The European diesel car boom –

environmental effects and global comparison

most parts of this presentation are published here:

http://www.enveurope.com/content/pdf/2190-4715-25-15.pdf

London, June 24, 2014

Eckard Helmers

Environment Campus – University of Applied Sciences Trier, Germany

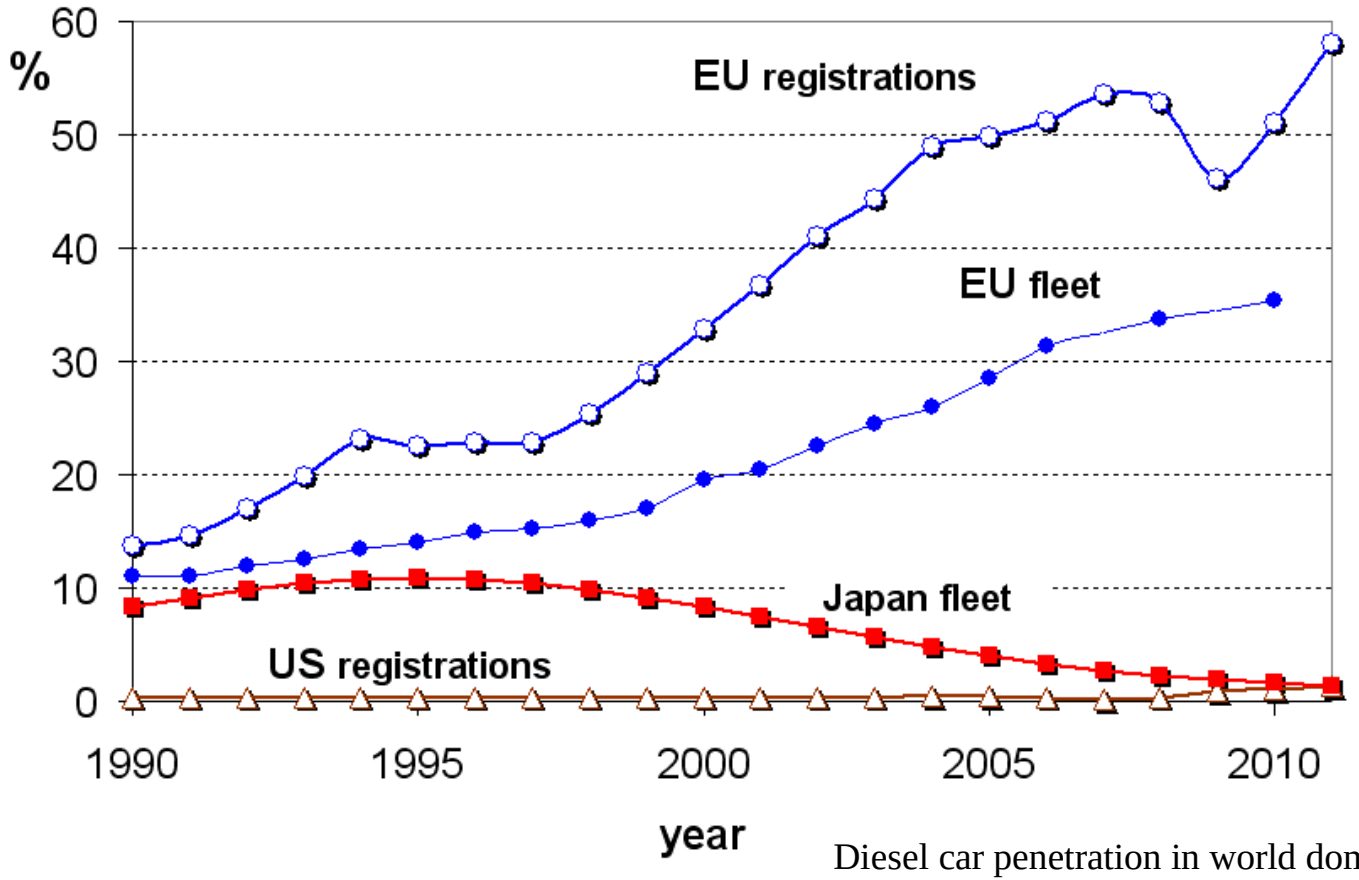
The European diesel car boom –

environmental effects and global comparison

- history US – Japan – Europe
- who initiated the European diesel car boom and why (how)?
- what is the environmental outcome ? ➔ climate mitigation
  - black carbon
  - NO_x
- supply chain
- future outlook

Until the mid 1990s: Europe followed technology leaps initiated in US with a certain delay

That changed in the mid 1990s:



+ 44 Mio diesel cars in Europe

1996-2011

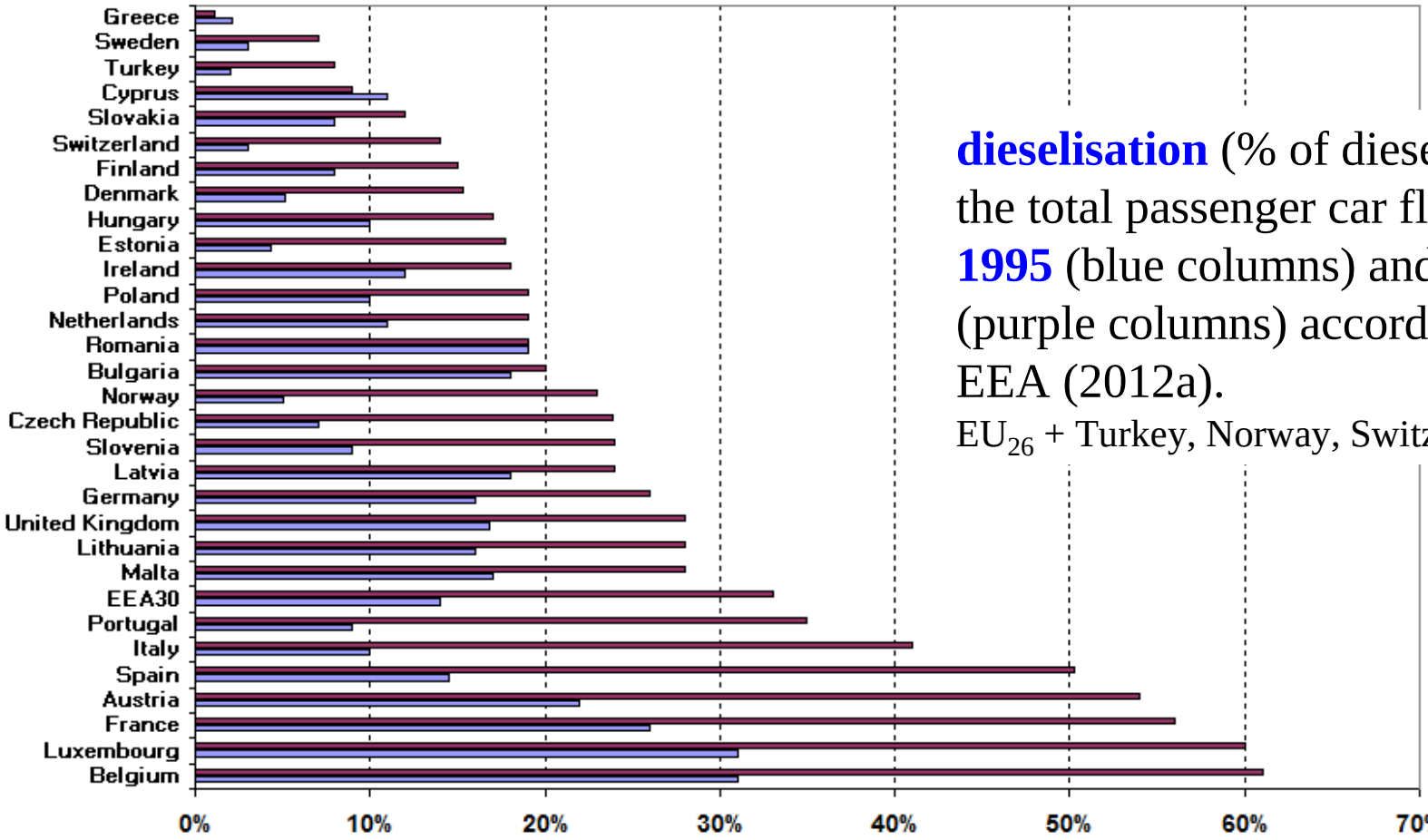
Cames & Helmers (2013)

Diesel car penetration in world dominating markets.

All data are percentages, either annual new car registrations, or annual entire car fleet composition.

Until the mid 1990s: Europe followed technology leaps initiated in US with a certain delay

That changed in the mid 1990s: a fundamental technology change was initiated towards diesel cars



dieselisation (% of diesel cars in the total passenger car fleet) in **1995** (blue columns) and **2009** (purple columns) according to EEA (2012a).

EU_{26} + Turkey, Norway, Switzerland

Cames & Helmers, 2013

Until the mid 1990s: Europe followed technology leaps initiated in US with a certain delay

That changed in the mid 1990s: a fundamental technology change was initiated towards diesel cars

principal questions

- who has initiated this techn. change and why?
- how was this techn. change realised/directed?
- what is the environmental outcome?

Until the mid 1990s: Europe followed technology leaps initiated in US with a certain delay

That changed in the mid 1990s: a fundamental technology change was initiated towards diesel cars

principal questions

- who has initiated this techn. change and **why**?

climate change mitigation discussion

- IPCC established 1988
- Kyoto protocol 1997, ratified by EU in 2002, committing to save 8 % GHG by 2012

a fundamental technology change was initiated towards diesel cars since the mid 1990s

principal questions

- **who** has initiated this techn. change and why?
- **how** was this techn. change realised/directed?

close co-operation between EU commission and European Industry:

- programs Auto-Oil I (1992-1995) and Auto-Oil II (1996-2000) with European Car and Oil Industry as main players
- the 1998 voluntary agreement between ACEA and EC with targets for 2008
- obviously all parties agreed to push diesel technology

a fundamental technology change was initiated towards diesel cars since the mid 1990s

principal questions

- **who** has initiated this techn. change and why?
- **how** was this techn. change realised/directed?

