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Alternative transport fuels: infrastructure needed

SUMMARY *The development of alternative fuels for transport is a necessity to reduce the EU's dependence on imports of crude oil, as well as to decarbonise transport and reduce greenhouse gas emissions.*

Significant innovation and technological progress have been made in new forms of fuels, to power different transport modes and using combustion or electric engines. One of the challenges which hamper the development of vehicles and vessels using rechargeable battery packs, hydrogen fuel cells or compressed or liquefied natural gas is the lack of infrastructure for recharging or refuelling. Insufficient coverage of fuelling points on the transport network and the low numbers of alternative-fuel vehicles interact in a vicious circle, preventing market take-up of these technologies.

The European Commission has therefore proposed a Directive which would set minimum requirements and targets for Member States to foster the deployment of infrastructure for the supply of these alternative energies for road and waterway transport on their territory. This Directive would also require technological standardisation in this area and improved information to users. The European Parliament is currently examining the proposal.

In this briefing:

Glossary

Conventional fuels: fuels derived from crude oil (petroleum) and most commonly used today in EU transport, such as gasoline or diesel[1].

Alternative fuels: new non-conventional energy sources for use in transport, such as liquid biofuels, synthetic fuels, liquefied or compressed gases (including hydrogen), as well as electricity taken from the grid.

Background

Energy use in transports

European energy consumption from transport (road, air, shipping and rail) has grown by over 30% since 1990. Since the historically high demand of 2007, energy use in transport declined (because of the economic recession) to stabilise between 2009 and 2011 at its 2005 level. Road is by far the largest energy-consuming transport mode (close to 82% of the total energy demand for transport[2] in 2011).

Crude oil represented 94% of the energy used for transport in 2010. European transport is still, for a very large part, dependent on petroleum as energy source. With a share of 55%, transport is by far the largest oil-consuming sector in the EU.

Crude oil use...

As for some other energy sources, notably fossil gas, the EU's needs for crude oil are highly dependent on imports. About 85% of oil has to be imported, for a bill of about €1

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billion a day, representing a trade balance deficit of about 2.5% of GDP.

In 2011, transport was responsible for 20.2% of EU Greenhouse Gas (GHG) emissions. Road transport alone accounted for 19.1% of EU GHG emissions, while navigation and civil aviation accounted for 0.4 % each.

...reduction for numerous objectives

The development of alternative fuels[3] in transport, with lower GHG emissions (particularly CO_2), contributes to several key EU policy objectives.

For example, the Commission's 2011 "Roadmap to a single European transport area – towards a competitive and resource efficient transport system" aims in particular at significantly reducing transport dependence on oil and reducing transport GHG emissions by 60% by 2050 (compared to 1990) - an objective approved by the European Parliament, though seen as quite ambitious by some Member States. In 2010, renewable energy in EU fuel consumption for transport was less than 5%.

Also, in line with the Europe 2020 strategy, technological development for alternative fuels and decarbonisation of the transport sector can increase EU competitiveness, stimulate economic growth and create jobs, claim some experts.

But challenges to alternative fuels

The market take-up of alternative fuels in different transport modes still faces numerous technological and economic challenges. One of the major obstacles lies with the lack of adequate and sufficient refuelling infrastructure for alternative energies, particularly those which cannot be supplied through the technological channels for conventional (liquid) fuels. There is also still rather limited knowledge (and acceptance) of alternative propulsion vehicles by the majority of potential users.

Conventional and alternative fuels

Combustion engines or electric motors

Internal combustion engines (ICEs) transform the chemical energy from the combustion of fuel with an oxidiser, usually oxygen (O_2) from the air, into mechanical energy useable for displacement. Fuels which are liquid in ambient conditions have a number of advantages compared to gaseous or solid ones, notably that they have a high energy density while remaining fluid. Considering also their easy storage (tanks) and relatively simple refuelling technologies, liquid fuels have imposed themselves - in association with ICEs - as the most widespread power modes for road, maritime and air transport.

In rail (and trams, metro, and trolley-buses), electric motors have for the most part supplanted (less efficient) combustion engines, thanks to infrastructure changes and direct connection of most of the rail network to the electricity grid. However, rail still operates in part (usually at local level) with ICE-powered locomotives.

