Travel Analysis.

Greenhouse Gas Output per Passenger.

In order to compare the relative merits (or demerits) of the different forms of transport we need some common measure. The measure we use here is:-

"The equivalent miles per gallon of petrol per passenger, used at ground level."

we have chosen this measure because it is familiar to most people as the consumption of cars. However it requires some clarification because:-

1. The greenhouse gases emitted will include gases other than CO_2, nevertheless we use CO_2 as the fundamental measure and use this as the basis of calculations.
2. Air travel is special because the emission of greenhouse gases at altitude results in their having a much larger effect than the same emissions at ground level this is compensated for by applying a multiplier.
3. Means of transport have a limited life and energy and greenhouse gas emissions are involved in their manufacture and maintenance. Also in the production and maintenance of the transport infrastructure – roads, railways, airports, ports, etc. We ignore these in our basic calculations, but have something to say about these in "The Embodied Energy Analysis" below.

In essence then in the main sections below we are looking at the consequences of fuel consumption in producing greenhouse gases.

Means of transport produce various gases as well as CO_2 [these include a lot of water vapour, and some oxides of nitrogen, CO (carbon monoxide) and unburnt or part burned fuel]. Apart from water vapour these other gases are produced in small quantities and do not persist in the atmosphere for long. For all forms of surface transport they have quite small effects and can be accommodated by a small factor adjustment – however in the case of aircraft the factor is large. Most engines also produce particulates (smoke); the effects of smoke are to give us cancer and respiratory diseases, but also to contribute to haze in the atmosphere, and to help in the formation of clouds. They get washed out of the atmosphere by rain. To some extent the hazy atmosphere reduces global warming, however the vehicles are only one of the contributory factors and since for health reasons we need clean air, we set about trying to reduce this effect. So we will ignore it for our calculations.

Occupancy Figures.

Obviously the efficiency of a means of transport depends on the number of people using the vehicle/etc.

Cars.	For private cars the actual number of people can be factored in.
Taxis	In this case the driver is not counted, and it must be recognised in many cases the taxi may have to return empty, doubling the consumption.
Public Transport	Here the situation is much more complex because the numbers of passengers is very variable. From over-full (more passengers than seats, often on London Transport) to completely empty (on parts of some rural bus routes). We give figures for full and 50% occupancy.
Air Travel	Aircraft except for flights to pick up points generally fly at an average of 70% Occupancy for short flights and 80% for long haul flights.

Equivalent CO2 Emission Figures.

For analysis of ones carbon footprint and for comparison with other uses of energy we give the equivalent global warming effect in terms of CO2 emission per 100 miles per passenger.

The relationship is straight-forward, for petrol:-

1122 / Miles per gallon = kgs of CO_2 per 100miles

Note. Every 1 gallon of petrol used produces roughly 11.2 kgs of CO_2 equivalent.

Every 1 litre produces 2.47 kgs.

Diesel fuel is denser than petrol and it produces more CO_2 per gallon

The conversion factor is 1.15

976 / miles per gallon = kgs of CO_2

Diesel or Petrol or LPG.

The choice between diesel and petrol fuel for internal combustion engines is in our view weighted heavily on the side of diesel. It is true that diesel engines produce more particulates than petrol engines of comparable performance and that these constitute a hazard to human health. But the fuel consumption and CO_2 output figures for a diesel engine are considerably superior to those of a petrol engine of comparable performance (about 0.8) and given the seriousness of the global warming problem this far outweighs the health risk. (Indeed if one wants to be really ruthless about it a few less human beings will ease the global warming problem!)

Road Transport.

For all road transport the analysis is straight forward, since vehicle consumption figures are usually given in terms of miles per gallon. The only adjustment that needs to be made is the conversion of diesel figures to the figure for the equivalent amount of petrol.

1 gallon of diesel fuel produces more CO_2 than 1 gallon of petrol.

The following table shows fuel consumption and CO_2 equivalent emissions.

1. Mpg	2 M/litre	3 L/100mls	4 CO_2/100mls
10	2.2	45.5	112
15	3.3	30.3	75
20	4.4	22.8	56
25	5.5	18.2	45
30	6.6	15.2	37
40	8.8	11.4	28
50	11	9.1	23
60	13.2	7.6	19
70	15.4	6.5	16

1 = miles per gallon. 2 = miles per litre

3 = litres/100miles 4 = kgs CO_2/100miles.

In order to obtain miles per gallon per passenger we multiply the figures in column 1 by the number of passengers. To obtain CO2 per passenger we divide.

Cars.

