

Sustainability, Road Transport And The Electricity Supply System: The Role Of The Plug-in Vehicle

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Abstract- Plug-in vehicles are promoted for a number of beneficial reasons that encompass environmental, economic, social and political motivations. This paper is the first in a quartet of investigative arguments that considers sustainability and the role of the plug-in vehicle in the context of the question: are they worthy of being called a sustainable energy technology?

This first paper reviews one of the motivational drivers behind changing fossil fuel use (People security) and the implementation of plug-in-vehicles and employs sociology, and psychology to demonstrate the worthiness of plug-in vehicles to be a sustainable energy technology. This is not a well-to-wheels analysis.

I. INTRODUCTION

The paper draws upon the three pillars of sustainability (People, Planet and Profit) and the 4 Ps of marketing mix (Price, Product, Place and Promotion) and applies these variables to resource management for fossil fuels in the context of use (see Fig. 1).

There is general concern for dependency on fossil fuels in terms of future sustainability because they are a finite resource [1]. They are finite because rate of use far exceeds rate of natural production. In reaching the UK fossil fuel imports cross many borders, making them vulnerable to stoppages (by accident or incident) [2] and prolonged stoppages would almost certainly lead to social upheaval.

In the UK, numerous alternative vehicle trials [3-5] and government incentives [6-8] are being put in place to encourage increasing numbers of low and/or nil-emission vehicles at point of use. This paper is the first in a series of investigative arguments that considers sustainability and the role of the plug-in vehicle in the context of the question: are they worthy of being called a sustainable energy technology?

This paper will focus on People security, and how plug-in vehicles relate to fossil fuel use in terms of future sustainability. This is not a well-to-wheels analysis. It is intended instead to emphasise the importance of alternative energy pathways and human priorities.

II. FOR THE PEOPLE

Motivations for changing fossil fuel use can be divided into two categories: prolonging the benefits, and reducing the detrimental impacts of their use.

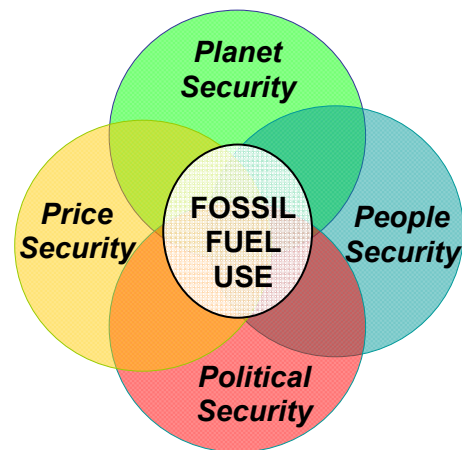


Fig. 1. How use of fossil fuels impact on security environmentally (Planet), socially (People), economically (Price), and governmentally (Political).

A. Prolonging the benefits

In the UK energy purposes are by far the largest use of fossil fuels [9], however non-energy uses of fossil fuels contribute towards the production of medicines, paints, aerosols, insecticides, adhesives, fertilisers and plastics [9-12], and this is world-wide. Demand for fossil fuels for energy and non-energy uses will continue to increase in the developing world in line with people's rising aspirations for quality of life [12]. It is essential for the continuation of civilisation, both national and global, that fossil fuels are conserved for non-energy use until such a time as they can be replaced by sustainable substitutes.

R. W. England in [13] describes the threat of social crisis resulting from the incompatibility of present social institutions and a new energy technology, and remarks:

"Despite the wonders of modern telecommunications and microelectronics [that could enable people once again to work where they live and vice versa], however, the reproduction of urban regions will still require the transportation of large numbers of human beings and of huge quantities of materials." (p.764).

These 'materials' will also include food and water distribution to urban areas, and the collection, treatment, and

disposal of sewage and other wastes e.g. industrial and municipal.

B. Reducing detrimental impacts

The most recent well-publicised negative aspect of fossil fuels has been anthropogenic climate change, commonly cited as being caused by Green House Gas (GHG) emissions released upon combustion of fossil fuels used for energy purposes. Electricity generation and road transport were cited as being the largest contributors to increasing GHG emissions in 2004 worldwide, and in terms of total global emissions electricity generation was responsible for the highest GHG emissions [14]. Publications such as the Stern Review [15] highlight the adverse implications to people worldwide of apathy towards climate change. Subsequently the EU has set binding targets for member states to reduce Green House Gas (GHG) emissions, and the UK government has signed an agreement to these [2].

