CAR INDUSTRY DEVELOPMENTS – OIL INDUSTRY CHALLENGES

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Automotive industry of Europe is one of the greatest economical powers, the „engine of Europe”. It employs directly 2.2 million people and 10 million in related industries and services. Combined turnover of automotive manufacturers reaches 700 billion EUR (retail another 520 billion EUR). The industry is the largest R&D investor in EU. On the other hand the transport sector carries a huge safety and environmental risk. Thanks to this fact the automotive industry is one of the most regulated sectors in the EU. As a result of these regulations: one average car built in 1970s produced as many pollutant elements as one hundred cars manufactured today.

These achievements are based on struggles of both the auto and oil industry as parallel with technology development in car industry fuel quality developments achieved by the oil industry drove to a much “cleaner” fuel quality (unleaded sulphur free petrol, reduction of aromatics, benzene; sulphur free diesel, reduction of density, poly-aromatics, etc.).

In the end of the 1990s, and especially for the last few years new challenges came into the focus of the auto and oil industry of the EU and the world. Concerns about high energy prices and price volatility, security of worldwide oil supply and climate change became a main policy agenda of the EU and the world. This new policy is reflected in new regulatory initiatives requiring cars using less energy more efficiently, emitting less carbon-dioxide and using growing proportion of renewable fuels. The European Commission declared the idea of “Cars for Fuels” instead of “Fuels for Cars”.

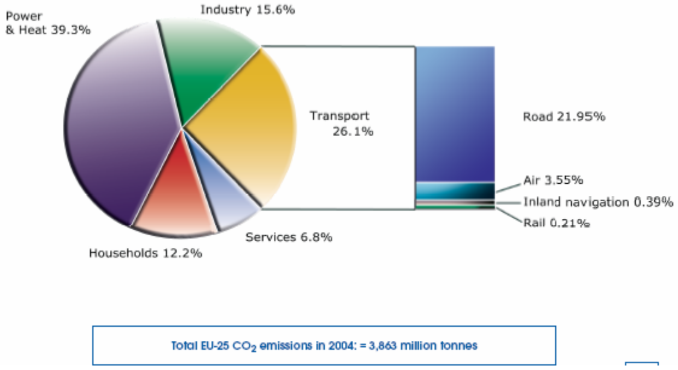
This article discusses in detail the regulations and challenges that rose towards oil and car industry during the recent years. It describes the possible solutions in order to fulfil the requirements of the EU. After that a wide picture is presented without going into much detail on developments of the automotive industry. Developments are divided between vehicle level, engine level and fuel level technologies, also paying attention to technologies that are less known or rather futuristic.

1 REGULATION OF THE AUTOMOTIVE INDUSTRY IN THE EU[1]

EU regulation related to the Automotive Industry focuses on strengthening the competitiveness of the European automotive industry by implementing an effective internal market regulatory framework of technical requirements, as well as enhancing co-ordination of policy areas affecting the sector. In order to make recommendations for better regulation “enhancing global competitiveness and employment while sustaining further progress in safety and environmental performance at a price affordable for the consumer” a high level group called CARS 21 was brought together in 2005.

Technical requirements are formulated in European Directives. These directives require third party approval – testing, certification and production conformity assessment by an independent body. The European Whole Vehicle Type-Approval System allows manufacturers to have a vehicle "type" approved in one

Picture 1 CO_2 emissions by sector in EU25 (Source: Eurostat, 2004)



Member State and then be able to market the vehicle in all other Member States without further tests. The system became mandatory for all passenger cars in January 1998 and for two and three wheeled motor vehicles in June 2003. Similarly, in July 2005, it also became mandatory for all new tractors, whilst the process to introduce such a system on trucks and buses is currently underway.

Recently CO_2 emission has become the main phenomenon to the automotive industry. The industry signed a voluntary agreement with the European Commission in 1998 to reduce CO_2 emissions rates of passenger vehicles sold in the European Union to a fleet average of 140 grams of CO_2 per kilometre (gCO_2/km) by 2008. This agreement has reduced CO_2 emissions from cars by an average of 12,4% but will not be met in 2008. Although recent years have seen a significant improvement in vehicle technology - particularly in fuel efficiency, which translates into lower CO_2 emissions – this has not been enough to neutralise the effect of increases in traffic and car size. While the EU-25 reduced overall emissions of greenhouse gases by almost 5% between 1990 and 2004, CO_2 emissions from road transport rose by 26% despite an average new-car CO_2 emissions reduction of 12.4% between 1995 and 2004. Picture 1 represents 2004 emissions by sector in EU25.

Consequently the European Commission in February 2007 published two communications on the future strategy to reduce CO_2 emission from cars and on the future regulatory framework in the car sector. As outlined in these papers, the Commission has decided to pursue an integrated approach with a view to reaching the EU objective of 120 g/km average carbon dioxide (CO_2) emissions from new cars by 2012.

This would entail:

- a mandatory reduction of CO_2 emissions to reach the objective of 130 g CO_2/km for the average new car fleet by means of improvements in vehicle motor technology;
- a further reduction of 10 g CO_2/km by an increased use of biofuels, and by other technological improvements:
    - minimum efficiency requirements for air-conditioning systems;
    - tyre pressure monitoring systems;
    - setting maximum tyre rolling resistance limits;
    - the use of gear shift indicators;
    - fuel efficiency progress in light-commercial vehicles (vans) with the objective of reaching 175 g/km CO_2 by 2012 and 160 g/km CO_2 by 2015.

These measures are still subject to debate in the European Parliament and in the Council. According to decision-making time-table agreement is possible in December.

