The Impact of Motoring

Part 1 - Environmental

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Cover images: The Old Mill, Bourton-on-the-Water, today home to the Cotswold Motoring Museum and Toy Collection and cars associated with the museum.

Source of right hand image above: Metropolia University of Applied Sciences, Helsinki, Finland.
http://green.autoblog.com/2013/05/30/biofore-concept-car-is-a-plant-laden-sustainable-ride/

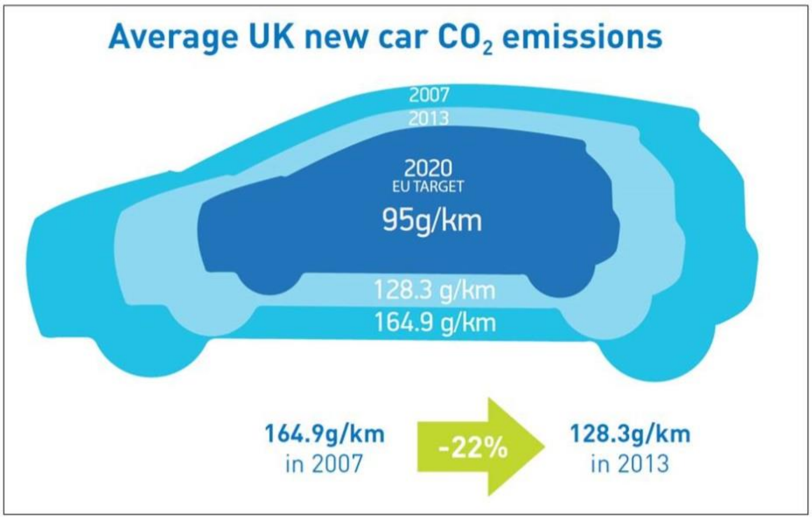
Contents of Part 1

Part 1 - Environmental

The change to our environment over the last 125 years as a consequence of motoring is clearly vast and in some cases the changes have crept up on us almost subliminally. Emissions from burning the products of fossil fuels in our cars and the depletion of the planet's reserves of oil and gas may be amongst the most prominent of our environmental concerns. A time-traveller from the turn of the 20th century however, would undoubtedly be astounded at the incessant noise levels around our main roads and the high level of artificial light, much of which is for the benefit of the motorist and which, largely, we accept as just part of modern life.

Equal astonishment would likely be aroused by the way in which the car and commercial vehicles have revolutionised what we today call our supply chain. Fresh produce to shops across the country within hours of being gathered or off-loaded at the ports provides choice and health benefits unavailable at the dawn of the motoring age, the car providing the final link to home in the chain.

In keeping with the personal responsibility theme of this book, there is an increasing realisation, clearly articulated by David MacKay[1] that if we are to leave a sustainable future to our children and grandchildren, then one action we need to take, above all else, is to use less of the planet's natural resources.



In this vein, the opening chapters of the book review how our usage and fuelling of the car may be managed to achieve this aim. An outline of global oil reserves is followed by a look at alternatives to oil and some renewable energy options. Not all are directly relevant to motoring but they could displace oil currently used for domestic and industrial power generation. Burning hydrocarbons to fuel our cars has produced measureable changes to the composition of the Earth's atmosphere. The role of legislation[2] in trying to slow and then reverse these changes is the subject of one chapter but this alone may not be sufficient, reducing our usage and better management of our journeys also has to be part of the solution.

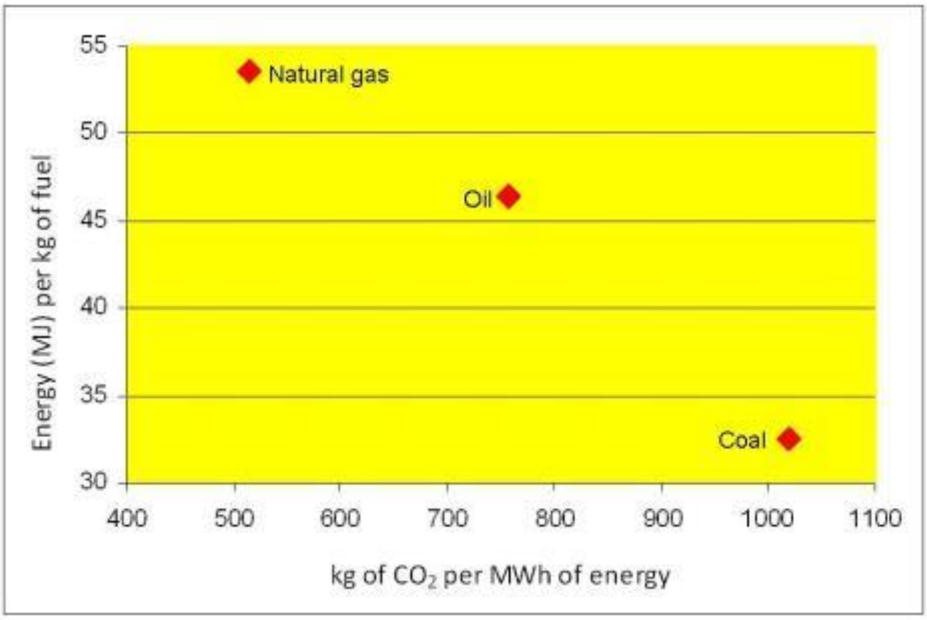
[1] "Sustainable Energy without the Hot Air". http://www.withouthotair.com
[2] The CO_2 graphic is taken from "The SMMT New Car CO_2 Report 2014"

Will the plastic dinosaur soon become extinct?

How much oil do we have left and how long will it last? What is known for sure is that with increasing use, the world's supply of crude oil will run out. In this chapter, we discuss whether estimates of the amount of oil still to be discovered and exploited are realistic or exaggerated. With an increasing global population and industrialisation in India, China, and African and South American countries, will there be enough oil to last beyond 2050? As readily accessible oil becomes scarcer, previously uneconomic and technically challenging reserves are now being exploited. Is the associated risk to our environment and personal livelihood acceptable? This chapter addresses these questions and briefly looks at alternative energy sources to oil, including sources of renewable energy.

Introduction

Fossil fuels are formed from the organic remains of plants and animals, subjected to the heat and pressure of the Earth's crust over tens of millions of years. The fuels in most common usage today are coal, oil and natural gas. In addition to burning oil and its derivatives to release stored energy, it is also used to make medicines, chemicals, plastics and fertilizers. In all cases, burning the fuel releases energy stored in the fuel to generate power for homes, agriculture and industry and to enable land, sea and air transport. The effect of burning each fuel is different. Burning 1kg of natural gas releases around 65% more energy than burning 1kg of coal and releases roughly half of the carbon dioxide (CO_2) produced in burning the same weight of coal. An indication of the relative properties of these three most common fossil fuels is shown in the chart. [MJ is an abbreviation for Mega Joules – a unit of energy and MWh is a measure of the rate at which energy is used]. The graph illustrates why Winston Churchill, First Lord of the Admiralty in 1911, was keen to fuel British war ships on oil rather than coal and why today, in a quest to reduce CO_2 emissions, power generators switch from coal to gas.



In 2010, when the first issue of this chapter on Oil Consumption was prepared in support of the Impact of Motoring exhibition at the Cotswold Motoring Museum, the emphasis was on the source of the fuel used by the motorist and when supplies of that conventional crude oil might be exhausted. Since that time, the number of oil and natural gas discoveries along with enhanced extraction techniques, for example 'fracking', have rapidly evolved and some estimates of the number of years of economically extractable fossil fuel remaining have stretched well beyond the end of this century. Given that coal and natural gas can be and are being used to manufacture liquid fuel and that at least one major oil company now makes more profit from gas than oil, it is appropriate that the scope of the Oil Consumption chapter has expanded to try to reflect an ever more complex picture of fossil and non-fossil fuels. At the same time, the focus remains on motoring and the motorist.

What is oil?

What is oil and when was it first discovered?

Crude oil, or petroleum, is a black treacly liquid found underground, formed from the remains of masses of animal and plant material, particularly from the relatively shallow seas, thick with algae, which covered the majority of the planet millions of years ago. It is generally accepted that the major sources of conventional crude oil were formed during periods of global warming approximately 90 and 150 million years ago. Organic material formed a carbon rich sedimentary rock, which over time sank below the surface, and subject to the Earth's heat and pressure, formed the dark dense liquid.

When was oil first used?

Oil was first exploited in China in approximately 200 B.C. Though only with the use of bamboo poles and brass fittings, they were able to penetrate some 3,500 feet. The properties of oil were known well before this. As early as 3000 B.C., in what is now known as Iraq, the Sumerian people used a bitumen as an adhesive for bricks, and as a sealant for boats. In 2200 B.C. the Babylonians built tunnels, bridges, walls, sewers and roads, including the famous Hanging Gardens and Tower of Babel, using asphalt in the bonding material.

The ancient Egyptians mummified their dead with, amongst other things, bitumen from the Dead Sea. The Roman scholar Marcus Terentius Varro wrote of the disinfectant properties of petroleum vapour. The Indians and Chinese also produced medicines from it.

Arab nations, by the late 11th century, had discovered that the crude oil could be distilled into fractions with varying properties.

The first 'conventional' drilled oil well of modern times in the western world is accredited to Edwin Drake of the Senecca Oil Company, who in 1859 drilled a well in Titusville, Pennsylvania. Using the same techniques as the salt miners in the area, his men were soon able to achieve a drilling rate of three feet per day! They began drilling in August, and by the 27th had reach sixty-nine and a half feet where the oil was discovered. Drake's discovery started an 'Oil Rush'. Within one year there were about seventy productive wells, and by 1864, Oil Creek, as the region had become known, was producing 200,000 gallons of crude oil per day, relatively easily transported in wooden 'barrels' by raft and road.

The next process discovered was the ability to separate crude oil into its constituent fractions by distillation. The most useful constituent at this time was moderately light paraffin oil for use in lamps. The highly volatile constituents (eg petrol) had no real use and were disposed of by burning in pits.

Since its first discovery, oil has been used in a multitude of forms, with different additives and properties, and as an essential lubricant to reduce friction wear, particularly when metal-to-metal contact wear has to be minimised.

Modern day oil usage

It was the commercialisation of the internal combustion engine in the form of sea, air and land transport, but especially the car, which rapidly and drastically increased the demand for fuel products from crude oil, and by 1910 the production of petrol had overtaken that of paraffin oil (kerosene). Previously the dense energy rich crude oil had been found to make a superior fuel to coal for powering shipping. Although with no indigenous supply of oil, the British government of the time, under the guidance of Winston Churchill, set about converting Royal Navy ships from coal to oil. High-octane petrol was to become the fuel of choice for piston engine aircraft. Subsequently jet engine aircraft were also to utilise their own fraction from the mix.

As well as advanced distillation techniques, ‘cracking’ using heat and, later, ‘catalytic cracking’ are able to produce a myriad of organic compounds for use in virtually every industry and in the manufacture of countless items from plastics to fertilisers. In addition to a fuel and lubricant, oil in a multitude of forms is used as a rust inhibitor, hydraulic fluid, a heat conductor in transformers and a cutting fluid. Oil now makes the world go round.

Availability of cheap fuel to the industrialised world also meant improved agriculture. In turn, this meant a vast increase in world population. At the beginning of the oil age (150 years ago), the world population was 1.3 billion. This reached 7 billion in 2012, and is projected to be 9.6 billion by 2050.

Today, the world appetite for crude oil *and* liquid fuels is nearly 90 million barrels[3] per day. This is projected to rise to a peak of 100 million barrels per day by 2030.

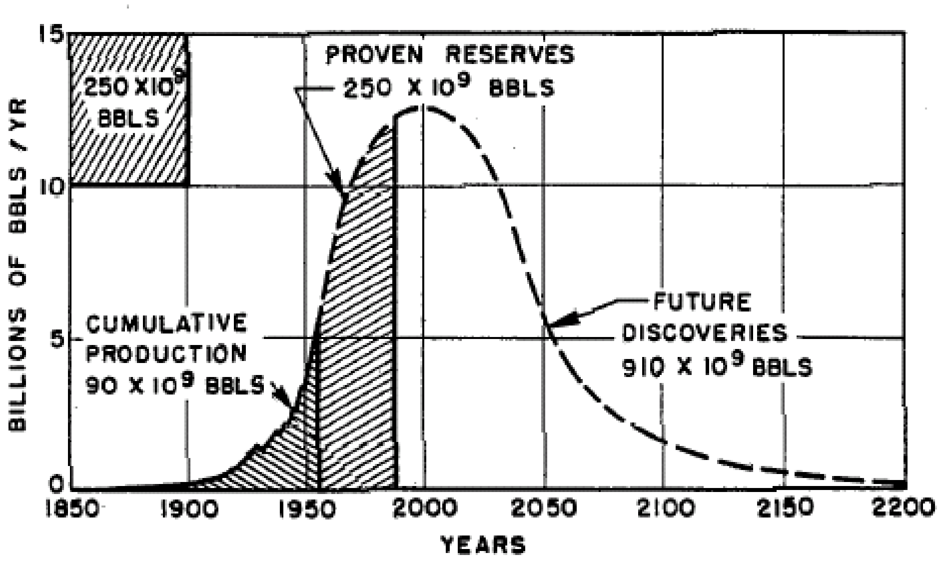
The top three oil-producing countries today are Saudi Arabia, Russia and the United States. About 80% of the World’s readily accessible reserves are located in the Middle East, with 62% coming from the Arab 5: Saudi Arabia, United Arab Emirates, Iraq, Qatar and Kuwait. A large proportion of the world’s total oil exists as what are termed ‘unconventional sources’. Examples include bitumen in Canada and Venezuela, and shale oil. Whilst significant volumes of oil are extracted from oil sands, especially in Canada, logistical and technical hurdles remain, and Canada’s oil sands are not expected to provide more than 3 to 5 million barrels per day; only around 3% to 5% of the projected requirement by 2030.

[3] One barrel is approximately equal to 159 litres, 42 US gallons and 35 Imperial gallons.

