**IEAGHG Information Paper 2017-IP49; Biofuels – Transport Sector Saviours or Villains?**

Biofuels are seen as an opportunity to reduce fossil fuel use and cut greenhouse gas emissions in the transport sector. As discussed in an earlier IP (2017-IP42; Electric Cars Lead the Transport Charge[1]) GHG emissions from the transport sector have more than doubled since 1970, and have increased at a faster rate than any other energy end-use sector to reach 7.0 Gt $CO_2$eq in 2010; representing 23% of global greenhouse gas emissions. Around 80% of this increase has come from road vehicles. Greenhouse gas emissions from this sector primarily involve fossil fuels burned for road, rail, air, and marine transportation. Almost all (95% in 2010) of the world's transportation energy comes from petroleum-based fuels, largely gasoline and diesel. The introduction of sustainable biofuels in the transport sector could be one route to reduce fossil-based emissions in the transport sector. Whilst we also see alternative options to biofuels in certain sectors of transport, like urban vehicles, where there seems to be a global drive towards electric vehicles[1], others like the aviation sector are very interested in the use biofuels in combination with increased engine efficiency and carbon offset programmes to reduce emissions in that sector. A significant number of civil airlines have tested biofuels including US Airways, American Airlines, Lufthansa, Air France, Etihad, Singapore Airlines, Virgin Airways and Aero Mexico to name just a few[2]. The US Air Force has also undertaken trials with biofuels[3].

A report on the **Sustainability of Liquid Biofuels** has recently been published by the Royal Academy of Engineering (RAE)[4] n the UK. The press release for the RAE study can be found at: http://www.raeng.org.uk/news/news-releases/2017/july/biofuels-made-from-waste-are-the-business,-says-ac

The full report can be found at: http://www.raeng.org.uk/publications/reports/biofuels

The study was commissioned by the Department of Transport and the Department of Energy and Climate Change (now the Department for Business, Energy and Industrial Strategy) to provide advice on the UK's future strategy for the development of biofuels. To add further context: the European Commission see biofuels as a renewable alternative to fossil fuels in the EU's transport sector, helping to reduce greenhouse gas emissions and improve the EU's security of supply. By 2020, the EU aims to have 10% of the transport fuel of every EU country come from renewable sources such as biofuels. See: https://ec.europa.eu/energy/en/topics/renewable-energy/biofuels. As (currently) a member of the EU, the UK has to meet the targets set for the introduction of biofuels into the transport sector. In the UK, The Renewable Transport Fuel Obligation (RTFO)[5] supports the government's policy on reducing greenhouse gas emissions from vehicles by encouraging the production of biofuels that do not damage the environment. Under the RTFO suppliers of transport and non-road mobile machinery (NRMM), fuel in the UK must be able to show that a percentage of the fuel (currently around 5%) they supply comes from renewable and sustainable sources. Fuel suppliers who supply at least 450,000 litres of fuel a year are affected.

[1] http://www.ieaghg.org/docs/General_Docs/Publications/Information_Papers/2017-IP42.pdf
[2] http://www.biofuelsdigest.com/bdigest/2012/06/05/aviation-biofuels-which-airlines-are-doing-what-with-whom/
[3] https://www.scientificamerican.com/gallery/military-green-us-air-force-flies-on-biofuel/
[4] The **Royal Academy of Engineering is** the UK's national academy for engineering which aims to advance and promote excellence in engineering. It provides analysis and policy support to promote the UK's role as a place to do business. See: http://www.raeng.org.uk/about-us
[5] https://www.gov.uk/guidance/renewable-transport-fuels-obligation

**Global Biofuels production in context and issues for deployment**

Over the decade from 2005 to 2015, world bioethanol production increased by a factor of three, from 33 to 98.3 billion litres. Biodiesel production increased from less than four to 30.1 billion litres. However, to put this in perspective in 2015, biofuels only accounted for about 4% of total transportation fuels used worldwide.

Global production of biofuels is dominated by the US and Brazil, which produce 72% of all biofuels in 2015 and then Europe which produced 12%. Production of bioethanol in the US is almost exclusively from corn, while sugar cane is used in Brazil. In Europe, the main feedstocks are corn for bioethanol and rapeseed for biodiesel production. Argentina, Brazil and the USA also produce significant quantities of biodiesel, predominantly from soybean, while Malaysia and Indonesia produce biodiesel from palm oil.

In terms of future demand, the RAE report refers to an IEA Road Map for the biofuels, which projects that biofuel production, could reach 27% of total transportation fuels used by 2050, although the RAE report infers this is based on a number of optimistic assumptions. Other organisations they reference, such as the OECD and BP, project approximately a 7% share of biofuels by 2030.

In terms of markets for future biofuel use, the RAE report considers that there are a number of issues that might affect deployment. In the ***light vehicle sector,*** there are plans to increase the biofuels component from 5-10% by volume. However, as noted earlier, with many Governments now looking to phase out the ICE for domestic cars, this route for biofuels growth might be curtailed by Government legislation in regions like Europe.

For the ***aviation sector***, the main constraint is the need for fungible fuels that meet the sector's high performance specifications. Production via hydrogenated vegetable oils is currently technically feasible but not cost competitive, requiring further development. The fuel weight per unit of energy is a critical factor in aircraft performance and operation. Biofuels are at a disadvantage as they have lower calorific value per unit volume than fossil fuels. This means that aircrafts must carry significantly more fuel, which reduces their efficiency and may require design changes.

