RSC response to the Environmental Audit Committee on Reducing Carbon Emissions from Transport.

The Royal Society of Chemistry (RSC) welcomes the opportunity to comment to the Environmental Audit Committee on the subject of Reducing Carbon Emissions from Transport.

The RSC is the largest organisation in Europe for advancing the chemical sciences. Supported by a network of 43,000 members worldwide and an internationally acclaimed publishing business, our activities span education and training, conferences and science policy, and the promotion of the chemical sciences to the public.

This document represents the views of the RSC and has been put together by our Environment, Sustainability and Energy Forum. The RSC's Royal Charter obliges it to serve the public interest by acting in an independent advisory capacity, and we would therefore be very happy for this submission to be put into the public domain.

The document has been written from the perspective of the Royal Society of Chemistry. The chemical sciences and chemical scientists will play an essential role in driving forward technological breakthroughs reducing carbon emissions from transport.

The evidence submitted was in the most part published in an RSC report entitled "Chemical Science Priorities for Sustainable Energy Solutions" [www.rsc.org/Gateway/Subject/EnvEnergy/].

SUMMARY

Oil derived liquids are at present the most cost efficient transport fuels and the most efficient energy storage materials available to us.

A number of different strategies for reducing carbon emissions from transport are required, the realisation of which will require contributions from chemical scientists. In essence technologies are required to make vehicles more efficient and to provide alternatives to fossil fuels:

- The fuel efficiency of vehicles must be improved through the use lightweight materials and fuel/engine additives to increase engine efficiency
- Development of battery technology for hybrid vehicles will enable their more widespread acceptability.
- Similar technological challenges face the development of fully electric vehicles as those facing the development of hybrid cars, except the electricity should be generated from renewable or non-carbon based sources to have a significant effect on carbon emissions.
- Biofuels are a renewable, carbon neutral source of vehicle power but many technological challenges must be overcome for their widespread use to be practicable.
- Hydrogen power vehicles too require many technological challenges be overcome before they can become a reality.
- Reducing carbon emission from air transport too presents challenges: use of lightweight materials will yield improved efficiency

STATE OF PLAY

In spite of current concerns about the constrained oil supply and high cost, most scenarios for the next 20 to 50 years suggest that the world's growing demand for energy will be primarily met by fossil fuels. Currently, about 74 million barrels of oil are consumed every day, **mostly for transport**, which is the sector where oil is most suited as the primary energy carrier, and where substitution is arguably most difficult. By 2020 this is predicted to have increased to about 110 million barrels per day (bpd). The demand for oil for transportation in the Asia Pacific countries is growing at 3.5% per annum from a current demand of about 18 million bpd compared to growth in Europe of just 0.5% from a demand of about 15 million bpd.

Trends in vehicle design are being driven by the **need to increase efficiency and reduce CO_2 emissions**. In 1997 there were 600 million vehicles on the world's roads, with engines operating at efficiencies of 10– 25% for petrol and 15–35% for diesels. Transmission, road and other losses reduce efficiency significantly for the overall vehicle. Vehicle engineers around the world are currently chasing every lead with a view to achieving the goal of improved fuel efficiency coupled with reliability and affordability. It is generally accepted that the **customer is unprepared to compromise his or her expectation of vehicle performance, reliability or cost**, so technological improvements are necessary alongside environmental developments.

Multidisciplinary teams including chemists and chemical engineers have already achieved significant improvements in the operation of the internal combustion engine by developing direct injection spark ignition systems and small diesels with more efficient turbo chargers. Efforts to improve engine efficiency by variable valve timing, cylinder deactivation, to reduce engine displacement during normal driving, reductions in engine friction and accessory loads, and sophisticated engine management systems all show promise.

