School of Engineering and Built Environment

Energy Resources, Generation and Utilisation

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Task Exercise No: 9

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Section 9: Saving energy: transportation

Transportation consumes a lot of energy, but is not easy to curb energy use for transport or to develop ways of moving on from fossil fuels. People value the freedom of private transport and find it difficult to reduce their dependence and embrace public transportation instead. We will consider the energy used moving freight and goods, and whether engines can be made more efficient, or modified to work on different principles that are less energy wasteful.

Personal transportation

Road transport uses 20% of the energy consumed in the UK, but, because of a long chain of overheads and inefficiencies, only a few percent of the primary energy, the total energy contained in the fuel consumed, ends up moving the actual 'payload'. There is clearly scope for a significant improvement in energy efficiency. However, many of the measures being proposed target personal transport and view the motor car merely in the context of mobility and fail to recognise the iconic role of the automobile in a modern consumer society. For this reason some of the actions being suggested to curb excessive use will tend to fail. Take car pooling, for example:

- Personal transportation is convenient, perhaps even essential, and a car is mainly purchased for the benefit of the individual or family.
- The car owner does not expect to be inconvenienced, and car sharing is no more (or less) feasible than house sharing.
- Cars maximise the use of time, and though it is recommended that short journeys be made on foot, valuable time is lost as a consequence.

The car is a potent symbol of freedom. Advertisements portray silent vehicles gliding along open roads and present the viewer with the glimpse of an enticing lifestyle, but the number of cars in the UK has steadily increased and the growth of the urban sprawl has made the typical real-life journey a slow-motion stop-start act of drudgery and reveals the notion of freedom as largely illusionary.

In spite of congestion, worldwide car sales are still rising. The growth in car use tends to proceed in explosive phases: the launching of the low cost Model- T Ford after WW1; the Volkswagen Beetle in Germany during WW2, the people's car; and now the projected massive sales in India and China as these economies continue to grow. It is possible this growth will continue unabated until the motor car is either too inconvenient or too expensive.

There is little that can be done to ease traffic congestion because the road system is essentially two-dimensional, and prioritising public transport by reserving network space makes the situation worse for the private car owner. Parking is an additional difficulty; 22% of the area in London and 44% in Los Angeles is set aside for parking.

The polluting gases produced by cars are already a problem and the problem is likely to increase. Can the world rely on increasing fuel costs to limit car use? Now in mid-2008 with fuel prices around $120 per barrel, and Nigeria and Mexico reaching peak oil, there is a hint of what is to come. Fuel prices are still not high enough to moderate demand, but the accepted rules of economics would suggest that prices will continue to rise until demand falls.

Task 9.1

Investigate by how much personal car use is taxed in the UK and compare to Sub-Saharan Africa.

Freight movement

Energy is consumed moving products and goods from manufacturer to consumer, convenient and unseen. And in an age of globalisation, the market for many products now spans the entire planet. Information technology in many ways helps mitigate the impact of carbon emissions and transport congestion, but also makes trade and communication cheaper and easier, sometimes with negative consequences. Using the internet, the customer can source products anywhere in the world at the best price. There is huge choice and the growth in demand means the movement of goods is increasing dramatically, and items are moving ever greater distances. A website like eBay is an effective mechanism for recycling and re-use, but the penalty is additional energy used moving goods about, more energy in some cases than was originally required in manufacture.

But only a fraction of goods will ever be 'mail order'. Food is moved about the UK in vast quantities, often in refrigerated containers, in order to offer maximum customer choice, but the centralisation and concentration of sales in supermarkets is also increasing our dependence on the motor car. Whilst supermarket chains are certainly driven by economic expediency in what is a very competitive sector, there is evidence of a desire to display corporate social responsibility.

Efforts are being made to reduce the environmental impact of food sales by broadening the supply chain, for example by sourcing locally from suppliers who do not necessarily offer the lower cost and uniform quality associated with mass production. The concept of **food miles** is applied as a measure of the carbon impact of different food types. In the UK, food transport accounts for 25% of all HGV vehicle kilometres in the UK, producing 20 million tonnes of CO_2 annually. Air freight produces 10 times the CO_2 per kilometre for the same quantity of food, but of course the consumer must make the choice to buy according to the lowest distance travelled if the presentation of food miles information on each product is to have any benefit.