GHGs are not the only emissions associated with energy use of fossil fuels, and several by-products of the combustion of fossil fuels are directly detrimental to human health e.g. Carbon monoxide and ultrafine particulates are harmful in the location where they are produced [16, 17]. Benzene – a highly carcinogenic chemical compound to humans – emissions come from the distribution and combustion of petrol [18]. Sulphur dioxide emissions from the combustion of fossil fuels (e.g. by various transport vehicles and in electricity generation) affect the lining of the nose, throat and airways of the lung especially amongst people who suffer from asthma and chronic lung disease [19].

Some emissions pose health risks because following their release they are involved in the formation of some secondary pollutant that is harmful to human health, e.g. Nitrogen oxides emissions the localised formation of low-altitude Ozone which irritates respiratory systems [20]. There are also crossovers between emissions concerned with climate change and those concerned with direct public health impacts, for example Nitrogen oxides not only facilitate the formation of low-altitude Ozone, but whilst they have little or no direct health impact they are in fact potent GHGs, impacting globally over long time periods [21].

C. The resolution is reduction

Fossil fuels continue to allow people many benefits e.g. transport of perishable goods around the globe, geographical separation of work from home, and modern medicine. There is a need to conserve fossil fuels so that these benefits a) can be extended to those people that do not yet have them and b) can be prolonged for as long as possible so that we have time to adapt to substitutes in each area of fossil fuel use.

The use of fossil fuels especially for energy purposes has negative impacts locally and directly upon the respiratory health of local people, but also globally and indirectly through climate change. There are measures that reduce emissions at point of use, such as catalytic converters and the promotion of cleaner fuels e.g. the banning of leaded petrol

and the setting of standards for the reduction of sulphur content in fuels. However, the simplest way to deal with all emissions is to not combust fossil fuels¹.

Subsequently if these motivations combined then in order to prolong the benefits and reduce the detrimental impacts of using fossil fuels, a single goal can meet them both: reduce fossil fuel use with particular emphasis on curtailing energy use.

III. PLUG-IN VEHICLES: PUBLIC ENEMY

If the goal is the reduction in actual amounts of fossil fuels used, do plug-in vehicles help or hinder this? Consider first the mix of energy inputs to generating electricity versus that for producing petroleum products (predominantly destined to be used as transport fuels) shown in Fig. 2 for the year 2007. Up to approximately 22%² of energy input to electricity generation came from non-fossil fuel sources, whereas practically 100% of the energy input to petroleum refinery was fossil fuel derived.

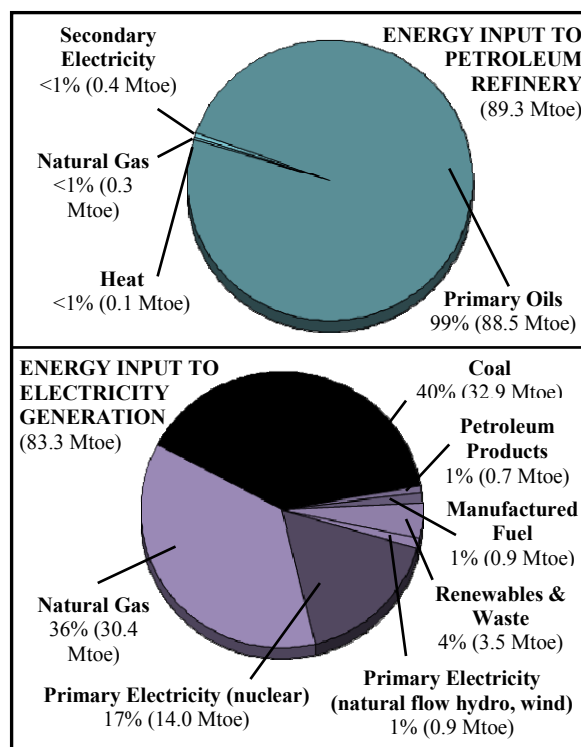


Fig. 2. Mix of energy inputs to electricity generation and petroleum refinery in 2007. Data taken from [22].

Fig. 2. omits the fact that renewable fuel must comprise 3.25% of total transport fuel supplied in 2009-10, rising to 5% by volume in 2013-14 [23]. However the possibility of environmentally-detrimental land-use changes being made abroad in order to produce transport-grade biofuel for export

¹ Or indeed not to use them at all in the case of Benzene. However, it should also be considered that in the case of natural gas, combustion may be preferable to allowing this chemical to be released in its natural form, as methane – the main constituent of natural gas, is a potent GHG.