What will be the respond of the auto industry? The use of bio fuels may be one of the easiest and cheapest options towards a low carbon car future. Some auto industry players are advocating for increasing bio fuel blending, developing flex fuel vehicles and including biofuels in the emission regulations. It is hard to predict which of the competing low carbon technologies and fuels will win out in the long term, but many automotive industry experts view biofuels mainly as a bridge to more sustainable options such as fuel cells.

Chapter 3 will introduce us into other present technology developments besides biofuels, indicating that there will come many more solutions with the years.

2 CHALLENGES OF THE OIL INDUSTRY

The car and oil industry are obviously closely connected sectors. On one hand the oil industry has to meet the product demand of the car park and on the other hand it has to meet requirements raised by fuel quality regulations.

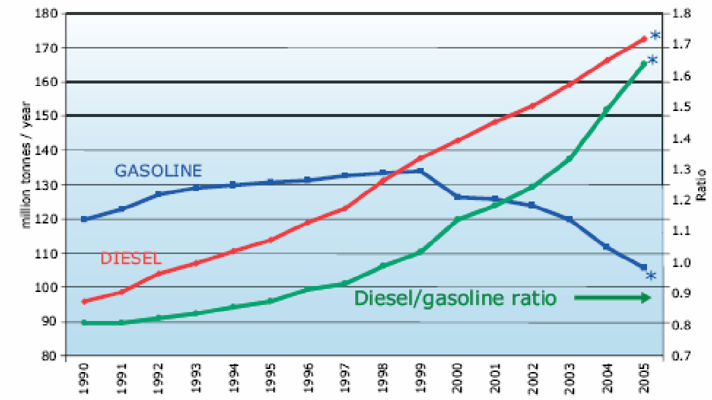
2.1 *DIESELISATION*

Picture 2 shows the dramatic change of the European fuel demand in the last 15 years. Diesel demand has almost doubled while gasoline demand has declined. Consequently large quantities of diesel should be imported predominantly from Russia and the EU exports 20 million tonnes per annum of surplus gasoline to the US.

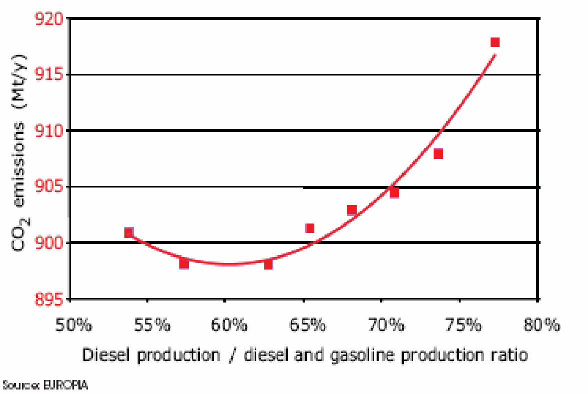
Diesel vehicles emit less CO_2 than comparable gasoline powered vehicles. To meet growing demand for diesel fuels in the future and to satisfy ever tighter product specifications, the EU refining industry has made -and will continue making- significant capital investments, especially in conversion units such as hydro crackers. These units are very energy intensive and, as a consequence, generate significant quantities of CO_2. According to a study carried out by EUROPIA (Refining capacity study) beyond a certain "critical" diesel to fuel ratio, the incremental refinery CO_2 emissions of the production of extra diesel fuels, exceed the CO_2 savings achieved in the diesel vehicle (Picture 3). This conclusion, which could question the reasonableness of continued dieselisation, is valid irrespective of the overall demand scenario considered.

Source: International Energy Agency (IEA)

Picture 2 Motor fuel demand in Europe



Picture 3 Well-to-wheel CO_2 emissions in



2.2 *INTEGRATED APPROACH TO REDUCE CO_2 EMISSION FROM CARS – USE OF BIOFUELS*[2]

The 98/70/EC "Fuel Quality Directive" (FQD) setting the most important technical and environmental specification for fuels is under review by the EU. The FQD and the EN standards elaborated on the bases of this directive guarantee that consumers can get the appropriate fuel for their cars in the whole EU. Car manufacturers guarantee a problem-free operation of cars if these fuels are used.

In the new version of the FQD it is proposed to increase biofuel blending limitation and to reduce the life-cycle GHG emission (carbon intensity) of fuels by 1% per annum from 2010 to 2020. A possible way to reduce carbon intensity of fuels is to mix biofuels into the fuel pool as blending components of standard fuels in today's' vehicles and in pure form or high blends for fleets in dedicated vehicles.

Fuel supply chain is one of the most efficient sectors in the EU. Using present 1st generation biofuels are not the most cost effective way of reducing GHG emission and there are other disadvantages associated with these biofuel types. Their environmental benefits are also questioned. From technical point of view they are not the appropriate fuel for present car park, consequently biofuel blending is limited. Increasing this limitation basically depends on car properties.

3 CAR INDUSTRY DEVELOPMENTS

3.1 TECHNICAL BACKGROUND

As it has been mentioned before, biggest challenge for the automobile industry at the 21st century is to find an optimal solution for decreasing crude oil reserves, rigid emission standards and higher power and better drivability demand of customers. Manufacturers test different technical ways to reach these goals. The different technical solutions can be divided in three major groups: vehicle-level technologies, engine based technologies and fuel pulled technologies. In the following chapters we give a short overview about the major tendencies.

CNG, which is barely used in Hungary and rather futuristic electric cars are discussed in more detail, together with the necessary car developments they raise in order to ensure wide spread utilization.

