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AQM 2016



Emission reduction of the main polluters

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مؤتمر ملی چهارم در زمینه مدیریت آلودگی هوا و صدا

Volker Schlickum, engineer, Berlin

What to expect from this presentation?

- **emission reduction potential**
- **desulphurisation**
- **road transport and DPF(CRT)-retrofitting**
- **low emission zone**
- **additional transport measures**



Emission reduction of the main polluters

the main polluters could be a few big sources

- power plants
- factories

or many small sources

- domestic heating (not in Tehran!)
- road transport
- other transport
- small industry
- others



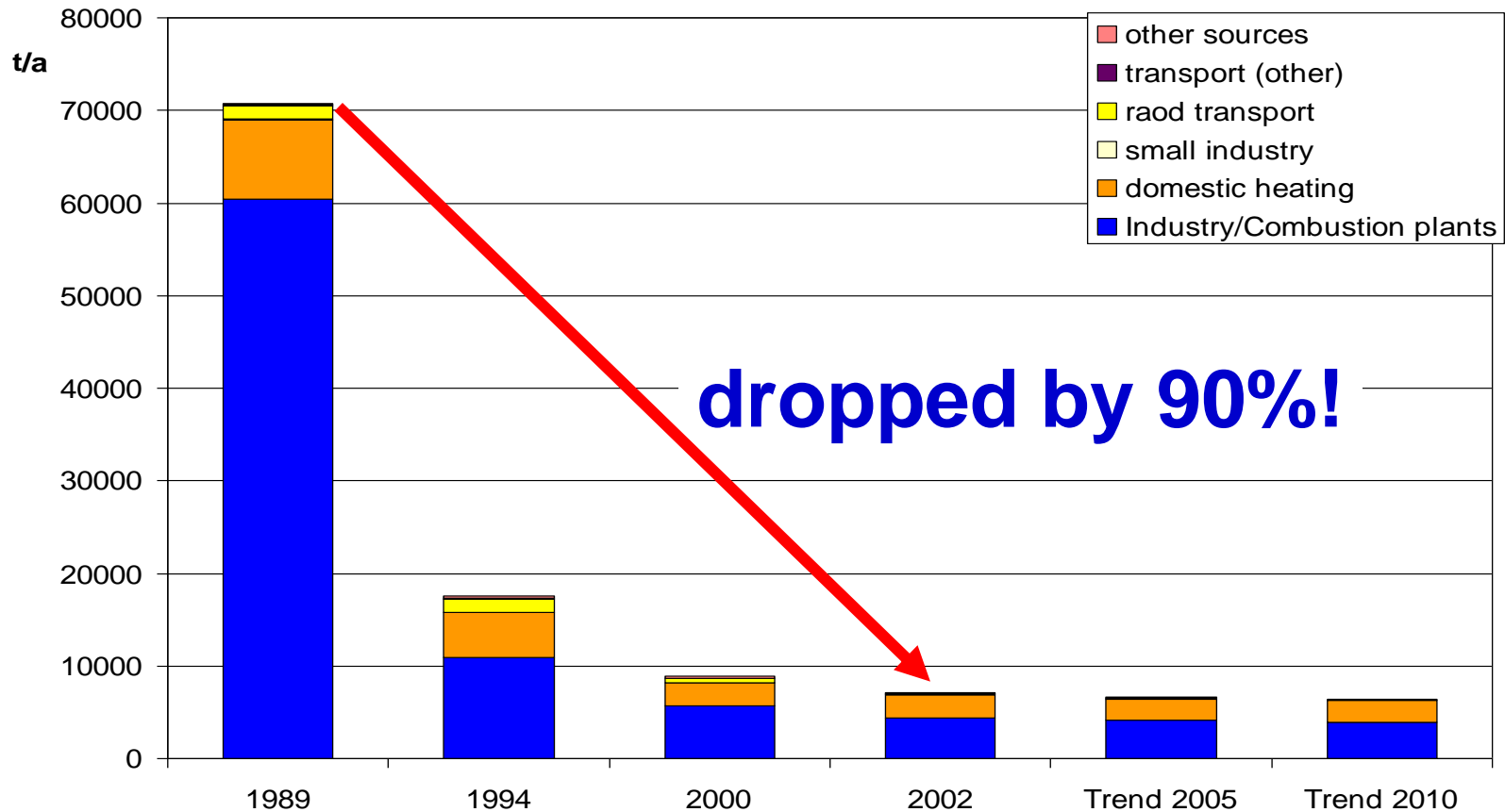
we had both, power plants/ factories as big sources
and **hundreds of thousands of domestic heatings powered by
browncoal** and city traffic with **more than 1 mil. vehicles** as many small
sources

in the 1980s – **desulphurisation:**
installation of fluegas scrubbers, fabric filters;
ban of high-sulphur fuels (brown coal and heavy fuel oil) in industrial
combustion
and beginning of the conversion of the domestic heating from solid fuel
like browncoal to district heating, and central heating (gas and low-
sulphur oil)

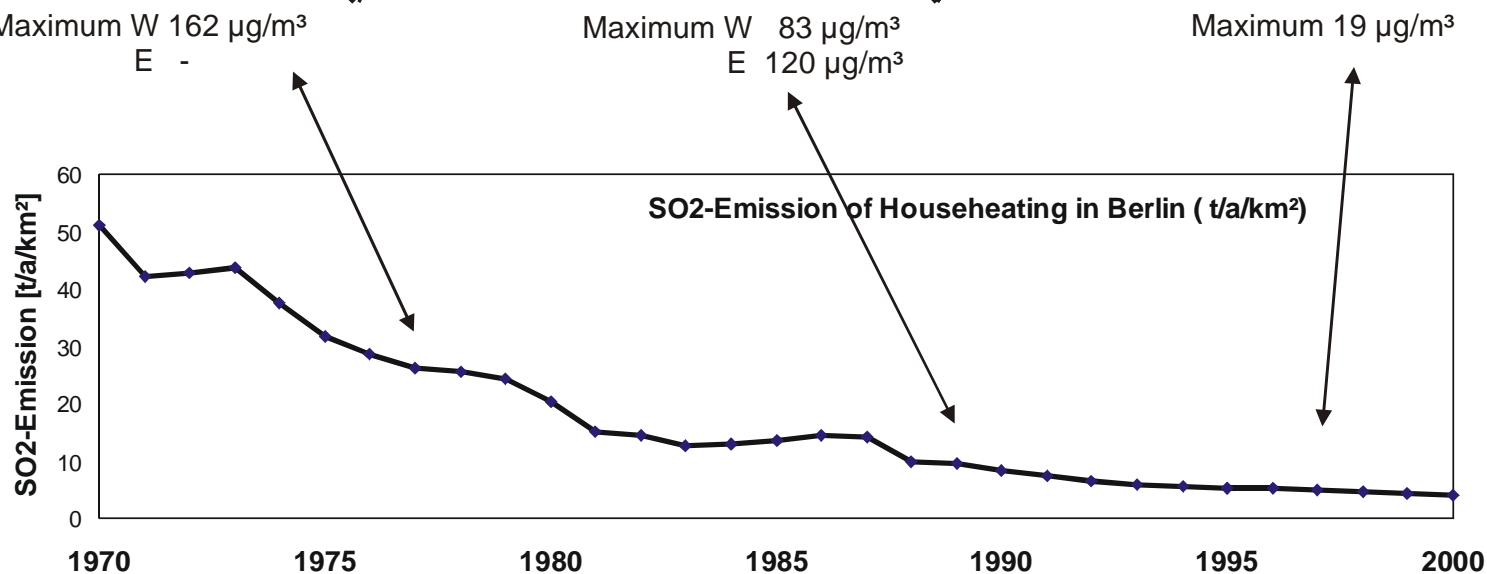
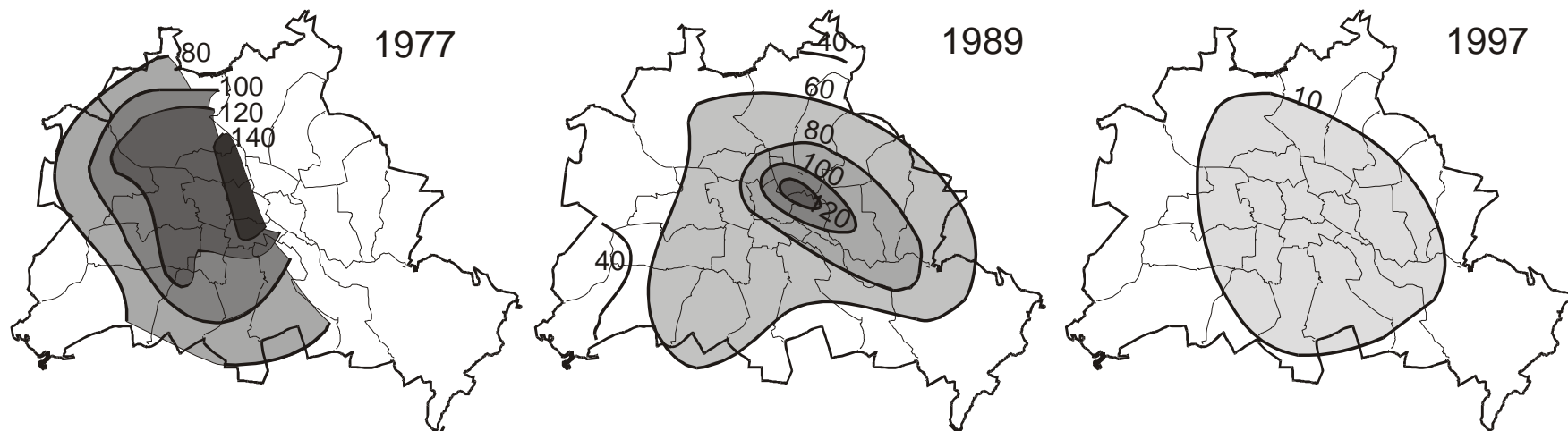
Furthermore:
step by step switch to the use of low-sulphur and sulphur-free diesel