Main oil-derived conventional fuels

Petroleum, or (crude fossil) oil, is a highly complex and varied mix of organic compounds, mainly hydrocarbons (i.e. made only of carbon and hydrogen). Distillation (refining) allows the fractioning of oil into different products. Some of these have become key liquid fuels for most transport modes: **petrol** (private cars), **diesel** (road, waterway, rail), **heavy (residual) fuel oils** (maritime navigation) and **jet-fuel** (aviation) for example, all contribute to oil being the dominant energy source for transport, supported by a wide distribution and refuelling network. A (slightly) pressurised by-product from the fuel chain, liquefied petroleum gas (**LPG**) has established itself as a niche fuel (3% of fuel for cars), with specific tank technology fitted to several million vehicles today[4] and served by an infrastructure of about 28 000 refuelling

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points in the EU (though unevenly distributed among MS).

New fuel sources for combustion engines

Fundamentally, all hydrocarbon compounds from varied renewable biomass resources (crop, plant and food waste, animal manure...) may allow direct production of **biofuels**. Fuelling a diesel engine with vegetable oil was trialled over a century ago. From the technical point of view, biodiesels (vegetable oils) and bio-alcohols (ethanol) can easily be mixed with, or substitute, some conventional fuels as they work with existing combustion engine technologies, tank-storage and refuelling systems, with no or only limited technological adaptation (e.g. bio-ethanol mix use in petrol engines).

Substantial transformation by chemical processing of different feedstock (e.g. BTL: biomass to liquid; CTL: coal to liquid; GTL: gas to liquid) may provide new or cleaner liquid **synthetic fuels** (e.g. DME: Di-Methyl-Ether) from both fossil or renewable sources, including biogas (methane). Like liquid biofuels, liquid synthetic fuels may easily work with existing ICEs, and tank and filing technologies. Refuelling systems may develop in parallel to existing conventional fuel distribution networks, using similar infrastructure.

Technological development and innovation have also contributed to making **natural gas** (**methane**) a likely alternative fuel source for ICEs in some means of transport, in the EU and other parts of the world. Methane can originate from fossil reserves or renewable sources (notably from biomass). To be compatible with transport activities however, the energy density of natural gas needs to be increased by compression (**CNG**: **compressed natural gas**) or even more by liquefaction (**LNG: liquefied natural gas**). However, these fuels need to be kept under high pressure and for both LNG refuelling and CNG refuelling, retail supply stations are still scarce.

Means of transport powered with hydrocarbon fuels all emit CO_2. The GHGs emitted by combustion of these fuels and their total carbon footprint vary, depending notably on the fuel itself (nature or quality) and its origin (fossil or renewable biomass).

Supplying electricity for electric motors

Permanent link to the grid

The conventional way to provide energy to an electric motor is through a permanent connection to the general electricity grid. For transport, this implies that transport routes must be equipped with parallel infrastructure for electricity supply (overhead lines or third-electrified rail), which has made it only realistic for rail (or specific city transport, e.g. trolley-buses).

Rechargeable batteries

Rechargeable battery (or super-capacitor) technologies have been developed with sufficient energy storage possibilities to become of some practical use in transport. Systems have been trialled and developed to recharge electricity directly from the general electricity grid (with different plug-in types or by wireless induction, with varied performances (notably in terms of energy capacity and charging duration). Batteries can also be recharged thanks to devices which convert other forms of energy produced by the vehicle itself into electricity (e.g. generators directly powered by an ICE, or systems allowing the recovery of part of the energy lost in brakes or suspension).

Fuel cells (direct production of electricity)

A fuel cell is an electro-chemical device in which a fuel and an oxidant (O_2) are channelled over electrodes (separated by an electrolyte), to produce electric current. Fuel cell technologies are today sufficiently developed to power electric engines for some transport purposes. Fuel cells convert the energy stored within fuels into electricity more efficiently than classical electricity generation from fuel combustion. While some fuel cell models can operate on methanol (liquid) or natural gas, **hydrogen** appears to be a suitable alternative to power fuel cells. Even when fully electric, hydrogen vehicles need to be equipped with a fuel tank, and to have access to refuelling points.

Means of transport operating exclusively on electric motors, powered by rechargeable batteries or hydrogen fuel cells, do not directly emit GHG (however, primary production of H_2 or electricity may do).

