

Automotive World Briefing

The Global Oil Paradox: Transforming the Automotive Industry

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One Birdcage Walk, Westminster, London

Dr Mark Barrett
Mark.Barrett@ucl.ac.uk

University College London

Topics

Panel 1. Comprehending Market Shifts and Oil Interdependency

- Global oil demand, reserves and supply
- Policy framework
- The vehicle industry and the economy
- Renewable energy sources

Panel 2. Transforming the Current State of the Automotive Industry

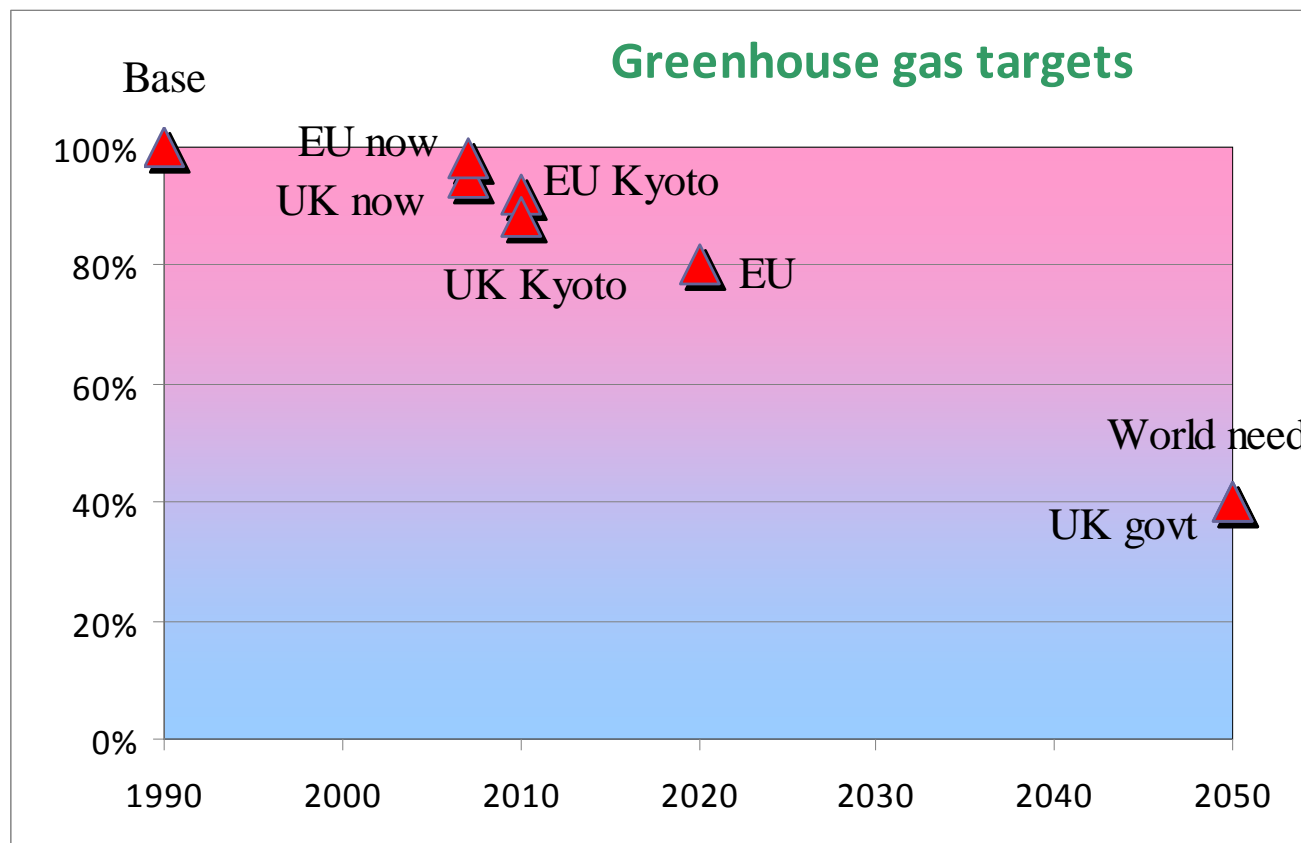
- Raw Materials costs and availabilities
- Consumer preference
- Outlook for the Future of Global Automotive Production
- Alternatives to current vehicles

Mark Barrett – transport work

- Low energy and emission scenarios (including transport) for Europe and the UK
- Recent study of transport demand with the DfT
- Financial Times report on the global vehicle industry
- Studies of aviation
- Consultant to European Commission for development of Euro III and IV standards

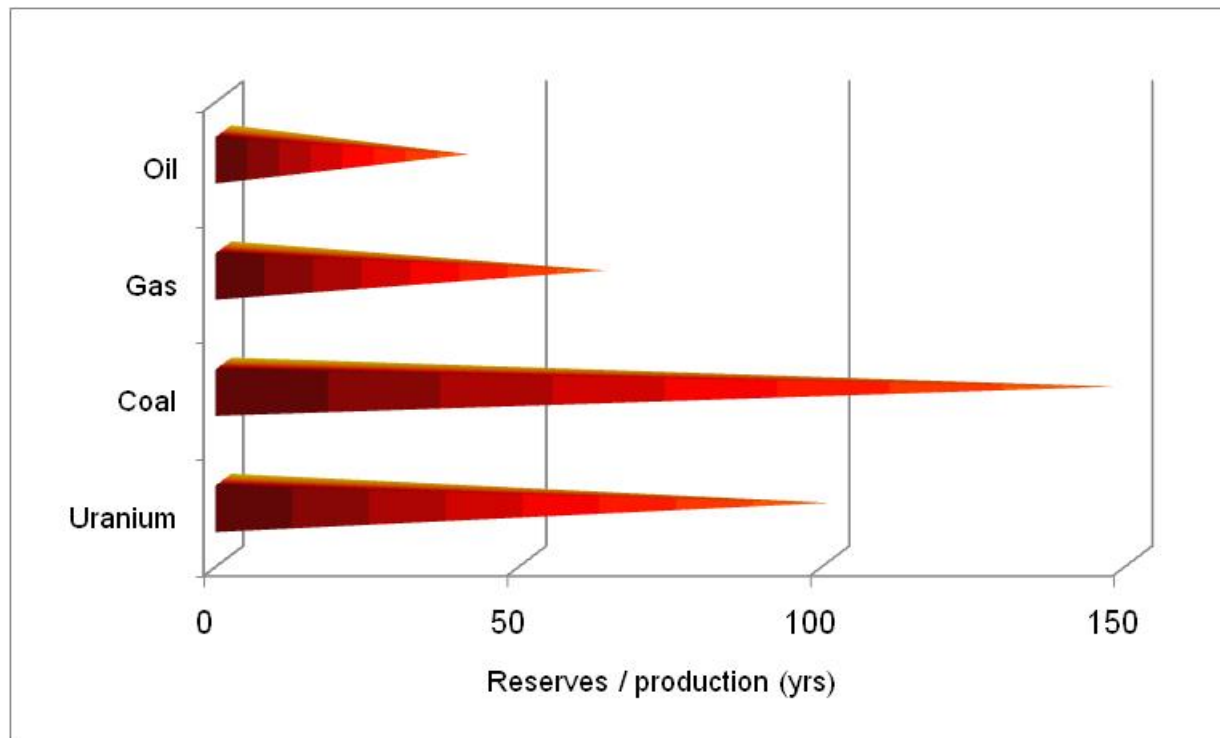
The environment: global warming

- Need 60% reduction in greenhouse gas emissions to stabilise climate. For equity, the richer countries should reduce emissions more than the average.
- Europe and UK may not make 2010 Kyoto and EU 2020 targets.



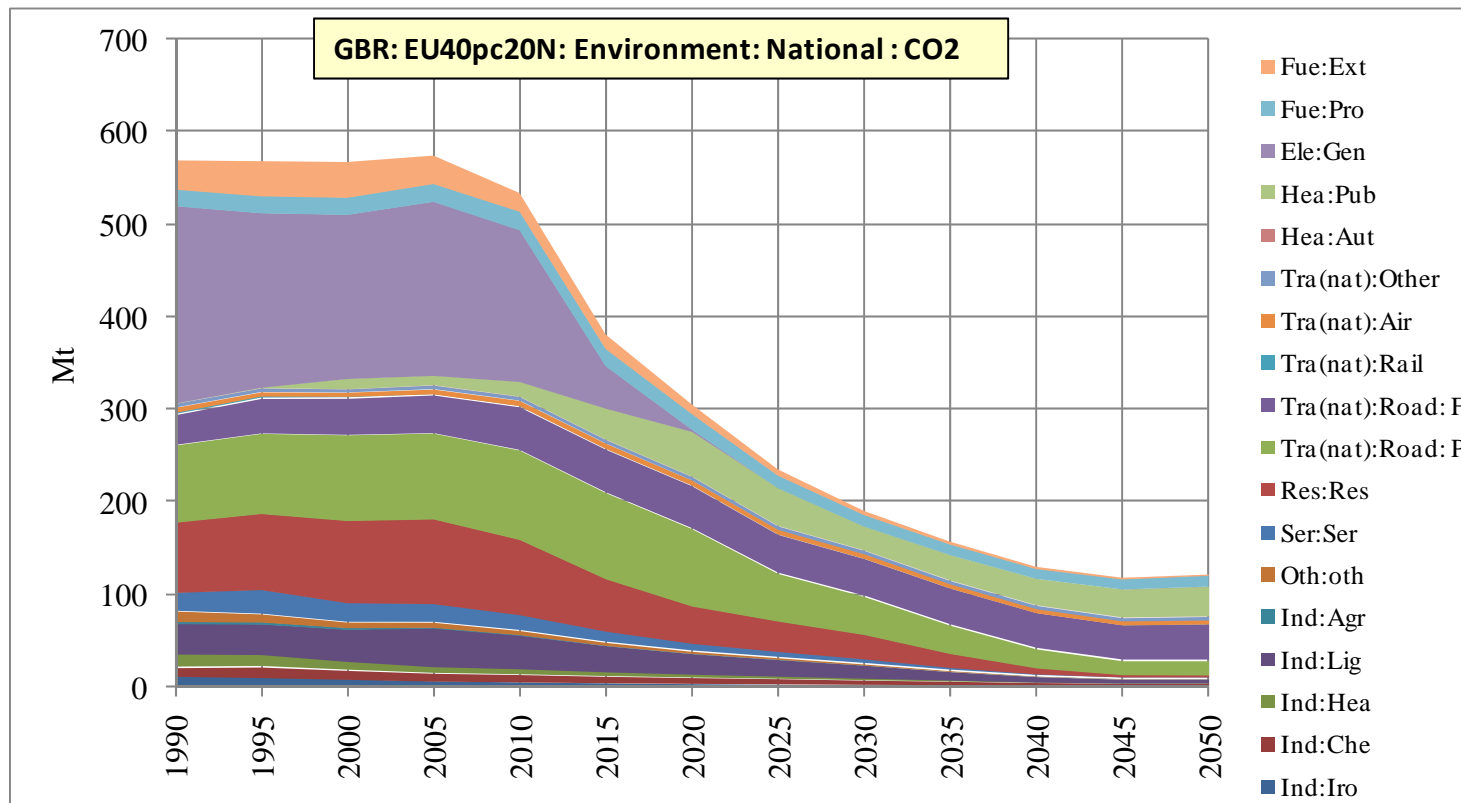
Finite energy reserves

- Remaining gas and oil reserves about 50 years at current production rates
- Gas and oil reserves concentrated in a few countries
- Availability increasingly limited, prices fluctuating and rising



UK CO₂: domestic emission (international aviation and shipping excluded)

Transport contributes an increasing fraction of CO₂ emission.



Vehicle energy supply pathway efficiencies

Primary		Crude oil	Biomass	Gas	Renewable	Renewable	Biomass	Fossil
Refine Transform		94%	50%				CHP 30%	CHP 30%
Transmission		Crude oil 99%	Biomass 99%	Gas 99%	Electricity 93%	Electricity 93%	Electricity 93%	Electricity 93%
Delivered Transform				Gas 85%	Electricity 70%			
				Hydrogen	Hydrogen			
Vehicle	Input	Liquid	Liquid	Hydrogen	Hydrogen	Electricity	Electricity	Electricity
	Store	Input Tank	100% Tank	100% Tank	100% Tank	100% Tank	90% Battery	90% Battery
		Output	100%	100%	100%	100%	90%	90%
	Conversion			Hydrogen 45%	Hydrogen 45%			
			Liquid	Liquid	Electricity	Electricity	Electricity	Electricity
	Engine to motive power	35%	35%	90%	90%	90%	90%	90%
Overall	Primary to power	33%	17%	34%	26%	68%	20%	20%

note: excludes CHP heat

Overview

- Policy framework
- Demand: structure of demand (trip length, mode..)
- Vehicle choice
- Technologies: conventional, new
- Energy supply pathways
- Scenarios: these include the above and modal switch to non-road (e.g. to rail)
- Conclusions

Policy framework

- Primary purpose of road vehicles
 - travel and communication, freight transport
 - How else can this be accomplished?

- Technology criteria
 - Safety
 - Environment
 - Global warming
 - Urban air pollution
 - Energy security
 - Economics

Passenger transport: Overview

Demand for transport:

- Purpose, distance, trip length, mode

Technology

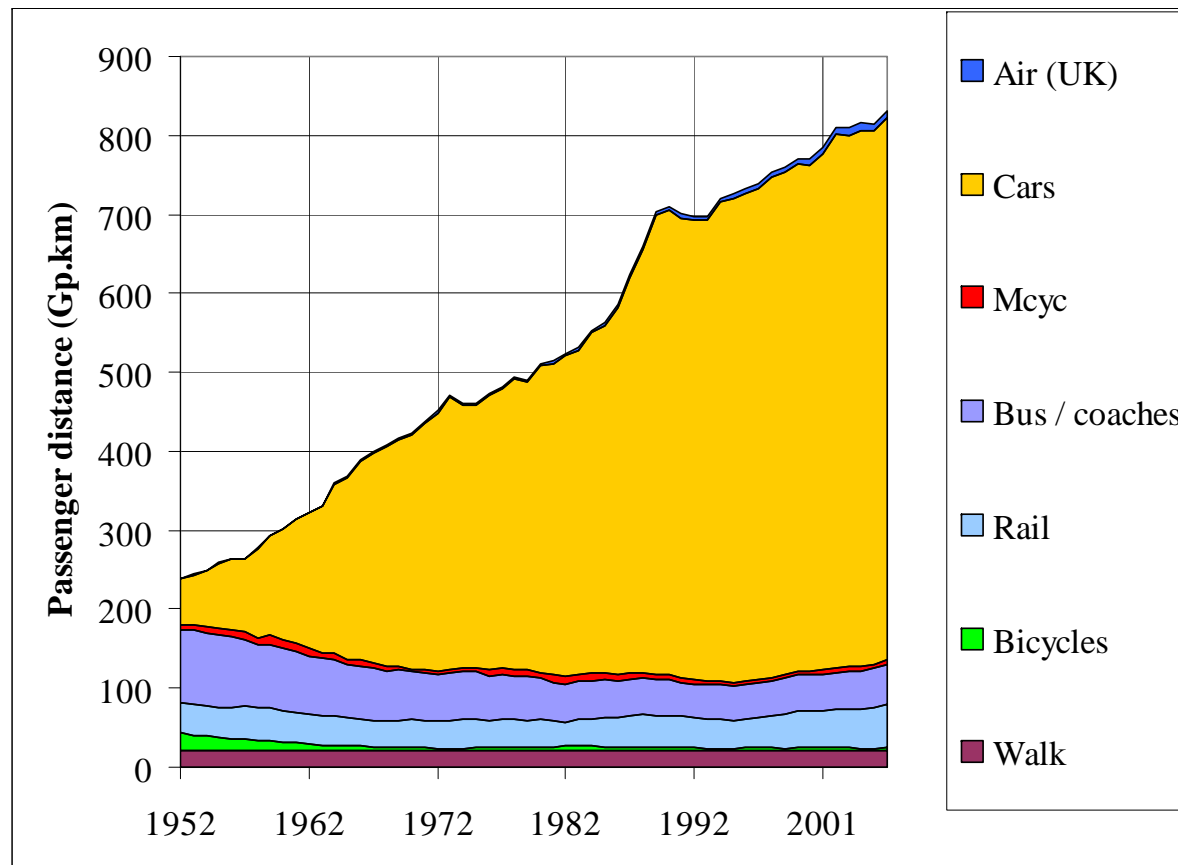
- Vehicle choice
 - Size, power, fuel
- Vehicle use
 - Speed, occupancy, load factor

‘Externalities’

- Safety
- Social dislocation, equity
- Impacts, climate change, air pollution noise ...

Passenger transport: history

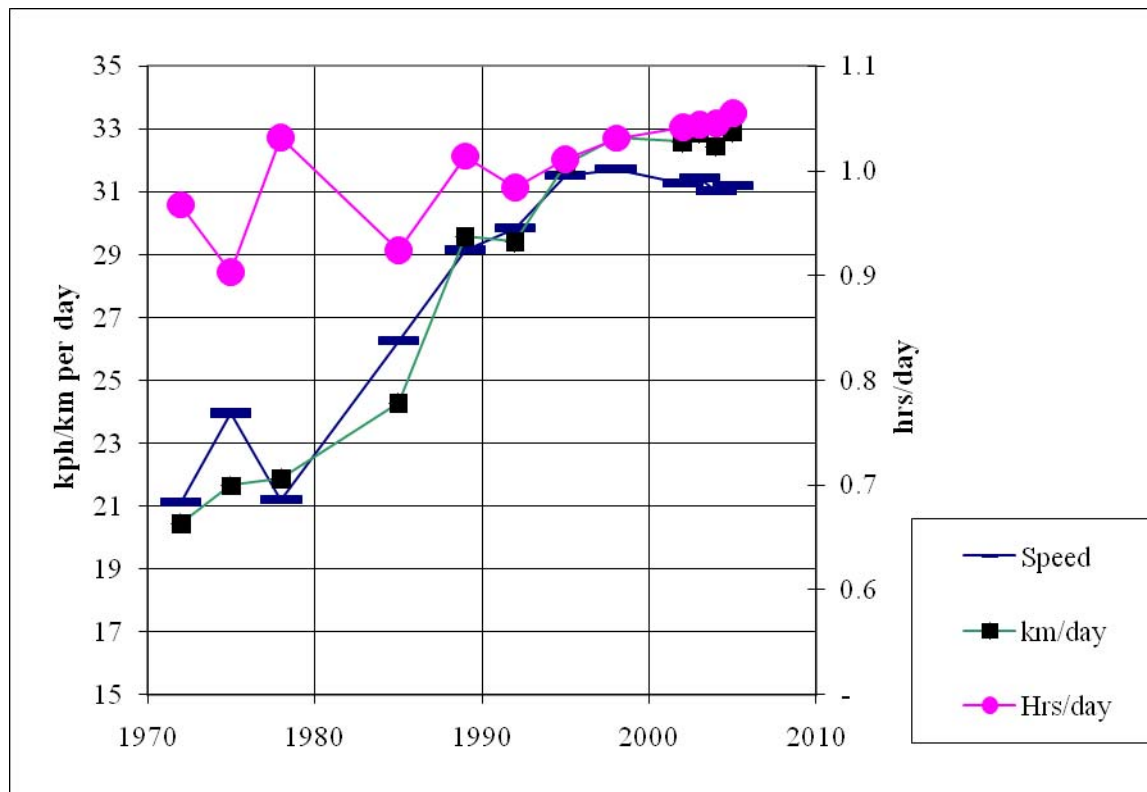
Fourfold growth in distance in 40 years,
All growth in distance by car



Passenger transport: distance, speed and time

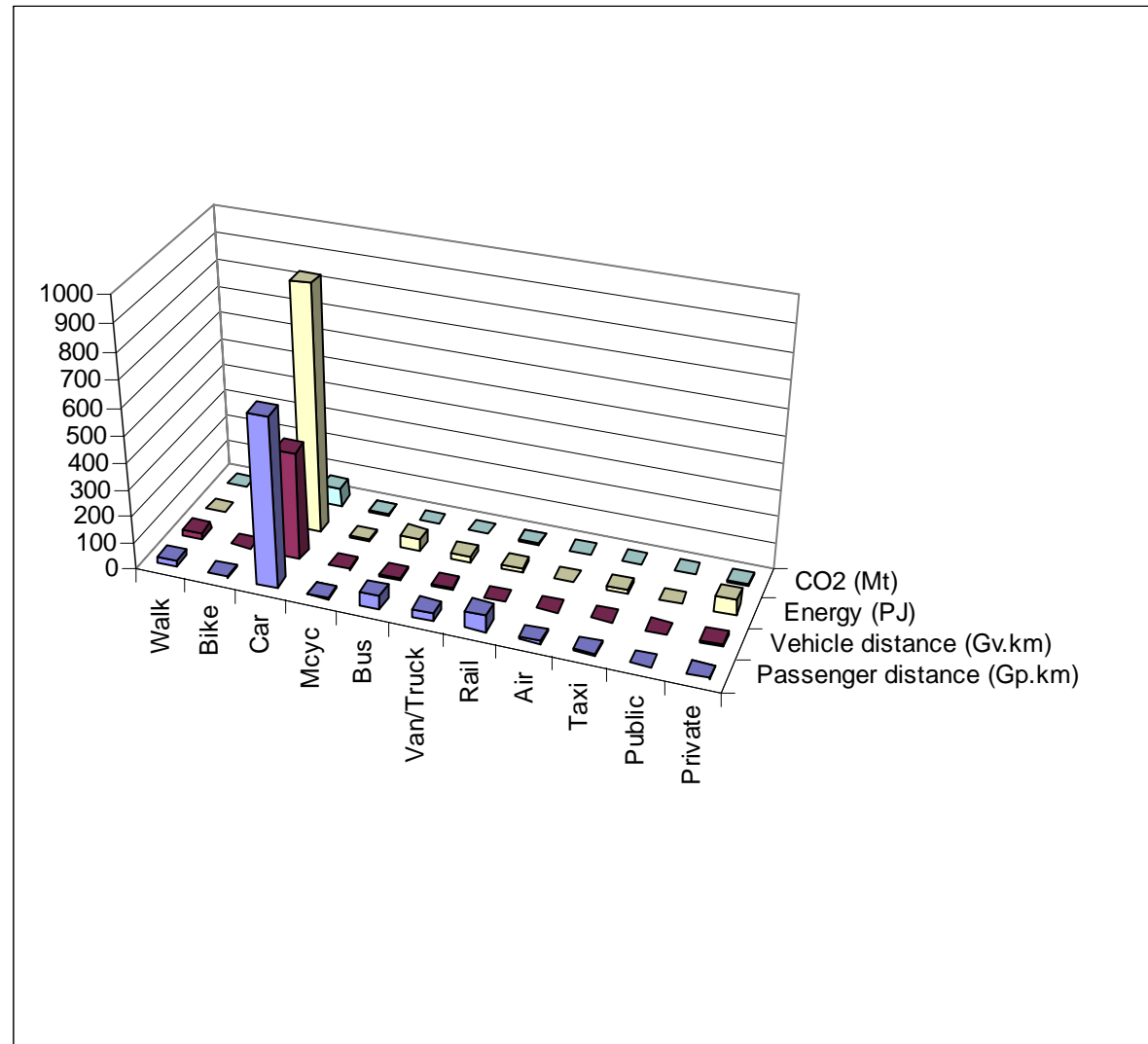
Saturation occurring in the UK.