The Peak Oil debate

The Peak Oil Theory refers to a point in time when the amount of oil extracted from a given resource, whether an individual oil field, region, or the planet as a whole, follows a bell shaped curve and reaches a peak, following which it begins to irreversibly decline. It was first proposed in 1956 by Dr. Marion Hubbert, a prominent geologist working for the Shell Oil Company. He predicted that oil production in the US would peak between 1965 and 1970. Ridiculed by his colleagues at the time, in 1970 US oil production peaked. In 1969, he went on to predict a peak for World oil production of between 1995 and 2000. This theory became known as the Hubbert Peak Theory.

World crude oil [*defined as: a mixture of hydrocarbons that exists in liquid phase in natural underground reservoirs and remains liquid at atmospheric pressure after passing through surface separating facilities*] production has stayed more or less flat at around 75 million barrels per day since 2004, amidst record high oil prices. Whilst it may be premature to say for sure, the longer that production continues at this rate, or declines, the more certain it will be that Peak Oil from conventional sources, has been reached.



Hubbert's Peak graph from his 1956 paper

Some facts on peak oil usage and discovery, plus further reference material, reinforce this conclusion:

- Oil production in 33 out of 48 countries has now peaked, including Kuwait, Russia and Mexico.
- The biggest growth in oil demand is actually coming from the Middle East itself. Saudi Arabia was a country of 6 million people in 1970. Today that number is 26.5 million and yet the 1970's peak in production has never been reached since.
- Worldwide discovery of oil peaked in 1964 and has followed a steady decline since
- Production from Europe's North Sea oil field is in decline

- World oil demand rose markedly in the decade to 2010 as improvements in energy efficiency did not offset the upward pressure from a growing world population and rising per capita income levels in developing countries

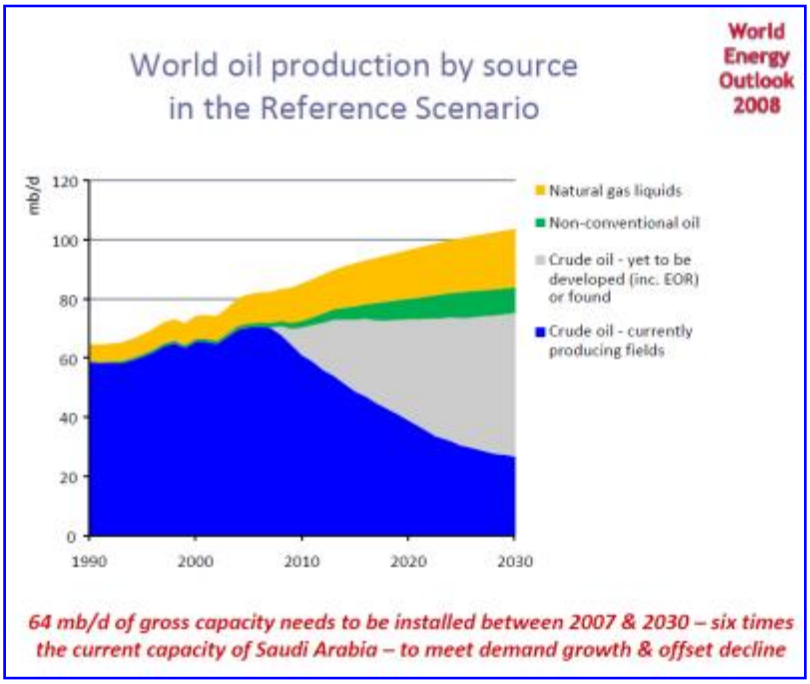
- Demand growth from China, India, Indonesia and the developing world will be extremely high over the next decade. This will by far outweigh any decline in consumption seen in the US, Japan and European countries

- Russian oil production, having seen a revival since the 1990's, is likely to be soon entering a precipitous phase. Russian oil reserves are estimated to be 77.4 billion barrels, a great deal lower than those of the Middle East

- The latest available data suggest that OPEC production has been flat since 2004

Many OPEC nations have 'manipulated' oil reserve data, making accurate forecasting of oil reserves difficult. Under the quota regime of the cartel, the OPEC countries were allowed to produce oil in proportion to their reserves. During the oil crash of the 1980's, many OPEC nations found themselves with a currency shortage and upwardly revised their oil reserve data facilitating an increase in their quota. In 1994, Kuwait doubled its reserve data on paper, without ever finding a single new oil field. Other nations followed suit. All these nations have produced billions of barrels since, yet without finding any significant new resources, their reported reserves have stayed the same since 1990. Some critics estimate that for the biggest Middle Eastern oil producers (Iran, Iraq, Kuwait, Saudi Arabia and the United Arab Emirates) the reserves are less than half of that their respective governments claim.

The Uppsala Hydrocarbon Depletion Study Group (UDGSG), Uppsala University, Sweden, has, among other research and recommendations, made a study of a crash program scenario for the Canadian Oil Sand Industry. It concludes that even in a very optimistic scenario, Canada's oil sands will not prevent Peak Oil. If a crash program was introduced immediately, it would only barely offset the combined decline of conventional crude oil production in Canada and the North Sea.



In considering the questions as to when peak oil will occur and what reserves are available, it is fundamental that these forecasts require accurate sources of information. Not only have the OPEC countries knowingly overstated their oil reserves, but the forecasts made by the International Energy Agency (IEA) appear to have been deliberately upgraded in terms of its estimate of the world's oil supplies, apparently in the interest of not frightening the markets. The Agency has been forced to downgrade its projection of daily oil supply requirements by 2030. In 2004 this forecast was 123 million barrels, by 2005 it was 120 million barrels, 116 million barrels in 2007, 106 million barrels in 2008 (see adjacent chart) and a 2011 projection (a BP figure) of 102 million barrels required per day in 2030. According to so-called 'whistle-blowers' from the agency, even the most recent figures are much higher than data supports.

The Uppsala report, published in the journal Energy Policy, anticipates that a maximum global production of all kinds of oil in 2030 will be 76 million barrels per day. Analysing the IEA's figures, it finds that to meet its forecasts for supply, the world's new and undiscovered oil fields would have to be developed at a rate "never before seen in history". Assessing existing fields, the likely rate of discovery and the use of new techniques for extraction, the researchers find that "the peak of world oil production is probably occurring now".

However, not all published estimates tell a tale of shrinking supply. A more optimistic, near-term forecast has been produced by Harvard University. Their summary states that "*Contrary to what most people believe, oil supply capacity is growing worldwide at such an unprecedented level that it might outpace consumption. This could lead to a glut of overproduction and a steep dip in oil prices*". They forecast global production by 2020, boosted by 'unconventional oil', to be 110.6 million barrels per day.

The UK Energy Research Council recently published a massive review of all the available evidence on global oil supplies. It found that the date of peak oil will be determined not by the total size of the global resource but by the rate at which it can be exploited. New discoveries would have to be implausibly large in order to make a significant difference. If a field the size of all the oil ever found in the US was miraculously discovered, it would delay the peak of oil by four years. As global discoveries peaked in the 1960s, such a find does not seem likely.

In summary, there is much debate between experts as to when the peak in World oil production will occur. This is perhaps not surprising when considering the discrepancies in the available data concerning estimates of oil reserves by certain oil producing countries.

A perhaps somewhat pessimistic view comes from Dr. Colin Campbell, Petroleum Geologist and Energy Consultant:

"The world's oil and gas production will start to decline within most people's lifetimes. Although this will have a dramatic effect on lifestyles and the course of civilization, vested interests have deliberately kept both policymakers and the public in the dark".

A more optimistic assessment is that of Richard Jones, deputy executive director of the International Energy Agency:

"We're the ones that are out there warning that the oil and gas is running out in the most authoritative manner. But we don't see it happening as quickly as some of the peak oil theorists".

In reality, the issue only becomes critical when world demand outstrips accessible world supply. If the economically depressed world markets continue for another decade and new discoveries continue, then the date of peak oil moves into the future. A further quote captures the current situation quite succinctly:

"The era of cheap oil is over, but we're a long way from peak oil - costs will go up but then technology will respond."

We are, however, dealing with a finite, non-renewable resource, so ultimately it is not a question of what will happen *if* we run out of oil, it is what will happen *when* we run out of oil?

Politics and the power of oil

The oil crisis of 1973 showed the vulnerability of 'superpowers' to a modest shortfall in global oil supply. In October, Middle East OPEC states stopped exports to the US and other western nations. It was in retaliation for their support of Israel and was a demonstration of the power that these countries held in being able to bring the rest of the World to a potential stand still. Blocking just 5% of the oil supply had the effect of raising the price of oil four-fold overnight. This was not the first time that the power to control oil supply was used for political ends: the sabotage of German fuel supply lines in World War II was considered a major factor in the outcome of the war.

In late summer of 1985, the US Reagan administration, with a clear knowledge that the economy of the Soviet Union was based on two exports, oil to Europe and military weapons and training to anti-western countries and organisations, decided to make a pact with Saudi Arabia. High oil prices from OPEC kept Soviet oil exports to Europe profitable. It also allowed Iran, Iraq and Syria to purchase advanced Soviet weapons. These countries had been a threat to Saudi Arabia for many years.

The plan was to have Saudi Arabia drop the price of oil below a level the Soviets could afford to sell. Once non-Soviet prices were lowered, former Soviet clients would cease buying from USSR, harming their economy. At the same stroke, Iran, Iraq and Syria, with their oil price so low, would no longer be able to afford to purchase Soviet arms. In December 1985, the oil price was $26.46 a barrel but by March 31st 1986, it had plummeted to $10.25 per barrel. The Soviet Union was unable to keep up and their economy began to collapse. Recognition of Saudi Arabia's valuable help in bankrupting the Soviets came later during Operation Desert Storm. This collaboration with Saudi Arabia subsequently had a down side. Having been shown once how to enhance the estimation of oil reserves and control market prices, it became common for other OPEC countries to adopt such a practise. Today, many OPEC countries see their oil reserves as more political than geological.

Recent oil discoveries

Before discussion of alternatives to conventional crude, we should note that, ironically, in very recent history, there have been significant new fields discovered, and others previously discovered by one region being made available, literally to the highest bidder.

Examples of reserves, which with the latest extraction technology are considered viable, include the Bakken oil field in North Dakota, possibly one of the largest ever found, with a disputed estimate of 250 billion barrels of recoverable oil. The Permian Basin in West Texas, an established oil field using the latest extraction technology, is estimated to increase its current oil production of 900,000 barrels per day to around 2 million over the next 4 years[4]. The recent discoveries of oil beneath California are estimated at 15 billion barrels whilst the estimate for Venezuela is 300 billion barrels, making it the largest reserve in the world, overtaking Saudi Arabia. An indication of the abrupt upturn in US oil production since 2005 is reproduced from the US Energy Information Agency on the BBC website.
Brazil's off shore Tupi oil field, with an estimated 14 billion barrels of recoverable oil, is being developed as two pilot projects and is forecast to yield 6 million barrels per day by 2020. There are also vast oil and gas reserves beneath Alaska yet to be exploited. Over 200 million barrels

[4] TIME Magazine 14 and 28 October 2013

were pumped along the Alaska pipeline in 2012. Estimates of Russian reserves are typically between 60 and 70 billion barrels but some are as high as 200 billion barrels.

In December 2009, the Iraq government held an auction, the second of two since the country's invasion in 2003. On offer were10 oilfields, providing a rare opportunity for oil companies from the West, China and India to obtain access to significant and readily pumpable Middle East oil reserves. Royal Dutch Shell and Malaysia's Petronas won the right to develop the Majnoon oil field, proven to have a massive 12.6 billion barrels of reserves. A consortium comprising the Chinese company CNPC, Total and Petronas, secured the 4.1 billion barrel Halfaya oil field. Several oil fields, such as those with 8.1 billion barrel reserves, in East Baghdad were considered too dangerous at this time for Western commercialisation. The Iraqi Oil Ministry are reportedly developing them on their own.

Recent oil discoveries are not universally popular. Those lobbying for reduced burning of fossil fuels on the grounds of the threat to the planet's climate through further increases in the CO_2 released as the fuel is burnt, fear that further affordable fossil fuel will shift the focus away from renewable energy sources which, ultimately, must represent the future.

Oil spills and pollution

The leak in 2010 from the well beneath the BP Deepwater Horizon offshore oil rig in the Gulf of Mexico, just like the grounding of the Exxon Valdez in 1989, brings into sharp focus the environmental risks associated with meeting the world's demand for oil. The Deepwater Horizon well was approximately 1.5km (5000ft) below the surface of the sea and a further 5.5km (18,000ft) beneath the ocean bed. At these depths, all work on the seabed has to be accomplished using robots; just one illustration of how technically challenging oil extraction has become as ready access to oil on land diminishes. [For comparison, the Brent Field in the North Sea is in 140m (460ft) of water]. Unsurprisingly, the risks posed by the leak to employment, dependent upon fishing, boating and tourism, as well as the risk to the coastline and wildlife habitat, resulted in an immediate reaction of "no more offshore drilling". For the USA, the increasing use of offshore, deep water drilling was meant to ease the transition to non-fossil fuels by buying time for those sceptical of climate change to accept the need to move away from fossil fuels and for renewable energy technology to gear up to meet future demand. Ironically, any moratorium on offshore drilling could have just the opposite effect and increase reliance on other national producers with lower environmental standards.

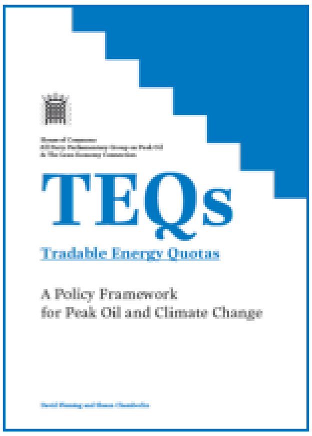
UK government view

The All Party Parliamentary Group on Peak Oil was set up in 2007 to review estimates of future oil production and to consider the effect of declining world oil production on the UK and world economy. An initial report was produced in July 2008 and a follow-up report in January 2011. The Chairman of the All Party Group introduces the 2011 report with:

"*I .... have raised the issue [of peak oil] with the government many times. Regrettably, the government is still unable to grasp how serious the threat of peak oil is, and so the UK remains inadequately prepared to cope with this looming crisis*."

