Letter to the Editor, Ingenia Magazine

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Dear Sir

We would like to commend the authors of the Royal Academy of Engineering's recent report 'Electric vehicles: charged with potential' [1] for an excellent analysis of the critical issues surrounding the future use of electric vehicles (EVs) and plug-in hybrid electric vehicles (PHEVs) in the UK. However we feel that the report's conclusions, that generally favour continued development and widespread introduction of EVs, do not follow from the arguments it presents.

Key issues raised by the report

The report identifies a number of barriers to widespread use of EVs as follows:

1. Renewable Energy Generation

> "EVs and PHEVs can only be as 'green' as the electricity used to charge their batteries. Recent results from EV trials show a typical carbon dioxide emissions rating to be around 100g/km, when the car is charged from a typical power supply in the UK. Given that a brand new Volkswagen Polo turbo diesel injection has an emissions rating of 91g/km, it is difficult to see how electric vehicles fed from today's UK electricity generation supply are significantly better than petrol or diesel vehicles. To have a major effect, the introduction of electric vehicles must be accompanied by an almost total decarbonisation of the electricity supply" [1].

2. EV Costs

> "To make a significant difference to emissions, electric vehicles will have to appeal to the mainstream family car and company car sectors, which means they will have to compete economically with petrol and diesel models. …The overall cost of motoring using conventional fuels, which has been falling in real terms for several decades, is unlikely to see a steep increase and EVs will have to compete with vehicles having capital and running costs broadly similar to those seen today" [1]

The cost of an EV in 2010 is typically £10,000-£15,000 more than an equivalent conventional vehicle.[1] Even if we assume the most optimistic projections for the price, capacity, and availability of batteries and electric power-trains, and account for the possibility that people might access electric vehicles as a service, rather than owning them outright, EVs are unlikely to be used in the numbers needed to make a significant difference to the composition of the vehicle fleet.

3. Charging infrastructure

> "The introduction of electric vehicles on a large scale can only have a beneficial effect on CO_2 emissions if low carbon energy, universal broad band provision and smart grids can be delivered.
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> ….The widespread introduction of EVs would require an unprecedented degree of international coordination. At its most basic, this would include the international harmonisation of safety standards and the standardisation of charging connectors. Beyond this there would be a need for interoperability of smart cards – possibly with the equivalent of roaming contracts. If fast-charging or battery exchange facilities are anticipated, the level of international technical and commercial coordination would have to increase yet again." [1]

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[1] The Nissan 'Leaf' EV, scheduled for release in the UK in February 2011, will cost £23,350, including the government subsidy of £5,000. The unsubsidised cost of the car is therefore £28,350. This can be compared with the Nissan 'Note', which retails at £10,895-£15,495. (Smaller, lower emissions cars from the same manufacturer start at £7,150.)

4. Battery technology

> ”…These studies suggest that, with a battery capacity of around 20kWh, on nine out of 10 days, the vehicle could be operated entirely by electric power. To increase this to 19 out of 20 days would require a further 20kWh, adding perhaps £10,000 to the battery cost and 100kg to the battery weight. … This extra cost … would probably not be seen as good value for money. In either case, drivers would be reticent to run their vehicles to the limit of the theoretical range to avoid the risk of being stranded with a flat battery. With the battery chemistries and costs presently foreseeable, electric vehicles are unlikely be economically attractive other than for predictable low-mileage uses, such as the second car in a multi-car household.” [1]

5. Timescale

> “Climate scientists have argued that, to have any hope of maintaining the level of CO_2 in the atmosphere to 550 ppm, emissions must peak in the next 10 years and then start to reduce. This means that there is no possibility of delay.” [1]

6. The ‘elephant in the room’

   The RAEng report focuses on implementation of EV technology in the UK. It does not address the issue of the hundreds of millions of low-cost automobiles that will be built in the coming decades to satisfy the desire for personal transport in the developing world. The UK’s CO_2 emissions will be a ‘drop in the atmosphere’ in comparison with projected emissions from transportation in China and India in the next 20 or 30 years. It seems inconceivable that EVs will satisfy the demand in the developing world because the barriers in 1-4 above will all have to be overcome on an international scale. In particular, there is no practical possibility of achieving the target price tag of less than $3000 per vehicle for these applications [2], with any foreseeable advances in EV technology. There is a discrepancy of an order of magnitude in the cost of the sophisticated technology needed for EVs.