² In the category 'Renewables and Wastes' some of the waste combusted was likely fossil fuel products such as plastics and rubber.

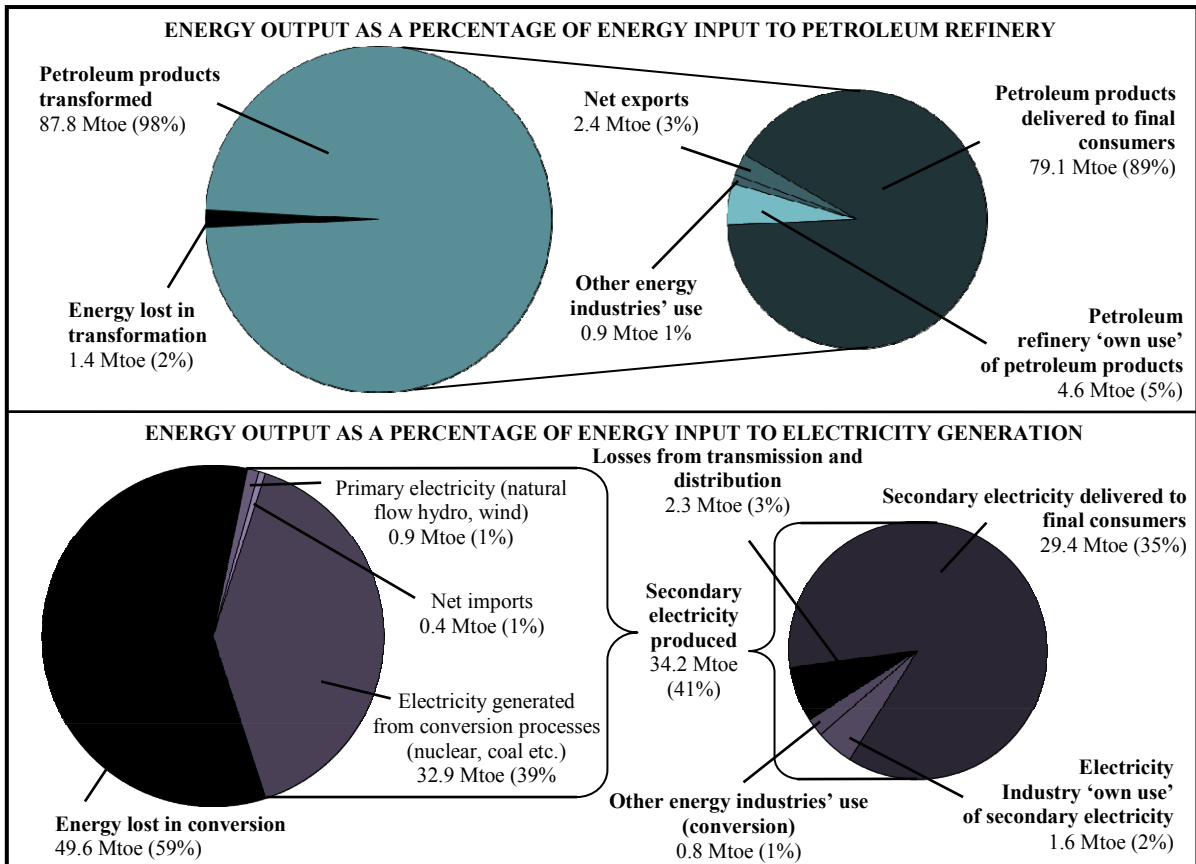


Fig. 3. comparative energy efficiency for the provision of energy to final consumers as electricity and petroleum products in 2007. Data analysed from [22]. Losses from pipelines and delivery of petroleum products were nil or negligible.

to developed nations, has forced a government policy shift away from the substitution of fossil fuel with biofuel for transport [23]. There are also aspirations to source 30% or more electricity generation from renewables. The energy mix argument is thus in favour of the plug-in vehicle.

Consider next energy efficiency for the provision of electricity to end users and compare this against energy efficiency for the provision of fossil fuel based transport fuels to end users (Fig. 3). Only 35% of the total energy input to electricity generation in 2007 was actually delivered to final end consumers – a compound efficiency estimate similar to that of the US electricity supply system as reported by [24]. The majority of these losses are thermal conversion processes (combustion of fossil fuel, nuclear generation). In contrast 89% of energy input to petroleum refinery was delivered to final consumers.

