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Energetic, environmental and economic performance of electric vehicles: Experimental evaluation

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ABSTRACT

Fuelled by a rapidly rising human global population, an increasing demand for freedom to travel and the affordability made possible by modern manufacturing there has been an exponential rise in the number of automobiles – in the year 2013 there were in excess of a billion automobiles in use! Three factors that are of serious concern are the consequential energetic, environmental and economic impacts. One solution that is being seen by a number of national governments is the advent (or rather re-introduction) of electric vehicles (EVs). However, one of the key factors that will need to be explored will be the source of the required electricity for the EVs that will define the level of their sustainability.

In this article an experimental evaluation of an electric vehicle has been undertaken. The Renault Zoe e-car has been used for this task with the 'car chasing' technique employed to measure the driving cycle. The speed and energy use were recorded for the vehicle that was driven along the principal arteries of the City of Edinburgh, Scotland. In a separate activity vehicle driving tests were also undertaken in one town in Slovenia (Celje). In both places urban and suburban routes were covered for different times of the day. Results are presented to quantify the energetic, environmental and economic performance indices for the driven vehicle. A discussion is also provided on the potential for reduction of carbon emissions from the transport sector by provision of environmentally-friendly means of generating electricity.

Introduction

The United Nations estimate that 60% of the world's population will be living in urban areas by 2030. Cities account for 2% of the world's area and for 75% of the world's energy consumption. For over a century, the automobile has offered affordable freedom of movement within urban areas. According to the WardsAuto (2014), global registrations jumped from 980 million units in 2009 to 1.015 billion in 2010. The world population exceeded 7 billion on March 12, 2012 and every seventh person now owns a vehicle which in all likelihood is powered by an internal combustion engine (ICE). Worldwide, 18 million barrels of oil are consumed each day by the automobile sector. Annually, the vehicles emit 2.7 billion tonnes of CO_2 (IEA, 2012).

From a climate change perspective the release of such large amounts of CO_2 will need to be examined. In this respect the possible link between human population growth, car ownership increase, global CO_2 concentration and temperature is

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presently explored. Furthermore, a critical review of the present road transport relating to energy demand for UK and Slovenia is carried out. A closer examination of the road transport energy needs was undertaken through experimental work in Edinburgh (Scotland) and Celje (Slovenia). A software program has been used to ascertain the savings in fossil fuel that may be achieved by using electric vehicles.

Climate change and the potential contribution of automobile: brief overview

General considerations

The issue of climate change has been discussed within the scientific community as well as in popular media to such an extent that it has become *a priori* to almost all discussions related to sustainable use of energy. In this section material is presented with a view to chronologically relate some of the causes and effects. In this respect Figs. 1–7 may be viewed in conjunction.

Fig. 1 shows the anomalous behaviour of global temperature change since the latter part of the industrial revolution when significant carbon loading of the planet had ensued, while Fig. 2 shows an exponential rise of atmospheric CO_2 concentration. That behaviour may then be, at least loosely, traced to Figs. 3–7 which show a combined effect of a sharp rise of human population, rise in the number of automobiles on the road and increased use of fossil fuels that are consumed to drive the vehicles. Note that for developed economies of Western Europe the transport related emissions are beginning to stabilize, as shown in Fig. 6 but for the world as a whole a rapidly rising profile is evident. Furthermore, as shown in Fig. 7 the present proportion of 23% share of CO_2 emissions for global transport is set to rise.

Fig. 6 may also be compared with Fig. 8 which shows that much greater emission efficiency has been achieved by tightening EU legislation, i.e. although there is an increase in energy use, the greenhouse gas emissions have a decreasing profile due to the trend shown in Fig. 9. There has also been a heavy thermal loading of sea waters as shown in Fig. 10 which ought to be seen in conjunction with Fig. 11 which demonstrates a sharp decline of solubility of CO_2 in sea water. Note that the annual average temperature of North Atlantic Sea which huddles the major economies is 6 °C during winter months and 17 °C in summer (MUMM, 2014). The seas of planet Earth hold 40 atmospheres of CO_2 by mass. Therefore, any slight sea temperature elevation would release an abundance of CO_2. This argument is particularly relevant to power plants including those that are nuclear-fuelled which would typically dump twice the amount of their useful energy output to their cooling systems. To address the issue of Climate Change the European Union has set itself a challenging task of a serious overall reduction of greenhouse gas (GHG) emissions. Fig. 12 shows those targets for the developed economies within the EU28 member countries.

Impact of automobiles

The resident population of England and Wales on 27 March 2011 was 56.1 million. The number of cars and vans available to households in England and Wales increased from 23.9 million in 2001 to 27.3 million in 2011. In 2001 there were on average 11 cars per 10 households whereas in 2011 there were 12 cars per 10 households. Scotland's population on census day 2011 was estimated to be 5,295,403. In 2011, 69 per cent of households had at least one car or van available, compared with 66 per cent of households in 2001. The total number of cars and vans available to households in Scotland in 2011 was 2.5 million, compared with 2 million in 2001 (Office for National Statistics, 2011).

Transport emissions make up just over a quarter of Scotland's total emissions, with more than two thirds of these emissions coming from road transport. For England and Wales a similar statistic is reported. Furthermore, poor air quality

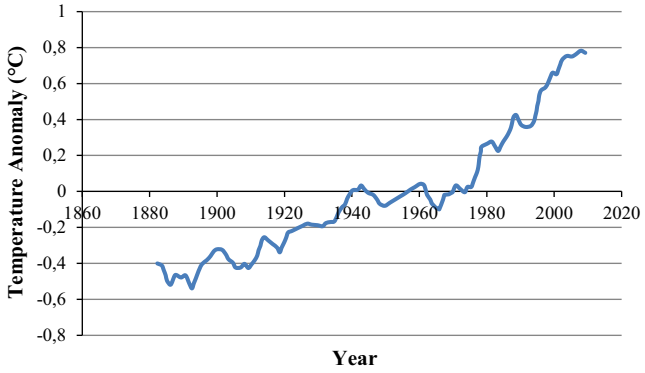

Fig. 1. Chronology of global temperature change (Morice et al., 2012).