Europe‘s diesel car boom –

Causes & Effects

Is there a future for diesel cars ?

København, 20 April 2016

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Vehicle emission control history

Until the mid 1990s: Europe followed technology leaps initiated in the USA

That changed in the mid 1990s:

1960‘s

USA decreased Pb content of leaded fuel, introduced unleaded fuel

1970‘s

USA introduced three-way catalysts to convert toxic emissions to N_2, CO_2

1980‘s

Europe introduced unleaded fuel and the catalyst technology for petrol cars; some 90 % of all cars based on clean technology in Germany by year 2000

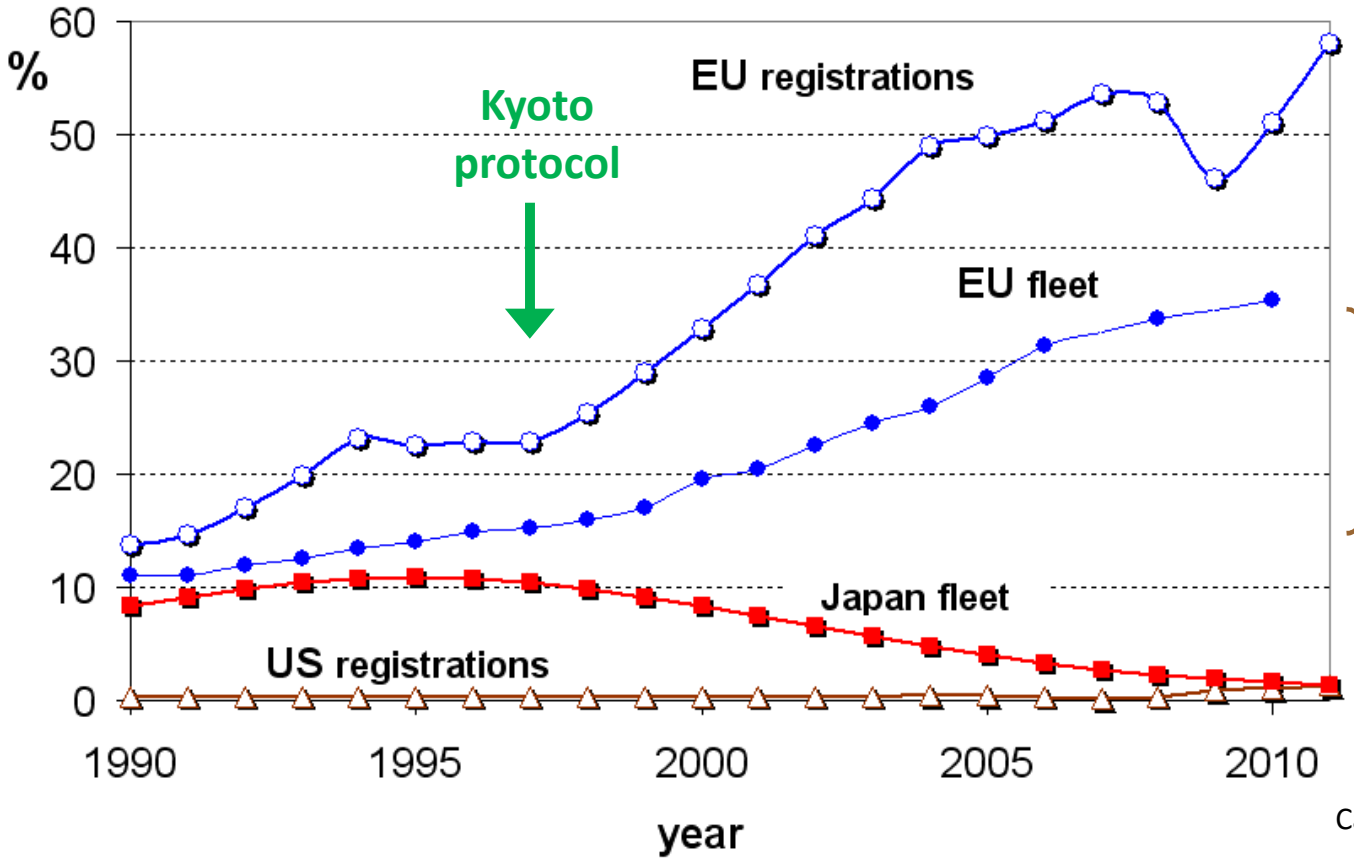
1990‘s, 2000’s: **European** diesel car boom got started