The report summary includes:

> "*Nations around the world are experiencing deepening energy scarcity. There is no doubt that the needed steep reduction in reliance on fossil fuels will not be achieved unless there is a sense of common purpose within nations, with citizens and communities fully involved and strongly motivated to invent their own solutions. We need a revolution in the way we use energy*."



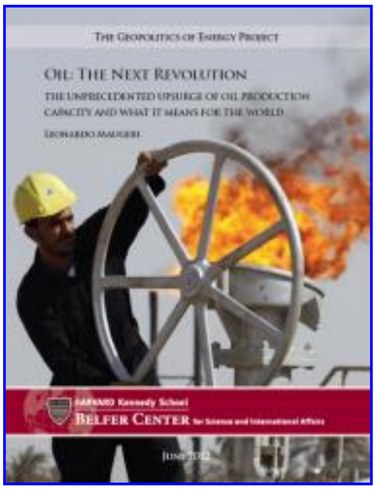
The focus of the report thereafter is on a concept of Tradable Energy Quotas (TEQs) in which individuals, business and governments would receive an annual allocation of TEQs. In practice, these would correspond to litres of fuel or kilowatt-hours of electricity; effectively an individual carbon footprint. The aim of the report's authors is to put in place a system of managing the use of a declining resource *before* the problem needs to be addressed as a matter of immediate urgency and ad hoc, inappropriate steps are taken. Whilst there have to be reservations about the complexity of implementing the specific concept of TEQs in the way presented in the report, the prospect of fuel rationing returning in some guise – maybe through financial affordability - cannot be ruled out and to be prepared for such measures seems eminently sensible.

Alternatives to oil

Whenever 'Peak Oil' is to occur, if it hasn't already, it is clear that the world will no longer be able to rely as heavily on a supply of cheap conventional crude oil for its energy requirements. Recent discoveries, whilst maintaining supply continuity, involve greater complexity and hence greater extraction cost. It is also probable that no one alternative energy source is ready or of sufficient magnitude to make up for a conventional crude oil deficiency. One leading school of thought is that our only alternative is several alternatives.

These can be categorised as 'unconventional' crude oil, that which thus far has not been able to be harvested due to logistic or economic barriers, other non-renewables such as coal, gas (and their products) and nuclear, and most topically, renewables such as solar, wind, wave, tidal, geothermal, hydroelectric, algal, fermentations etc. Each of these has their limitations and challenges, but the technologies for their use are either in their infancy or at differing stages in development and require investment by energy companies and governments. This urgency, accompanied by the threat of irreversible 'global warming', has been focusing attention for some time, such that now it is barely missing from the headlines.

Alternative 'unconventional' crude oil and liquid fuel sources



Over the next 20 years, the ability to extract oil from sources previously technically too difficult and / or economically unviable will shift. Included in these resources are the 'tar sands', a mixture of sandy clay and black viscous bitumen, predominantly found in Canada[5,6] and Venezuela, 'shale oil', a sedimentary rock containing kerogen and liquid fuels produced from coal or liquefied gas.

The International Energy Agency (IEA) estimates that these forms of reserves total 9 trillion barrels or nine times the volume that the world has utilised since the beginning of the oil age. However, such are the difficulties in terms of energy and other costs involved in their processing, until recently, less than 2 million barrels per day were produced from these materials. This figure is increasing. In December 2011, 530,000 barrels per day were produced from the shale oil in North Dakota. A forecast, in a June 2012 report from Harvard University, suggests the possibility that oil from these unconventional sources may result in a global surplus of 110 million barrels of crude oil and natural gas liquids per day by 2020. A BP Energy Outlook for the year 2030 estimates that 57% of the US gas supply could be met from these shale gas deposits.

Production from 'unconventional sources' usually involves a greater release of carbon emissions than conventional refining. There are also concerns that horizontal drilling and fracturing the oil/gas bearing rocks – fracking technology - can cause contamination of aquifers and even minor earth tremors.

Globally, only about 35% of the oil in any well is extracted[7]. The primary approach is that oil is recovered under its own energy, secondary production supplements this with pumping water or gas injection and then a third strand of advanced methodologies are employed. In an effort to develop the recovery, several techniques are being progressed including Steam Assisted Gravity Drainage (SAGD) and Toe to Heel Air Injection (THAI). Similarly, several techniques are being investigated to heat shale oil underground prior to its conventional recovery by drilling. This includes the use of microwaves, high temperature gas injection and radio waves combined with Supercritical Fluid Extraction (SFE).

Methane Hydrate is a crystalline form of natural gas found in layers beneath the sea bed. The methane is trapped in a crystal lattice of water and research to mine and utilise this gas has been undertaken by the US and Japan since the early 1980s. Estimates of reserves vary enormously but the one thing they have in common is that they are vast. The relevance of natural gas to the transport sector is as a displacement for oil in power generation (thus 'freeing-up' oil for transport and manufacturing), as a fuel, in the form of compressed gas replacing diesel, for buses, lorries or ships and for conversion into liquid fuel.

[5] Engineering & Technology, Volume 8, Issue 4, May 2013, p16
[6] New Scientist, 16 August 2014, p10
[7] Engineering & Technology, Volume 8, Issue 1, February 2013, p48

Manufacture of liquid fuel from coal and natural gas

The production of liquid fuel from coal was a process developed by two German Chemists in 1920. The Fischer-Tropsch process involves the heating of coal to release a mixture of hydrogen and carbon monoxide, subsequently catalysed to produce diesel and kerosene. The process was used in Germany during the Second World War and in South Africa during the time of sanctions over apartheid. Some petrochemical companies in the UK during 1930-1945, namely Carless and the National Benzole Company (NBC), also produced a liquid fuel from coal for use as a 'motor spirit', although utilising a different process from Fischer-Tropsch, resulting in a mixture of 50% benzene and the rest a mixture of toluene and xylene. This would not be acceptable today, as even if mixed with conventional petrol, benzene is now known to be a potent carcinogen.

The same Fischer-Tropsch process can be used to produce high quality liquid fuels from natural gas. The process emits less carbon than coal to liquid fuel, but takes up to 300 cubic metres of gas (half of which is burnt in the reaction) to produce one barrel of liquid fuel. Despite this, there are three small plants at present producing 50,000 barrels of synthetic liquid fuel per day. This is estimated to rise to 200,000 barrels per day with new plants in Qatar and Nigeria coming on-line.

Underground Coal Gasification (UCG) has taken on a higher profile in recent years. Although the same process that was performed in the town gas works fifty years ago, in UCG the coal is partially burnt in-situ, a few hundred metres below ground. Oxygen and steam are pumped at pressure through boreholes into the coal seam and the gases (carbon dioxide, carbon monoxide, methane and hydrogen) forced to the surface[8].

In some parts of the world, coal has made a resurgence. In the UK, it remains at present the most utilised fuel for electricity generation in power stations. In this respect, the production of liquid fuel from coal is releasing oil reserves for purposes coal cannot fulfil eg manufacturing.

Biodiesel

Most people are now aware of biodiesel made from crops such as corn, soya beans, palm oil and even bananas. However, there are problems with biodiesel made from crops. These include the displacement of food, environmental damage as large areas of Amazonia, Malaysia and Indonesia are cleared for biofuel growth and the amount of crops needed to produce a gallon of oil. In June 2013, the European Parliament's Energy Committee voted to cap the proportion of food-crop fuel at 6.5%. In September 2013, the Parliament backed proposals to limit the amount of food crops used to a maximum of 6% by 2020, amending the target from 10%.

Biodiesel produced from algae[9] has been widely discussed among experts in the petroleum industry and conservationists who are looking for a more reliable and safer source of energy that is both renewable and easy to attain. One of the key reasons for this is their yield. The US Department of Energy has reported that algae can give up to 30 times more energy per acre than

[8] New Scientist 15 February 2014
[9] Engineering & Technology, Volume 5, Issue 5, March 2010, p42

land crops such as soya beans, and some estimate even higher yields of up to 15,000 gallons per acre. Action of sunlight on algae, in the presence of water and carbon dioxide, produces lipids or oils from which fuel can be processed. Solazyme claim “Solazyme’s renewable oil production technology allows us to do in a matter of days what it took nature millions of years to do”. Genetically engineered organisms, designed to optimise fuel production, have been developed by Joules Unlimited with pilot production demonstrated at their plant in Austin, Texas.

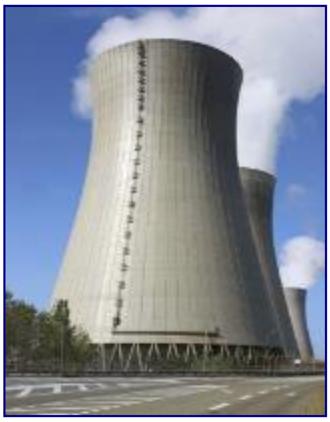
Ethanol

One product of the fermentation of organic matter, such as maize or sugar cane, is ethanol (or ethyl alcohol). When mixed with petrol, it has a long history of powering motor vehicles. Some brands of motor spirit in the 1930s and 1940s were sold as a mixture of petrol and alcohol, one example is Cleveland Discol, advertised as ‘the alcohol blend’ being able to provide more power than petrol alone when used in some internal combustion engines. In America, during the oil crisis of the 1973, a similar mixture of alcohol and petrol (gasoline in the US) was marketed as ‘gasohol’. Today, in Europe a 5% ethanol mixture (known as E5) is in widespread use and since 2013 the standard (BS EN228) for petrol allows up to 10% (E10). The objective of these measures is to cut the amount of fossil fuel burnt. Some manufacturers already produce vehicles that run on a 25% ethanol mixture, for example in the Brazilian market, however, for older, classic vehicles, even the E10 blend will cause problems.

The trend with biofuels has been to move away from food crops with second-generation biofuels being created largely from non-food material such as corn stalks, leaves, hardwood and softwood, while algae-derived fuels represent the current (third) generation[10].

Nuclear power

Although not strictly an alternative to oil in terms of transportation fuel replacement, in a world of inevitably increasingly scarce and expensive oil, no discussion on oil and its alternatives would be complete without a mention of nuclear power. Nuclear-fuelled power stations have been a part of our society for many years, along with much criticism of their use, based largely on the unique associated dangers. On the positive side, carbon emissions are lower than those from conventional coal fired power stations. They are also comparatively efficient in financial terms. The main problems arise from the radioactive materials used, together with the radioactive waste products produced in the process, their transport and disposal. These materials remain hazardous due to typical radioactive half-lives of many hundreds of thousands of years.



Other concerns also focus on safety. The disastrous consequences of a major accident on 26th April 1986, when nuclear reactor number 4 at a power station at Chernobyl in the Ukraine (then part of the Soviet Union) suffered a catastrophic power excursion, led to the worst industrial accident of all time. Radioactive fallout was 400 times higher than that formed by the Hiroshima atomic bombing in World War II. An estimated 800,000 people were exposed to radiation. The number of deaths attributed to related cancers may never be known. Today and for generations

[10] Engineering & Technology, Volume 9, Issue 4, May 2014, p56

to come, children growing up in the areas of Ukraine and Belarus affected by the fallout suffer a disproportionately high rate of serious illness due to their contaminated environment.

The consequences of nuclear accidents such as Chernobyl, together with other radioactive incidents and leakages, such as the problems surrounding the Fukushima nuclear plant damaged in March 2011 by the earthquake and tsunami, highlight concerns over nuclear safety. Additionally, the proliferation of radioactive materials and concerns about material falling into the hands of terrorists, whether for producing a weapon of mass destruction or a 'dirty bomb' have a negative influence on this method of powering our societies.

Nuclear reactor technology has been used as an alternative to oil to power military ships and submarines. Again, the risk of accidents remains an environmental concern. Very few nuclear powered cargo ships remain operational today, the remainder interestingly having been converted to diesel. 'Nuclear Batteries', refrigerator-sized reactors, have been discussed since the 1950s and are again newsworthy. Modest scale schemes have also been proposed that use nuclear waste products in a molten salt reactor to produce carbon free energy and to address the disposal of hazardous waste.

There are differing opinions regarding the world supply of uranium and how long it can be sustained. These range from 40 to at least 200 years at today's rate of use. One alternative to uranium is thorium but in spite of being a more abundant, less hazardous material than uranium, this has not moved beyond demonstrations of feasibility.

All nuclear power generation is based on nuclear fission. By comparison, the production of commercial nuclear fusion energy has been the topic of research for more than 50 years and remains a distant – more than 30 years – possibility to solve global energy requirements.

Biomass and waste to energy

Biomass, burnt along with coal in a power station is, in a similar way to nuclear power, a displacement technology for oil, gas and coal. The efficiency of the biomass pellets can be increased by 'toasting' the pellets: a process known as torrefaction. Conversion from coal to biomass is a means by which some of the UK's coal burning power stations will meet their reduced CO_2 targets. Processing of household waste into energy in the form of methane, used for electricity generation, is also providing an alternative to fossil fuels as well as avoiding the waste going to landfill.

Ammonia

Ammonia has been proposed as an alternative fuel, since it can run in spark ignited or diesel internal combustion engines with minor modifications and despite its toxicity, some references claim it to be no more dangerous than petrol or LPG. It can be made from renewable electricity and having half the density of petrol or diesel can be readily carried in sufficient quantities in vehicles. On combustion, it has no emissions other than nitrogen and water vapour. During and following WWII it was used to power buses in Belgium.

For more information see New Scientist and the Wikipedia link.

Renewable energy

A brief mention of renewable energy sources has a place in a chapter on Oil Consumption in the transport sector since 'renewables' become 'displacement technologies' for oil; leaving oil to be used in roles for which it is uniquely suited such as manufacturing, plastics and pharmaceuticals.