Moving the same weight of goods an equal distance by rail rather than road is less environmentally damaging, with only one-fifth of the greenhouse gas emissions of lorries. Whilst sea and rail can only deliver between ports or stations, and not point-to-point, the universal adoption of containers means that transfer for the final road connections can be made with ease and should not be an impediment to greater use of rail and sea routes for freight movement.

In spite of the existing benefit of rail over road, there are still ways that rail can improve. More line electrification can increase efficiency and enable regenerative braking to be adopted: Instead of using friction to slow down the train (and producing unusable heat), the train is slowed by reversing the motor and allowing the forward momentum to generate electricity which is then transferred back onto the overhead line. Regenerative braking can save up to 20% of the energy consumed. Rail efficiency in general can be improved a further 20% by adopting such measures as switching off electric trains at night, matching train length to capacity, reduce idling, and weight and drag reduction.

If many more passenger and freight road journeys were to be displaced to the railways, the benefit would not necessarily include reduced road congestion; the number of cars on the road might merely expand to fill up the released capacity.

Task 9.2

How effective do you think a food mile labelling scheme might be?

Public transport

Huge reductions in energy use can be achieved by persuading the majority of the population to adopt public transport instead of private vehicles. An extensive, reliable, integrated public transport system with frequent services reaching all areas of every community is a necessity, but only a very basic infrastructure is established in the UK. However, even as it stands, the network is for the most part underused. In 2003, the average number of passengers on a bus was just nine. An underused public transport system merely adds to greenhouse gas emissions. Raising seat occupancy can be achieved by making public transport free, but the policy has the drawback of encouraging unnecessary journeys.

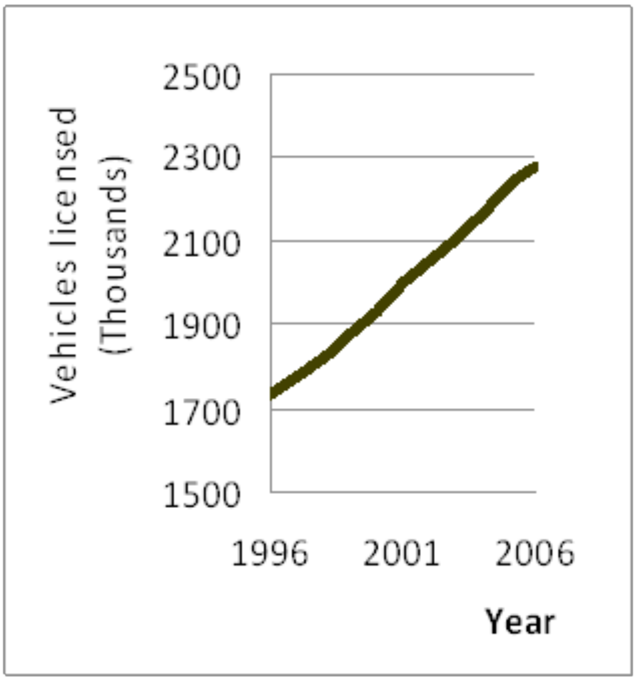
It should also be noted that hydrocarbon and transport taxation are an important source of revenue, bringing £32 billion into the Treasury in 2003. By significantly reducing car use, revenue would drop and the difference would have to be found elsewhere. It is no wonder that government often seems to pay no more than lip service to public transport.

In some cities a good public transportation system emerges as a necessity out of a chaotic road network, otherwise the cities could not function. London, one of the most congested cities in the world, has been voted as having the best public transport network of any city. Congestion alone is not the only factor that can drive public transportation; the usual 'carrot and stick' regulatory tools can also be applied. This includes economic penalties, initiatives and incentives, including variable pricing schemes to modify behaviour, but again, all with an eye on revenue alterations that might result.