➔ weaker emission standards granted to diesel cars by EU-commission since Euro 2 (1992) – unlike in USA (and Japan)

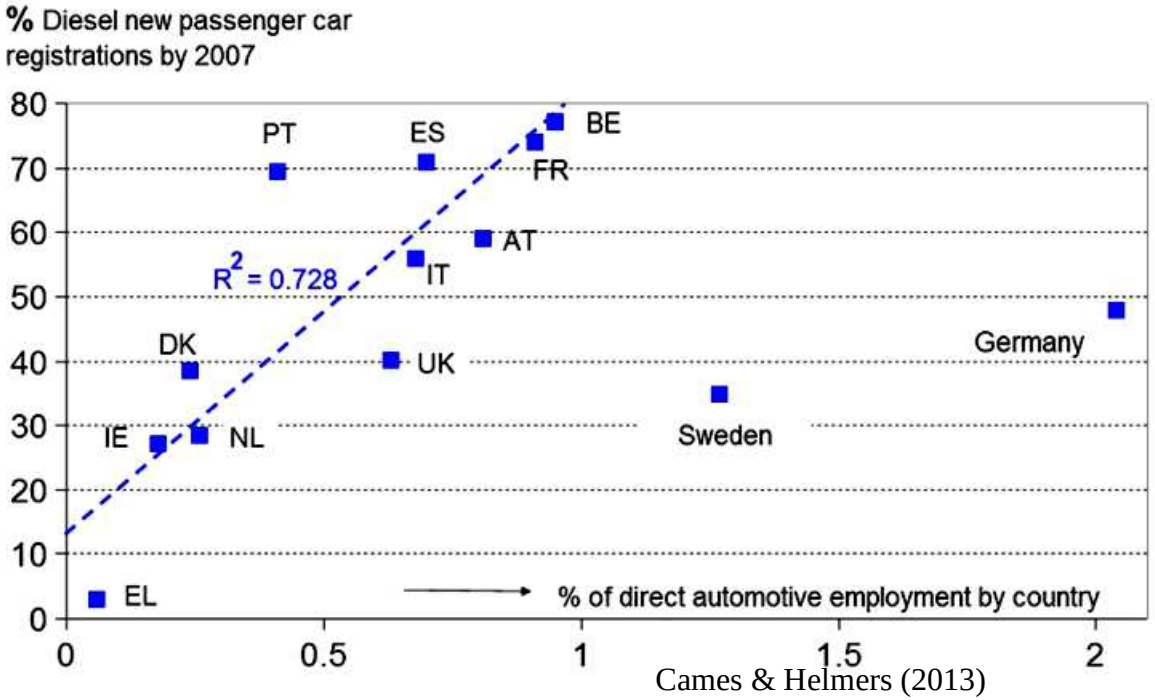
➔ fiscal measures in the EU member states

➔ varying dieselization rates

a fundamental technology change was initiated towards diesel cars since the mid 1990s

principal questions

- **who** has initiated this techn. change and why?
- **how** was this techn. change realised/directed? **- on a national level**



Cames & Helmers (2013)

dieselization rate versus direct automotive employment.

The coefficient of determination R^2 and regression line have been calculated excluding Sweden and Germany.

a fundamental technology change was initiated towards diesel cars since the mid 1990s

principal questions

- **who** has initiated this techn. change and why?
- **how** was this techn. change realised/directed? **- on a national level**

Table 2 Dieselization in several European countries

Country	Assumption 1 Car/supplier industry?	Assumption 2 Ecologically backward?	Assumption 3 Fuel tourism?	Assumption 4 'Corporatist'?	Diesel cars attractive?
France	**	*		**	5
Germany	***			*	4
Belgium	**	*		**	5
Netherlands				**	2
Spain	**	**	*	**	7
Austria	*		**	**	5
Norway		*		**	3
Luxembourg	*	*	***	**	7

Rating: 0 minimum, *** maximum.

Cames & Helmers (2013)

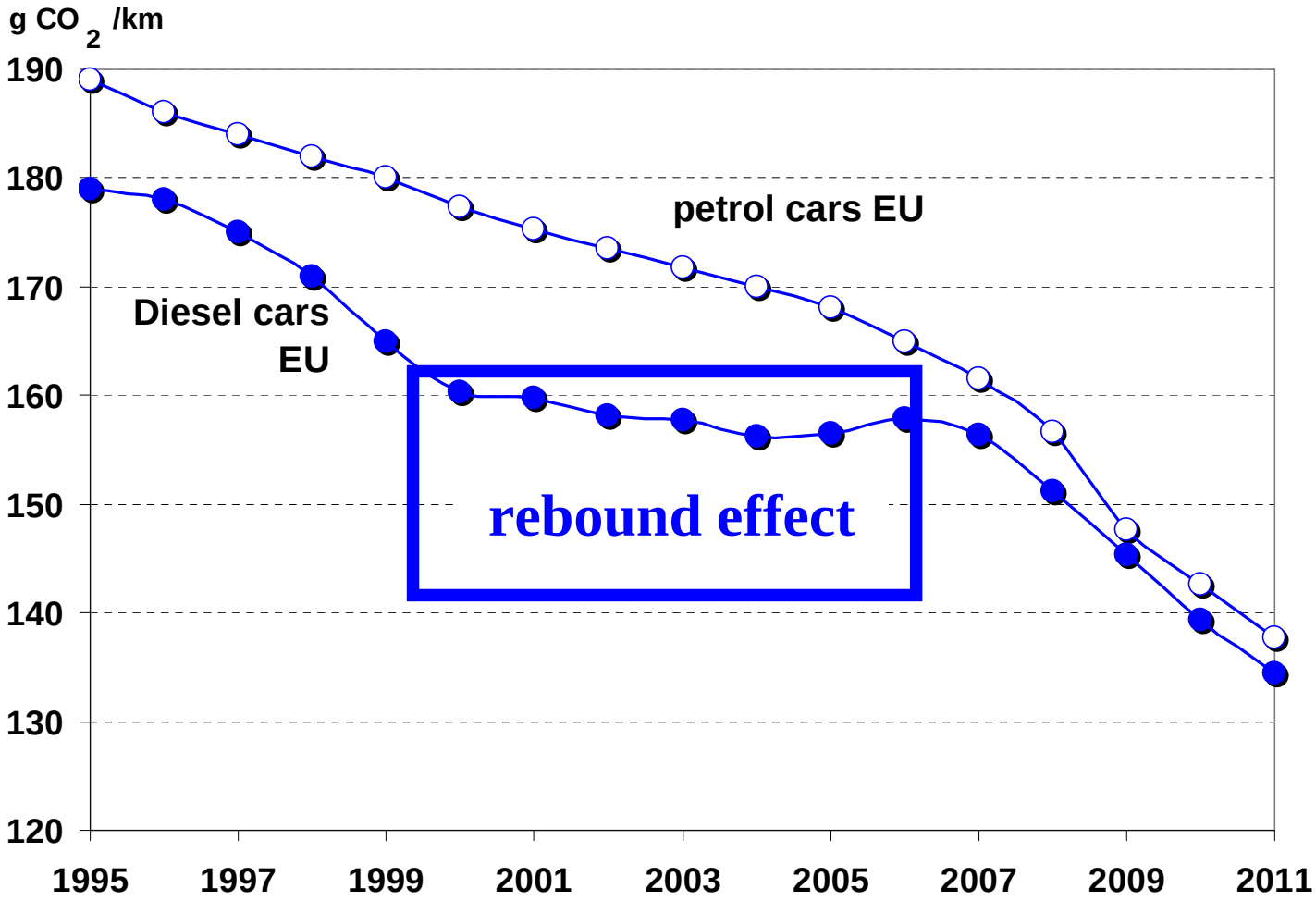
Until the mid 1990s: Europe followed technology leaps initiated in US with a certain delay

That changed in the mid 1990s: a fundamental technology change was initiated towards diesel cars

principal questions

- who has initiated this techn. change and why?
- how was this techn. change realised/directed?
- **what is the environmental outcome?**

ecoefficiency analysis of the European diesel car boom



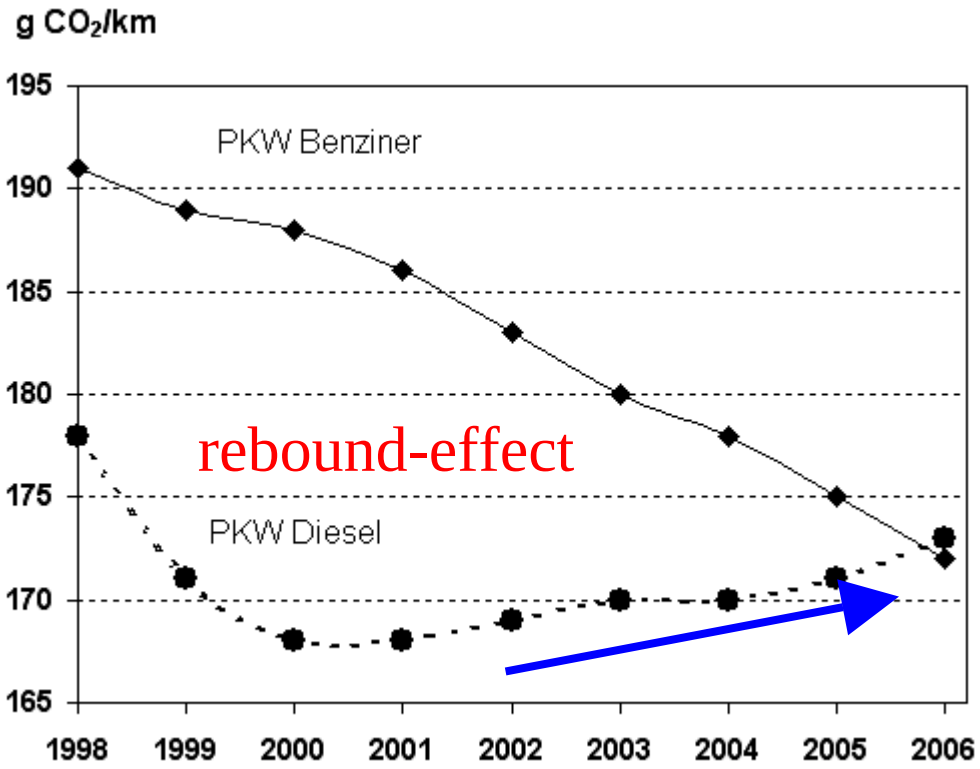
CO_2 emission time trend of new registered cars in the EU

