THE ImpEE PROJECT
IMPROVING ENGINEERING EDUCATION

Road Transport

The Cambridge-MIT Institute

UNIVERSITY OF CAMBRIDGE

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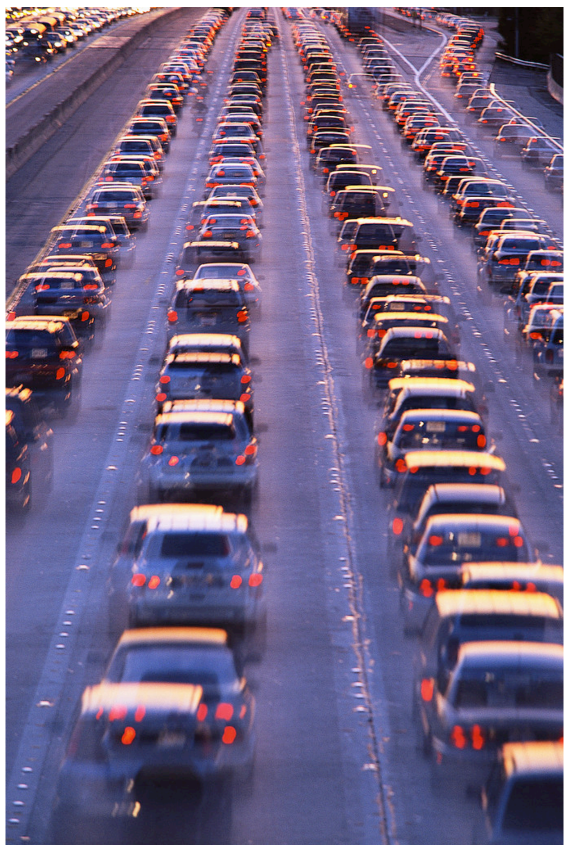
version 2. Modified by Dr. Tamás Bertényi
February 14th, 2006

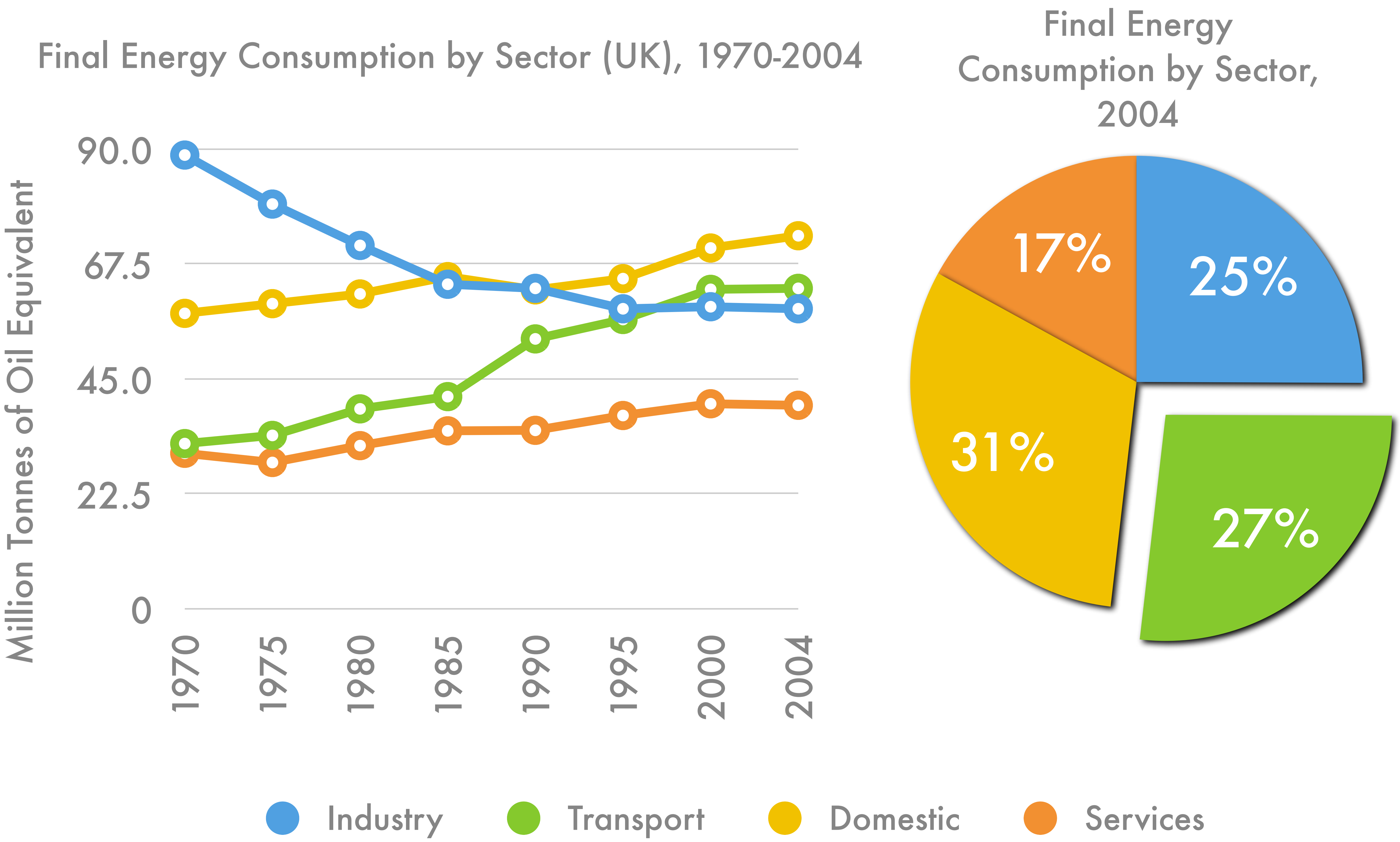
Road Transport



- It goes without saying that motor cars are very common and wide spread in our society
- As a result, they are inevitably going to have a strong influence on our society's sustainability through energy consumption, greenhouse gas emissions and unintended social impact
- At the same time, let us not forget that road transport has very positive economic and social benefits to our society
- This resource provides figures for some major quantifiable issues and points out other relevant factors. It explores the role that engineers can have in this topic

This is the outline for the rest of the resource: some of the most important issues relating to energy consumption, greenhouse gas emissions, and unintended social impacts of road transport.
It proceeds to outline both technical and social solutions.
The key issue is that road transport is so widespread in our society - and so strongly woven into our lifestyles - that they inevitably have an enormous impact.