Annual emission of SO₂ in Berlin



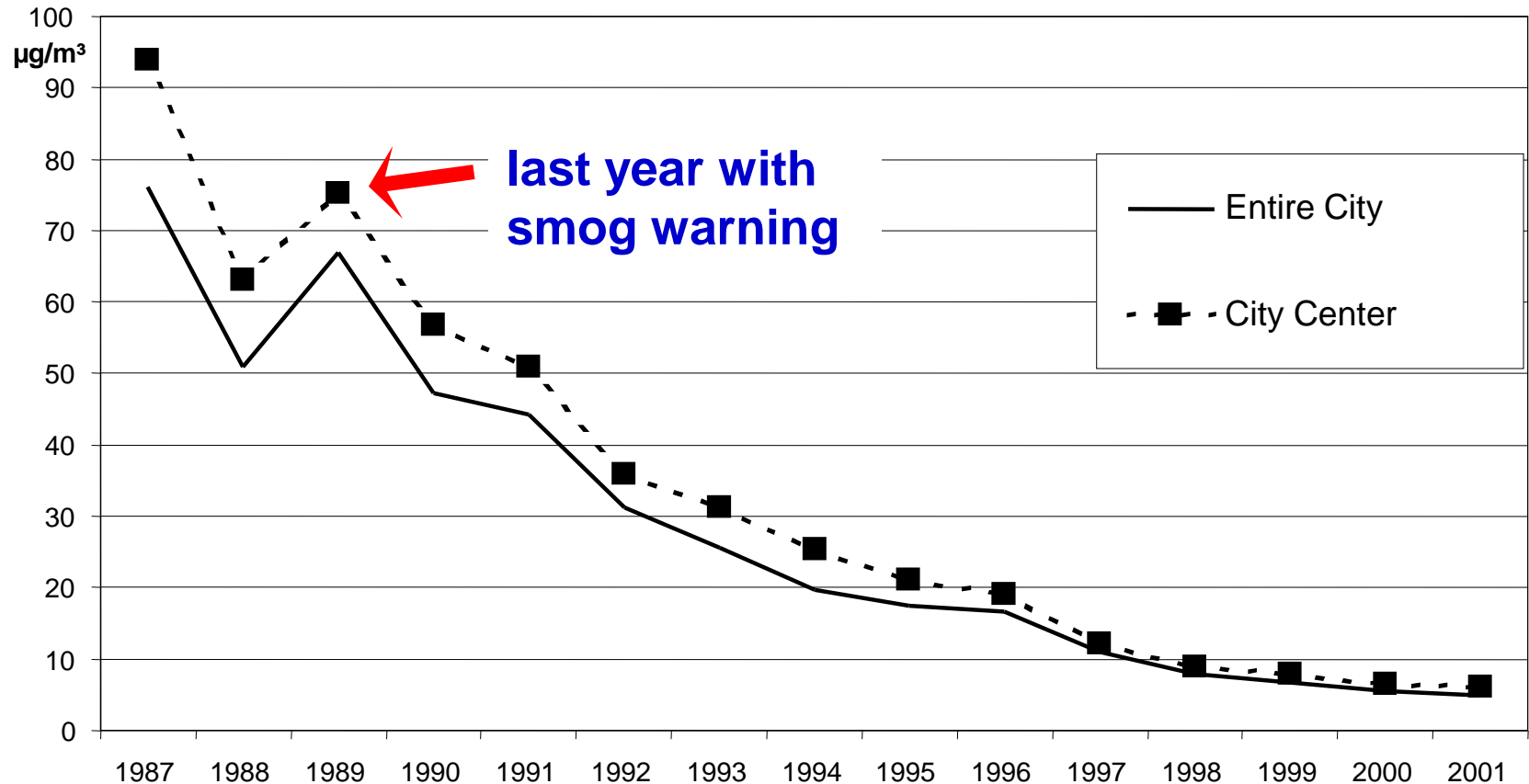
Annual averages of SO₂-concentration in Berlin



SO77_97.cdr, 9.10.98,ps



Annual mean of SO₂ in Berlin 1987 - 2001



Road transport

essentials:

fixing of standards for petrol and diesel

unleaded petrol and motors with injection instead of carburettor

↪ **The 3-way catalyst with lambda probe was possible and every new petrol car with catalyst and all the refitted petrol cars emitted minus 90% HC, NO_x and CO**



For public transport diesel and electricity are the standard

Overview of Berliner Verkehrsbetriebe (BVG)

BVG

12,224 total staff
8,712 blue-collar workers
3,512 white-collar workers
(incl. 405 trainees / apprentices)



1,035.2 million passenger trips / year

Underground

- 144.9/120.3 km total route length (day/night)
- 9 day-time lines
- 7 night lines
- 170/145 stations (day/night)
- 1,372 underground vehicles
- 2,791 staff
- 456.8 million passenger trips / year

Tram

- 285.5/59.7 km total route length (day/night)
- 21 day-time lines
- 5 night lines
- 6 depots
- 374/115 stops (day/night)
- 602 vehicles
- 1,634 staff
- 171.3 million passenger trips /year

Bus

- 1,626/751 km total route length (day/night)
- 150 day-time lines
- 54 night lines
- 6 depots
- 2,601/1,504 stops (day/night)
- 1,388 buses
- 3,931 staff
- 407.1 million passenger trips /year

Mr. Eberwein, BVG

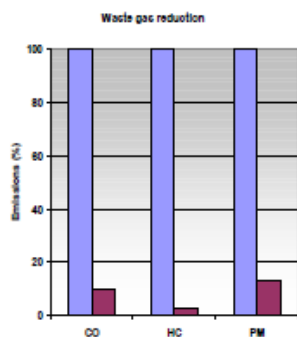
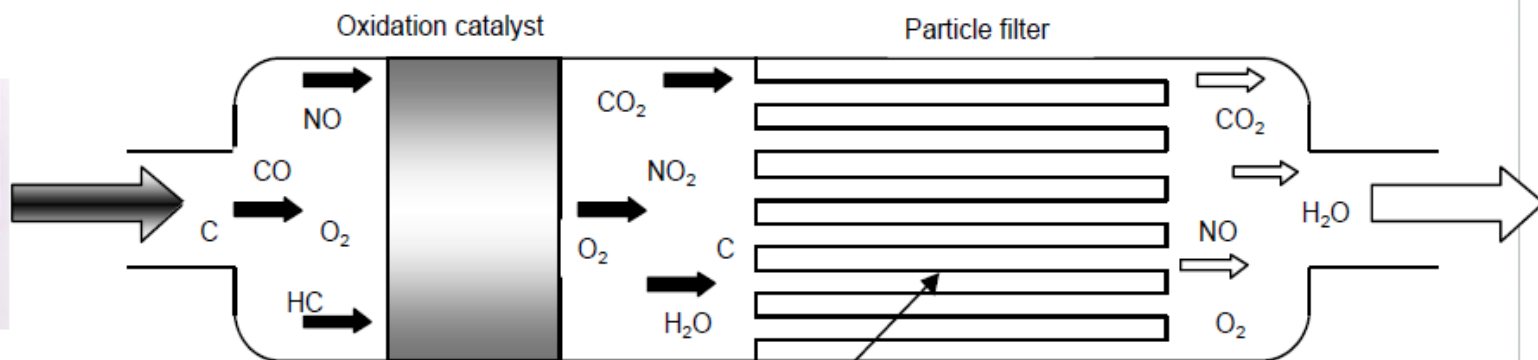


