

ENERGY OPTIONS TO POWER TRANSPORT

Institution of
**MECHANICAL
ENGINEERS**

The Climate Change target of reducing greenhouse gas (GHG) emissions by 80% (relative to 1990 levels) is unlikely to be met through a reduction in demand, so our transport modes must be significantly decarbonised to meet this 2050 target^[1]. Somehow a solution needs to be found to break the UK's dependency on fossil fuels.

Currently the European Union (EU) governs the fuels used within our transport sector by two directives: the Renewable Energy Directive (RED) and the Fuel Quality Directive (FQD)^[2]. The Institution believes that there are still three key issues that remain:

1. The modification of vehicles to allow the transitions to new fuels;
2. The exact energy demand and hence fuel mix options to meet the reduced target;
3. The clarification that the new regime really does represent the emission reduction demand when all the lifecycle issues are taken into account.

The Institution of Mechanical Engineers therefore recommends that:

- The Engineering and Physical Sciences Research Council (EPSRC) continues to provide research & development (R&D) funding to focus on the growth of advanced and flex fuel vehicles (vehicles which run efficiently on different fuels), focusing on combustion, engine durability and material compatibility.
- The Department for Transport develops a roadmap of different energy pathways to show the optimum trajectory for transport within the UK, so that the consequences of decisions are understood.
- The Department for Transport must work proactively with the European Commission (EC) to report on the variety of biofuels available (including issues such as energy security, sustainability and lifecycle emissions) to develop a framework to define the optimal fuel and modal relationships.

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FOSSIL-SOURCED LIQUID FUELS

The UK's energy consumption across transport continues to increase in terms of tonnes of oil equivalent, shown in Graph 1^[3], demonstrating the need to reduce the UK's dependency on fossil fuels.

Petrol and Diesel

These remain the most popular hydrocarbons and the last decade has seen them develop into cleaner fuels with increased sales. Manufacturers' R&D funding and research programmes run by the EPSRC must continue to encourage the development of smaller, more-efficient engines that have reduced exhaust and lifecycle emissions. Hydrocarbons will continue to dominate, but supply and price will become bigger concerns than emissions^[1].

Fossil-sourced gaseous fuels

These can improve energy efficiency, lowering carbon emissions and reducing transport's reliance on oil^[4]. In 2011, the UK's gross natural gas production fell by 20.8%, with production falling by 58.3% since its peak in 2000^[1]. Depending on the source of the gas, there are implications regarding CO₂ emissions.

Liquid Petroleum Gas (LPG)

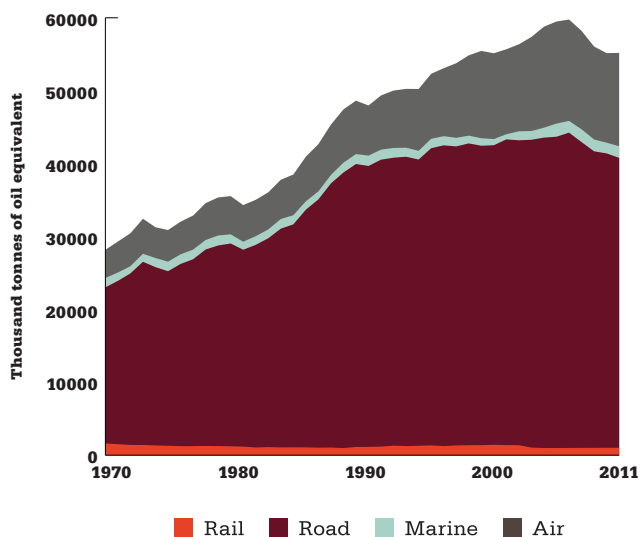
LPG represents 1% of the European passenger car market. LPG is predominately a blend of propane and butane, produced either as a by-product of oil refining or from natural gas or oil fields. As an alternative it is suitable for cars and light vans, rather than for heavy vehicles^[5]. Vehicles running on LPG emit about 10% less CO₂ compared to their petrol equivalents.

Compressed Natural Gas (CNG)

CNG engines offer a direct alternative to diesel and petrol internal combustion engines (ICEs); they can produce up to 5% less CO₂ compared to a diesel engine and up to 30% compared to a petrol engine. They produce up to 80% fewer nitrous oxide (NOx) emissions and have zero particulate emissions. The main constituent of CNG is methane from oil and gas fields^[6]. It is a short to medium-term option for heavy-duty diesel vehicles, as it burns more cleanly than diesel or petrol. CNG vehicles require specific engines and a dedicated distribution and refuelling infrastructure^[7]. Biomethane can be incorporated in the fuel, leading to the potential to reduce lifecycle emissions for CNG vehicles in an evolutionary manner.

Liquid Natural Gas (LNG)

LNG has very similar applications to CNG but instead of being stored at high pressure, the gas is



Graph 1: Transport energy consumption by type of transport; UK 1970–2011^[3]

liquefied to -165°C. Its advantages over CNG include higher energy density, lower weight of storage tanks (allowing additional carrying capacity/payload), and lower costs^[4], but boil-off of gas is potentially a serious issue, given the far greater global warming potential of methane in comparison to CO₂.

BIOFUELS

Biofuels are split into categories: first generation manufactured from feedstock, eg sugarcane or rapeseed; second and third generation from bioethanol (non-feedstock), biodiesel (dedicated energy crops) and biogas (energy from waste). Sustainability of biofuels remains a controversial topic, with concerns over food production, deforestation and other unacceptable land-use changes^[1]. This debate on indirect land use change (iLUC) was addressed by the EC in October 2012 and will now be included when assessing the GHG performance of biofuels.