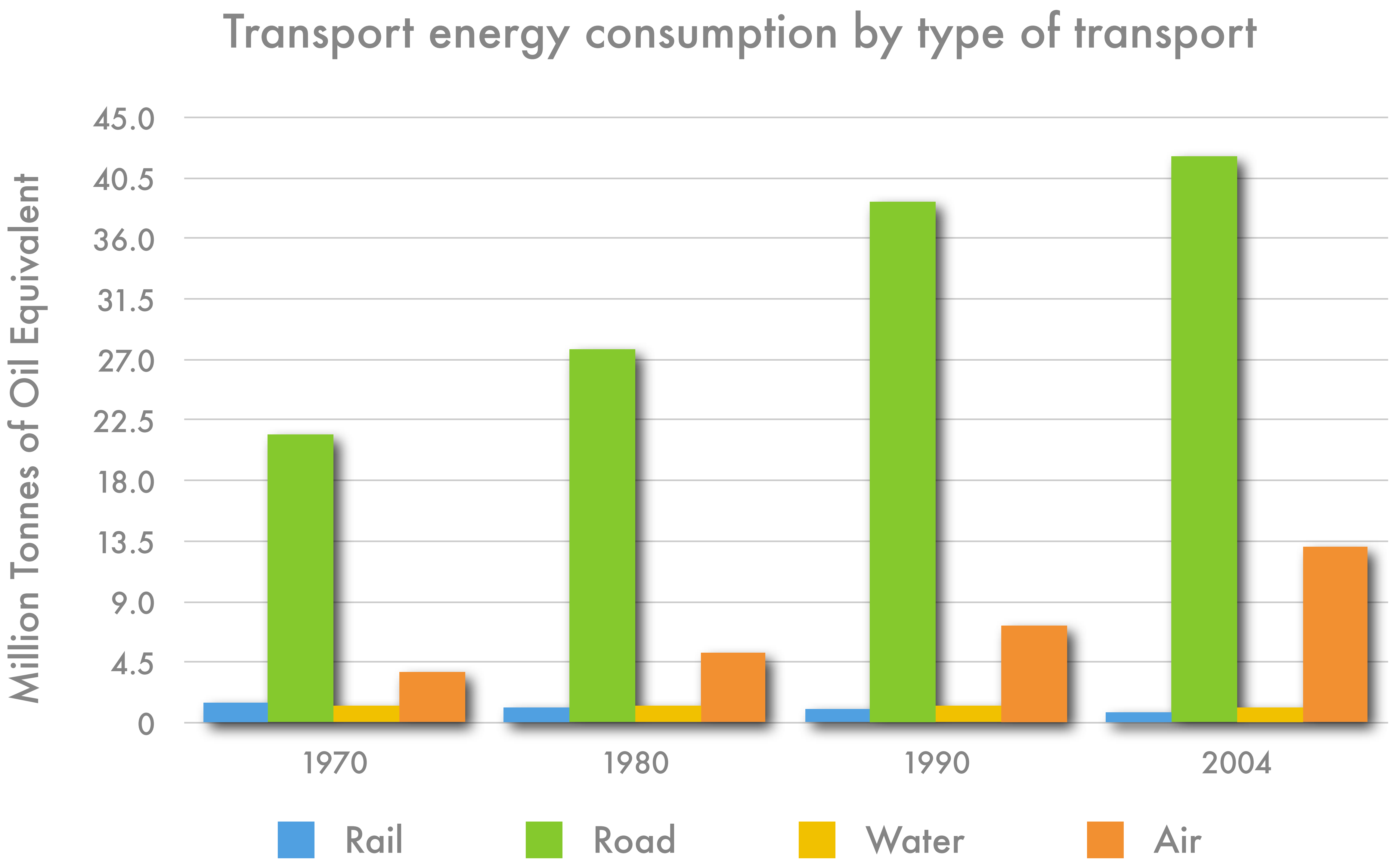
Transportation Energy



Between 1970 and 2005, transportation has grown to account for more than a quarter of the overall UK energy consumption, from an original 15%. (Total energy consumption has grown from 210.1 MTOE to 234.9 MTOE. In the same period, the population has grown from 54.83 million in 1970 to 59.7 million in 2005.
The decrease in energy consumption by the industrial sector is mostly due to the decline of industry in the UK during this period.
Similar data for the US can be found at the Department of Energy website. For example, the tabular data for energy use by sector http://www.eia.doe.gov/emeu/aer/txt/ptb0201a.html

Energy data from DTI Annual Report on Energy Consumption: http://www.dti.gov.uk/energy/inform/energy_consumption/ecuk.pdf Main DTI site includes most current raw data for download.
Population data available on-line from UN Dept. of Economic and Social Affairs http://esa.un.org/unpp