Cames & Helmers (2013)

Sources: EU-15 figures 1995-1999 (European Commission, 2005); EU-27 figures (EEA, 2010a); Japan 1995-2006 figures recalculated by JAMA (2008) data; Japan 2007-2010 figures recalculated by JAMA (2012) data

ecoefficiency analysis of the European diesel car boom

Germany



CO_2 emission time trend of new registered cars

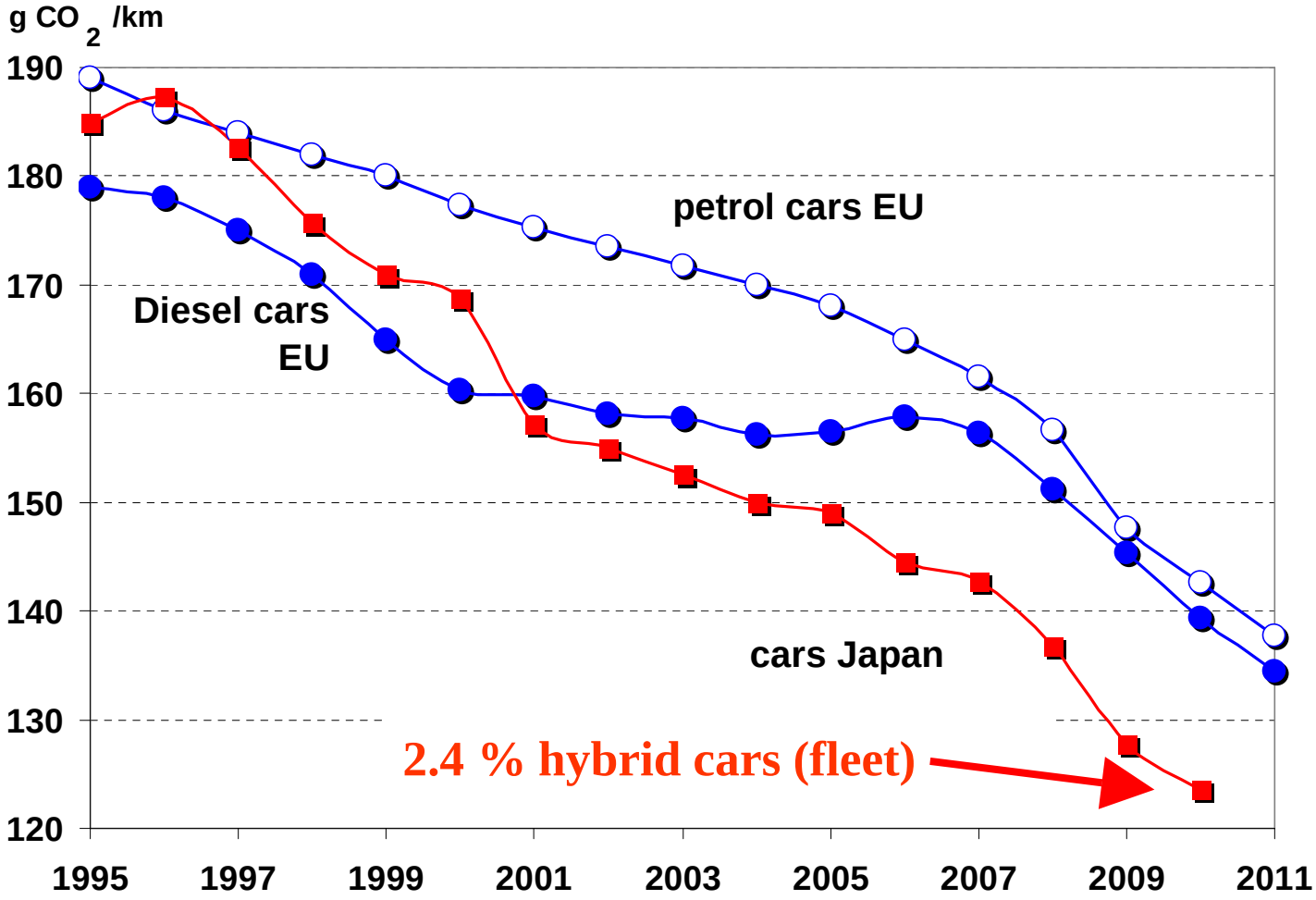
in Germany

Source: BUND, 2007 with data from Federal Motor Transport Authority,

figure taken from Helmers, 2010

ecoefficiency analysis of the European diesel car boom

Japan



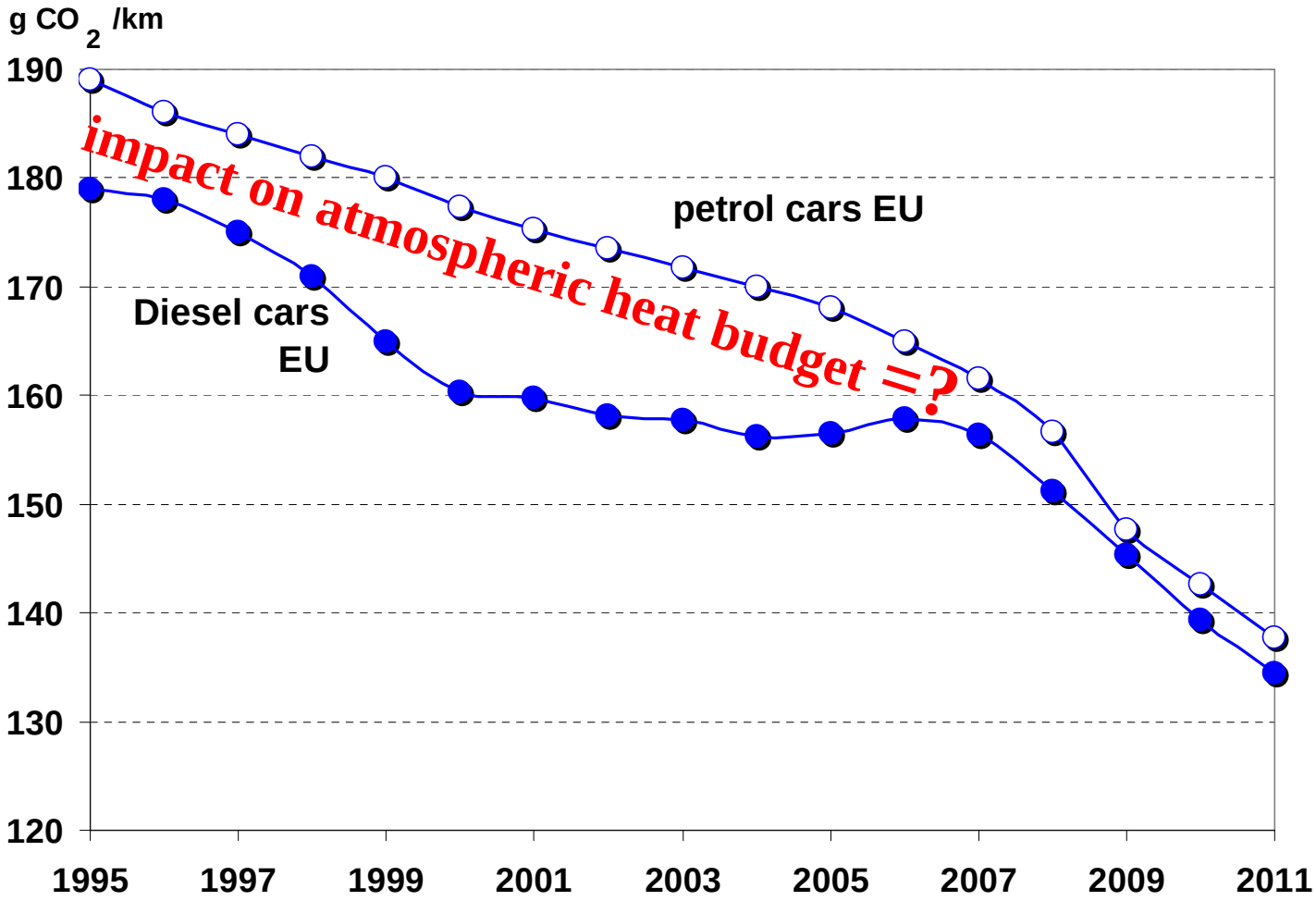
CO_2 emission time trend of new registered cars

EU/Japan

Cames & Helmers (2013)

Sources: EU-15 figures 1995-1999 (European Commission, 2005); EU-27 figures (EEA, 2010a); Japan 1995-2006 figures recalculated by JAMA (2008) data; Japan 2007-2010 figures recalculated by JAMA (2012) data

ecoefficiency analysis of the European diesel car boom



CO_2 emission time trend of new registered cars in the EU

Cames & Helmers (2013)

Sources: EU-15 figures 1995-1999 (European Commission, 2005); EU-27 figures (EEA, 2010a); Japan 1995-2006 figures recalculated by JAMA (2008) data; Japan 2007-2010 figures recalculated by JAMA (2012) data

soot as main actor next to CO_2 in atmospheric warming ?

