KING REVIEW

Low Carbon Cars

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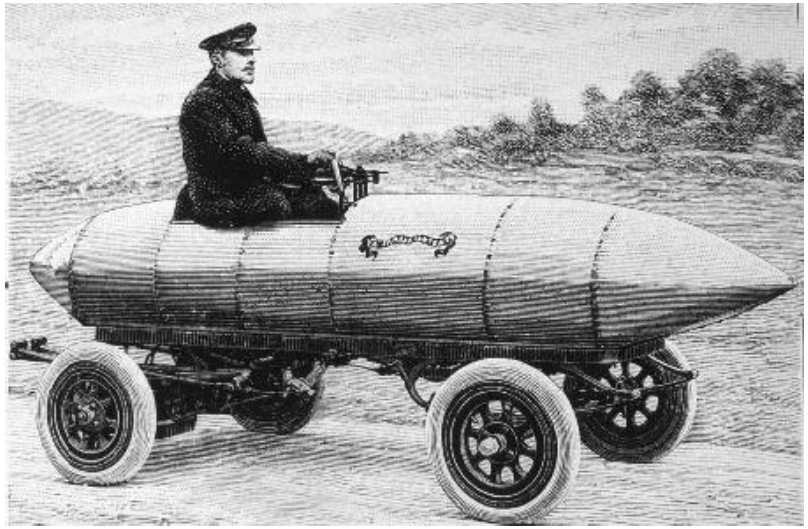


Decarbonising road transport

Professor Julia King Aston University, Birmingham, UK

Royal Society 18th November 2008

The Climate Change Challenge

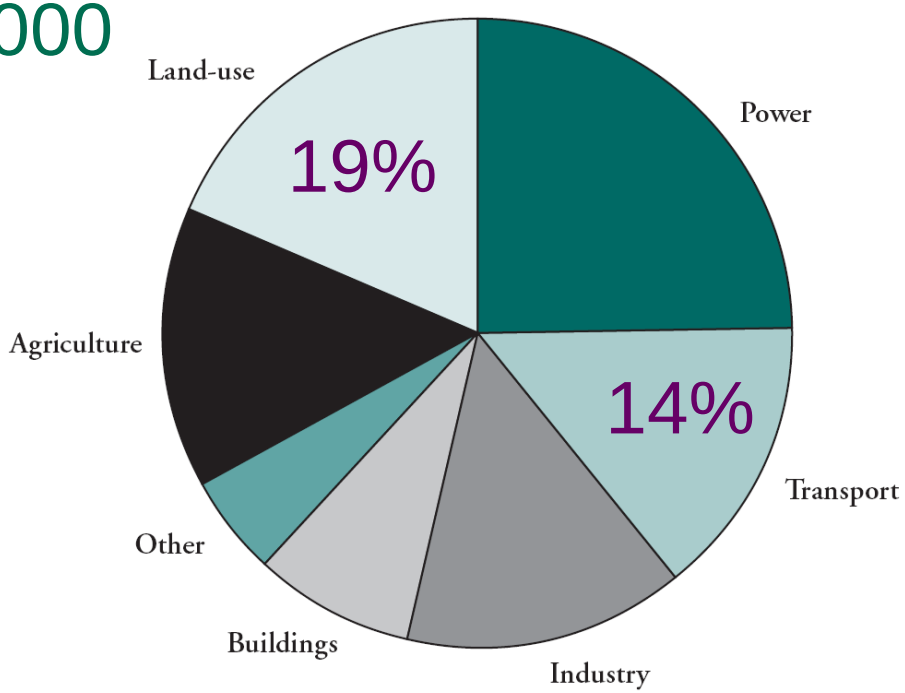
To have a reasonable chance of restricting average global increases to close to 2°, and to avoid a significant probability of as much as 4°:

the developed world will need to reduce emissions by a minimum of 80% by 2050

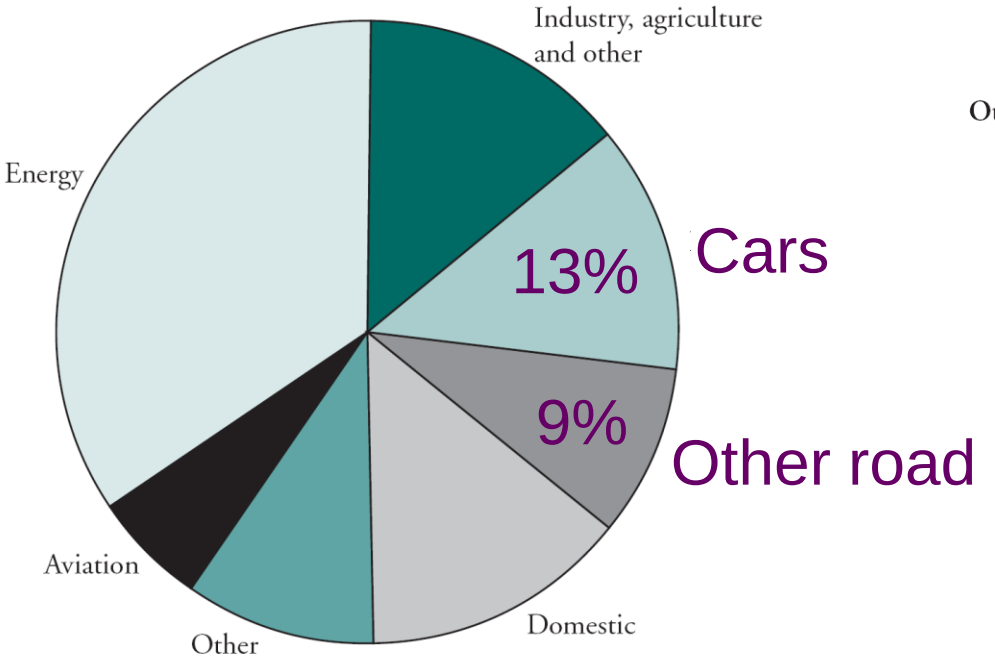
in countries where transport is the second largest contributor to CO_2 emissions

