development of new hybrid vehicles running on a biofuel ratio exceeding 10/15%. Ethanol and gasoline/ ethanol blends cannot be transported through existing pipelines that carry gasoline.Water present in petroleum can pull ethanol out and cause ethanol gasoline blends to separate into two phases. It must thus be transported within an independent distribution system from the production facility to distribution terminals where it is blended with gasoline just before delivery to retail stations.

Most actors in the alternative fuel industry agree that the long term success of bioethanols will depend on the development of their second generation. Indeed they have a higher GHG emission reduction potential and have no adverse effects on food prices, biodiversity and labour. For example, they are made from non-food cellulose, waste wood, straw and cellulose based waste.

> Social and ethical considerations

Beyond the GHG emissions, prices, pollution and infrastructure considerations, the question is "whether there are sufficient ethical justifications for bioethanol production to override the negative consequences" (11) as increase of food prices (as a consequence of land use changes) and eviction or marginalization of vulnerable groups or individuals.

A point in case is the massive investments in sugar cane plantations aimed at producing ethanol in Brazil. Beyond meeting completely the domestic bioethanol demand, Brazil became the second ethanol exporter in the world and will soon take over the US position, all this, to some extent, to the prejudice of the local people and of biodiversity. "Our kids are dying of starvation because your cars are thirsty" is in a nutshell the message delivered by the Indian representative to the European Authorities in Brussels in December 2010. It is all the more worrying that Europe relies on Brazilian ethanol to reach its 10% green transport objective as of 2020. Second generation forms of biofuels have a role to play.

1.2. Biodiesel

The conventional diesel/gasoline consumption ratio in the EU-27 was in 2010: 2.1 (192 to 90 million tons/year) (12) which is much higher than in the US and causes a major supply/demand imbalance in Europe. Because of this high share of diesel, large quantities of biodiesel will be needed to meet the European objective of 10% of renewable energy in the transport sector by 2020.

Biodiesel is produced by converting oil from e.g. rape, soybean, palm tree, animal fats and recycled cooking grease to fatty acids which in turn are converted to esters. Oils and fats can also be converted directly to methyl or ethyl esters (Fatty Acid Methyl Ester: FAME) using an acid or a base to accelerate the transesterification reaction. In Europe, the main crops are rape (colza) in the centre and north and of less importance, sunflower in the south. There are a number of by-products, the most important being the residue after pressing (cake) and glycerine produced during the esterification step. The cake is a protein rich animal feed used in substitution of otherwise imported soy meal. Glycerine is used in many food and cosmetic applications.

> GHG emissions and environment

Biodiesel provides significantly reduced emissions of carbon monoxide, particulate matter, unburnt hydrocarbons and sulfates compared to petroleum diesel fuel.

There are essentially two sources of GHG emissions from the field which are responsible for a large portion of the GHG emissions: nitrogen fertilizer and emissions of N_2O."Because the powerful greenhouse effect of this latter gas (300 times that of CO_2), even relatively small emissions can have a significant impact on the overall GHG balance" (13). The GHG emissions for biodiesel pathways vary between about 35 gCO_2/km to about 80 g/km according to the production process compared to about 160 g/km for conventional diesel.

However when taking ILUC into account, US Midwest soybeans biodiesel GHG emission, for instance, would increase from 27 gCO_2/MJ to 69 g/MJ. The worst case scenario is converting Indonesian or Malaysian tropical peatland rainforest to palm biodiesel production which would take about 420 years to repay its biofuel carbon debt (14). Indonesia, for example, is the world's third largest GHG emitter and 80% of Indonesia's emissions come from forest loss and peatland degradation (15).

> Cost

The cost of biodiesel is higher than the one of petrodiesel. It is highly dependent on feedstock process, land type, crop yield and credit for by-product like glycerine, fatty acids and filter cakes. The feedstock price is the largest single component of biodiesel production costs. Yellow grease is much cheaper than soybean oil but its supply is limited.

Cost reductions are expected from economies of scale of new processes.

> Performance

Biodiesel's energy density is about 40 MJ/kg by mass and 32 MJ/l by volume which is much better than bioethanol. It is also less energy intensive than ethanol as the manufacturing process involves only relatively simple, low temperature/low pressure steps. It is a better lubricant than petro-diesel which contributes to extend the working life of engines and offers efficient combustion. However its performance in cold conditions is worse than that of petroleum diesel.

