SUSTAINABLE ELECTRICITY, TRANSPORT FUELS AND HEAT

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In the UK and other developed countries, electricity is about 20% of final energy, transport fuels 30% and heat 50%. Hence energy and climate policy must consider much more than electricity supply. In the UK, considering electricity in isolation has resulted in very high losses, with about 20% of primary energy being rejected to cooling towers and the sea. This could be avoided by thermally integrated solutions, as practised widely in Continental cities and in most industrial process plants.

Sustainable energy supply solutions must use renewable sources, mainly solar heat and electricity, wind electricity, and biomass electricity, fuels and heat. Hydro-electricity and geothermal energy are limited to certain regions and their overall contribution would be small, while tidal, marine current and wave electricity generators are not yet in volume production, so cannot be fully evaluated and costed.

As an annual average, the world final energy demand is about 10 TW, of which electricity is about 2 TW. (1 TeraWatt is 1 billion kiloWatts). The global wind electricity resource has been estimated as 72 TW, so most countries should be able to meet their total energy demand, never mind their electricity demand. In practice, other renewable electricity sources would increase the overall reliability. Measurements in Germany have shown that the electricity load can be met almost entirely from renewable sources, with wind electricity 61%, solar electricity 14%, biogas electricity 25% and smaller amounts from pumped-storage and imports.

TRANSPORT FUELS AND HEAT

The world transport fuel demand is some 3 TW, and the heat demand about 5 TW. Compared with heat and electricity, transport is the least tractable because the world's vehicle fleets are almost all powered by internal combustion engines using petroleum-based liquid fuels. Transport fuels are also the most urgent, because the world production of conventional oil is peaking about now. While similar fuels could be produced from unconventional oil from tar sands and oil shale, and from coal, these would be much more energy- and carbon-intensive. Moreover, this would increase until the energy cost exceeded the energy gain.

BIOFUELS

Liquid fuels made from biomass may have lower net carbon emissions and some biofuels may be used in existing engines. However, they are constrained by land, water, and nutrients and cause 'food-fuel' conflicts when the world population is still increasing. Moreover the potential for most developed countries is only 10% to 30% of all transport fuel. Yet the constraints are already apparent at less than 5% of road transport fuel.

HEAVY DUTY VEHICLES

Heavy duty vehicles are heavy trucks, buses, trains, and ships, using diesel; and aircraft, using kerosene. Compared with conventional liquid fuels in tanks, the energy density of hydrogen at 700 atmospheres in tanks is lower by a factor of about 5, and that of electricity in batteries lower by about 100. Moreover, these penalties are fundamental and cannot be overcome by R&D. Hence replacement liquid fuels are required to retain the payloads and ranges of such vehicles. Since they use about 50% of all transport fuel, almost all would have to be renewable synthetic liquid fuels.

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LIGHT DUTY VEHICLES

Light duty vehicles are passenger cars and light trucks, using petrol and diesel. Because the payloads and ranges of such vehicles are less critical, fuel cell and battery electric vehicles might still be considered.

However, while batteries and hydrogen fuel cells have been demonstrated in passenger cars, their weights and costs are higher by a factor of 2 or more. Yet cars are used only about 5% of the time, so could not repay the added investments of 'embedded' (materials and manufacturing) energy and of money within lifetimes of 10 to 15 years. Moreover, most would have to be purchased by private individuals, with little availability and high cost of capital. Thus most, if not all, countries could never afford all-new battery electric and hydrogen fuel cell vehicles and their energy/fuel infrastructures.

In addition, several vehicle companies are near bankruptcy and none can afford to write off their existing assets for making internal combustion engines and invest in huge new plants for batteries and fuel cells. In any case, such vehicles could only offer major reductions in carbon emissions when using near-zero carbon renewable energy. Yet this could instead be used to produce near-zero carbon liquid fuels for use in existing and new affordable vehicles with internal combustion engines.