Hydrogen and fuel cells

Hydrogen (atom H) is the most abundant chemical element in the universe. The hydrogen molecule (H_2) is gaseous under atmospheric pressure and it liquefies at 253°C below zero. Not naturally found on earth, H_2 can be produced from practically all energy sources (fossil and renewable hydrocarbons and electricity) to further serve as an energy carrier. Able to chemically react with oxygen (O_2), H_2 can serve as fuel for an internal combustion engine or for a fuel cell (electric motor). The reaction between (pure) H_2 and O_2 only results in water (H_2O) and energy, and emits no CO_2 nor any other greenhouse gas.

H_2 production and use as fuel still faces technical and economic challenges (e.g. efficiency of production processes; low energy density and high-pressure storage needs, safe storage, transportation and fuelling, lack of distribution network). Fuel cells' pros and cons also make them a technology still challenging in some aspects (e.g. high costs). However, the technological progress already made and good prospects for future development make fuel cells and hydrogen a possible alternative to conventional fuel to power some transport modes, notably electric cars.

The fuel cells and hydrogen joint undertaking (FCH JU) – a public-private partnership established under the European Strategic Technology Plan (SET-Plan) with a budget up to nearly €1 billion for 2008-13) – aims to accelerate market development of these technologies.

Transport modes and alternative fuels

Overview

Biofuels and biomass-derived synthetic fuels could technically replace fossil energy sources and suit all transport modes. However, the future of biofuels face limiting factors (e.g. limits on land surface, water needs and technological possibilities), including societal considerations (e.g. food vs. energy production, protecting biodiversity). Long-term transport needs will have to be satisfied with a mix of alternative fuels.

According to experts, the most likely options for alternative fuels in transport are:

Road: electric batteries for short to medium distances; compressed gases, particularly H_2 (fuel cells) and CNG (ICEs), for intermediate distances; liquid fuels (biofuels, synthetic fuels and liquefied gases, LPG, LNG) for long distance transport.

Waterways: liquid biofuels (all vessels), liquid gases (LNG for maritime activities, LPG in short-sea transport), compressed H_2 (inland navigation, small boats) (and possibly nuclear for large maritime vessels).

Air: biofuels-derived jet fuel.

Rails: electric grid as much as possible (or biofuels).

Electric road vehicles

Despite various technical choices and important challenges, notably in terms of costs and public acceptance, the global outlook for electric vehicles (EVs) is generally seen as relatively positive by experts. In 2012, car manufacturers had developed over 20 different models of EVs, representing a global stock of over 180 000 units. EVs can be all electric (batteries only) but numerous models provide for varied hybrid combinations of electric motors and conventional ICEs. Hybrid EVs reduce consumption of conventional fuel or increase driving range (range-extended EVs). Except where electricity is only provided from on-board generators, plug-in electric vehicles (PHEVs) need to be recharged, with fast-charging (taking about 2 hours) or slow-charging (12 hours on average) systems. Replacing empty battery packs with charged ones is also technically possible, but this has not yet developed as a

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viable market option. The EV industry sector is also subject to regular surveys by consultants. According to analysts, EU sales of battery EVs and plug-in hybrid cars increased from a few hundred in 2010 to about 23 000 in 2012. However this level of sales represents less than 0.6% of all new cars sold in the EU.

Developments in electric vehicles not only concern personal cars or two-wheel vehicles. Experts consider that electric and fuel cell heavy-duty vehicles can be viable options to bring zero emission trucks to market. However, bringing EVs to the mass market also depends on policy interventions.

A need for refuelling infrastructure

A vicious circle

As alternative fuels for transport, electricity, hydrogen and natural gas face the 'chicken and egg' problem. Private investment in retail supply infrastructure is discouraged while the number of users is low. Citizens and professionals will not turn to alternative-fuelled vehicles (or vessels) in the absence of refuelling infrastructure, if refuelling systems are not standardised and interoperable, or if information on compatibility of fuels and vehicles is lacking. In parallel, technologies and production of alternative fuel vehicles cannot become price-competitive while market demand remains low.

A proposed EU directive on deployment of alternative fuels infrastructure

Having assessed different options to address this problem, the Commission tabled, in early 2013, a proposal for a directive which would require Member States to adopt a national framework for the market development of alternative fuel and to ensure that minimum infrastructure for the supply of some alternative fuels in road and navigation transports is set up.