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The use of low-sulfur or sulfur-free diesel is the precondition for CRT-retrofitting

Exhaust gas after treatment CRT Continuously Regenerating Trap

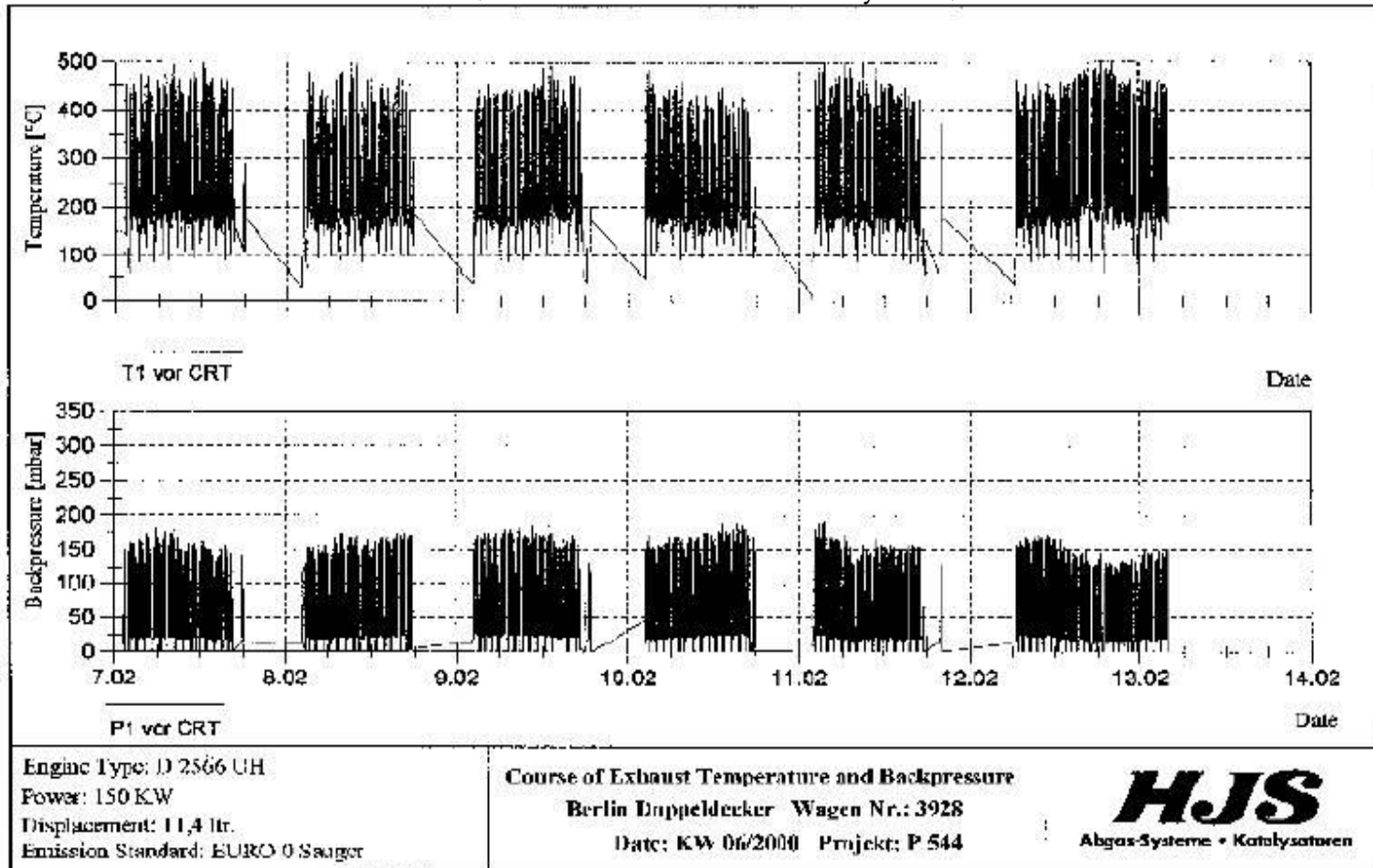
Best conditions are 10-50ppm sulphur and an exhaust gas temperature window between 250°C and 450 °C



The backpressure and temperature with CRT

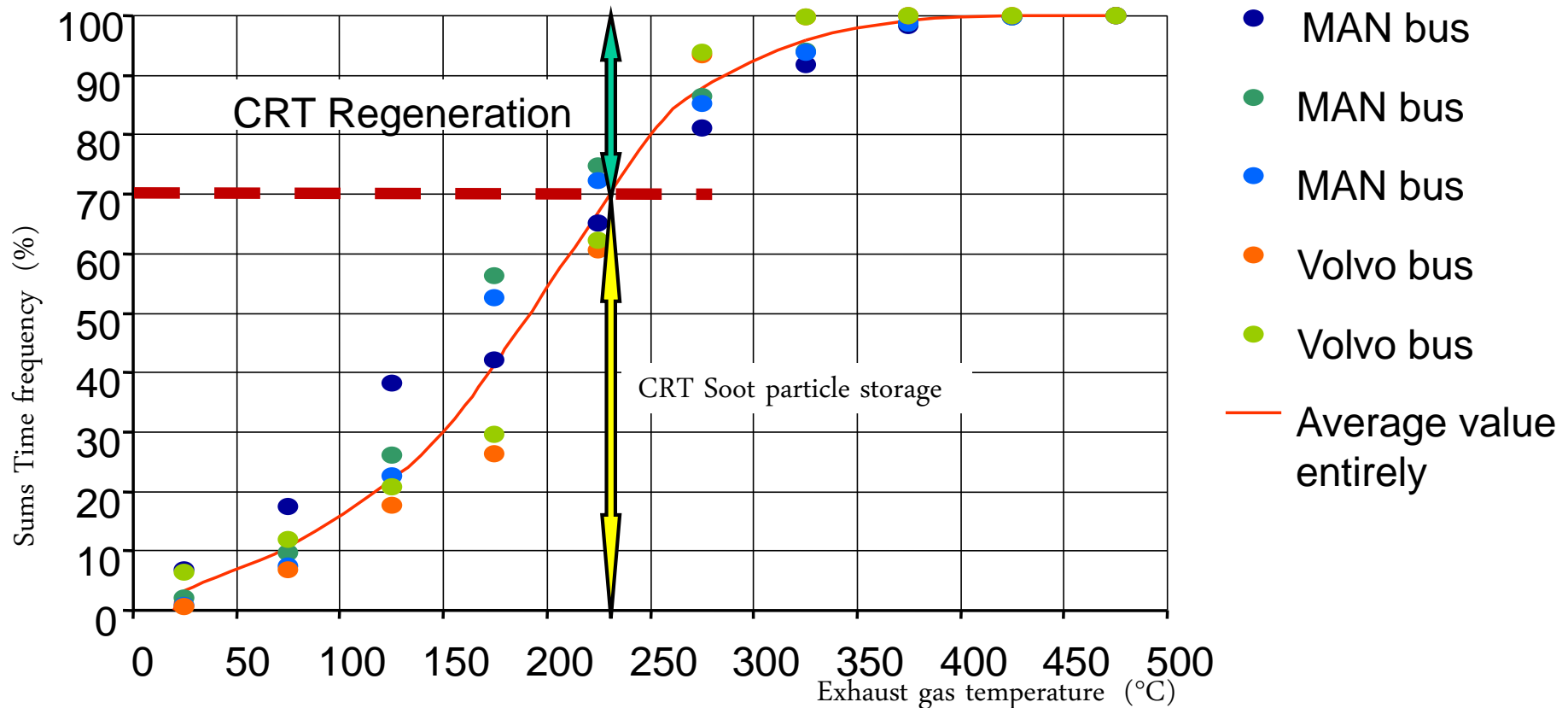
Temperature and exhaust-gas back-pressure ahead of CRT

(Berlin double-decker, February 2000)