Average per day: 30 km at 30 kph for 1 hour

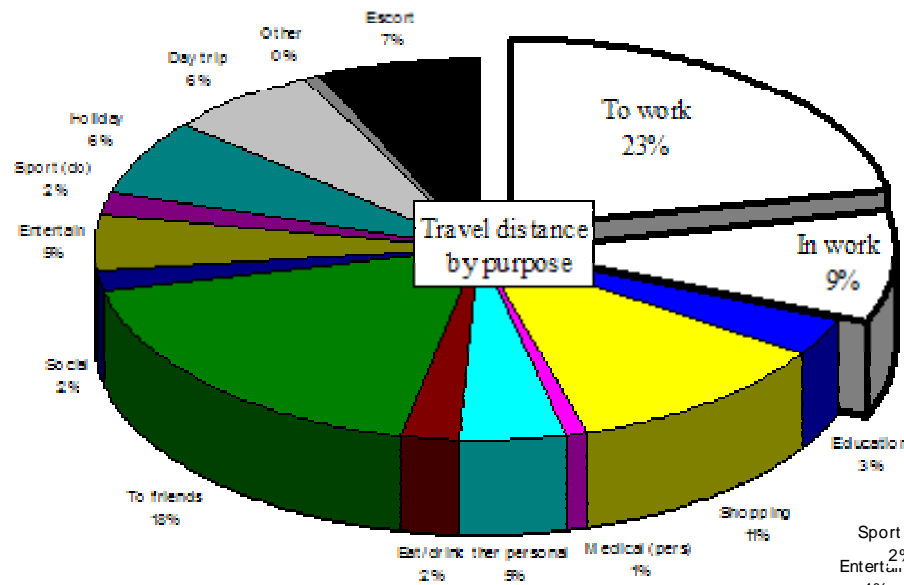


Passenger transport: summary by mode

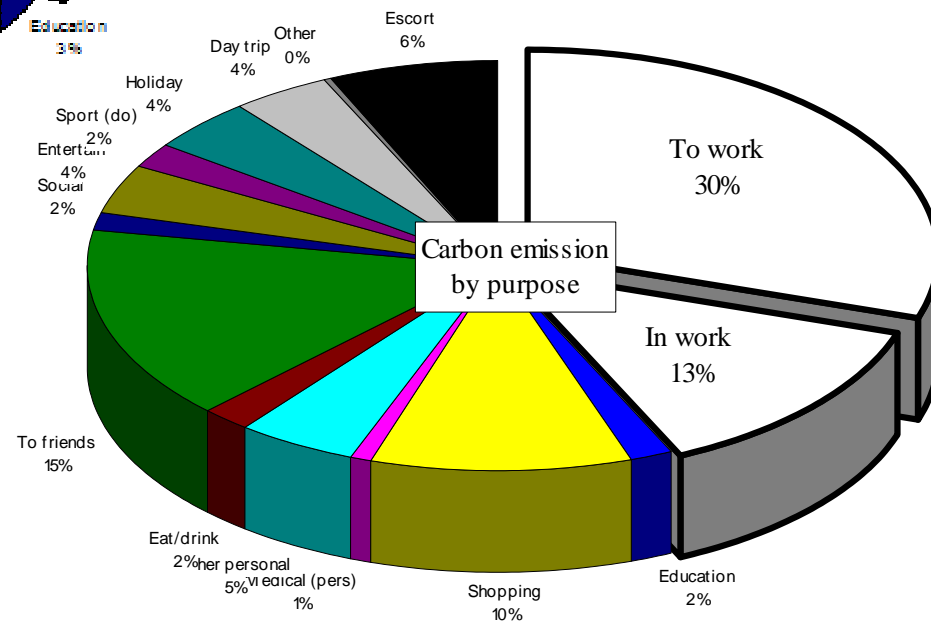
Car dominates



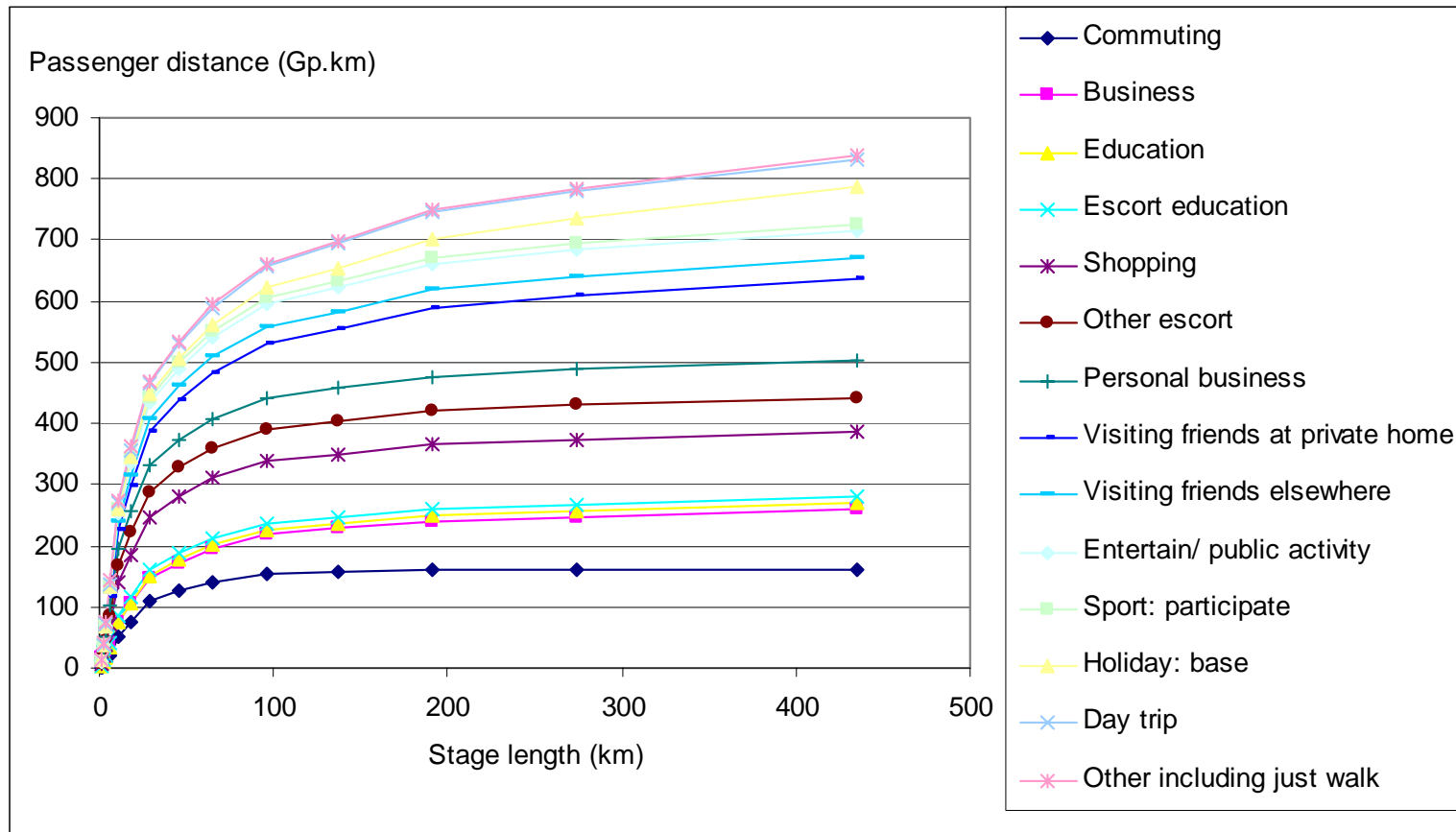
Passenger transport: carbon emission by purpose



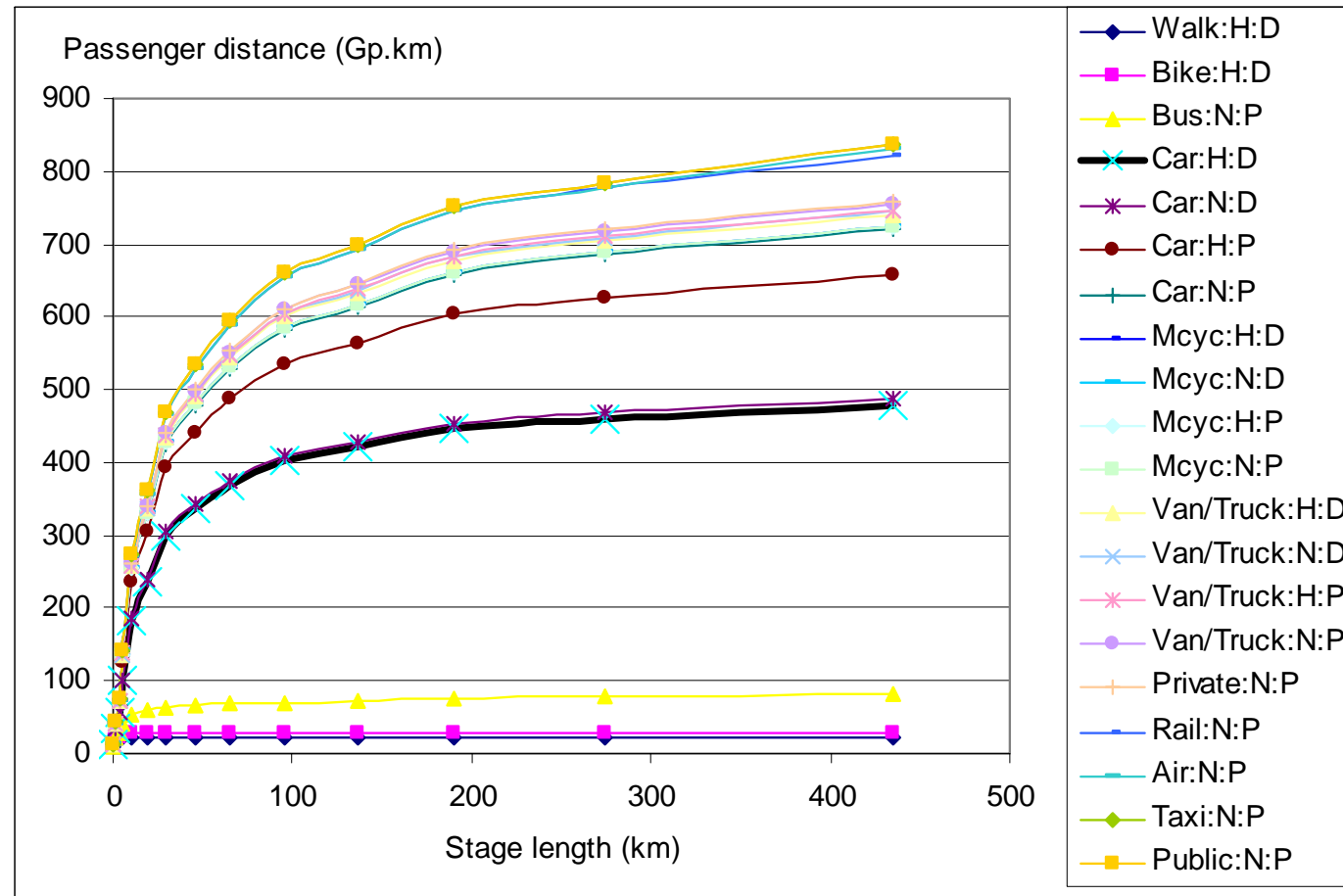
Commuting and travel in work account for 40-50% of emissions



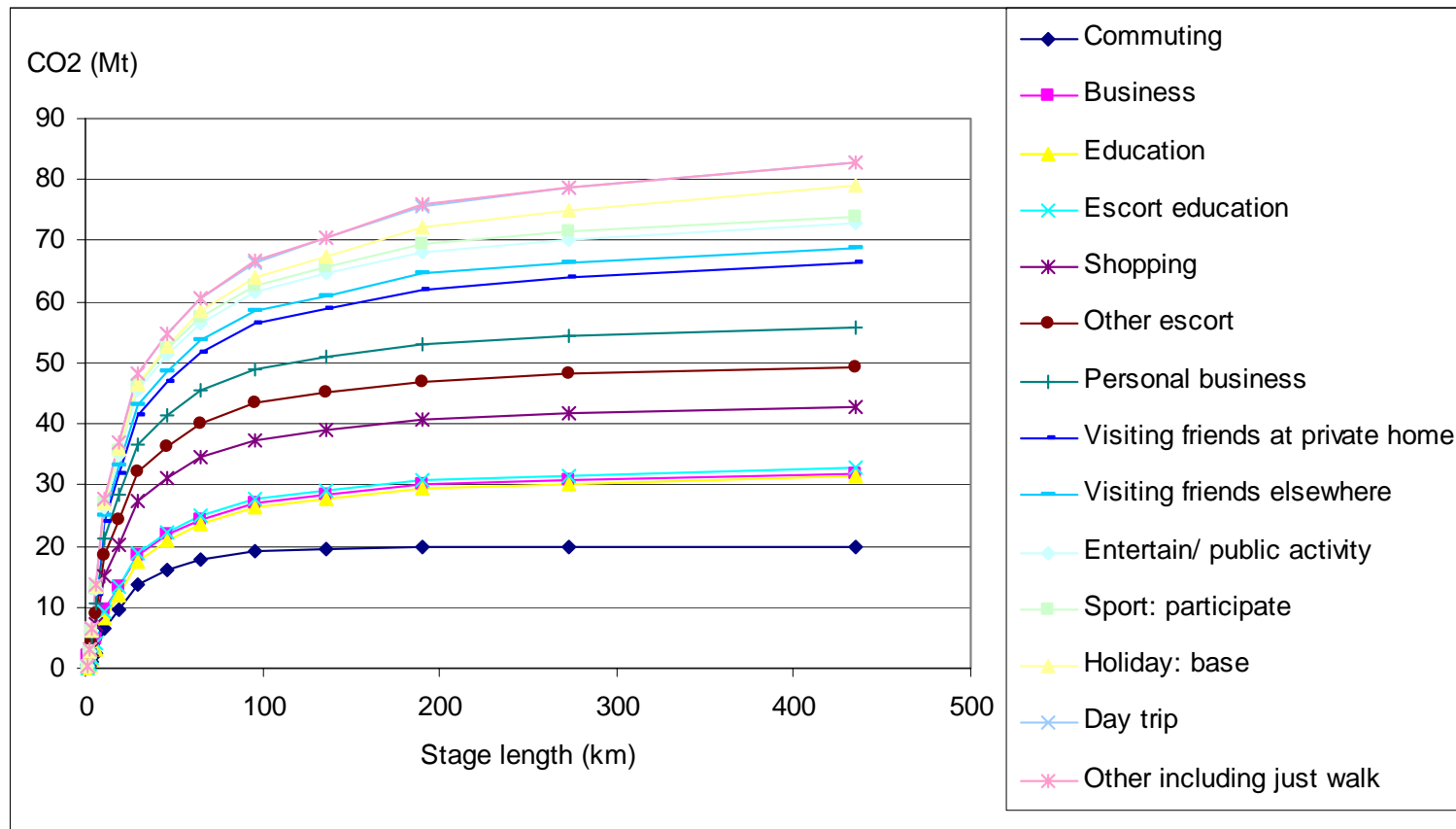
Passenger transport: Passenger distance by purpose (cum) and stage length (cum)



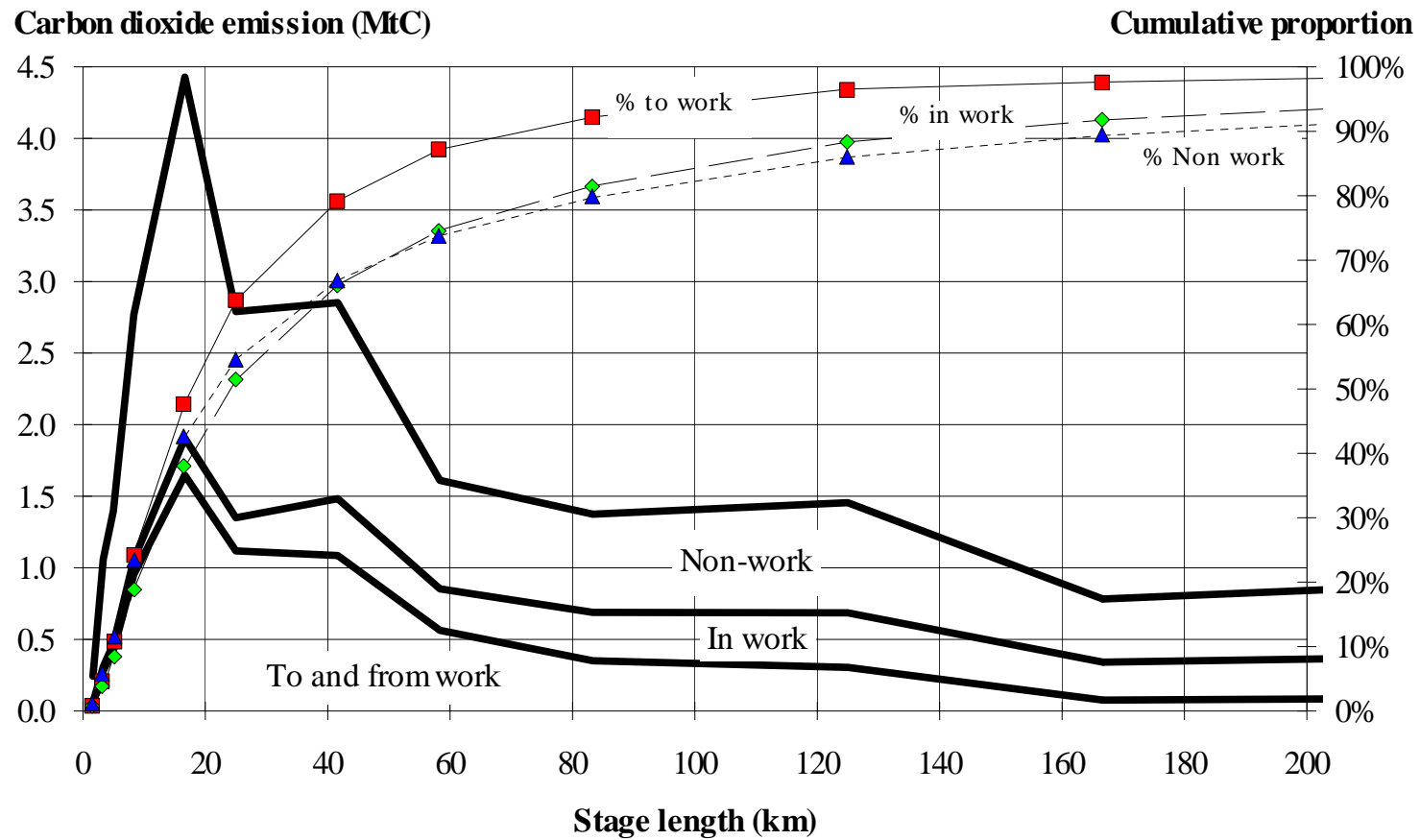
Passenger transport: Passenger distance by mode(cum) and stage length (cum)