The chemical sciences have been, and continue to be, pivotal in the development of systems that **offer significant improvements to fuel and exhaust systems in vehicles**; this has been demonstrated through the development of unleaded petrol (eradicating harmful lead additives), detergent additives (that have increased fuel economy and increased engine lifetime), oxygenated fuels (that improve fuel efficiency) and catalytic converters (to reduce harmful carbon monoxide, volatile organic compounds and NO_x emissions).

FUTURE CHALLENGES

Reducing vehicle weight

Vehicle performance can be considerably improved by reducing weight through the use of lighter construction materials. The past 20 years has seen a steady decrease in the amount of iron and steel in a typical family car with a corresponding increase in the amount of polymer composites, aluminium and even magnesium. Increased attention to the various bulk, surface and compositional chemistry aspects of the forming, joining and recycling of these materials, **to reduce manufacturing, design and assembly costs without compromising safety**, will greatly enhance the use of lightweight materials in vehicle construction. This will require **polymer and synthetic chemists** to create new structural materials and designs to reduce radically vehicle weight without compromising safety. Such materials are also required to conform to legislation such as the EU ELV (End of Life Vehicles) directive and thus be demonstrably recyclable.

Systems engineering approach

A further fruitful area of research might be to **consider personal mobility as a systems engineering problem consisting of the engine and fuel, the transmission system**, the vehicle itself including the wheels, the road surface and construction, the refuelling infrastructure and the eventual recycling of the components. Much of this will require a deep understanding of the chemistry and chemical engineering aspects of the fuels, their combustion characteristics, the engine and vehicle shell materials, the control systems and sensors required, transmission and energy storage and the re-use of the component materials. The task of creating a sustainable transport system when cars will continue to be the preferred means of personal mobility in the urbanised regions of the developed world is considerable and will require the ingenuity of chemists as well as engineers.

Hybrid vehicles

In the past few years some vehicle manufacturers have introduced hybrid drive trains into the market place. Various arrangements are possible but the combination of a smaller gasoline or diesel engine coupled to electric batteries and electric drive motors, together with recovery of the vehicles momentum through regenerative braking, have led to dramatic increases in energy efficiency. Further improvements in this approach will **require lightweight construction materials and technology, efficient low emission engines and improved battery or alternative energy storage technology**. Introduction of hydrogen fuel cells, alone or in hybrid configuration with a battery, offer the possibility of removing the car from the environmental debate, as well as allowing the use of renewable and sustainable fuels.

Electric vehicles

Fully electric vehicles have a number of issues in common with hybrid vehicles in so much as **energy storage technology** (e.g. battery technology) is **absolutely critical to success**. Electric vehicles differ from hybrid vehicles in that there is **no back up supply**, so when the battery runs down, the vehicle stops. Therefore the **range** of the vehicle is dictated by **battery technology** available and also the **weight** (and thus **efficiency**) of the vehicle is related to the **number/size of the batteries required**. For low emission vehicles the electricity must be supplied through low emission electricity sources, such as that derived from**, renewables, nuclear power or fossil fuels coupled with carbon capture and storage technology**. Therefore there is a need for **an infrastructure to supply “charging points”** for electric vehicles. An electric vehicle supplied by low carbon technologies would in theory be a **very low carbon emission vehicle**.

Biofuels

Today, biomass provides about 20% of Brazil's primary energy supply, with much of this being alcohol fuel, which accounts for about 30% of gasoline demand. In early 2003, the European Commission issued a **directive promoting the use of biofuels for transport**, setting out two indicative targets for EU member states – 2% biofuels inclusion in the fuel pool by December 2005 and 5.75% by December 2010. **The UK is currently not on track to meet the 2010 target.**

The relatively low conversion efficiency of sunlight into biomass means that large areas of arable land would be required to allow a significant amount of the existing fuel pool to be substituted with biofuels. Scenarios developed for the US and EU indicate that short term targets of up to **6% displacement of fossil fuels with biofuels** appear feasible using conventional biofuels. A 5% displacement of gasoline in the EU would require about **5% of available cropland** to produce ethanol and **15% to produce diesel** (land requirements for diesel are higher than for ethanol because of lower yields of liquid fuel per hectare). Kheshgi *et al* estimate that the equivalent of 12% of US cropland would be required to produce enough ethanol to replace the energy content of 10% of the US gasoline consumption in 1990. However, if all the carbon dioxide emissions associated with the production, harvesting, and conversion of corn to ethanol were to be offset, the land area required would be nearer to 50% of available cropland.