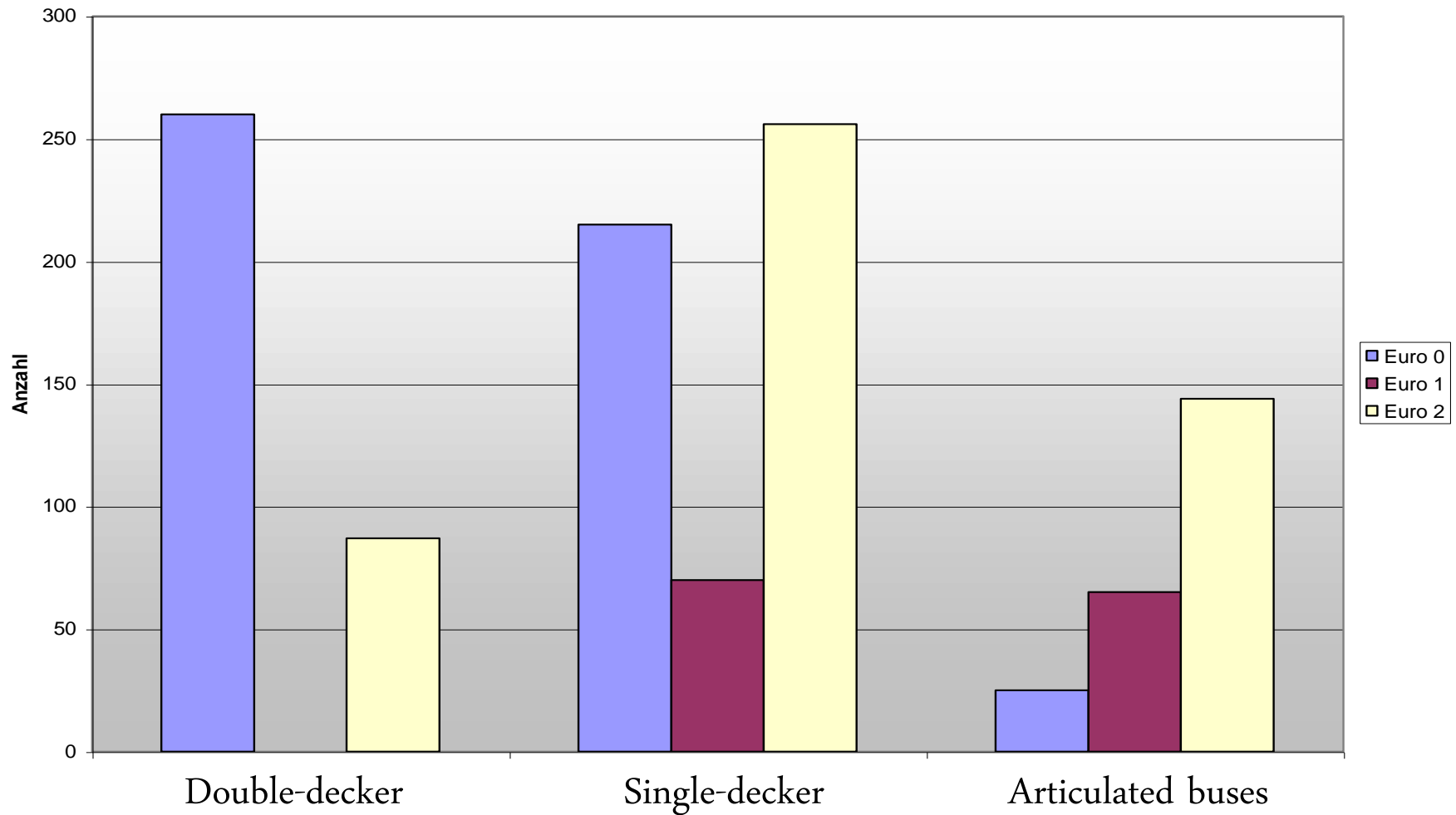


Cumulative probability of bus exhaust-gas temperatures

(CRT filter regenerates above curve, but accumulates particles below curve)



BVG bus fleet composition (number of buses) in 1998



CRT Filter mounting

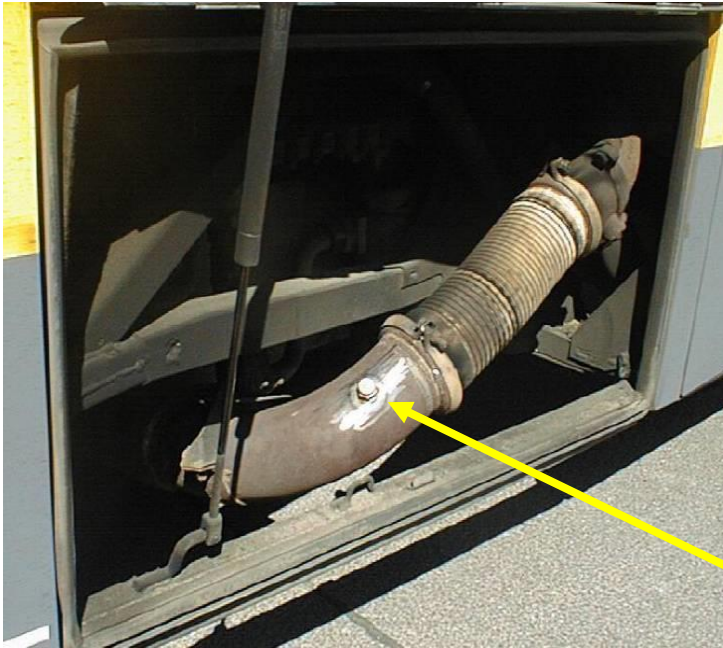
By the end of 1999, BVG had retrofitted 126 city buses. By the end of 2002, 1.000 of its total 1.350 buses were retrofitted with this system. All new vehicles purchased after 1999 came with the CRT ex-factory.

since 1999 the BVG
has bought fuel with
max. 50ppm \equiv
50mg/kg \equiv 0,005%
sulphur, later with
10ppm



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Back-pressure instrument and location



- Exhaust-gas back-pressure measurement
- Vehicle warmed up (75°C)
- Connect instrument
- Run engine at limiting RPM for 1 minute
- Read exhaust-gas back-pressure
- If the back-pressure exceeds prescribed level, then filter cleaning is necessary



Exhaust-gas back-pressure alarm display in new buses



Quality assurance software

(Screen shot of bus data, e.g. type, filter, date, odometer, test history, etc.)

Microsoft Excel - Fahrzeuge.xls

File Bearbeiten Ansicht Einfügen Format Extras Daten Fenster ?

Arial 12

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
		Fahrzeug		Filter		Messungen eingeben		1. Prüfung		Blatt exportieren		2. Prüfung		
	lfd. Nr.	Nummer	Typ	Typ	Einbau-datum	Nummer	Datum	Kilometer	LL-Wert in Millibar	VL-Wert in Millibar	Datum	Kilometer	LL-Wert in Millibar	VL-Wert in Millibar
85	83	1271	E13	60M	22.09.03	603290/703528	02.01.05	177.495	5	20	27.04.05	194.260	5	37
86	84	1272	E13	60M	23.09.03	603281/703530	17.01.05	174.977	5	43	19.04.05	194.718	12	42
87	85	1273	E13	60M	23.09.03	603295/703225	27.04.05	182.162	6	51				
88	86	1274	E13							94	18.04.05	194.975	4	42
89	87	1275	E13							33	28.04.05	184.819	5	42
90	88	1276	E13							53	09.02.05	180.312	6	50
91	89	1277	E13							55	09.02.05	176.766	8	62
92	90	1278	E13							52				
93	91	1279	E13							55	10.05.05	185.216	6	46
94	92	1280	E13							51				
95	93	1281	E13							44				
96	94	1289	E13							49				
97	95	1291	E13							58				
98	96	1292	E13							40				
99	97	1294	E13							46				
100	98	1297	E13							47				
101	99	1299	E13							38				

Dateneingabe für CRT-Messungen

Fahrzeugnummer : 1271

Messung Nummer : 2. Prüfung

Datum : 27.04.05
(z.B. 4-1-5 für den 04.01.2005 oder anderes Datumsformat)

Tachostand : 194260

Leerlaufwert : 5 Vollastwert : 37

Übernehmen Beenden (ESC)

Fahrzeugliste 2/3

Zeichnen AutoFormen

Bereit



HJS older cleaning method for CRT systems

Step 1: Filter washing filter rinsed with warm water solution in turbulent counter flow. Ash detaches from the filter and is washed out. Water is cleaned in a closed loop and re-circulated.