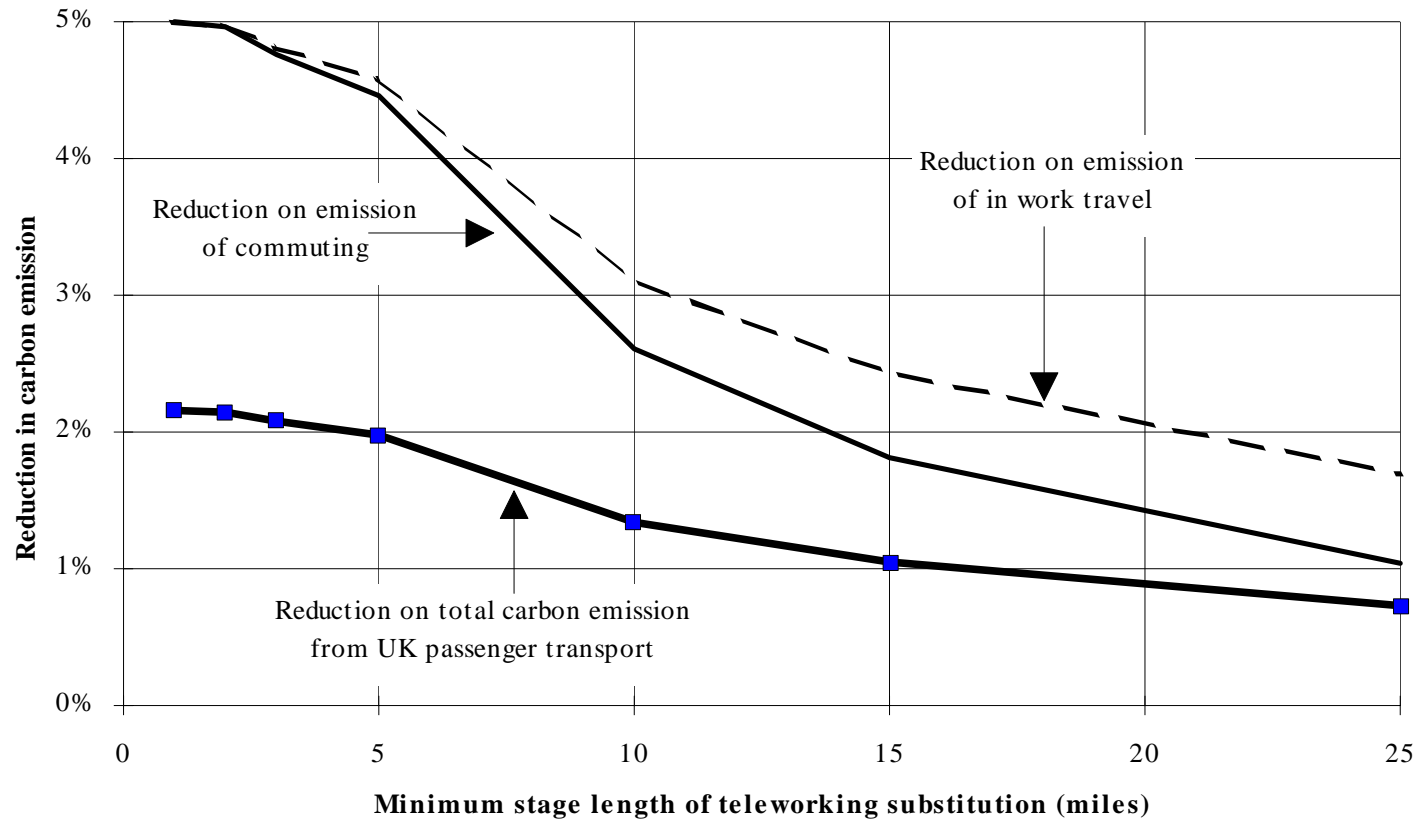
Passenger transport: CO2 by purpose (cum) and stage length (cum)



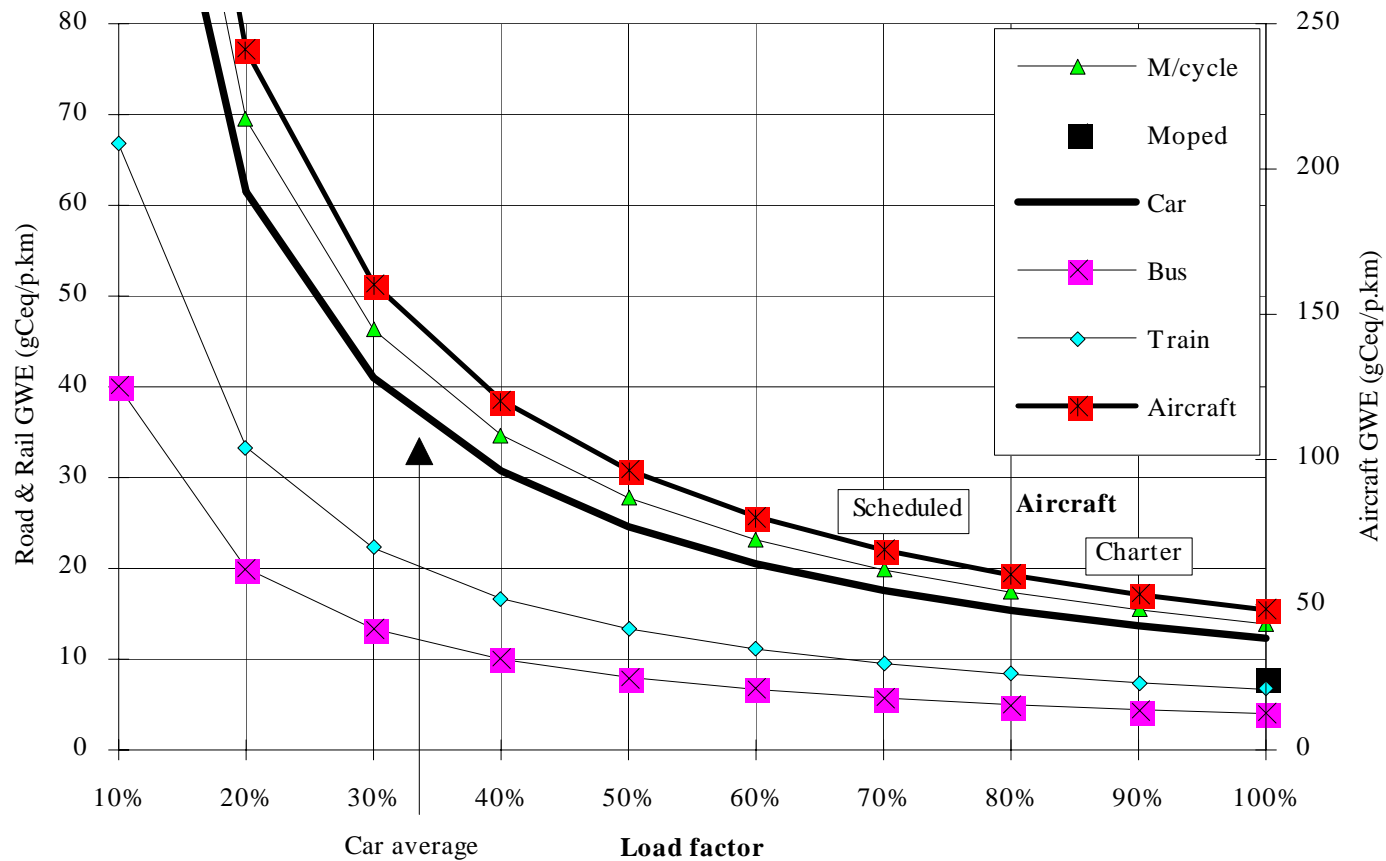
Passenger transport: carbon emission purpose and by trip length



Passenger transport : potential effect of teleworking

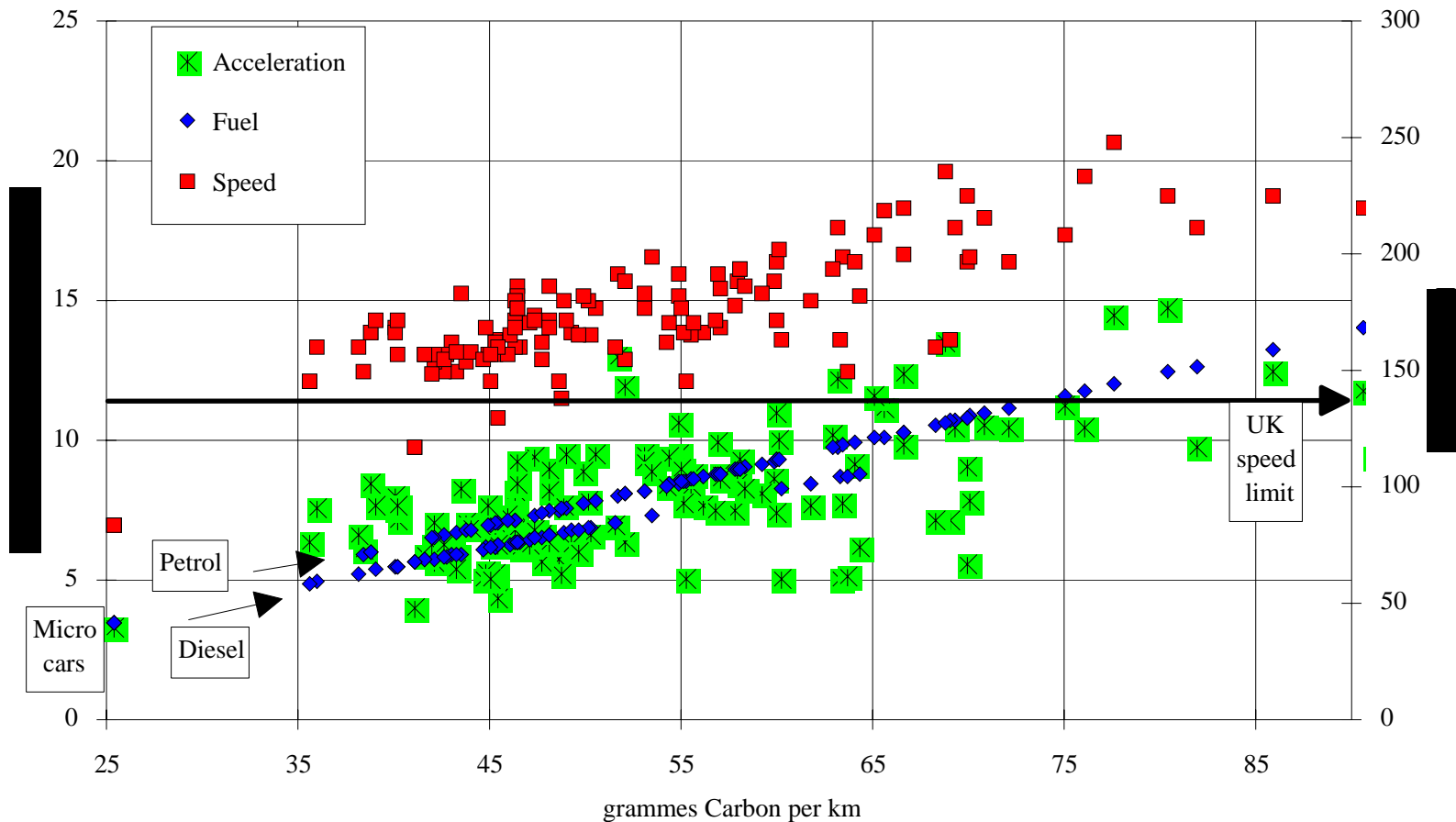


Passenger transport: carbon emission by mode of travel

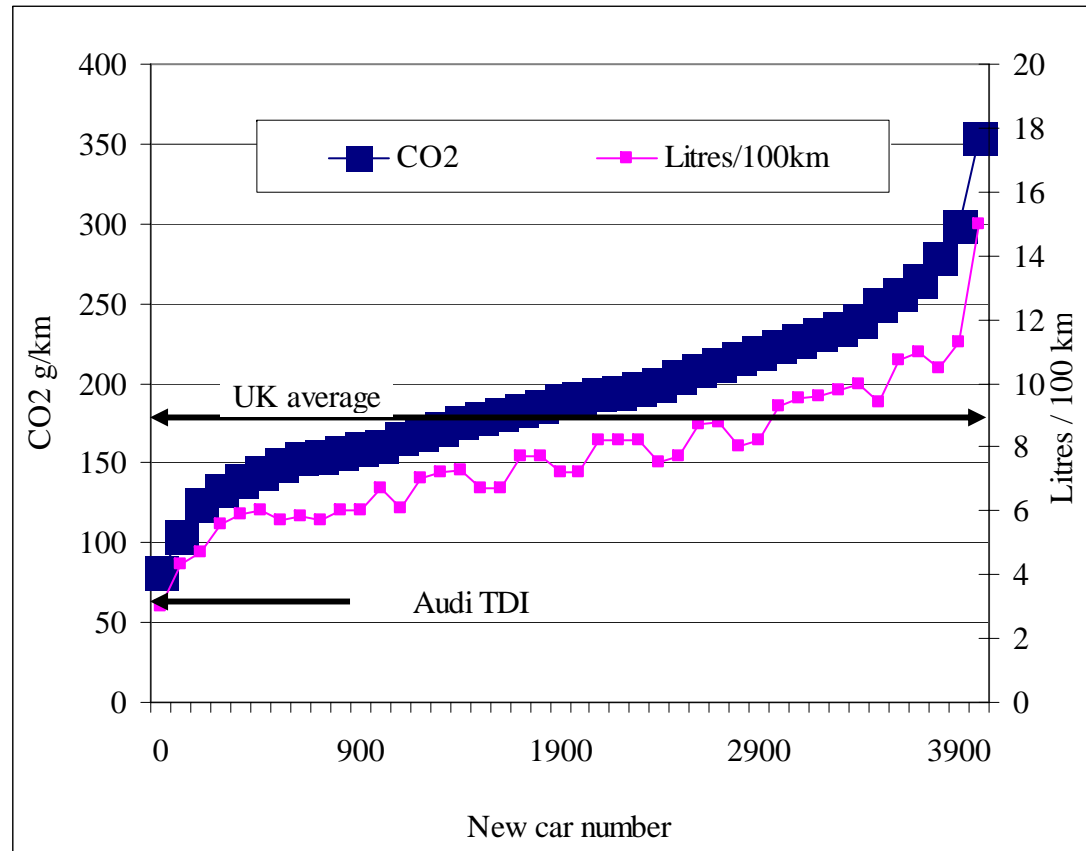


Passenger transport: carbon emission by car performance

Car carbon emissions are strongly related to top speed, acceleration and weight. Most cars sold can exceed the maximum legal speed limit by a large margin. Switching to small cars would reduce car carbon emissions by about 50% in ten years. Switching to micro cars and the best liquid fuelled cars would reduce emissions by about 90% in the longer term.



Passenger transport: car fuel consumption and carbon emission

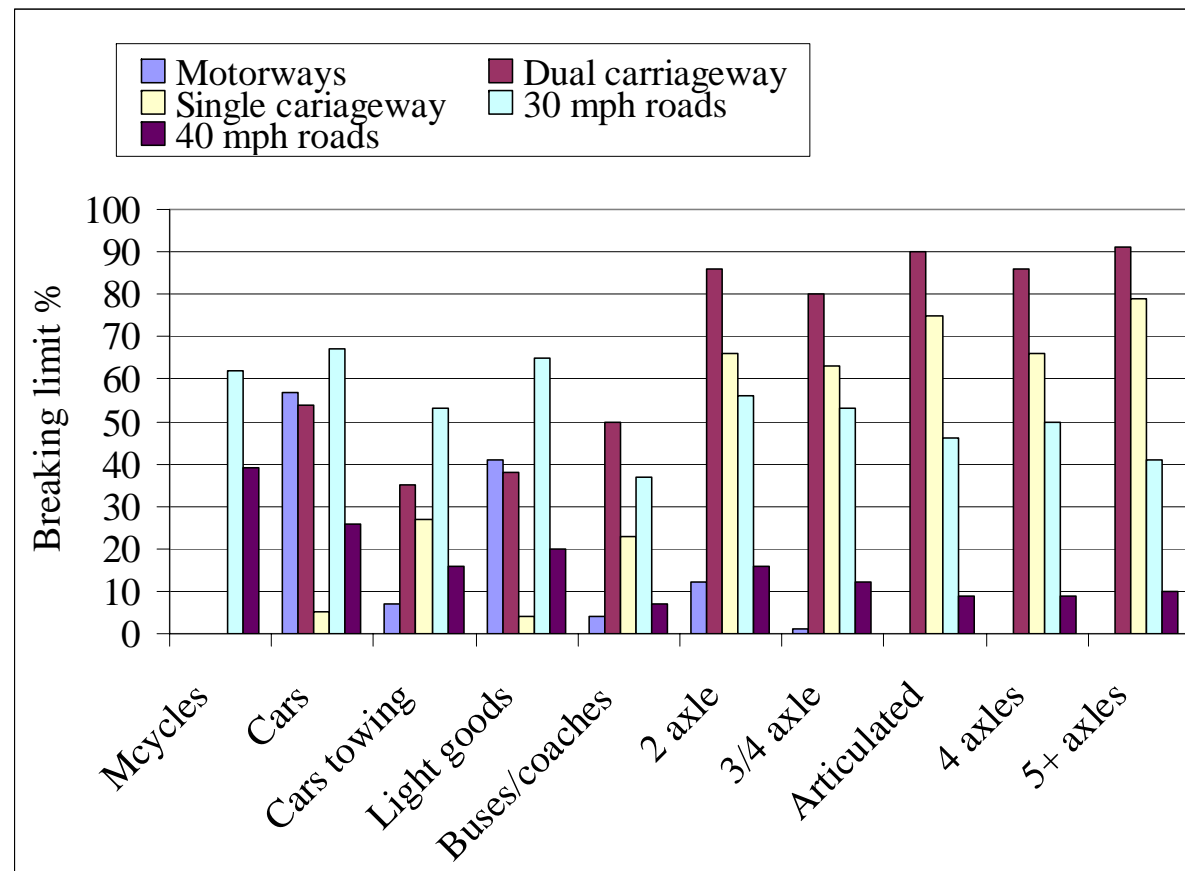


Switching to 5 seat, 95 mph, 3 cylinder Audi Tdi with ~95 mpg combined drive cycle consumption would reduce car stock energy and CO2 by about 60%.

It isn't made any more. A switch to small cars would reduce total UK emissions by 5-10% in 15 years.

Transport: road speeds

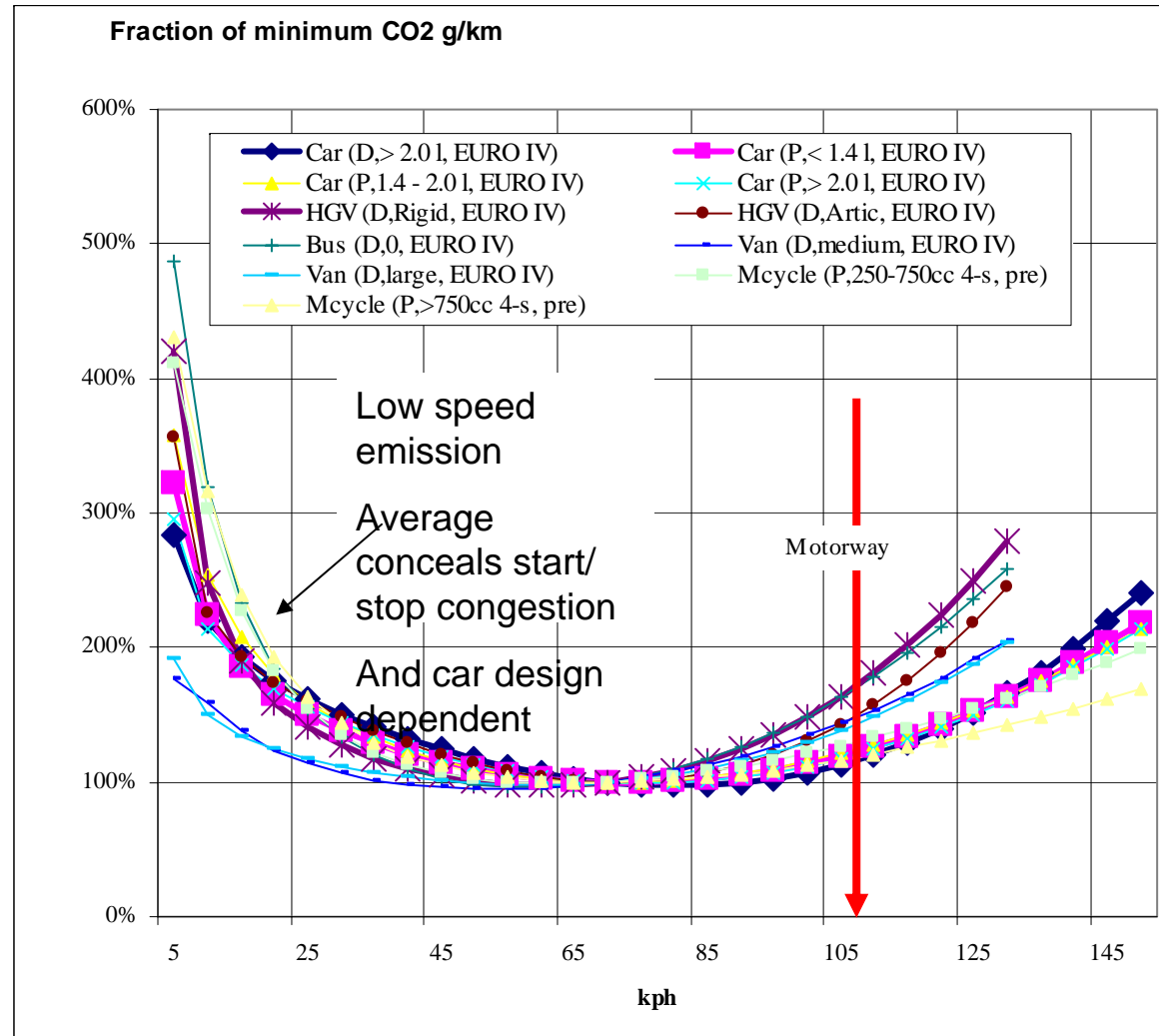
A large fraction (40-50%) of vehicles break the speed limits on all road types. This law-breaking increases carbon and other emissions, and death and injury due to accident. Enforcing the existing limits, and reducing them, would significantly reduce emissions and injury.



Transport: road speed and CO2 emission

Energy use and carbon emissions increase strongly with speed. Curves for other pollutants generally similar, because emission strongly related to fuel consumption.