One of the most important characteristics of diesel fuels is their ability to auto-ignite (quantified by the cetane number). The cetane number of biodiesel from soybean is well above that of petroleum diesel.

Pure biodiesel and biodiesel blended with petroleum diesel provide very similar horse power, torque and fuel mileage compared to petrodiesel. In its pure form, it has an energy content 5 to 10% lower than petroleum diesel. When blended at B20 (16) level, there is less than 2% change in fuel energy content.

The well-to-wheel energy requirement varies from about 50 MJ/100km to 80 MJ/100km according to the production process.

The calorific value of biodiesel is about 37 MJ/l which is 9% lower than regular n°2 petrodiesel.

> Infrastructure

Because biodiesel is chemically very similar to conventional diesel, the existing distribution system can be used with only a few modifications. However since biodiesel is a rather aggressive solvent, it can cause deterioration of rubber and polyurethane materials (e.g. seals).

In contact with moisture it produces fatty acids which could damage the fuel injection system and the engine itself. It also oxidizes much faster than petrodiesel and therefore proper care is needed to avoid premature ageing during storage. Thus limiting exposure to airborne moisture and water deposits and using suitable additives improve biodiesel's ability to withstand long term storage.

> Social and ethical considerations

"Two ethical issues are now emerging in the storyline of biofuels. The first is the food-fuel trade-off. Rising global food prices have accompanied rising fuel prices, and we should not be surprised that people make an association between reports about food riots in Haiti or Mexico and the thought that farmers are devoting larger and larger portions of their output to biofuel production.

The second ethical issue concerns the environmental implications of the push toward biofuels. Farmers would happily grow more food for hungry people, but they do and will continue to base this decision on their expected monetary returns. The ethical decisions here occur in terms of how policies and technology affect farmers' incentives… Any displacement of land currently used for food production can be expected to interact with a number of other forces that will contribute to a steady increase in the price of food. Because they spend a great share of their income on food, this will disproportionately harm the poor" (17).

The obligation imposed by the EU to increase the share of renewable energy in the transport sector up to 10% within 2020 will worsen the situation. Indeed such an objective cannot be attained without massive importation of biofuels from developing countries with negative consequences such as deforestation, displacement of food crops, poor labour conditions or even loss of jobs, large scale integration replacing progressively small farming and so on. This is already the case in a huge region covering south Brazil, north Argentina, Paraguay and east Bolivia.

As far as nature is concerned, "there is still a need for explicit articulation of environmental ethics for two reasons.

One is that people value nature for many different reasons, ranging from commodity production to ecosystem services and aesthetic appreciation.

The second is that our ability to put the environment in danger through pollution and anthropogenic climate change means that we must articulate obligations to future generations, also a daunting task... To the extent that shifting land use to production of biomass for fuel production is viewed as an action undertaken by established economic and political interests, it will be a natural target for the core constituency of a social movement that defines itself in terms of resistance to these interests" (18).

2. Hydrogen and fuel cells (FC)

Although it is the most widespread element in the universe, free hydrogen does not exist in nature. Its extraction from hydrocarbons or water, requires energy input and results in GHG emissions to varying degrees depending on the source of energy and the specific pathway chosen.

Hydrogen can be used in fuel cells or directly in an internal combustion engine (ICE). The maximum efficiency of hydrogen ICE (carried either in compressed form at 70 MPa (19) or in liquid form at atmospheric pressure in a cryogenic tank) is expected to be very close to the best 2010 diesel engines. Compression or liquefaction account for a significant portion of the WTW energy requirement.

Fuel cells are chemical converters fed by gaseous hydrogen (in our case) and ambient air producing DC current, heat and water. Their main upside is their high energy conversion efficiency compared to thermal engines.

Two of the many challenges facing developers are to increase the FC lifetime and to reduce the heating up time to normal operation. A battery (hybrid engine) offers to start without waiting but at the expense of mass and cost.

Fuel cells being more efficient than ICE's, a smaller quantity of hydrogen is necessary and the tank can therefore be smaller and lighter than for hydrogen ICE's.