Step 2: Filter drying hot air drying to expel residual water droplets.

Regeneration duration 5 to 6 hours



HJS new cleaning method for CRT systems

Step 1: Heat filter

Step 2: Cool filter

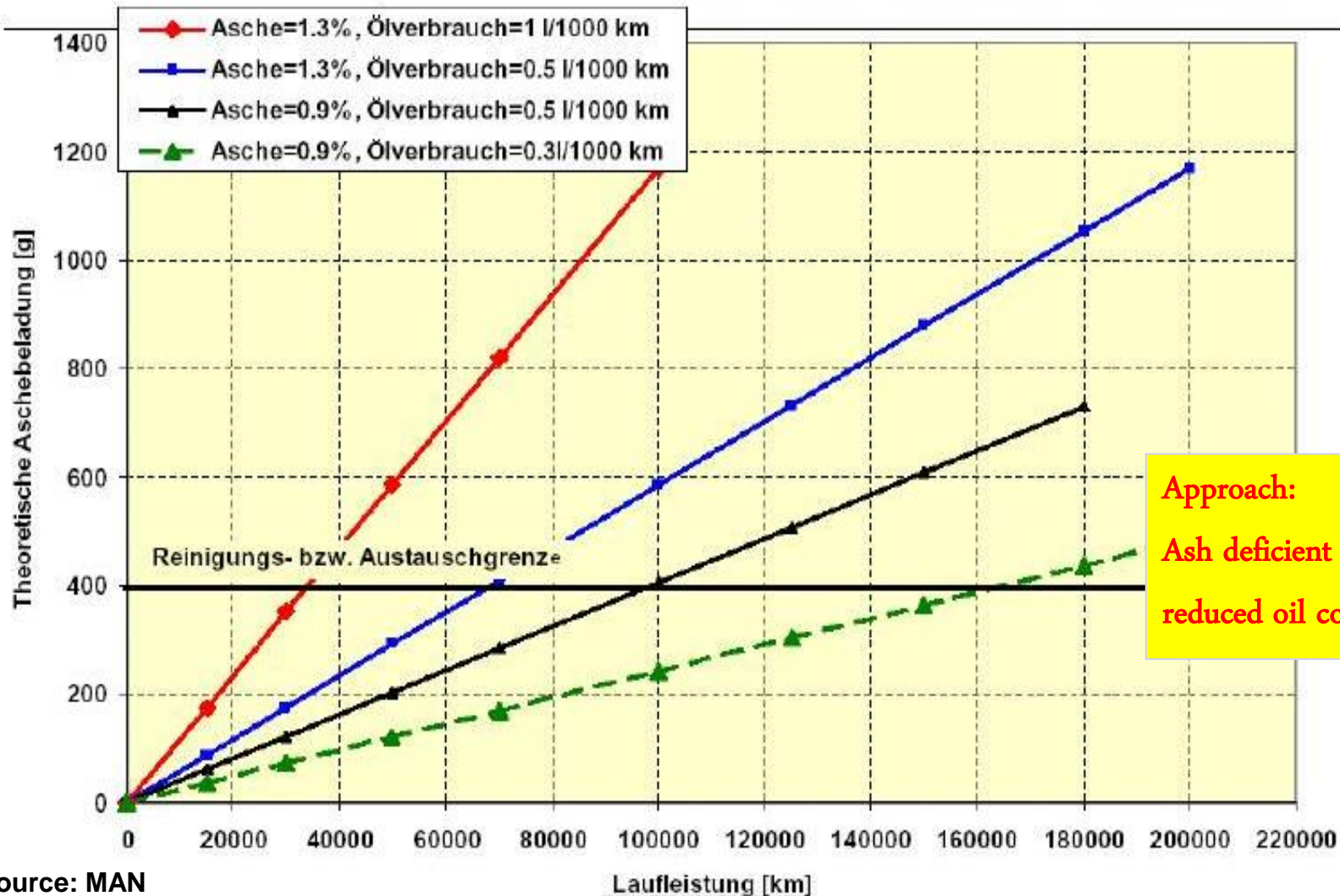
Step 3: Blow out oil ash



SMF



Low-ash oils and lower lube consumption prolong cleaning intervals



Approach:
Ash deficient motor oils +
reduced oil consumption

Source: MAN

Lines are:

1.3% ash content at oil consumption 1.0 and 0.5 liters per 1,000 km

0.9% ash content at oil consumption 0.5 and 0.3 liters per 1,000 km

Vertical axis is calculated ash burden [g]

Cleaning or replacement recommended at 400g ash burden

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Defective CRT filter



CRT costs

	Material cost	Wage cost
CRT retrofitting	5,500 to 7,000 EUR	150 EUR
CRT regeneration		200 EUR

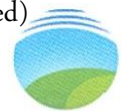
CRT failure	0.5% p.a.
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Environmental measures so far tested in BVG's buses

<i>Technology</i>	<i>Vehicle</i>	<i>Additional costs compared to diesel</i>
Methanol (1985 - 1988)	7 MAN SL 200 7 Mercedes Benz O305	approx. 28%
CNG (1996 - 1999)	4 MAN NG 232 2 Mercedes Benz O405 GN 4 Mercedes Benz O405 N	approx. 20%
Aquazole* (1999)	15 buses	approx. 8% / 100km additional consumption
CRT (1999 - 2001)	800 buses retrofitted OM 457 and D2666 and all new buses	approx. 5500 EUR/unit
Euro 5 / EEV (2003 – to date)	25 VOLVO buses	Funded by the German Ministry of Environment
Euro 5 / EEV	new buses to be commissioned in 2006	series
Hydrogen (2006 – to date)	4 MAN suction engine (in operation) 1 ICE / FC hybrid (in operation) 10 MAN ICE turbo charged (planned)	

* Diesel water blend helping to reduce NOx emissions



1400 Busses for municipal public transport

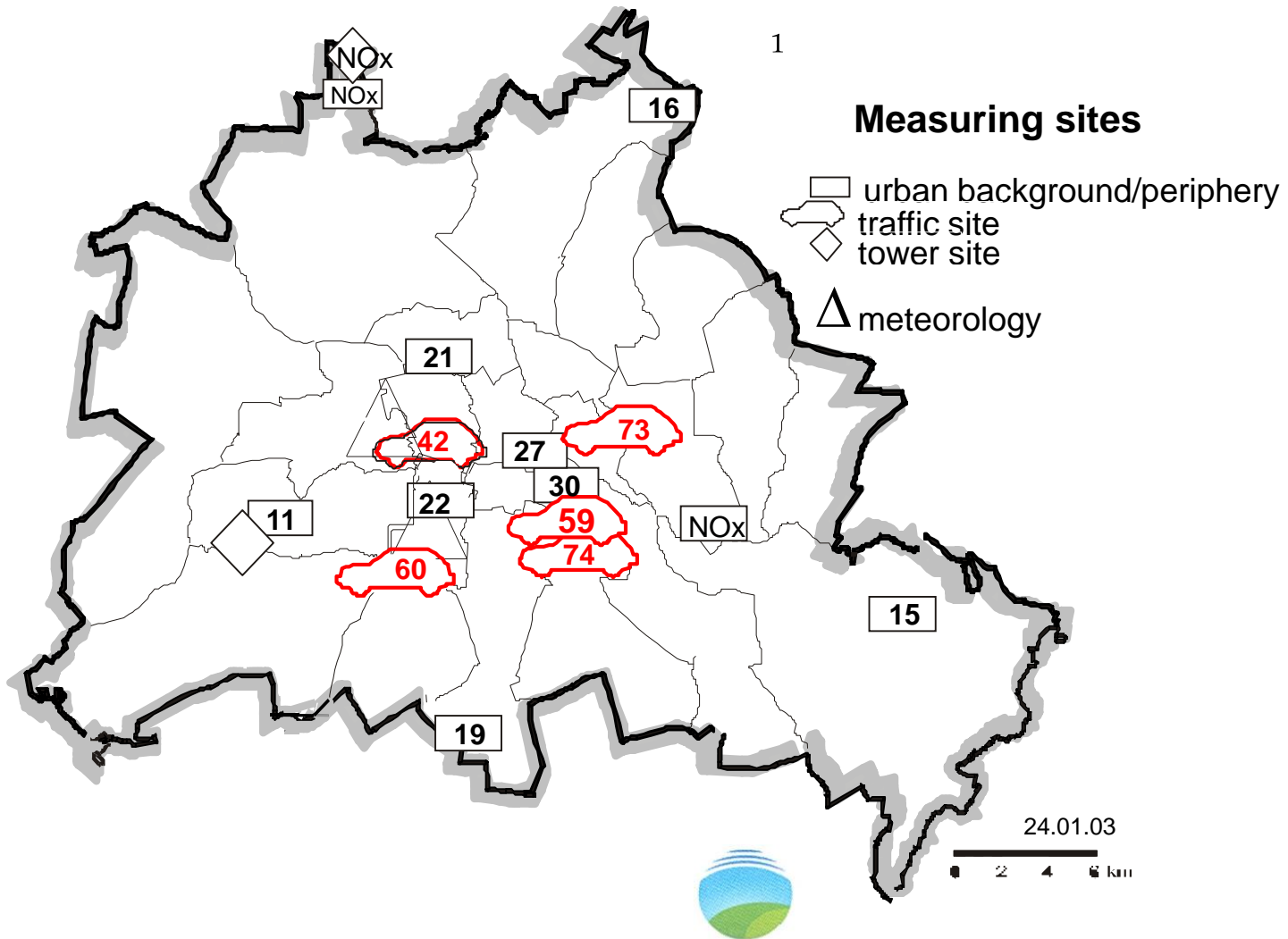
100% in only 8 years with particulate filter