Energy by Transportation Type

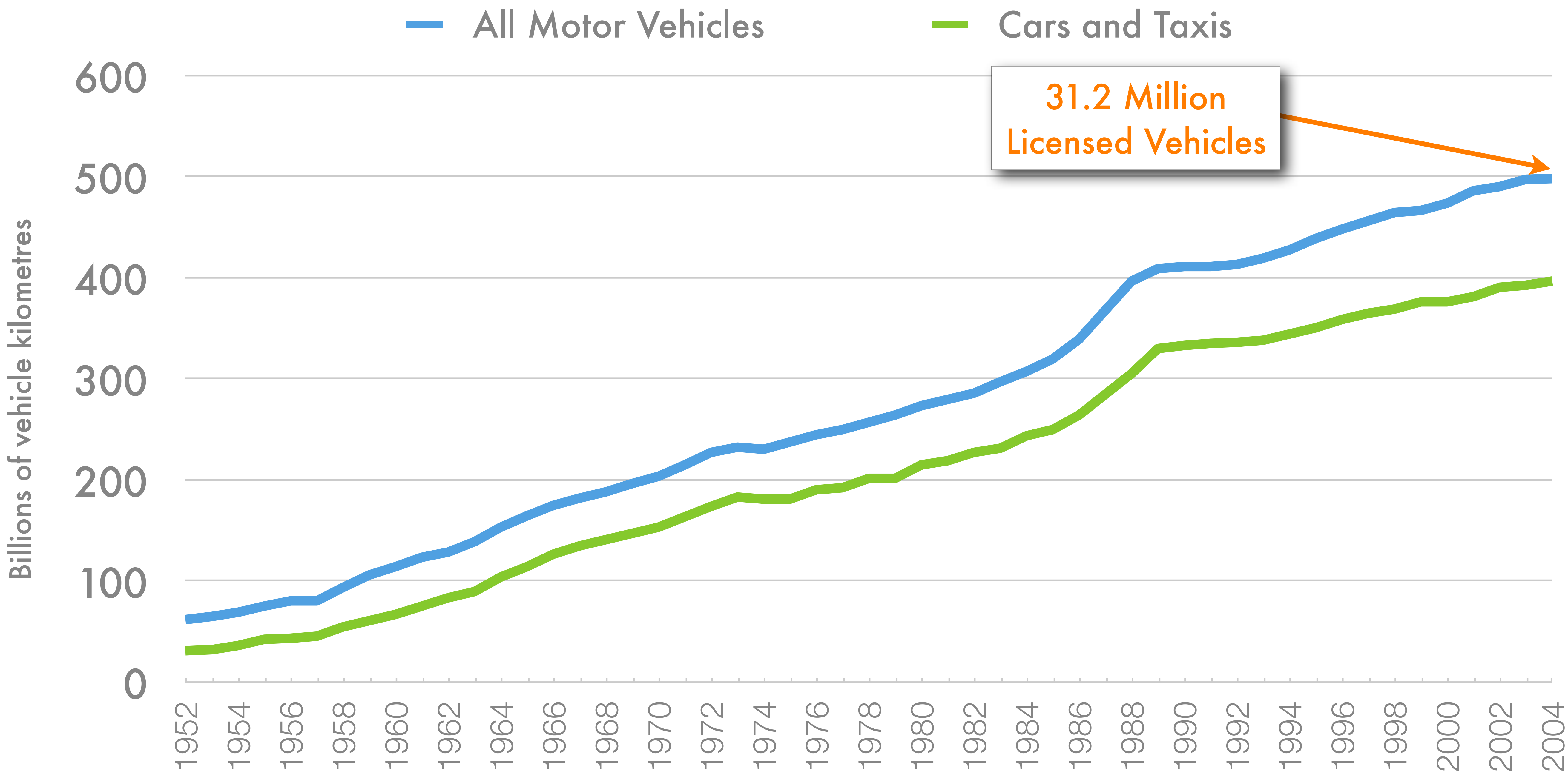


Transport energy consumption has almost doubled between 1970 and 2004, whereas the population has only increased from 54.83 million to 59.7 million.
The largest increase has been from air transport, which has more than tripled since 1970
Energy consumption from rail and water transport has fallen this 34 year period by 25% and 34% respectively, whereas consumption from road transport has almost doubled.

The primary energy source for rail includes coal, electricity and petrol.
Road transport includes passengers and freight.
The primary energy source for water includes coal and petroleum.

Source: DTI Annual Report on Energy Consumption: http://www.dti.gov.uk/energy/inform/energy_consumption/ecuk.pdf
Population data available on-line from UN Dept. of Economic and Social Affairs http://esa.un.org/unpp