Obviously there are big cars, small cars, cars with 2 seats, cars with 6 or 7 seats. For some common types of car the following are typical figures.

A Family Car.

Has 4 comfortably usable seats and does 35 mpg giving:-

For driver only	35 mpg/passenger	32 kgs of CO_2 per 100 miles
For 2 people	70 mpg/passenger	16 kgs
For 3 people	105 mpg/passenger	11 kgs
For 4 people	140 mpg/passenger	8 kgs
For 5 people	165 mpg/passenger	6.3 kgs

An Efficient Diesel Car.

Has four comfortable seats and should manage 55 mpg. adjusting for diesel gives:-

For driver only	48 mpg/passenger	23 kgs of CO_2 per 100 miles
For 2 people	96 mpg/passenger	12 kgs
For 3 people	144 mpg/passenger	8 kgs
For 4 people	192 mpg/passenger	6 kgs
For 5 people	240 mpg/passenger	4.6 kgs

A 2 Seat Luxury Sports Vehicle.

Has only 2 seats and might do as little as 18 mpg. Giving about:-

For driver only	18 mpg/passenger	62 kgs of CO_2 per 100 miles
For 2 people	36 mpg/passenger	31 kgs

Coaches Buses and Mini-buses.

These larger motor vehicles are one of the most efficient forms of travel, because of the large numbers of seats in a single vehicle, in general the bigger the vehicle the more efficient.

A Typical Mini-bus.

Has 14 seats and does 22 mpg petrol or 34 mpg if diesel giving:-

For 7 people	154 mpg/passenger	7.3 kgs
For 14 people	308 mpg/passenger	3.6 kgs

If diesel

For 7 people	208 mpg/passenger	5.4 kgs
For 14	415 mpg	2.7 kgs

A Typical Luxury Coach.

Has 50 seats and does about 12 mpg of diesel, gives:-

For 25 people	260 mpg/passenger	4.2 kgs
For 50 people	520 mpg/passenger	2.1 kgs

(Figures from Volvo coaches – Luxury coach 49 – 53 seats, 10-13 mpg)

Buses.

Come in all shapes and sizes but still typically achieve about 7 mpg for a double decker in town, to about 15 mpg for a small rural bus. What is critical is the number of passengers.

A full (50 passengers) London bus achieves about 400 mpg/passenger but more typically runs at about 140 mpg (for 20 passengers). An average sort of figure may well be about:-

Full double-decker	300 mpg	3.6 kgs
Half full	150 mpg	7.2 kgs.
Full small bus	400 mpg	2.8 kgs
Half full	200 mpg	5.6 kgs

Trains.

The travel efficiency figures for trains are quite surprising. It might be expected that trains would be super-efficient, because they run on smooth rails and have a small frontal area compared with the numbers of seats. In fact they are not super-efficient. Though this statement needs considerable qualification. The problems with trains arise from 2 factors.

Firstly, many trains are surprisingly heavy. Typical inter-city trains weigh about 1 ton per seat, this compares with about 0.3 tons per seat for a typical 4 seat car and about 0.2 tons per seat for a typical coach.

Secondly, fuel consumption per mile increases approximately linearly as the train goes faster; so, a train travelling at 120 mph uses about twice as much fuel per mile as a train travelling at 60 mph. Railways are progressively working towards making trains go faster the consequence is that their fuel consumption, and hence their CO_2 output, is tending to get worse.

Accepting both the above problems is not to say that trains are particularly inefficient, simply that some are not as efficient as might have been expected.

There is not a great difference in CO_2 efficiency between diesel and electric trains. Diesel trains output CO_2 directly – electric trains while clean at the train require electricity to be produced and this is a process which produces lots of CO_2.

Commuter Trains.

Are both lighter (more like 0.5 tons per seat) and not as fast (typically 45 mph) as inter-city trains in consequence their consumption and CO_2 output per seat is good, at:-

Full train	500 - 700 mpg	2.2 – 1.6 kgs of CO_2 .
Half full	250 – 350 mpg	4.4 – 3.2 kgs.

Inter-city Trains.

Suffer from the weight problem at about 0.9 to 1.2 tons per seat and go faster (perhaps 75 mph). This leads to higher CO_2 figures at about:-

Full train	300 – 400 mpg	3.5 – 2.5 kgs of CO_2.
Half full	150 – 200 mpg	7 – 5 kgs.

High Speed Trains.

Current designs of High Speed Trains pay the price of being both heavy and fast. In consequence they are worse than slower trains about:-

Full train	150 – 250 mpg	7 - 4.5 kgs of CO_2.
Half full	75 – 125	14 – 9 kgs

Light-Rail/Tram Systems.