> Prices

50% to 80% of costs stem from primary energy and hydrogen production (20), the balance comes from refuelling stations, distribution, transport and the like.

In the coming years, natural gas (with rather large reserves which could substantially increase if the production of shale gas is widely adopted) is likely to be the cheapest source of hydrogen (21) and when produced in a large central plant, the cost per MJ (megajoule: 1 million joules) may approach that of conventional fuels, particularly in a gasoline high price scenario. However in the longer term, electrolysis is likely to be a better pathway.

One obstacle to develop hydrogen vehicles is the cost of the platinum catalyst. This difficulty could be overcome if platinum is replaced by Ni, Fe or cobalt e.g. by fixing those metals on carbon nanotubes.

Hydrogen distribution involves substantial investment cost to provide adequate pipeline networks and refuelling stations, practically non-existent for the time being.

The price premium over the basic gasoline vehicle is estimated to be 25% for hydrogen ICE vehicles and at least 50% for fuel cells (22). However it is expected that with technological advances, the price of fuel cell system will decrease in the future.

According to GermanHy roadmap, hydrogen price at German refuelling stations would be 4-5.5 EUR/kg in 2020 and 3.5-4.5 EUR/kg in 2030. Is it reasonable to expect that in Germany over 70% of all cars and light duty vehicles (LDV) may run on hydrogen and fuel cell technology by 2050 (23)?

> Infrastructure

"Hydrogen production can be envisaged either centrally in a large plant or, in a number of cases, locally in a small plant serving one or a few refuelling sites. This "on site option" is plausible for natural gas reformers, wood gasifiers and electrolysers.

Although central plants tend to be more efficient, the downside is the need to transport hydrogen... The development of a large scale hydrogen pipeline distribution network would be costly and would require a European regulatory framework to ensure safety and public acceptance. Those hydrogen pipelines that already exist in Europe cover relatively short distances to link major industrial sites and would be of limited use in this respect.

For small volumes, transport of gaseous hydrogen using tube trailers is feasible, but the mass of the containers is very high compared with the amount of hydrogen transported. It has been estimated that up to 19 trucks might be needed to deliver the same amount of energy delivered by one gasoline truck.

Even in liquid form, hydrogen remains a low-density carrier with implications on the options for road distribution channels (as an illustration supplying a hydrogen refuelling station might take five times as many trucks as is the case for conventional fuels)... Ensuring reliably fast and safe refuelling, at pressure as high as 70 MPa is a challenge" (24).

Vehicles with on-board reformers converting methanol for instance into hydrogen which is fed to the fuel cell, offers the advantage of avoiding the distribution infrastructure but on-board storage are counterbalanced by the much greater complexity of the vehicle and its higher mass. Using normal liquid fuels, those vehicles also emit CO_2 and other pollutants.

Hydrogen is not more dangerous than other fuels although some specific characteristics as wide range of inflammability, quick diffusion, density lighter than air and so on, must be taken into account. Linde is already installing hydrogen refuelling stations in Europe although it is not justified by the current demand.

> Performance

The potential performance of hydrogen fuel (in fuel cells) exceeds that of all other alternative fuels. Fuel cell vehicles are significantly more efficient than gasoline engines. However the fuel cycle emissions from the production of hydrogen fuel to tank (WTT) could diminish its excellent environmental performance depending on the primary fuel used (type of electrical plant supplying power for hydrogen production).

Thanks to their outstanding performance, their reduced maintenance and high flexibility (high efficiency even at low capacity) and to the fact that hydrogen can be generated from different energy sources, fuel cell vehicles could be a better option, for longer distances, than electrical vehicles in 15/20 years (or less?) time when their technology will be mature including lifetime concerns (25), and when the relating distribution system will be sufficiently developed. All this requires political involvement. "It is expected that the hydrogen share as a transport fuel will increase until 2050 in Germany to reach a stake equivalent to biofuels" (26).

However this is not a common view. For example, the US Secretary of Energy Steven Chu announced that the government would cut research into fuel cell vehicles in his department energy budget. "Biofuels and batteries, he said, are a much better place to put our money".

3. Electric vehicles

According to the European Automobile Manufacturers' Association, electric cars could make up to 10% of the market of new vehicles by 2020-2025. However the European companies are lagging behind Asia and even the US in terms of investment in the electric transport sector and in particular in battery technology.