Solar power

Domestically, solar energy is used in two ways to provide power. Solar heat exchanger panels for water heating and the more expensive photovoltaic (PV) panels for direct generation of electricity are increasingly being installed on home and business rooftops. Of renewable energy forms, solar photovoltaic is one that has benefitted from financial incentives, in the form of feed-in-tariffs, helping to increase its presence over recent years. Beyond use in individual domestic premises, a few large-scale, industrial arrays have been deployed. In 2011, a 30 acre, 21,000 PV panel solar park was completed in Cornwall and is providing power for local businesses and a feed-in to the National Grid. Also in SW England, near St Austell, is the National Solar Centre whose aim is to increase deployment of PV capacity through cost reduction and to improve efficiency, which, under ideal conditions, is currently around 20%.

On a small scale, it is easy to fit solar panels to the roof of a domestic dwelling or outhouse. Even some road signs, particularly in remote areas, now carry their own mini solar panels and the use of solar power to operate LED road studs (basically an 'active' cat's eye) is well established.

When the environmental impact of producing solar PV panels is factored into the equation, there is an argument that they are not as 'green' as they may first appear. The materials used in their production and end-of life disposal can be harmful to humans and the environment and the fossil-fuel-derived energy used in their mining, fabrication, installation and maintenance may exceed that produced during their working life.

Returning to the direct use of solar thermal energy on a large scale, for those with the appropriate climate, concentrated solar power[11] has a lot to offer. The Ivanpah project in California is the biggest solar thermal plant in the world. The 150m high tower is at the focus of 173,000 steerable mirrors that reflect the sun's energy onto the top of the solar tower where the steam produced is used to power turbines for the generation of electricity. In comparison with photovoltaic power generation, the short-term loss of sunlight does not mean a fall in the power fed to the grid. The thermal inertia of the massive boilers provides continued power should the occasional cloud pass over the dry Californian lake. The unit shown above is the first of three planned for the site[12].

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[11] Engineering & Technology, Volume 8, Issue 5, June 2013, p30

[12] TIME Magazine, 24 June 2013

Hydroelectric power

Generation of electricity by driving turbine generators with water stored by the damming of a river has been exploited for many years. This clean and renewable source is obviously geographically dependant and has traditionally required a large initial financial investment. It provides one way in which renewable energy can effectively be stored. For example, wind power that may be available at times of low consumer and industrial demand, can be used to pump water for storage behind the dam until it is required for power generation.

Whilst hydropower has long been used for milling and industrial purposes, there is renewed interest in old mill sites as locations for hydroelectric power generation.

One interesting new use for the Archimedes spiral, used for centuries to raise water for irrigation, is in such generation schemes. The picture shows an installation on the River Dart in Devon. Water flowing *down* the spiral drives a generator via a gearbox. The spiral can operate with a head of water as low as 1m and with a flow rate of a few cubic metres per second and is capable of generating a few tens of kilowatts. The spiral has been demonstrated to be particularly ‘eel and fish friendly’. A further installation, powering a renovated mill and feeding surplus energy back into the national grid, is on a tributary of the River Thames in Oxfordshire.

Wind power

Like water power, wind power is nothing new. Man has used wind power for hundreds of years, including windmills for the production of flour from wheat and the wind pump for land drainage.

Wind power is renewable, does not cause pollution at the point of power generation and does not need fuel. However, obviously, it is only available when the wind is blowing! Despite a widespread acceptance that this is a resource of the future that should be exploited now, some concerns are voiced over the effect on the landscape, the effect on birds and interference with TV and radar signals. Increasingly, new capacity is likely to be built in coastal waters (up to 25m depth) and further out to sea at depths of up to 60m. Successful bidders for the next ‘round’ of UK offshore wind generation were announced in early 2010. Physically, these towers will rise 100m above the water surface and, in 50m of water, will place 500 tonnes of blades and turbine on top of a 150m cantilever [13]. A formidable and expensive, civil engineering challenge! One proposed method to ease the construction task is to assemble floating wind

[13] Engineering & Technology, 6-19 February 2010, 40-43. http://www.theiet.org/resources/magazines/

turbines in the shelter of the quayside and then tow these, once assembled, to be moored in their designated, deep-water location[14].

Estimates of just how much energy can be generated by offshore wind farms vary depending on the underlying assumptions. They range from around 4kWh per person per day, which assuming a UK population of 60 million equates to around 90TWh per year[15], to around 250TWh per year by 2050: approximately 70% of current national annual usage. The Offshore Valuation Group, which produced the 250TWh estimate, goes on to state that, with significant further investment, this figure could be exceeded, making the UK a net exporter of wind power generated electricity. This however, would only be feasible with a very expensive, Europe-wide electricity 'super grid' to smooth the effect of variable wind across the continent. An interesting, real-time insight into just how much wind generation is contributing to UK power demand is available at the BMRS website (Generation by Fuel Type – Table & Graph).

Like solar panels, 'mini' wind turbine generators are now available for rural road signage and domestic use, although their efficiency is low and they are particularly poor in urban areas.

Wave and tidal power

The Atlantic coast of UK and Ireland is an ideal location to generate wave energy. The wave energy is produced from the action of the prevailing westerly winds across the Atlantic and will therefore vary with wind conditions. To make a significant contribution to the UK energy requirements, many hundreds of kilometres of coast would need to be lined with wave generation hardware but for west coast islands, from Islay to Alderney, wave generation is highly likely to have a role in providing renewable energy.

Tidal power, unlike wind, wave and solar power, is entirely predictable and using tidal lagoons, energy can be stored to deliver power on demand. Given the spread of high tides around the UK coast, a number of tidal farms around the coast could provide a uniform feed of power into the grid and, unlike wind generation, the visual impact would be minimal.

Proposals for harnessing the tidal range of up to 14m in the Severn Estuary have been reviewed by UK government. One scheme, based on a barrage between South Wales and Weston, using the ebb tide to drive over 100 turbines, could provide 17TWh per year; 5% of the current UK power requirements. A further four, smaller and less expensive schemes were also included in the review, however, plans to exploit this energy source are, depending on the information source, either unlikely as they are considered too expensive to develop, or, back on the agenda.

Another approach to harnessing tidal energy is through the use of underwater, impeller-driven or hydrofoil-driven turbines anchored to the sea bed. These do not present the visual impact of a barrage and also present a lower impact on wildlife[16]. The installation of one such turbine in Pembrokeshire at Ramsey Sound is currently the subject of a 12 month trial.

[14] Engineering & Technology, 23 Oct – 12 Nov 2010, p46-47
[15] TWh: a Terawatt hour is equal to one billion kilowatt hours (kWh)
[16] Engineering & Technology, Volume 7, Issue 12, January 2013, p38

Ocean Thermal Energy Conversion (OTEC)

OTEC[17] is a technique that exploits the natural thermal gradient found in many equatorial regions. To be effective, a minimum temperature difference between surface water and the deep ocean needs to be at least 20ºC although in some parts of the globe differences of up to 50ºC can be found in depths as little as a few hundred metres. Using a closed system with a refrigerant such as ammonia, the refrigerant is vaporised by heat from the warm surface water and used to drive an electric generator. Cold water, pumped from the deep ocean, circulates through a second heat exchanger and cools the ammonia ready to repeat the vaporisation / condensation cycle.

The technology has attracted a number of serious investors, including Lockheed Martin, and projects ranging from pilot trials to modest scale installations are underway in several equatorial countries.

Geothermal power

Geothermal energy has been used for thousands of years in some countries for cooking and heating. More recently this resource has been used to generate electricity. It relies on residual volcanic activity to heat water to generate steam to drive turbine generators. Geothermal energy is an important resource in volcanically active places such as Iceland and New Zealand. Disadvantages, include geography and the presence of toxic gases and mineral compounds that have to be taken into consideration from a safety standpoint. This however, has not stopped Iceland looking at the feasibility of a 730-mile long cable to provide geothermally generated power to Scotland.

In non-volcanic areas, extraction of energy from hot rocks at a distance of 5km to 10km below the surface has been attempted. In the UK a pilot at Rosemanowes in Cornwall, was terminated in the 1980s as it was unlikely to prove technically or commercially viable at that time. New drilling techniques that offer lower cost and faster drilling speeds were scheduled to be tried on the site of the Eden Project in Cornwall during 2012/13 but are currently stalled and awaiting finance.

Storage

The availability of many sources of renewable energy is intermittent. Dependence on the output of solar, wind, wave and to some extent tidal generators is not ideal for the energy supply business where a steady base load capability and rapid on-demand power is required. In theory, one solution is to capture energy when it is readily available and store it until domestic, commercial and industrial demand increases. Whilst OTEC provides a massive, constantly replenishing store of thermal energy in the top 100m of ocean, there are many areas of the globe where this is not a viable option.

A number of novel techniques have been developed to address storage with the hydroelectric example mentioned above being one example. Other techniques use 'surplus' energy to refrigerate a material from a gas to a liquid or a liquid to solid and then use the latent energy released as the material changes state to drive electricity generators.

Looking at more conventional battery storage in the context of the requirements of a national power grid, costs for the batteries can greatly exceed generation costs. One new technology that

[17] New Scientist, 1 March 2014

offers some promise is that of flow batteries[18]. These use organic electrolytes, have been demonstrated to survive hundreds of charge / discharge cycles and have the potential to be developed at an industrial scale.

Conclusion

Finally, two quotations that summarise the world's consumption of oil and the realisation that it is a finite resource:

'If today's teenagers have children and live to be grandparents, the population of the planet will be 9 billion by 2050' – Sir David Attenborough, 1999

and

"*Anyone who believes in indefinite growth in anything physical, on a physically finite planet, is either mad or an economist*" – Kenneth Boulding[19] -
(Environmental Advisor to President Kennedy, 1966 – from the 2011
Presidential address by David Attenborough to the RSA, March 2011)

Today's global population is around 7 billion. With that figure increased to 9.6 billion by 2050 (note the increased estimate since the 1999 quote above) and greater prosperity, health and expectations in the developing world, there will be even greater pressure on oil and other, non-renewable natural resources to provide for our way of life and even our survival. Even if the fossil fuel supply is maintained at a level to meet demand, the associated CO_2 and methane emissions are likely to continue to increase the greenhouse gas composition of the atmosphere.

Whilst globally, the peak of conventional crude oil may be upon us, the exploitation of reserves of 'unconventional' crude oil and gas in the Americas: the USA, Canada, Venezuela and Brazil, will delay the inevitable exhaustion of economically exploitable fossil fuels for perhaps two or three generations. Even then, the viability of exploiting these options will be determined by local geography, environmental considerations, political alliances and by the size of population served by the new oil / gas reserves.

In the next 20 or so years, the shift of the USA from being a net importer of oil and gas to being self-sufficient or even an exporter, could seriously disrupt today's oil exporting nations that rely on the USA as their market. Similarly, if the UK and continental Europe exploit the available shale oils and gas, the eastern European exporters, particularly Russia, may find their market diminishing. Just further examples of the heavy interplay between oil and politics!

In conclusion, for the UK, wave or tidal power may supply the majority of energy for a Hebridean island but for the majority of the mainland population, all forms of renewable energy[20] along with serious energy saving measures are likely to be needed to offset the diminishing North Sea supply and increasing cost of alternative fossil fuel derived energy.

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[18] Engineering & Technology, Vol 9, Issue 2, March 2014
[19] Kenneth Boulding ***was*** an economist
[20] For a detailed, quantitative and objective analysis of sustainable energy, the publication of "Sustainable Energy Without the Hot Air" by David MacKay is an excellent source of reference. http://www.withouthotair.com/

Picture Captions and Credits

Page 6: Edwin Drake. http://en.wikipedia.org/wiki/Edwin_Drake
Page 7: Fuel pump from Cotswold Motoring Museum collection
Page 7: Grangemouth oil refinery. Source unknown
Page 15: National Benzole tanker. Source unknown
Page 15: Palm Oil nuts
Page 16: Cleveland Discol sign from Cotswold Motor Museum collection
Page 16: Nuclear power generation: http://www.freedigitalphotos.net/
Page 18: Energy Resources website: http://www.darvill.clara.net/altenerg/solar.htm
Page 18: Solar powered road stud
Page 18: Concentrated Solar Power: photos-and-videos | BrightSource Ivanpah
Page 19: Hoover Dam: http://www.darvill.clara.net/altenerg/hydro.htm
Page 19: Hydropower being generated by an Archimedes spiral, River Dart Country Park, Devon.
Page 19: Inshore wind farm, Caister, Norfolk
Page 20: Pelamis Wave Power website: http://www.pelamiswave.com/
Page 21: Energy Resources website: http://www.darvill.clara.net/altenerg/geothermal.htm

Why is it called a "Bowser Pump": surely, it's just a fuel pump?
The word "Bowser" is not in common usage today but, when used, it usually refers to a tanker for water or fuel. However, this is an example in changing use over time. In 1885, Sylvanus F Bowser invented and produced a measuring and pumping device for dispensing paraffin; the forerunner of today's fuel pump.

How many of us, when we stand at the filling station, fuel nozzle in hand watching the price digits rolling up faster than the litres, remind ourselves that what we are pouring into our tank is derived from a finite, irreplaceable natural resource that within a generation or two may be so scarce as to be unaffordable?

Tucked behind the Mark V Jaguar in a corner of the Cotswold Motoring Museum's Mill Gallery is a petrol pump that, despite being bright red and 2.5m high, is not particularly imposing and could be passed over quite easily. But missing it would be a pity because this pump earned its place as one of the "Ten Objects" in the museum's history of motoring. Made in about 1925 by S.F. Bowser & Company, the Bowser Standard Pump (type 1041) was operated by turning a large crank handle. By means of a ratchet, this operated pistons in two brass cylinders that pumped the fuel. Conveniently, one full stroke of the cylinder delivered one Imperial gallon, but by using a clever stop lever the amount could be adjusted to deliver half gallons, quarts or pints. Various dials, counters and glass viewers were used to ensure accurate delivery.