The ***shipping sector*** the RAE suggest is more flexible terms of fuel specifications; however, biofuels are currently not used for marine shipping. The price, availability and speed of loading are the key factors that determine choice of fuel for ships. Storage fuel on board ships for long periods could be an issue for biofuels, which can hydrolyse and lead to corrosion, ingress of water and microbial growth. It is noted that the ISO 8217 standard on Marine Fuel Specification currently precludes the use of biodiesel as a marine fuel, although this may change. MARPOL International Convention for the Prevention of Pollution from Ships currently covers sulphur emissions and energy-efficient ship design[6]. In response to changes in MARPOL, shipping operators are switching to lower sulphur fuels, with LNG ships in operation[7], methanol is being considered as a fuel and even electric ferries are planned in Norway[8].

Diesel engines generally power ***Heavy Good Vehicles (HGVs)*** and this is likely to continue for the foreseeable future. As with passenger car manufacturers, there is a general acceptance of biofuel/diesel blends (7% of biofuel by volume added to conventional diesel) in the HGV sector.

---

[6] http://www.ieaghg.org/docs/General_Docs/Publications/Information_Papers/2016-IP26.pdf

[7] http://www.shell.com/energy-and-innovation/natural-gas/lng-for-transport/news-and-media-releases/shell-to-fuel-worlds-first-lng-powered-crude-oil-tanker.html

[8] https://www.iims.org.uk/fully-automated-electric-ferries-norway/

However, the RAE report suggests that operators have been reluctant to embrace the use of biofuel blends in this sector.

Overall, the RAE report suggests that the light fuel vehicle sector is currently the most advanced in deploying biofuels, with aviation next but little progress has been made in the shipping and HGV sectors.

**The Key sustainability issues associated with liquid biofuels**

Biofuels offer advantages but also pose risks in terms of environmental, economic and social sustainability. Drivers for biofuels are: GHG emissions reductions in the transport sector, energy security and rural development. On the other hand, there are concerns related to the increasing production of biofuels, such as upward pressure on food prices, the risk of increase in GHG emissions through direct and indirect land use change (LUC) from production of biofuel feedstocks, as well as the risks of degradation of land, forests, water resources and ecosystems.

For Environmental groups, the use of first generation feedstocks, such as corn, has become a particularly contentious issue, largely owing to competition with food production and concerns over diverting agricultural land into fuel production. A growing demand for agricultural produce risks an increase in deforestation and use of land with a high biodiversity value to meet this demand, as well as associated usage of freshwater, fertilisers and pesticides, with negative consequences on the environment.

Some of these issues could be addressed by using second-generation feedstocks; however, RAE considers that the economic viability of some second generation of biofuels remains doubtful in the current economic context, largely because of the low oil prices.

Third generation (algal) biofuels could also avoid the issue of food competition and land use because microalgae can be grown on non-arable land and in wastewater, saline or brackish water and they grow extremely rapidly. However, the production of biofuels from microalgae is energy intensive and remains economically unviable.

**Carbon footprint of biofuels**

This is the focus of the report and, the issue that is of most interest to IEAGHG, is that of the carbon footprint of biofuels. The study has reviewed life cycle environmental impacts of biofuels as reported in the LCA studies published on biofuels. Here, we have focused on the results in terms of GHG emissions; the report goes on to discuss issues relating to energy use and water demand.

The review suggests that:

For first generation biofuels i.e. bioethanol and biodiesel:

- If you include LUC emissions bioethanol cannot meet the EU Renewable Energy Directive target of 50% reduction in GHG emissions relative to petrol regardless of the type of feedstock.
- Bioethanol production from sugar cane that involves deforestation of tropical rainforest, the carbon footprint can be up to 60% higher than that of petrol.
- Again, if you include LUC then biodiesel from all feedstocks has a higher average carbon footprint than conventional diesel.
- Biodiesel from palm oil on peat and forest lands can have up to 40 times higher GHG emissions than conventional diesel

For second generation biofuels:

- Therefore, the quality of the available data is not as robust as in the case of the well-established first generation biofuels.
- Lignocellulosic bioethanol from agricultural and forest residues has a lower carbon footprint than bioethanol from energy crops. This is because of $N_2O$ emissions during the cultivation of energy crops, related to the use of fertilisers, are avoided in the case of residues.
- Lignocellulosic bioethanol in general has a lower carbon footprint than petrol if you assume the ligin will be utilised to generate heat and power.
- LCA studies of biodiesel from used cooking oil (UCO) report carbon footprints 60% to 90% lower than conventional diesel.

For third generation biofuels i.e. algal biofuels the study suggests that:

- Considering the average values across all the studies, the carbon footprint of microalgae diesel is around 3.5 times higher than that of diesel.
- The AAE study concludes that at the present state of development, algal biofuel does not represent a feasible alternative to fossil diesel.

The study refers to a second UK study that indicates that despite the negative values for GHG emissions for some second-generation biofuels, that their potential to reduce the carbon footprint of transport fuels at the national level is small. At the current blending levels of 5%, application of these second-generation biofuels it would be equivalent to an average total reduction in GHG emissions of 0.35% per year in the UK.

**Summary**

Overall, it would seem that the overwhelming case for the use of biofuels to reduce greenhouse gas emissions from the transport sector is not there yet. In fact, early production options increase the carbon footprint compared to standard fossil fuels, which they are supposed to be better than. Whilst some third generation options do show considerable promise, they are at an early stage of development. This a potential area for further R&D investment provided the future benefits of the production technology and product are verified by LCA.

In terms of market potential, this may restrict their developments; the biggest market sector is that of light vehicles (domestic cars) but other developments in that area in particular many governments now moving to phase out petrol and diesels cars and replace with electric vehicles will limit demand for biofuels in regions. The aviation sector is trailing biofuels and there is potential for their application in that sector, neither the marine transport sector nor the HGV sector seems to be looking to embrace biofuel use in the near future.

**John Gale & Jasmin Kemper**

**24/08/17**