Although battery costs are likely to fall, electric cars may remain more expensive than conventional vehicles for the next two decades according to a report by a green transport campaign group " Transport and Environment". Because of their limited driving range, pure electric vehicles will probably mainly be used for daily commuting and urban traffic. They will therefore generally be lighter and smaller than fossil fuel cars.

Most of the figures given hereafter under "performance" and "GHG emissions" are taken from a report of the European Association for Battery Electric vehicles (www.going-electric.org).

3.1. Performance

Electrical motors are more efficient than internal combustion engine and they do not consume energy while at rest. Moreover some of the energy lost when braking is captured and re-used through regenerative braking. Battery sizes and weight are a major concern. Indeed, for instance, to store the equivalent of 1kg of oil, a lead battery of 300 kg is required.

Tank-to-Wheel (TTW) energy efficiency, i.e. the ratio of the energy transmitted to the wheels divided by the energy input into the car.

> Fossil fuel vehicle

TTW energy efficiency of the best ICE (internal combustion engine) is in ideal conditions less than 22% for diesel and 18% for gasoline. Of course those figures depend on driving style and traffic conditions. They are significantly lower in congested urban traffic.

> Electric vehicle

TTW energy efficiency (from electrical plug to the wheels) is comprised between 55 and 65% for lead acid batteries and between 65 and 85% with lithium ion batteries. These figures vary little with driving style and conditions, since electric motors efficiency is rather constant at most speeds and because electric vehicles consume no energy when idle. TTW performance of electric vehicles is about three times higher than fossil fuel vehicles in ideal conditions.

Well-to-Wheel (WTW) energy efficiency

> Fossil fuel vehicle

The Well-to-Tank (WTT) energy efficiency, including production and distribution of the fuel is about 83%-85%. With TTW energy efficiencies of 18% for gasoline and 22% for diesel, WTW efficiencies are:

0.83 x 18 = 15% and
0.83 x 22 = 18%

> Electric vehicle

The Well-to-Tank energy efficiency varies widely with the type of power plant:

up to 40% for conventional power plants
up to 58/60% for combined cycle power plants
up to 85/90% for cogeneration plants

The energy efficiency of electricity distribution is comprised between 90and 95%. For the sake of comparison, let us take an average generation efficiency of 50% and an average distribution efficiency of 92.5%. The WTT efficiency is therefore:

0.925 x 50 = 46.25%

With TTW efficiency of 60% for lead acid batteries and 72% for lithium ion batteries, WTW efficiencies become:

0.60 x 46.25 = 27.75% and
0.72 x 46.25 = 32.4%

3.2. GHG emissions

Well-to-Wheel CO_2 emissions i.e. emissions generated by the vehicle as well as by the power plant or the refinery and by the distribution system amount to:

> For gasoline vehicle

CO_2 emission from gasoline combustion	2.35kg/l
including WTT: 2035 x 1.17 (27)	2.74kg/l
or in g/MJ with the energy produced by 1 l of gasoline combustion of 37 MJ/l: 2,740/37	74 g/MJ
or in g/kWh, with an efficiency of 18%, 1/0.18 x 3.6 x 74	1490 g/kWh

> For diesel powered vehicle

CO_2 emission from diesel combustion	2.7kg/l
or including WTT: 2.7 x 1.19 (28)	3.21 kg/l
or in g/MJ, with the energy produced by 1 l of diesel combustion of 38 MJ/l	84.5 g/MJ
or in g/kWh, with an efficiency of 22%, 1/0.22 x 3.6 x 84.5	1,370 g/kWh

> For electric vehicle with lead acid batteries

CO_2 emission from production and distribution of 1 kWh of electricity (29)	443 g/kWh
Energy input/kWh to the wheel: 1/0.6	1.7 kWh
WTW CO_2 emission: 443 x 1.7	753g/kWh

> For electric vehicle with lithium ion batteries

CO_2 emission from production and distribution of 1 kWh of electricity (30)	290 g/kWh
Energy input/kWh to wheel: 1/0.72	1.4 kWh
WTW CO_2 emission/kWh: 290 x 1.4	406 g/kWh

3.3. Cost

Electric and hybrid vehicles are significantly more expensive than comparable conventional vehicles. Batteries represent the primary factor of the additional cost.