Electricity supply

Each Member State should ensure the establishment by the end of 2020 of a defined minimum number of recharging points for EVs (e.g. 321 000 for the Netherlands and 1.5 million for Germany, compared respectively to the 1 700 and 1 937 which existed in 2011), at least 10% of which should be publicly accessible. MS should also ensure that ports are equipped with shore-side electricity supply for vessels by the end of 2015.

Hydrogen supply

At distance of under 300 km between each, hydrogen refuelling points should be set-up in sufficient number to allow circulation of hydrogen vehicles throughout the entire national territory by the end of 2020[5].

Gas supply (LNG and CNG)

LNG should be available for navigation along the Trans-European Transport (TEN-T) core network in all maritime ports by 2020 and inland ports by 2025. LNG refuelling points should also be developed to sustain heavy-duty road transport along the TEN-T core network (refuelling points at less than 400 km apart). By the end of 2020, MS should also ensure the setting up of a sufficient number of CNG refuelling points (at least every 150 km) to sustain circulation of all CNG vehicles across the Union.

Technical standardisation

The proposed directive would require harmonisation of technical specifications of alternative fuels and refuelling systems based on common standards.

Consumer information

Information on compatibility between fuels on the market and vehicles should be made available widely (e.g. at refuelling points, vehicle testing facilities, and in vehicles themselves).

According to the Commission, the overall estimated costs for such infrastructure would be about €10.5 billion (by 2020). This could be covered by private investment if Member States make efficient use of the wide possibilities to mobilise such financing, notably to attract 'first-mover' investors.

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A European strategy for alternative fuels for transport

The proposed directive on infrastructure deployment is part of an overall European strategy for alternative fuels presented simultaneously by the Commission in January 2013. It aims at setting, for all transport modes, a long-term policy framework to guide technological development and investment in alternative fuels and increase consumer confidence. This strategy is also accompanied by an action plan dedicated to the development of LNG for alternative fuelling of shipping.

European Parliament

EP positions

In 2008, the EP agreed to simplify the approval system for hydrogen powered cars, a move already seen as a step forward in the development and marketing of hydrogen vehicles. In a 2010 resolution on electric cars, the EP called, among other things, on the Commission and Member States to establish the necessary conditions for the existence of a single electric-vehicle market.

Next steps

The proposal for a directive on the deployment of alternative fuels infrastructure (2013/0012(COD)) has been referred to the Committee on Transport and Tourism (TRAN) which has appointed Carlo Fidanza (EPP, Italy) as rapporteur. According to press reports, the proposed measures generally received positive support from MEPs when initially presented and discussed in the Committee, though some MEPs expressed concerns notably with regard to the infrastructure costs[6] and the challenge in attracting private investors. The financing of the proposed measures was also among the concerns raised by transport ministers during their preliminary debate on the proposed directive in March 2013, together with concerns about the proposed targets for recharging/refuelling points, and the deadlines for implementation.

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Endnotes

[1] Some English (EN)/French (FR) translations in this domain have the potential to confuse: e.g. fuel (EN) = carburant, combustible (FR); petrol, gasoline (EN) = essence (FR); petroleum, crude oil (EN) = pétrole (FR); diesel, diesel oil (EN) = gazole, gasoil (FR); gas (EN) = gaz, carburant (FR).

[2] Eurostat statistics on transport: see in particular pp 115-116.

[3] This briefing focuses on alternative fuels for use in transport and related technical aspects (particularly alternative fuels which do not work with conventional combustion engine technologies and existing refuelling systems and infrastructure). It does not cover other technical means (e.g. progress in quality and purity of petroleum-derived fuels, energy efficiency of engines) and other policies which contribute to reducing dependence on fossil energy sources and reducing emissions of GHGs.

[4] An expert report published in 2011 refers to about 5 million LPG-powered cars in Europe. In 2013, the Commission refers to a fleet of about 9 million cars using LPG.

[5] This network of public hydrogen supply points would be required in MS where hydrogen refuelling stations have started to be established at the time the directive enters into force.

[6] The initial appraisal of the Commission impact assessment by the EP's Impact Assessment Unit (June 2013) recalls that the European Commission considers that there will be no implication for the EU budget and that national budgets may be affected depending on the specific measures chosen by the Member States. However, the appraisal underlines that no quantification of the implications for national budgets has been provided.

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