Helmers (2016)

Vehicle emission control history

Until the mid 1990s: Europe followed technology leaps initiated in the USA

That changed in the mid 1990s:



diesel car penetration in world dominating markets

+ 45 Mio diesel cars in Europe

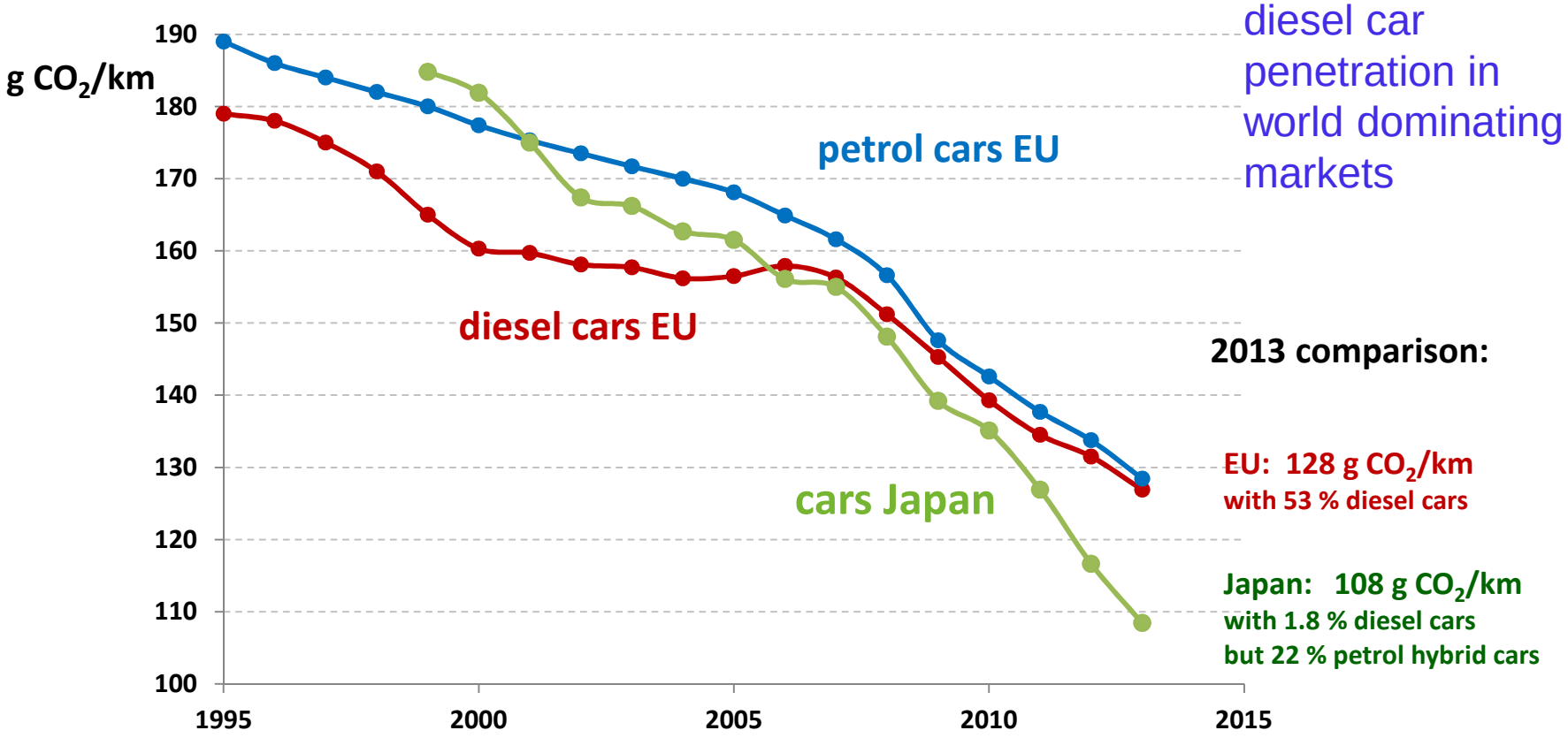
1996-2011

Cames & Helmers (2013)