UK Road Usage

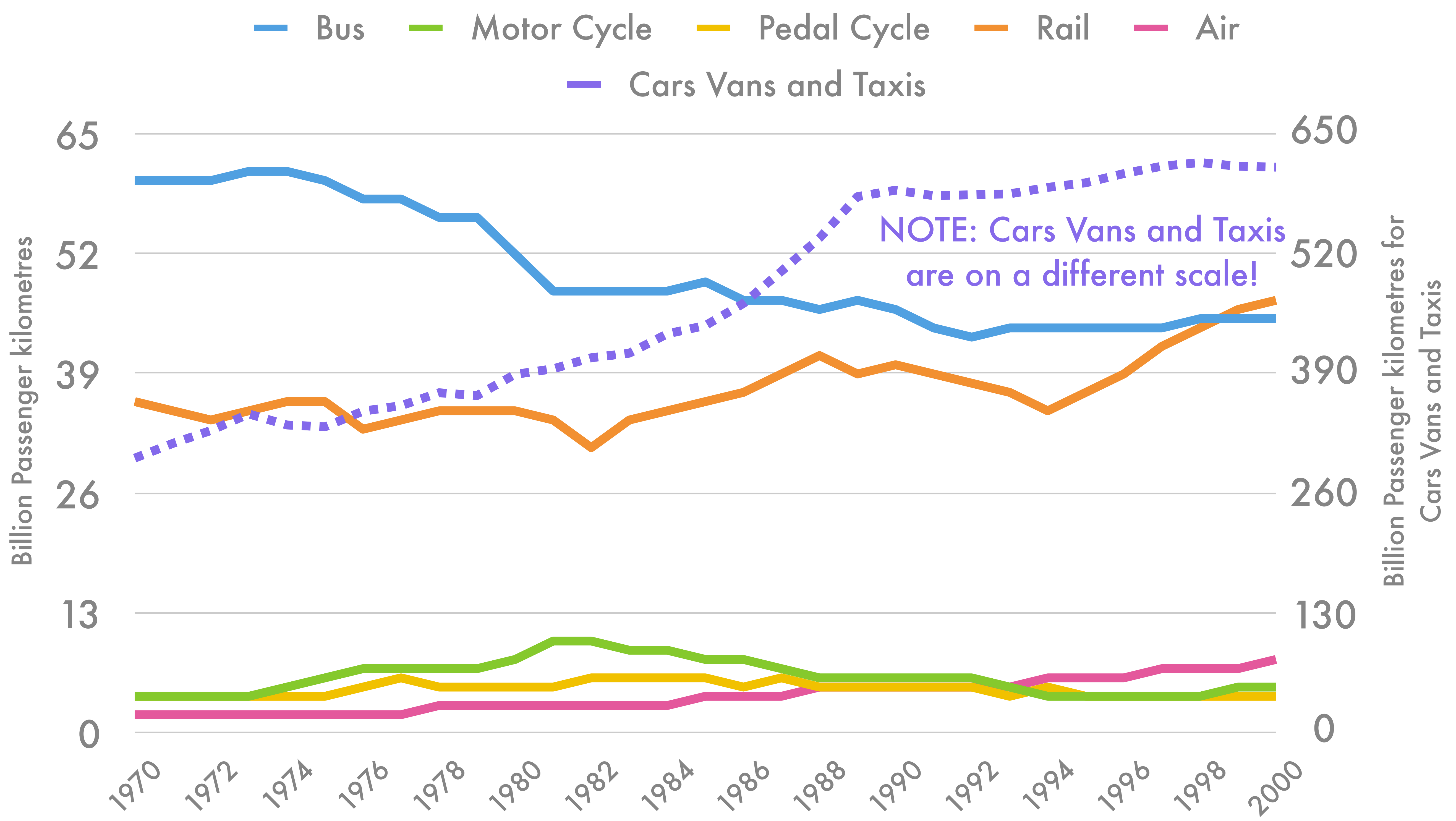


UK Road Traffic has increased 8-Fold in the last 50 years, there are 31.2 million registered vehicles, but overall road length has only increased by a 25%.

Cars and Taxis account for the majority of road traffic. (But not necessarily fuel consumption! Freight and commercial transport typically consume more fuel per kilometre. They also have greater impacts on air quality, accidents and infrastructure wear and tear. Annual vehicle kilometres of this category is represented by the delta between the two curves).
Motor vehicles travelled 490 billion km in 2003 in Britain
There are 31.2 million licensed vehicles in Britain (up from 9 million in 1962)
But the overall road length in Britain has only increased by a quarter in the last 40 years, to 392,000km
(source: National Statistics Online, www.statistics.gov.uk)

Similar information for the US is available from the Department of Transport www.dot.gov, or for example http://www.infoplease.com/ipa/A0004727.html

UK Transport Usage



Passenger kilometer = vehicle kilometer X passengers

This chart show the evolution in UK transport usage by mode between 1970 and 2000
Note that Cars, Vans, and Taxis are on a scale that is 10x the other modes
Usage is given in “passenger kilometres” which factors in passenger density
The distance travelled by bus fell by 25% between 1970 and 2000
Passenger kilometres from motorcycles and pedal cycles are at similar levels to 1970, with the slight boom in motor cycle use enjoyed in the early 1980s having disappeared by 2000
Rail passenger kilometres increased by 31% between 1970 and 2000
But travel by cars, vans, and taxis dominates the UK transport usage, having double between 1970 and 2000
Domestic Air transport passenger kilometres have almost quadrupled during the 30 years shown

Source: Chart 27 from DTI. http://www.dti.gov.uk/energy/inform/energy_consumption/ecuk.pdf

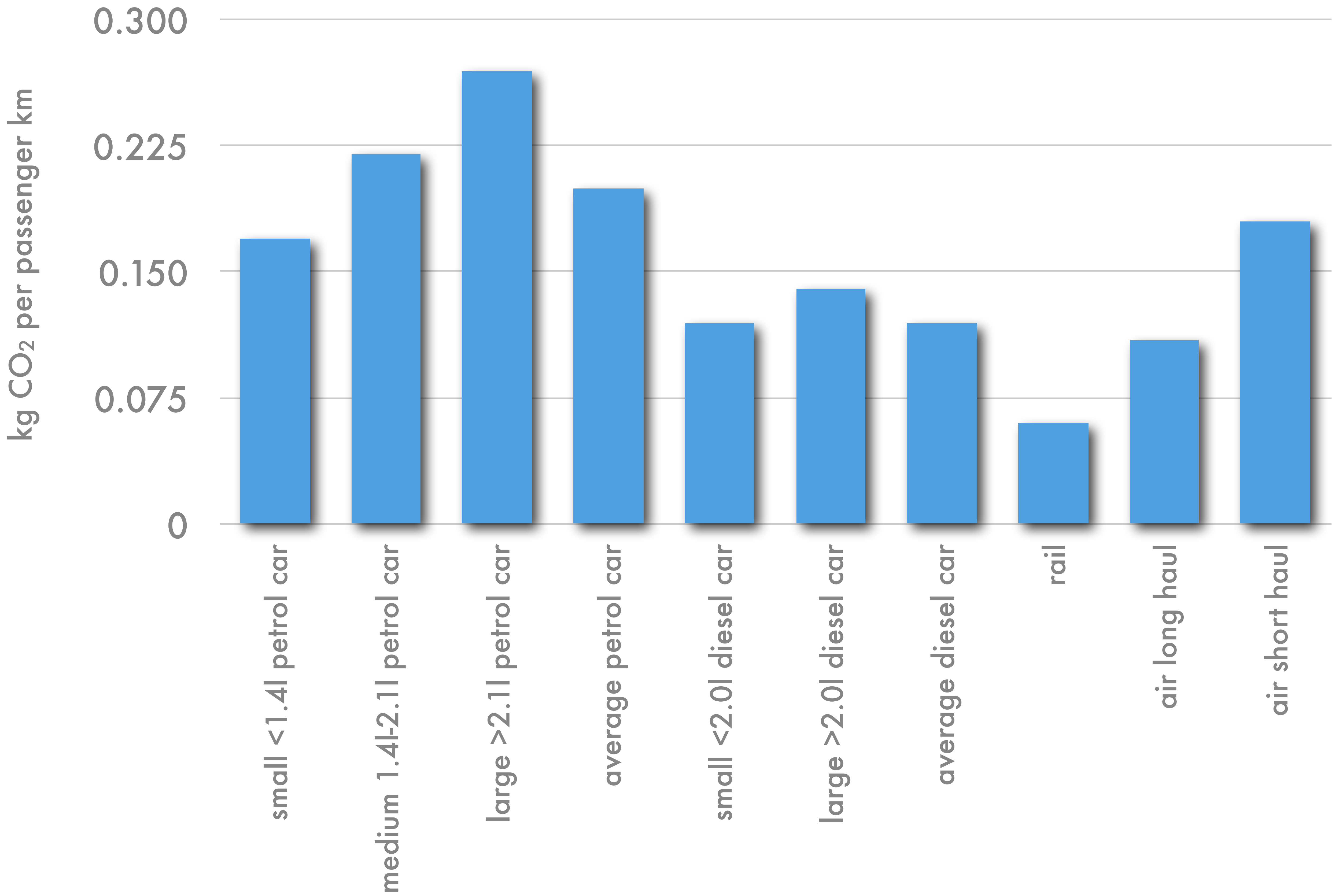
Consumer Demand

- Travel time budget: research shows that the mean time travelled per day is independent of income. Worldwide it is 1-1.5 hours.
- Likewise, around the world a person devotes on average 10-15% of their income to travel.
- Trend shows that as GDP/capita increases, passenger kilometres travelled increase. Therefore, growing economies demand ever higher speed transport.