CO_2 from Transport

Global:2000



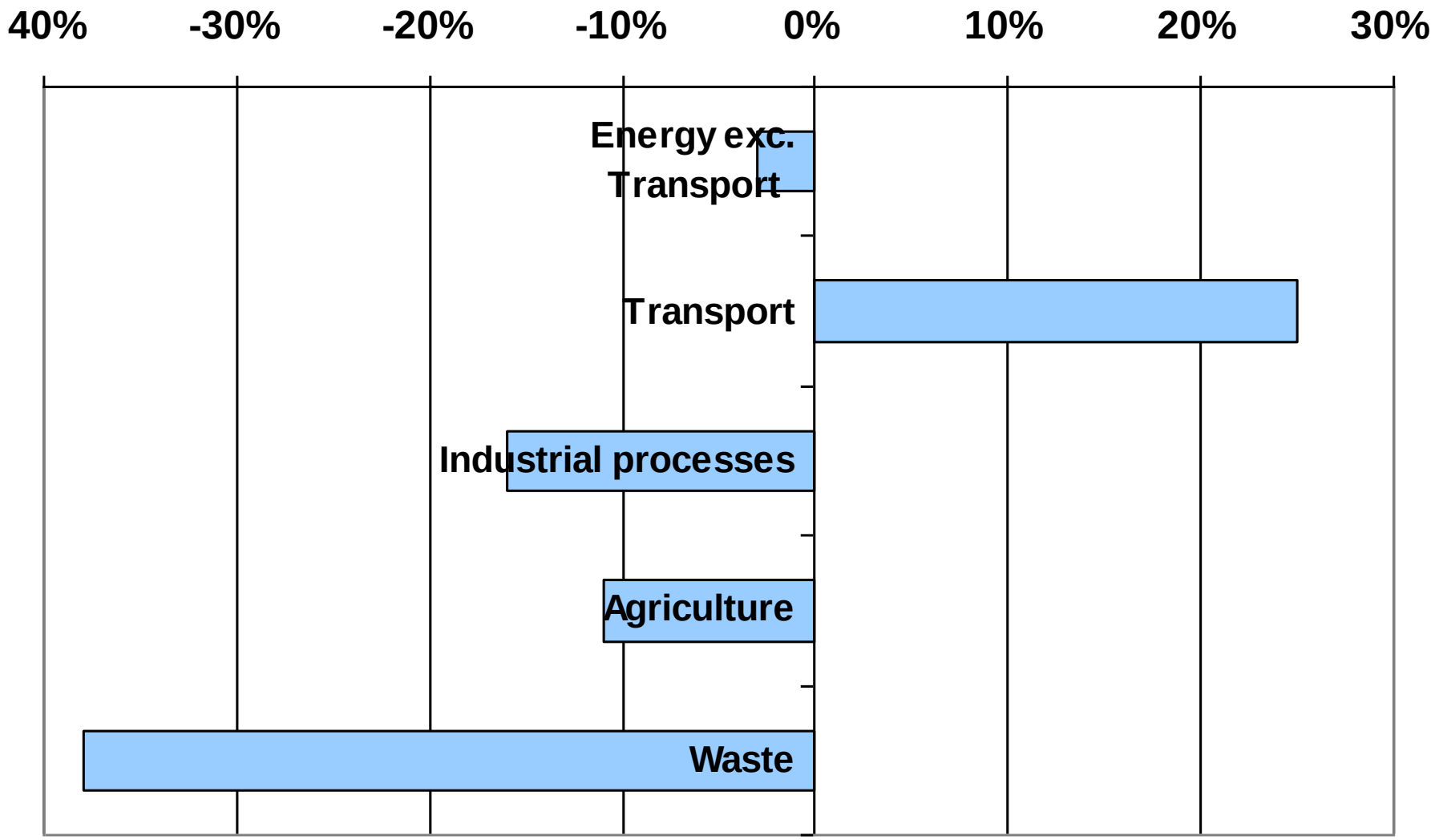
UK:2005



UK road transport:
22% of total emissions

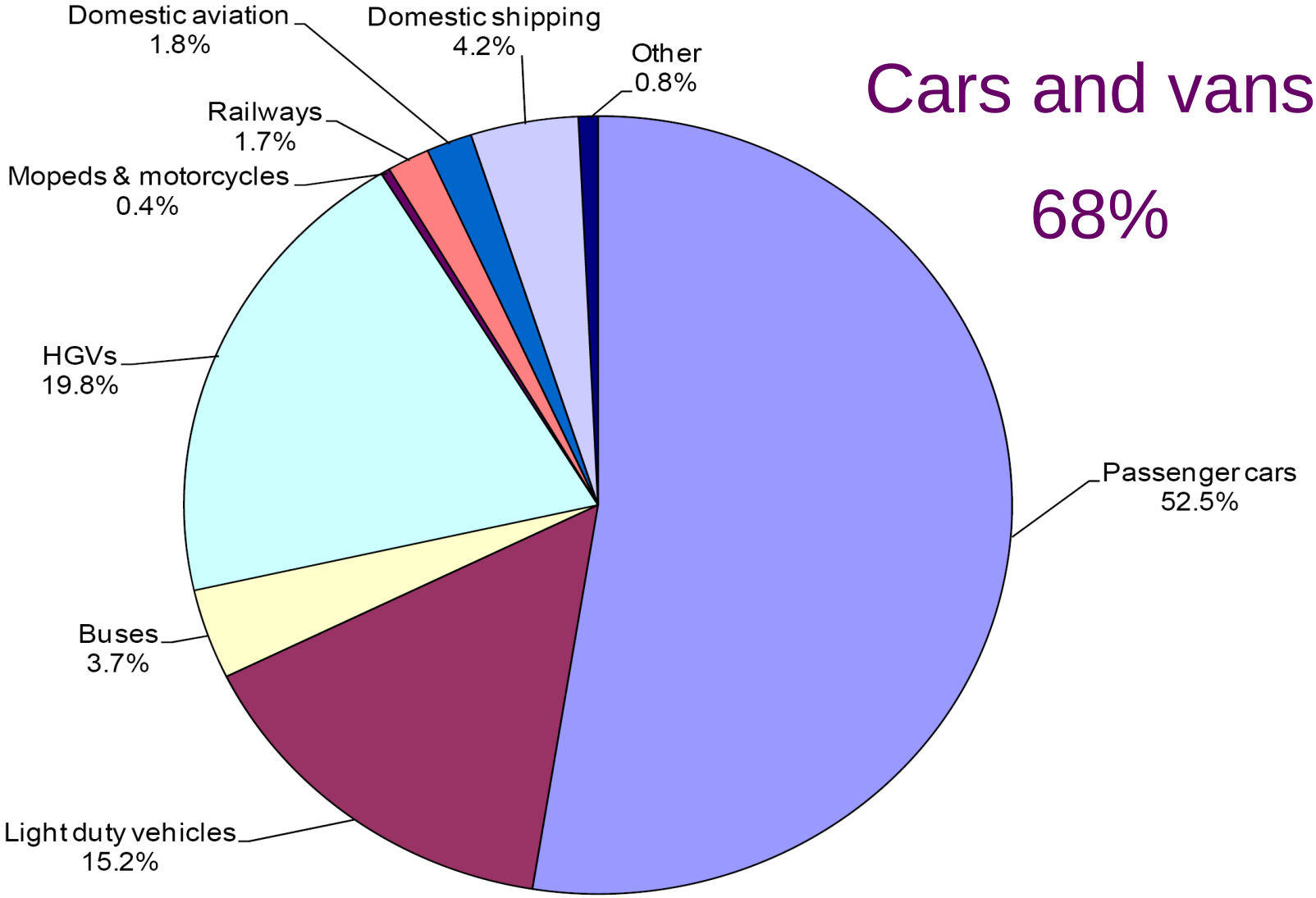
Source: WRI (2006)