It is obvious that a reasonably priced well-run public transport system must be in place before people will reduce car use, and there is little point in pressurising car users to adopt public transport until this is the case. However, in common with all other activities needed to reduce greenhouse gas emissions, there is a high initial capital cost in setting up a modern transit system that goes well beyond the basic infrastructure that currently exists. Nevertheless, public transport use can be increased by steadily improving the system and responding to the views of the travelling public.

The situation and trends in Scotland is reported in the December 2007 Scottish Transport Statistics. Fig. 9.2 shows how car use is steadily increasing whilst the number of bus journeys taken each year is more-or-less static (having fallen from just under 900 million journeys in 1975). The effect of the Scottish Government initiative to offer anyone over 60 free bus travel (and a number of free ferry journeys), which came into effect from 1st April 2006 will distort more recent statistics.

The number of rail journeys is increasing, largely because the journey time can be less than the same trip by road, and the degree of comfort is generally good. An expansion of the rail network is therefore the best way to significantly increase public transport use.



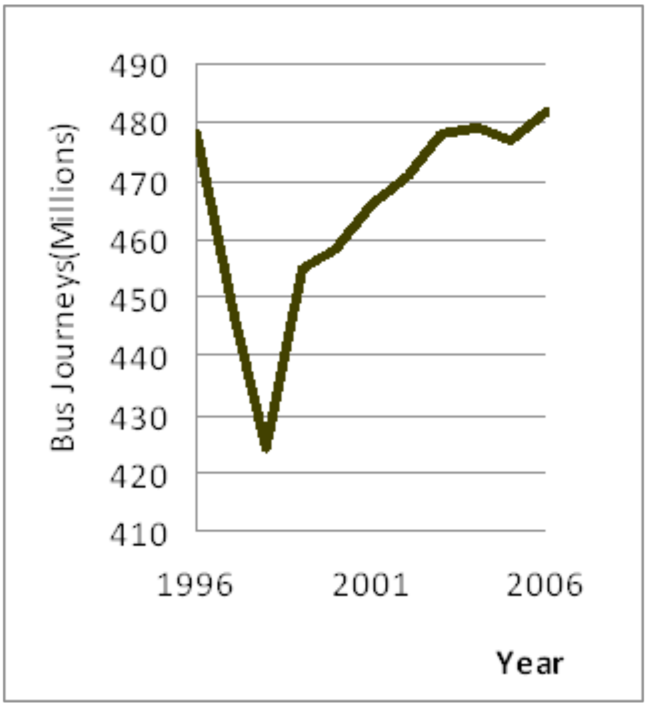


Figure 9.2: The transport statistics for Scotland between 1996 and 2006 show a relentless increase in car use, whilst bus use appears to be levelling off.

Task 9.3

A reasonable and fair level of fuel taxation is claimed to be the exact difference between the social cost and the private cost, where the levy then acts as a deterrent. Is taxation an effective deterrent in this case?

Engine and vehicle development

Given the difficulty in achieving any reduction in car use, an alternative approach is to make vehicles use fuel more efficiently. The combustion engine and even the form of the car itself can be modified in a number of ways to improve efficiency, and give a better miles per gallon (mpg) mileage performance (note that the imperial unit is preferable in this case to the SI unit - litres per kilometre - because it is a measure of car performance that everyone understands).

The reason why a vehicle consumes fuel is two-fold. As speed increases, the kinetic energy rises and this energy must be supplied by the engine. The kinetic energy is proportional to mass, hence a lighter, unloaded vehicle will use less fuel when accelerating (Fig. 9.4). Energy is also lost by a moving car through frictional contact with air molecules and through contact with the road. Fuel can be saved by making the car aerodynamic in shape to reduce the air turbulence that increases friction, and by keeping tyres at the correct pressure to reduce slippage.

