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Electric Vehicles and the Environment

12.1 Introduction

Humankind is becoming increasingly concerned about the damage it is causing to the environment and electric vehicles are perceived to play a part in redressing the balance. It is therefore important that the environmental impact of electric vehicles is thoroughly understood.

Ultimately electric vehicles *may* be of substantial benefit, reducing both the release of carbon dioxide and harmful emissions. There is considerable misunderstanding at present as to precisely why electric vehicles can be of benefit, and the extent of that benefit. Firstly, it must be remembered that energy has to come from somewhere, normally power stations – it does not just appear. A key part of the consideration of the environmental impact of vehicles is the so-called 'well-to-wheels' analysis, where the pollution of all parts of the energy cycle in the use of a vehicle is considered, not just the vehicle itself.

A second point to be borne in mind is that IC engine vehicles can be run entirely from sustainable fuels, as the Brazilian programme of using ethanol made from sugar cane has proved. IC engines could also be made to run with virtually zero emissions, burning hydrogen for example, and thus giving an exhaust gas of (almost) just water and air. Perhaps fortunately, it is becoming easier and more efficient to use fuel cells, and electricity for charging batteries can be derived from renewable sources.

A third aspect is how the availability of electric vehicles could move people towards more environmentally responsible modes of transport. For example, if electric bicycles worked well, and were widely available, could this persuade some people to abandon their private cars, which can generate considerable pollution whatever their power source?

12.2 Vehicle Pollution – The Effects

Before we look at solving environmental problems it is worth pausing to look at precisely what environmental problems are currently caused by the majority of vehicles.

Electric Vehicle Technology Explained, Second Edition. James Larminie and John Lowry.

There are two main problems caused by conventional vehicles. Firstly, they ruin the immediate environment with noise and pollutants. Secondly, they burn irreplaceable fossil fuels producing carbon dioxide which is a major cause of global warming and climate change.

You do not need to be a scientist or engineer to understand that motor cars spoil the immediate environment. You simply need to walk along a busy street or sit at a roadside café. The motor vehicle has emerged over a century and we simply accept it as a fact of life. Normally when people who live in the country come to a big city they find both the noise and the fumes quite unacceptable.

The health hazards associated with motor vehicle exhausts are particularly worrying. If you place a stationary diesel engine with the exhaust near a wall, the wall very quickly turns black with what can loosely be described as soot. Again you do not need to be a medical scientist to realise the effect that this might have on your lungs. You would need to smoke a lot of cigarettes to get the same level of deposit, and we all know the health effects of tobacco smoke. While you do not have to stand behind diesel exhausts, you are bound to inhale a fair amount walking along a busy street and crossing the road, which often involves passing directly through vehicle exhaust.

Accepted health problems associated with car exhausts makes depressing reading and one has to wonder why society keeps quite happily emitting these substances.

The major IC engine pollutants include carbon dioxide, carbon monoxide, nitrous oxides, volatile organic compounds (VOCs), particulate matter (PM) and sulfur dioxide.

Carbon monoxide inhibits the ability of the blood to carry oxygen, and in particular is dangerous to smokers and people with heart disease. It can also cause permanent damage to the nervous system.

Nitrous oxides (NOx) exacerbate asthma, affect the lungs and increase the susceptibility of young children and the elderly to respiratory infections. In the presence of VOCs and sunlight, NOx react to produce ground-level ozone. This in turn irritates the eyes, damages the lungs and causes respiratory problems. NOx contribute to the formation of acid rain, whose acidity kills plants and fish. Benzene, a known carcinogen, is an example of a toxic VOC found in vehicle exhaust.

PM causes lung problems including shortage of breath, worsens cardiovascular disease, damages lung tissue and causes cancer. Ultra-fine PM makes its way past the upper airway and penetrates the deepest tissue of the lungs and thence to the blood stream. At concentrations above $5\,\mu g\,m^{-3}$ PM presents a significant cancer risk. Many PMs are recognised as toxicants and carcinogens, as well as hazards to the reproductive and endocrine systems.

New discoveries on the risks of cancer from exhaust fumes continue to emerge. Researchers have apparently isolated a compound called 3-nitrobenzanthone which is a highly potent mutagen (Arlt, 2005).

Clearly this is cause for alarm. It must also be remembered that new research is constantly emerging and the overall picture may well be extremely grim. Certainly there have been large rises in asthma, many allergies and cancers that may well be linked to exhaust fumes.