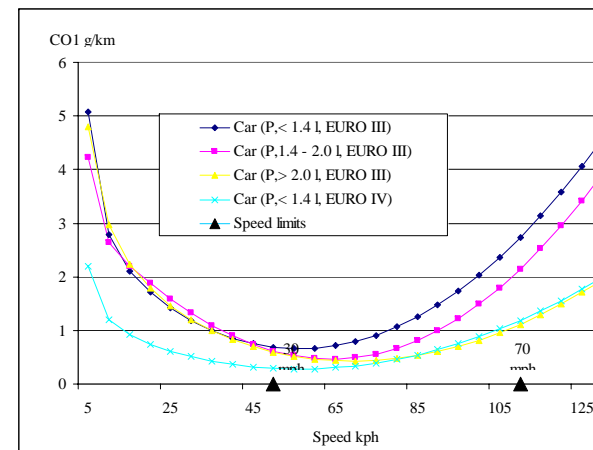
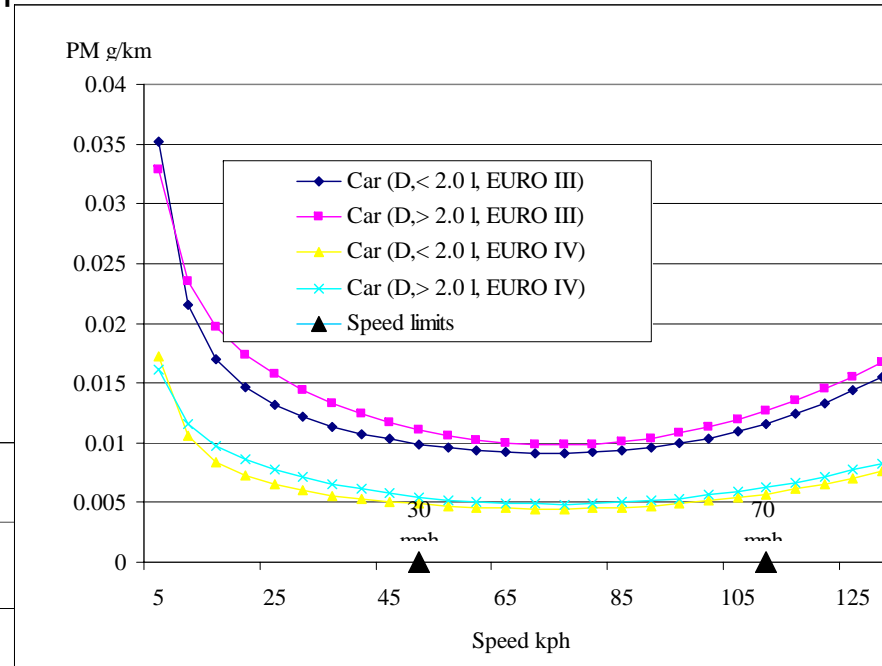
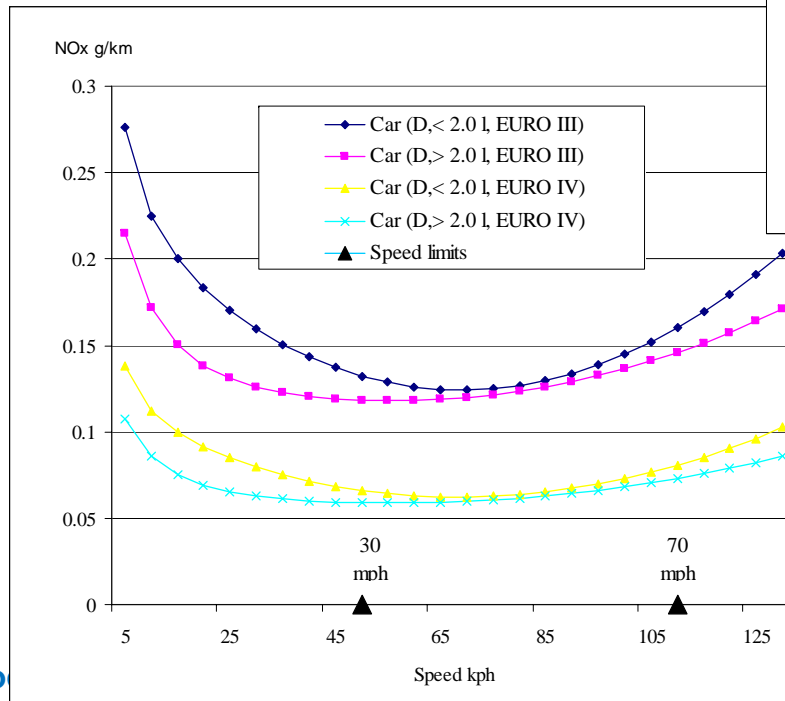
These curves are only applicable to current internal combustion vehicles. Characteristics of future vehicles (e.g. urban internal combustion and electric powered) would be different. Minimum emission would probably be at a lower speed, and the fuel consumption and emissions at low speeds would not show the same increase.



Transport: road speed and other emissions

The emissions of PM, NO_x and CO generally increase at higher speeds and lower speeds.

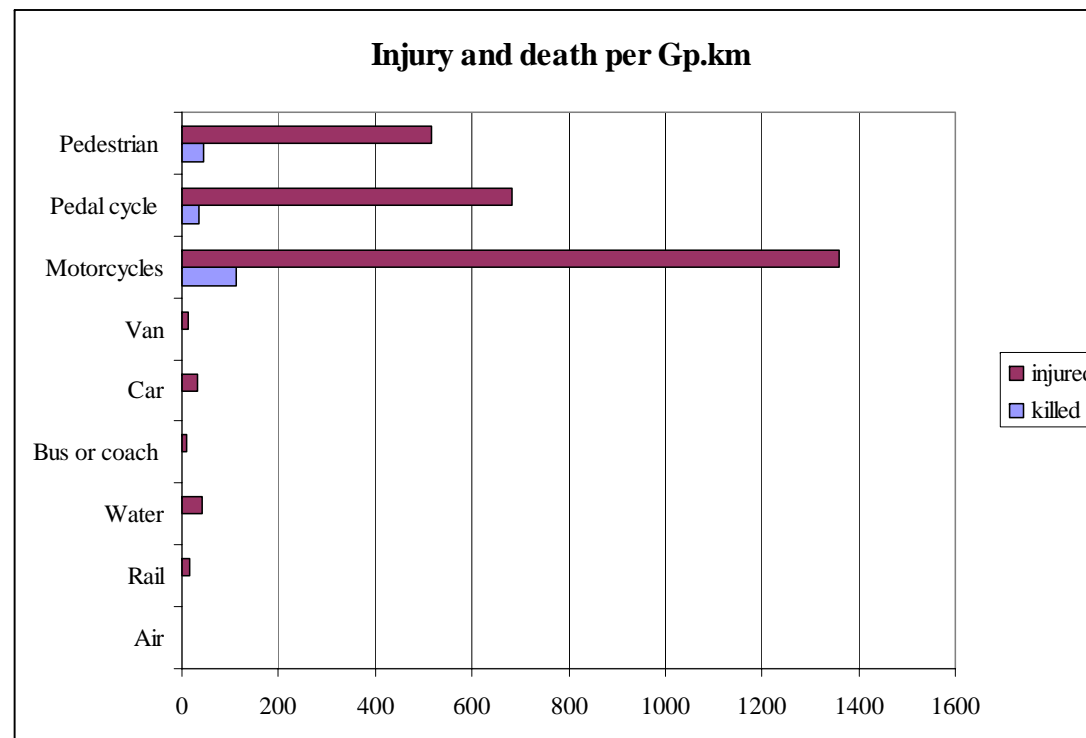
So: less speed on motorways and more speed because of less congestion both lead to lower emission



So

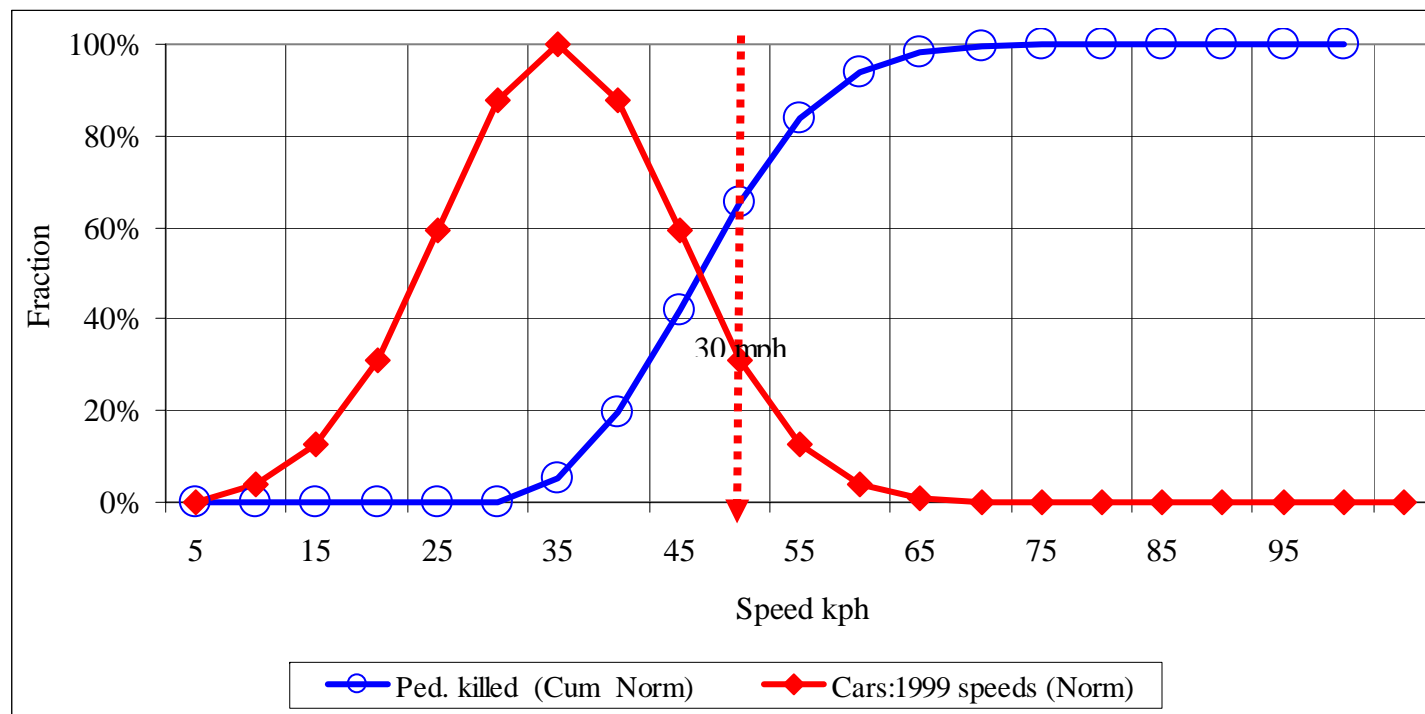
Passenger transport: risk of injury by mode by distance

A major reason for modal choice is risk of injury and death. A child has 10-20 times the risk going to school by foot or bicycle as compared to going in a car. From TSGB tab 1.7



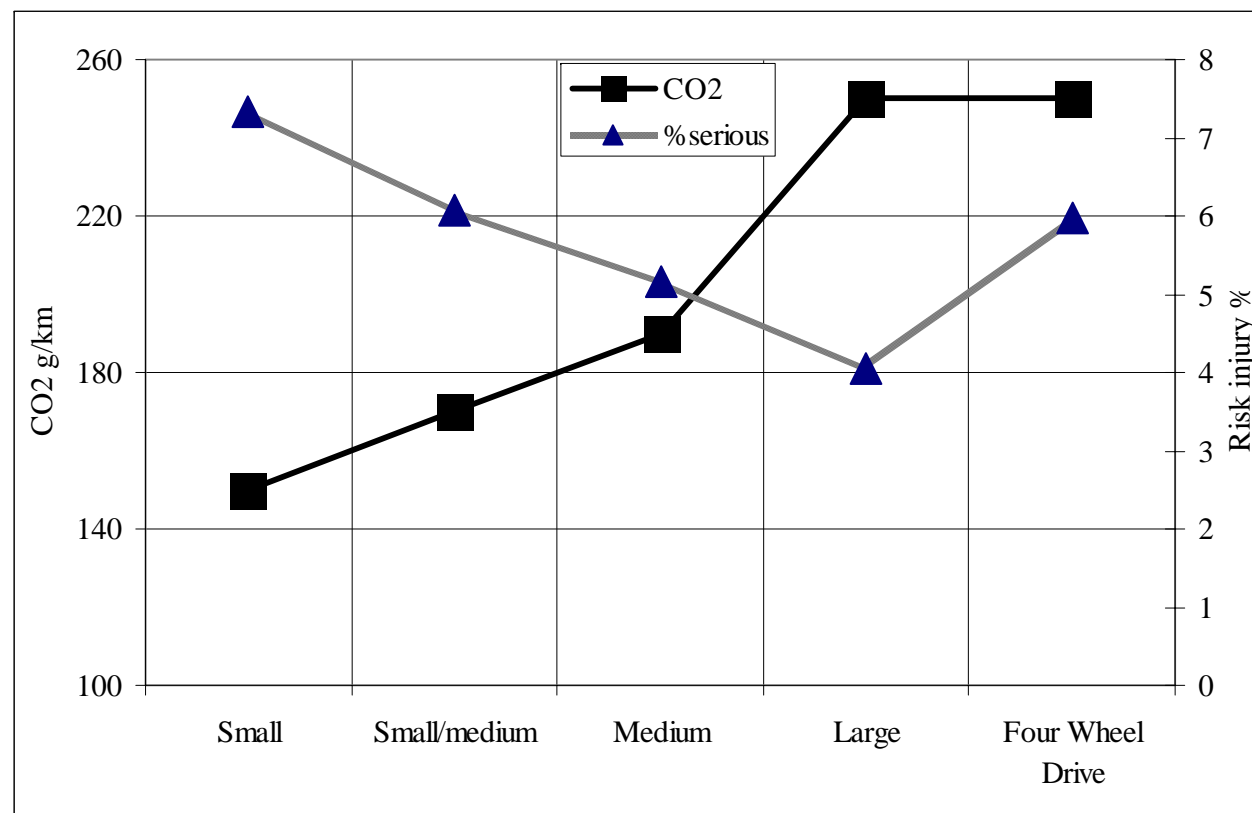
Transport: speed and death

Increasing speed increases accident rate and injury



Passenger transport: Risk of injury to car drivers involved in accidents between two cars

Cars that are big CO₂ emitters are most dangerous because of their weight, and because they are usually driven faster. In a collision between a small and a large car, the occupants of the small car are much more likely to be injured or killed. The most benign road users (small cars, cyclists, pedestrians) are penalised by the least benign.



Vehicle energy supply pathway efficiencies

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Delivered Transform				Gas 85%	Electricity 70%				
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Vehicle	Input	Liquid	Liquid	Hydrogen	Hydrogen	Electricity	Electricity	Electricity	
	Store	Input Tank	100% Tank	100% Tank	100% Tank	100% Tank	90% Battery	90% Battery	90% Battery
	Conversion	Output Liquid	100% Liquid	100% Liquid	100% Electricity	100% Electricity	90% Electricity	90% Electricity	90% Electricity
	Engine to motive power		35%	35%	90%	90%	90%	90%	90%
	Overall Primary to power		33%	17%	34%	26%	68%	20%	20%

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Further analysis: electric vehicles

Electric (EV) or hybrid electric/liquid fuelled (HELV) vehicles are a key option for the future because liquid (and gaseous) fossil fuels emit carbon, will become more scarce and expensive and are technically difficult to replace in transport, especially in aircraft.

Electric vehicles such as trams or trolley-buses draw energy whenever required but they are restricted to routes with power provided by rails or overhead wires. Presently there are no economic and practical means for providing power in a more flexible way to cars, consequently electric cars have to store energy in batteries. The performance in terms of the range and speed of EVs and HELVs is improving steadily such that EVs can meet large fraction of typical car duties; the range of many current electric cars is 100-200 miles. A major difficulty with EVs is recharging them. At present, car mounted photovoltaic collectors are too expensive and would provide inadequate energy, particularly in winter, although they may eventually provide some of the energy required.

Because of these problems it may be envisaged that HELVs will first supplant liquid fuelled vehicles, with an increasing fraction of electric fuelling as technologies improve.

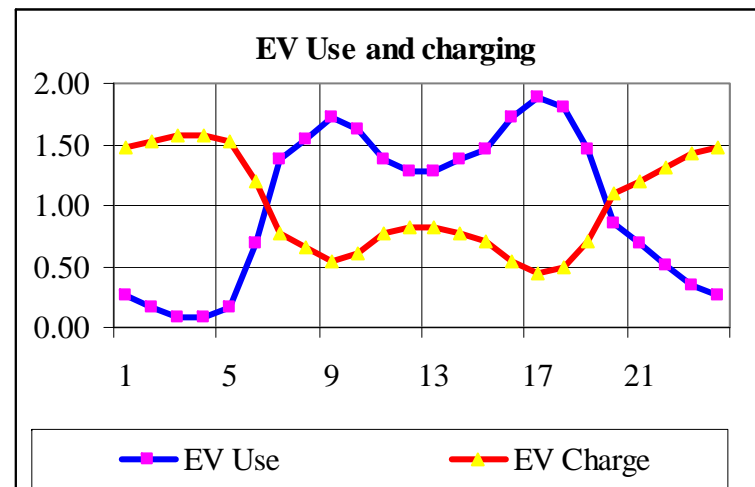
Hydrogen is much discussed as a transport fuel, but the overall efficiency from renewable electricity to motive power via hydrogen is perhaps 35%, whereas via a battery it might be 70%. For this reason, hydrogen is not currently included as an option. If the efficiency difference were narrowed, and the refuelling and range problems of EVs are too constraining, then hydrogen should be considered further.

Further analysis: electric vehicles

The logistics and economics of these options are complex to explore, especially with HELVs, and the best compromise might be some combination of the refuelling options.

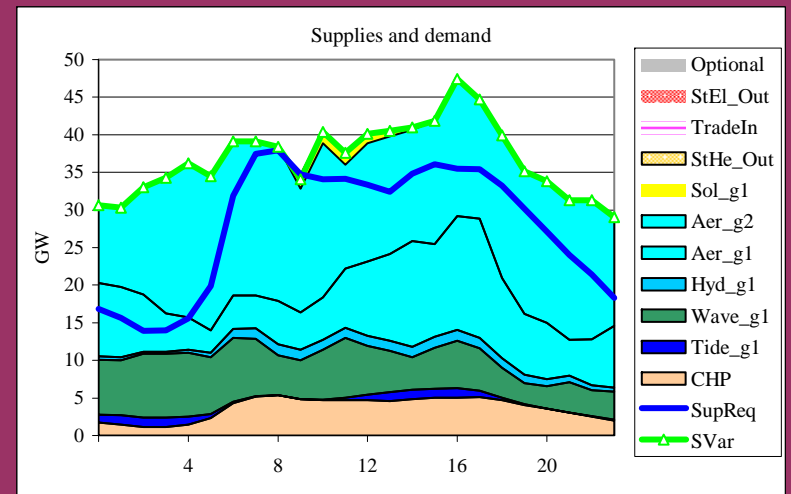
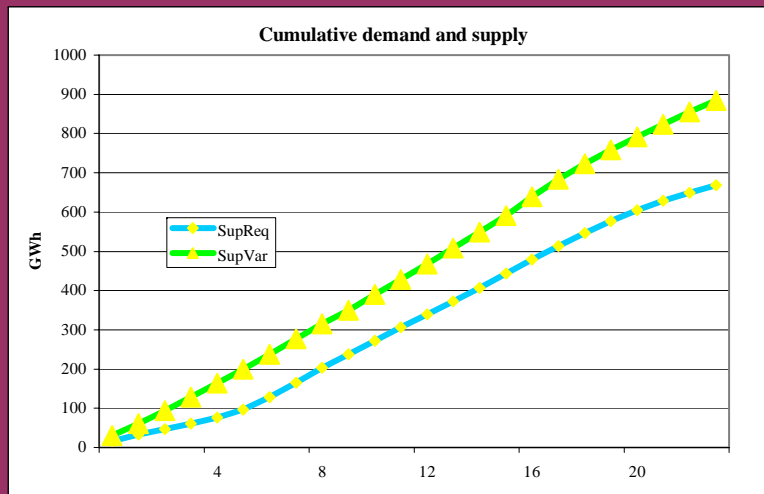
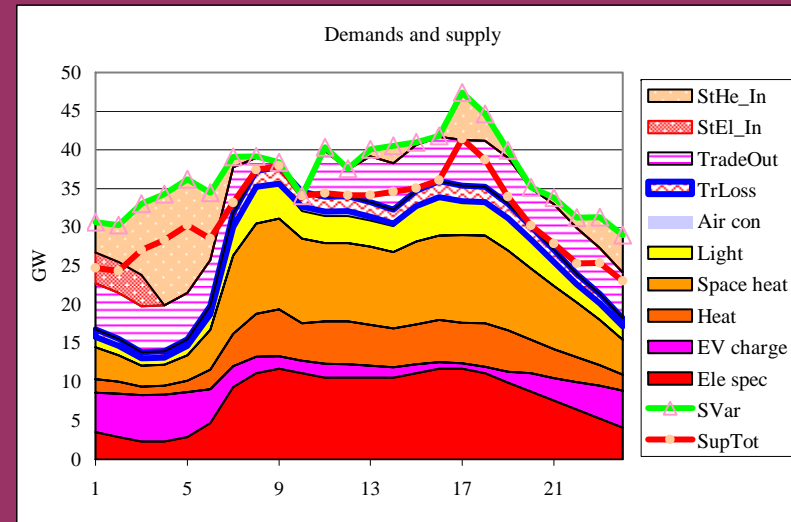
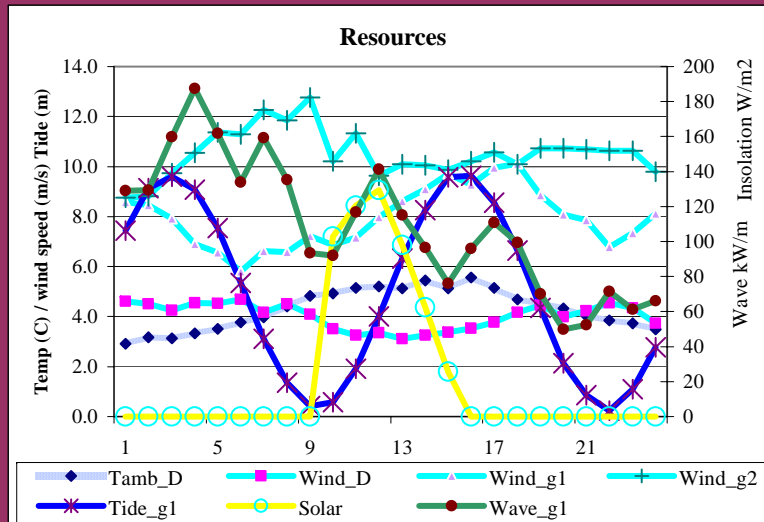
If hydrogen were to be competitive with electricity on economic or technical grounds, it would make little difference to the optimisation since, from the electricity system 'viewpoint', hydrogen in fuel cells is more or less indistinguishable from electricity storage in batteries.