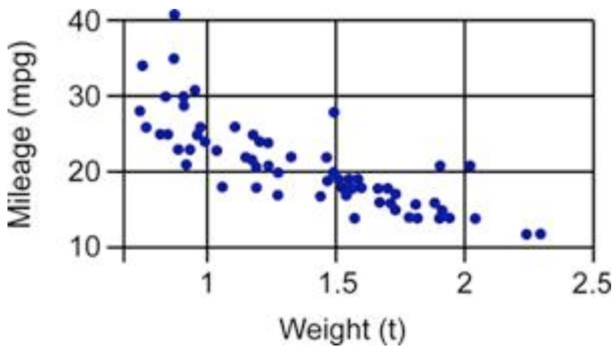


Figure 9.4: Mpg performance of a car is correlated with mass. Encouraging the use of smaller cars would reduce fuel consumption

Energy can also be saved by avoiding idling, i.e. keeping the engine running whilst disconnected from the drive system, by trying to keep the engine running at its optimal firing frequency, and by anticipating use of the brakes.

No matter what measures are taken, the thermodynamic operation of the internal combustion engine means that a maximum of 30% of the energy in the fuel can be converted to work. In contrast, an electric motor can convert electricity to kinetic energy with better than 90% efficiency. An electric vehicle would require sufficient battery storage to give an acceptable range on full charge of perhaps 300-400 miles. In spite of improved efficiency and the ability to use regenerative braking to recover energy, a lot of batteries are required. These are expensive and heavy, but battery technology is continuously improving.

Hybrid vehicles have an electric motor, but also use a conventional engine as backup. Power can also be generated onboard using stored hydrogen. A fuel cell can be very small and produce electricity with a theoretical efficiency approaching 90%, though in practice the efficiency is of the order of 55-60%. There is also the problem of storing the significant quantity of hydrogen gas required to ensure a reasonable range. In spite of these problems, this is a promising technology, not least because hydrogen can be produced from intermittent renewable sources and stored indefinitely. There are a number of hydrogen-powered vehicles available on the market, but the refuelling infrastructure is very limited.

The hydrogen car is termed a zero emission vehicle (ZEV), so long as the hydrogen is produced using a renewable source of electricity.

There is little doubt that changes in vehicles, or how they are used, is necessary - it is considered unacceptable to maintain the *status quo* using biofuels because of the environmental damage and rising food costs.

Task 9.4

Calculate the quantity and cost of batteries required to power a 0.5 tonne car for 300 miles. How long would the batteries take to charge, and at what cost?

Notes

Data logging
A data logger is an instrument that will capture data from sensors at regular intervals and store the information until required. They are generally small, battery powered, portable, and equipped with a microprocessor, internal memory for data storage, and programmed to accept a variety of standard sensors. Some data loggers are merely add-on peripheral devices that connect to a PC. These are usually cheaper, but are only suitable for laboratory measurement. A stand-alone device is required for environmental measurement, and these generally have a local interface device (keypad, LCD).

Data may be collected from a data logger and transferred to a PC for analysis through a wired RS232 link, an RF channel, a modem, or by physically taking the device to a PC and establishing a connection.

Data loggers are extremely useful for renewable energy applications. The climate at an intended site for renewable energy devices can be determined by long-term monitoring of wind, air temperature, sunlight, rainfall, and soil temperature. Water flow and wave height for planned hydro or wave power devices can also be measured.

Once renewable energy devices are installed and working, the performance of the complete system can be monitored to see if it behaves according to the original design.

Data loggers can have a long battery life because it is not necessary to take continuous measurements. Environmental parameters are fairly stable and it is normal to take only one measurement in an interval of between 10 seconds and 1 minute. Data acquisition takes around 1 millisecond, so the data logger goes into sleep mode (where very little power is consumed) until the next measurement.

A real-time clock (RTC) is used to generate an alarm that will wake up the system when a measurement is required.

Summary

We have seen that transportation uses a large fraction of the energy used in the world, but it generally uses only one type of fuel, oil, and uses it very inefficiently. There is a need to reduce oil consumption, and though cars are beginning to consume fuel more efficiently, the number of cars is increasing rapidly and there will be a situation where oil demand will exceed production, resulting in huge price rises. The crisis may be averted by alternative power mechanisms (electric vehicles) or by a shift to public transportation, but public networks are poorly developed at the moment.