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

Vehicle emission control history

One of the diesel car myths upheld until today in Europe:
"Diesel cars are essential to decrease CO_2 emissions of passenger cars"



Data sources: EU 1995-2011: Cames & Helmers, 2013. EU 2012 + 2013: EEA 2014. Japan: JAMA 2015

Vehicle emission control history

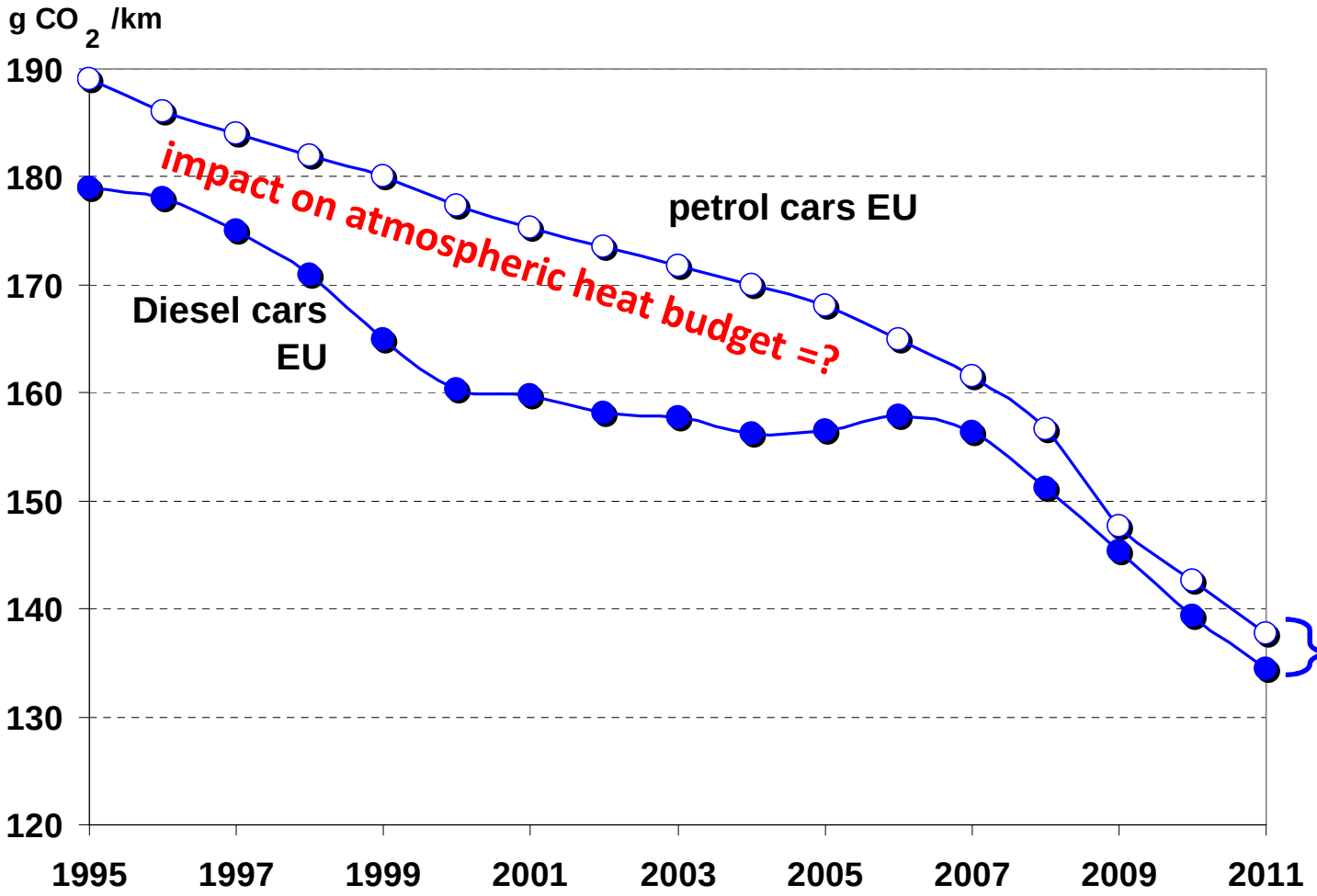
EU emission standards for petrol and diesel cars