Currently, in **Green Light** it is simply assumed that the diurnal pattern of electric vehicle (EV) use reflects typical car traffic pattern, and that the demand for battery charging is the mirror image of this; EVs are connected for charging when they are not in use.



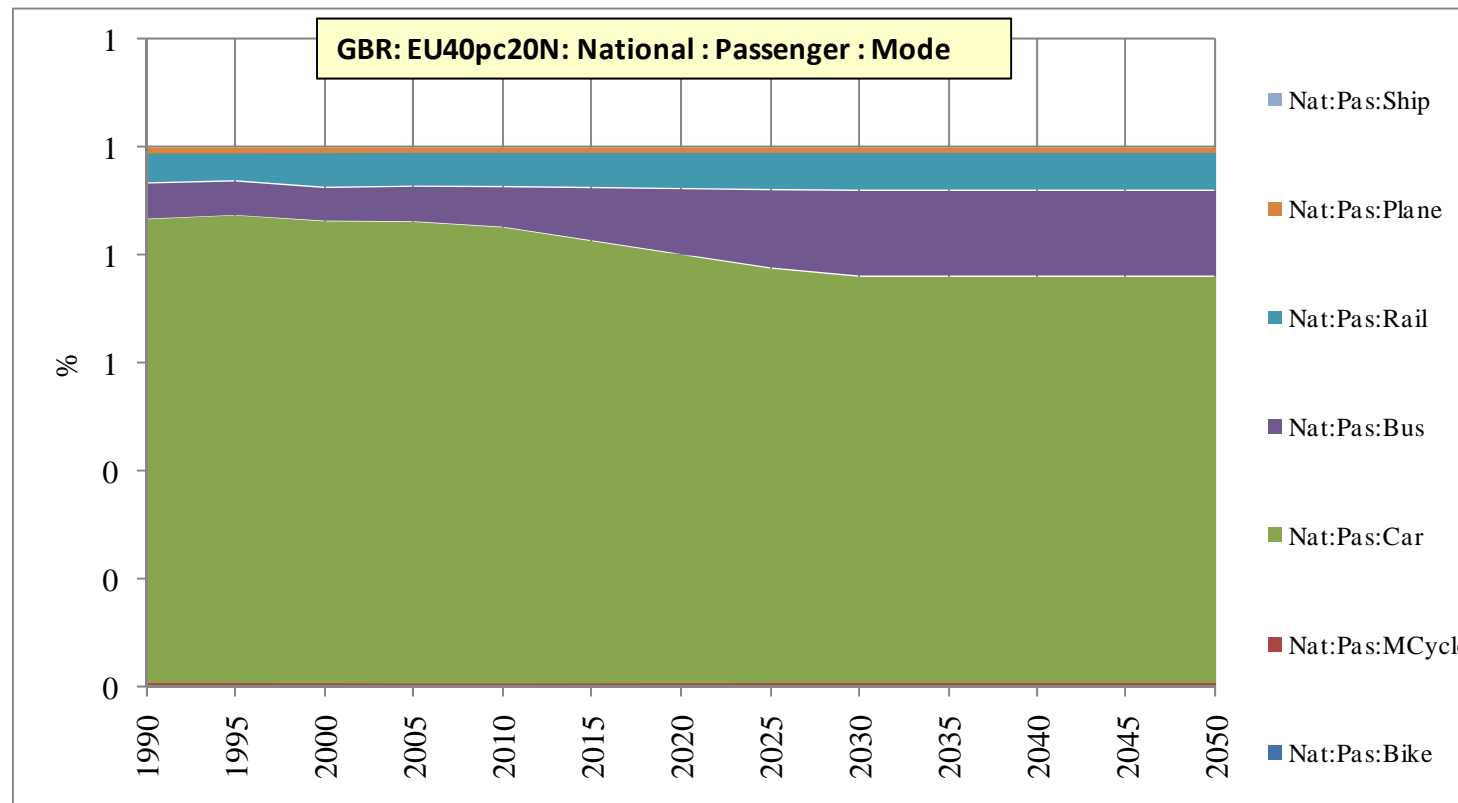
VarInt : Sample day : winter's day of variable supply excess

SENCO Energy, space, time model Demand and supply day sampling Month 1 Dummy data Days sampled 1



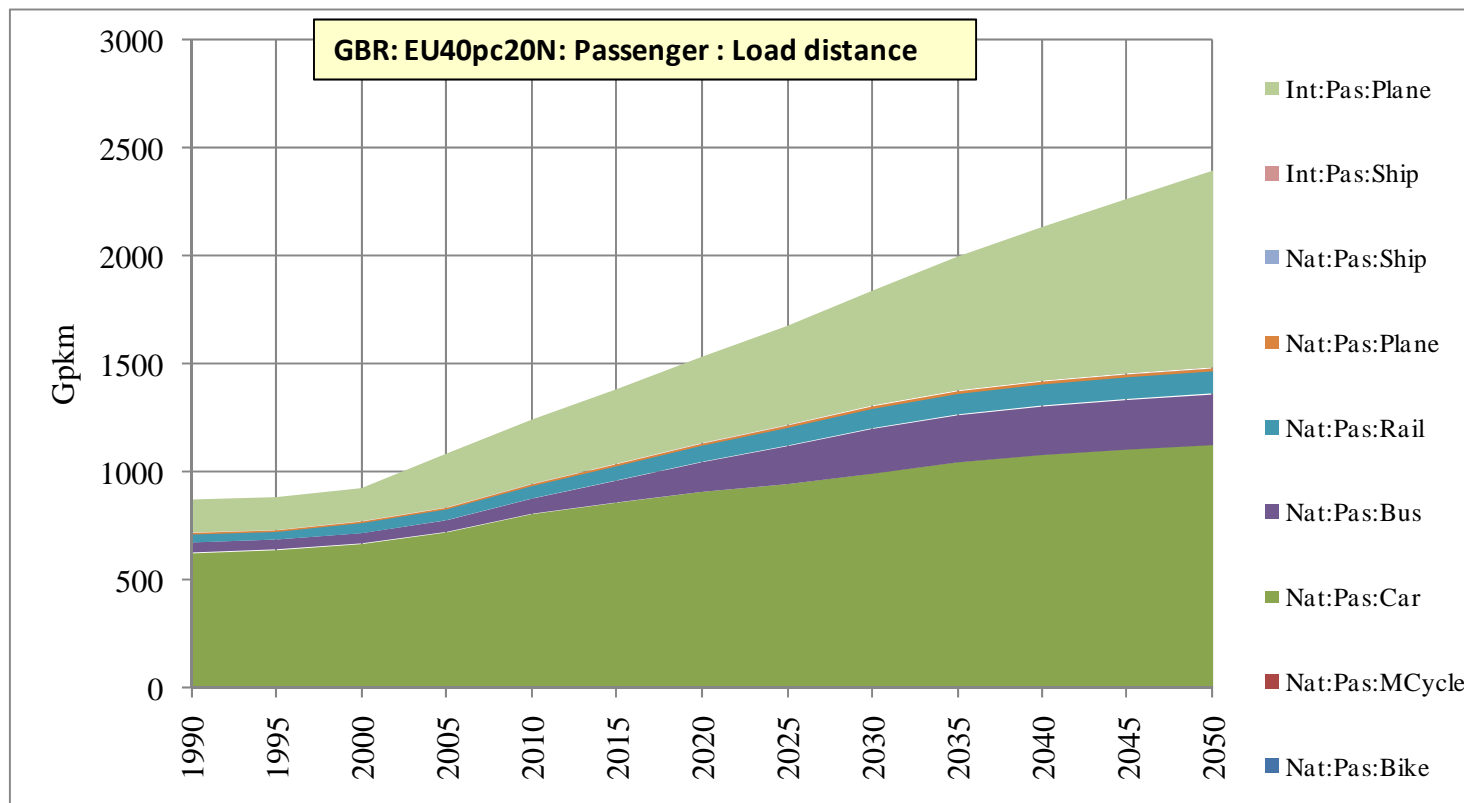
Transport, national: passenger mode

A shift from car to fuel efficient bus and train for commuting and longer journeys is assumed. The scope for modal shift from air to surface transport is very limited without the development of alternative long distance transport technologies.



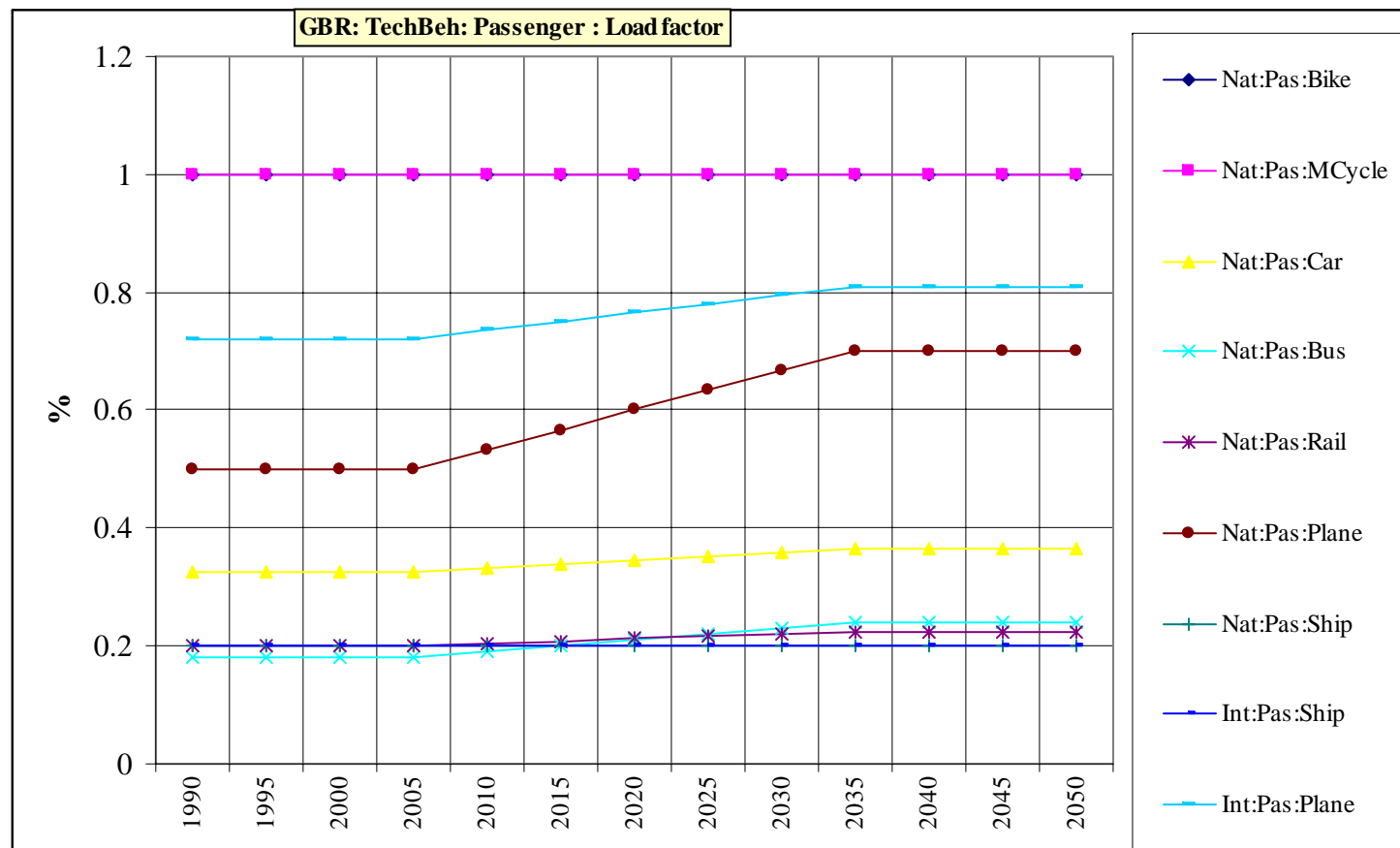
Transport: passenger demand by mode and vehicle type

Demand depends on complex of factors: demographics, wealth, land use patterns, employment, leisure travel.
National surface demand is limited by time and space, but aviation is not so limited by these factors.

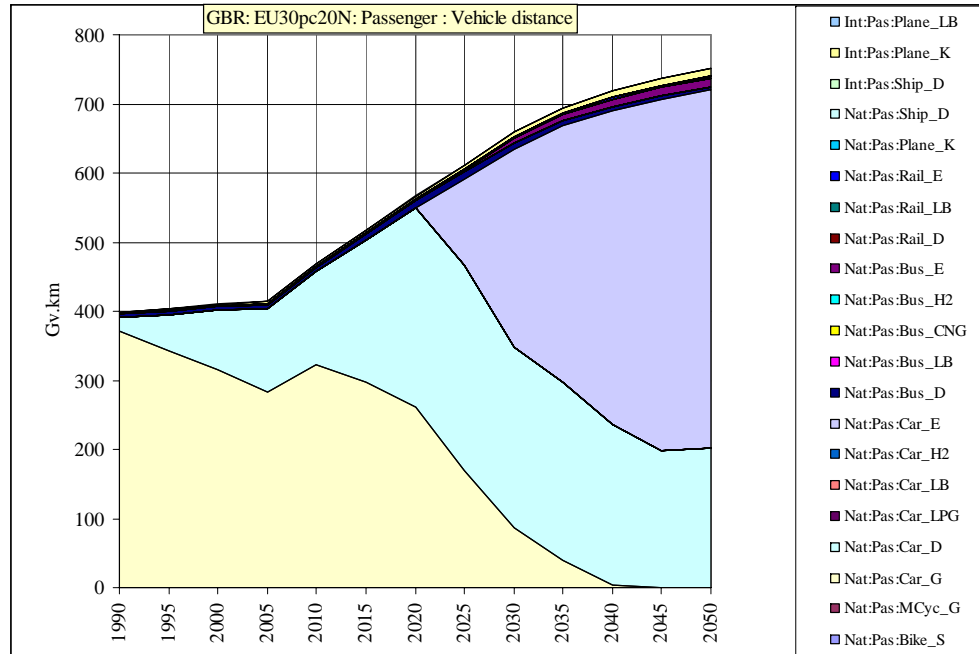


Transport: passenger vehicle load factor

- Load factors of vehicles, especially aircraft, assumed to increase through logistical change.
- Vehicle load capacities (passengers/vehicle; tonnes/truck) assumed unchanged.

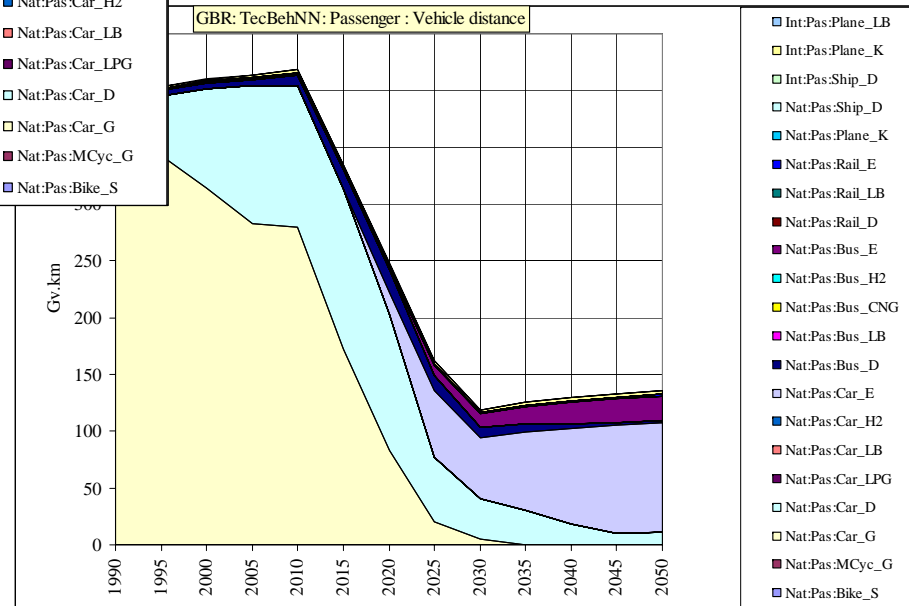


SEEScen sample: Transport: passenger vehicle distance



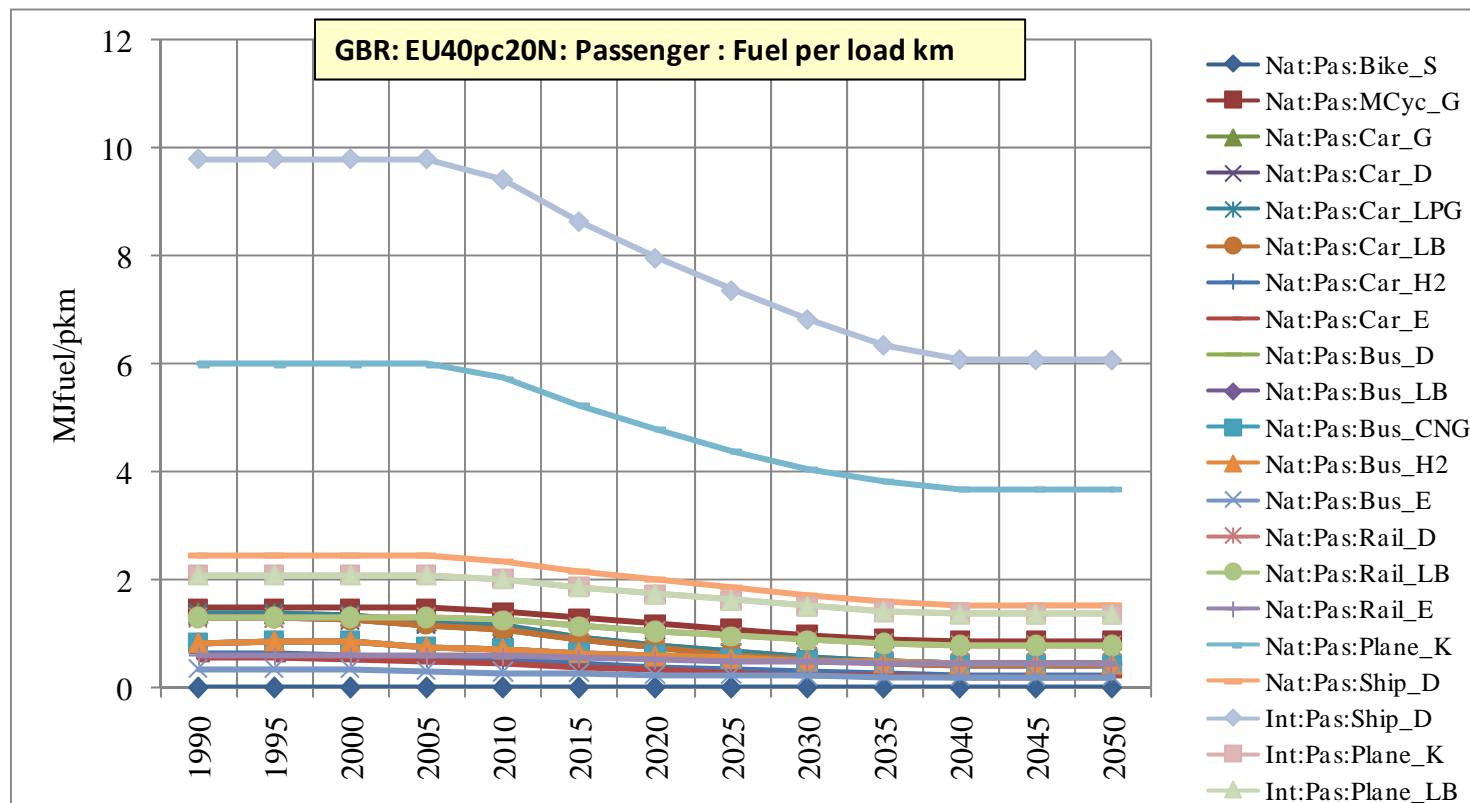
Demand management and modal shift can produce a large reduction in road traffic reduces congestion which gives benefits of less energy, pollution and travel time.

Assumed introduction of electric vehicles to replace liquid fuels, and reduce urban air pollution.