EU 25: Emissions growth 1990 - 2005



Source: EEA 2006

UK Transport: 150Mt per annum

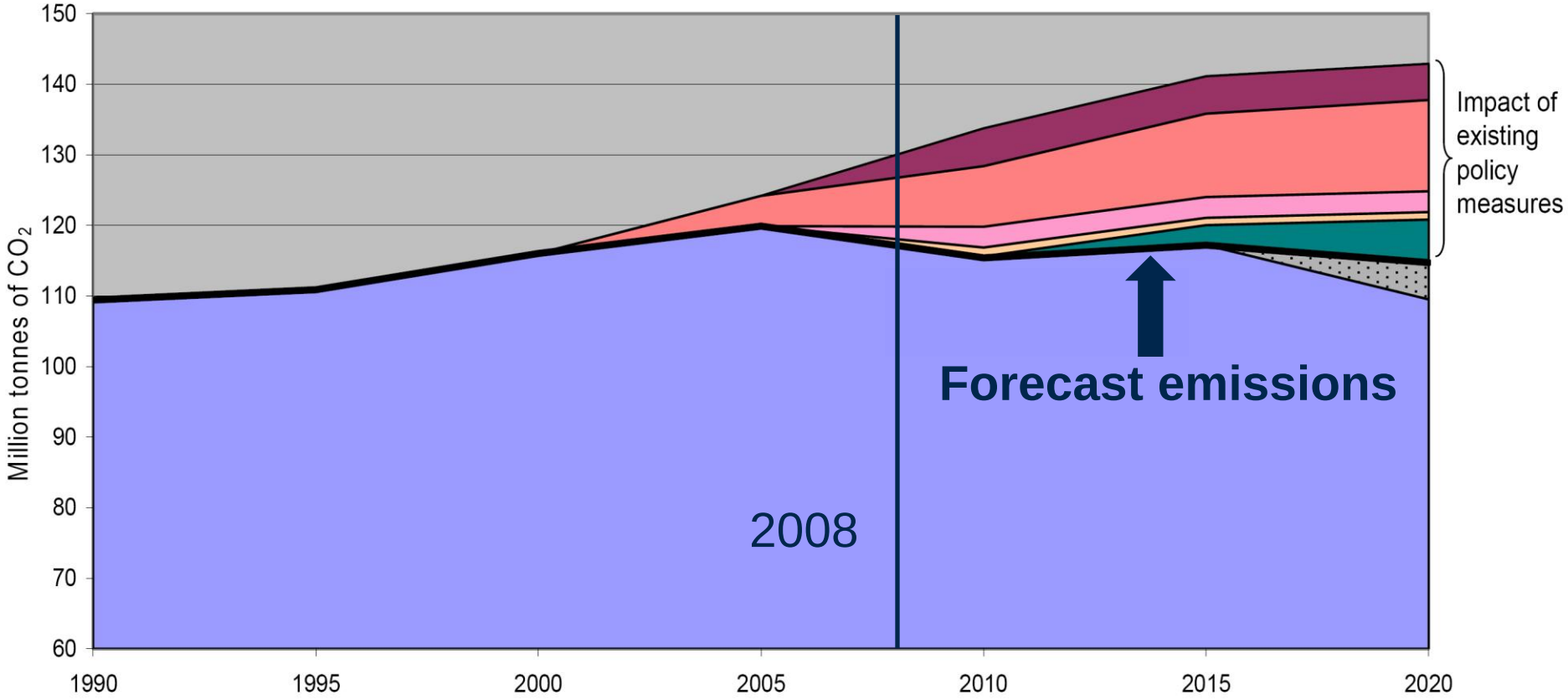


Cars and vans:

68%

Source: DfT 2008

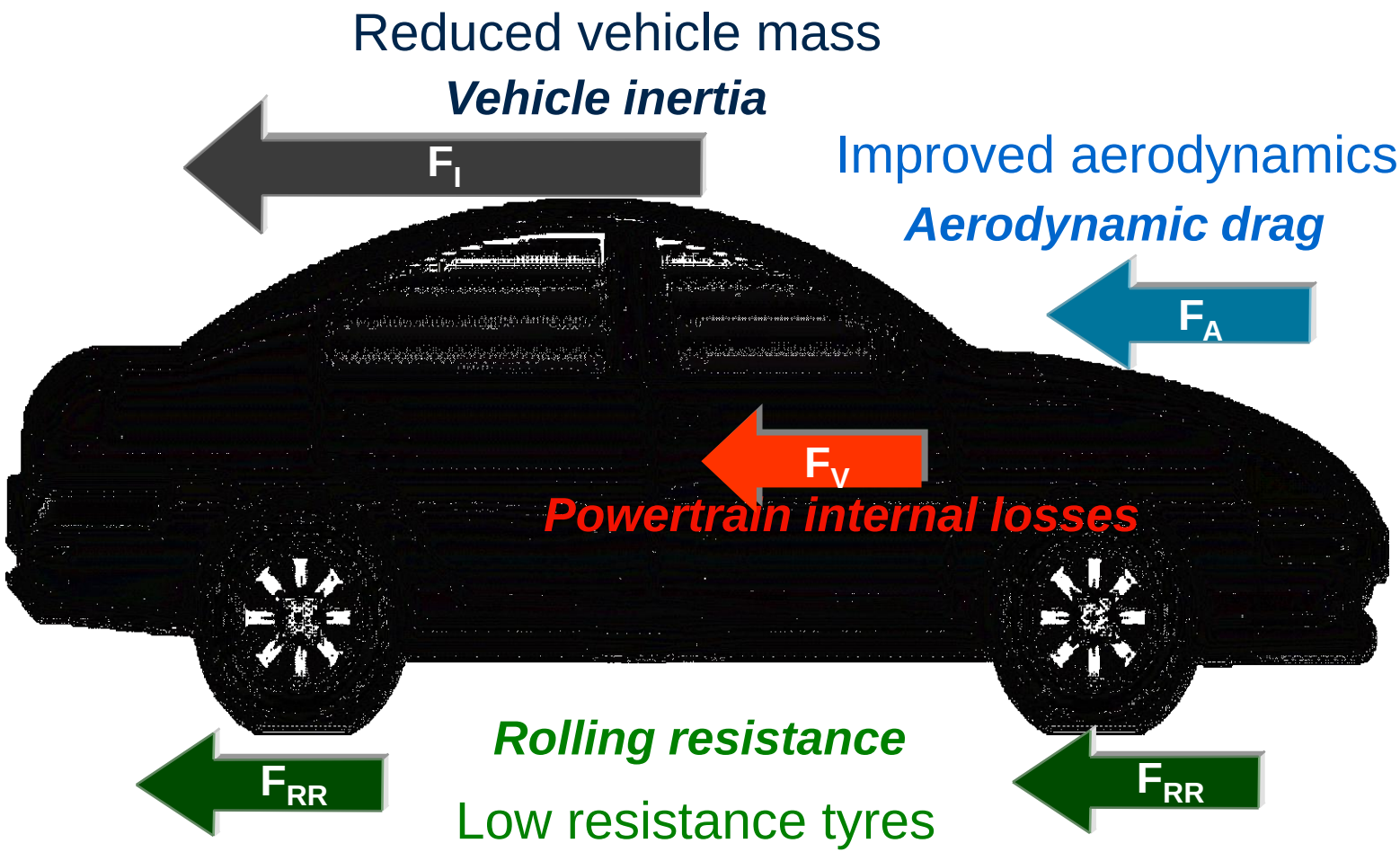
UK road transport emissions



On track for 80% reduction by 2050?

Source: DfT 2008

Cars: technology for 30%+ savings available now



Improved efficiency of internal systems:

electronics, entertainment, air conditioning etc

Courtesy Patrick Oliva, Michelin

‘Close to market’ efficiency options

New engine and transmission efficiency savings and indicative costs

Technology	Efficiency saving	Cost per vehicle (£)
Direct injection and lean burn	10 – 13 %	200 – 400
Variable valve actuation	5 – 7%	175 – 250
Downsizing engine capacity with turbocharging or supercharging	10 – 15%	150 – 300
Dual clutch transmission	4 – 5%	400 – 600
Stop–start	3 – 4% *	100 – 200
Stop–start with regenerative braking	7%*	350 – 450
Electric motor assist	7%*	1,000
Reduced mechanical friction components	3 – 5%	Negligible

** Figure quoted is for the whole drive cycle. Savings are much greater in urban driving conditions.*

Ranges derived from a number of sources, including the International Energy Agency (IEA), Institute of European Environmental Policy (IEEP), California Air Resources Board (CARB), Ricardo. Cost estimates derived using approximate conversion to Sterling.