3.2 VEHICLE LEVEL TECHNOLOGIES

Vehicle level technologies contain the technical solutions involving more than engine development. They combine the engine development with drive, chassis and weight improvements and very often with new energy saving types. The three most important vehicle technologies improvements are the following:

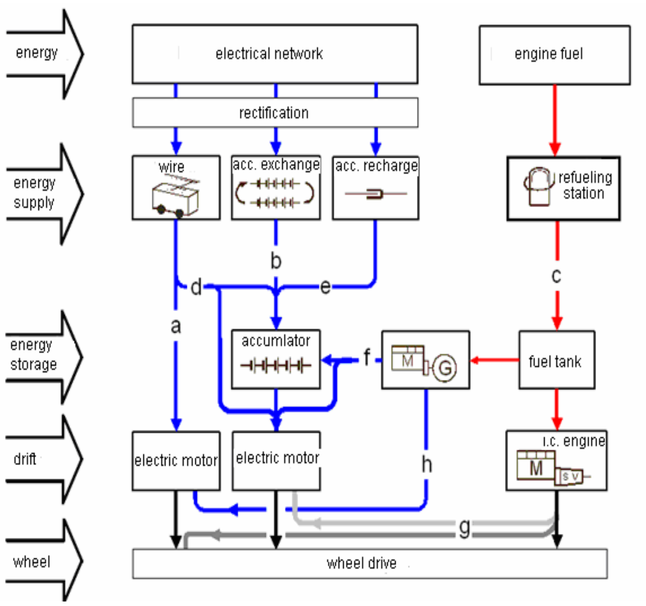
3.2.1 Hybridization

Hybridization combines the benefits of the well known and worldwide used internal combustion engine and an electronic motor. Different car manufacturers developed different solutions for this. The most known type is the gasoline-hybrid.

Hybrid vehicles were produced first by Anton Porsche in the early 1900. It had axle engines complemented by a 2kW gasoline engine. Up to the end of the twenties more other models developed, but they have not been comparable with the fast grown gasoline engine.

The main and first investigator of these hybrids nowadays is Toyota from Japan. It is obvious to develop a gasoline hybrid for a Japanese manufacturer while in Japan gasoline has a dominant market share. Toyota launched its first hybrid car named Prius in 1997. In ten years they sold more than 1 000 000 pieces. Honda and Ford were the first followers.

Fig 1 Frame of vehicles drives[3]

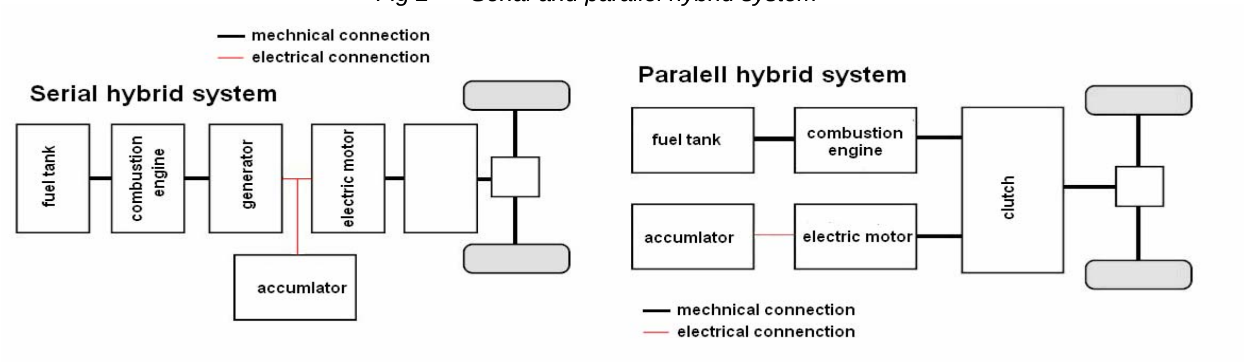


There are different ways to combine the internal combustion engine with electric motor. Fig. 1 gives a global overview about it, where the different combinations are:

a) overhead cable vehicle (trolley bus)
b) replaceable accumulator
c) internal combustion engine
d) overhead cable combined with accumulator (for shorter distances, emergency cases)
e) rechargeable accumulator
f) serial hybrid

g) parallel hybrid
h) overhead cable combined with internal combustion engine

Fig 2 Serial and parallel hybrid system[3]



Main advantage of the combined use of electric and combustion engine is based on the idea that the high torque of the electric engine is usable in part loads where the combustion engine operates on low efficiency level. The two base combinations are shown on Fig.2. These are the basis of all other combinations.

The essence of the parallel hybrid system is that both engines are in mechanical connection with the driven wheels. They contain two engines (one combustion engine and one electrical motor), two pieces of energy storage equipment (fuel tank and accumulator) and a special clutch. The vehicle can be operated by one of the systems or with the two systems together. It means that smaller engines are enough to reach the same peak power level.

The combustion engine is not in direct contact with the driven wheels, only through the electric motor. The engine runs a generator for the electric motor or for the accumulator. The vehicle can not operate with the engine alone, but can be operated with the motor only. In addition, the double energy conversation causes additive energy losses.

The fuel consumption and emission level of gasoline hybrids can be reached by the newest diesel technologies for lower price. On that basis the European manufacturers started to develop diesel-hybrid systems. These can unite the combustion benefits of the latest diesel engines with the advantages of the hybrid systems in urban areas.

In the fuel point of view hybrid systems use the same fuels as traditional engines, and it is completed by electricity mostly produced on the board. It is expected, that the number of hybrid vehicles will increase in the future parallel with the improvement of internal combustion engine. The two main ways will be the driveability increasing (for example Lexus) and the fuel consumption optimization (Minimal hybrid).