These projections are based on a model designed to predict long-term scenarios. It has been determined that on average, fixed budgets of time and money are devoted to travel. (Time travel budget and money travel budget data is given in reference). That means that as income rises, so does the amount of spending on travel.
Levels of future mobility depend on population estimates. The World Bank 1992 projections estimate an increase in world population to 10.1 billion in 2050. Growth is strongest in developing countries which account for 85% of the world population by 2050.
A fixed travel time budget requires that the mean speed of travel increases in proportion to the projected rise in total capita mobility. There may be an increase in luxury travel as travel budget increases.
As traffic congestion becomes greater, people will adjust when they travel and where they live. Businesses will also change where they are located.
For more details, see reference.

Schafer, A., and Victor, D.G. “The future mobility of the world population”. Transportation Research Part A 34(2000) 171-205

CO_2 Emissions by Transport Mode



Numbers extracted from the DEFRA “Guidlines for Company Reporting on Greenhouse Gas Emissions”.

http://www.defra.gov.uk/environment/business/envrp/gas/envrpgas.pdf

CO_2 Emissions by Transport Mode

Fuel Life-Cycle Energy Consumption and CO_2 Emissions for urban transport modes

Mode	Seats	MJ per vehicle km	kg CO_2 per vehicle km	MJ per seat km	Grams CO_2 per seat km
Electric Train	300	117	11.7	0.39	3
Diesel Train	146	74	8.8	0.50	0
Light Rail	265	47	10.1	0.18	38
Underground	555	122	26.0	0.22	46
Single Deck Bus	49	14.2	1.6	0.29	33
Double Deck Bus	74	16.2	1.9	0.22	26
Minibus	20	7.1	0.8	0.36	40
Medium-Sized Car	5	3.5	0.39	0.70	78

Road transport makes up around 21% of total man-made CO_2 Emissions in the UK

(RAC Report 2003)

This table provides further insight into CO_2 emissions by urban public transport modes, including a "medium-sized car" for comparison.

These figures include the "per seat" figures built into the transport mode.

In general, the slower forms of public transport using lighter vehicles consume less energy and produce the least CO2 emissions

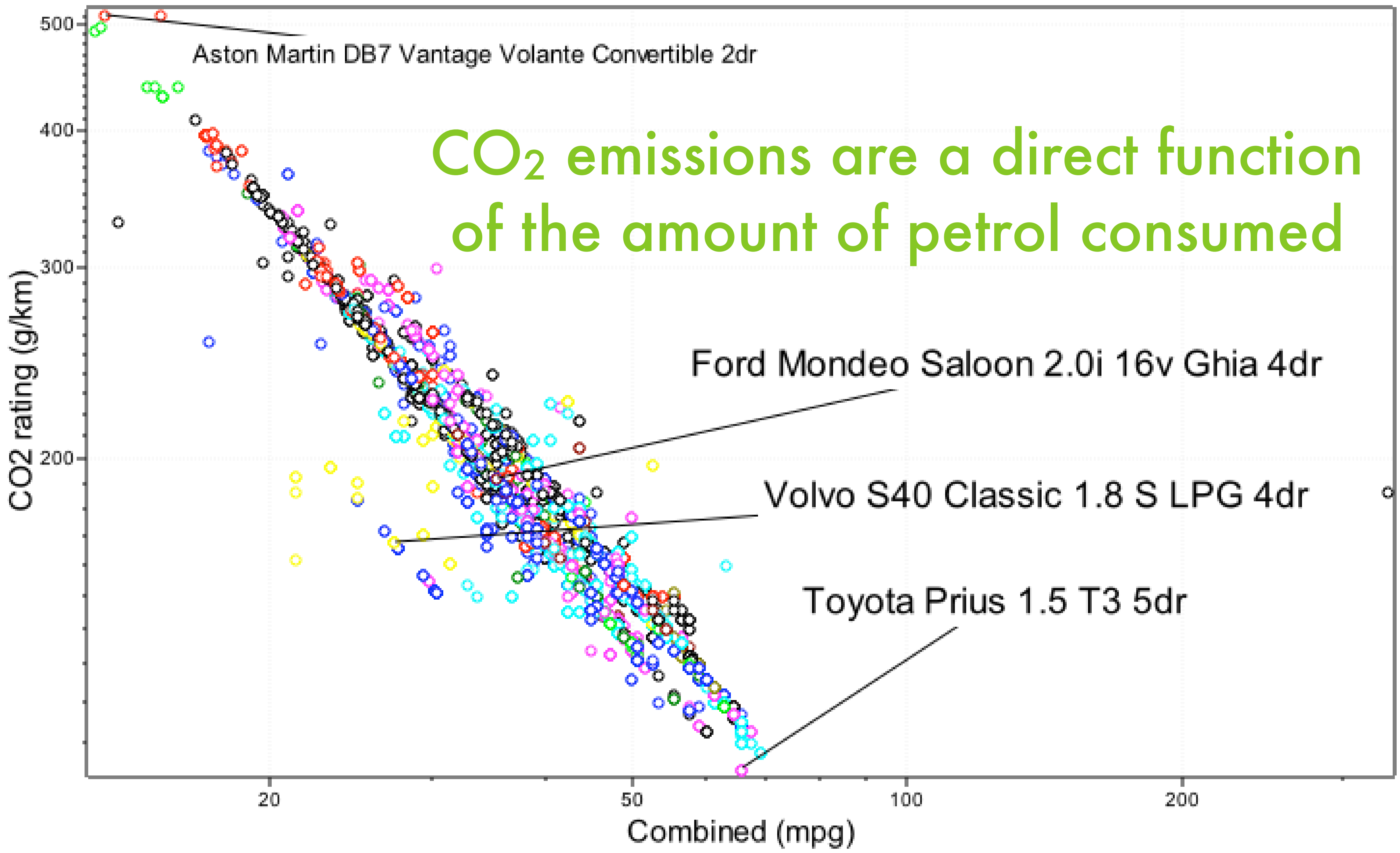
The Underground appears to have high CO_2 emissions per seat km, but this is because (a) the system is old and (b) the figure is normalised by the number of seats, only, and does not include the standing capacity which makes a significant difference.