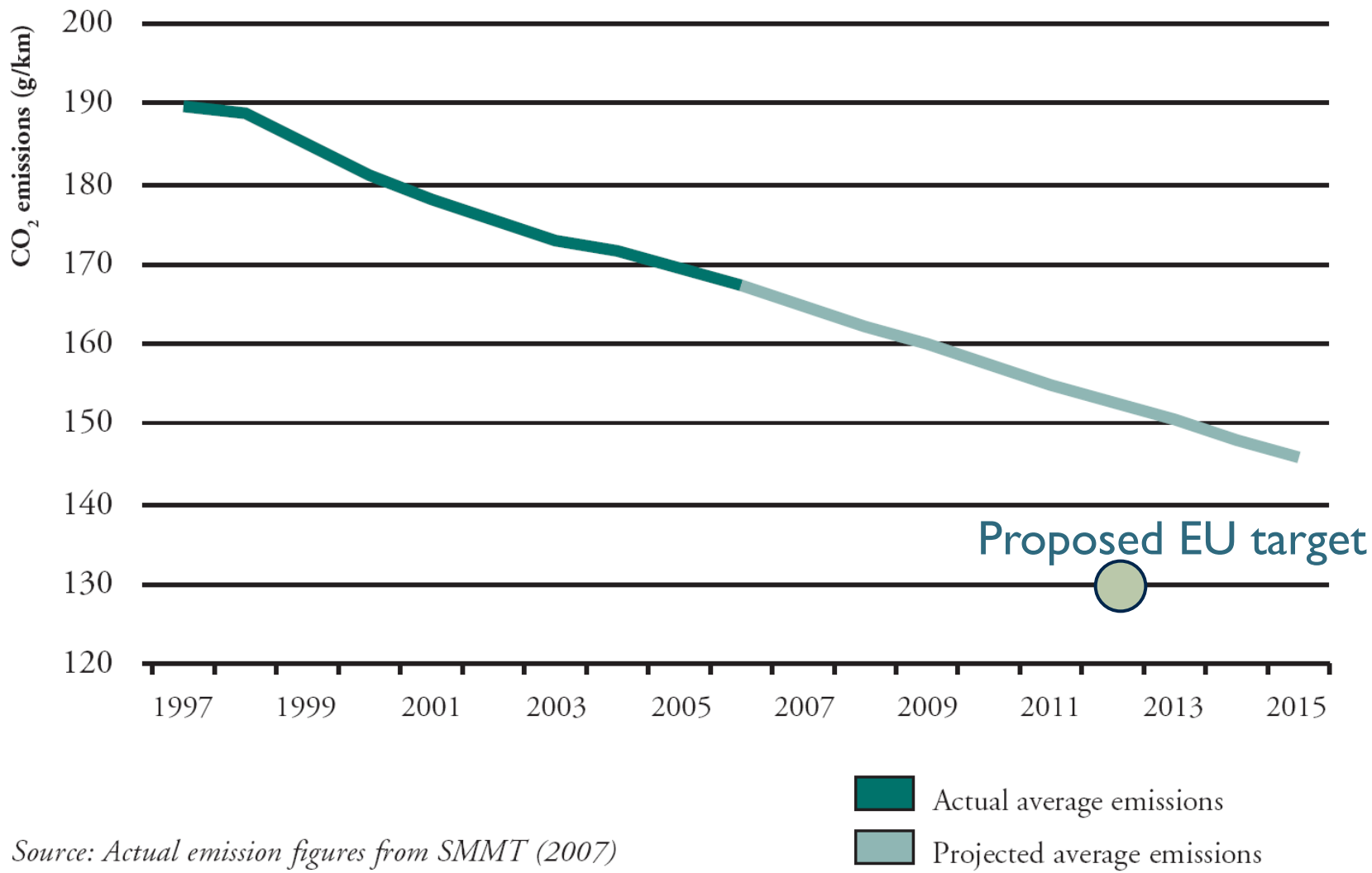
and some exciting UK developments…

Torotrak continuously variable transmission	15 – 20%	cost as automatic
Ricardo 2/4 stroke research engine	27%	research prototype

Short term: 2012

- Conventional, available technology could reduce CO_2 emissions per car by 30%
  - direct injection, variable valve actuation, cylinder-deactivation, regenerative braking, stop-start, variable drive technology, weight reduction, improved lubricants, surface treatments to reduce mechanical friction, low resistance tyres…
  - *could* be standard within 5 years
  - UK average new car: 160g/km
  - Polo Blue Motion and the Seat Ibiza Ecomotive: 74mpg or 99g CO_2/km
- Cost-effective for the user
  - cost premium estimates £500 - £1500
  - better fuel efficiency gives 2 – 4 year payback
  - improved residual value
  - some technologies give greatest benefit for particular duty cycles – eg stop-start
  - ***must also be applied to light commercial vehicles***
- Barriers delaying deployment pose a challenge for policy
  - supply-side: manufacturers need to be confident of a profitable market
  - profits (and advertising) still concentrated on large/luxury vehicles
  - demand-side: consumers have to want the vehicles – at the price
  - vans are not covered by national or European legislation
  - carbon pricing/trading won't deliver results in the short term

EU 2012 Target: 20% reduction is ‘doable’ with technology



Source: Actual emission figures from SMMT (2007)

Short term: no technology - smart driver choices

Behaviour change could deliver this level of reduction with NO NEW technology

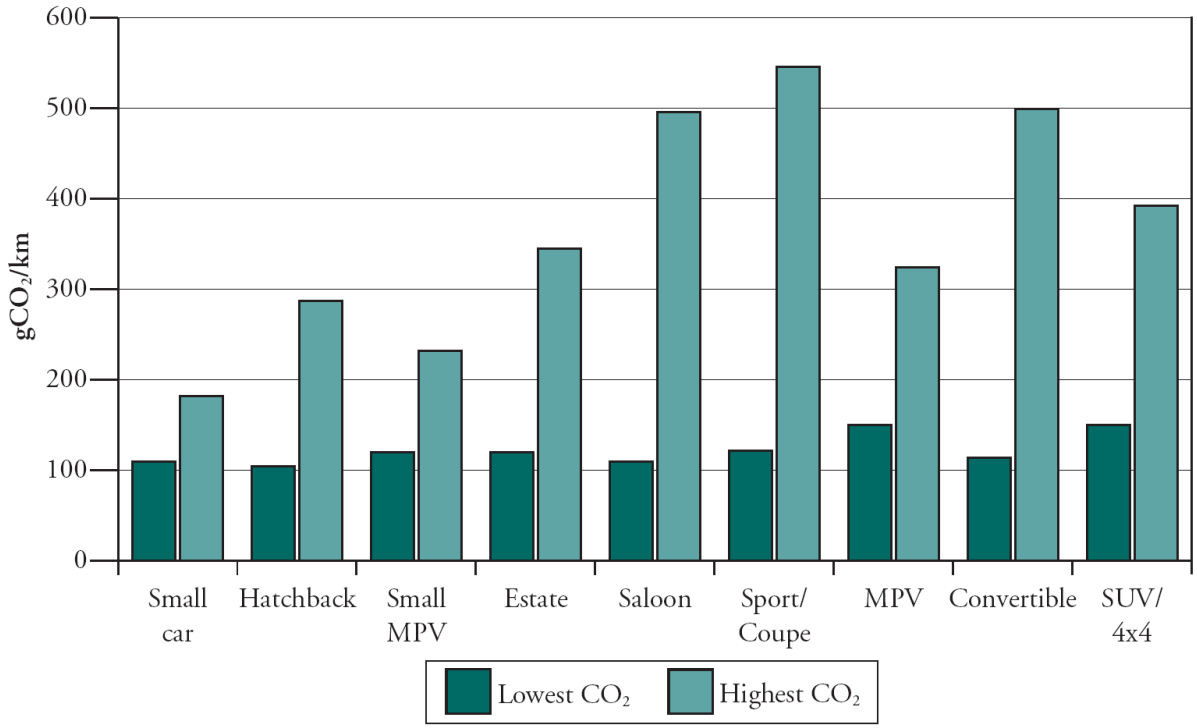
- Consumer/driver behaviour has a big effect on CO_2 from road transport
  - vehicle choice: best in class 25 - 30%
  - downsize….
  - eco driving: up to 15%
  - enforced and lower speed limits
  - reduced marginal car use
  - car clubs, car sharing, modal shift…

- Potential for 50% reduction in emissions?
  - at near zero cost
  - with ongoing savings to the consumer/fleet operator

- Policy challenges:
  - environmental awareness and action in road transport lags other sectors
  - powerful cars are symbols of status – and are where profit is made
  - people tend to discount heavily future fuel cost savings
  - acceptability of ‘restricting personal freedom’
  - avoiding the rebound effect