Forty years before this particular pump was made, the company's founder, Sylvanus F Bowser, invented a safe and efficient means of delivering fuel. The original version had marble valves and wooden plungers. It was used for pumping paraffin (kerosene in the USA) for heating and lighting, but this was in 1885 and the world was about to change.

The introduction of the car greatly increased the demand for fuel. In 1888, Bertha Benz borrowed her husband's newly commissioned automobile and set out with her two young sons on a pioneering 65-mile journey across Germany from Mannheim to Pforzheim. The little car could only do about 25 miles to the gallon and given that a world without cars was also one without petrol stations, Bertha had to plan her route carefully. Fortunately for her, she knew of a pharmacy along the way where she could buy fuel (Ligroin), which was actually being sold as cleaning fluid. The Weisloch town pharmacy still exists today and is regarded by many as the world's first filling station.

The practice of buying fuel in two-gallon cans from chemists, blacksmiths, hardware stores and even hotels, became the accepted practice for many years. As motoring became more popular and the demand for petrol increased, providing a quick and safe means of storing and delivering fuel became a priority. Modest, hand-operated machines such as the 1925 Bowser pump were soon replaced by electric pumps capable of gushing gallons of petrol to quench the automobile's insatiable desire for fuel.

Consequently, kerbside Bowser pumps began to appear outside country garages and newly established filling stations as businesses expanded to meet demand. Storage tanks were placed underground and the pumps were moved to a central island, sometimes covered with a canopy to protect the customer from the elements and keep rain out of the fuel. Once fuel was no longer dispensed from calibrated, glass measuring cylinders, either pumped or under gravity, assurance that fuel really was flowing into the car's tank was provided by a clear glass window or dome with a rotating paddle inside indicating fuel flow. The accuracy of metering improved and, over time, hand-operated pumps were completely replaced by electrically powered pumps. We said goodbye to the attendant as we entered a world of self-service and, eventually, pay-at-the-pump.

Petrol stations today provide a quick and convenient method of refuelling. No longer are pumps individually branded and competing side by side on the forecourt; instead the whole setting expresses the image of a single company from the glowing canopy to the massive logo-emblazoned price sign at the entrance. Fuel delivery is now part of a self-service retail environment offering the motorist life's essentials, ie milk, bread, flowers and £50 of premium unleaded.

Footnote:
Supplying the pumps with the fuel needed by today's motorist is a much wider story. The first drilled oil well of modern times is accredited to Edwin Drake of the Senecca Oil Company, who in 1859 drilled a well in Titusville, Pennsylvania. Drake's discovery started an 'Oil Rush' which was soon producing around 300 barrels[21] of crude oil per day. By comparison, global consumption is now around 88 million barrels of oil every day. There is a serious debate about whether the human race has passed the date of 'peak oil' – the date from which future discoveries of oil will be less than the volume already extracted. For more on future oil supplies and alternative energy sources, see the previous chapter on Oil Consumption.

Picture Captions and Credits

Page 24: Bowser pumps and photograph of Jack Lake's Garage from Cotswold Motoring Museum

Page 25: Items on display at the Cotswold Motoring Museum

Page 26: Garage forecourt from The Vintage Garage website:
http://vintagegarage.co.uk/garage%20photos/gaspumpgary%20collection.htm
and its modern equivalent

[21] One barrel is approximately equal to 159 litres, 42 US gallons and 35 imperial gallons

Is the air we breathe becoming more or less polluted?

This chapter on Air Pollution attempts to address questions such as just how polluting is the car and how has the situation changed over time? How has legislation helped to reduce the harmful components of the exhaust gases from our cars in everyday use and is this the whole story of the environmental impact from our use of cars? What improvement do electric vehicles provide given that the energy for re-charging the vehicle's batteries may have been derived from power generated using fossil fuels?

In this chapter, these questions are expanded, some answers are offered and historical and technical background, plus further references, provided.

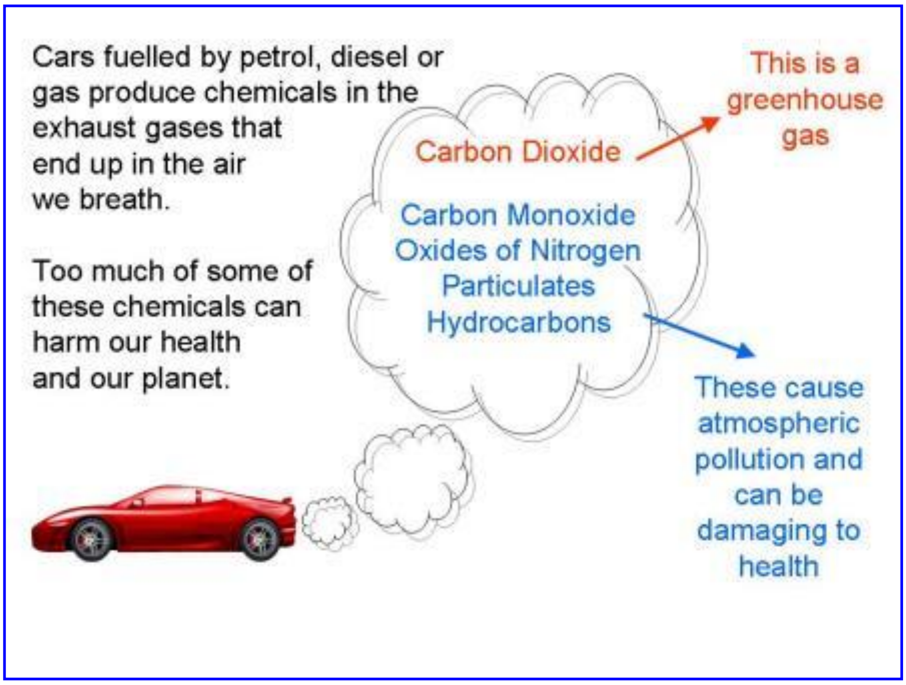
Introduction

With the 40th anniversary of the first Apollo moon landing still fresh in our memories, it is interesting to recall the impact that those first, widely seen images of Earth from space had on our perception of the planet. In particular, there was a heightened awareness of the fragility of Earth's atmosphere and of the importance of protecting the few hundred kilometre thick layer that plays such a vital role in sustaining life on Earth. The global initiative on reducing damage to the ozone layer through the reduction of compounds of hydrogen, chlorine, fluorine and carbon (CFCs) in domestic and industrial appliances is one example of the benefit of this increased awareness. The former UN secretary-general Kofi Annan has hailed the Montreal protocol to phase out CFCs as "perhaps the single most successful international agreement to date". Whilst, in the Western world, much of the visible urban atmospheric smog that characterised the first half of the 20th century has been largely eliminated, attention continues to focus on the less visible but equally harmful emissions produced by domestic power generation, industry and rapidly increasing global transport. Additionally, in spite of a downward overall trend in the UK's annual production of greenhouse gases, the cumulative increase of these gases in the Earth's atmosphere is a further cause for global concern.

Car exhaust gases

In the case of road transport, the mixture of gases from the exhaust system of a motor vehicle comprises those that, when present in sufficient volume, can be harmful to our health and over a prolonged period, affect the Earth's climate.

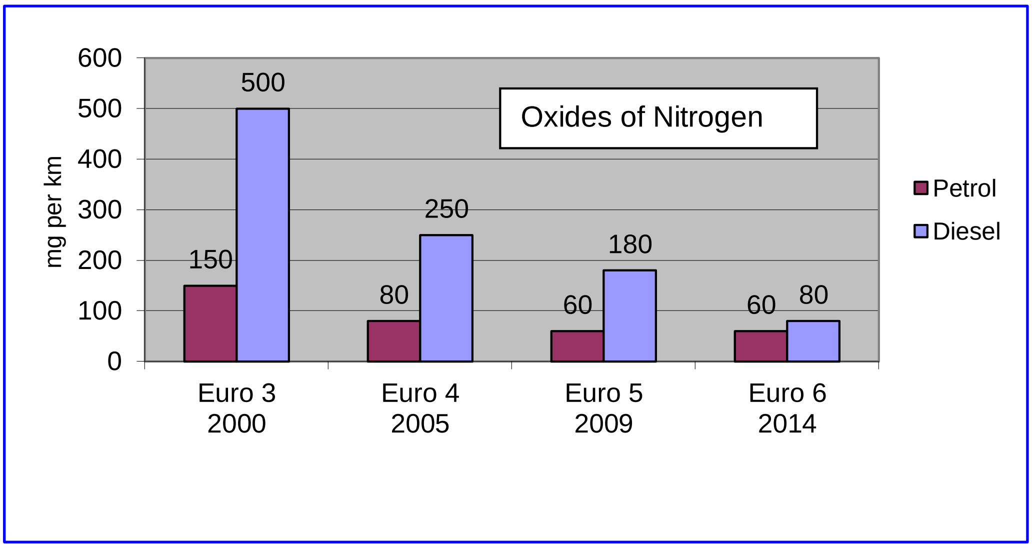
Historically, attempts to reduce atmospheric smog arising from vehicle exhaust emissions started in California with the California Air Resources Board (CARB) being at the forefront of legislation to reduce the harmful components of vehicle exhaust gases. Emissions legislation is now common throughout the United States, the European Union and other countries, with increasingly tight restrictions being placed on those global vehicle manufacturers who offer vehicles for sale in these markets.



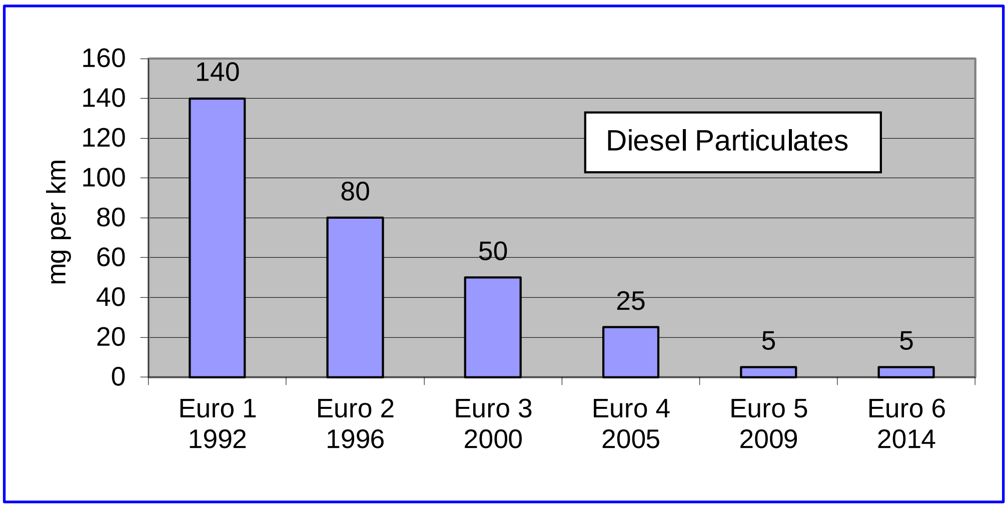
The magnitude of the effect on human health, particularly in a dense urban environment, is not easy to quantify. Globally, the World Health Organisation estimate 7 million people died in 2012 as a result of air pollution. In the UK, estimates of the number of premature deaths attributable to road transport emissions, range from 5,000 to 29,000 respiratory deaths per year with nitrogen dioxide (NO_2) from diesel vehicles being a particular source of concern in areas of high traffic density. A recent report[22] claims 4,200 premature deaths per year, in London, are due to air pollution. For comparison, the number of fatalities through road traffic accidents in Great Britain during 2012 and 2013 were 1,754 and 1,713 respectively.

European legislation

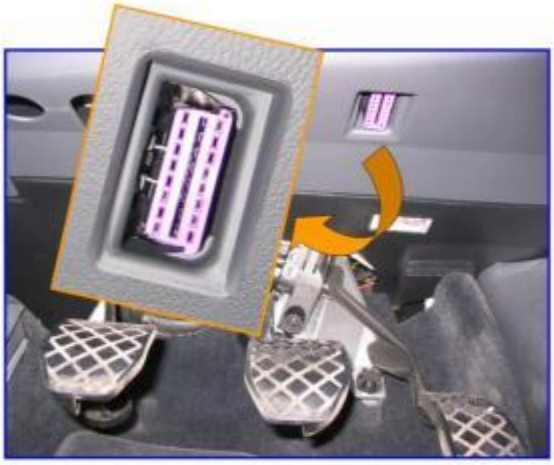
The latest EU legislation, Euro 5 (2009) and Euro 6 (2014), addresses both petrol and diesel cars and continues the trend of legislating for decreasing levels of harmful gases and fuel-derived particulates. (Particulates produced by wear from tyres and brakes are excluded from these figures). Two examples of the Euro 5 and 6 levels, along with earlier limits, expressed as milligrams (mg) per kilometre driven, are shown in the adjacent graphs.



[22] New Scientist, 1 March 2014, p6

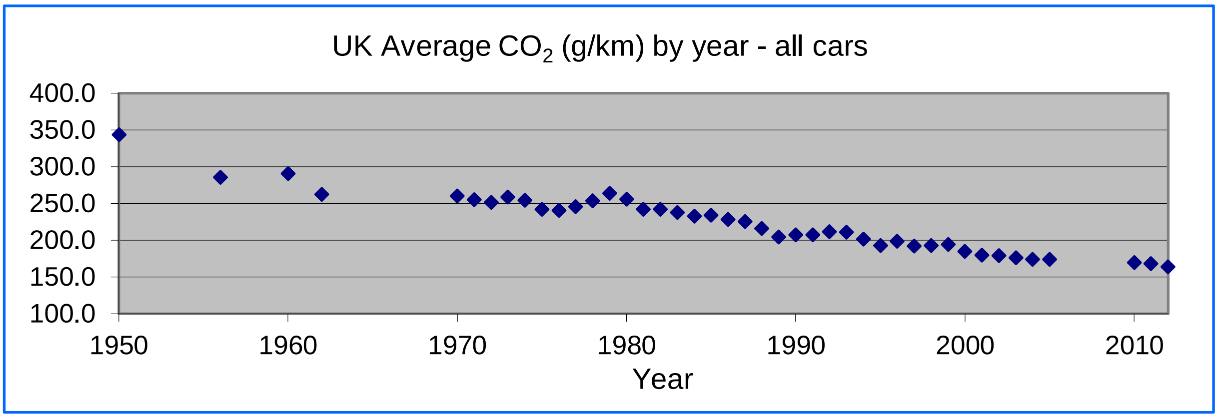


In addition to specifying the emission levels to be met by new vehicles, Euro 5 also specifies levels of access to manufacturer-specific coded electronic fault information and to the manufacturer's supporting repair information. The fault codes, including those compliant with the European On-Board Diagnostics (EOBD) standards, are viewed on a PC via the car's electronic diagnostics port. The purpose behind legislating this access is to facilitate, throughout Europe, a commercially competitive vehicle servicing network required to maintain low emission levels throughout the car's life.