JOURNAL OF GEOPHYSICAL RESEARCH: ATMOSPHERES, VOL. 118, 5380–5552, doi:10.1002/j

2013

Bounding the role of black carbon in the climate system: A scientific assessment

T. C. Bond,[1] S. J. Doherty,[2] D. W. Fahey,[3] P. M. Forster,[4] T. Berntsen,[5] B. J. DeAngelo,[6] M. G. Flanner,[7] S. Ghan,[8] B. Kärcher,[9] D. Koch,[10] S. Kinne,[11] Y. Kondo,[12] P. K. Quinn,[13] M. C. Sarofim,[6] M. G. Schultz,[14] M. Schulz,[15] C. Venkataraman,[16] H. Zhang,[17] S. Zhang,[18] N. Bellouin,[19] S. K. Guttikunda,[20] P. K. Hopke,[21] M. Z. Jacobson,[22] J. W. Kaiser,[23] Z. Klimont,[24] U. Lohmann,[25] J. P. Schwarz,[3] D. Shindell,[26] T. Storelvmo,[27] S. G. Warren,[28] and C. S. Zender[29] *)

The best estimate of industrial-era climate forcing of black carbon through all forcing mechanisms, including clouds and cryosphere forcing, is +1.1 W m^{-2} with 90% uncertainty bounds of +0.17 to +2.1 W m^{-2}. Thus, there is a very high probability that black carbon emissions, independent of co-emitted species, have a positive forcing and warm the climate. We estimate that black carbon, with a total climate forcing of +1.1 W m^{-2}, is the second most important human emission in terms of its climate forcing in the present-day atmosphere; only carbon dioxide is estimated to have a greater forcing.

IPCC (AR5*, 2012): + 0.3 Wm^{-2} time scale?? *) 5 authors both on paper and AR5

2007

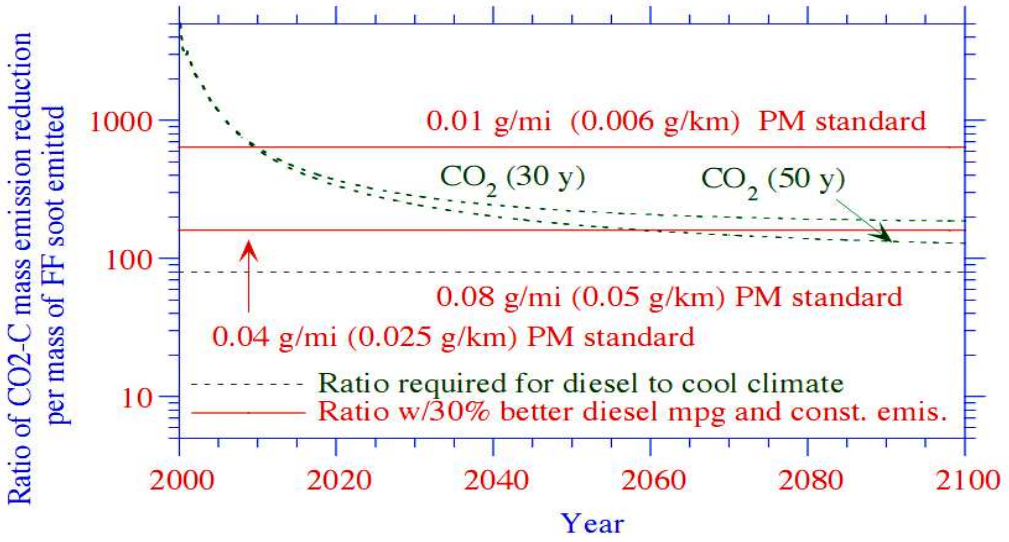
STANFORD UNIVERSITY

Atmosphere/Energy Program

Department of Civil & Environmental Engineering
Terman Engineering Center, M-31
Stanford, California 94305-4020

MARK Z. JACOBSON
Professor of Civil & Environmental Engineering
and, by courtesy, Energy Resources Engineering

Testimony for the Hearing on Black Carbon and Global Warming
House Committee on Oversight and Government Reform
United States House of Representatives
The Honorable Henry A. Waxman, Chair
October 18, 2007



is it useful to replace gas cars in USA by diesel cars?

GWP of BC relative zu CO_2

Black carbon has a GWP …

… of 1,870 for the 100-year horizon and, and of 4,470 for
the 20-year horizon, respectively (Jacobson, 2007).

… of 680 for the 100-year horizon and
a GWP of 2,200 for the 20-year horizon (Bond & Sun, 2005).

A GWP of 680 means that “1 kg of BC produces as much forcing as
680 kg of CO_2” (Bond & Sun, 2005)

EU emission standards for petrol and diesel cars

threshold limit	**particles/soot** mg/km	
	diesel	**petrol**
EU 2 < 2000	100	(1-5)
EU 3 2000-2005	50	(1-5)
EU 4 2005-2009	25	(1-5)
EU 5 2009-2014	5	5
EU 6 2014 -	62% BC 5	8% BC 5

+ 76 g CO_{2eq}/km

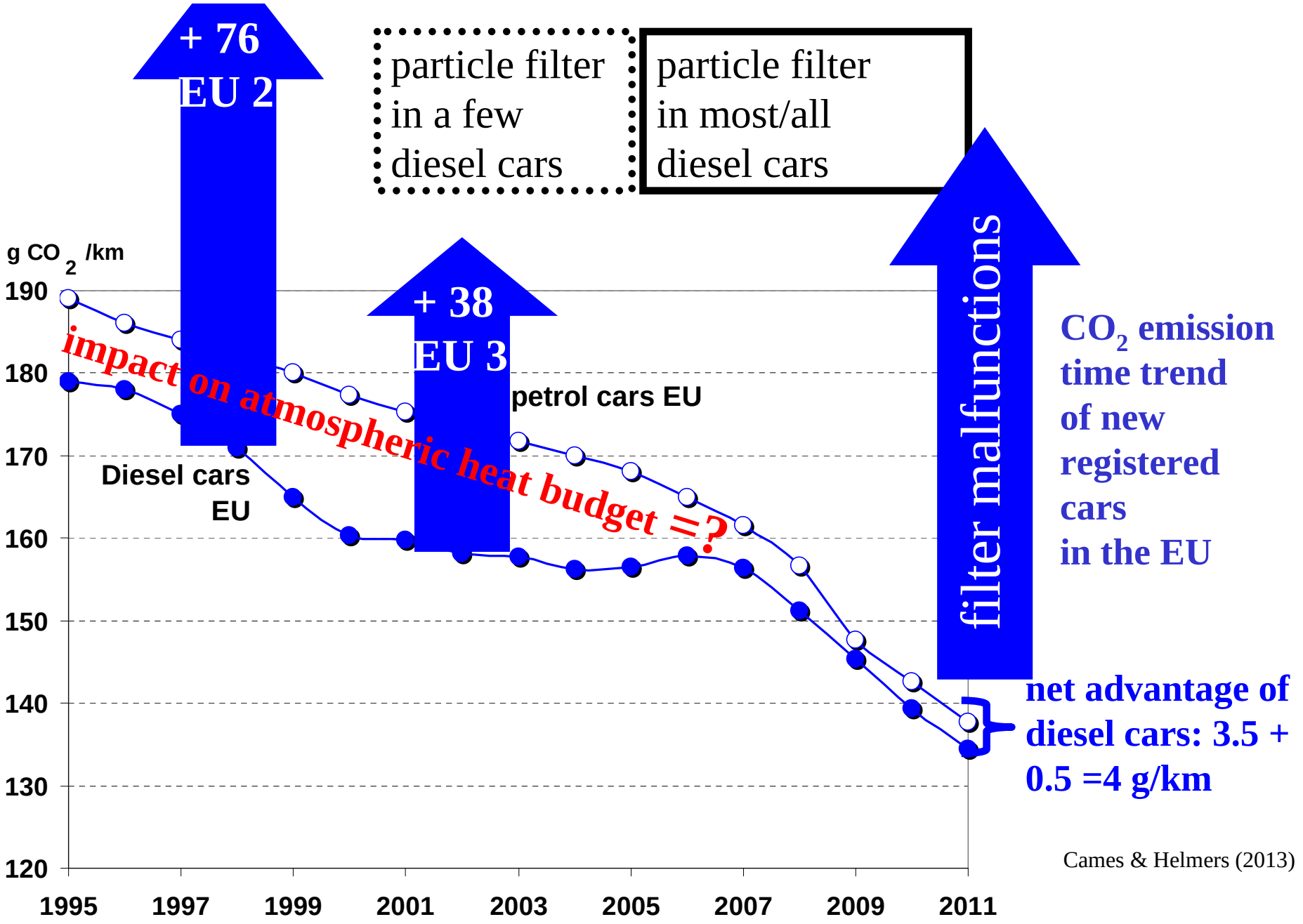
+ 38 g CO_{2eq}/km

+ 19 g CO_{2eq}/km

+ 4 g CO_{2eq}/km

+ 1.3 g CO_{2eq}/km

***) <u>with</u> filter: 1 mg soot 0.8 g CO_{2eq} /km**



Sources: EU-15 figures 1995-1999 (European Commission, 2005); EU-27 figures (EEA, 2010a); Japan 1995-2006 figures recalculated by JAMA (2008) data; Japan 2007-2010 figures recalculated by JAMA (2012) data