Taken separately, surmounting each of these barriers represents a very large technological, political and social project. Taken together, the overall barrier to decarbonising the transport system by electrification, on an international scale, is a project of unprecedented magnitude. By any normal engineering judgment, it is unachievable.

Electric vehicles will not have significantly better total CO_2 emissions than conventional vehicles until the electricity generation system is decarbonised – ie for two or more decades. Current UK and EU policy providing consumer subsidies or reduced congestion charges, etc, to promote use of EVs are therefore (at best) of zero net benefit in CO_2 terms. They simply represent a very expensive ‘rearrangement of the deck chairs’. Relying on the dream of electrification will likely cause a long, detrimental delay in achieving a significant level of decarbonisation of road transport.

It is essential that the engineering community recognises this fundamental problem with the EV project and develops and promotes a more practical and realistic strategy. This strategy should address the tactical need for substantial reductions of CO_2 emissions from transport within the next decade and it should blend seamlessly into a strategic initiative for complete decarbonisation in the long term. Ideally, this should be achieved without requiring a technological revolution.

An alternative strategy

The alternative strategy proposed here assumes that the principal objective of the project is major reduction in CO_2 emissions from transport, worldwide, in the shortest possible time. A secondary objective is coping with the anticipated problem of ‘peak oil’ in coming decades. The proposed approach is based on four key elements:

1. The best of existing internal combustion powered vehicles generate equivalent or lower total CO_2 emissions (‘Well to Wheel - WTW’) than existing EVs, at a price that is typically £10,000 lower. There is little or no barrier to introducing these vehicles into the mass market immediately. Introducing them on a wide scale to replace the current automobile fleet would substantially reduce overall emissions of CO_2 from road transport in the near term.

2. Hydrocarbon fuels have a fundamental advantage of approximately two orders of magnitude higher specific energy content (ie MJ/kg) than electrical, mechanical or hydraulic energy storage systems. Only hydrogen storage can compete with hydrocarbon fuels on specific energy content – but widespread use of hydrogen as a transport fuel has a raft of other difficulties, including its low energy density (ie MJ/m^3) – meaning that fuel tanks have to be very large to achieve adequate range – as well as extremely challenging generation, cryogenic storage and infrastructure problems[2]. It should also be borne in mind that for electrically produced hydrogen, only about 25% of the energy reappears after an electrolysis/fuel cell route [3].

3. There is a large, flexible and complete existing infrastructure for distribution of hydrocarbon fuels world-wide. Using this existing infrastructure, instead of building an entirely new one for hydrogen or electric refuelling of vehicles would save hundreds of billions of dollars. ($500b is the estimated cost of hydrogen infrastructure for the US alone [4]). This would sweep away one of the critical barriers instantly; and would accelerate the project by decades.

4. Hydrocarbon fuels - and low energy vehicles that can use them - are available now. It is not necessary to wait until the entire electricity supply system is decarbonised – using renewable or nuclear sources - before substantial reductions in CO_2 emissions can be achieved in road transport. There is a large enough challenge to provide sufficient renewable electricity for domestic and commercial heat and power, without having to generate renewable electricity to fuel all road transport as well.

Our proposed strategy for decarbonisation of the transport system has five steps:

1. Continue to encourage use of alternative transport where possible: walking, bicycles…, along with reduced use of transport: ride sharing, public transport, home-working, teleconferencing etc. Implement measures to minimize traffic congestion, which is a strong driver of fuel consumption.

   Widespread implementation of such measures might be sufficient to counteract the increase in emissions due to transport growth over the next 10-20 years.

2. Promote use of the best of existing low emission hydrocarbon-fuelled vehicles, powered by internal combustion engines, so as to minimize ‘Tank to Wheel’ (TTW) energy consumption (MJ / km). By this route, substantial reductions in emissions can be achieved immediately, at low cost and without the penalty of the low range and high cost that are intrinsic to EVs.

   A reasonable estimate is that down-sizing of the passenger car fleet and transitioning to the most efficient available vehicles for a given duty, may reduce average TTW energy consumption in the next 10-15 years by up to 30%.

3. Encourage development of even better hydrocarbon-fuelled vehicles using proven technologies that are available now: reduction of vehicle mass; extreme downsizing of engines with turbo/super-chargers; addition of energy storage (electrical, mechanical (flywheel) or hydraulic) for regenerative braking/acceleration and engine start-stop operation; as well as reductions in aerodynamic drag and rolling resistance. Incremental improvements in efficiency via, for example, attention to engine and transmission friction, and the combustion process itself, continue to be developed. Plug-in hybrids (PHEVs) also have a part to play in this mix and will provide full emissions benefits once the electricity supply is decarbonised. They also have significantly more practical ranges than EVs and consequently much simpler requirements for charging infrastructure.