Consumer choices

Range of emissions by vehicle class, 2006



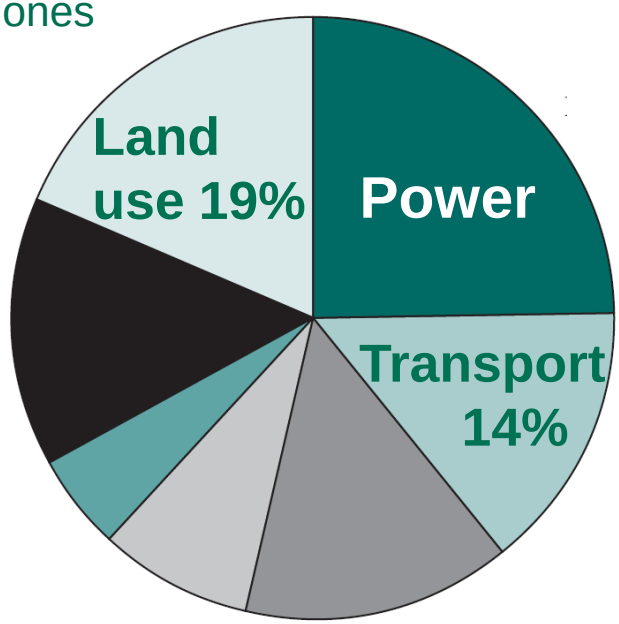
Least important factors in choosing a car, 2006 survey:

- environment, vehicle emissions, alternative fuel

Choosing the lowest emitter in class would improve fuel efficiency by 25 - 30%

Short term: biofuels aren't essential

- Biofuels look appealing
  - minimal cost to convert old vehicles and develop new ones
  - distribution infrastructure in place
- Apparent life cycle CO_2 savings for biofuels
  - 5 – 75% compared to fossil fuels
- Actual CO_2 savings remain controversial
  - dependent on land use change, fertiliser, water use…
  - value of by-products
- Least cost-effective way to use biomass
  - versus heat, CHP, coal plant co-firing
- Policy challenges:
  - addressed by Gallagher:
    - discriminating 'good' biofuels from 'bad' ones
    - preventing deforestation and other damaging land-use change
    - avoiding damaging impacts on food prices
  - important for the future: encouraging industry investment whilst restricting use
  - focus on essential use in air travel and military?



Global CO_2 emissions

Lowest emitters by segment: 2007

Segment	Average	Lowest emitter	Make/model	Lowest vs average
A – mini	128.5	0	smart Fortwo Coupe	-100%
B – supermini	141.8	99	VW Polo	-30.2%
C – lower medium	158.6	109	Honda Civic	-31.3%
D – upper medium	169.1	104	Toyota Prius	-38.5%
E – executive	192.6	136	BMW 5-series	-29.4%
F – luxury	273.8	210	Audi A8	-23.3%
G – sports	224.0	124	Vauxhall Tigra	-44.7%
H – dual purpose 4x4	228.3	171	Suzuki Jimny	-25.1%
I – MPV	179.7	127	Ford C-Max	-29.3%

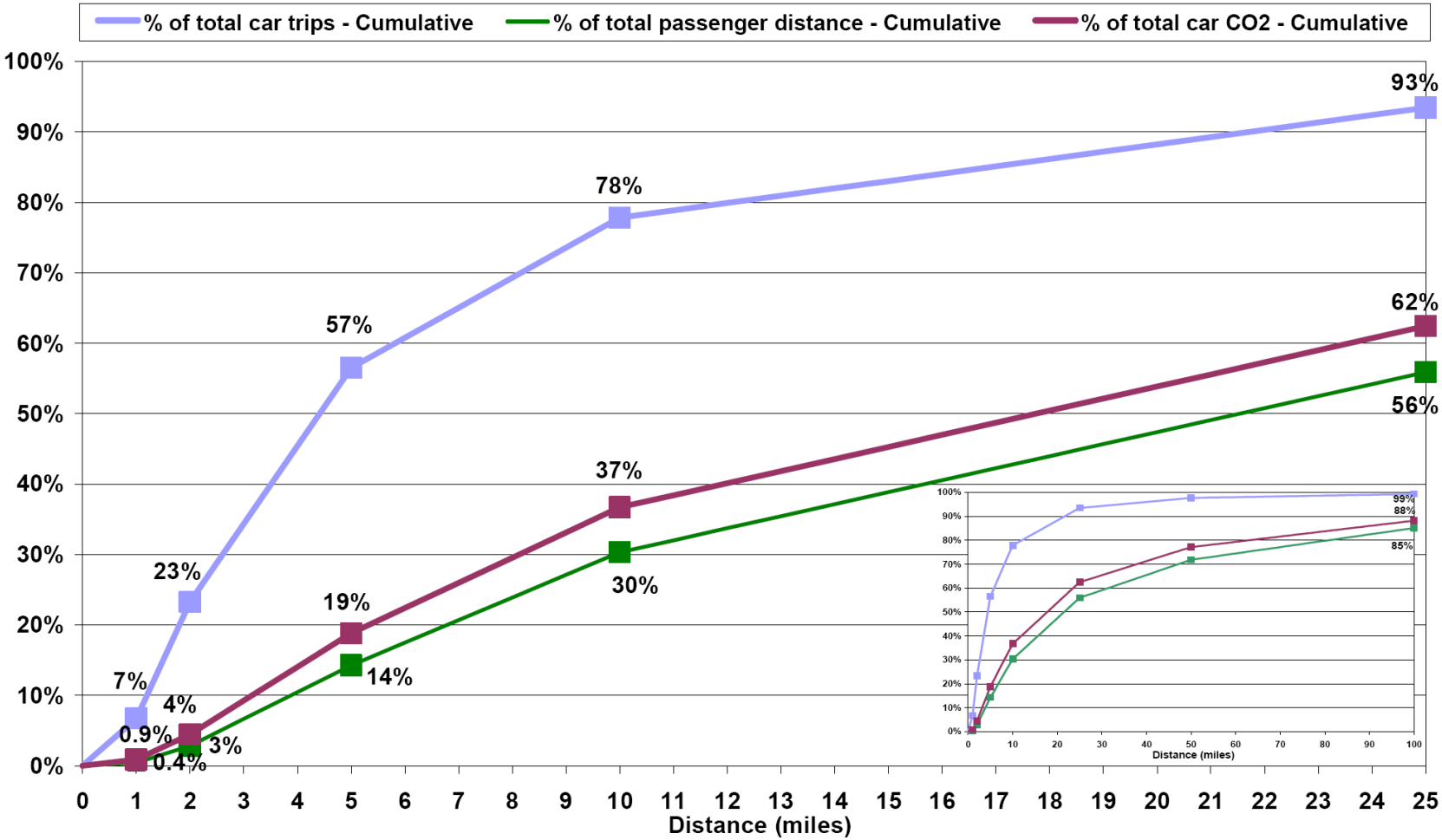
Source: SMMT 2008

Proposed 2020 target: 100g/km 40% reduction

- Growing numbers of plug-in hybrids and full-electric vehicles
  - additional infrastructure requirements are limited
  - 17% extra grid capacity for all cars to be electric
  - battery charging on smart meters
  - load balancing opportunity for intermittent wind power
  - highly efficient
  - battery technologies available today for 50 - 150 mile ranges

- Issues
  - battery/vehicle costs
  - battery range & recharge time
  - battery life
  - recharging infrastructure
  - standardisation
  - low carbon electricity
  - manufacturing capacity
  - acceptability