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
			under-performing	**over-performing**

Helmers, 2009 ff.

Climate impact of black carbon emissions

additive effect of
black carbon
NOT considered



CO_2 emission time trend of newly registered cars in the EU

„on paper“
net advantage of
diesel cars (2013):
1.6 g CO_2/km

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

Climate impact of black carbon emissions

GWP of Black Carbon (BC) relative to CO_2

Black carbon has a global warming potential (GWP) …

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

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

"100 year GWPs for BC in the literature range from 330 to 2,240. That is to say, 330 to 2,240 tons of CO_2 would be required to produce the same integrated radiative effect over 100 years as one ton of BC".

"The Kyoto Protocol is based on GWPs from pulse emissions over a 100-year time frame" (US EPA, 2016) – but does not consider BC.

Helmers (2016)

Climate impact of black carbon emissions

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	5	5
		62% BC	8% BC

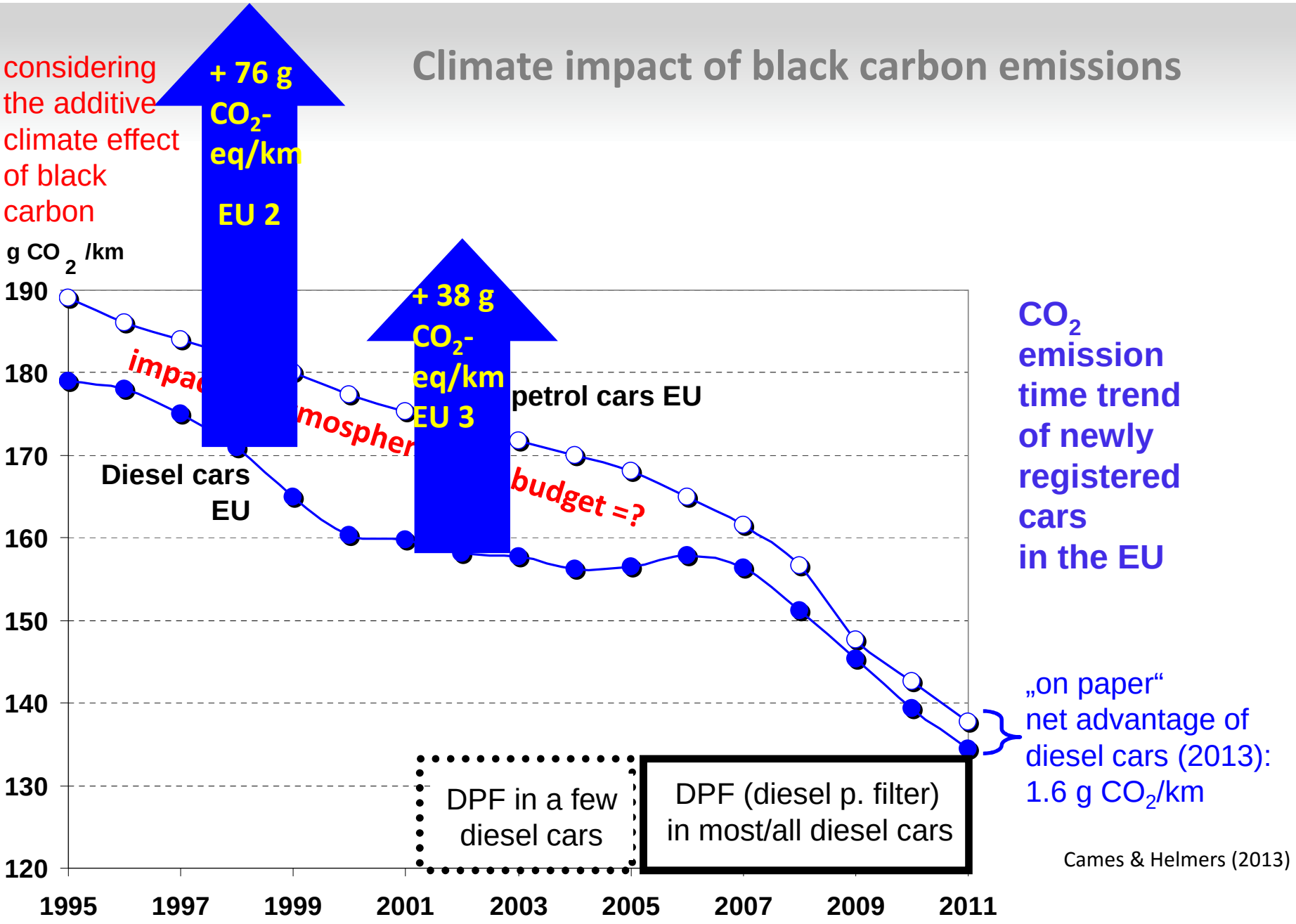
BC GWP considered
(BC = black carbon)