On the other hand Light-rail and tram systems like the London Docklands light rail etc. Are both light and slow. They are super-efficient at about:-

Full system	700-1000 mpg	1.5 – 1 kgs of CO_2.
Half full	350-500 mpg	3 – 2 kgs

(Figures from Transport for London for Croydon Tram – 74 seats on tram but up to 240 including standing room –treat as 200 when full about 6.6 kwh per mile)

Planes.

Aircraft are the great bugbear as far as travel and global warming are concerned. This is because they encourage us to travel more and to travel long distances. Further in global warming terms they are a highly inefficient means of travel; ie they produce more global warming effect per seat than almost anything else. This inefficiency is however rather more complex than for the other means of travel. Aircraft are even initially quite inefficient in terms of fuel consumption and simple CO_2 output compared with other forms of transport.

The general picture of flying fits into the following scenario. Aircraft use quite large quantities of fuel for the take-off and climb, and for the descent and landing stages of a flight. The cruise phase in the middle is more economical. The average flight includes some manoeuvring distance, which may involve stacking, this is independent of the flight length. As a consequence of these factors short flights are considerably less fuel-efficient than long flights. More recent aircraft are more fuel-efficient than older aircraft, but there are considerable numbers of old aircraft flying (when you have paid £25 million for a plane you do not scrap it). Aircraft are configured with very different numbers of seats. Thus a Jumbo jet, which incidentally can be up to 20 years old, can have anything from about 300 to 550 seats. There is also the problem of seat occupancy. World wide the accepted figures are about 80% for long haul and 70% for short haul. Aircraft gas emissions at altitude have considerably more global warming effect than the same gasses emitted at ground level. The size of this effect is not yet understood very well and more research is on-going, current research shows that the effect is between about 2 times to 5 or more times - most calculations (and those below take a value of 3).

Taking all these factors into account gives the following figures for full planes:-

100 mile flights	8 mpg	140 kgs per passenger.
300 mile flights	14 mpg	80 kgs per passenger.
3000 mile flights	20 mpg	55 kgs per passenger

Really appalling figures, particularly in view of the long journeys which are typical.

Helicopters.

Helicopters are as in-efficient as planes. While they do not fly as fast as planes and do not fly at high altitudes they use a lot of energy simply to stay in the air. Fortunately they are not a common means of transport. Figures for helicopters are of the order of:-

Small (4 –6 seat) helicopters typically consume about 25 galls per hour and this figure is not very different whether the helicopter is hovering or cruising. Typically they cruise at about 120 mph. Giving:-

Small helicopters	20 - 30 mpg	60 - 40 kgs of CO_2 per seat.

The figures for bigger helicopters are worse rather than better.

Thus for a Chinook there are 44 seats and the cruising fuel consumption is about 350 galls/hr giving:-

Big helicopters 12 - 17 mpg per 90 – 65 kgs of CO_2.

The Embodied Energy Adjustments.

So far in analysing the problem we have concentrated only on the fuel consumption effects. But vehicles have to be manufactured, maintained and have a limited life. These processes of construction and maintenance use energy and produce CO_2. This energy is not negligible so we should adjust the figures to take account of it.

Our data in this area is somewhat sketchy at present (If you can improve it –please be in contact) but we give the best estimates we can.

Cars.

The average British car only does about 120,000 miles in its life. So, as we said in our main campaign leaflet, it produces about 50 tons of CO_2 during its life. Its manufacture and maintenance involves energy that amounts to about 16 tons of CO_2. Therefore for a typical car its raw fuel costs should be increased by about 30% to take account of this energy.

It is true that car re-cycling has improved considerably in recent years. Also that cars are perhaps lasting longer and covering more miles before being scrapped, but for the time being these are the best estimates we can come up with.

Other Vehicles.

Our data on these is even more tentative, nevertheless……. . Public transport vehicles do vastly more miles within their service lives. Figures are much more in the region of 1-2 million miles than the 120,000 of private vehicles. Further in terms of overall complexity per seat they are much lower (there is only 1 set of steering gear or braking system for the 50 seats of a coach compared with the typical 4 seats of a car).

The embodied energy component for trams, buses, trains etc. is, for these reasons, much lower than for the private car. We are using a figure of 5%, though this is insecure (perhaps in the range 2-8%).

Aircraft have the same features as public transport vehicles. But they clock up huge mileages 20-50 million miles. Equally they are very complex and require rigorous and extensive maintenance. We apply a figure of 10% to them.

These adjustments appear as column 3 in table in the Travel Facts and Our Advice section.

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