Lead acid batteries are still the most used form of power for most of the electric vehicles today.

The batteries must be replaced because charging forms deposits inside the electrolyte that inhibit ion transport and diminishes the capacity. A standard Li-ion cell that is full most of the time, irreversibily loses approximately 20% capacity/year at 25°C. Otherwise Li-ion batteries incur very low maintenance costs.

US and British car buyers seem to be unwilling to pay more for an electric car. This would prohibit the mass transition from gasoline to electric cars without attractive incentive schemes. This is not the case in other countries like Japan, for instance, where hybrid electric cars sale performances are excellent.

Both the US and China have pledged substantial amounts of money in grants for the electric car industry: vehicles and batteries.

3.4. Infrastructure

Electric vehicles do not require, in a first stage, any significant modification of the electricity infrastructure. The majority of users will prefer to recharge their electric vehicle during the night (off peak hours) to benefit from cheaper tariffs. In doing so, they are using the most efficient electricity generation because power stations operated over night are base load plants having lower marginal operating costs, their investment costs being depreciated over a large number of operating hours. The increase in electricity consumption during off-peak hours will contribute to a levelling of the electricity demand.

In Europe, it is estimated that about 20/25% of the car fleet can be electric without requiring significant modifications of the electric infrastructure.

The market penetration growth of electric cars obviously require a substantial price reduction of their battery pack. The driving range of the BEV's (31) and the development of public/private recharging infrastructure to overcome the "range anxiety" is another concern.

A number of projects have been launched to promote electric vehicles. They are sponsored by car manufacturers and by power suppliers. In Berlin, for example, Daimler has provided more than 100 electric vehicles while RWE has financed 500 charging points, within the territory of the city, powered by renewable energy. EnBW (Energie Baden-Würtenberg, a German utility) plans to have over 700 charging points in its region by the end of 2011, along with two to three hydrogen filling stations. The power supplied by EnBW charging points will be 100% hydrogenerated.

4. Natural gas powered vehicles

In spite of the fact that the technology for natural gas (NG) powered cars is available, NG is being overlooked for cars although energy supply security is a major concern and gasoline prices are increasing. NG powered cars emit less CO_2 than comparable sized conventional ones and are less polluting than gasoline or diesel engines. Moreover gas is the only fossil fuel gaining significantly more reserves over the last decade.

The natural gas grid developed in most areas of Europe to serve domestic, commercial and industrial customers can be used for supplying NG to refuelling points. For a road market penetration up to the 10% mark, it is generally accepted that sufficient capacity would be available in the existing grid. However some areas in Europe are not served by the grid and it is unlikely that transport demand alone would justify extensive additions to existing networks (32).

Large gas powered vehicle market penetration suffers from a number of obstacles. They are not enough stations selling NG to make them practical for cross country drives. They do not have as much driving range as gasoline powered cars and their fuel tanks take up much space.

To give an example of lack of market penetration, only about 1000 of the more than 300,000 civic subcompacts that Honda currently sells in the US are NG version.

5. European policy

The European Commissioner responsible for energy said that "in the years to come, biofuels are the main alternative to gasoline and diesel used in transport, which produces more than 20% of the greenhouse gas emissions in the EU… We have to ensure that the biofuels used are sustainable".The 2009 Renewable Energy Directive sets binding targets for renewable energy. The new directive for renewable energy sources call for the promotion of only sustainable biofuels i.e. those that save at least 35% CO_2 compared to the oil that would be consumed instead. This threshold will rise to 50% in 2017 and 60% in 2018.

This applies to all biofuels instead of promoting only those which are the most efficient and with the less negative impacts as explained above.

The efficiency issue is particularly important for the transport sector whose energy consumption is the highest of any sector. Energy saving and efficiency enhancing should be the top priority of the EU. Unfortunately it does not appear to be so except in speeches. As Jennifer Rankin (33) put it: "The general EU policy objective is to increase energy efficiency in the EU as to achieve saving of 20% of the EU's energy consumption by 2020 with respect to the 1990 level. This 20% goal has been restated in an endless stream of strategy papers, action plans and Council of Ministers conclusions but the EU is still falling short". Instead, the EU is still promoting across the board, through massive subsidies and "green protectionism", the production of biofuels in Europe whatever their negative impacts.