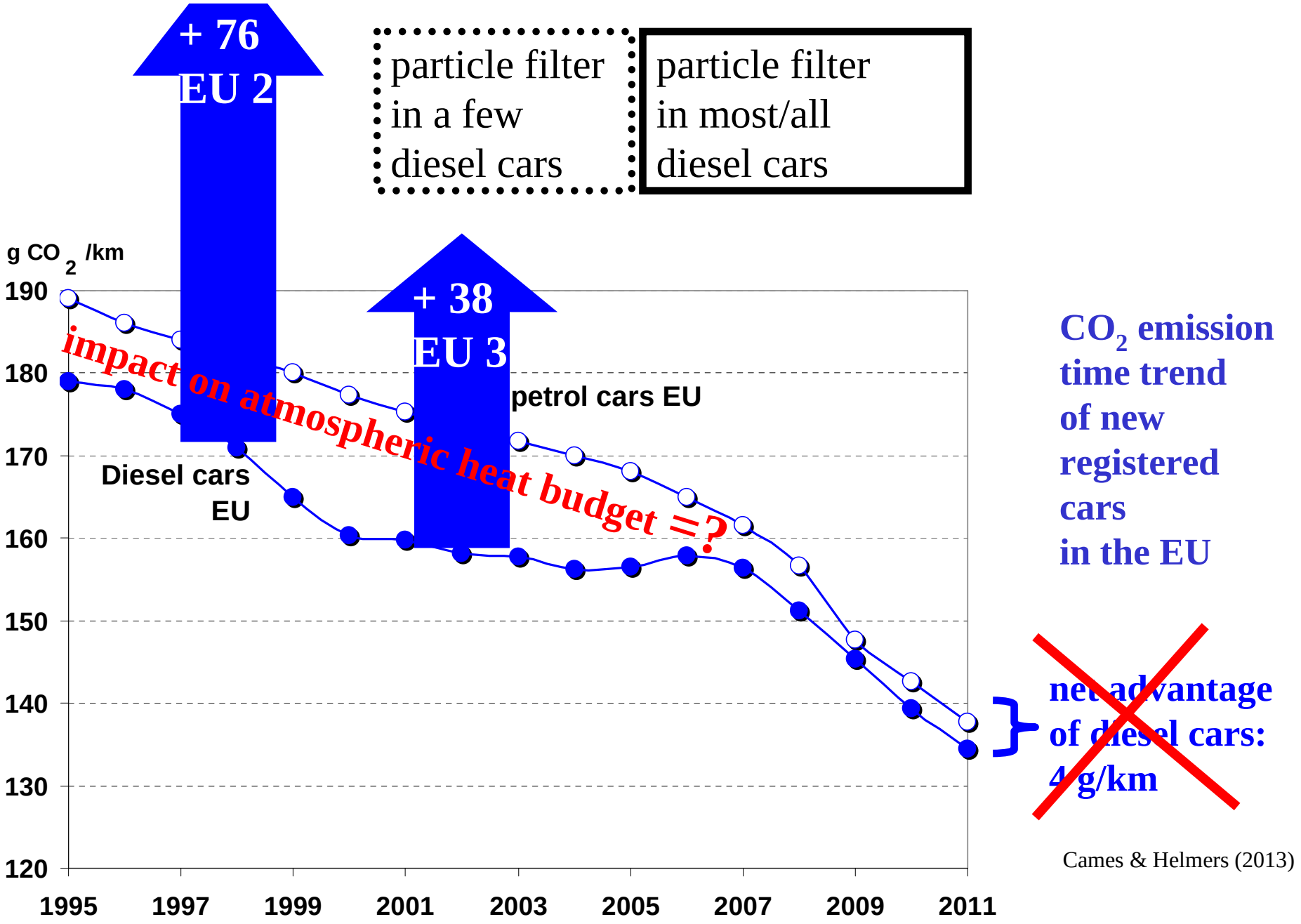
EU emission standards for petrol and diesel cars

- emission standards formally guaranteed for 160,000 km (since Euro 5)
- no sanctions to carmakers if standards are not met
- no official test stand experiments with aged cars in the EU
- no regular exhaust emission measurement (in Germany: CO)
- diesel part. filter malfunctions often discussed in the public, no statistics available, however almost no filter works > 200,000 km

EU emission standards for petrol and diesel cars

How many diesel cars on the streets may have filter malfunctions?

- assumption: 10 % of all cars > 100,000 km with PF malfunctions ➔ then 100 mg soot/km ➔ + 76 g $CO_{2\text{-eq}}$/km
- with 235,000 km driven **roughly** 5 % of all cars on street have PF malfunctions
- ➔ in a diesel car pool with average direct CO_2 emissions of 135 g/km **roughly 4** g $CO_{2\text{-eq}}$/km have to be added



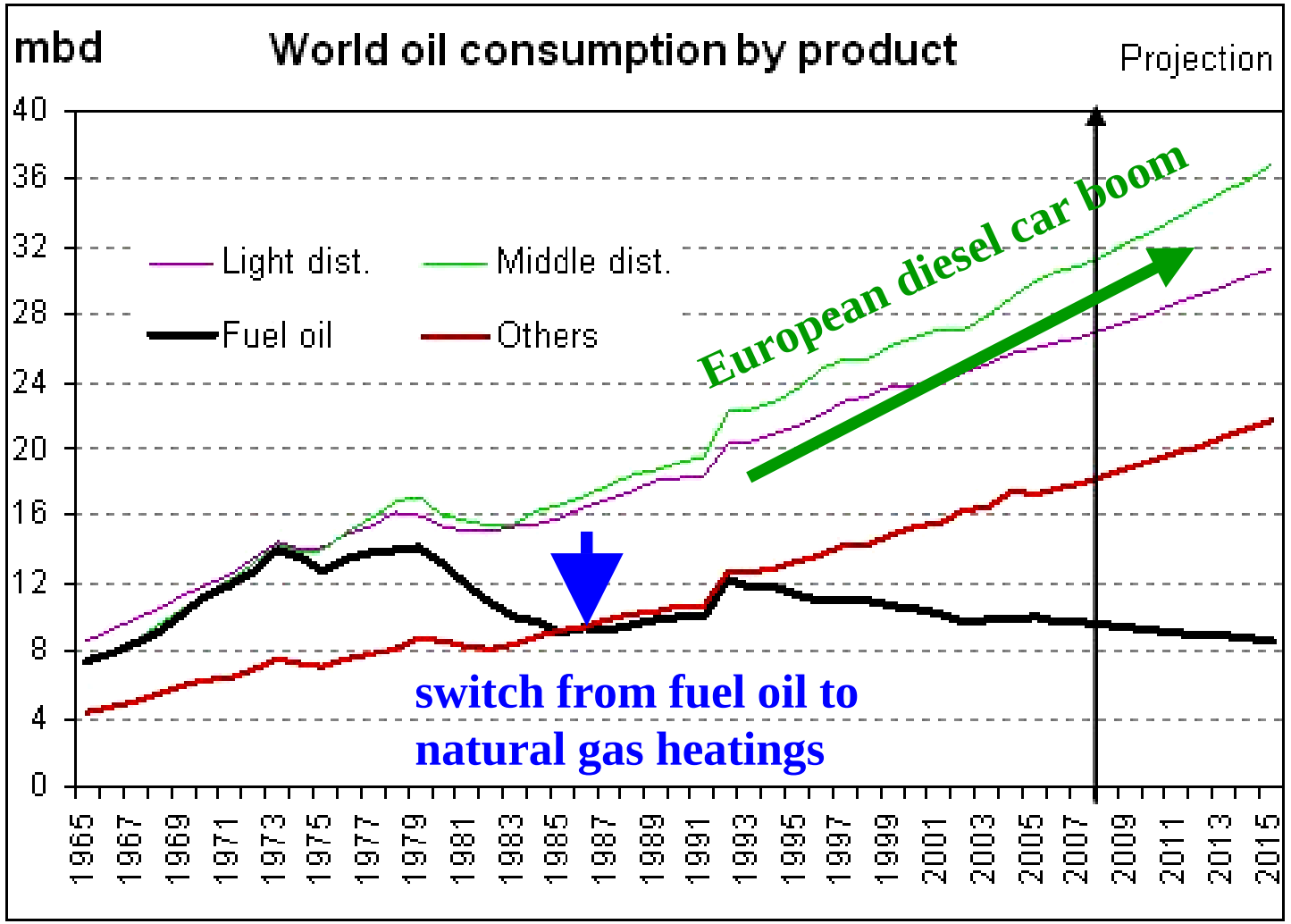
Sources: EU-15 figures 1995-1999 (European Commission, 2005); EU-27 figures (EEA, 2010a); Japan 1995-2006 figures recalculated by JAMA (2008) data; Japan 2007-2010 figures recalculated by JAMA (2012) data

next problem: supply chain CO_2 emissions

impact on atmospheric heat budget =?

supply chain CO_2 emissions

million barrels
per day



www.intertanko.com 2008 based on IEA data

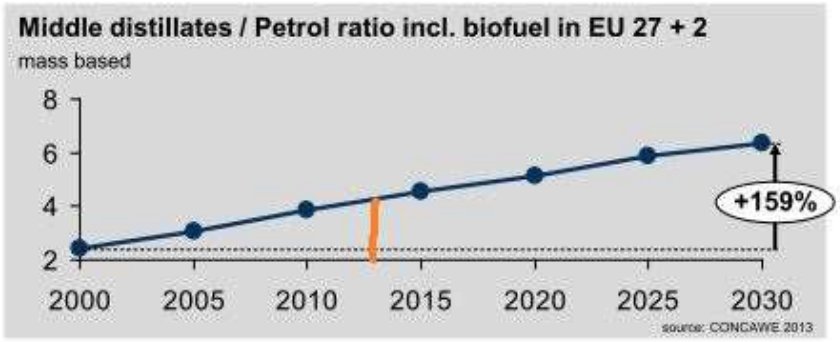
supply chain CO_2 emissions

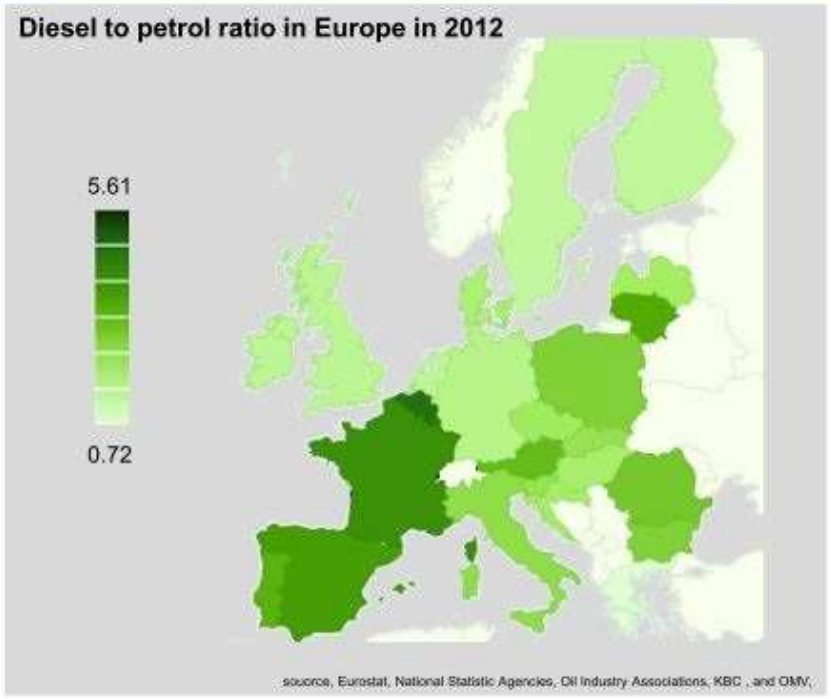
diesel: from 1/3 of road fuel to 2/3 from 1980 – 2010 (Dings, 2012)