Data is from empirically compiled information Carpenter, Potter, and Roy, Potter and Yarrow.

Carbon dioxide emissions from road transport in Britain in 2001 were 31 million tonnes with emissions per vehicle having fallen from 1.08 tonnes per vehicle in 1993 to 0.95 tonnes in 2001. Road transport makes up around 21 per cent of total man-made carbon dioxide emissions in the UK. (RAC Report 2003)

Carpenter, T. G. (1994) The Environmental Impact of Railways, John Wiley.
Potter, S. (2000) Travelling Light, Theme 2 of T172 Working with our environment: technology for a sustainable future, Milton Keynes, The Open University.
Roy, R., Potter, S. and Yarrow, K. (2002) Towards sustainable higher education: phase 1 final report, Design Innovation Group, Milton Keynes, The Open University.

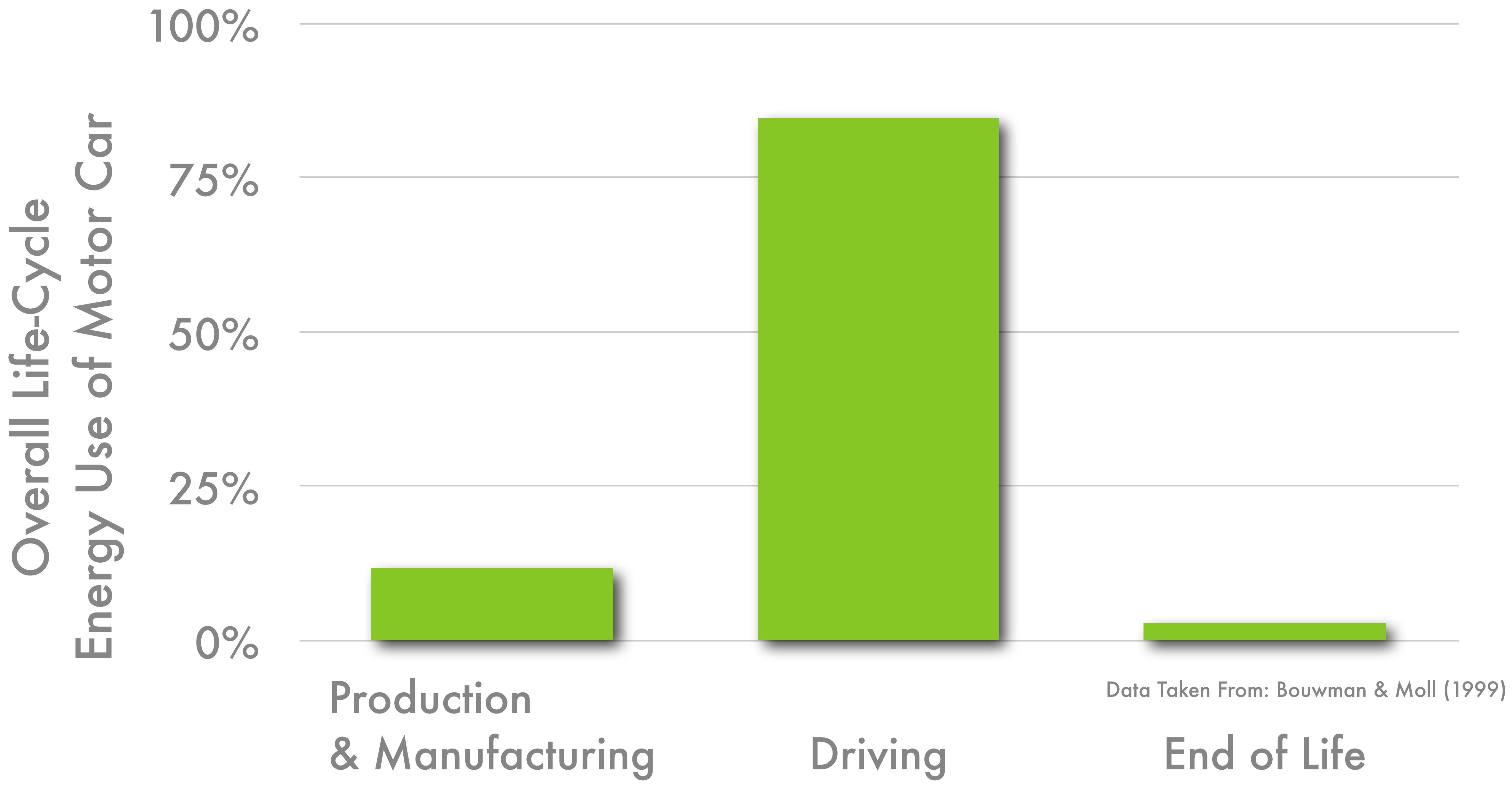
CO_2 and Fuel Economy



CES and Mike Ashby

•The plot is based on data for 6818 popular car models in the world market. Data courtesy of Granta Designs from their "Cambridge Eco-Selector" database. An educational version is available.
•It shows Fuel consumption (miles/gallon) vs. CO_2 emissions (grams/kilometer)
• “Combined” refers to combined cycle fuel economy rating, “CO2 rating” refers to CHECK THESE WITH MIKE ASHBY!!
•Note that all Greenhouse gases are converted to CO_2-equivalent using appropriate conversion factors, similar to what is shown in LINK TO CLIMATE CHANGE RESOURCE
•There is a strong correlation between fuel economy and GHG emissions

Motor Car Life-Cycle



In a typical motor car's life, the Use Phase (driving and maintenance) dominates energy consumption at 85%. This is typical of durable goods. The average car in OECD countries lasts for 13 years and travels 120,000 miles.