Typical car use



93% of trips and 62% of CO_2 emissions: journeys of less than 25 miles

97% of trips and 77% of CO_2 emissions: journeys of less than 50 miles

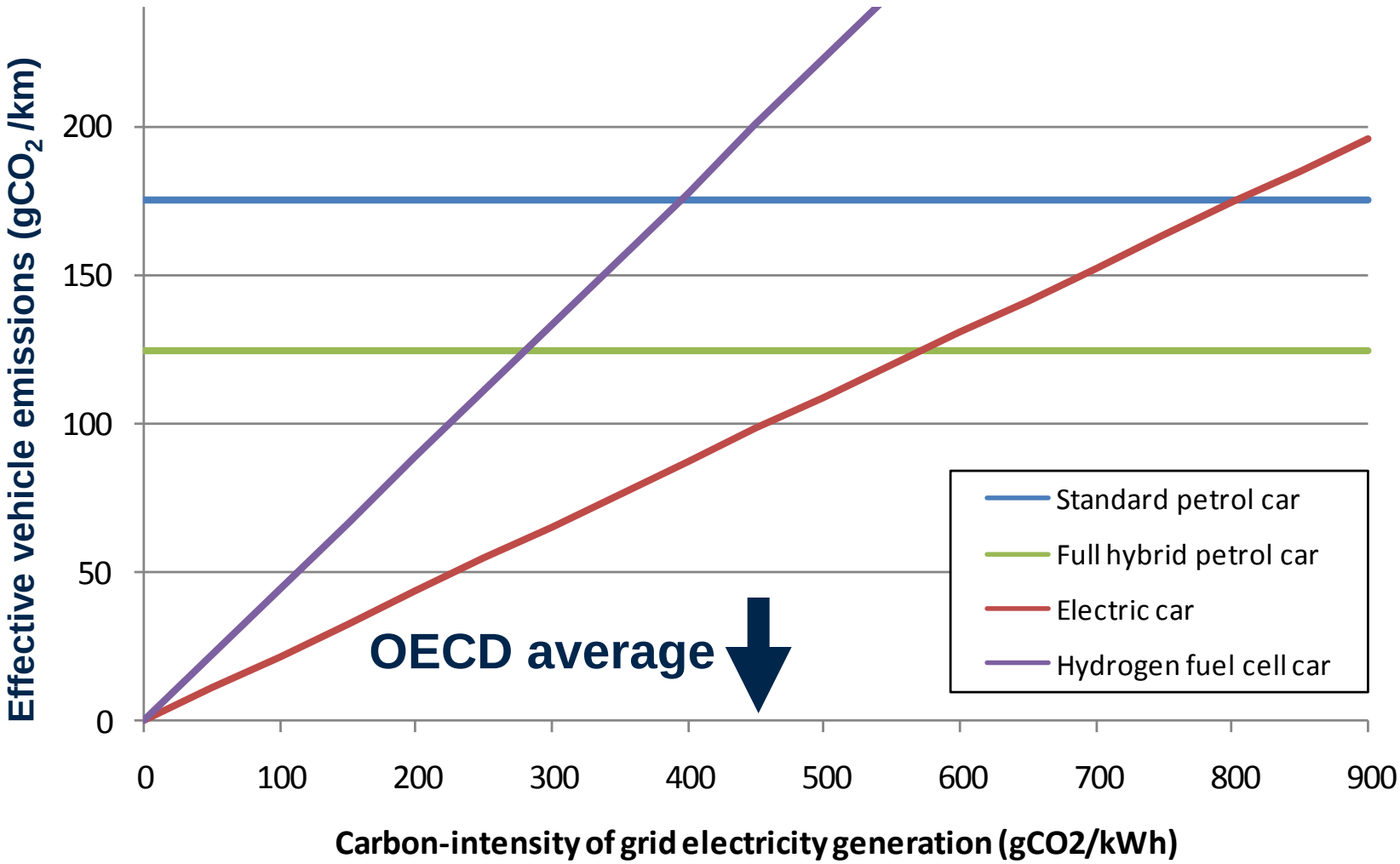
Source: DfT 2008

Electric vehicle emissions

- 6g CO_2/km in Sweden
- 12g CO_2/km in France
- 72g CO_2/km in Germany
- 120g CO_2/km in Greece