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[2] On 7th May 2010, the US Energy Secretary (and Nobel prize winning physicist), Stephen Chu cut the funding for the US DoE’s long-running US Hydrogen transport program to zero, citing several barriers to the technology for hydrogen cars including infrastructure and the development of long-lasting portable fuel cells.

Substantial reductions in TTW energy consumption are possible through applying a range of such measures – probably up to 50% for a given duty, as quantified in [5].

4. Provide incentives for production of hydrocarbon fuels that have lower ‘Well to Tank’ (WTT) emissions of CO_2 (kg CO_2 released / MJ energy delivered). There are a number of available routes, including: fuel from waste biomass, and (non-recyclable) waste plastics [6]; second generation, (sustainable) bio-fuels; and synthetic fuels.[3]

   These alternative fuels can reduce average WTT emissions in the fuel mix significantly. A reasonable target might be 20% reduction in average WTT by 2030. (This can be compared with the EU’s target of 10% biofuels by 2020). Importantly, lower WTT hydrocarbon fuels can be used by existing vehicles and can be distributed through the existing infrastructure.

Because WTT x TTW = WTW; ie (kg CO_2 / MJ) x (MJ / km) = (kg CO_2 / km), improving either WTT or TTW gives a proportional benefit in CO_2 emissions. Improving both ‘squares’ the benefit and is the key to a successful programme of decarbonisation. Defined in this way, these metrics, WTT and TTW, could reasonably be used as a basis for unbiased incentives for both vehicle manufacturers and the fuel supply industry.

Using the percentage reductions identified in steps 2-4 above, it could be possible to reduce overall WTW emissions, within the next 20 years or so, to (1-0.3)(1-0.5)(1-0.2) = 0.28 – ie a 72% reduction. This is a good part of the 80% reduction target for 2050.

5. In the long-term, it will be necessary for transportation systems to continue to be powered by synthetic hydrocarbon fuels. Given sufficient electrical energy, hydrogen can be electrolyzed from water and combined with almost any source of carbon to make hydrocarbon fuel. It is even thought viable to use CO_2 scrubbed from the atmosphere [8], thus reversing the combustion process and making a truly carbon-neutral fuel. When sufficient decarbonised electricity becomes available, it can be used to make this synthetic hydrocarbon fuel – just as it is proposed to use renewable electricity to make hydrogen, or distribute it directly to electric vehicles via new infrastructures. The effect of these long-term innovations in fuel technology would be to provide further reductions in WTT emissions. For example, a further 25% reduction in WTT between 2030 and 2050 (ie a total reduction of 40% from today’s fuel mix) would satisfy the target overall reduction in WTW emissions of 80%.

The fundamental point here is that hydrocarbons provide the best medium for fuelling vehicles because of: (i) their very high specific energies, which are impossible to achieve with any alternatives, and (ii) the existing distribution infrastructure. So, when it becomes necessary to distribute synthetic energy in a future low carbon economy, it will be practical and low cost to use synthetic hydrocarbons; whereas distributing hydrogen or electricity through new vehicle fuelling infrastructures would be complex and prohibitively expensive. In the mean time, it is not necessary to have a technological revolution in order to make substantial progress in the right direction. The world can benefit quickly from much lower CO_2 emissions from road transport, without having to overcome all of the serious barriers presented in the Royal Academy’s report [1].

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[3] As ‘peak oil’ bites, it may be necessary to generate synthetic fuel from coal. (For example, Sasol uses a version of the Fischer-Tropsch process to produce economically, 28% of South Africa’s liquid fuel from its abundant reserves of coal [7].) As long as any excess CO_2 is sequestered, the WTT performance of these fuels is similar to current liquid fuels. (See also ‘Underground coal gasification’, *Ingenia*, June 2010, Vol 43, p42-46).

References

[1] ‘Electric vehicles: charged with potential’, Royal Academy of Engineering, May 2010.

[2] ‘The race to build really cheap cars’, Bloomberg Business Week, April 23, 2007.

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[6] Sarker, M, ‘Converting waste plastic to hydrocarbon fuel materials’ Proceeding of World Energy Engineering Congress, Washington, DC, USA November 4-6, 2009. see also www.naturalstateresearch.com

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