This slide introduces life-cycle analysis of motor cars by considering energy use over their life-time. This method of analysis can be applied to other attributes material use, cost, land occupied etc. LINK TO MIKE ASHBY LCA RESOURCE

The chart shows energy use in the dominant phases of a motor car's life-cycle. It can be seen that the driving phase (including vehicle maintenance and fuel use) dominates.

This distribution is expected since the car is a durable good. The data used assumes an average vehicle life of 13 years and 120,000 miles (Waste online: http://www.wasteonline.org.uk), this is the average for cars in OECD countries.

Energy use in the Production, Manufacture and End-of life-management phases are relatively low because of 2 reasons:

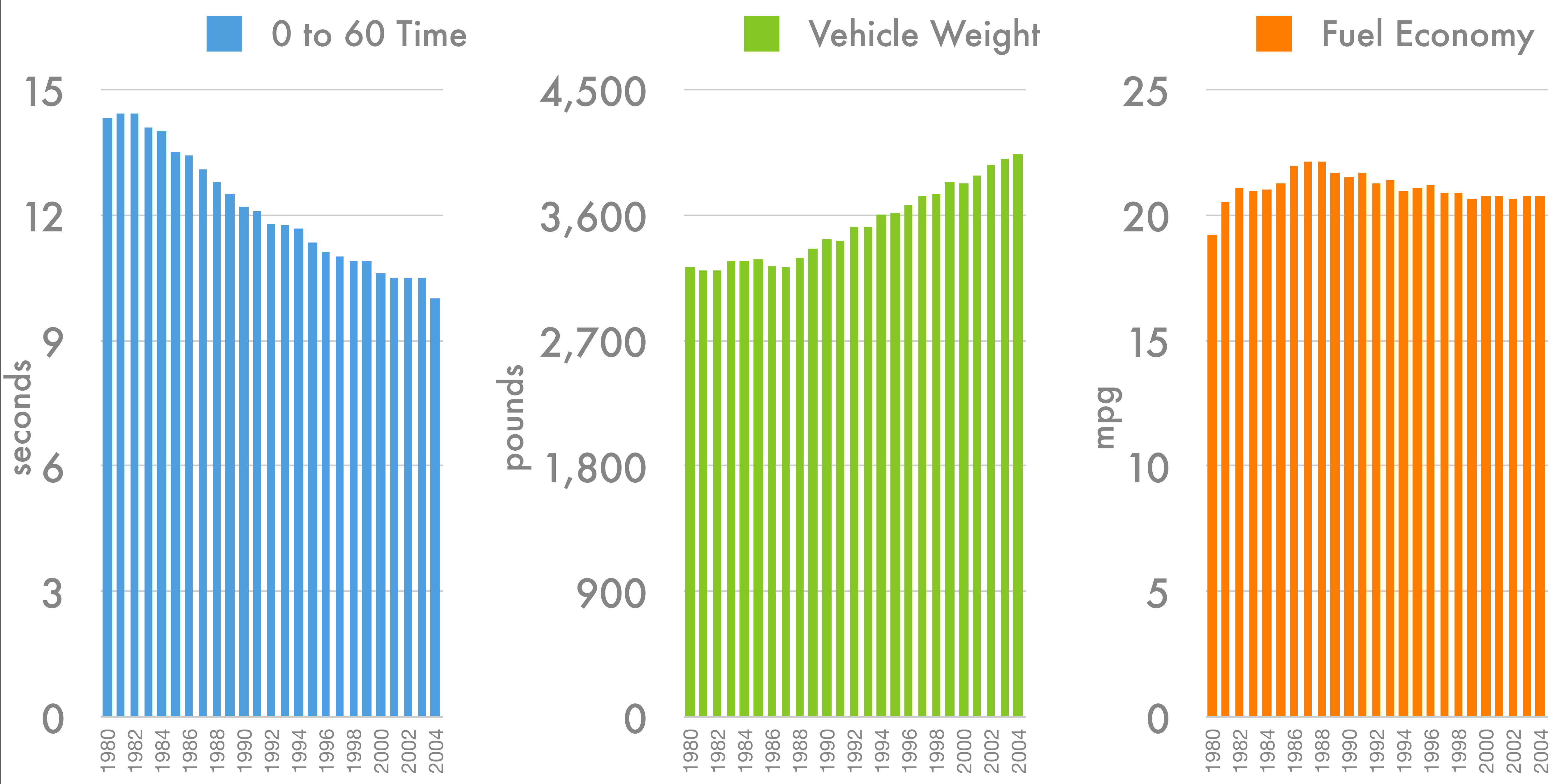
1. Energy use is dominated by fuel use in the driving phase
2. Mass production of motor cars (since Ford's production of the model-T) has greatly improved the energy efficiency of the car-manufacturing process.