Since renewable liquid fuels would be needed for heavy duty vehicles, it would be logical to use them also for light duty vehicles, rather than changing to new infrastructures and fuel cell or battery electric vehicles. In any case, the latter would be limited to short-range, local usage, for which a much better solution is public transport, which would also relieve congestion. By being used up to 75% of the time, the costs of the latter could be repaid well within the lifetimes of 30 to 50 years.

SYNTHETIC LIQUID FUELS

Spark ignition engines are much less costly than diesels, and have far lower particulate emissions. Also, methanol has been shown to give much higher energy efficiencies than petrol. Moreover, engines capable of using up to 100% methanol could also use up to 100% ethanol. So developed countries could produce synthetic liquid fuels, including methanol, while many developing countries could produce bio-ethanol. 'Flex-fuel' and 'Total Flex' light duty vehicles can use high blends of ethanol and methanol with petrol, to suit the transitions in the different countries. For heavy duty vehicles to retain their payloads and ranges, methanol would be converted to kerosene (for jet aircraft) and diesel (for heavy trucks, trains, and ships). This would also avoid the need to re-develop and re-qualify such vehicles for payload, range and safety, when their lifetimes may be about 20 to 30 years.

Energy and Fuel Options for Light Duty Vehicles	Renewable Sources – eg Wind Electricity	Conventional Oil	Unconventional Oil – e.g. Tar Sands
Internal Combustion Engine Vehicles	Methanol, Ethanol	Petrol, Diesel	Petrol, Diesel
Fuel Cell Vehicles	Hydrogen		
Battery Electric Vehicles	Electricity		

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Synthetic liquid fuels can be produced from renewable hydrogen and CO_2 captured from fluegas and the air. The energy input could be provided by wind and other sources of renewable electricity. The electrolytic production of hydrogen and the capture of CO_2 would be very large loads, but they would be 'interruptible', and the liquid fuels storable – so increasing the reliability of grid electricity. Yet this is less necessary for wind turbines than for fossil and nuclear plant, which have much larger units needing corresponding backup.

The capture of CO_2 from the fluegas of power plants would reduce their output and efficiency and they may run only 50% of the time. Conversely, units to capture CO_2 from air could be installed independently of power plants and run up to 100% of the time. Moreover, the use of captured CO_2 for renewable synthetic liquid fuels would avoid the need for costly sequestration, by displacing fossil oil with its ever-worsening carbon emissions. As well as being environmentally sustainable, such fuels would be indigenous, and could reduce oil imports and defence costs and increase energy security right up to self-sufficiency. Moreover, with a strong home market, the UK could make and sell such plant and equipment for export.

The renewable liquid fuel synthesis efficiency may be about 40% to 50%, with a similar proportion available as reject heat. Hence locating the air CO_2 capture units, electrolysis and synthesis plant at power station sites and cascading the reject heat into city-wide heat networks could meet about two-thirds of the heat demand. Such thermally integrated solutions would displace considerable natural gas, so greatly reducing costly imports, further increasing energy security and further reducing carbon emissions.

DELIVERY OF THE TRANSITION

Governments are concerned about energy security, the costs of imported coal, oil and gas and climate change. Hence – after consultation – they should set the framework for the transition to a sustainable energy system. Logically, the cost should be borne by companies whose fuels cause the problems and who are well able to bear it, rather than by Governments or private individuals. Oil and energy companies are well aware of the ever-increasing cost of replacing declining capacity, let alone that of increasing the supply. Renewable electricity, synthetic liquid fuels and heat would be sustainable, yet such plants would run from 35% to 95% of the time. With carbon targets set and enforced by Governments, the companies could be relied on to deliver the transition, since it would be compatible with their existing businesses while also reducing their risks.

This proposal was developed with Dr Richard Pearson of Lotus Engineering, Hethel, Norwich, Norfolk. A presentation and the full paper, with references, is available at: http://www.energypolicy.co.uk/cast.htm