The group of experts (34) appointed by the Commission to report on the future transport fuels emphasized in their January 25, 2011 document that "the main objective of a long term strategy should be a sustained effort to increase the energetic efficiency". They also pointed out that "the development of the alternative fuels will depend on their technical and economical viability, on their compatibility with the current infrastructure, the efficient use of the primary energy and the market." It is interesting to note that, although Greenpeace participated in the drafting of the report, the Greenpeace responsible for transports Franziska Achterberg casts doubt about the biofuels. It is, according to her, the weak point of the report. She claimed that the Commission did not want to include in the report that the biofuels could have a more negative carbon footprint than the oil products. This is also the view of ActionAid : "To provide the biofuel needed to meet the EU's targets, EU companies are busy buying up land. But in doing so, they could cause another food crisis in Africa… For some African farmers, biofuel amounts to one time cash inflow from the sale of their land. For their communities though, it produces few jobs, little biofuel and a greater risk of hunger."

In a letter sent to the heads of the Commission's secretariat general, departments for energy and climate action, John Hontelez, the Secretary General of the European Environmental Bureau stated "we are worried that a pattern of scientific obfuscation and intransparent working is emerging within the Commission regarding the impact of the EU's biofuel policies". In February 2008, a study published in "Science", suggests that because of ILUC, US maize based ethanol caused more GHG emissions than it saved.

Moreover "the Renewable Energy Directive" is inconsistent with several core GATT articles.

It violates rules on like products: any advantage given to one product must also be given to like products… When there is a direct competitive relationship between domestic and foreign products that might be changed in favour of the domestic product due to a new regulation, it is even more difficult to square a regulation with GATT rules on national treatment and non-discrimination" (35).

"What started as a genuine attempt to substitute fossil fuels with biofuels has now become a grand story of industrial policy, protectionism and political naivety... There are also expedient excuses for those who are interested in getting protection from foreign competition and have no moral objections to corrupt environmental policies with protectionist ambitions" (36).

6. Conclusions

In spite of the improvements of the efficiency of the new vehicles sold in the EU, the GHG emissions from transportation has increased by 24% between 1990 and 2008 to reach 19.5% of the GHG emissions of the 27 member states.

Therefore, a report from a group of European experts on the fuels of the future for transportation, calls for a global strategy (covering the whole transportation sector) based essentially on batteries, fuel cells running on hydrogen and biofuels. Intermediary solutions are also proposed like biomass to liquid (BTL), coal to liquid (CTL) and so on. Moreover, the report reminds that biofuel from vegetable plants are limited by land avaibility, water resources, efficiency and sustainability linked to lifecycle analysis.

The evaluation of the trade-off of food supply against biofuels from the conversion of natural landscapes is difficult because it is based on societal values. A point in case is palm oil. Some studies report that biodiesel from palm trees from cleared rain forests and peatland, produce more GHG emissions than fossil fuel does. However, the social fallout (in terms of jobs for instance) should also be taken into account when assessing the global benefit from biofuel production.

Second generation biofuels (wood, straw, agriculture waste and ligno-cellulosic materials) appear to better meet the sustainability, efficiency and price criteria than 1st generation ones. Although there is not yet commercial production of the second generation biofuels, the feasibility of their industrial production at competitive prices could be proven in the short term according to IFP (Institut Français du Pétrole). If ligno-cellulosic biofuels are not competitive for the time being with fossil fuels, their commercialization could marerialize within 2020 if promotion measures are maintained like financial support and relevant legislation.

Algae are another alternative to fossil fuels. They are considered as very efficient organisms thanks to their rapid growth rate. Algae grow best in sea water whose supply is almost unlimited. It can be produced using a device called photobioreactor-PBR (expensive pathway) or in open ponds. Although technical problems are being addressed successfully by the industry the high up-front investment is seen as a major obstacle to the success of this technology. Unless cheaper ways of processing algae for biofuels production are found, their great technical potential may never become economically accessible.

In their December 2010 meeting, the EU energy ministers clearly identified energy efficiency as the top priority.