- EU 2 → + 76 g CO_{2eq}/km
- EU 3 → + 38 g CO_{2eq}/km
- EU 4 → + 19 g CO_{2eq}/km
- EU 5 → + 4 g CO_{2eq}/km
- EU 6 → + 1.3 g CO_{2eq}/km

Diesel with filter: 1 mg soot = 0.8 g CO_{2eq} /km

Cames & Helmers (2013)

Climate impact of black carbon emissions



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Climate impact of black carbon emissions

What is a modern diesel car with DPF emitting in reality – and long-term?

2014: 351 diesel-powered taxis serving five cities (Berlin, Frankfurt, Hamburg, Cologne, Munich) were inspected for fine dust emissions:

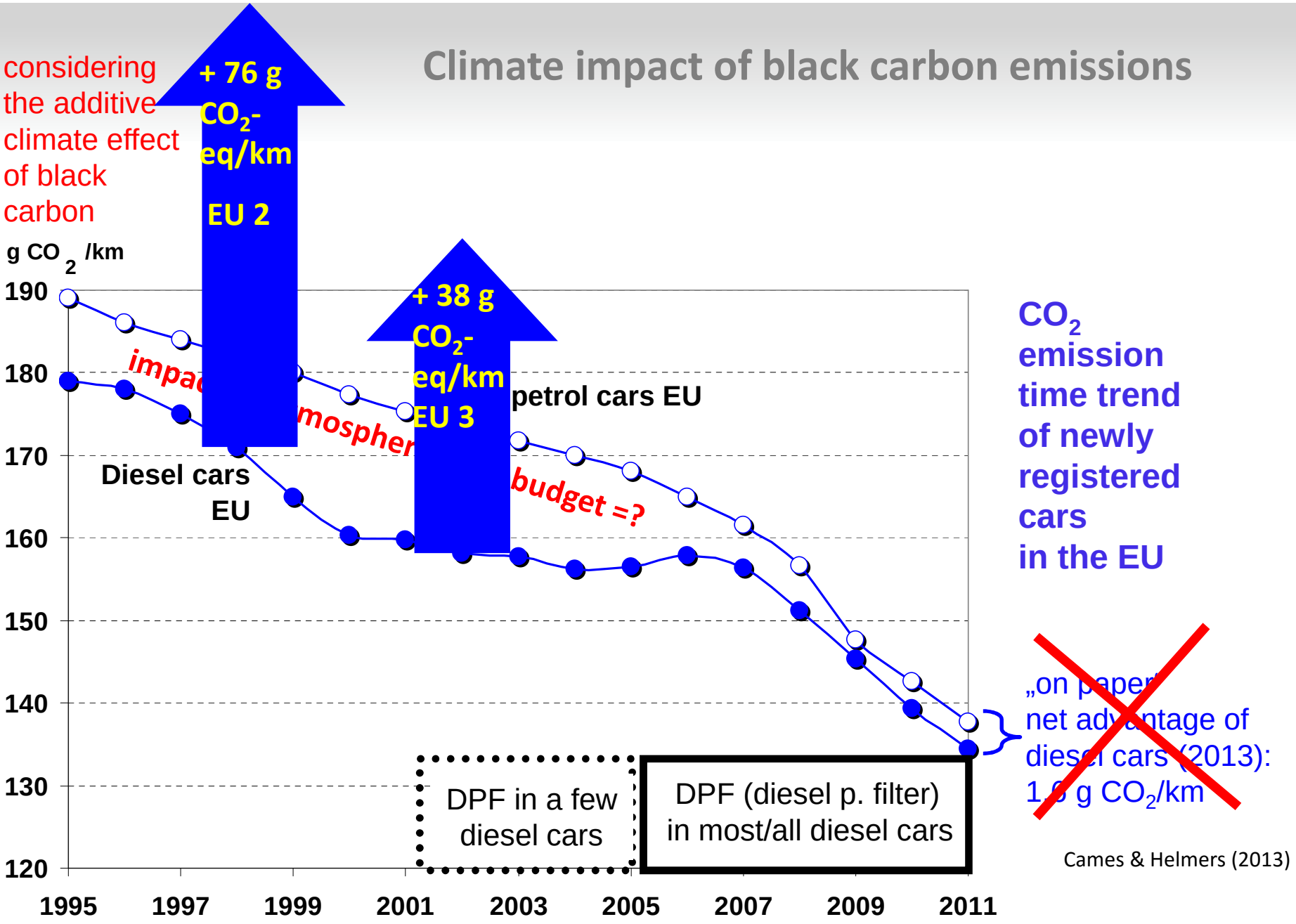
➔ At 1 out of 10 diesel taxis, the filter was removed or did not work

- careful assumption: 10 % of all cars > 100,000 km with PF malfunctions, returning to 100 mg soot/km ➔ + 76 g $CO_{2\text{-eq}}$/km
- with 235,000 km driven on average (Germany) **roughly** 5 % of all diesel 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

Diesel demand tripled over the last 20 years:
+ 2-10 g CO_2/km extra expenses over supply chain (on top)

Helmers (2016)

Climate impact of black carbon emissions



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Real-world emissions of diesel cars over lifetime

What is a modern diesel car with DPF emitting in reality – and long-term?

DPF = diesel particulate filter

Pillot D., A. Legrand-Tiger, E. Thirapounho, P.Tassel, P.Perret (2014):
"Impacts of inadequate engine maintenance on diesel exhaust Emissions":
(Transport Research Arena, Paris)

➔ Pollution abatement equipment was not working correctly in 126 out of 168 diesel cars randomly tested in France, with up to four individual problems per car

➔ With engine malfunctions, the complex emission aftertreatment system of a diesel car cannot properly work

Between 1.57 and 2.75 million **used** cars are exported from Germany in a year (Umweltbundesamt, 2013), mostly towards Eastern Europe.
What does this mean for the emission behaviour of these aged cars?

Real-world emissions of diesel cars over lifetime

What is a modern diesel car with DPF emitting in reality – and long-term?

PDF removal in Great Britain

Independent, Oct 2015

"An Independent on Sunday investigation has found that more than 1,000 garages, backstreet mechanics, and tuning firms are offering this service, often for as little as £250. It is only an offence to drive a car without a factory-fitted DPF.
… The filter has been mandatory on any new diesel vehicle since 2009, but can become blocked after 80,000 miles and can cost up to £1,500 to replace."

The Guardian, 17.4.2016: „More than 1,000 diesel cars caught without pollution filter."

Real-world emissions of diesel cars over lifetime

What is a modern diesel car with DPF emitting in reality – and long-term?

