Renewable synthetic fuels for transport **Gordon Taylor** **2018-11-20**

I have authored and co-authored several documents on energy in transport: http://cms.energypolicy.co.uk/transport/
In so doing, I have learnt a lot and meanwhile the technology has advanced hugely.

2002-04-05 Response to Draft of 'Powering Future Vehicles', http://cms.energypolicy.co.uk/transport/273
I compared early production gasoline hybrid vehicles with prototype hydrogen fuel cell vehicles.
This showed that the former were similar to the latter in well-to-wheel efficiency.
However, for carbon-neutral fuels, I suggested methanol and ethanol, as well as hydrogen.

2003-04-15 The Future of the Hydrogen Economy: Bright or Bleak?, http://cms.energypolicy.co.uk/transport/254
Page 29 includes:
‘Even assuming ideal processes and current industrial practice, the analysis reveals that considerable amounts of energy are lost between the electrical source energy and the hydrogen energy delivered to the consumer. For road delivery of compressed hydrogen, Path A, the electrical energy input exceeds the HHV energy of the delivered hydrogen by a factor of at least 1.69. In the case of liquid hydrogen, Path B, the factor is at least 2.12. For on-site hydrogen production, Path C, the factor is at least 1.69. For delivery of hydrogen by chemical hydrides, Path D, the factor is at least 1.95. It is unlikely that any of these would be attractive. Hence elemental hydrogen may provide practical solutions in some niche markets, but it cannot become important in a future energy economy’.

Page 34 The Conclusions were:
'The analysis shows that an elemental "Hydrogen Economy" for road transport would have a low well-to-tank efficiency and hence a low environmental quality. In particular, if the electrical energy were generated in coal-fired power plants, the well-to-tank efficiency might fall below 20%. Even if the hydrogen were used in fuel cells, the overall energy efficiency would be comparable to that of steam engines in the early half of the 20th century, while the CO 2 emissions would have significantly increased due to the growth of overall energy consumption.

The time has come to shift the focus of energy strategy planning, research and development from an elemental “Hydrogen Economy” to a “Synthetic Liquid Hydrocarbon Economy”. This means directing the limited human, material, and financial resources to providing technical solutions for a sustainable energy future built on the two closed clean natural cycles of water (for hydrogen) and CO 2 (for carbon). Fortunately, much of the technology exists already – e.g. for growing biomass, and for fermentation and distillation to produce ethanol. Both methanol and ethanol could be synthesized from water and carbon. Provided that the carbon is taken not from fossil resources ("geo-carbon"), but from the biosphere or recycled from power plants ("bio-carbon"), the "Synthetic Liquid Hydrocarbon Economy" would be far superior to an elemental "Hydrogen Economy", both energetically and environmentally'.

2003-10-20 New Automotive Powertrains and Fuels, http://cms.energypolicy.co.uk/transport/255
I commented: 'One significant finding is that - of the various Hydrogen Fuel Cell Vehicle prototypes - the Toyota FCHV5 has the best overall 'Well-to-Wheel' efficiency. The second is that even this is inferior to the 2004 model Toyota Prius engine-electric hybrid car that is already in high-volume production'.

2008-10-10 Renewable Synthetic Fuels for Transport, http://cms.energypolicy.co.uk/transport/256
In the Presentation, the Outline is:
'• Renewable energy is needed for deep cuts in CO 2
• Vehicle makers and buyers could not afford Battery Electric Vehicles or Fuel Cell Vehicles
• Fuel companies could afford to produce renewable synthetic liquid fuels
• These would provide Compatible Affordable Sustainable Transportation'.

This study also found that biomass could supply only 10-30% of the transport fuel supply, so that synthetic fuels would also be required.

2010-05-03 The CRI Renewable Methanol Process and Potential, http://cms.energypolicy.co.uk/transport/257
This discusses one synthetic liquid fuel - methanol. But while technically possible, the energy density is only half that of gasoline.

2010-05-03 Pathways to Renewable Transport Fuels, http://cms.energypolicy.co.uk/transport/276
This gives summary information on key renewable fuel plants in Europe.
The most significant is 7) Solar-Fuel GmbH, Germany (of 25 kWe input, built by ZSW, Stuttgart) which used 'Power-to-Gas' (i.e. electrolytic hydrogen, then methanation) to produce methane.
This document has many relevant links dated 2009 and 2010.

This has been followed by:
2012 - a PtG plant of 250 kWe in Stuttgart, used for process development.
https://www.zsw-bw.de/en/research/renewable-fuels/topics/power-to-gas.html

2013 - a PtG plant of 6300 kWe in Werlte, built for Audi. This produces some 'e-gas' for refuelling (Audi) CNG vehicles.
http://www.cedec.com/files/default/8-2014-05-27-cedec-gas-day-reinhard-otten-audi-ag.pdf
* Slide 33 shows that the Greenhouse Gas Footprint (i.e. fuel production, vehicle use and vehicle production) of an ICEV using 'e-gas' made with wind electricity is less than that of a BEV using wind electricity.

Solar-Fuel became ETOGAS and is now owned by Hitachi Zosen Inova.
See: http://www.hz-inova.com/cms/en/home?page_id=4896

I recently noted:

2018-10-16 Gasunie, TenneT and Thyssengas reveal detailed, green 'sector coupling' plans using power-to-gas technology, https://www.tennet.eu/fileadmin/user_upload/Company/News/German/Hoerchens/2018/20181016_PM-Gasunie-TenneT-Thyssengas-Power-to-Gas-Pilot-Element1_EN.pdf
This includes: '
• The electricity and gas grid operators are planning to build a 100-MW power-to-gas plant in Lower Saxony
• These new facilities are intended to couple the energy, transport and industrial sectors
• Power-to-gas can help stabilise the electricity grid, limit the curtailment of wind energy and reduce the future need for grid expansion.

Although this is to produce only hydrogen, it is almost 17 x the capacity of the Audi plant at Werlte.

It also includes: 'Background:
The availability of renewable energies to the grid is weather-dependent. To date, there are no technically and economically viable solutions for storing large amounts of electricity. Power-to-gas technologies can contribute to solving this problem. They convert renewable energy into gas (green hydrogen or methane) that is transported or stored in the gas grids. Once converted into gas, the renewable energy can be used in other sectors, which ultimately accelerates the energy transition'.

This shows that they are aware of using 'methanation' of hydrogen to produce methane.
This may be better suited to gas transport and storage, and for use in vehicles.

'Drop-in' liquid fuels (gasoline, kerosene, diesel) may be produced from methane via:
- Methane to methanol, e.g. Lurgi MegaMethanol process, http://chem.engr.utc.edu/ench430/2006/Teams/TOPS/FT%20vs%20MM%20ppt.pdf
- Methanol to Gasoline, e.g. ExxonMobil process, http://www.uschinaogf.org/Forum7/7Topic%2023-%20Samuel%20Tabak-%20ExxonMobil-%20English.pdf
(Slide 4 shows that, compared with F-T, MTG produces twice as much naptha, and far less gases and waxes).