The middle distillate-to-petrol ratio is increasing, continuously, albeit there are regional differences

European middle distillate demand

4x petrol demand by 2014

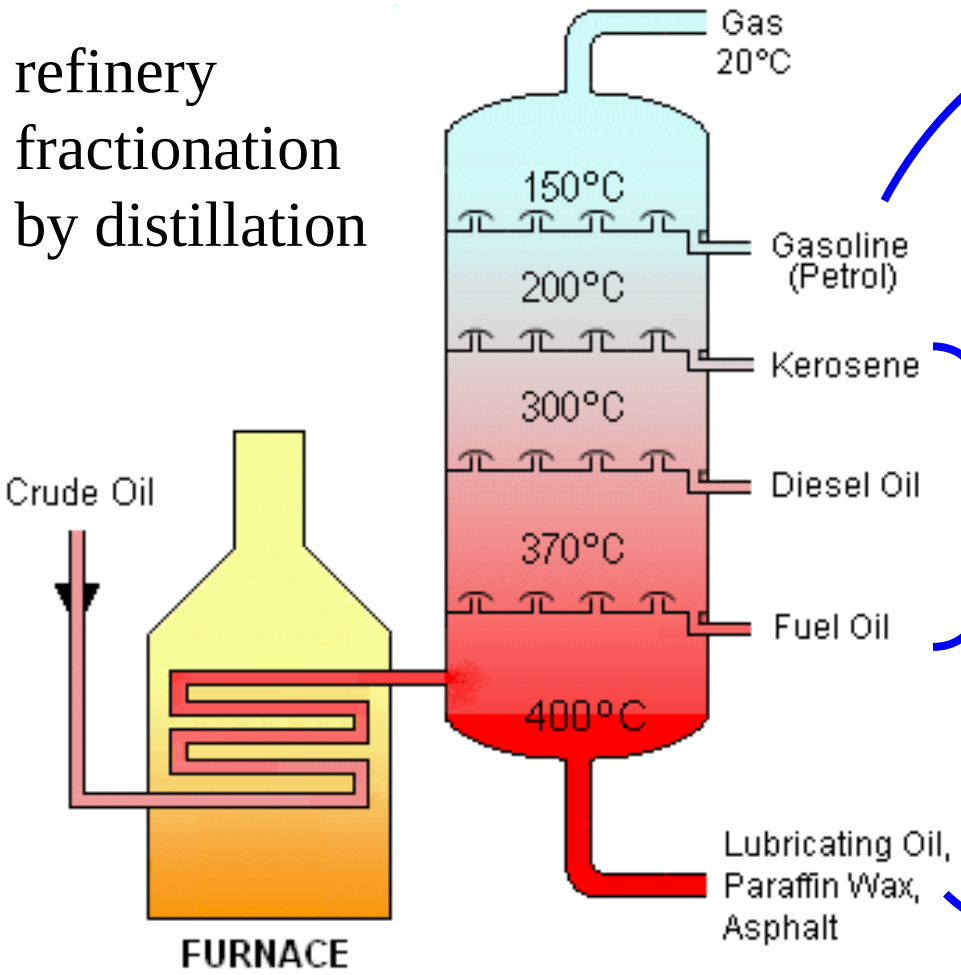




modified after D. Tuppinger, OMV AG, 2014

supply chain CO_2 emissions

refinery fractionation by distillation



(middle) distillate

~ 35 %

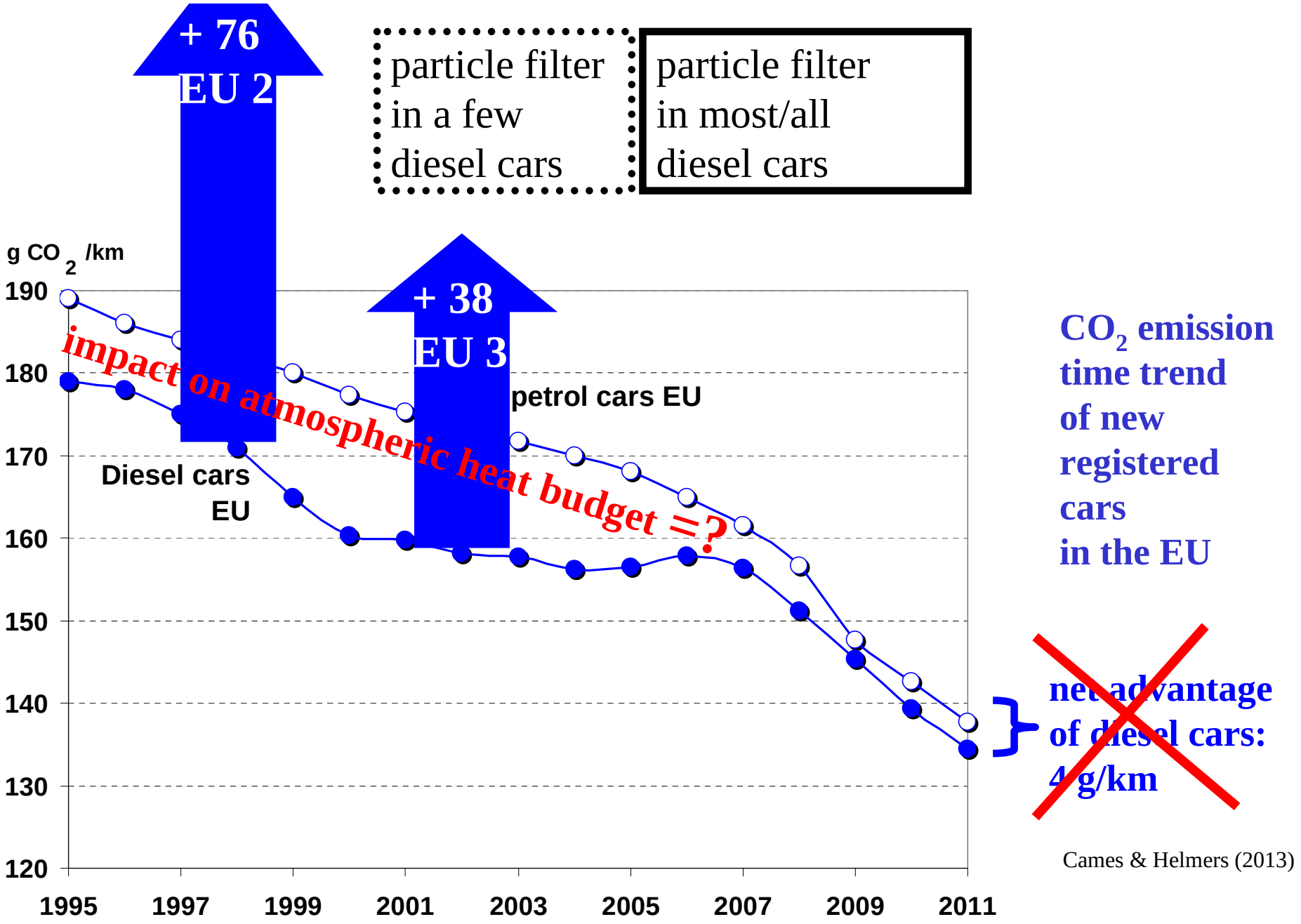
petrochemical conversion e.g. cracking

➔ + 9-58 % in supply chain emissions*

➔ + 2-10 g CO_2/km

www.answers.com/topic/fractional-distillation 2014

*) 20 % surplus to direct emissions



Sources: EU-15 figures 1995-1999 (European Commission, 2005); EU-27 figures (EEA, 2010a); Japan 1995-2006 figures recalculated by JAMA (2008) data; Japan 2007-2010 figures recalculated by JAMA (2012) data

EU emission standards for petrol and diesel cars

threshold limit	particles/soot mg/km		nitrogen oxides mg/km	
	diesel	**petrol**	**diesel**	**petrol**
EU 3 2000-2005	50	(1-5)	500	150
EU 4 2005-2009	25	(1-5)	250	80
EU 5 2009-2014	5	5	180	60
EU 6 2014 -	5	5	80	60

Helmers, 2009 ff.

EU emission standards for petrol and diesel cars

threshold limit	particles/soot mg/km		nitrogen oxides mg/km	
	diesel	petrol	**diesel**	**petrol**
EU 3 2000-20			500	150
EU 4 2005-20	**these data are usually modelled!**		250	80
EU 5 2009-20			180	60
EU 6 2014 -	5	5	80	60

x 3 ?

… used as basis in highlevel reports (OECD)

Helmers, 2009 ff.

EU emission standards for petrol and diesel cars

threshold limit	particles/soot mg/km		nitrogen oxides mg/km	
	diesel	petrol	**diesel**	**petrol**
EU 3 2000-2005	50	(1-5)	500	150
EU 4 2005-2009	25	(1-5)	250	80
EU 5 2009-2014	5	5	180	60
EU 6 2014 -	5	5	80	60

30

x 10 ?

… registration data published by ICCT* (2012) imply **10:1** ratio in diesel : petrol NO_x emissions

*) International Council on Clean Transportation

Helmers, 2009 ff.