Fig. 4 shows the comparison between providing the same amount of energy to a vehicle in the form of electricity versus in the form of fuel. [23] states that substituting transport fossil fuels for transport biofuels will likely be feasible up to a maximum of 6.5% by energy, limited partly due to vehicle manufacturer warranties. Even so, more than double the amount of fossil fuel energy must be input to the electricity pathway to deliver the same amount of energy as the petroleum pathway, despite the electricity pathway having a far larger proportion of non-fossil input energy mix.

This could be a lot worse if plug-in vehicles add to peak demand, as peak power in the UK is predominantly fossil fuel generated. The timing of added electricity demand from plug-in vehicles has also been shown to influence emissions [20, 25].

IV. PRIORITISING NEEDS

In Maslow's 'hierarchy of needs' [26], immediate physiological and safety needs such as an urgent need for food or to escape from fire, are given higher priority by an individual than less urgent, less self-threatening needs such as the need to belong and be socially accepted by others.

It can be drawn from Maslow that a physical danger is prioritised above a non-physical danger, a danger nearby (geographically) is prioritised by a danger far away or unseen, an immediate danger is prioritised by a danger not expected to have impact until later, and the closer the danger is to oneself at a given level of self then the higher the priority that danger will receive. Human prioritisation processes thus assess and designate the level of threat and necessity for action based upon these sliding scales of proximity (geographic, temporal) and severity (physical/non-physical, level of harm posed) of danger in relation to the sliding scale of 'self'³, prioritising which threat must be dealt with first.

³ Identification of self here is envisioned to act on a sliding scale of priorities: "my family" comes before "my country" and "my species".

V. PLUG-IN VEHICLES: A MUCH-NEEDED FRIEND

It is from Maslow's hierarchy of needs that plug-in vehicles can also now be seen to be a much-needed development. Following Maslow's interpretation of human prioritisation, it is impractical to ask people to concern themselves with reducing energy use, and committing to other actions that are 'for the greater future public good' without a) dealing with more basic needs first and b) marketing the extension of self and thus the importance of action to the individual. Reducing fossil fuel use out of concern for the greater environment, future generations, or for the benefit of strangers geographically distant constitutes a market failure so long as there are other more basic needs at stake.

The removal of locally-generated air pollution harmful to human health constitutes the meeting of a more basic need than reducing fossil fuel use. It is a necessary step to improve the quality of life of a large population of people and to reduce the financial burden of respiratory illness on the National Health Service, which will again benefit people when taxpayer's money can be directed to other public interests.

To explain the importance of air quality to people, consider the success of the urban clear zone. In the UK, the 'urban clear zone' concept was originally intended to create more liveable, accessible and lively urban centres [27]. They were originally intended to include a highly pedestrianised city centre where only select nil-emission (at point of use) public transport would be allowed e.g. electric trams and buses. It was similarly envisioned that nil-emission road vehicles would be permitted within a wider nil-emission zone. It was suggested that this be coupled with park & ride facilities at city outskirts or in suburban areas where drivers could exchange their polluting vehicles either for public transport, or for a nil-emission personal vehicle. At the time of conception nil-emission vehicle technology was still premature and nil-emission public transport was also still under-developed⁴.

Even so, the appeal of the clear zone is such that nearly every urbanised area in the UK now has one, albeit over a far smaller area than was originally intended, meanwhile the emergence of small, Home Zones also recognises the importance to people of having a safe environment (safer because of less traffic, slower traffic, and reduced air pollution)⁵. Now the clear zone may yet be reborn, as Battery Electric Vehicles (BEVs) look set to enter the market with competitive daily mileage potential, hybrids grow in popularity, and Fuel Cell Vehicles (FCVs) look set to follow

⁴ The Foresight Vehicle documents are currently unavailable. However, information regarding the original intentions laid out in the reports were obtained from John Parry [pers. comm.] who was a member of the committee.

⁵ The aim of the Home Zone is to improve the quality of life in residential streets by making them places for people (pedestrians, cyclists, children), not just for traffic [27].