The effect of carbon dioxide on the planet is another cause for alarm. The greenhouse effect of carbon dioxide is now well known. Basically some of the short-wave radiation from the sun is absorbed by the earth and then re-emitted at a longer wavelength. This is

absorbed by carbon dioxide and other gases and then re-emitted, the downward radiation warming the surface of the earth. The atmospheric concentration of carbon dioxide has increased by about 25% over the past 100 years.

While a warmer earth may sound appealing to those living in cold climates, there are side effects which could prove absolutely devastating. Firstly the earth relies on a reasonably set weather pattern for growing food. A change of climate in the grain-growing belt of North America, for example, could itself have serious consequences on food supply. Secondly the 'warm-up' is melting the polar ice caps and this could cause permanent flooding in low-lying areas. Bearing in mind that many major cities, namely London, New York, Barcelona, San Francisco, Perth (Australia) and scores of others, are built on the coast, this could have very serious repercussions throughout the world.

One significant problem with IC engine vehicles in slow traffic is that fuel consumption rises very dramatically as vehicles crawl along at slow speeds and pollution gets considerably worse, as illustrated in Figure 12.1. It should be noted that this assumes there are no lights, heaters or air-conditioning on. With electric vehicles there will be a small decrease in efficiency of the electric motor when used at low speeds, but the efficiency of batteries such as lead acid increases, resulting in a fairly steady efficiency across the speed range. In cities such as London and Tokyo the average speeds are normally less than 15 kph and in the rush hour are considerably less.

The simplest way of eliminating these problems from town and city streets is to enforce zero-emission vehicles into the towns and cities by legislation or other means. Conventional IC vehicles ruin the environment in their vicinity, particularly in towns and cities.

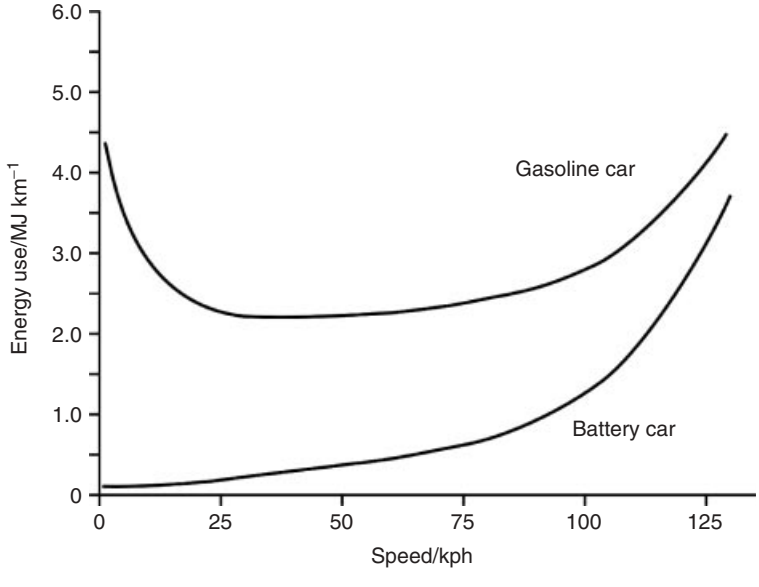

Figure 12.1 Indicative energy use for IC engine and battery-powered cars. Obviously the precise figures vary greatly with size and design of vehicle. These figures are *not* the whole well-to wheel energy figures, but just the tank-to-wheel or battery-to-wheel figures

The simplest way of creating zero-emission vehicles is to adopt electric vehicles, or at least hybrid vehicles which solely run on electricity when in the town and city environment.

12.3 Vehicle Pollution in Context

The extent and importance of the pollution from vehicles is sometimes questioned, especially by certain motorist lobbying organisations. Table 12.1 gives figures for Britain regarding energy usage over the years 2000–2010.

The amount of carbon dioxide produced is more or less directly proportional to the mass of petroleum used, though it should be remembered that the table is not really talking about tonnes of petroleum but an energy equivalent, and a move to more natural gas and less coal will help a little. Road transport represents about 25% of the energy used, and thus about 25% of the greenhouse gas production. It will be much the same in other western countries. The conclusion is that a more efficient transport system can make a very substantial contribution to the reduction in greenhouse gas emission.

In terms of other pollutants, personal transport probably has an even greater impact. Especially in our cities, a very high proportion of such air pollution comes from IC engines.