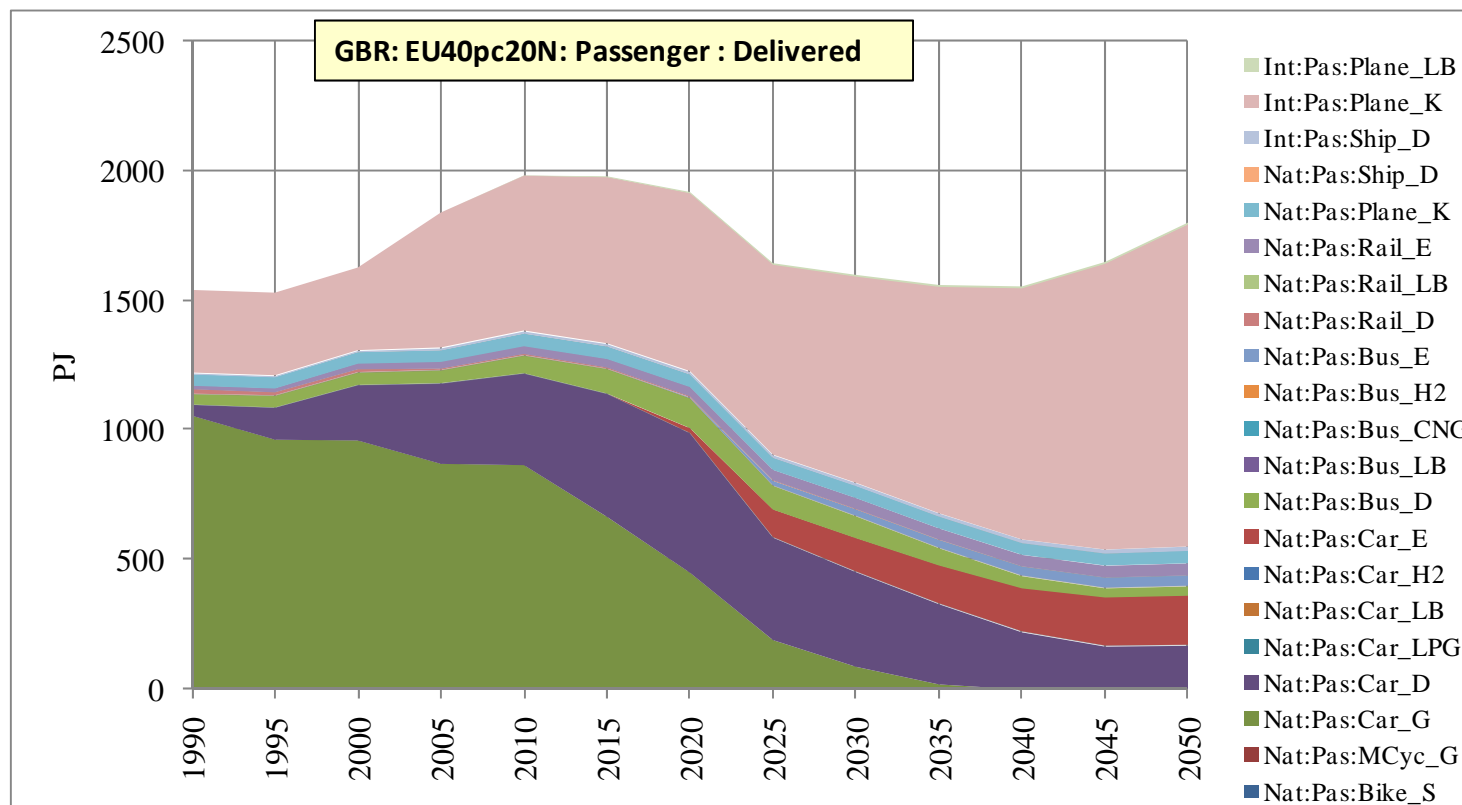
Transport: passenger: fuel per passenger km

Reductions in fuel use because of technical improvement, better load factors, lower speeds, and less congestion.



Transport: passenger: delivered energy

Future passenger energy use dominated by international air travel.



Freight transport: Overview

Demand for transport:

- Purpose, distance, trip length, mode

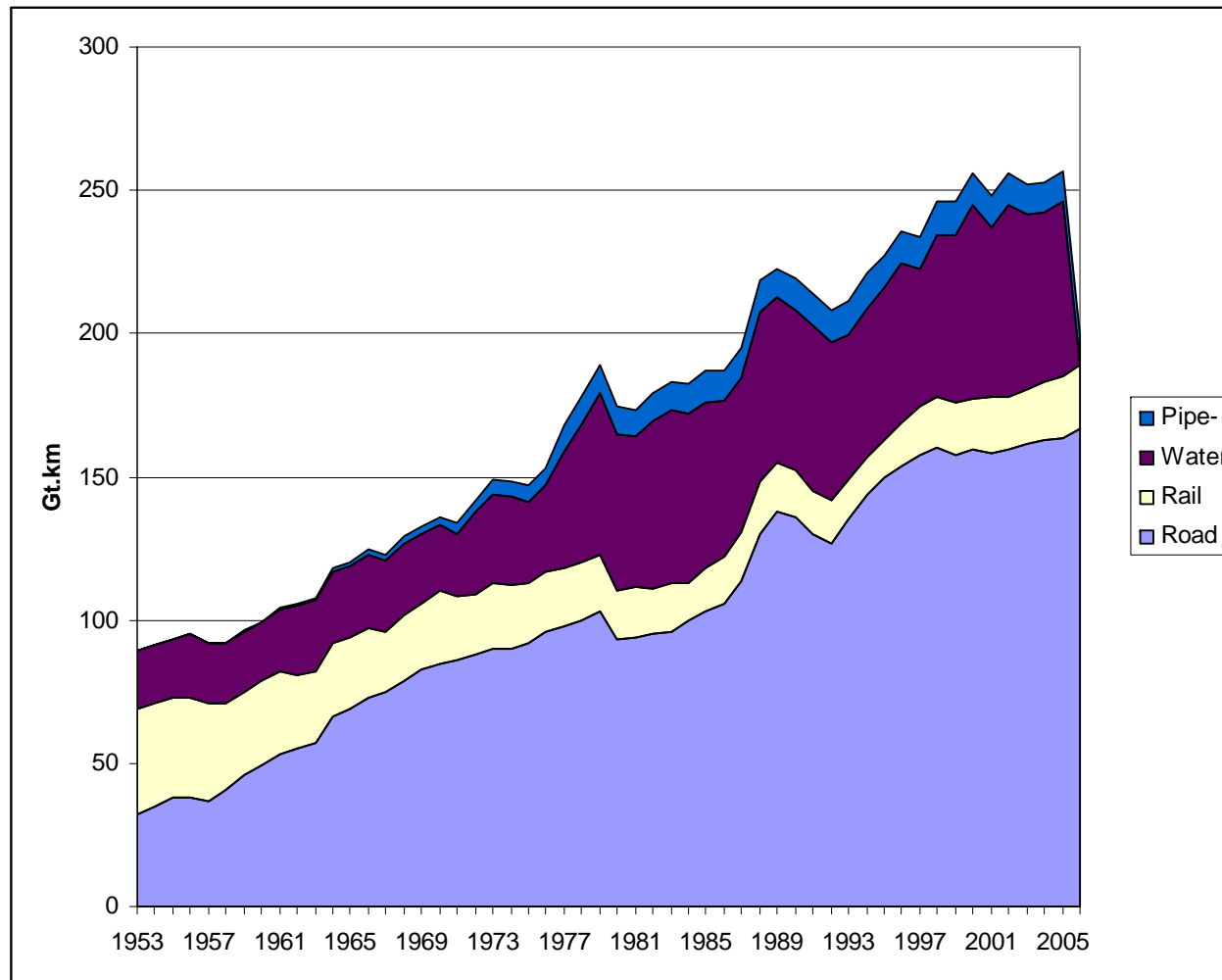
Technology

- Vehicle choice
 - Size, power, fuel
- Vehicle use
 - Speed, occupancy, load factor

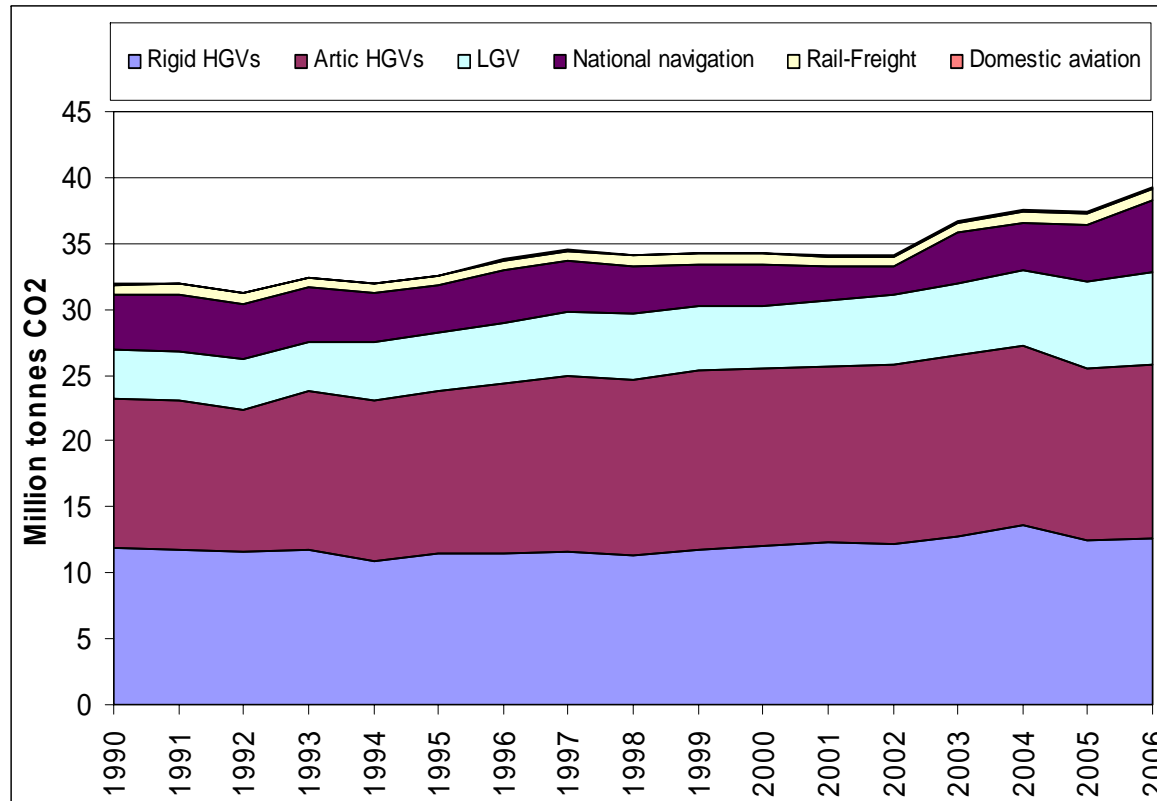
‘Externalities’

- Safety
- Social dislocation, equity
- Impacts, climate change, air pollution noise ...

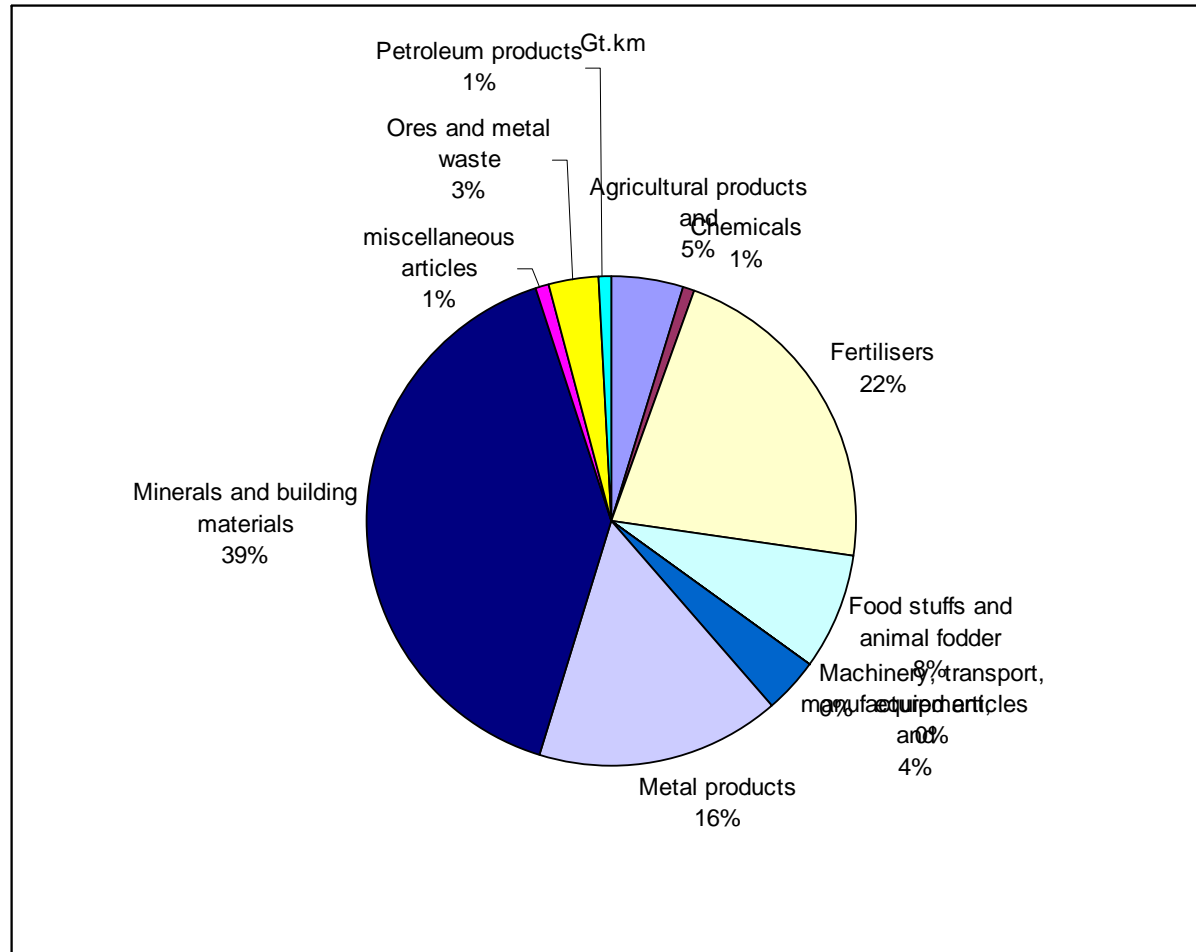
Freight transport : history



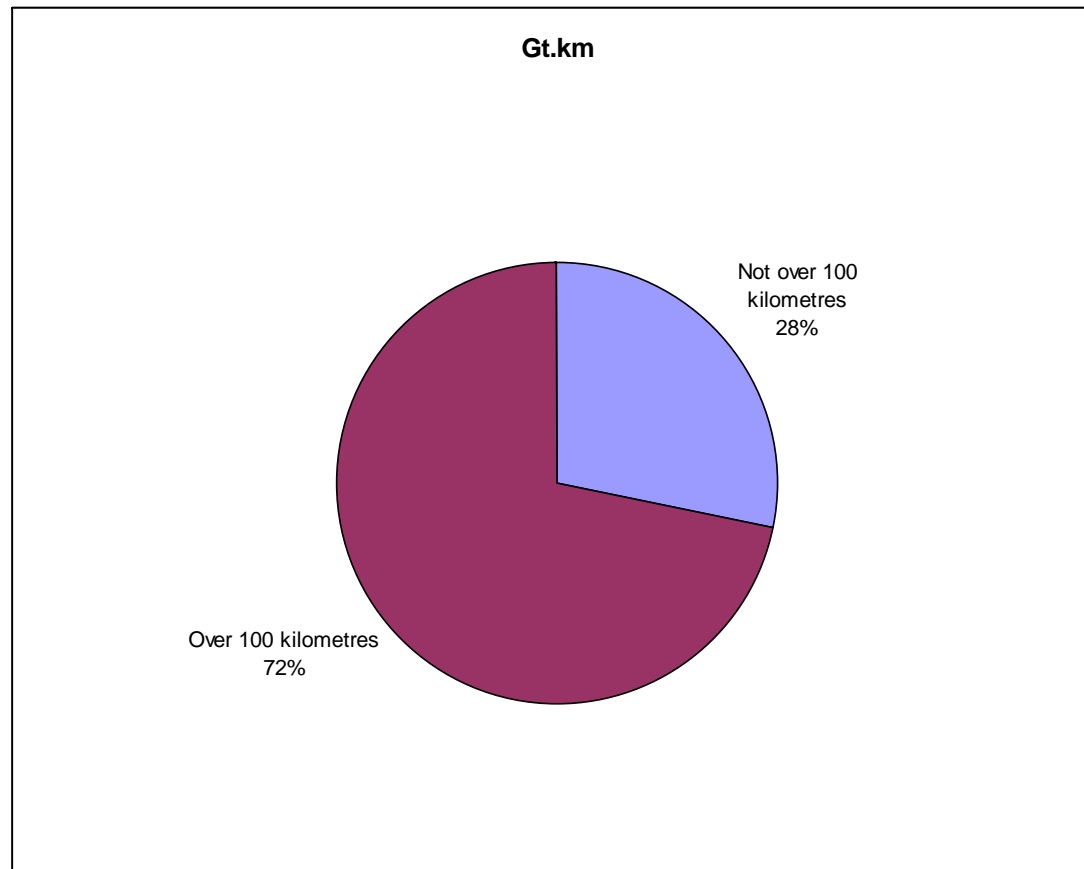
Freight transport : Historic emissions from freight (all modes exc pipes)



Freight transport : tonne km by commodity

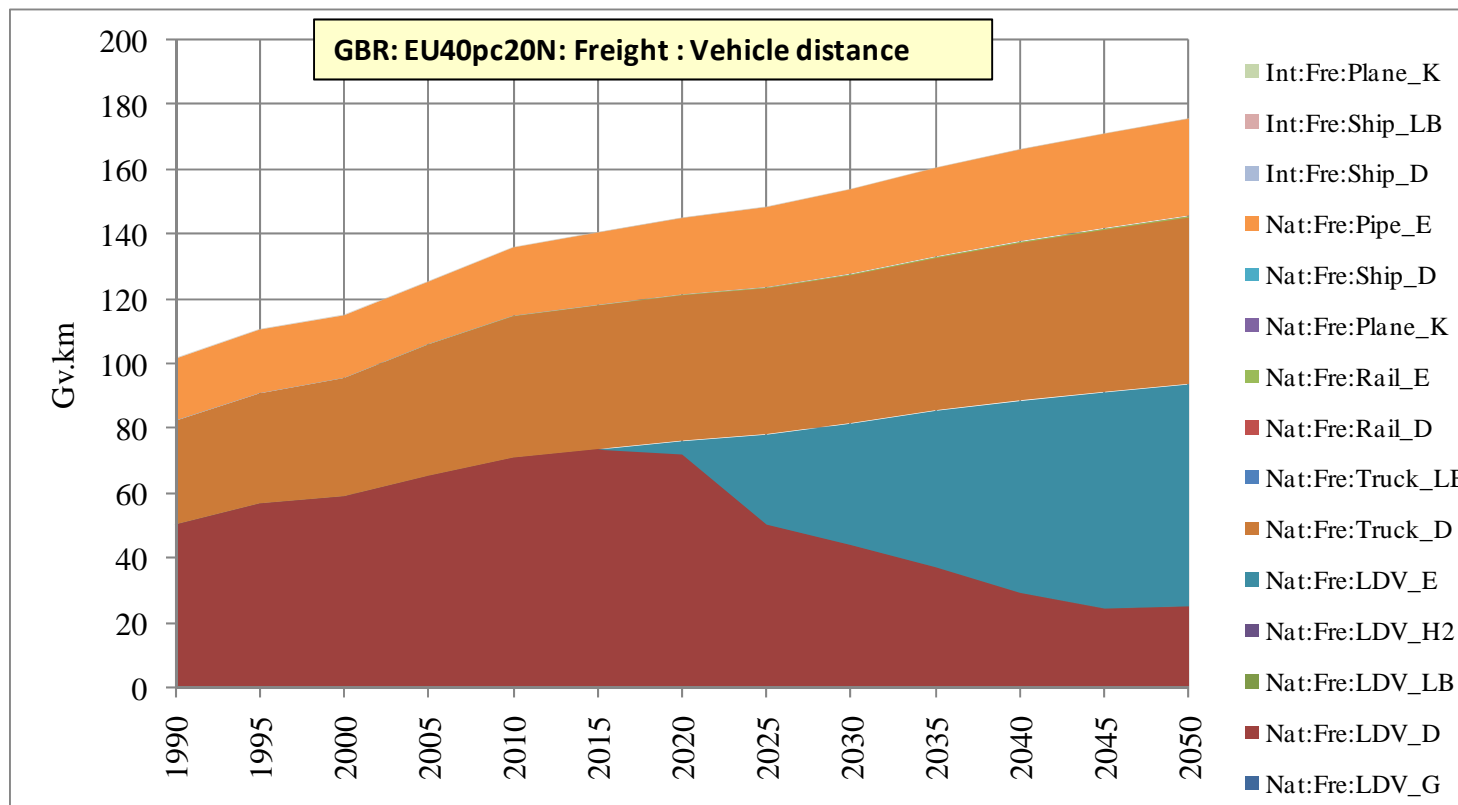


Freight transport : tonne km by distance



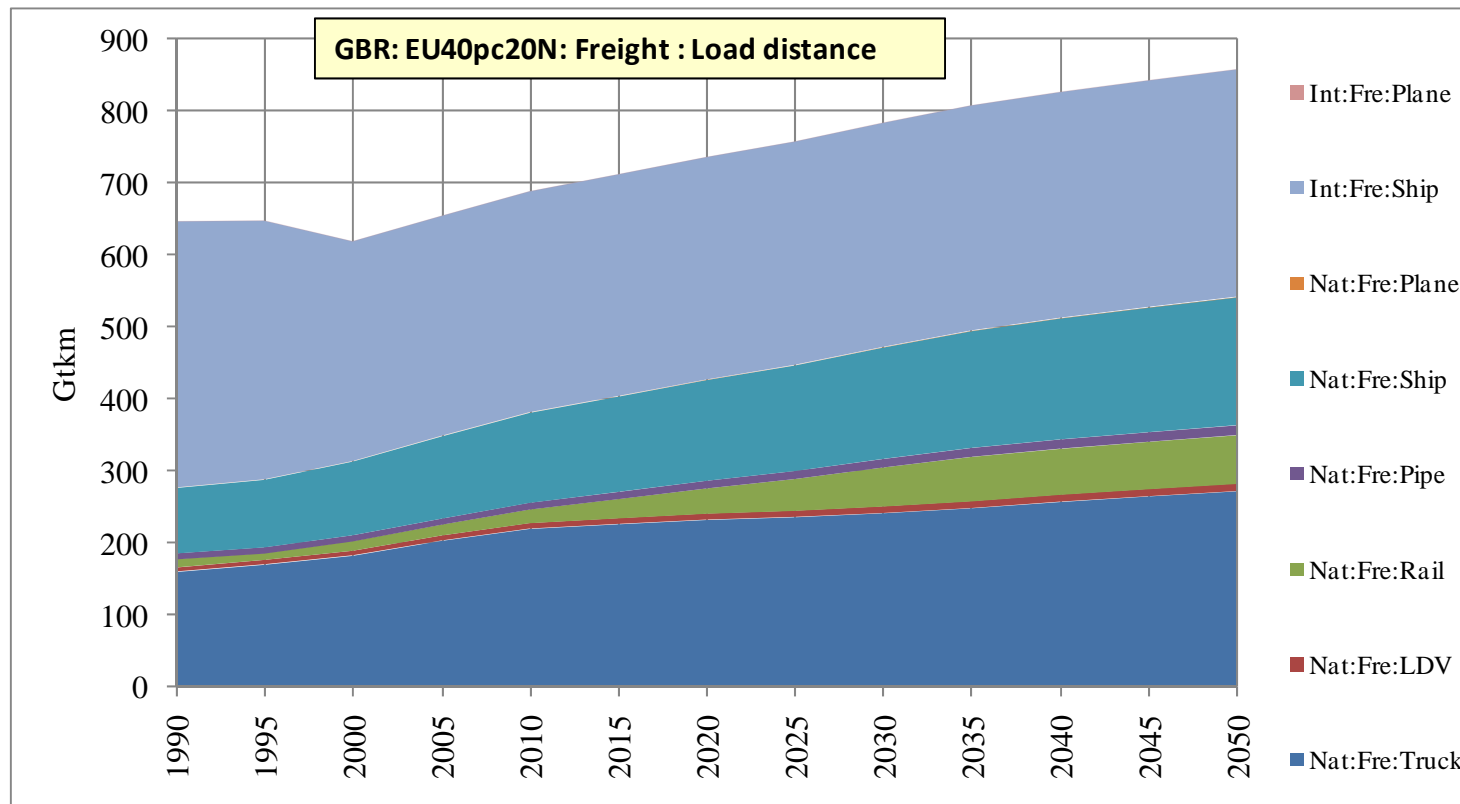
Transport: freight vehicle distance

Some growth in freight vehicle distance. Vehicle capacities and load factors important assumptions