3.2.2 Fuel cell

Fuel cells are another well investigated area. It could be a second step after hybrid vehicles, leave the internal combustion engine and utilize with an electromotor only. It needs different energy storage forms; the most applicable of these is the fuel cell. It will replace the fuel system and the combustion engine. It has lot of difficulties the main one is the low energy density of the fuel cells (power cells today offer only 20 Wh/kg with the potential of 60 Wh/kg in the next few years and the goal of 200 Wh/kg). Chemical limit of the storage capacity is approximately at 1500 Wh/kg, but it will be reached only at 2020. With these it could be enough energy stored for 400 km in 100 kg battery weight and with 300 kg additional drive chain[4] (a modern combustion engine is app. 150 kg plus the fuel tank with fuel 50kg being enough for 750 km). An alternative for the energy storage could be that the vehicles take compressed hydrogen. There could be more H_2 stored on board. Unfortunately for hydrogen production power is needed.

If the energy is stored in cells recharging facilities are needed, in some cases it could be done from the power system. If energy stored in hydrogen than hydrogen refueling stations required.

3.2.3 Compressed air vehicle

Compressed air "fuelled" vehicles are a very innovative solution to decrease dependency on oil. The car is able to perform 200 km with one charging, that takes 4-5 minutes. A cost of one recharging is approximately one fifth of the conventional fuel price. There is not any combustion in the engine so the lifespan could be much higher. This technology has a lot of hindrances. The obtainable top speed is only 130 km/h, and if there is not any compressed air, recharging could take up to 3 hours. Storage of the 300 bar compressed air is still an issue to solve[5].

This type of vehicles will need a compressed air recharging facility.

3.3 ENGINE BASED TECHNOLOGIES

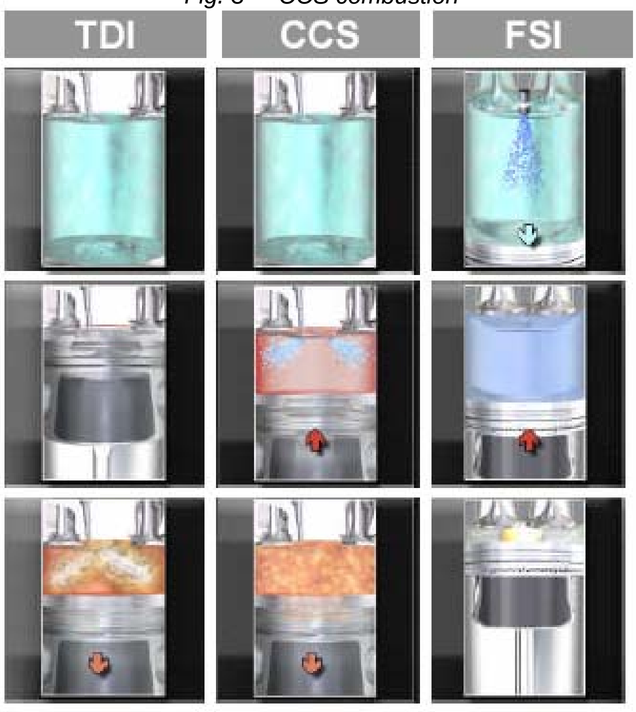
The internal combustion engine can be developed with the aid of the newest production technology results. These help top reach higher injection pressures, better combustion, lower weight etc. In the next part some of these new technologies are described.

3.3.1 HSDI – high speed diesel injection

High speed diesel injection covers all the technical solutions that are used to reach higher injection pressures for diesel engines. Increasing injection pressures are essential to fit the even sharper emission standards. The main orientation of the development is the common rail system with hydraulic increased pressure. The common rail technique is available on the automotive market since 1995. Peak pressure of the system is increasing since that. Nowadays it exceeds 2000 bar. These systems need very clean, ultra-low sulphur diesel fuels that are very stable at these pressures.

3.3.2 HCCI / CCS / DiesOtto – combined combustion technologies

Fig. 3 CCS combustion[6]



There are more investigations to combine Otto burning and Diesel burning. In order to meet tightening emissions standards and ever higher demands for fuel efficiency, car producers recognised that they have to abandon conventional petrol and diesel engines in favour of a new type of motor altogether. HCCI and CCS are different attempts to this direction.

CCS mixes the most favourable characteristics of both petrol and diesel technology to make one low emission, high efficiency power unit that runs on synthetic biofuel. The main investigator of this technology is the VW AG. Their engine was designed to meld the homogeneous combustion and low nitrous oxide emissions of a typical small capacity petrol power plant with the self ignition and low fuel consumption properties of a modern day diesel. Fig 3 shows the differences and similarities between Diesel (TDI), CCS and Otto (FSI) burning.

The engine uses the latest piezo injector. CCS engine is able to begin the combustion process within each cylinder much earlier than in existing diesels, which tend to start shortly after the piston reaches top dead centre. As the fuel is ignited for longer period of time the CCS engine proves to be more economical.

To ensure that the CCS process will be possible to achieve, the manufacturer has worked closely with oil industry companies to develop a new synthetic Fischer Troops fuel. This fuel is a CO_2-neutral biomass mixture containing no petrol or diesel, but rather created using forest or industrial waste as well as bio-degradable rubbish, animal waste and specially planted crops. It does not require any dramatic alteration to existing infrastructure.

Homogeneous Charge Compression Ignition, or HCCI, is a relatively new combustion technology. It is a hybrid of the traditional spark ignition (SI) and the compression ignition process (such as a Diesel engine). Unlike a traditional spark ignition or compression ignition engines, HCCI combustion takes place spontaneously and homogeneously without flame propagation. This eliminates heterogeneous air/fuel mixture regions. In addition, HCCI is a lean combustion process. These conditions translate to a lower local flame temperature which lower the amount of Nitrous Oxide (NO_x) produced in the process. NO_x is a gas that is believed to be responsible for the creation of ozone (O_3).