	Referenz 2004	2005	2006	2007	2008	2009
EURO 0	28%	22%	10%			
EURO 0 with CRT- Particulate filter	11%	7%	7%	4%		
EURO 1 with CRT- Particulate filter	12%	12%	12%	12%	3%	
EURO 2 with CRT- Particulate filter	35%	35%	35%	35%	35%	26%
EURO 3 with CRT- Particulate filter	12%	21,9%	22%	22%	22%	22%
EURO 4 with CRT- Particulate filter	0,1%	0,1%	12%	12%	12%	12%
EURO 5 with Particulate filter / EEV	2%	2%	2%	15%	28%	40%



Air quality monitoring network

👉 Number of days above $50 \mu\text{g}/\text{m}^3$ PM10 in 2005



Large stationary sources:

- **Best Available Technology**; already largely exhausted

Domestic heating:

- cleaner fuels (nat. gas), heat&power cogeneration
- promotion of energy saving measures
- renewables (but strict emission limit values for wood fired burners)
 - option: stricter emissions standards for wood heating systems ($< 10 \text{ mg/m}^3$)
- ☺ only few single coal fired stoves left ($< 2\%$ of all flats);

Construction:

- Guidelines & information about dust abatement measures
- Regulations based on Berlin's regional Pollution Control Act

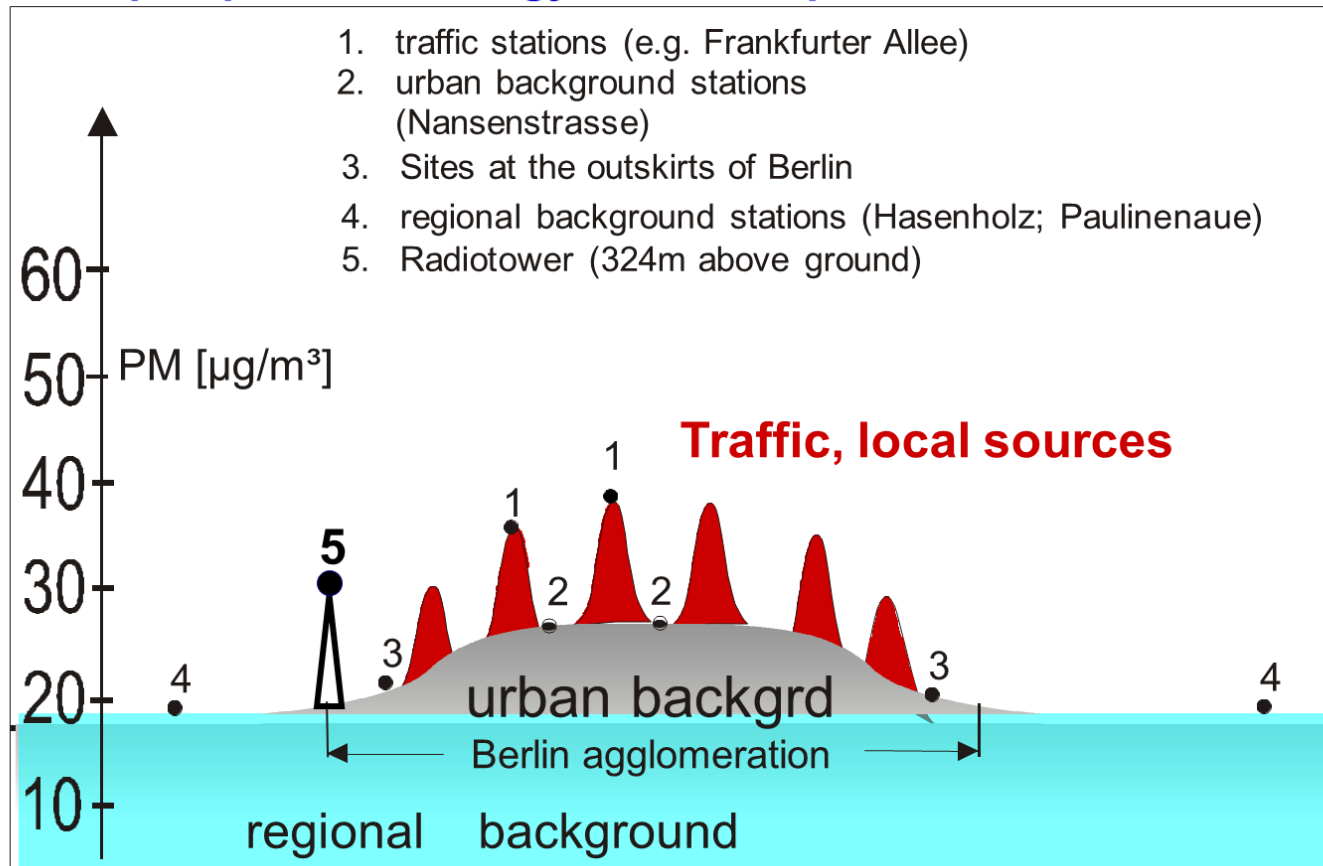
Transport:

- **Cleaner vehicles and fuels**
 - municipal vehicle fleet (CRT retrofit & CNG)
 - filter retrofit of passenger cruising ships
 - **LEZ** (low emission zone)
- **Less traffic through sustainable transport- and city planning**
 - master plan transport, "StEP"
- **Optimized traffic management**
- **Speed limits (30 km/h)**
- **Ban of heavy duty vehicles in single streets**
- ...

source analysis

👉 where does it come from & how much ?

Example: phenomenology of the PM-pollution around Berlin



Cleaner vehicles and fuels.....

cleaning up the **municipal vehicle fleet**

- **particle filter:** police, buses
 - 1000 old buses retrofitted with CRT since 1999
 - **full CRT coverage by 2008**
- **compressed natural gas & biogas:**
 - 25% of garbage collection vehicles, **50% by 2008**
 - **15 buses running on CNG and 5 on hydrogen**
- **SCRT retrofit** for public buses
 - retrofit programme of about 100 buses planned



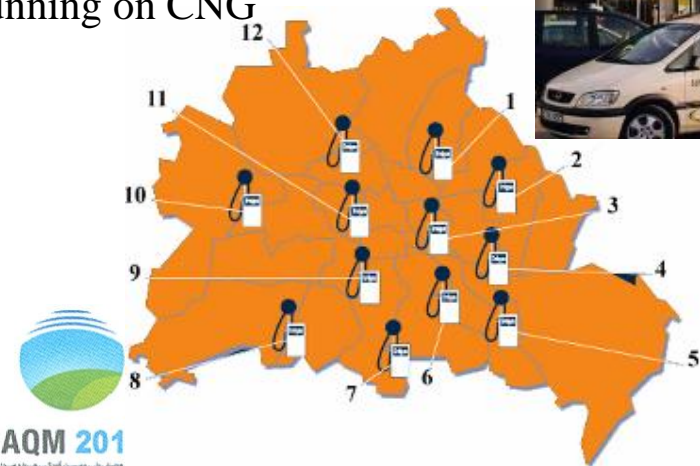
CNG (compressed natural gas) for **private & commercial Diesel vehicles**