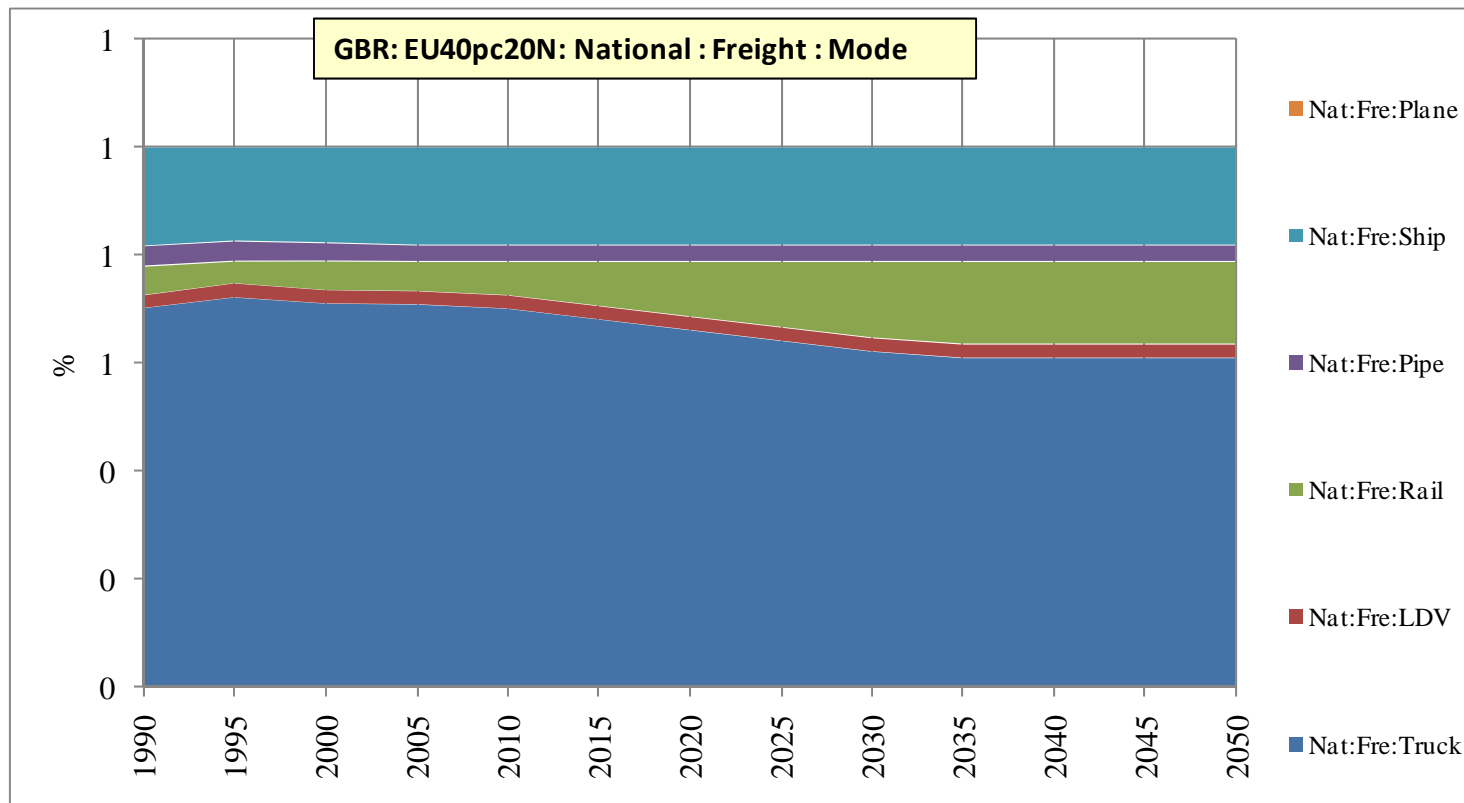
Transport: freight demand by mode and vehicle type

The scope for load distance reduction through logistics and local production is not assessed. International freight is estimated.



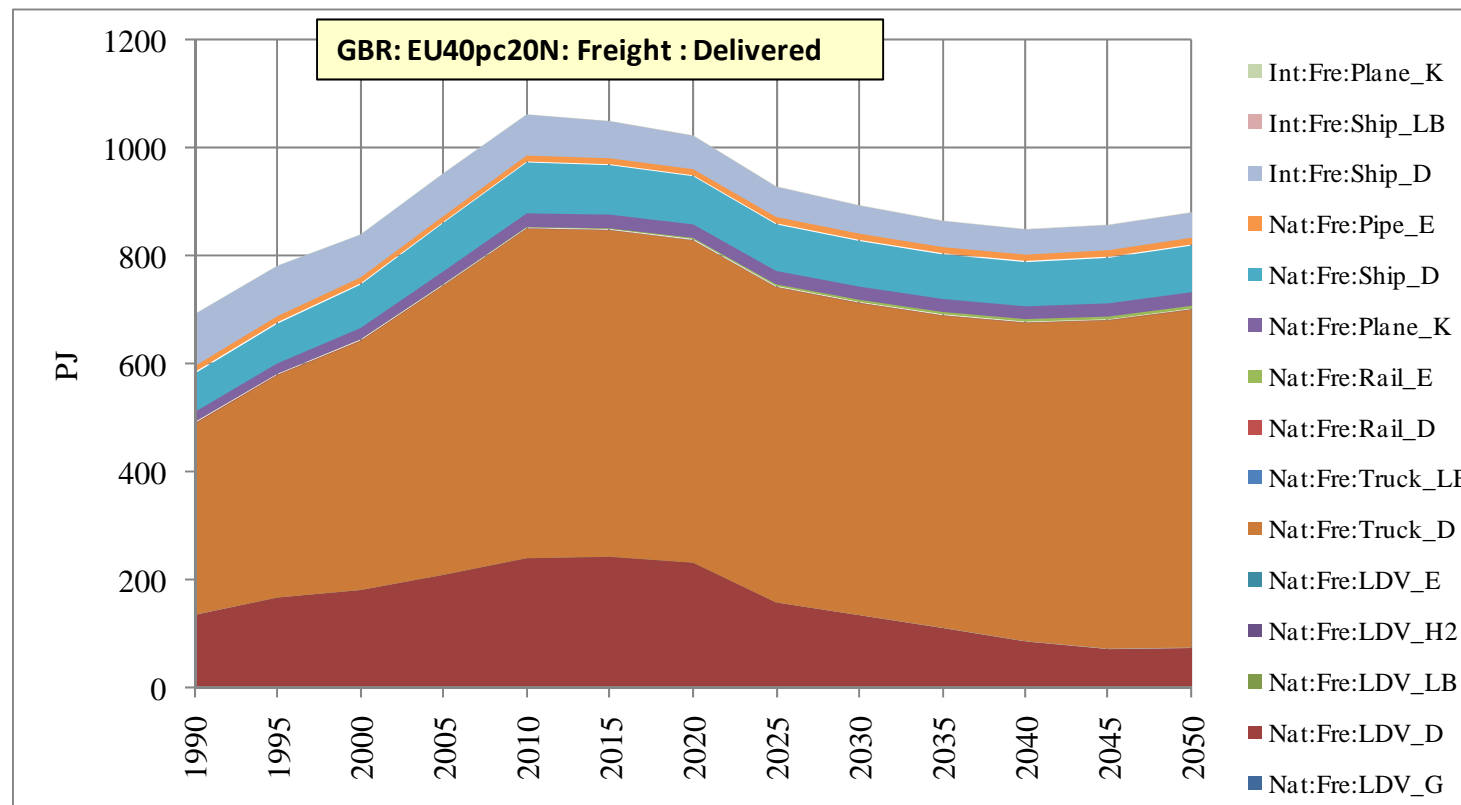
Transport: national : freight mode

Shift from truck to rail. Currently, no assumed shift to inland and coastal shipping.



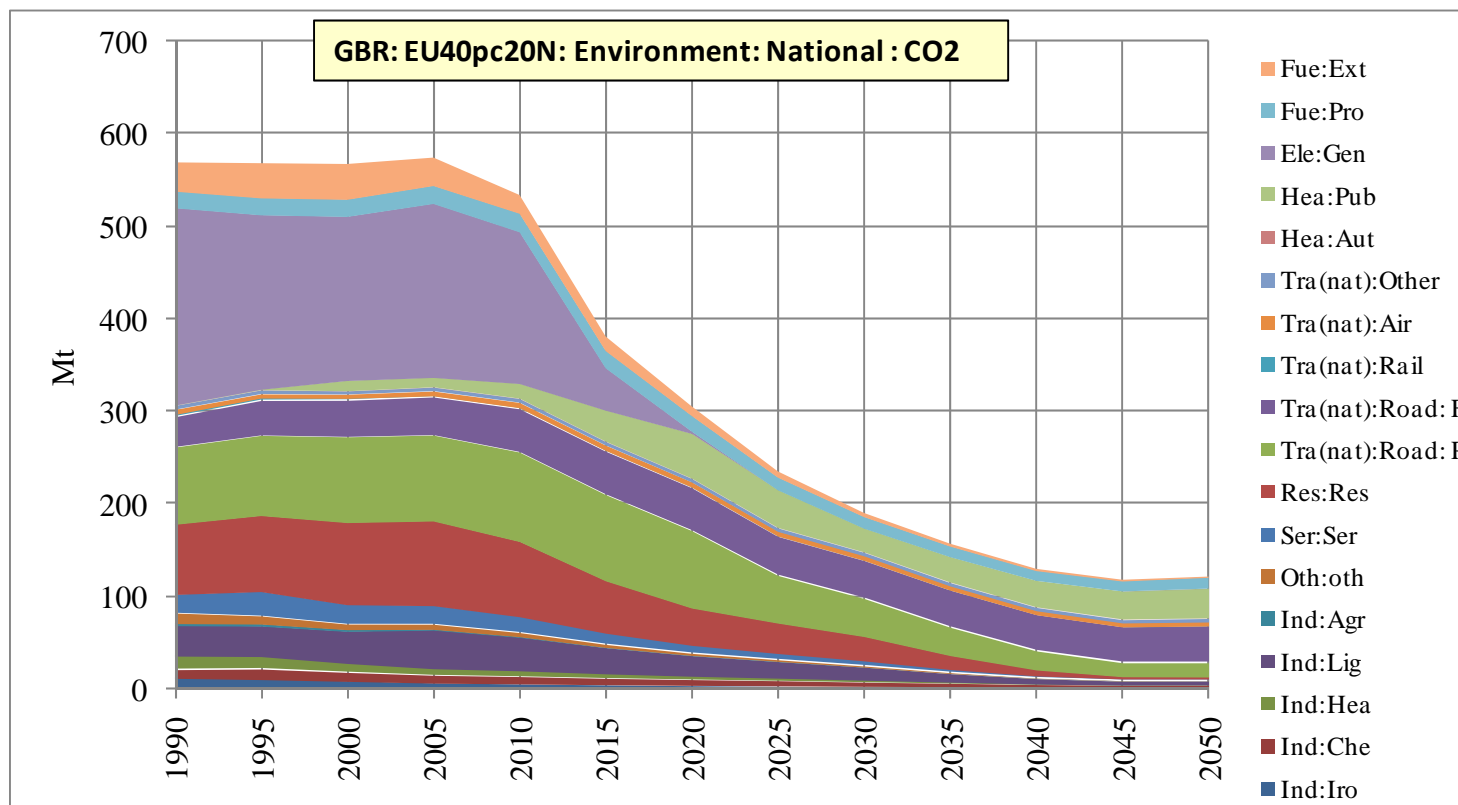
Transport: freight delivered energy

Freight energy use is dominated by trucks. The potential for a further shift to rail needs investigation.



UK CO₂: domestic emission (international aviation and shipping excluded)

Transport contributes an increasing fraction of CO₂ emission.

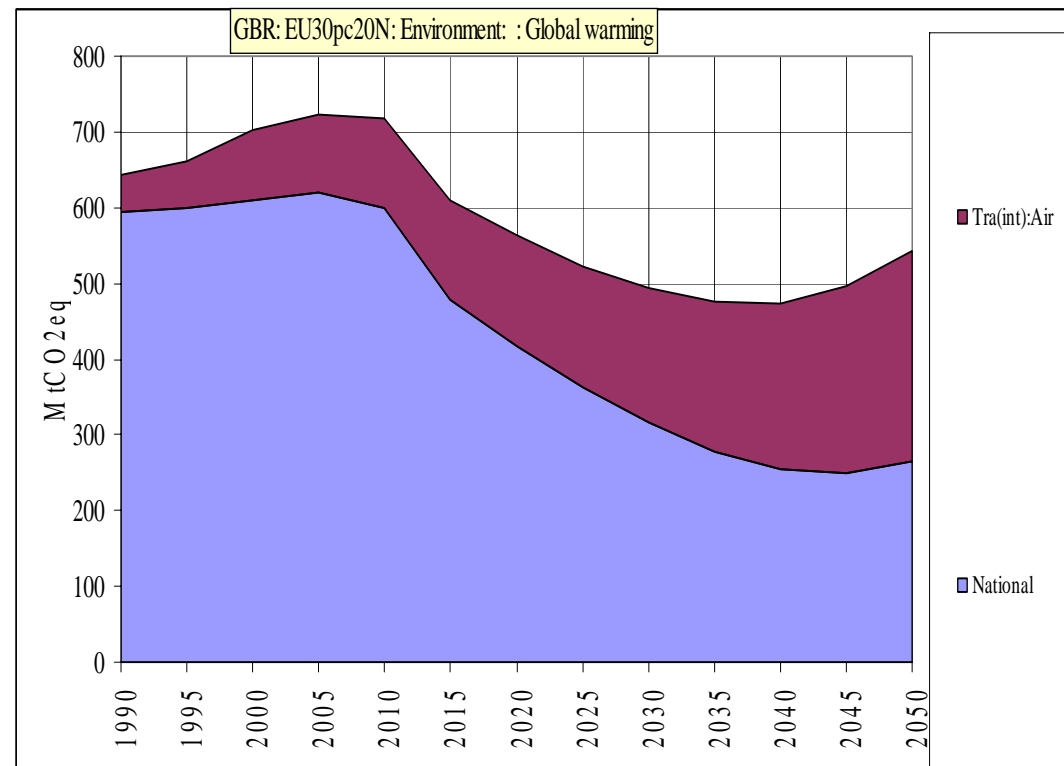


Further issues: aviation

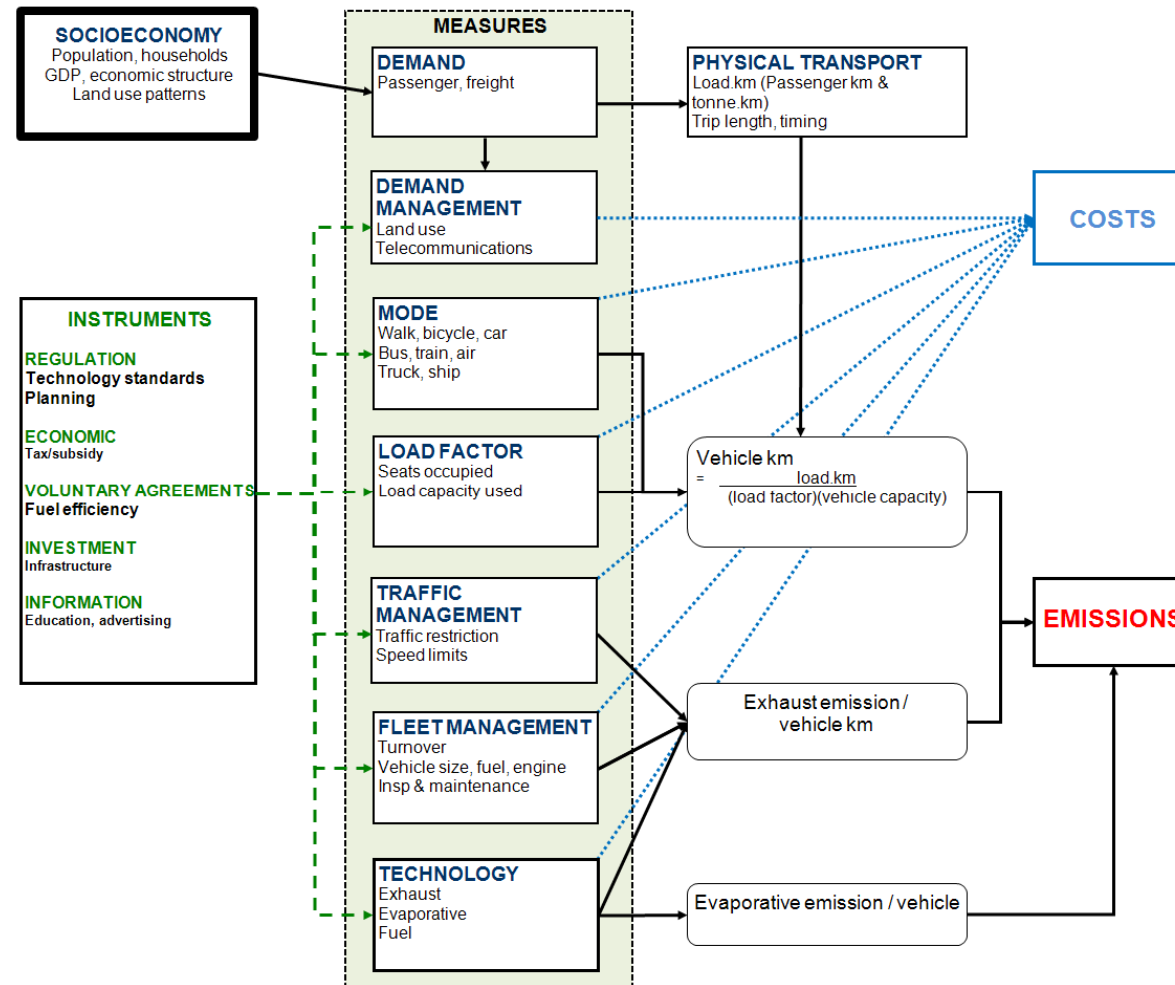
International aviation and shipping should be included in GHG inventories because their GHG emissions will become very large fractions of total.

- **Low level.** Airports are emission hot spots because of aircraft taxiing, and landing and take-off, and because of road traffic.
- **Tropospheric emission.** Aircraft emit a substantial quantities of NO_x whilst climbing to tropopause cruising altitude (about 12 km). This will contribute to surface pollution.
- **Tropopause/low stratosphere emission.** The high altitude emission of NO_x and water vapour cause 2-3 times the global warming due to aviation CO₂. Aviation may well become the dominant energy related greenhouse gas emitter for the UK over the coming decades.
- Of all the fossil fuels, kerosene is the most difficult to replace.

Further information on this is given in the references.