PDF removal in Germany, in Austria, …

An advertisement example from the internet (translated from German, April 2016):

„You have problems with the DPF? No more self-regeneration possible?
Not for long.

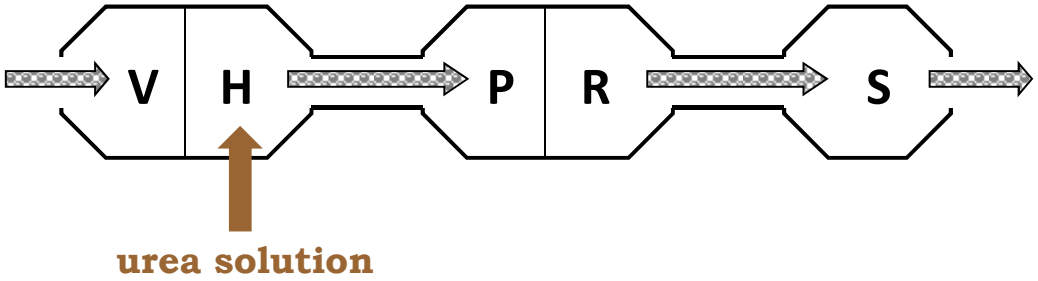
We‘ll remove it for 200 €.

You will not longer see the error lamp and also the fuel consuming injection will be deactivated. No error messages“

Helmers (2016)

Real-world emissions of diesel cars over lifetime

The “clean diesel” – efficient but complex and expensive



SCR-technology (selective catalytic reduction) to reduce NO_x down to petrol engines emissions

V-Kat oxidation catalyst: oxidizing of NO $2\ NO + O_2 \rightarrow 2\ NO_2$

H-Kat urea decomposition to ammonia and isocyan-acid $CO(NH_2)_2 \rightarrow NH_3 + HNCO$

P-Kat particle filter trap: deposition of soot und continuous oxidation

a) isocyan-acid generates active ammonia $HNCO + H_2O \rightarrow NH_3 + CO_2$

b) NO_2 burns deposited soot (C) $2\ NO_2 + O_2 + 2\ C \rightarrow 2\ NO + CO_2$

R-Kat excess NO and NH_3 are being reduced: $NO + NO_2 + 2\ NH_3 \rightarrow 2\ N_2 + 3\ H_2O$
and $4\ NO + O_2 + 4\ NH_3 \rightarrow 4\ N_2 + 6\ H_2O$

S-Kat lock up catalyst: oxidation of remaining ammonia: $4NH_3 + 3O_2 \rightarrow 2N_2 + 6H_2O$

Helmers, 2009

The Danish Ecological Council:

„Tomorrow‘s environment is created today“

Conclusions

- ➔ It is essential to quickly switch to vehicles, which are clean(er) long-term, because it takes many years for a significant fleet penetration of cleaner technologies.
- ➔ Diesel cars will never be „clean“ long-term because necessary emissions aftertreatment (5-step) is complex, costly, and monitoring intensive - but an appropriate, independent monitoring needed is not available in the entire EU.
- ➔ Diesel cars continue to represent a threat for both climate and health. Therefore, they should be removed from the market and be replaced with petrol cars (with particles filtration), in the long term they should be replaced with electric vehicles.

Further readings

Does the European diesel car boom mitigate global warming?

E. Helmers, Briefing to the European Parliament, 17 February 2016
http://green-budget.eu/wp-content/uploads/2016-02-17_Helmers_European-diesel-car-bias-makes-climate-worse1.pdf

The truth about diesel cars.

Open letter of 24 leading scientists from 10 countries, posted 11 December 2015
http://iaqm.co.uk/the-truth-about-diesel-cars-open-letter/

Critical evaluation of the European diesel car boom - global comparison, environmental effects and various national strategies.

M. Cames & E. Helmers, Environmental Sciences Europe 2013 (25):15
http://enveurope.springeropen.com/track/pdf/10.1186/2190-4715-25-15?site=enveurope.springeropen.com