Data source for diagram: http://www.grida.no/climate/ipcc_tar/wg3/100.htm

Technical Solutions: Improved Efficiency

Efficiency does not equate effectiveness

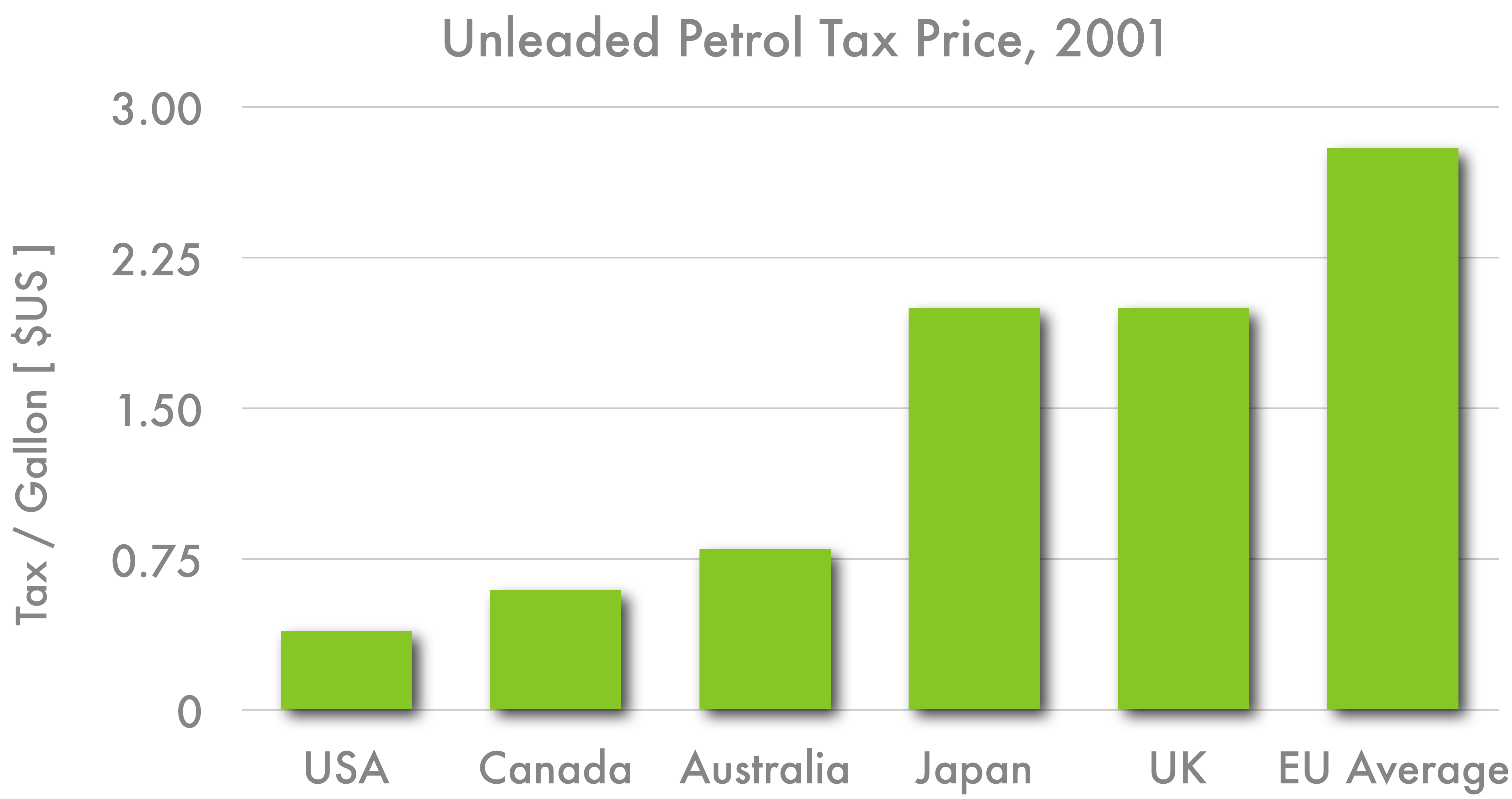
US EPA Data Averages for Light Vehicles 1980-2004



Between 1980 and 2004 there were dramatic improvements in automobile technology and thus greatly improved engine efficiency
However, this was focused towards making the cars larger and better performing rather than reducing fuel consumption
Data based on US Environmental Protection Agency data for “light vehicles”.

Hakim, D., “E.P.A. Holds Back Report on Car Fuel Efficiency”, New York Times, July 28, 2005.

Social Policy: Tax



Does the big difference in petrol tax between Europe and the US partially explain the difference in private car ownership: 450cars/1000 people in EU and about 700 cars/1000 people in the US?

The motor vehicle has a very beneficial role in society, too. To curtail its negative impacts (such as fuel consumption, GHG emission, and social costs due to accidents) requires society to enact policy. One of the most favoured and effective policy tools governments have at their disposal is taxation.

Does the big difference in petrol tax between Europe and the US partially explain the difference in private car ownership: 450cars/1000 people in EU (DTI, 2000) and about 700 cars/1000 people in the US (US dept of transport, 2001)?

Source: The Economist, 19th May, 2001. Unleaded Petrol/Gasoline Tax of Various Countries

Social Policy: Public Transport

Intelligent transport systems such as timed entry freeways and on-board traffic directors could reduce congestion and increase the mean speed of automobiles by 15%

Another option for curtailing private road transport use is the positive incentive of provide effective public transportation.

A global viewpoint

- New technologies may come to market first in China
- In 2005, China has six of the world's ten most polluted cities.
- The market for replacing batteries in electric bicycle with fuel cells is likely to be the earliest to be commercialised.

In China, things might be different, as problems of air quality, a desire to lead in a new technology, lower power requirements for vehicles as eight speaker stereos and air conditioning are not demanded, and the need to build a new infrastructure for fuelling, make fuel cells somewhat more attractive.
China's two main cities, Beijing and Shanghai, have been selected by the Global Environment Facility (GEF) of the World Bank for the Fuel Cell Bus Demonstration Project. Under this project, the GEF will sponsor the deployment of six fuel cell buses and one hydrogen filling station each to both Beijing and Shanghai.
China's National Development and Reform Commission (NDRC) has issued a new Automotive Industry Development Policy. The new policy, that became effective on June 1, 2004, stipulates that average fuel consumption of new cars should be reduced by 15% by the year 2010.
Public and private investment in fuel cell development in China over the next few years is projected to be over (US)$500 million.
The market for replacing batteries in electric bicycles is expected to be the earliest market to be commercialized, followed by buses.
Approximately 1 million buses were produced in China in 2002. This was an increase of 25% over production in 2001.
Under China's fuel cell roadmap, more than 100 buses will have been tested under demonstration projects between 2005 and 2010. More than 1000 fuel cellpowered buses will be utilized in regular bus operations between 2008 and 2020.
The annual alternative fuels market in China is projected to grow from $75 million in 2002 to $1.8 billion by 2008.
Source:http://ecoworld.com/Home/Articles2.cfm?TID=352

Summary

- Road Transport impacts the environment by consumption of non-renewable fossil fuels and emissions, society by unintended consequences
- Road transport is also hugely beneficial to society and the economy
- As engineers, solutions include social systems (public transport) and technological improvements (hybrid cars, engineering for sustainable design).

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ImpEE is based at the Department of Engineering at the University of Cambridge and is funded by the CMI Institute.