EU emission standards for petrol and diesel cars

threshold limit	particles/soot mg/km		nitrogen oxides mg/km	
	diesel	petrol	**diesel**	**petrol**
EU 3 2000-2005	50	(1-5)	500	150 30
EU 4 2005-2009	25	(1-5)	250	80
EU 5 2009-2014	5	5	up to 4000*	60
EU 6 2014 -	5	5	80	60

x 20

*) Steven, 2011

uphill city conditions (Stuttgart)

„real world“

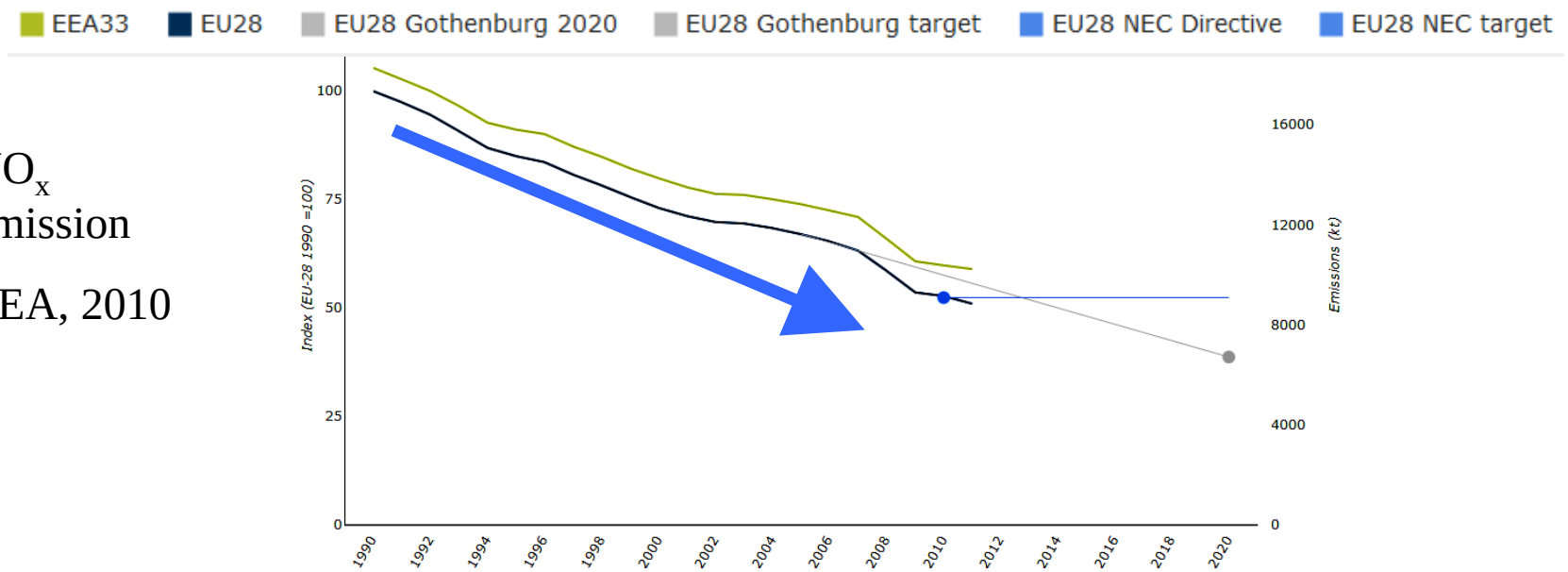
Helmers, 2010.

EU emission standards for petrol and diesel cars

➔ NO_x increase in European cities with high diesel car share ?

NO_x emission

EEA, 2010



http://www.eea.europa.eu/data-and-maps/indicators/eea-32-nitrogen-oxides-nox-emissions-1/assessment.2010-08-19.0140149032-3

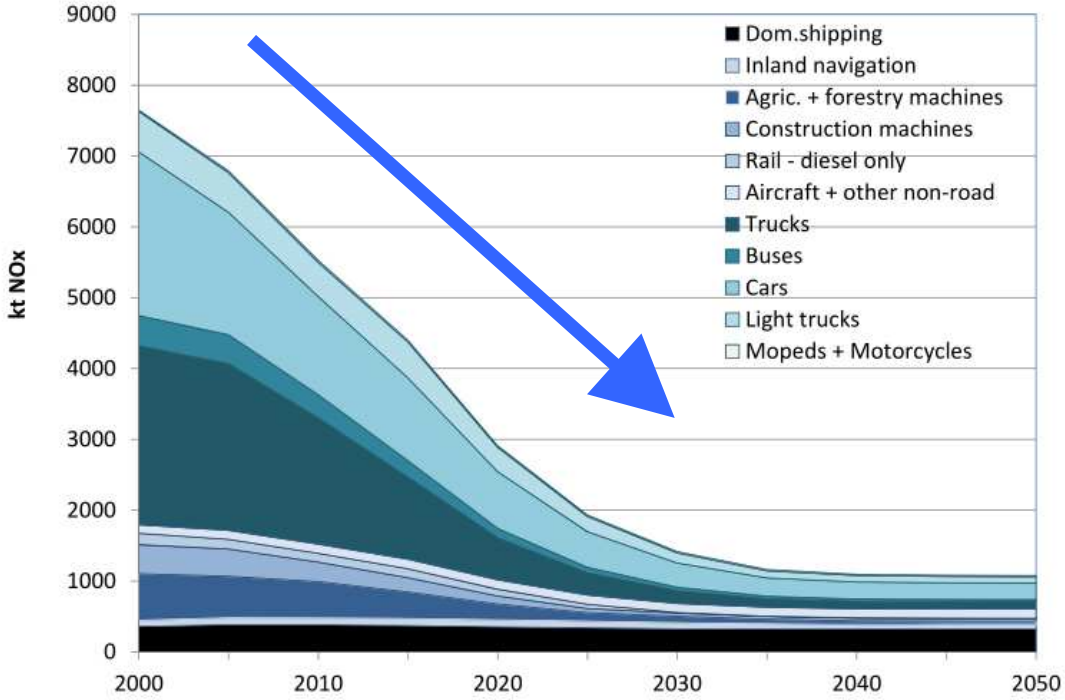
EU emission standards for petrol and diesel cars

➔ NO_x increase in European cities with high diesel car share ?

It is very difficult to investigate trends in actual **i**mmission burden in European cities based on internet publications

➔ almost all **data/trends published are based on models** (which are based on **e**mission standards/laboratory tests) !

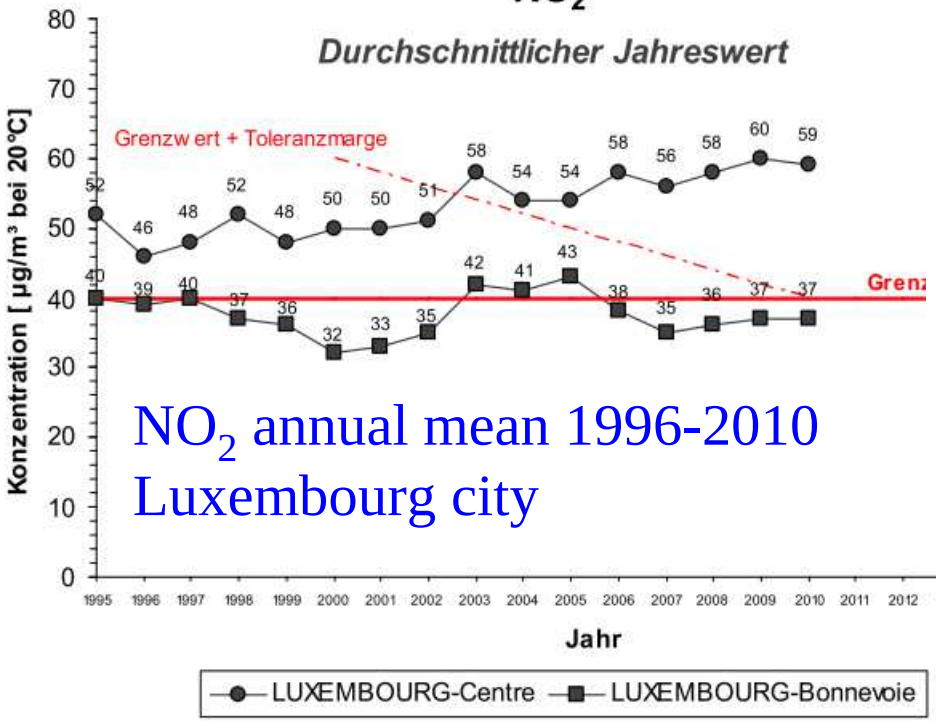
Development of NO_x emissions from mobile sources in the EU27 for the TSAP 2012 the Baseline scenario



http://ec.europa.eu/environment/air/pdf/review/TSAP-TRANSPORT-v2-20121128.pdf

EU emission standards for petrol and diesel cars

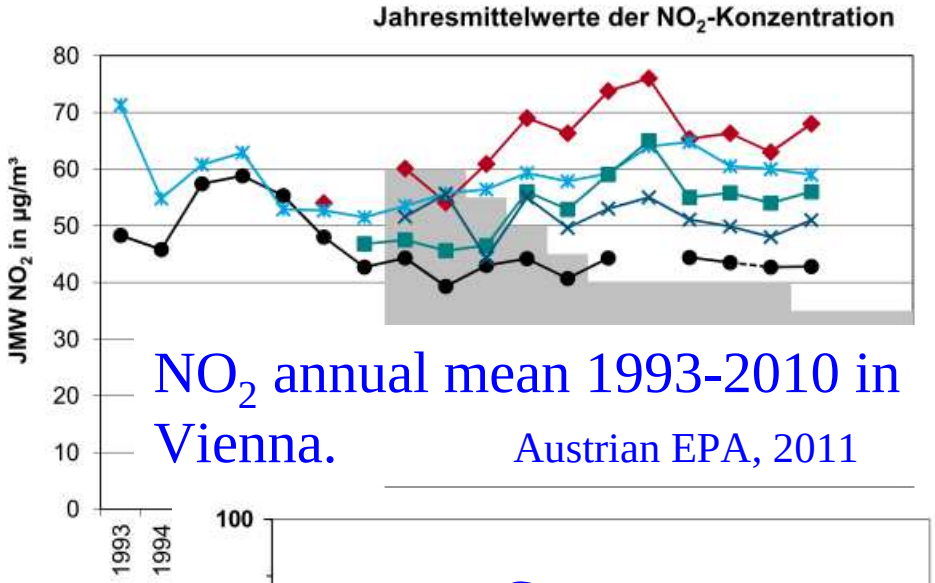
➔ NO_x increase in European cities with high diesel car share ?