12.4 The Role of Regulations and Lawmakers

The question which is bound to be asked is if society develops suitable electric vehicles using rechargeable batteries or fuel cells 'Can we use only sustainable energy for transport and totally eliminate exhaust pollutants?' The answer is undoubtedly 'Yes', particularly in the long term, and if society is prepared to pay for this. However, the power of law

Table 12.1 Transport energy consumption by type of transport and fuel (thousand tonnes of oil equivalent), 2000–2010. (*Source*: Department of Energy and Climate Change – Digest of UK Energy Statistics Annex, Table 1.1.5 and bespoke analysis of data supplied by AEA Energy and Environment)

	Rail Total	Road Total	Water Total	Air Total
2000	1380	41 071	1032	55 461
2001	1423	41 097	844	55 137
2002	1389	41 936	702	55 685
2003	1373	41 823	1234	56 366
2004	1047	42 222	1196	57 374
2005	1027	42 511	1365	58 759
2006	984	42 745	1805	59 532
2007	993	43 254	1612	59 764
2008	989	42 220	1757	58 474
2009	989	40 783	1625	56 148
2010	992	40 955	1469	55 704

and regulation is important in making individual people make choices – in favour of less pollution at a higher price. One of the major roles of society is a 'collective coercion to be good', and this can be seen very clearly in the case of electric vehicles.

This is best illustrated by the actions of California through its Air Resources Board (CARB). This organisation was a major promoter of the now almost universal catalytic converter on IC engine exhausts. It has had a huge impact on the development of electric vehicles.

The story began in the late 1980s, when the CARB enacted a directive that required that any motor manufacturer selling vehicles in the state would have to ensure that 2% of vehicles sales in 1998, rising to 5% in 2000, would have to be zero-emission vehicles. The California vehicles market is huge, about 1 million per year, so this had massive implications, which the motor manufacturers reacted to with great energy. Two major consequences were the production of high-technology vehicles like the General Motors EV1 and also major developments in fuel cells. However, despite great efforts, it became clear that the targets were highly unrealistic. Also, developments in hybrid vehicles, and

Table 12.2 Credit table, as being proposed by the CARB in April 2003, for different types of PZEVs, for the years 2005–2011

Vehicle type	Zero-emission range	Base credit	Zero-emission range credit	Advanced components credit	Low-fuel-cycles emission credit	Total credit
Low-voltage HEV	0	0.2	0	0	0	0.2
High-voltage HEV	0	0.2	0	0.4	0	0.6
High-voltage, high-power HEV	0	0.2	0	0.5	0	0.7
CNG ICE car	0	0.2	0	0.2	0.3	0.7
CNG ICE-based hybrid ($>10\,kW_e$)	0	0.2	0	0.6	0.3	1.1
Hydrogen ICE car	0	0.2	1.5	0.3	0.3	2.3
MeOH fuel cell car	0	0.2	1.5	0.5	0.3	2.5
Grid hybrid with 20 mile (32 km) electric range	20	0.2	1.25	0.5	0.12	2.1
Grid hybrid with 30 mile (48 km) electric range	30	0.2	1.4	0.5	0.15	2.3
Grid hybrid with 60 mile (96 km) electric range	60	0.2	1.82	0.5	0.15	2.7
Hydrogen ICE-based hybrid ($>10\,kW_e$)	0	0.2	1.5	0.7	0.3	2.7
CNG ICE-based hybrid with 20 mile electric range	20	0.2	1.25	0.7	0.3	2.5

PZEV, Partial Zero-Emission Vehicle; CNG, Compressed Natural Gas; MeOH, Methanol.

a greater understanding of the total 'well-to-wheel' emissions of battery vehicles, which we have been discussing here, led to constant revisions of the regulations.

These revisions came in two forms. The first was a rolling back of the targets in time. The second was to make them much more complex – though this complexity correctly reflects the complexity of the issues. Vehicles that are not fully 'zero emission' might actually produce fewer emissions in the whole well-to-wheel analysis than a zero-emission vehicle (ZEV). So, although it is easy to criticise the CARB for caving in to motor industry pressure, this would not really be fair. The regulations now incorporate a system of credits, which a motor manufacturer can use (Table 12.2). So, for example, it can sell two vehicles with credit 0.5 and this counts as 1 fully ZEV. The latest indications[1] are that manufacturers will not need to produce any fully ZEVs as part of their fleet of sales.

The total credit is an indication of the perceived 'environmental value' of a vehicle. Regulations such as these from the CARB will certainly be a very major influence on the future development of EVs. Particularly, they will encourage the development of a wide range of EVs, which data would indicate is a very good way of reducing the total environmental damage of vehicles.

Further Reading

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[1] In April 2003.