However the Commission will only consider proposing binding targets for energy efficiency by 2012 if by that time the EU is still unlikely to meet its target of 20% improvement in energy efficiency by 2020. This 20% goal has been restated in an endless stream of strategy papers, action plans and Council of Ministers conclusions but the EU is still falling short.

Instead of strongly further promoting energy efficiency and allocating the means to achieve that goal, the EU is still massively subsidizing biofuels like first generation bioethanol, in spite of the serious controversy around this type of fuel and in particular their damaging impact, sometimes more than the one of the fossil fuels they are replacing.

The EU's approach to alternative fuels and vehicles is not sufficiently holistic. It is too much focused on transport carbon footprint and does not take enough account of all stakeholders like costs, economics, people acceptance and well being, etc. Subsidizing, in Europe, first generation biofuels should be phased out to concentrate on more efficient, less expensive, less damaging to the environment alternative fuels and vehicles, including adequate integration of infrastructure requirements.

The development of electric and hydrogen fuel cell transport technologies should continue to be supported although the latter technology still needs more time to mature.

Thanks to their outstanding performance, their reduced maintenance and high flexibility (high efficiency even at low capacity) and thanks to the fact that hydrogen can be generated from different energy sources, fuel cell vehicles could be a better option, for long distances, than electric vehicles in 15/20 years (or less?) time when their technology will be mature and when the relating distribution system will be sufficiently developed. All this requires political involvement. Hence, these two technologies could be complementary: pure electric vehicles for daily commuting and urban use and the hydrogen fuel cells for longer driving range.

Notes

(1) EIA (US International Information Administration), *International Energy Outlook 2010*, July 2010.

(2) *European Energy and Transport Trends to 2030*, update 2007.

(3) Concawe, *Well-to-wheel report*, May 2006.

(4) *Ibid*.

(5) WTW corresponds to the lifecycle GHG (greenhouse gas emissions), which aggregate quantity of GHG emissions (but excluding, in Europe, land use changes) including all stages of fuel and feedstock production as well as distribution from feedstock generation or extraction through distribution and delivery and use of the finished fuel to the ultimate consumer.

(6) SPP research papers, Energy and Environment, University of Galgary (Canada), December 2010.

(7) Institute for energy and environmental research, Heidelberg (Germany).

(8) IEA/IFP (on the basis of 1 EUR=1.3 USD), cited by A. Rojey, Institut Français du Pétrole - Energies renouvelables, November 2007.

(9) BP analysis.

(10) Cornell professor in the College of agriculture and life sciences, Encyclopedia of Physical Sciences and Technology, September 2001.

(11) UN Human Rights Council, May 2008.

(12) Europia white paper on EU refining, May 2010.

(13) Concawe, *op. cit*.

(14) Carbon debt is defined as the amount of CO_2 released during the first 50 years of the process of land conversion.

(15) Sebastian Riso, EU forest policy director of Greenpeace.

(16) B20: 20% biodiesel, 80% petroleum diesel.

(17) Paul B. Thomson, *Agricultural biofuels: two ethical issues*, Michigan State University (USA), 2008.

(18) *Ibid.*

(19) 1 bar = 100,000 Pa.

(20) GermanHy, study financed by the German Federal Ministry of Transport (BMVBS), 2009.

(21) Concawe, *op. cit*.

(22) *Ibid.*

(23) GermanHy, *op. cit.*

(24) Concawe, *op. cit*.

(25) Energy density is a major issue as a 15 to 30 kg (30 l) hydrogen tank is required to store the equivalent of 1 kg of gasoline.

(26) GermanHy, *op. cit.*

(27) Joint Research Centre of the European Commission (JRC), Report N°010307, 2006.

(28) *Ibid.*

(29) *Ibid.* This figure is taken for comparison purposes but it varies widely according to the type of power supply and from one member state to the other.

(30) Ibid.

(31) Battery electric vehicle.

(32) Concawe, *op. cit*.

(33) *European Voice*, September 23, 2010.

(34) This group created in March 2010 consists of representatives of 50 European organizations dealing with fuel and environment, as well as representatives of the European Commission.

(35) ECIPE (trade policy think tank), *Occasional paper* N°1, 2009.

(36) *Ibid.*

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