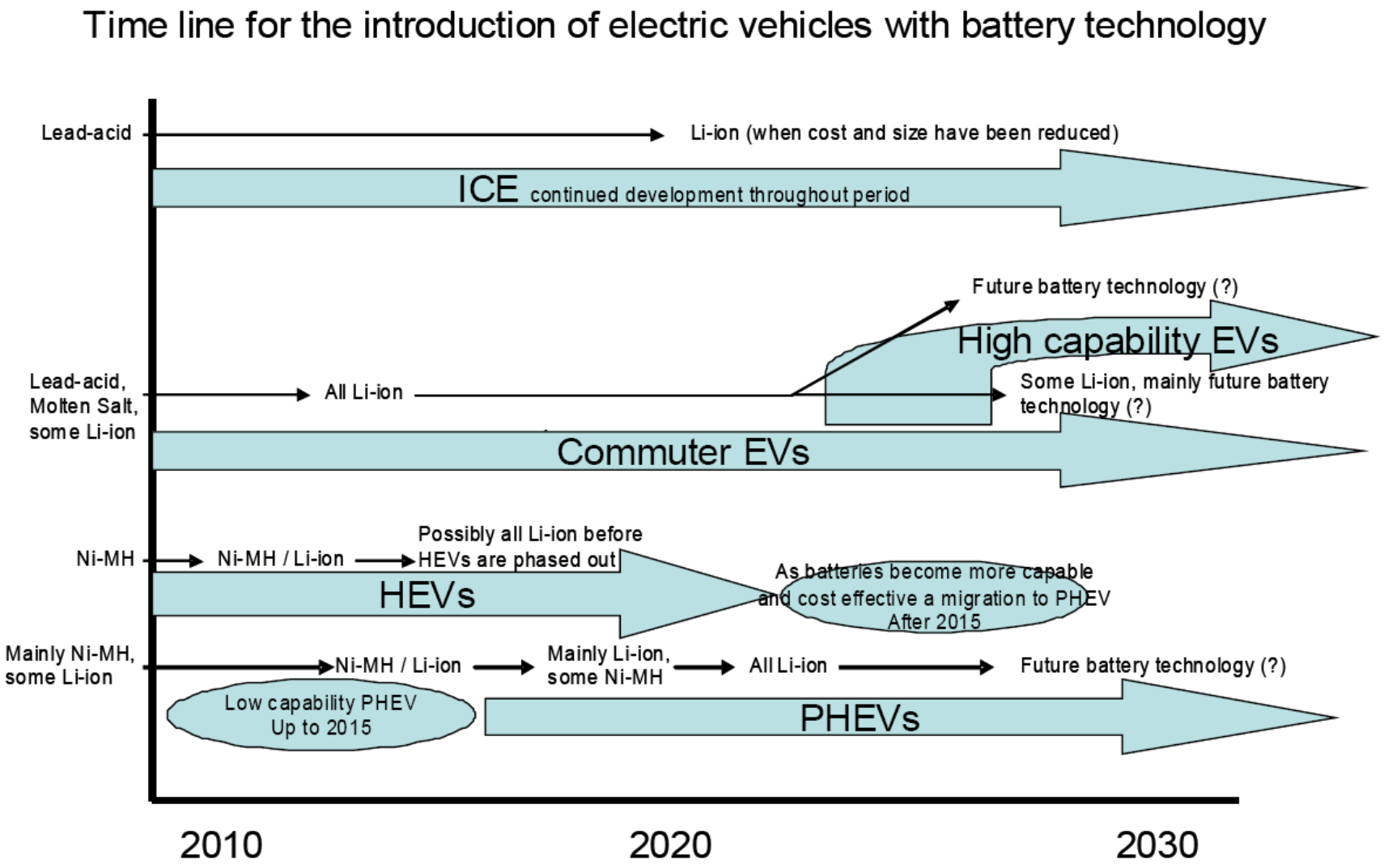
Courtesy Patrick Oliva, Michelin

2030-2050: Battery (or hydrogen fuel cell) vehicles



Courtesy David Joffe, Committee on Climate Change 2008

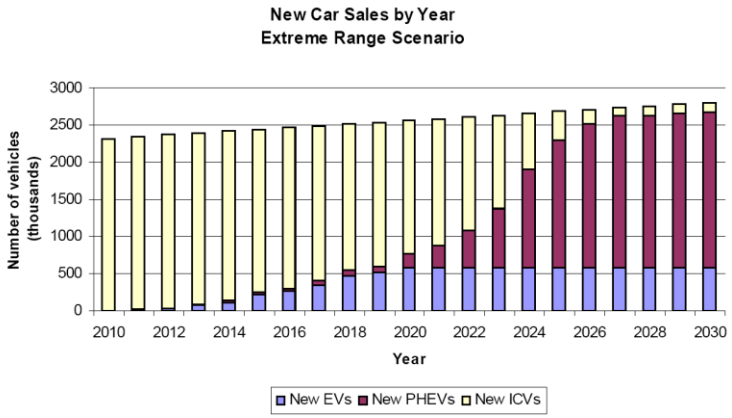
Electric vehicle technology development

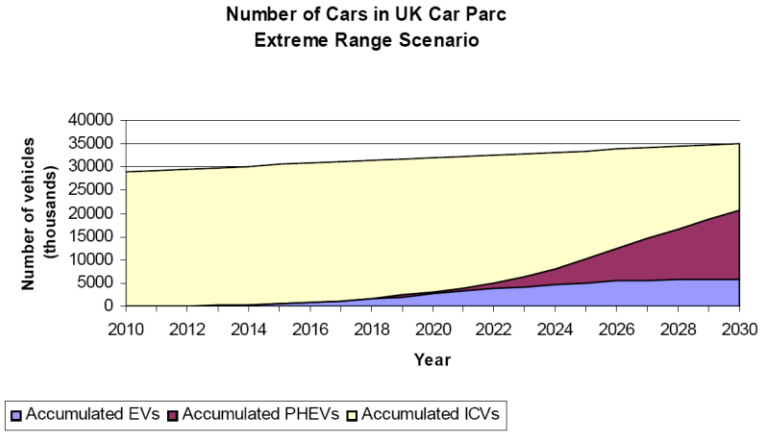


Arup/CENEX report for BERR and DfT 2008

EVs: addressing the issues

- New ownership concepts
  - cities: own a car for 99% usage, hire/share/club for 1%
  - information cities: all you need to know via your mobile ‘phone
- Significant impact of policy
  - purchase taxes
  - free parking, congestion charging, use of bus lanes
- New business models
  - car as mobile ‘phone (Better Place)
  - own the car, rent the battery (Think!)
  - personal car leasing (Toyota)
  - green generators own the batteries
  - ‘second life’ for batteries?
- Manufacturing cost reduction
  - suppliers confident to invest in a major new market
- Next generation batteries optimised for automotive
  - R and D focus and funding
  - better batteries and lightweight vehicles
- Large scale demonstrations in major cities





Scenarios: Arup/CENEX report for BERR and DfT 2008

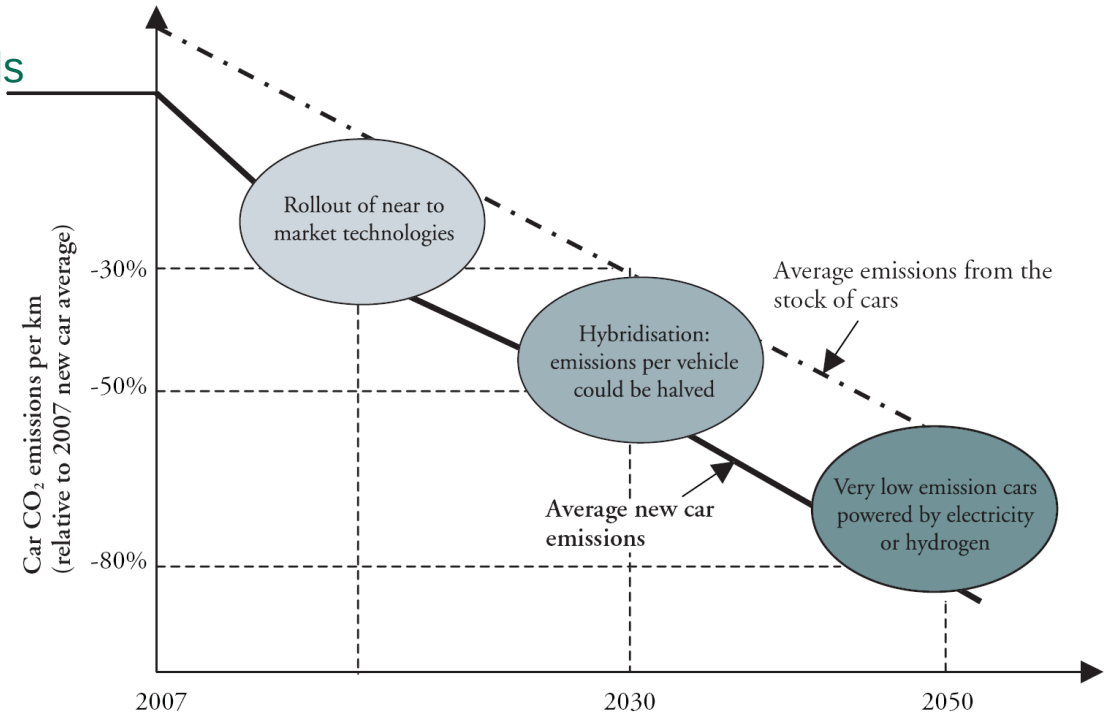
2050: 90% reduction in CO_2 per km - risk mitigation

- Electric vehicles?
  - new battery and energy storage technologies
  - or consumer acceptance of different vehicle use
- Hydrogen fuel cell powered vehicles?
  - hydrogen economy - PV in deserts; CO_2 injection into coal seams…
  - new fuel cell and hydrogen storage technologies
  - extensive new infrastructure developed: hydrogen tankers ship fuel from Africa and Middle East to Europe and US
- Novel biofuels?
  - no longer requiring land – algae growing in tubular reactors?
  - but focused on air travel and defence applications?
- Information Cities?
  - with autonomous electric vehicles linking intercity travel by fast train?
- For the long term we need technology development for multiple visions
  - none is risk-free

Technology road to ‘zero-carbon’ vehicles

KING REVIEW

- In the next 5 years: 30% CO_2 reduction with ‘available’ technology
- Cars that emit 50% less CO_2 than today could be on the road by 2025-2030
  - plug-in hybrids with a small internal combustion engine, electric vehicles
- By 2050 electric vehicles could reduce CO_2 emissions per vehicle by 90%
- Technology challenges
  - new technology and skills
  - recycling/sustainability
  - energy storage
- Manufacturing challenges
  - cost reduction
  - supply chain
  - investment and skills
- Policy challenges
  - accelerating technology
  - developing the market
  - low C power generation
  - infrastructure and skills