DiesOtto powertrain is a further development of spark-ignition engine that includes features such as direct gasoline injection, turbo charging, variable valve timing and variable compression. It will be used in conjunction with a hybrid integrated starter/generator module. At its core a controlled auto ignition lies, a highly efficient combustion process similar to that of a diesel.

3.3.3 Downsizing

Reducing the engine swept volume – downsizing – offers the potential to meet reduced CO_2 vehicle emission standards in Europe and gives reduced fuel consumption. In downsizing the gasoline engine a key challenge is controlling octane requirement without sacrificing fuel economy. There are five common alternative approaches on a turbocharged direct injection gasoline engine:

- Conventional $\lambda=1$ operation with reduced compression ratio (CR)
- Lean Boost Direct Injection (LBDI) with lean operation at full load to control octane requirement while maintaining a high CR
- EGR Boost with cooled EGR dilution rather than excess air to control octane requirement
- Miller cycle concept, where valve-timing strategies are employed to reduce the effective compression at high load
- Dual spark strategies

Higher octane number fuels are very useful in downsized gasoline engines, while they enable the use of technical solutions above without any enrichment.

3.3.4 After-treatment technologies

During the selective catalytic reduction (SCR) nitrogen oxides are removed, through chemical reaction between the exhaust gases, a reactive agent (additive), and a catalyst. A gaseous or liquid agent (most commonly ammonia) is added to a stream of flue or exhausts gas and is absorbed onto a catalyst. It reacts with NO_x in the exhaust gas to form harmless H_2O (water vapour) and N_2 (nitrogen gas).

3.3.5 Start-stop solutions

The use of the start-stop systems can provide 10% fuel saving in the city. Start-stop systems switch off the internal combustion engine when the vehicle is at a standstill, for example in traffic jams or at red lights. This helps effectively reduce fuel consumption and CO_2 emissions, particularly in urban traffic.

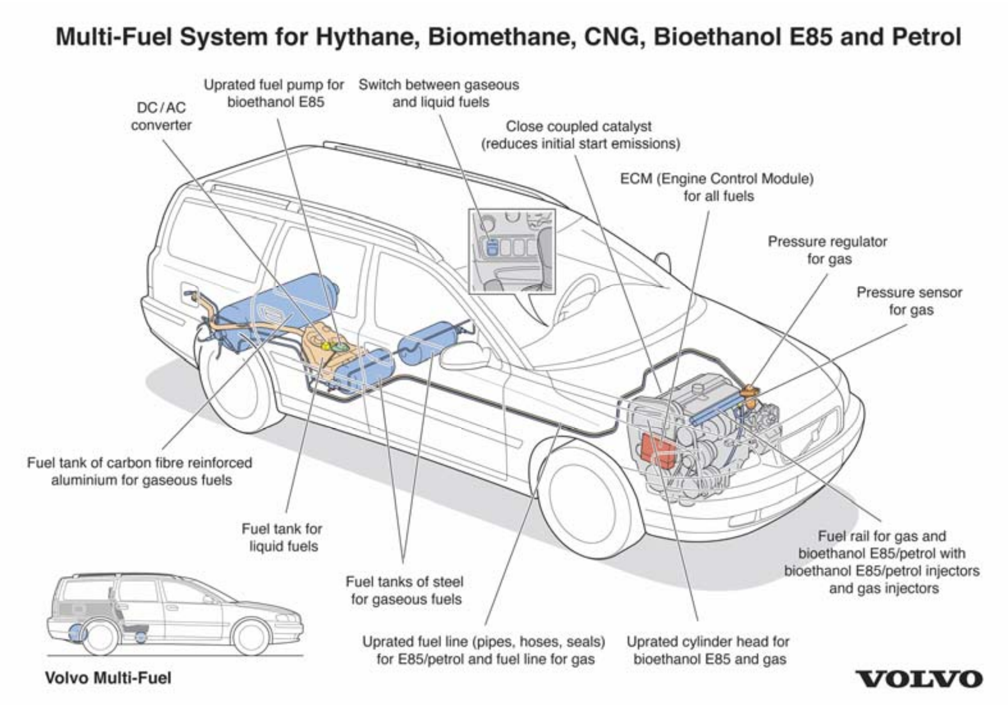
3.3.6 Multi-fuel vehicles

To prepare the vehicles for the differentiated fuels automotive manufacturers have constructed cars that can be run by more types of fuels.

Flexible fuel vehicles (FFVs) are designed to run on gasoline or a blend of up to 85% ethanol (E85). Except for a few engine and fuel system modifications, they are identical to gasoline-only models. FFV's were produced first for the Brazilian market in the mid '90. More and more OEM producing FFV's, the first producers were Ford/Volvo, GM/Saab.

Volvo produced a five fuel vehicle, called Multi-Fuel. It is optimized for running on five different fuel types; hythane (10% hydrogen and 90% methane), biomethane, natural gas, E85 and gasoline. The Multi-Fuel vehicle contains one large and two smaller tanks of totally 98 litres for gaseous fuels (hythane, biomethane and CNG), and one 29 litres tank for liquid fuels (E85 and petrol). The small gaseous fuel tanks are made of steel. The large tank has a durable, gas tight aluminium liner, reinforced with high performance carbon fibre composite and an exterior layer of hardened fibre-glass composite. The fuel tanks are fitted neatly under the luggage compartment floor, which means that full loading capacity is preserved. Engine automatically adjusts itself to the right blend of gaseous or liquid fuels. To switch between fuel types, the driver simply needs to presses a button.

Fig 4 Volvo Multi-Fuel vehicle[7]



3.4 NEW FUELS, NEW RESOURCES

New engine technologies recommend new fuel qualities and at the same time decreasing fossil resources and rigid emission standards aspirate to look after new energy sources. This section describes new fuels and resources.