Carbon dioxide

Historically, carbon dioxide (CO_2) emissions from road vehicles have not been covered by EU legislation. With the increasing evidence that rising CO_2 levels have a role in global warming, this changed in 2007. The pre-industrialisation level of CO_2 in the Earth's atmosphere was around 280 parts per million (ppm) but today this annual average has increased to nearly 400ppm with peaks in excess of 400ppm having been recorded. The Commission for Integrated Transport in their advice to UK government back in 2007 concluded that the UK transport sector generates 28.4% of the country's carbon emission and of this 54% is produced by cars. At that time, transport was the only sector (in comparison with Industry, Energy Supply, etc) to have increased CO_2 emissions since 1990.



EU legislation now requires the CO_2 emissions to be achieved by 65% of new cars registered in the EU from 2012, from each manufacturer, not to exceed 130 grams per kilometre (g/km). A sliding scale of limits applies from 2012 to 2015 at which time 100% have to meet the 130 g/km value. The European Commission is looking at the feasibility of a 95g/km target by 2020. The historic trend in the UK since 1950 is shown in the graph above.

Today's average for all cars on the UK roads is around 164 g/km. For cars first registered in 2012 the average figure is 133.1 g/km. These compare very favourably with all cars on display in the Cotswold Motoring Museum. For example, the stylish 3.4 litre XK140 Jaguar was manufactured in 1956. In that year, there were around 3.4 million private cars on the UK roads in comparison to today's 29.08 million. The average annual mileage was less than 8000 miles per year[23] compared with a 2012 figure of around 8200 miles (an annual figure that has been falling since the mid-1990s as the number of cars per household has increased). Hence average CO_2 emissions of just under 300 g/km in 1956 (and the XK140 is undoubtedly above average) equates to a total equivalent CO_2 emission figure of 13 million tonnes in 1956 in comparison with 63 million tonnes[24] in 2012. Over the last 56 years the benefit of 'cleaner' cars has been more than offset by increased numbers and increased usage.

The UK Vehicle Certification Agency has a website to help car buyers make an informed decision on the CO_2 emissions of the vehicles that they intend to buy. However, no matter how efficient the design, cars propelled just by petrol or diesel will struggle to achieve levels of CO_2 much below about 80-90 g/km. One frequently proposed way to reduce CO_2 emissions from cars below this figure is to consider electric rather than internal combustion power: either stand-alone electric or as a hybrid with internal combustion. The rapidly evolving topic of Electric Vehicles forms a seperate chapter to this book.

Production and end-of-life

So far in this chapter, only the CO_2 produced during normal driving of the vehicle has been considered. If the overall CO_2 emitted during the manufacture of raw materials from which the vehicle is built, the vehicle build itself, fuel production and energy expended when the vehicle is scrapped is taken into account, then the additional effect on the CO_2 emissions over the vehicle life is significant. Work by the University of Technology, Finland in 2006 has quantified the CO_2 emissions for an average 2004 European light vehicle[25] over its life. If the CO_2 produced during manufacture of the vehicle and its fuel, distribution and end-of-life scrappage of the vehicle is taken into account, then over a car's 10 year life, the CO_2 per kilometre driven was calculated as 295g/km. If averaged over a 20 year life, this reduced to 265g/km. These compare with a 2004 average of 174g/km for UK cars in normal driving. Assuming the '2004 European light vehicle' of the Finnish study is roughly comparable with the average 2004 UK car population, then this implies the CO_2 created during production, distribution and when scrapped would account for approximately 34% of the CO_2 produced during a 20 year vehicle life.

[23] DfT statistics: 3.61 million vehicles covering a total of 46.2 billion kilometres
[24] The product of 164g/km, 8200 miles (13,197 km) and 29.02 million cars
[25] Assumptions: kerb weight 1290kg, travelling 8440 miles per year, fuel consumption of 38.7mpg. Data used is an average for new vehicles sold in 2004 and is based on >14 million cars and 1.8 million vans and pick-ups

The same university used data from nearly 5000 *global* vehicles (European and US markets) that are " … used as cars …" (this includes pick-ups and SUVs) and concludes that taking account of emissions of CO_2 during vehicle and fuel production, distribution and vehicle scrappage adds on average 54.7% to the normal operation figure. Restricting the analysis to just 2006 model year European cars, results in a one-off manufacturing contribution of around 35% of the lifetime average figure of CO_2 produced during normal vehicle operation (assuming a vehicle lifetime of 14.4 years and annual mileage of 8420 miles).

A more recent reference by Professor Julia King to an SMMT (Society of Motor Manufacturers and Traders) figure, quotes just 15%: 10% in manufacture and 5% in disposal. A higher figure is quoted by the ERTICO[26] who state "Fuel consumption during vehicle operation, for example, contributes to around 60% of the life-cycle greenhouse gas emissions of a passenger car"; leaving 40% down to manufacture and scrappage.

The differences between these sets of figures are not surprising since a lot will depend on the assumptions made. For example:

- was the energy used in the steel and other raw material production taken into account?
- was this derived from coal-burning power stations or from renewal energy sources?
- how consistent is the vehicle mix between the various studies?
- how old is the data? Production techniques have become more efficient in recent years.

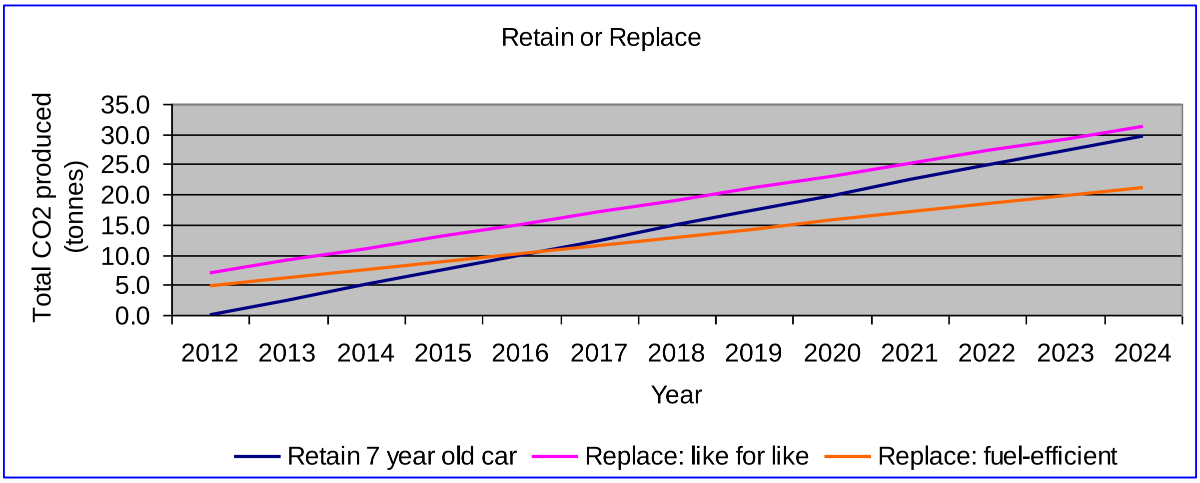
What is clear however is that the energy used and CO_2 released in the manufacture of the vehicle is significant in comparison with the CO_2 emissions throughout its life but becomes a diminishing proportion if that life is extended. Hence, from an environmental point of view, there is a strong argument for maintaining a car well beyond the average life of 7.9 years (in 2013: up from 6.6 in 2005).

The economics of modern vehicle ownership and maintenance however, do not encourage this approach.

Replace or retain

To quantify the conclusion stated above and to look at what happens if we decide to change the type of vehicle we drive, consider the case of an owner of a 2005 car contemplating replacing that car with a *similar* 2012 model. Consider the decision to be made solely from a CO_2 emission point of view, assume the owner travels 8900 miles each year and both the old car and potential replacement have average CO_2 for the year in which they were registered: namely, 173.1g/km for 2005 and 133.1g/km for 2012. For the older car, assume the one-off energy associated with manufacture, distribution and scrappage is 35% of the operational emissions over 14 years and that this reduces to 25% for the new car. How do the CO_2 budgets compare?

[26] An EU organisation devoted to Intelligent Transport Systems



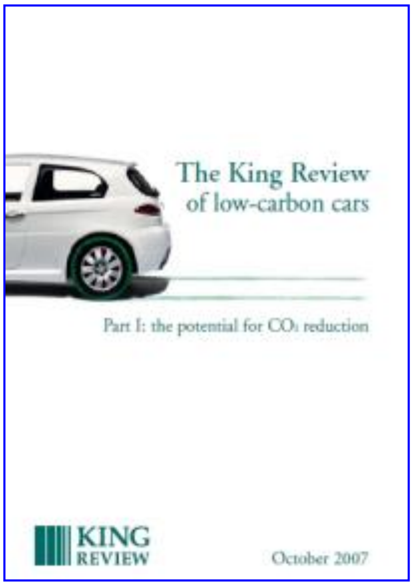
At the time of making the decision, the 7-year old car will have generated 29.6 tonnes of CO_2: 12.2 tonnes in manufacture and 17.4 tonnes in 7 years of use. If it is given a further 7 years of life, the additional CO_2 contribution will be a further 17.4 tonnes by 2019. If a newer car is chosen, then, after 7 years it will have generated 22.4 tonnes of CO_2: 7.5 tonnes in manufacture and 14.9 tonnes in 7 years of use. In this example, both cars would need to be kept running for over 10 years before the total CO_2 budget of the newer car fell below that of the older car. However, if one of the most fuel-efficient 2012 cars was chosen, producing less than 95g/km, then the decision would be justified, on CO_2 emission grounds, in less than 5 years. The graph above illustrates, for these three examples, the effect that the customer's choice can have on their CO_2 motoring emissions.

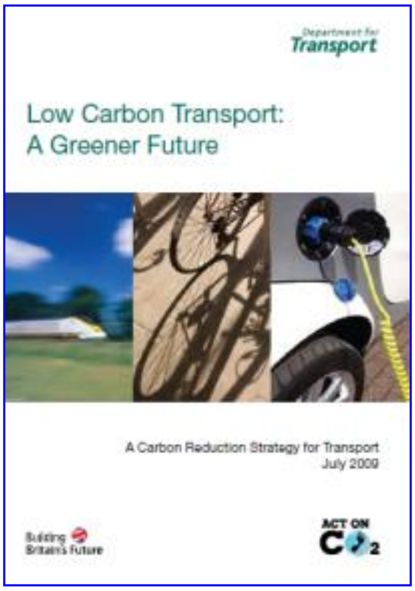
In summary, apportioning the up-front energy used in vehicle production and distribution, plus the energy used during scrapping the vehicle, over as long a life as possible, especially for low mileage, well-maintained cars, can make more environmental sense than scrapping and replacing the vehicle. On the other hand, a small, efficient modern vehicle replacing one of average emissions performance from 7 years ago, covering high annual mileage, can provide an emissions benefit within the following few years.

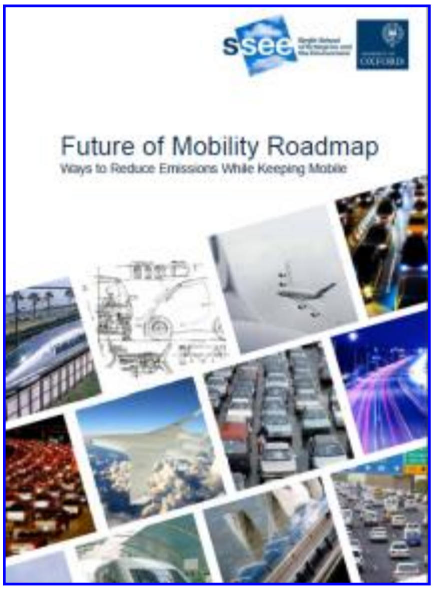
Further information

For further information on the future of low carbon cars, five recent documents are particularly relevant.

A report produced for the UK government and published in April 2009 addressed Ultra-Low Carbon Vehicles in the UK. It envisages a technical evolution from ever more efficient internal combustion engines, through hybrid to mass-market electric vehicles and ultimately to hydrogen powered vehicles in which energy is produced by fuel cells and the only bi-product of the process is water. A similar trend towards hydrogen-powered vehicles by 2050 is outlined by Prof Julia King in a two-part review of the potential for low carbon cars and recommendations for action. This also addresses overall CO_2 emissions associated with running the vehicle, its production and the extraction and processing of materials used in construction: sometimes referred to as the 'Well-to-Wheels' energy use. A July 2009 Department for Transport publication, "Low Carbon Transport: A Greener Future" sets out a strategy, statistics and targets for reducing CO_2 emissions within the UK and global transport sector. Finally, in January 2010, a report by the University of Oxford entitled "Future of Mobility Roadmap – ways to reduce emissions while keeping mobile" addresses the diminishing supply of fossil fuel and increasing greenhouse gas emissions across the transport sector.







Picture Captions and Credits

Page 27: From the Greenpeace website
Page 27: Earthrise taken by Apollo 8 crew, December 1968. © NASA
Page 29: Diagnostic Connector J1962 specification. Mandatory on all cars sold in the EU
Page 30: Jaguar XK140 at Cotswold Motor Museum, Bourton-on-the-Water, Gloucestershire.