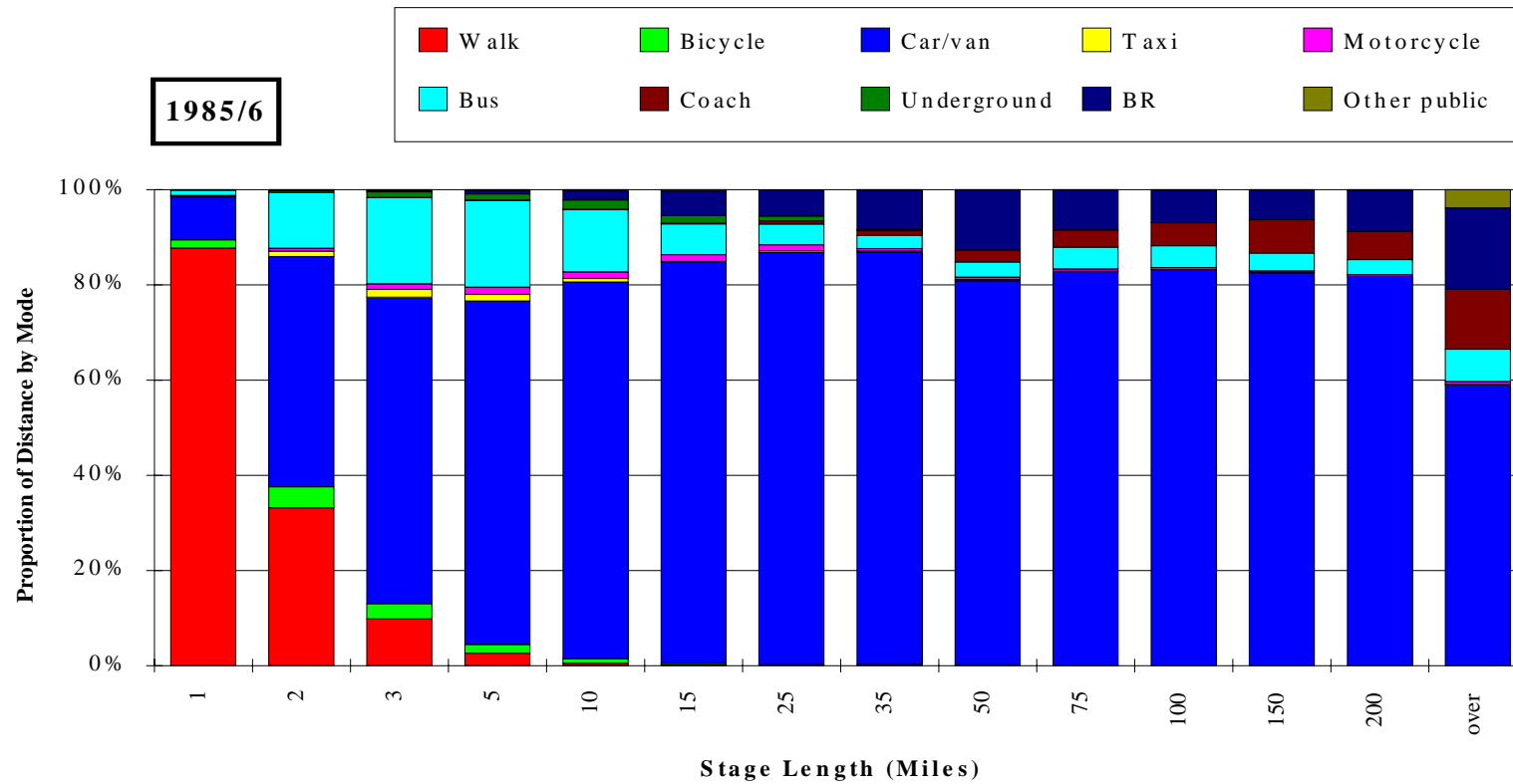
Transport : instruments and measures



Some conclusions

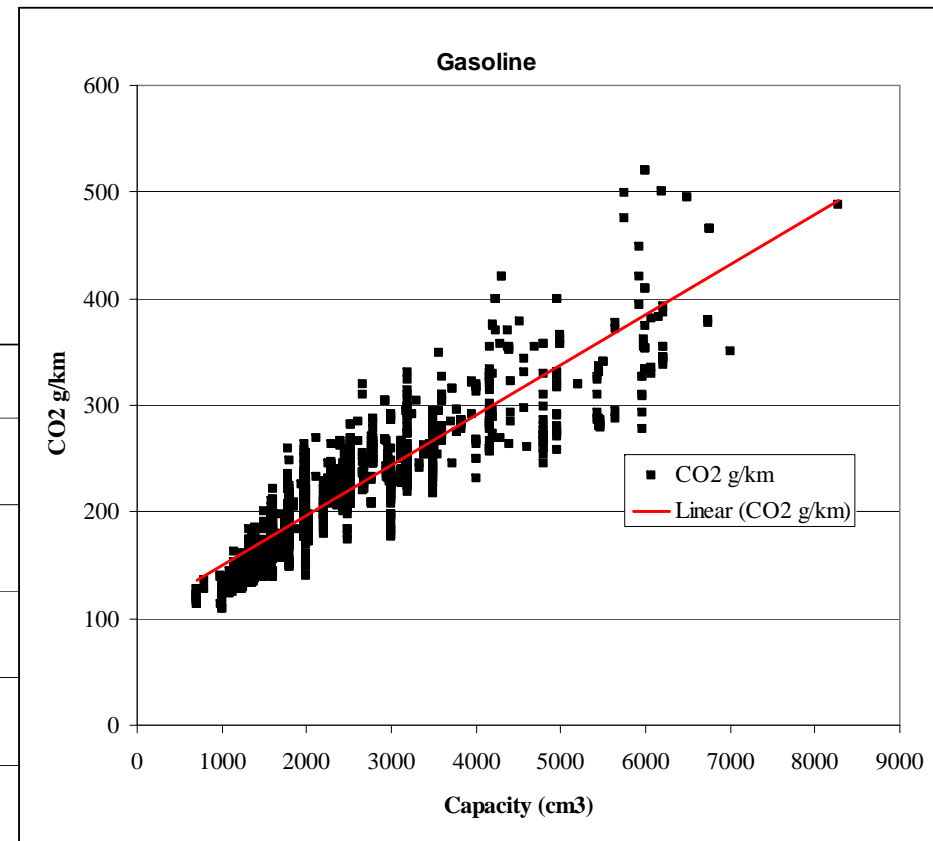
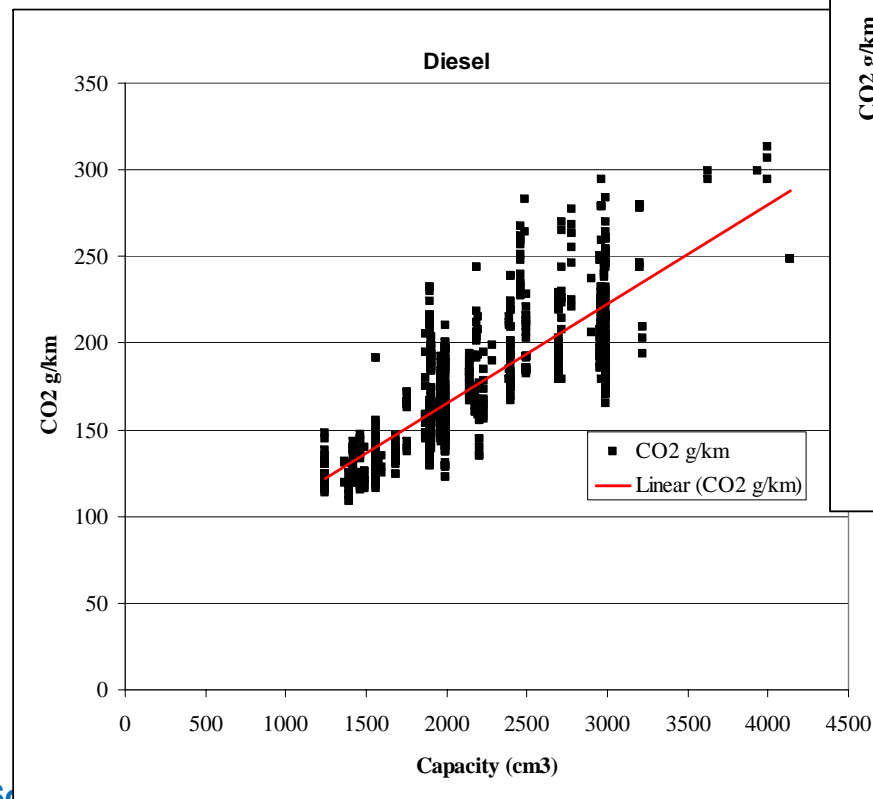
- About 90% of passenger travel energy and CO₂ emission arises from trips less than 60 km.
- Car choice and change in use can reduce energy and CO₂ by 50-70% with current cars, and by 90% with future small ICE cars. This would reduce total UK emissions by 5-10% in 15 years.
- High performance, heavy vehicles are energy intensive and dangerous to others.
- Longer distance trips and freight haulage should switch to rail.
- Electric power trains are more efficient and lower emitting than biomass/fossil ICE or hydrogen fuel cell trains. Refuelling and range are problems of electric vehicles.
- Transport will contribute and increasing fraction of global warming and energy use.
- Liquid fossil fuels are difficult to replace.

Passenger transport: mode of travel by distance



Cars: carbon emission and capacity

- Carbon emissions strongly correlated with engine capacity
- Emissions do not have intercept at zero capacity because of engine idling losses

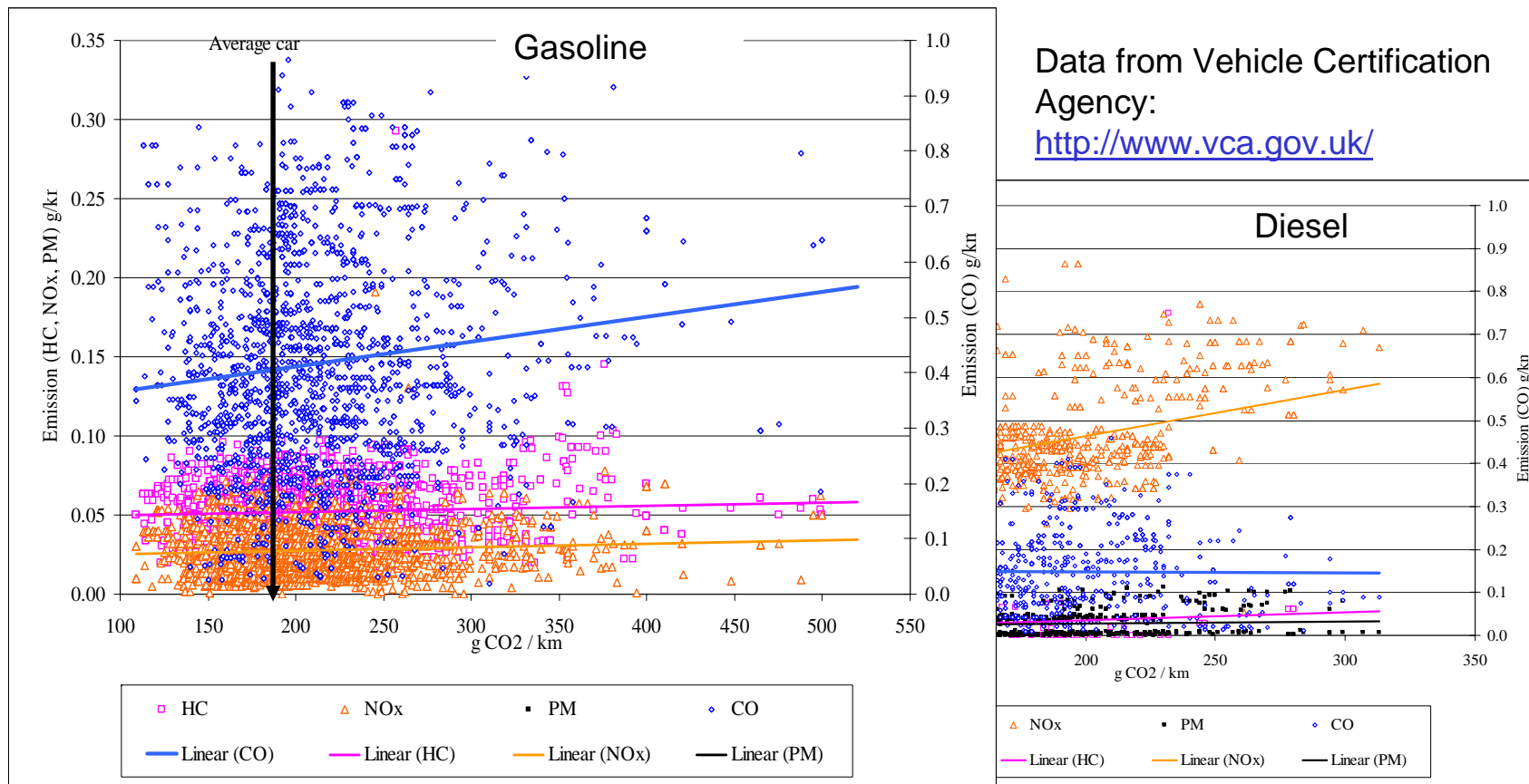


Data from Vehicle Certification Agency:
<http://www.vca.gov.uk/>

Cars and air pollution

Cars: carbon emission and NOx, HC, CO emission: 1

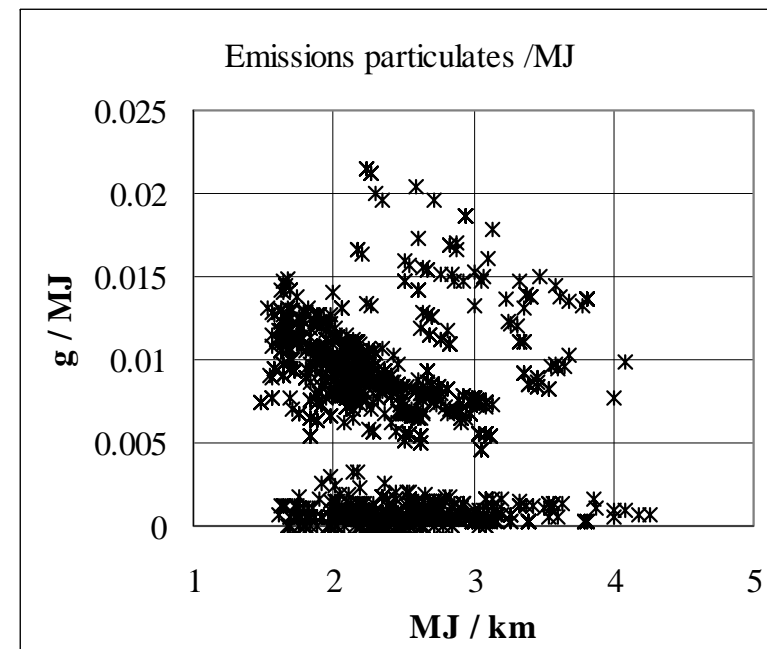
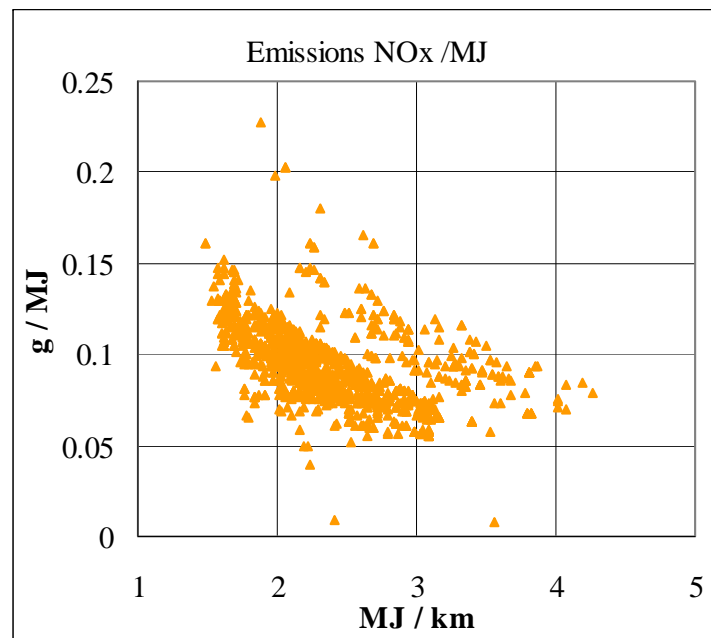
- The emissions of air pollutants increase with fuel and CO₂ consumption, but only marginally. This is because of standards, not technical limits, as minimum emissions from BAT should correlate strongly with CO₂; a vehicle that emits no CO₂ emits nothing else.
- For a given CO₂ emission, the best cars emit a small fraction of the worst.



Cars: emissions, energy and CO2

- Big cars emit less pollution per energy and CO2
- Why? Because emission control is better.
- So applying large car BAT to small cars would reduce emissions
- So the constant g/km of Euro standards for all sizes should be challenged?

Diesel



Cars: carbon emission and NO_x, HC, CO emission

The amounts of pollutants created in an engine are primarily related to the amounts of fuel burned, and the engine's combustion volume. Engines are designed to minimise primary pollution production, whilst meeting other criteria.

- NO_x – arises when nitrogen and oxygen react to form various nitrogen oxides under the high pressure and temperature conditions in an engine.
- VOCs - emissions result when the fuel is not completely burnt in the engine.
- CO - carbon monoxide arises when the fuel carbon is not fully oxidized
- PM – particulates (primary) result from the incomplete combustion of the fuel, and from incombustible material in the fuel
- CO₂ – is created by the oxidation of fuel carbon

Cars: carbon emission and NOx, HC, CO emission : 2

- On-road emissions of vehicles should be closely related to certification emissions.
- If so, then the approximate reductions may be estimated by eye from the preceding graphs (shown in the Table), for:
 - downsizing
 - switching to the best cars for 180 g/km CO2 emission per km
- If these indicative estimates are of the right magnitude, then large reductions of emissions are possible by influencing consumer car choice – e.g. by tax on the pollutant(s) of most concern.
- Presumably other vehicle types, such as trucks, also show variation, though perhaps not as large.
- If on-road emissions are not closely related to certificated emissions testing, then certification is not an accurate guide to current and projected emissions.
- It might be possible to use annual emission testing in place of standards for older vehicles.
- Plainly this issue needs analysis, if not already carried

INDICATIVE EMISSION REDUCTIONS

Downsizing

	Petrol	Diesel
NOx	10%	15%
CO	7%	0%
HC	2%	30%
HC+NOx	0%	25%
PM		10%

Best for given CO2

	Petrol	Diesel
NOx	88%	24%
CO	89%	57%
HC	89%	72%
HC+NOx	33%	36%
PM		80%

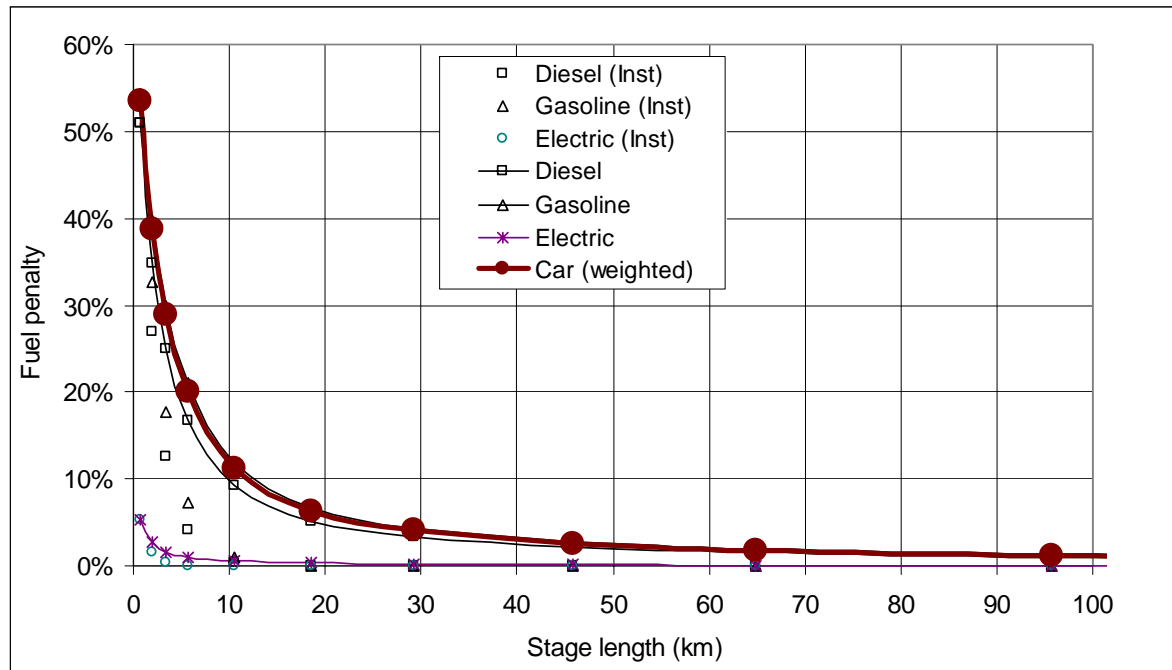
Cars: carbon emission and NOx, HC, CO emission : engine

1. Other things being equal (engine temperature, pressure, speed,...), the amounts of pollutants created approximately in proportion to the volume of the engine's cylinders and the fuel consumption; i.e. a 2 litre engine will produce twice as much primary NOx, VOC, CO, PM as a 1 litre engine. This is generally also true for CO₂, so reducing CO₂ by 50% will reduce other emissions by the same amount. All of these emissions must go to zero as the engine volume and fuel consumption go to zero.
2. Primary pollution is reduced by treating the exhaust gases with technologies such as catalysts and particle traps (EOP). In principle, a technology which will reduce a pollutant by a given fraction for one engine, will do the same for another of the same type, but different size. For example, a catalyst can reduce primary NOx by 90% on any sized engine.
3. European emissions standards (Euro IV etc.) for cars are defined in grammes/km and are the same for cars with different sized engines and fuel consumptions. Therefore, given assumption 1, the smaller cars have less effective emission EOP.
4. It should therefore be possible for the engine of a 1 litre car to emit half the emissions of a 2 litre car for a given engine duty cycle (power output, variation, duration etc.).

Cars: carbon emission and NO_x, HC, CO emission : on-road

1. The **on-road** g/km emissions depend on the load imposed on the engine by other features of the car such as ancilliary services (e.g. air conditioning), transmission system, weight, rolling resistance and drag, as it is driven with different speeds and acceleration. This is complex, but in general fuel consumption of a car does not increase exactly in proportion with the capacity (litres) or power of a car – a 2 litre
2. The conclusion is that reducing fuel use and CO₂ emissions by 50%, will also reduce other emissions (NO_x, CO, VOC, PM) by about the same fraction for a similar engine and transmission system, **if** the best available emission control technologies are used.
3. The current EU emission limits in g/km do not represent the application of the best available techniques for small cars.

Passenger transport: car fuel consumption and carbon emission



CO2 emissions of domestic transport and PPP adjusted GDP per capita, 2005