3.4.1 Hydrogen

Hydrogen can be a long term solution for the transportation sector to have a low emission energy source. It can be used in vehicles in more ways: direct combusted in engines or with the help of the fuel cells. Both solutions are well investigated. The use of hydrogen in external combustion engines have the benefit of the well known engine technology combined with a new fuel. Some automotive manufacturers (Mazda and BMW) are near to produce in series vehicles with this technology. Fuel cell application is investigated by more manufacturers. Yearly more studies are presented with this technology.

One benefit of using hydrogen is that it does not emit any CO_2, since it does not contain any carbon. The high burning temperature cause higher NO_x emission, but it can be controlled. Use of fuel cells is one way to eliminate this problem. High energy content is beneficial, but the very low density causes storage difficulties. Based on that, it can be stored in vehicles only at high pressure and low temperature or gulped in metals. Still remain the tasks to produce hydrogen effectively, develop the infrastructure and lower the vehicle production costs.

3.4.2 Biofuels

As Chapter 1 described, in shorter timescale biofuels can have a role to set off a part of fossil fuels and they can be bridge to more sustainable options. First generation biofuels are already on the fuel market and second generation biofuels will come in the next years. These will be more similar to the fuels of the present and they will be more efficient in the full life-cycle.

Second generation ethanol or cellulose ethanol will easily replace the first generation ethanol with a better energy turnout. It could be easily fitted to the new engine technologies (i.e. downsizing) due to its high octane number.

Biomass to Liquid (BtL) fuels as second generation biodiesel – named also Fischer Troops Diesel – will be more suitable for diesel engines and CCS engines.

Biofuels will remain important blending components and pure fuels for captive vehicle fleets while their resources are limited and they can be produced from the agricultural overflow and wastes.

3.5 Compressed Natural Gas (CNG)

In 2001, the White Paper on a Common Transport Policy estimated that 20% of crude oil based motor fuels will be replaced with alternative fuels in the European Union until 2020. Ten percent of this replacement is planned to be Compressed Natural Gas (CNG However, looking the pace of spreading of CNG in Europe the 10% forecast proved to be extremely ambitious targets, still CNG is a potential and, what is more, an existing alternative fuel, which has several advantages (it is environmental friendly, operates economically, promotes fuel diversification, etc.) and disadvantages (lack of infrastructure, has high investment cost, allows shorter range, etc.).

Several successful projects proved that CNG could be a real alternative fuel even nowadays, especially in public transportation. One good example is public transportation in the Indian capital. The Supreme Court of Delhi resolved on the conversation of the entire public transportation to CNG involving 10,000 buses. This radical transformation is under process, but researches have already proved a significant improvement in the air quality of Delhi due to use of CNG[8]. Experiences show that only a large scale transformation could be successful, from both an economical and environmental point of view, which is also proved by the transformation in Argentina.

Due to favourable emission indices of CNG, several European governments provide various subsidies (tax allowances, financial aid for investments, etc.) for the implementation of CNG. Despite its favourable operational costs, CNG could not compete with conventional fuels because of its high investment needs (filling systems, new or converted vehicles) and limited infrastructure. Therefore these subsidies are essential in starting the transformation.

In the recent years, significant development in the quality of motor fuel and the efficiency of diesel engines have lessened the relative environmental advantages of CNG, in comparison with oil based fuels.

At the moment there is a bigger chance that CNG remains an opportunity for more environmental friendly local public transportation, than a wild-spread alternative for private use (except some countries, like Argentina, India, Pakistan), but that is sure, for a more promising CNG future, developments are essential, because without maintaining and increasing the remained environmental advantages the current (necessary) subsidy systems can not be justified.

Vehicle and engine developments

In comparison with other alternative fuels (such as LPG, B100 or E85) CNG has quite considerable car manufacturer background: all of the big bus manufacturers plus more and more car producers have their vehicles available with CNG system, which helps the future developments.

CNG tanks need significant space, so one of the initial developments was to find the ideal and safe place for them. In case of passenger cars, tanks are usually built into the floor (with boots remaining the same size), while tanks of buses are built over the roof. Besides, the weight of the tanks has been decreased significantly with the use of new materials, such as carbon-fiberglass, which has a favourable affect on consumption and safety, as well.

Fundamentally, CNG as motor fuel may be used in four ways, based on the specifications of engine and fuel. This usually depends on vehicle type and the compromise between emission and motor performance. The four types are: mono-fuel (spark-ignition motor dedicated to CNG), bi-fuel (spark–ignition motor with gasoline or CNG), and diesel motor with spark plug dedicated to CNG and dual-fuel (diesel motor fueled by a mixture of diesel and CNG).

In case of CNG engines/kits, neither the intensity of, nor the time spent on developments can be compared with diesel developments, meaning that there could be still considerable potential in CNG. However, developments in diesel technologies have decreased the comparable environmental advantages of CNG; several additional diesel technologies (e.g. particulate traps, so-called NO_x absorbers, urea injection system, etc.) increased the cost of diesel systems, and therefore significantly decreased or eliminated the gap between the price of CNG-based and diesel vehicles.[9]

CNG engines are made by transforming conventional engines, so developments are focusing on CNG kits. However, in case of changed and mixed fuel systems manufacturers have to make a compromise between optimized emission and performance for the different fuels, producers often prefer these solutions because of limited filling station infrastructure.

In case of limited range vehicles, for example in urban public transportation, this limited infrastructure should not be a serious issue. That is why the dedicated CNG engines/kits for buses represent one of the most successful developments in the CNG field.