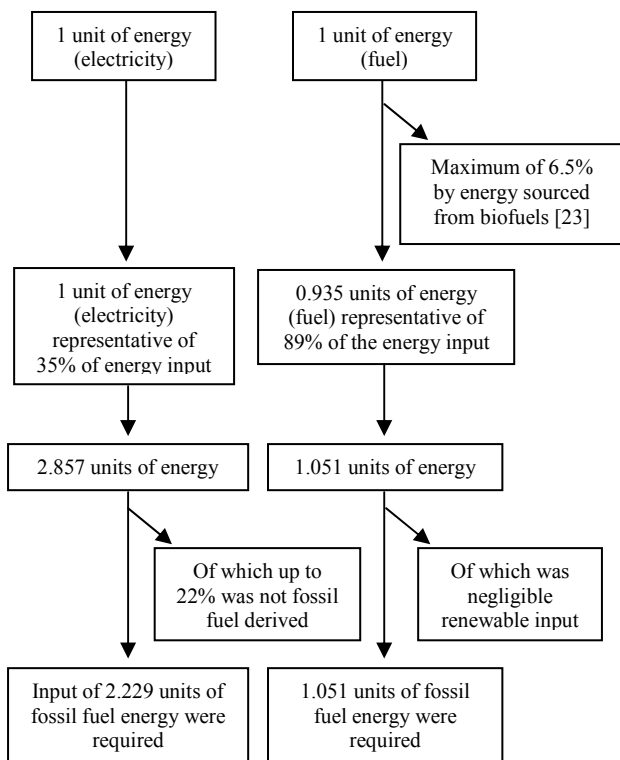


Fig. 4. Snap-shot of UK electricity and vehicle fuel pathways in 2007 using annual efficiencies as analysed using figures from [22, 23].

It could be said that growing interest in plug-in vehicles is a demonstration of Maslow's hierarchy of needs in action on a communal scale.

Air pollution is directly and immediately harmful to human health impacting upon individuals and communities, and these are the individuals and communities that may be part of a person's identification of 'self' - of particular interest here is the identification of self by a powerful decision-maker. It then follows that dealing with air pollution will have a greater positive impact closest to 'self' (both in terms of actual health improvements but also political popularity) and thus have a higher priority than dealing with the broader, less specific, indirect and less immediately obvious problems associated with GHG emissions, and depletion of fossil fuel resources.

It could be argued that electricity generation should be made sufficiently independent of fossil fuels (or at least made a lot more efficient) before use of plug-in vehicles is encouraged. However, Maslow's patterns for prioritisation may thus explain why plug-in vehicles are already being encouraged: they are potentially a solution to multiple problems (and therefore an efficient allocation of resources) in that they are believed to remove air pollution from the areas it has the highest impact (high population density urban areas), and if electricity is sufficiently decarbonised they can also potentially mitigate threats associated with climate change. Plug-in vehicles thus represent a 'silver bullet' to decision-makers.

soon as vehicle trials get underway for various alternative vehicles across the UK [3-5].

Plug-in vehicles can offer significant improvements locally especially where BEVs and FCVs are used because neither is reliant upon fuel combustion processes. Any nil-emission vehicle placed within a densely populated urban area context represents a means of meeting local air-pollution reduction targets. This is effective so long as whatever energy they do use (be it Hydrogen or electricity) is generated either locally without emissions, or geographically placed so that for example the creation of secondary pollutants such as Ozone does not take place in or near highly populated areas.

VI. CONCLUSION

One aspect of considering fossil fuel use is People Security, and the overall reduced use of fossil fuels – especially for energy purposes – would best accommodate human needs for prolonging the benefits and curtailing the detrimental impacts of fossil fuel use in a sustainable future. The goal of the paper was to investigate whether the plug-in vehicle is a sustainable energy technology.

At first plug-in vehicles appear to be contrary to the aforementioned goal because the petroleum energy pathway uses less fossil fuel to deliver the same amount of energy as the electricity energy pathway. It is often noted that vehicles that have to rely on mains electricity for energy input also have to be far more efficient with their energy use than a fuelled vehicle because of the added weight of batteries, and their comparatively poor energy density as a storage medium compared against a tank of fuel. However, mating the best vehicle energy efficiency with the most inefficient upstream energy pathway severely curtails the benefits of changing road transport dependency from fuel to electricity.

Plug-in vehicles are still a benefit to the people because they reduce the generation of localised air pollution from combusting and using fossil fuels. This can be attributed to Maslow's hierarchy of needs which shows that it is impractical to ask people to concern themselves with changing their energy use, and committing to other actions that are 'for the greater, future, public good' without dealing first with their more basic, immediate, personal needs. Plug-in vehicles potentially improve local air quality thus fulfilling a more basic need. This in turn allows them to play an important part as a sustainable energy technology in the context of People Security.

The next papers in the series will cover Political Security, Price Security, and Planet Security.

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