Is technology the route to lower usage?

Driving into an unfamiliar town, setting off on a route that we have not travelled before, avoiding

road closures with enforced detours; these are all perfect opportunities to become lost and incur additional mileage. Car drivers who are lost or stuck in congestion are clearly using more fuel than if they were to complete their journey by the optimum route and without being held up. This in turn results in a potentially avoidable addition to the vehicle's exhaust emissions during the journey. This chapter describes how driver information technology has developed to support services aimed at reliable route guidance and congestion avoidance. In addition, can we improve the management of our roads to reduce congestion? Is road charging part of the solution? What steps are open to us as drivers to achieve lower usage and are they worth the effort?

Introduction

Given that there will always be journeys that need to be undertaken by car, then knowledge of the optimum route and prevailing traffic conditions are key to minimising our travelling time and / or distance. If the route is an unfamiliar route, then basic knowledge such as our starting and finishing point are quite important as well. Whilst mapping and in-car satnav are the subject of separate chapters, the dynamic information on road traffic conditions that can be used to make our journeys less stressful and more environmentally friendly are addressed in this chapter. A summary of advice from national motoring organisations on how best to ensure we arrive at our destination by the optimum route and with the minimum of congestion, concludes the chapter.

Traffic Information

Satellite navigation technology can help us when we are lost, or can help us avoid becoming lost in the first place, and hence should help us to minimise unnecessary mileage on our journeys. Traffic information technology is aimed at helping us to avoid congestion. We may listen to traffic news before setting off on our journey or keep up-to-date en-route via the car radio. Visual indications of congestion are available on our PC or portable device and may be on display in some motorway service areas. Increasingly though, as described in the satnav chapter, the information is used to influence the route displayed, in-car, by our satnav device or satnav application on a portable device.

Gathering the data

Inductive Loop detectors and CCTV are the most common types of technology employed by the Highways Agency to detect congestion on the motorway and trunk road network. The number of vehicles per minute crossing a loop detector on a motorway is used, together with variable speed limit signs, to reduce traffic speed and smooth the vehicle flow rate, as congestion increases. The lifetime costs of loop detection can be high and the need to close the carriageway whilst work takes place is also not ideal. Consequently, other less disruptive techniques are being investigated and developed.

Watching a map display screen, overlaid with the track of a vehicle fitted with a GPS receiver as it reports its position at regular intervals, enables a visual indication of the speed of the vehicle. Widely spaced locations along the road network indicate unimpeded progress; a cluster of points along the road indicates a slowly moving or stationary vehicle. This is the principle behind the use of Floating Vehicle Data (FVD) to provide information about traffic congestion. Piloted in the UK by ITIS Holdings (now owned by INRIX), the use of FVD is the basis of the traffic information that INRIX provide to such customers as broadcasting organisations and the Highways Agency. Information providers such as INRIX typically have partnerships with vehicle fleet operators and mobile phone network operators. The GPS equipped fleet vehicles provide their location information to enable both real-time and historic congestion data to be derived. The back-office software has to be 'smart' enough to recognise when a vehicle is intentionally stationary and when it is stationary because of congestion. In addition to using GPS locations, mobile phone locations are also used, anonymously, to provide FVD. Although not as accurate as GPS locations, they are far more numerous. Working with a mobile phone network operator benefits the operator by increasing the usefulness of data already available in their network and provides an additional service to their customers.

Trafficmaster was founded in 1988. It started to gather data on traffic speeds on the UK motorway network using speed sensors mounted over each carriageway of the motorway. Over the years, cameras on both motorway and trunk roads have replaced these speed sensors. The blue camera system is based on automatic number plate recognition. A coded tag derived from the vehicle number plate is used to identify vehicles travelling between cameras and hence to calculate the average speed. The congestion data derived from these sensors is displayed on the Trafficmaster website and is supplied to broadcasters, car manufacturers, route-planning applications, telephone services and in-car devices.

Using the data

One widely used and standardised method of coding traffic congestion data into a form that is useful for an end user has been through the development of RDS-TMC: Radio Data System-Traffic Message Channel. The original development work took place under an EU programme and, although now rather dated, the detail of RDS-TMC is well described in this link.

RDS-TMC is based on a coding process for events (ie congestion and its cause; ice, snow, accident, etc) and locations. Assuming the same coding and decoding protocols are used by the originator of the traffic message and the end user (ie the driver), a simple code can be transmitted via an RDS-TMC broadcast. The radio receiver in the car then only needs to de-code the incoming data in order to reconstruct the original message. For this to work reliably the receiver must always have an up-to-date copy of the code database. However, there is one big advantage: namely, it is language independent. UK drivers travelling through mainland Europe can continue to receive traffic information in English from RDS-TMC broadcasts in the countries through which they are travelling. The language benefit of RDS-TMC is clearly important if the traffic event is described in text on a vehicle display but, much more commonly, it is used to update the satnav's recommended route; a process that may even occur without the driver being aware.

Although Event Codes are standardised, clearly Location Codes are country specific. Hence, for the coded location of the traffic event to be compatible with the driver's satnav, the unique link identifiers used in the digital mapping database must be assigned the same Location Code by the originator of the traffic message and the supplier of the satnav map data. Since there is more than one RDS-TMC provider in UK and there is more than one digital mapping data provider to the satnav manufacturers, this can lead to some incompatibility.

Distributing the information

The RDS-TMC data is transmitted with FM and digital radio broadcasts as well as via mobile phone networks.

Many FM radio broadcasts carry the RDS-TMC data on a sub-carrier of the broadcast channel: this means that it is inaudible to the listener. From a driver perspective, probably the most effective way to benefit from RDS-TMC traffic information is to use a navigation system with this feature incorporated. Many manufacturers offer this as an option with new vehicles but it is also possible to use RDS-TMC with several of the portable, after-market satnavs. These may require a separate FM radio receiver, dedicated to picking up the RDS-TMC broadcast, with a data link to the satnav.

Traffic information, in RDS-TMC format, is also distributed over the mobile phone packet data network (GPRS) to in-car satnav equipment. This can be either via an integral SIM card in the satnav or via a Bluetooth link from a phone to the satnav. In the case of a smartphone, the navigation device and the phone may be the same piece of hardware!

No matter how the information is delivered to the satnav device, the effect of congestion on a link(s) is to increase the impedance of that link(s) so that the satnav will conclude that a faster journey is possible through a change of route and, either automatically or with a prompt from the driver, will calculate a new route.

From around the mid-90s until 2011, relatively low cost, in-car devices were available that received traffic information about a motorway and the neighbouring trunk road network from short-range radio transmitters alongside the road. Alerts typically occurred within a radius of one or two junctions on an urban motorway and information was conveyed to the driver by either coloured lights or a voice prompt. These devices and their associated networks are no longer supported.

Over a similar period, Trafficmaster provided national traffic information coverage to a customer's in-car unit. In this instance, a 4", monochrome LCD screen displayed a map of the UK road network at multiple levels of zoom. On this map were superimposed icons showing those locations at which the TrafficMaster sensor network had detected traffic speeds of 25mph or less. The driver's own location was not displayed on the screen: there was no GPS within the unit. It was designed purely as an information tool to enable the driver to spot congestion on their planned route and to re-route around the congestion if desired. Information was conveyed to the unit via the Vodafone paging network.

The cost of 'Lost'

Having considered the technology available to help a driver find their destination with the minimum of delay, it is appropriate to look at the cost-benefit of guidance and information technology. Is it possible to quantify the cost, in terms of pounds spent on wasted fuel and emissions, associated with lost drivers? Is reliable data available to enable a realistic estimate to be made of wasted fuel and associated additional CO_2 emission because of drivers losing their way or being forced into unplanned diversions? The Annex to this chapter shows the spreadsheet used to estimate this figure.

Department for Transport (DfT) statistics provide a reliable source for some of the required data. The average annual mileage covered by drivers of company cars and private cars is available from the DfT website and this is subdivided into usage categories of Business, Commuting and Private. In addition, the number of company and private cars is known from the same source.

In terms of arriving at a figure for the average CO_2 output from the company car and the private car, a reasonable assumption may be to take the figure for a typical company car: for example, a 2012, 2 litre diesel-engine Ford Mondeo (140PS) Automatic Estate. The UK average of CO_2 per km of all cars, taken from the 2013 SMMT report on CO_2, is the basis of the private motorist's figure.

The lowest quality data (not much more than an intelligent guess) comes from estimates of the frequency with which drivers become lost and the impact of the departure from the planned route on addition mileage. It may be 'reasonable' to assume that, due to increased familiarity, the company car driver becomes lost less frequently than the private car driver on business journeys and that when commuting, the occasions when additional mileage is incurred is no more than two journeys per year (0.4%) for both groups of drivers: for example, through a road closure. It has been assumed that in becoming lost an additional mile is added to a 20 mile journey ie a 5% increase. These however are just guesses and as such will reflect on the validity of any result derived from their use. The spreadsheet used to calculate an estimate of annual excess CO_2 and increased fuel costs as a consequence of becoming lost, shows colour coding used to represent the quality of the data: red, amber and green.

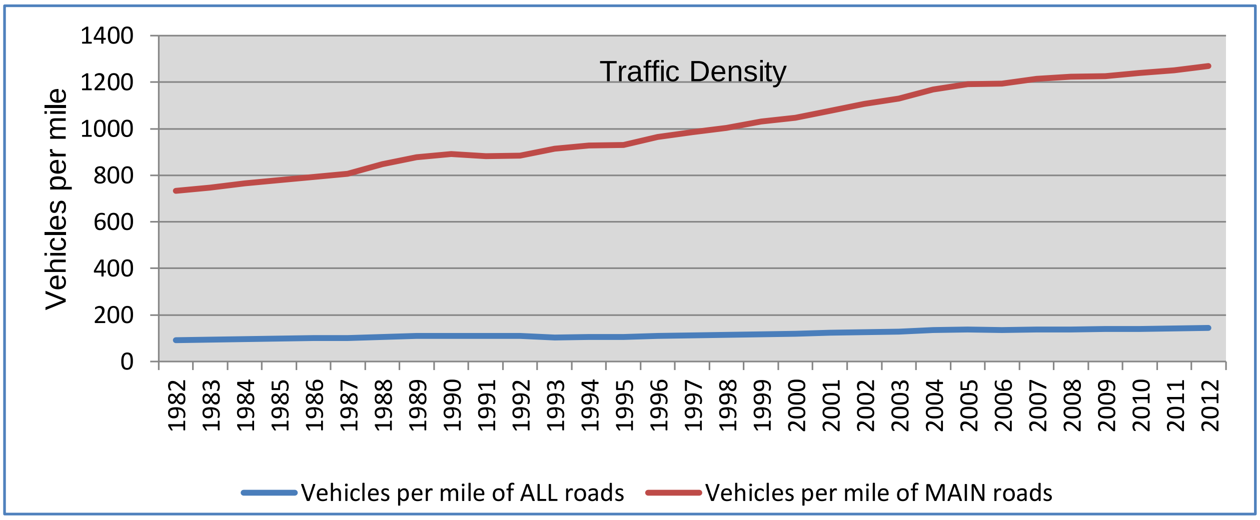
Making what appear to be 'reasonable' assumptions about the frequency and impact of drivers departing by accident from their planned route, the annual, avoidable increased fuel cost is around £30 million whilst the increase in CO_2 is over 46,000 tonnes or around 0.07% of the 63 million tonnes[27] CO_2 generated annually by all cars in the UK. For comparison, this is of the same order of magnitude as the CO_2 output of 6,200 UK families in one year. Note however, that this figure is just based on the UK's car population and excludes the effect of lorries, vans and public transport. According to the Commission for Integrated Transport, (before it was abolished!) cars are responsible for 54% of all UK transport sector CO_2 emissions whilst lorries, vans and buses account for a further 38%. Simply scaling the lost driver figure for cars, suggests that at least a further 33,000 tonnes of CO_2 may result from other road transport.

[27] The product of 164 g/km, 8200 average mileage and 29.2 million cars

Congestion

Many of the roads on which we travel today owe their origins to some of the early animal tracks mentioned in the satnav chapter of this book. They were later used by drovers and then developed for wheeled, animal drawn carts and marching Roman legions[28]. In the UK, some of the earliest roads are based on Ridgeways dating from between 5000BC and 2000BC. Those that survive include the Hogs Back in Surrey and parts of the Pilgrims Way over the North Downs. Trade routes developed on these Ridgeways: one example being the old salt road from Droitwich to the River Severn cutting through the Malvern Hills at the Wyche Cutting[29]. (Wyche or Wich – as in Nantwich and Droitwich - meaning salt in old English).

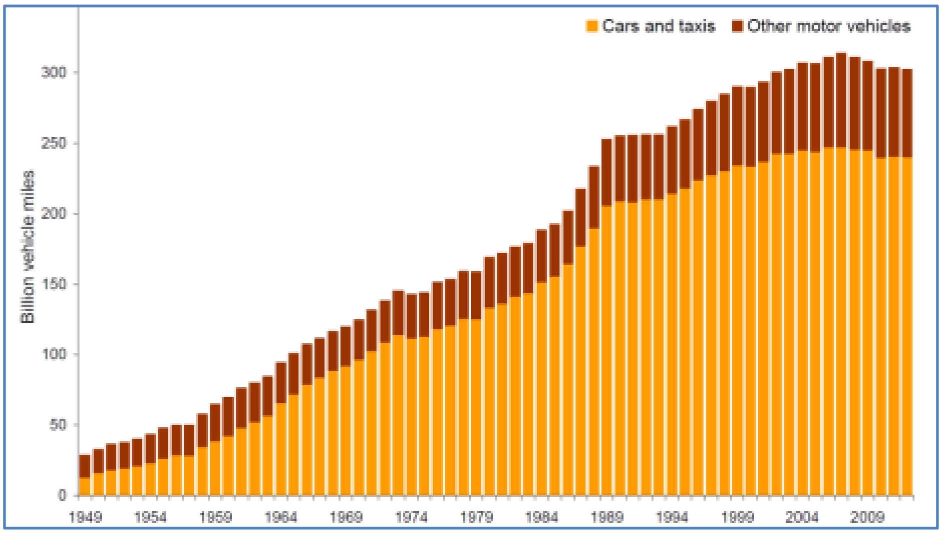
Today, there are over 31,300 miles of motorways, trunk roads and other primary 'A' roads and, in total, over 245,370 miles of driveable roads of all categories in the UK. This sounds plenty to avoid ever seeing another vehicle! However, given that, in September 2013, there were approximately 29.2 million cars and 6 million other licensed (and license exempt) vehicles in the UK, the trend



in the ratio of vehicles per mile of road, as shown in the graph, is quite clear.