The initial development of natural gas engines is based on a so-called "lean burn technology", but – due to NO_x emission - the latest generation of CNG buses are coming up with stochiometrically controlled natural gas fuelling, and the so-called closed-loop three way catalyst emission control systems. This has resulted in significant reduction of NO_x and PM emissions.[9]

Through developments of electronically controlled fuel injection systems, it was possible to significantly decrease the emission in case of CNG dedicated and dual-fuel engines, as well.

In a dual-fuel pilot project in 2005, the NO_x + NMHC (non-methane hydrocarbon) emission of buses have been reduced by one-third.[10] To ensure that gas/diesel ratio remains within a suitable range, the most advanced systems can continually assess the combustion's air/fuel ratio. Electronic signals of both gas and diesel injectors provide the correct fuel mix in each combustion cycle, ensuring optimal efficiency, power, and fuel usage. Efficiency of these engines can be further improved by the use of supercharging, increased compression ratio or exhaust gas recirculation. This way the efficiency of these engines can become equal to the lean burn CNG engines'.[9]

The after-treatment of vehicle engines is also under development. The more intelligent the electronic control unit is, the more flexible the calibration utility will be in producing low emissions. Future electronic control units can learn from data being fed back from engine sensors, and make on the road refinements to the base calibration, entered into the computer for a particular type of vehicle. This reduces calibration effort and kit installation costs, making CNG a more available and economic technology. [9]

Mixed developments for CNG future

In general, CNG is a technically feasible alternative fuel at present, which does not require revolutionary transformation. However, beyond all of its advantages, CNG still has its own limits: it may not reach a breakthrough in fuel market in any point of view. Consequently, CNG can only be a medium term and partial solution for the diversification and environmental problems, until other, currently developing technologies (such as the use of pure bio-fuels, hydrogen, solar energy, etc.) can be used widely and economically.

Some researches are also envisaging the role of CNG in the pathway to potential future fuels and solutions.

One of these researches focused on hybrid electric vehicles, which may be fuelled by natural gas. Projects still under progress have already proved that an optimized hybrid internal combustion engine, which uses a clean fuel such as CNG, may present lower life cycle emission and much better economics than so-called hydrogen PEM fuel cell vehicles. This combination is of high importance because hybrids are commercial reality whereas fuel cell vehicles still need significant development.

Another survey focused on exploiting environmental advantages of hydrogen - natural gas mixture ("H/CNG" or "hythane"). At public transportation, buses applying 20/80 vol% H/CNG mixture can significantly reduce NO_x and NMHC emission (by 50% and 58%, respectively). Using H/CNG does not require high technology development, and the experiences of using hydrogen as motor fuel could be important on the route to a hydrogen-based economy, as well.[11]

CNG-biogas mix or pure biogas could significantly increase environmental advantages of gas-running vehicles, and therefore fuel-related developments took place with biogas, as well.

The above mentioned CNG-connected developments are in initial phase and huge progress would be necessary for economical usage and spreading, but they predict a long-term application of natural gas as motor fuel (especially in local public transportation).

Role of the oil industry

Considering the natural gas supply chain, CNG may give a growth opportunity and a chance for gas suppliers to enter the motor fuel market, while generating competition to oil companies. This competition is probably manageable for oil companies, though, as CNG spreads quite slow, and in the European market it mainly takes away consumers from the short diesel market (e.g. public transportation). Considering this, a few oil companies, which reside in countries with extensive CNG-connected state subsidies, have already stepped into CNG business themselves - relying on their existing retail infrastructure. These companies with a "green logo" derive marketing and PR benefits from CNG, as well.

It is hard to define certainly where the break-even point is for an oil company to enter CNG business. However, due to changes of economic conditions (state subsidies, gas lobby, results of car developments, etc.) CNG may transform from a diversification chance to a market condition for oil companies (as it happened in case of bio-fuels). In this case, an oil company may benefit from CNG transformation by not purely reacting on changes as an external player, but to participate in, influence and take advantage of the process.

3.6 ELECTRICITY/ SOLAR ENERGY - ELECTRIC CARS

An electric car is a battery electric vehicle that utilizes chemical energy stored in rechargeable battery packs. It uses electric motor (typically one instead of the engine or one for each wheel) and motor controller instead of internal combustion engines (ICEs). Vehicles using both electric motors and ICEs are examples of hybrid vehicles, and are not considered as pure electric vehicles.

Many are capable to exceed acceleration of conventional vehicles, they are quiet, and do not produce noxious fumes, since they do not exhaust anything. Total pollution if charged from most forms of renewable energy is confined to pollution connected to fabrication (life cycle greenhouse gas emissions are now in the range of 25-32 g/kWh). It reduces dependence on petroleum, and mitigates global warming by reducing the greenhouse effect.

Historically electric vehicles had limited widespread adoption, since they have had issues with heavy weight, high battery costs, charging time, battery lifespan, and limited travel distance between battery recharging. Ongoing battery technology developments have addressed many of these problems. New models have recently been prototyped, and some future production models have been announced.[12]

Battery developments[13]

Battery pack plays the same role in an electric car that petrol tank does in a normal car, storing power for future use. Electric cars use different type of batteries including Lead-acid batteries, Nickel-Metal hydride batteries (NiMH), Nickel-Cadmium batteries (NiCad), Lithium ion batteries and Lithium polymer batteries. Lead-acid batteries are less expensive and easier to work with but have lower power to weight ratio (these are used as batteries for conventional cars as well). The latest electric car releases use Lithium ion batteries (well known as battery for portable electronics), as these can be charged quicker than lead acid batteries, offer greater speed, range and acceleration. Additionally this technology has one of the best energy-to-weight ratio, no memory effect, and a slow loss of charge when not in use. Also they are less affected by variations in temperature.