The USA has led the way in biofuel development since the US Government invested \$510 million in 2011 for the growth of advanced drop-in biofuels, which, along with tax breaks for new biofuel plants, loans and research grants, has stimulated their market^[8]. Currently up to 7% of biofuels are used in those fuels available on the common market without consumers needing to consider the impact on vehicle performance. More work is needed to encourage the development of flex-fuel vehicles.

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Bioethanol

Bioethanol has a 41% share of the UK biofuel market^[8] with many considering it as an alternative to petrol. Regarded as a renewable fuel (dependent on the raw materials), it provides reductions in CO₂ from Well To Wheel (WTW). Its high octane levels enable increased compression ratios, and favourable spark timings to improve engine efficiency. However, the oxygenated nature of the fuel leads to a greater volumetric fuel consumption (even though energy utilisation is actually better) and the low volatility of high ethanol blends can lead to cold-start problems at low temperatures (although counter-measures are available and well understood)^[9].

Biodiesel

Biodiesel (or fatty acid methyl ester (FAME)) dominates the UK biofuel market with a 59% share^[8]. It is biodegradable, so if spilt does not pollute. Discussions about the sustainability (including iLUC factors of biodiesel derived from food crops) and research in advanced 'drop-in' biodiesel must be encouraged, as the diesel market makes up more than 50% of the UK automotive sector. The quantity of FAME-based biodiesel that can be safely put into a vehicle is limited by the Original Equipment Manufacturers (OEMs) and consequently more research is required (OEMs currently won't accept more than a 7% FAME mix in biodiesel; this limits what can be done to control emissions in conventional diesel engines).^[10]

Biogas

Biogas is produced by decomposing organic matter or landfill waste by means of anaerobic conversion in a digester. To be used as a fuel, biogas can be upgraded to liquid biomethane (LBM) and be used in vehicles modified to run on CNG or LNG. Commercial vehicle trials suggest a 60%+ plus CO₂ WTW saving compared to an equivalent diesel vehicle. NOx emissions are lower with reduced particulate emissions^[11].

Other Biofuels

Other biofuels include derived jet fuels, manufactured from algae or crops. The largest feedstock comes from cooking oil, making up 30% of the total^[8]. Cellulose feedstock-based jet fuels are being developed from waste products from the forest industry or sugarcane. In October 2011 the UK witnessed its first commercial flight, with a Boeing 757 engine powered by a 50/50 blend of Jet A1 fuel and hydro-processed esters and fatty acids fuel (with the sustainability being approved by the WWF and without technical modifications)^[12].

SYNTHETIC ORGANIC FUELS FOR TRANSPORT (SOFT)

Synthetic organic fuels for transport are created when renewable energy is stored in hydrogen via

the electrolysis of water, and, with a small energy penalty, this hydrogen is reacted with CO₂ to form an infrastructure-compatible hydrocarbon fuel. Using this approach, hydrogen is used in the fuel rather than being used as the fuel. If these processes are powered throughout by carbon-free energy and the CO₂ used is captured from the atmosphere, then the combustion of this fuel would result in a zero net increase in the atmospheric CO₂ concentration^[13]. These fuels are being developed and demonstrated. They could be low-cost liquids that provide high-energy density solutions to work with existing vehicles and the current refuelling infrastructure^[1].

Electricity

Electricity is transferred in the form of batteries. Lithium-ion chemistries are favoured, but metal-air batteries' storage capabilities may increase as development continues in laboratories^[13]. Batteries are the dominant cost and weight within an electric vehicle (EV). To maximise the benefits that EVs offer, they must be powered from a smarter decarbonised electricity supply^[1].

Hydrogen

Hydrogen fuel is produced from the breakdown of a hydrocarbon source or by the electrolysis of water^[14]. Technical obstacles include incompatibility and cost of supplying an entirely new, safe, energy-efficient distribution infrastructure and the costs of hydrogen fuel-cell vehicles (HFCVs)^[13]. HFCVs offer zero emissions at the point of use, WTW CO₂ emissions are reduced when compared to ICE vehicles (depending on the source of hydrogen), and high efficiencies when chemical energy is converted directly into electrical energy^[15]. The UK is a global player in niche markets for HFCVs, including motorcycles, light vans and taxis. The Government and industrial partnership, UK H2 Mobility, is to define a strategic vision for the development of a refuelling infrastructure to support commercial roll-out of HFCVs from 2015^[15].

ENERGY CARRIERS AND ENERGY STORAGE

Energy carriers are used in EVs and hydrogen HFCVs. Energy storage systems enable the transfer of abundant low-value, off-peak energy to markets and sectors where demand is strong and the value of the energy is permanently high^[13].

Liquid Air (Nitrogen)

While not a fuel, nitrogen is emerging as a proxy for an energy carrier, as it has been demonstrated that it could be used within the transport sector. Companies have shown in static systems that it could be up to 70% efficient at converting waste heat back into power. This technology requires further funding to look at efficiency levels compared to the alternatives, but it is an interesting known technology option.

CONCLUSION

With global economies and population growing, the amount of liquid fuel will increase. Current EU directives state through the RED that member states are to source 10% of the energy used in road and rail transport from renewable sources by 2020, and the FQD sets environmental requirements for reductions in air pollution from petrol and diesel fuels, including fuel quality, as well as binding targets to reduce the fuel's lifecycle GHG emissions^[16]. Even with these directives imposed difficult questions must be answered: we need to look at how fuel is used, what is available and with which modes. We also need an energy policy that transcends political boundaries. This work will need to include more research into combustion engines, encouraging the development of more-efficient engines, as well as a better understanding of the advantages and disadvantages of different energy pathways, to produce a roadmap that will demonstrate the optimum trajectory for transport within the UK.

RECOMMENDATIONS

The Institution of Mechanical Engineers recommends that:

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