It is of little consolation that the Department for Transport (DfT), "Annual Road Traffic Estimates 2012", states that:

"In the last ten years, traffic volumes for all vehicle types have decreased (eg, cars and taxis: -1.0%; HGVs: -11.6%) except for LGVs which have increased by over a fifth (21.5%)."



The graph alongside shows these recent

[28] "Roads and Tracks of Britain" by Christopher Taylor
[29] "Ways of the World – A History of the World's Roads and of the Vehicles That Used Them" by M G Lay

falls in the context of earlier decades of rapid increases in vehicle usage. Two points to note from these graphs and the DfT 2012 Estimates:

a. the increase in LGVs coincides, of course, with a decade of rapid growth in internet shopping

b. the first graph shows the number of vehicles per mile of road increasing annually while the second shows that the annual mileage per vehicle must be decreasing: a point addressed in the chapter on “Responsibilities of Ownership”.

Assuming these recent trends to be the short-term effect of an economic downturn and a couple of particularly harsh winters, the issue of how to manage and ideally reduce congestion is a question that is likely to continue to be highly relevant.

Measures to reduce congestion – the road network

Over the last two decades, much effort has been devoted to the study of traffic management with the aim of reducing congestion. Within Europe, the EU DRIVE project (1988) provided an impetus to work on applying Information Technology to the improvement of road safety and the reduction of environmental pollution caused by road traffic.

Smoothing the flow

A publication from the University of California at Riverside contains the results of a study and computer modelling of measures to mitigate the effect of congestion on CO_2 emissions. It measured the range of speeds on a motorway and compared these with levels of congestion. As congestion increased, so the *range* of speeds increased: on a clear motorway speeds from 47mph to 75mph were recorded; on a congested motorway this range widened to zero to 50mph. As CO_2 emissions rise with increased acceleration and deceleration, so the congested motorway scenario produced more CO_2 than a smoothly flowing scenario. The aim of the mitigating measures was therefore to achieve a smooth flow of traffic within a narrow band of speeds. Recommendations made to achieve this objective were:

- Manage congestion on the motorway through measures such as ramp metering – something that is now appearing on UK motorway entry slip roads in some urban areas eg M6 J10S – and better incident management eg Highways Agency Traffic Officers
- Variable speed limits to reduce ‘bunching’ and hence the amount of acceleration / deceleration – a feature on parts of the M1, M25, M6 and M42
- Variable speed limits to reduce excessive speeds

The ‘bottom line’ to the study was that “ ….. each of the three methods above could potentially lower CO_2 by 7-12%”.

The point that free-flowing traffic is essential to minimise CO_2 is made by the International Road Transport Union (IRU) with their headline about a 40 tonne lorry travelling at 30mph. If it stops twice per kilometre (due to congestion) the CO_2 emissions increase by 300% in comparison with maintaining a steady 30mph.

In the UK we have also seen the extension of hard-shoulder running that was first implemented on a section of the M42. This effectively creates an additional motorway lane at times of peak traffic flow and is part of an overall Active Traffic Management (ATM) scheme. Results from the initial M42 ATM were encouraging with an extra capacity provided by hard-shoulder running of 7% to 9%, an extra 7% of users reporting no congestion on their journey and between 4% and 10% reduction in vehicle emissions.

Road pricing

Road pricing has been proposed as one candidate to reduce congestion. In the UK, the first large-scale scheme was the London Congestion Charge introduced in February 2003. On the first anniversary of the introduction of the charge, the then Mayor of London, stated that:

" …..traffic had been cut by 18% and delays were down 30%".

However, subsequent Transport for London publications have updated that early conclusion:

"Sadly, congestion has risen back to pre-charging levels but would be much worse without the charge"

In summary, London road pricing did provide a short-term benefit in easing congestion but other factors are, and will continue, to cancel out the initial gain.

In Stockholm a congestion charge was introduced in January 2006 and traffic is down by 18% and CO_2 emissions in the inner city have been cut by between 14% and 18% or 25,000 tonnes annually.

In June 2005 the then UK Transport Secretary, Alastair Darling, admitted that changes to road transport policy were needed to prevent complete gridlock, and unveiled proposals to replace fuel tax and possibly road tax with a satellite-operated, distance-based road charging system which would cost motorists up to £1.30 a mile to use the roads. In 2008 however, this proposal for a UK national road-pricing scheme was ruled out by the government in favour of extending hard shoulder running to more motorways and possibly using the extra capacity created for high occupancy vehicles or a tolled lane.

Measures to reduce congestion – the driver

A list of steps, that we as individuals can take, to minimise our risk of delay is in the Conclusions section to this chapter. A couple of measures however, are worth expanding here.

As well as being intuitively self-evident, a number of studies have demonstrated that a smooth, safe driving style is one that results in good fuel efficiency. To encourage such behaviour in fleet drivers, some organisations are fitting driver monitoring equipment to fleets of vehicles. This monitors, location, harsh acceleration and deceleration and other business-specific parameters. Used constructively, so that they are not perceived as a 'big brother', these measures can help to encourage fleet drivers to adopt an economical driving style.

Humans in general are very tolerant. We largely accept the inconvenience, delay and frustration that accompany traffic congestion as an inevitable part of life. However, such acceptance is likely to have its limits. The improvement of fixed and mobile broadband and the beneficial economics of 'hot-desking' in the office have helped to bring about a change in some working practices over the last decade. It is now easier to work from home, to video-conference ('Skype'), to arrange meetings at motorway service areas, conference centres and other out-of-town locations whilst still having access to corporate IT systems and the internet. A consequence of this is going to be less traffic on the busiest roads at peak times. Are we saying, “enough is enough” and taking a solution to congestion into our own hands? Is this part of the reason that the DfT figures for congestion are showing an unprecedented fall or is it just the present economic climate? All may become clearer in the next decade!

The cost of congestion

The DfT has estimated the financial cost of congestion to the country: *“Congestion poses a very real long-term economic threat. If left unchecked it could cost us an extra £22 billion a year in wasted time by 2025, in England alone*.”

An overall figure for the incremental CO_2 produced because of vehicle congestion is not easy to find in published literature. In response to a 2001 Freedom of Information request, the Highways Agency estimated a reduction of 32,000 tonnes per year as a consequence of tolling the Dartford Crossing – in comparison with the ‘no toll barrier’ scenario that now prevails. However, with this rather dated figure and those for reductions in CO_2 from the Stockholm and London congestion charges, there must be a suspicion that these ‘savings’ are actually partly offset by drivers taking alternative, un-tolled or uncharged routes. Admittedly, very difficult to quantify.

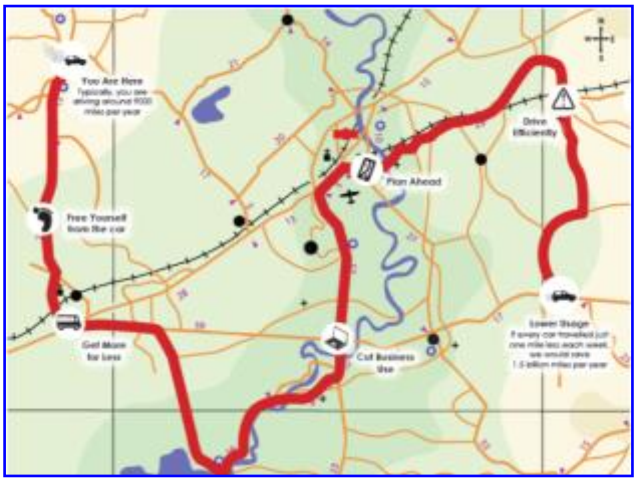
As a ‘sanity check’ on the previous estimates of CO_2 produced through becoming lost and through vehicle congestion, it is interesting to compare figures with the environmental statement from the Teletrac website, namely:

“*Teletrac is currently saving 28 million gallons of fuel and 280,000 tonnes* of *CO_2 annually by encouraging smarter driving. Combining intelligent navigation and fleet management, we have the power to cut average fuel consumption by 28% and driving time by a third (32%)”.*

So, in summary, recognising that the 46,000 tonnes of CO_2, estimated as a consequence of car drivers becoming lost, 33,000 tonnes from other lost road users, individual figures of 32,000 tonnes as ‘savings’ through *reducing* congestion at the Dartford crossing, then Teletrac’s annual figure of 280,000 tonnes suggests that the estimates are consistent and of the correct order of magnitude.

Conclusion

From a review of technology available to help us on our car journeys (satnav is addressed in a later chapter of this book), it could appear that if we embraced all of this technology, then we should never become lost or encounter congestion. (Arguably, with a satnav we should never be actually *lost*, even though we may not be in the place that we intended). Sadly though, it seems unlikely that technology is the sole answer to these two characteristics of modern motoring.



This chapter has shown that, making ‘realistic’ assumptions, there are significant additional contributions to the environmental CO_2 that are produced as a consequence of drivers becoming lost or held up in congestion during their journeys. In mitigation, what can be done? What is the elusive “Route to Lower Usage”?

All of the main motoring organisations have advice to offer and the following summary has been compiled from the websites of: AA, Britannia Rescue, Green Flag and RAC.

- Journey preparation is crucial. Use either up-to-date paper or website maps
- Ensure the satnav maps are up-to-date
- If using in-car navigation, ensure batteries are charged and that the charger is available and working
- Don't assume the satnav knows best. Even if using an updated Satnav, be careful not to follow it blindly. Use common sense, and if in doubt about the route being offered, turn around and try another one
- Keep an up-to-date map in the car as back-up, just in case

Avoidance of congestion is perhaps less under the direct control of the car driver. The random nature of traffic accidents and other incidents causing a tail back means that avoidance of congestion includes a strong element of luck. However, some mitigation steps are possible, for example:

- Travel outside of peak times if possible. This can help to reduce the stress of the journey as well as the risk of delays
- Check for Traffic Information on the intended route using local radio or websites such as the Highways Agency or TrafficMaster
- Check the Traffic Information features of the satnav (if included)
- Check the Traffic Information available through the mobile phone eg dial 1740 (59p per minute)
- For regular routes eg commuting, rehearse alternative routes and diversions for the day when the main route is closed or congested
- When in heavy traffic, drive smoothly: avoid acceleration and sudden braking, not only does this reduce fuel consumption it helps towards a steady flow of the traffic
- Consider car sharing
- Consider splitting the journey before congestion starts eg Park and Ride
- Consider alternative modes of transport for the entire journey
- Consider avoiding some journeys eg work from home some days, use video / audio conferencing

As illustrated in the earlier DfT chart, reducing usage is happening today in the UK. Whether this is a temporary blip, following an economic downturn, or the start of a longer-term trend, remains to be seen.

Annex: An estimate of the CO_2 'cost' and financial cost of becoming lost on our journey

		Company Cars (Type of Journey)			Private Cars (Type of Journey)		
		Business	Commuting	Private	Business	Commuting	Private
Average annual mileage (2012)		7600	7100	4600	600	2500	4700
Probability of becoming lost / enforced detour		1.5%	0.4%	2.0%	2.0%	0.4%	2.0%
Effect on journey length of becoming lost - incremental journey distance		5.0%	5.0%	5.0%	5.0%	5.0%	5.0%
Company cars on UK roads in 2012	2,376,600						
Privately owned cars on UK roads in 2012	25,701,121						
Annual incremental mileages when lost (millions of miles)		13.55	3.37	10.93	15.42	12.85	120.80
Average CO2 in g/km for company cars	149						
Average CO2 in g/km for private cars	164						
Annual incremental CO2 as a consequence of becoming lost (tonnes)		3,248	809	2,622	4,070	3,392	31,882

Annual Cost	£30.187	million	Annual CO2	46,023	tonnes

DfT National Travel Survey September 2012 Table NTS0901	https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/243957/nts2012-01.pdf
Statistical Data Sets Cars (VEH02) Table VEH 0202	https://www.gov.uk/government/statistical-data-sets/veh02-licensed-cars
VCA (part of DfT)	http://carfueldata.dft.gov.uk/search-new-or-used-cars.aspx
SMMT New Car CO2 Report 2013	http://www.smmt.co.uk/co2report/

Picture Captions and Credits

Page 34: Variable Message Sign
http://webarchive.nationalarchives.gov.uk/20120801131740/http:/www.highways.gov.uk/knowledge/334.aspx
Page 35: Traffic Information displayed in a 2013 VW Beetle
Page 36: TomTom RDS-TMC Traffic Receiver - TMC module for GPS receiver
Page 36: TrafficMate, TrafficMaster Freeway, RAC Traffic Alert 1210
Page 36: TrafficMaster YQ2
Page 38: © John V Nicholls, www.geograph.org.uk/photo/83470
Page 39: Active Traffic Management signage.
http://webarchive.nationalarchives.gov.uk/20120801131740/http:/www.highways.gov.uk/knowledge/334.aspx
Page 41: The Route to Lower Usage display, Cotswold Motor Museum, Bourton on the Water

The Cotswold Motoring Museum and Toy Collection is not just about cars. Toys that our parents and grandparents played with as children, everyday artefacts from the Victorian and Edwardian era plus an insight into the social history of the village of Bourton-on-the-Water and much more can be found in the Old Mill, alongside the River Windrush.