BATTERY SPECIFICATIONS	LITHIUM ION	LEAD-ACID
Energy/weight (Wh/kg)	160	30-40
Energy/size (Wh/L)	270	60-75
Power/weight (W/kg)	1800	180
Cycle durability (cycles)	1200	500-800
Travel range per charge (km)	400-500	130
Cunsumer price ($ / car)	20000	2000

Limited travel distance between battery recharging, and charging time are two issues that can be solved with carrying the energy generator on the vehicle. Most often it is carried out with the use of solar panels. An alternative, half-way measure is to charge the batteries at night or while parking with the help of its own windmills. Replacement of batteries instead of charging (and charge them while the other battery is in use) can be also an option to consider.

Solar technologies

A solar car is an electric vehicle powered by solar energy obtained from photovoltaic (PV) solar panels on the surface of the car (not through grid connection, coming from a power plant i.e). PV cells convert the sun's energy directly into electrical energy.

Solar energy is a source of energy that utilises radiation emitted by the Sun. Though it is a renewable energy source, solar panels must still be manufactured, producing various pollutants. Recycling panels and definitely needed batteries are still issues to solve in an environmentally friendly way, instead of putting out a large amount of dangerous wastes.

A solar array consists of hundreds of PV cells. There are a variety of solar cell technologies available, most often polycrystalline silicon, mono-crystalline silicon, or gallium arsenide. Price of a most commonly used mono-crystalline 10cm x 10cm solar module is 6$[14]. Most panels are warranted for 25 years and see about 35+ years of useful life. Payback time of a modern photovoltaic module is usually under five years depending on the type and where it is used. They are considered as net energy producers, meaning that they generate more energy during their lifetimes than their production requires.

Silicon is a material that (measured by mass) makes up 25.7% of the Earth's crust and is the second most abundant element in the Earth's crust, after oxygen. Sand, amethyst, agate, quartz, rock crystal, chalcedony, flint, jasper, and opal are some of the forms in which silicon dioxide appears, therefore it is available in a wide range. On the other hand, price of silicon solar cells (due to high energy need of processing) is much higher than other newly developed technologies. Scientists of The New Zeeland University have worked out a new technology that is made of titan-dioxid allowing the price of solar cells to be one tenth in the future.[15] Developments also make it possible to perfectly utilize diffuse radiation as well, while earlier technologies have been limited to the utilization of direct/beam radiation. Recycling of titan-dioxid cells is less costly and problematic than for silicon.

Power produced by the solar array depends on the weather conditions, the position of the sun and the capacity of the array.[1]

Economics

The price of an electric vehicle is set by market factors and not cost. For equivalent production volumes electric vehicles could be cheaper than conventional vehicles as they have much less parts. This also means they are cheaper to maintain. They are ten times less expensive to operate (depending on the price of electricity) over gasoline.[16] Using regenerative braking, which is standard feature on electric cars, allows getting the efficiency even doubled (than without this feature) in extreme traffic conditions, and 10-15 % more efficient in city driving, of course depending on terrain conditions.

For the time being purchase price of an electric car is around 80% higher than of a petrol or diesel equivalent (and very often the batteries are not included because they are also expensive). Ownership costs can be quite high as well, due to the battery need of the vehicles. Batteries either have to be replaced every 3-5 years, that costs $2000-20000 (lead-acid / li-ion) every time, or another solution is to lease the batteries ($116-$135 / month), which still results in quite high running costs.[13]

One can save money on the upkeep with the use of solar panels (not paying for the electricity coming from the grid), but that increases investment costs. In case of a 2 square metres solar car roof, the costs referring to the above assumptions would be around $1200 (216 HUF Th), but the purchase price would be 2-3 times bigger than that.

Summarizing the above: Though electric cars, and solar powered electric vehicles are not only prototypes anymore and they have been put to (a limited) standardized production, there are still quite a few challenges they have to face with. These challenges are price, limited driving distance, expensive and pollutant batteries, poor availability of public charging stations. Some promising brand new releases that have been put to production in 2007 are shown below.

Tesla Roadster[17]

- Electric vehicle for 2
- Weight: 1400 kg
- 6831 Li-ion batteries (3rd of the car's total weight)
- Est. battery life: over 160,000 km
- Full charge time: 3 ½ hours
- Price: $98,000 (17.6 HUF mn)
- Range: over 400 km
- 0 to 100km/h in 4 seconds (248 hp)
- Two gears: from 0 to 101 and then on to 210km/h (top speed)

Venturi Eclectic[17]

- Solar/wind-powered car for 3
- Weight: 350 kg
- Liquid-cooled NiMH batteries
- 2.5 square metres of solar cells
- Both chargeable from a mains unit at home or using its windmill
- Price $30,500 (5.5 HUF mn)
- Range: 50 km
- Top speed 50 km/h (22 hp)

[1] At solar noon on a clear March or September equinox day, the solar radiation at the equator is about 1000 W/m². Thus, a 22% efficiency solar cell having 1 m² of surface area in full sunlight at solar noon at the equator during either the March or September equinox will produce approximately 220 watts of peak power. For an average 2.5m^2 panel it is 550W. In one hour time it means 0.55 kWh energy (W=J/s; 1kWh= 3.6 MJ). This amount of energy is i.e. enough to supply an ordinary 60 W bulb for 9 hours or a rather economical 20 W bulb for 27 hours.

3.7 AFTER WORD

Regulations of the automotive industry push towards a large variety of car and fuel developments, creating challenges for oil companies to be able to adapt them. Only in the longer term it is going to turn out whether technologies that fit well to oil industry value chain or others that are less suitable will be wide spread. Until then oil companies should be ready and prepared for both ways.

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