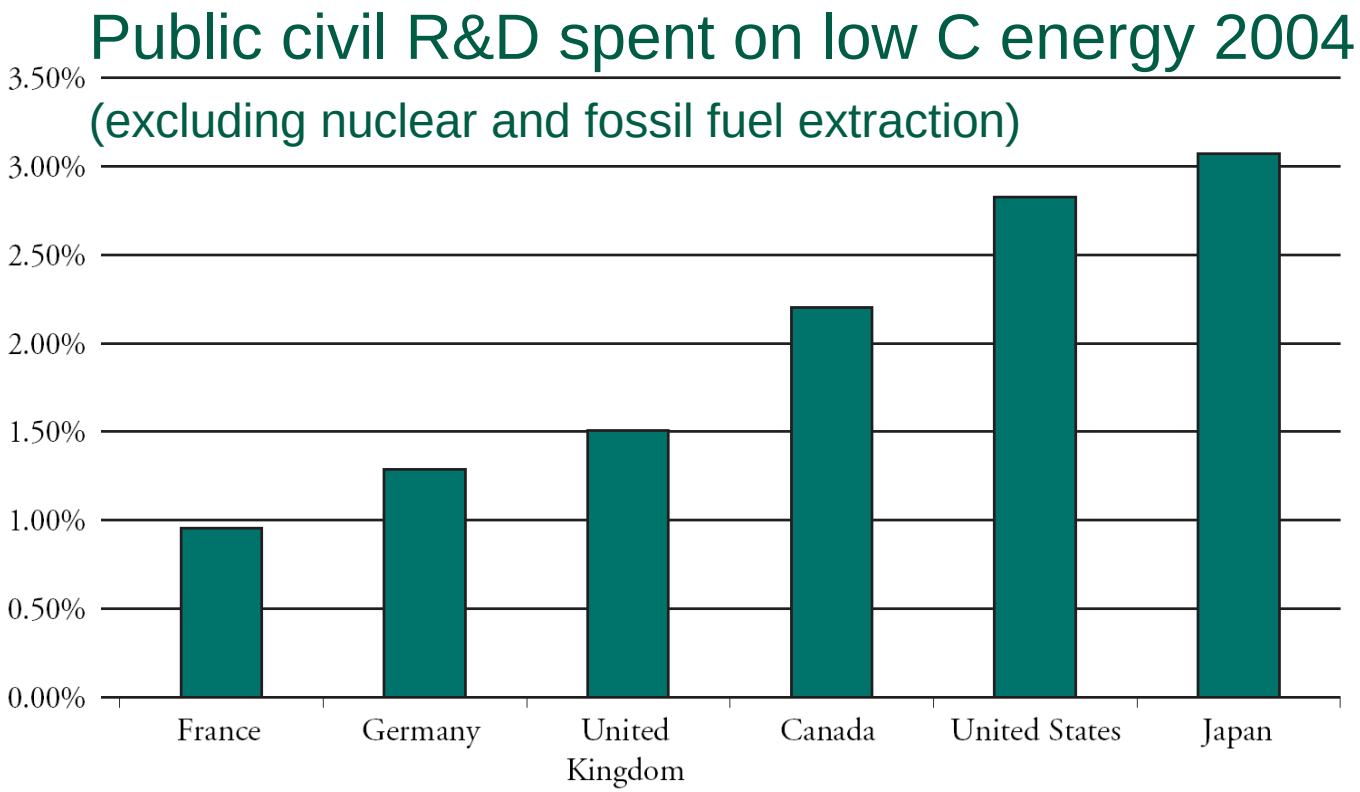


King Review: policy to reduce vehicle emissions

- Support for the EU 130g/km regulatory emissions target by 2012
  - to accelerate close to market low emissions technologies “from shelf to showroom”
- Ensuring that industry has the right signals to deliver step change technologies in the medium term
  - an EU-wide 100g/km level for 2020 and regular target every 7 to 10 years beyond this
- Stimulating the market for low emissions cars through:
  - informing consumers: car labelling, advertising and tax discs
  - incentivising consumers: through fiscal measures and local incentives
  - particularly appealing to reduced running costs
- Measures to change consumer behaviour
  - dashboard technology
  - Act on CO_2
  - education
- Including light commercial vehicles in all regulations

King Review: research and development

- Support for demonstration:
  - major electric vehicle demonstration - vehicles and infrastructure
  - opportunities for technology demonstration/procurement support for low C vehicles
- Focus: a much larger share of Public/Government R & D funding on low C R&D
- R&D collaboration with developing and emerging economies



Source: Derived from IAE data 2004

A final thought: in the developing world…

KING REVIEW

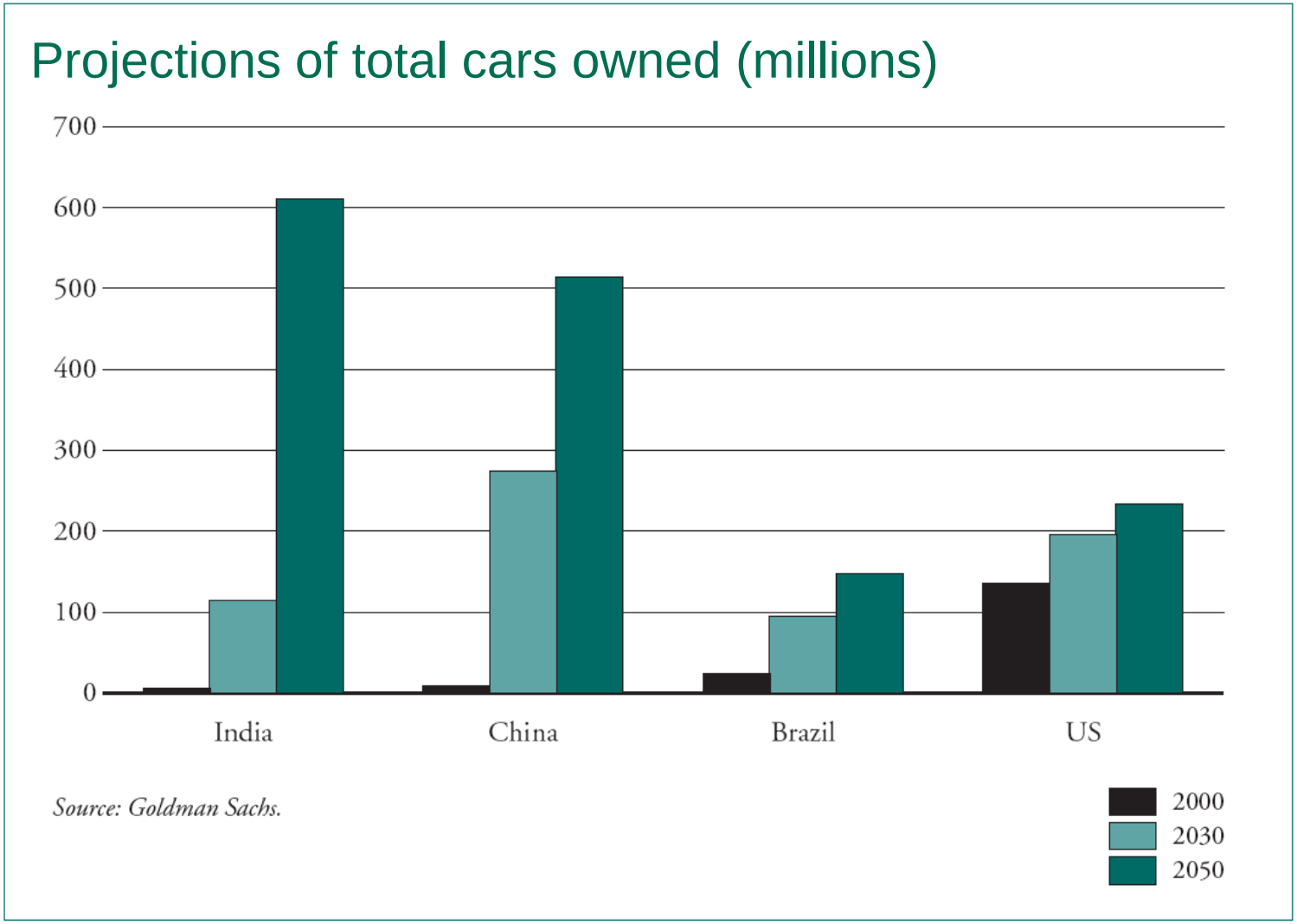
Projection of car ownership per 1,000 people

	India	China	Brazil	US
2000	5	7	137	480
2030	81	188	429	538
2050	382	363	645	555

Source: Goldman Sachs.
The BRICs and Global Markets: Crude, Cars and Capital, Goldman Sachs Global Economics Paper No. 118, 2004.

An environmental challenge - and a market opportunity

KING REVIEW



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