Biofuels are more expensive than conventional transport fuels, but improved conversion technologies will broaden the range of feedstock. For example, the **cost effective hydrolysis of lignocelluloses** (for example wood or straw) would considerably increase the source of biomass for bioethanol production to include woody and grass crops as well as bio-waste. Work is underway in a number of countries and in particular the US to reduce the cost of converting cellulose to sugars, although a considerable amount of biomolecular and chemical engineering is required in order to achieve commercially attractive prices. Recent work in this area has led to the concept of a ‘bio-refinery’ similar to a petroleum refinery, **which would use the whole of the biomass feedstock to produce a number of products in addition to biofuels**, such as high value chemicals and co-generated electricity. Encouragement by US government and EU funding and targets for inclusion of biofuels in the transport fuel pool should see rapid developments in this area. **There is considerable research interest in the UK in the area of the bio-refinery**.

Gasification and thermochemical technologies are receiving increased attention as methods of converting biomass into transport fuels. Gasification to syngas (a mixture of hydrogen and carbon monoxide) **enables the production of a variety of fuels** including methanol, ethanol, dimethyl ether and synthetic diesel.

Hydrogen vehicles

On-board storage of hydrogen is posing significant obstacles to delivering hydrogen-powered vehicles. Hydrogen is a gas at room temperature and therefore needs to be **liquefied, compressed or stored in some other way** to have enough onboard to travel a reasonable distance. Nearly all of today’s prototype hydrogen vehicles use compressed gas, but this is relatively bulky. Liquid hydrogen could provide an ideal way to transport hydrogen, but the boiling point of hydrogen at -253°C means that this storage method would be extremely energy intensive, requiring considerable energy to keep and maintain such low temperatures. Other advanced storage materials are being developed, such as carbon based adsorbents (carbon nanotubes) and metal hydrides. **However, the high temperatures and pressures required to liberate H_2 and slow-H_2 release are posing serious obstacles to these storage materials**.

There are also significant economic considerations surrounding **the cost of fuel cells *versus* the internal combustion engine**, with the latter typically costing $30 for each kilowatt of power it produces while **fuel cells cost a hundred times more**. Technical challenges such as making fuel cells rugged enough to withstand the stress of driving, reducing their size and weight while increasing power density and fuel flexibility also still exist. In the interim, while fuel cell technology is preparing for mass commercialisation, it is likely that more and more hybrid electric vehicles will be deployed, offering significant improvement in terms of energy use and significant reductions in carbon emissions in comparison to the conventional internal combustion engine.

Air travel

Air transport is receiving increasing attention because of **environmental concerns linked to CO_2 emissions, air quality and noise**. Continuing atmospheric chemistry research into the impact of aircraft emissions in the upper troposphere (extends from about 14 to 18 km) and lower stratosphere (extends from the troposphere to about 50 km) is required. To reduce emissions, designs with reduced weight will benefit fuel economy and efficiency. Embedded sensors and controls (in intelligent gas turbine engines) could reduce noise, emissions and costs through more effective diagnosis and maintenance processes. New materials are required (e.g. low-cost composites, corrosion-resistant, damage-tolerant alloys and smart materials) to reduce manufacturing, life-cycle costs and reduce travel time, whilst advanced coatings for the next generation of gas turbine engines are required for improved fuel efficiencies and emission reductions. There is a real need for innovative work in this area. **Multidisciplinary teams of chemists and engineers are needed to develop viable solutions**.