- 1000 private cars: gas-vouchers & tax refunds
- **1000 taxis** and driving schools: funding of new CNG-vehicles
- **100 HGVs&LGVs:** funding of new vehicles running on CNG



network of **natural gas** refilling stations (14 stations by now)

- increasing share of biogas



☞ particle filter in passenger cruise ships



pilot project 2008-2010:

- retrofit of 3 vessels with different filter systems
- monitoring of filter efficiency, performance and handling during routine operation





Problems in Berlin...

again (after 2 years compliance) **excess** of PM10

widespread excess of NO₂ (up to 50%) in central **main roads**

local scale traffic restrictions merely shift problem to other roads

short-term temporary traffic restrictions **not effective** during pollution episodes

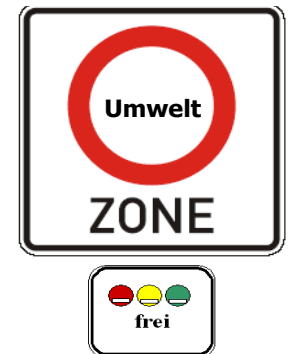
previous measures insufficient

- modernisation of municipal fleet,
- funding scheme for CNG-vehicles
- shift to clean transport modes by traffic planning

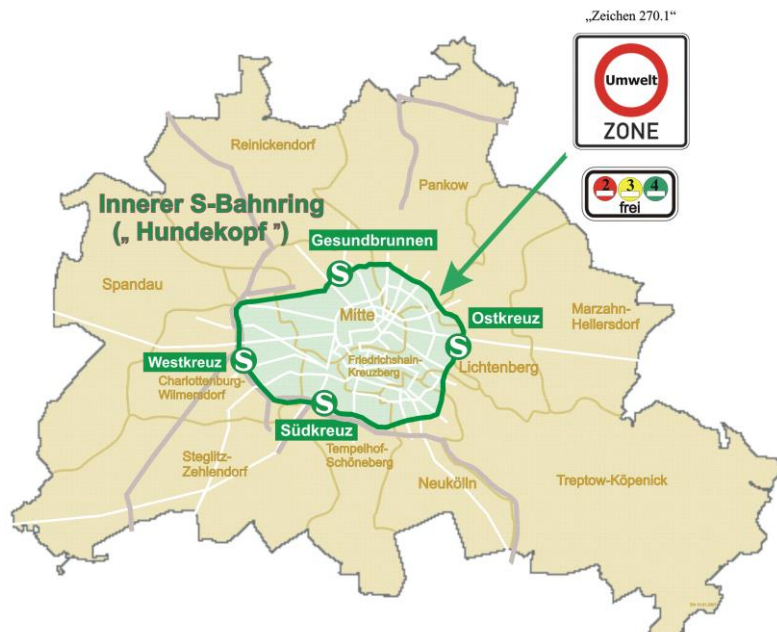
Solution for wide-spread traffic-related pollution...

☞ **LEZ: selective traffic ban for high polluting vehicles**

- **large-scale:** not only in single roads but covering the whole (potential) non-attainment area
- **durable:** not only on days in excess of 24h-limit value
- **transition period** (Berlin > 2 ½ years) prior to the start
 - ensures **proportionality**
 - **Berlin: no general exemptions** for residents and commercial traffic
 - **some individual** temporal exemptions possible



Berlin LEZ emission criteria






Area:

about 88 km²
(Berlin total area: 892 km²)

Inhabitants:





about **1 Million**
(Berlin total: 3,4 Mio)

Stage 1: since 1.1.2008

-  Diesel vehicles: at least **Euro 2** or Euro 1 & retrofit
-  Gasoline vehicles: at least **Euro 1**
-  **7%** of vehicle fleet **affected**



Stage 2: since 1.1.2010

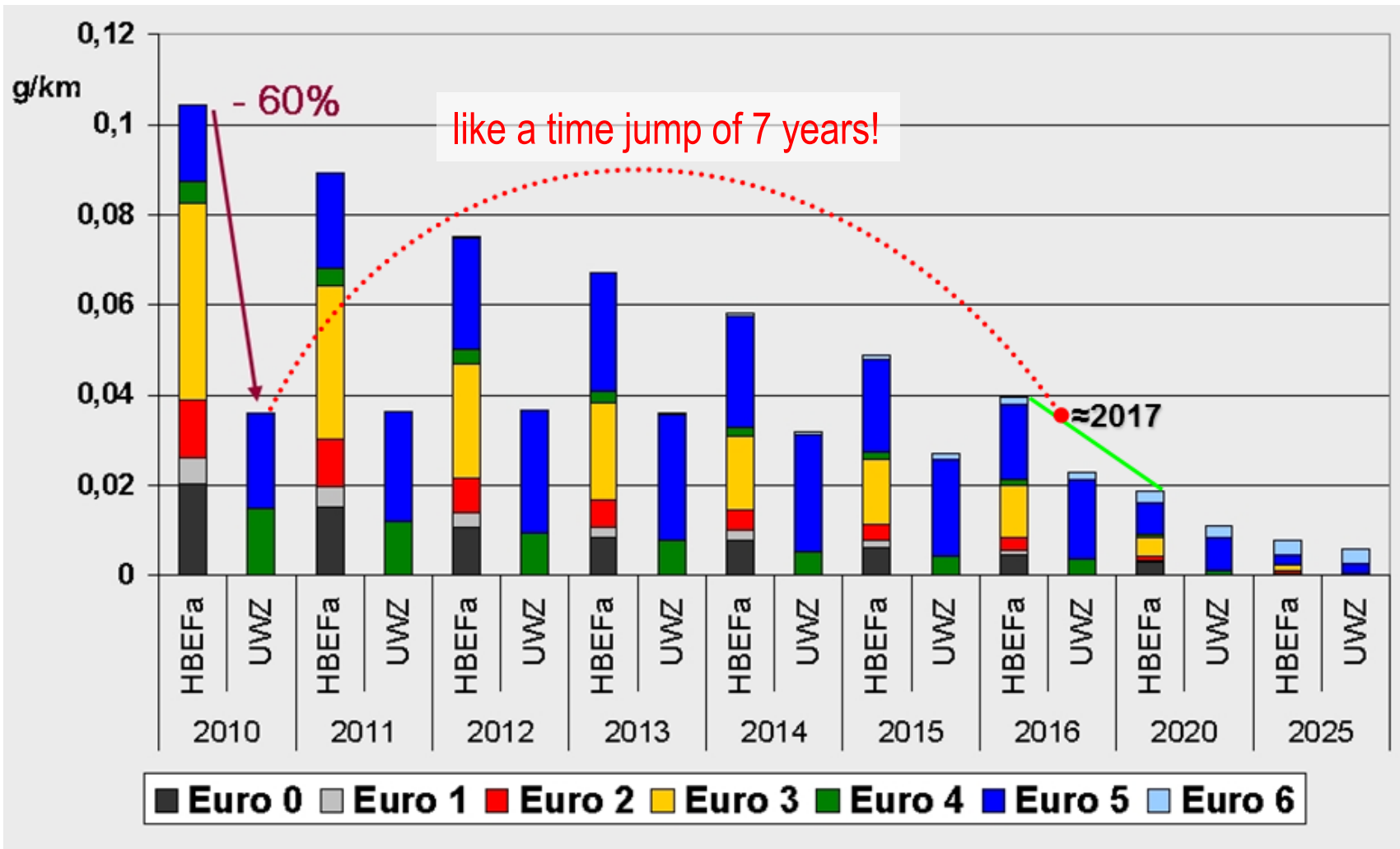
-  Diesel: particle emission **Euro 4**:
-  cars: **Euro 3** + **particle filter** or better
-  goods vehicles: also **retrofit** of Euro 1-3 towards Euro 4_{Particle}
-  **10%** of the vehicle fleet **affected**



 more than 40 LEZ planned/in force in Germany, another 30 LEZ in the EU, but with different emission criteria