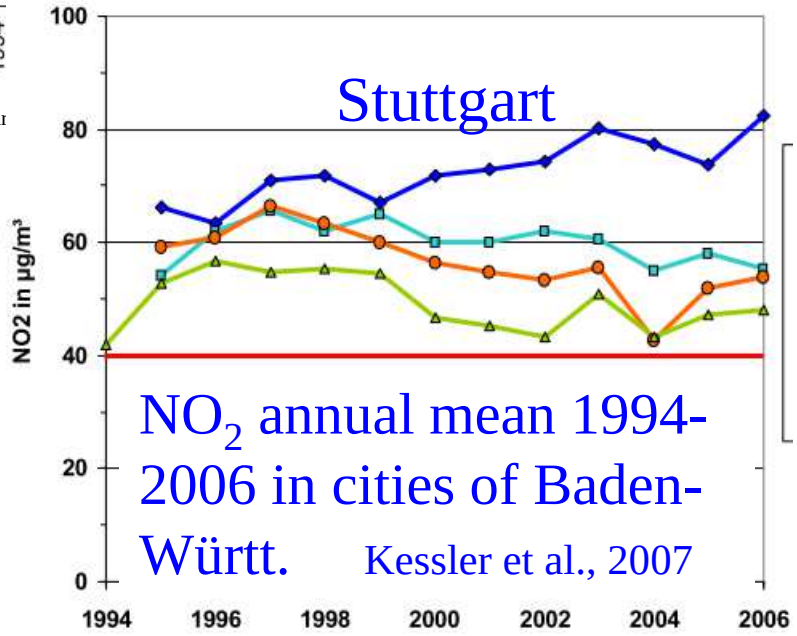
NO_2 annual mean 1996-2010 Luxembourg city

Luftqualitätsplan für den Großraum Stadt Luxemburg. 12/2011

http://www.environnement.public.lu/air_bruit/dossiers/plan_qual_air_ville_lux/pdf_plan_qual_air_ville_lux.pdf



NO_2 annual mean 1993-2010 in Vienna. Austrian EPA, 2011



NO_2 annual mean 1994-2006 in cities of Baden-Württ. Kessler et al., 2007

EU emission standards for petrol and diesel cars

fine dust in Paris at spring 2014: up to 180 µg/m^3

diesel cars reach 60 % of the fleet in France.

Paris: some 5 Mio cars registered

➔ 3 Mio diesel cars, probably around 1.5 Mio without particle filter

NO_x

- ~ 50 % of NO_x in European countries is from traffic sources (up to 80 % at highly polluted sites)
- EU member states and EU itself signed Gothenburg (Geneva) multicomponent protocoll 1999 (effective in 2005) with obligations to strongly reduce NO_x emissions, also NO_x red. is required by internal NEC directive (2001/81/EC)
- by EU air quality directive NO_x/NO_2-threshold has been decreased to 40 µg/m^3 (calender year, human health) or 30 µg/m^3 (calender year, vegetation), since 1.1.2010
- at the same time a technology (diesel cars) is allowed to spread on the streets with 20fold NO_x emissions compared to it‘s alternative (petrol)
- most European countries can follow Gothenburg obligations with the help of (theoretical) modelling vehicle emission data below reality (diesel cars)

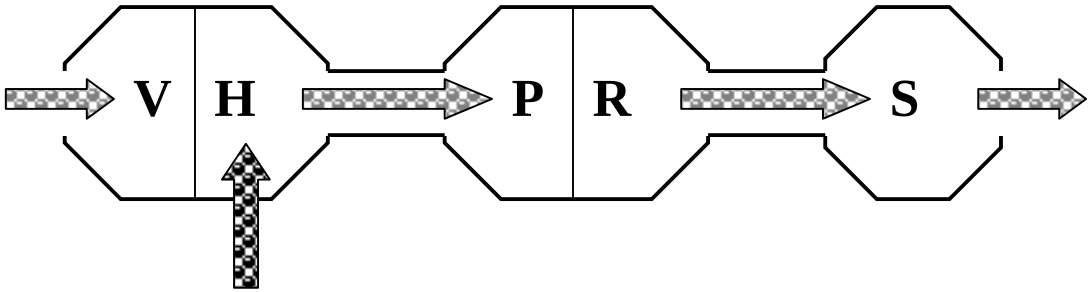
EU emission standards for petrol and diesel cars

threshold limit	**particles/soot** mg/km		**nitrogen oxides** mg/km	
	diesel	**petrol**	**diesel**	**petrol**
	EU 6 requires urea injection in most cases – the solution for diesel vehicles emission problems ?			
EU 6 2014 -	5	5	80*	60

*) US Tier2-Bin5: 25 mg/km

Helmers, 2009 ff.

exhaust aftertreatment to reach EU 6 emission standards



selective catalytic reduction (SCR) brings NO_x down to emissions comparable with petrol engines

stable over 160,000 km ?

235,000 km ?

600,000 km ?

cheaper (less efficient) aftertreatment techn. available

„It is not to be expected that the real-world NO_x emissions of Euro 6 diesel passenger cars will be close to emission limit value of the NEDC test“ (TNO report 2013)

Helmers, 2009

Are we on the right track ?

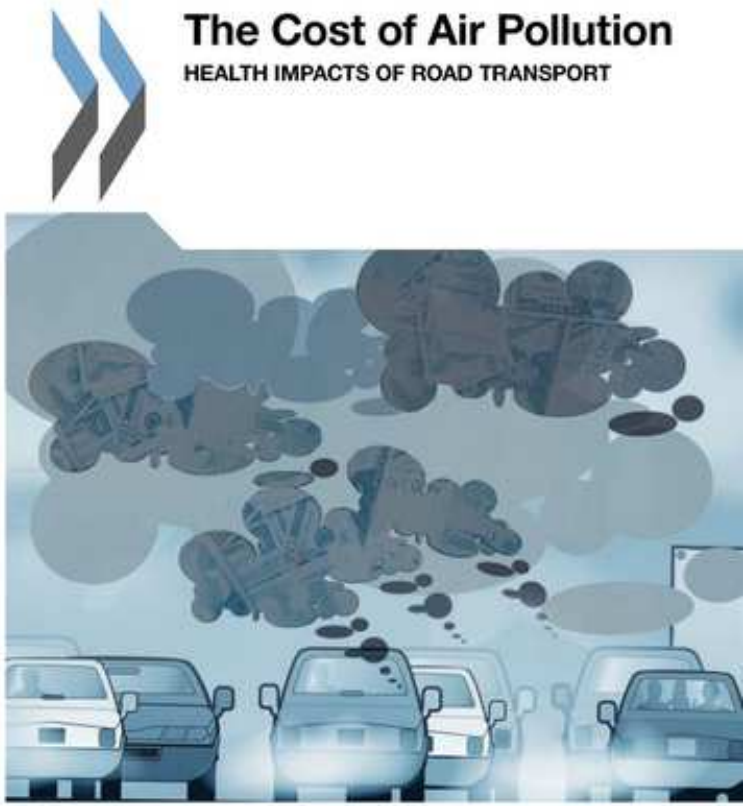
Simultaneously Mitigating Near-Term Climate Change and Improving Human Health and Food Security

Drew Shindell,[1*] Johan C. I. Kuylenstierna,[2] Elisabetta Vignati,[3] Rita van Dingenen,[3] Markus Amann,[4] Zbigniew Klimont,[4] Susan C. Anenberg,[5] Nicholas Muller,[6] Greet Janssens-Maenhout,[3] Frank Raes,[3] Joel Schwartz,[7] Greg Faluvegi,[1] Luca Pozzoli,[3†] Kaarle Kupiainen,[4] Lena Höglund-Isaksson,[4] Lisa Emberson,[2] David Streets,[8] V. Ramanathan,[9] Kevin Hicks,[2] N. T. Kim Oanh,[10] George Milly,[1] Martin Williams,[11] Volodymyr Demkine,[12] David Fowler[13]

Tropospheric ozone and black carbon (BC) contribute to both degraded air quality and global warming. We considered ~400 emission control measures to reduce these pollutants by using current technology and experience. We identified 14 measures targeting methane and BC emissions that reduce projected global mean warming ~0.5°C by 2050. This strategy avoids 0.7 to 4.7 million annual premature deaths from outdoor air pollution and increases annual crop yields by 30 to 135 million metric tons due to ozone reductions in 2030 and beyond. Benefits of methane emissions reductions are valued at $700 to $5000 per metric ton, which is well above typical marginal abatement costs (less than $250). The selected controls target different sources and influence climate on shorter time scales than those of carbon dioxide–reduction measures. Implementing both substantially reduces the risks of crossing the 2°C threshold.

Science (2012)

Are we on the right track ?



(May 2014)

OECD-secretary general Angel Gurría (2014):

"There is no environmental justification for taxing diesel less than petrol. Air pollution is destroying our health and the planet. Phasing out tax incentives on diesel would be a step towards reducing the costs to both and in fighting climate change".

http://www.oecd.org/newsroom/rising-air-pollution-related-deaths-taking-heavy-toll-on-society.htm

The European diesel car boom –

environmental effects and global comparison, summary

- huge deviation between modelled air quality and actual e/immission
- promotion of diesel cars in Europe over 20 years probably did not cool down the atmosphere
- European people and the enviroment have been and are exposed to excess toxic atmos. species by diesel cars
- inconsistency of European policy:
  improvement of air quality ←→ GHG abatement
- isn‘t it smarter to go together in the same direction ?
  → reduce fine dust/BC, reduce NO_x/O_3