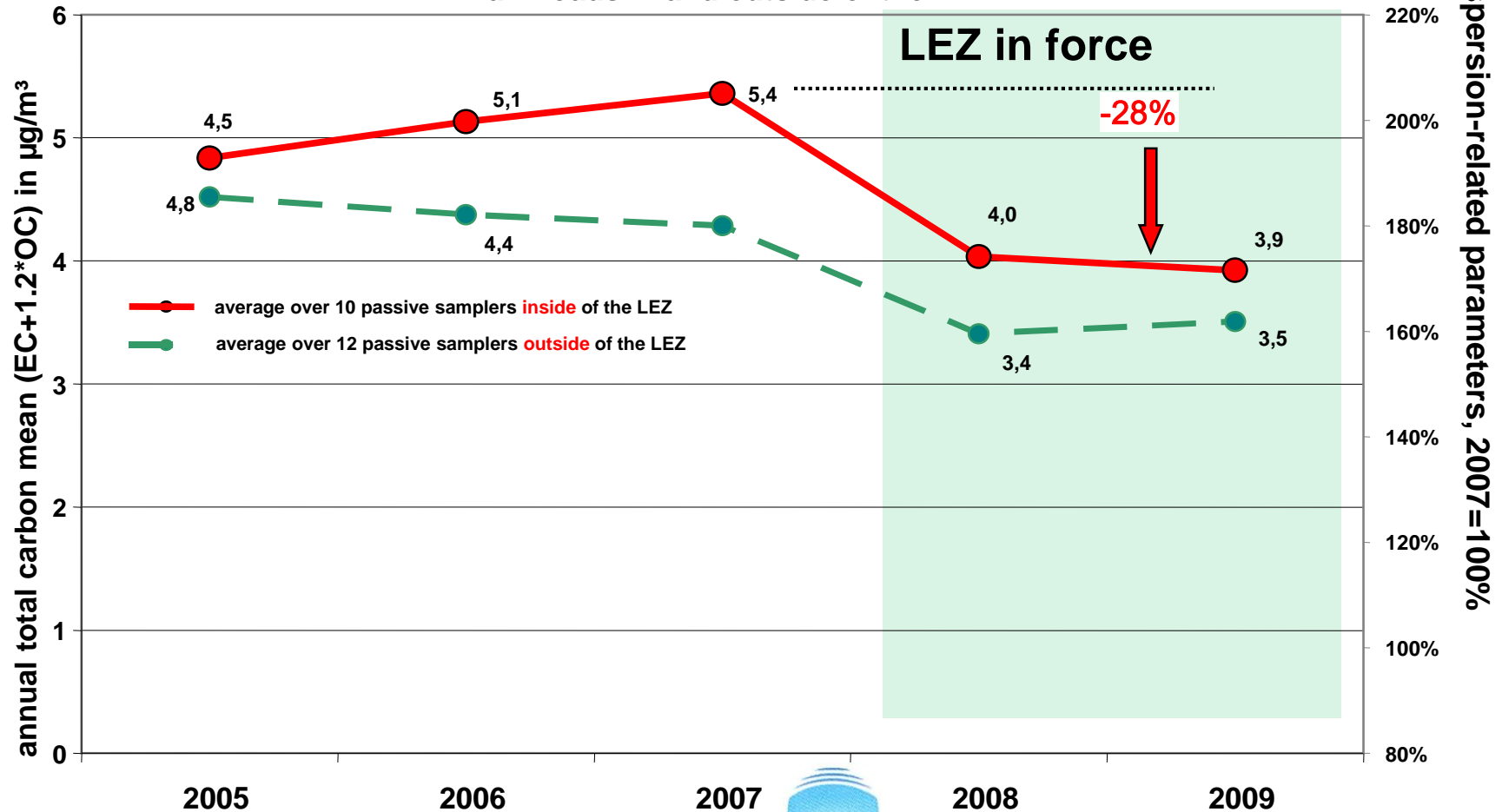
Reduction which has been achieved in road traffic



Berlin LEZ – real impact analysis

👉 total carbon concentration

traffic-adjusted trend of the **local traffic increment** of **total carbon** concentrations in main roads in and outside of the LEZ





no visible **shift** of **traffic** into surrounding areas

significant change in the **vehicle fleet composition**:

- **fewer „dirty“ vehicles** (<E1):
 - LGV/HGV: only **1-3%** instead of **20%**
- **more clean vehicles** (E4):
 - cars **90%** instead of **50%**,
 - lorries **75%** instead of **25-30%**

decrease of **traffic emissions** on top of trend :

- exhaust particles: **about 50%**; NO_x: - **19%**

LEZ is most **effective** single measure, **if**

- based on **ambitious** emission criteria
- covering a **larger area**
- **exemptions** are **limited**

possible benefit for the air quality

👉 **10% reduction** of PM_{10/2.5} & NO₂, black carbon decrease **~30%**

👉 **10-15** less excess **days** > 50 µg/m³ PM₁₀



LEZ pros & cons


■ Objective:

- faster modernisation of vehicle fleet


■ Criteria: When should a LEZ be considered?

- ☑ high contribution of urban **traffic-related** air pollutants
- ☑ air quality limit values **exceeded** in **many** urban **streets**
- ☑ low proportion of **through traffic** or no alternative routes

■ Advantages:

- ☺ aims specifically at the highest emitting vehicles
- ☺ **rewards** vehicle owners who invested in clean vehicles
- ☺ reduces the emission of the overall vehicle fleet all over the LEZ
 - decrease in all streets → decrease of urban background concentrations
 - decreasing urban population exposure
- ☺ proven benefit for air quality
- ☺ **controls** the most **hazardous component** of PM ( black carbon)

■ Disadvantages:

- ☹ in Germany: every car owner has to buy a sticker to facilitate control
- ☹ administrative effort for granting individual exemptions
- ☹ financial burden for owners of high emitting vehicles
 -  in particular for small businesses

However, fears of **destructive impact** on the local economy prove **wrong**

But, LEZ alone not **sufficient**, needs to be supplemented by...

„Zeichen 270.1



Modal-split shares

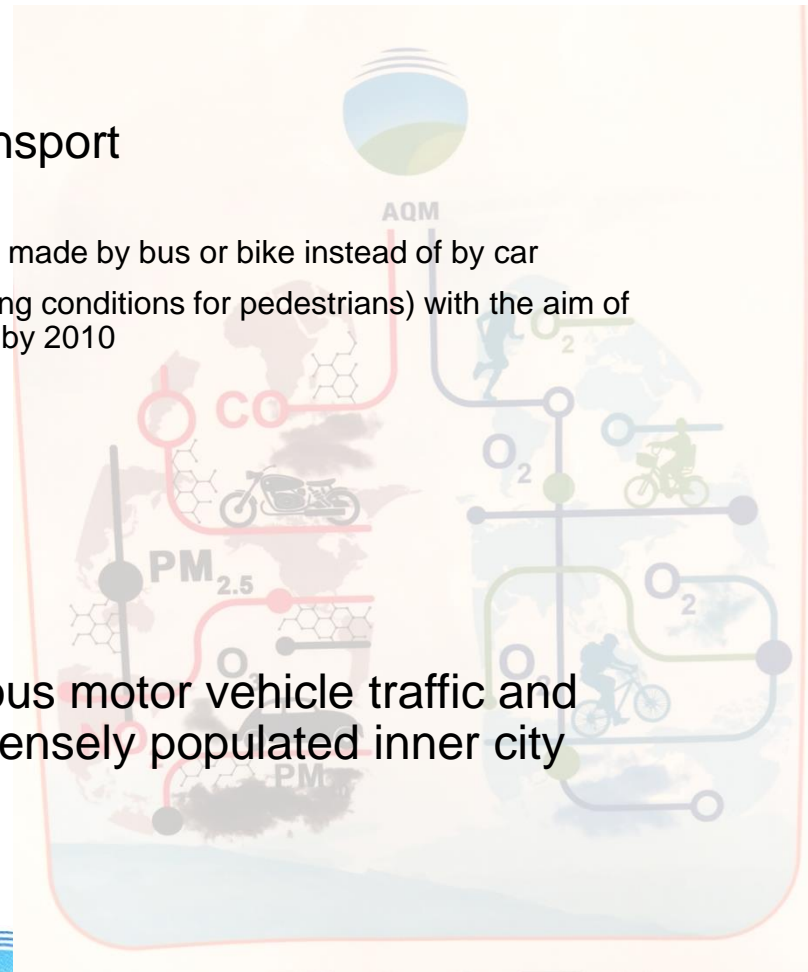
Consistent promotion of non-motorised transport
almost 50% of all journeys are under 5 kilometres

- given the right conditions, in many cases trips can be made by bus or bike instead of by car
- For this reason we have a bicycle strategy (+ improving conditions for pedestrians) with the aim of increasing the share of bicycle travel from 10 to 15% by 2010

An effective local public transport system

- by making it faster
- improving the connections
- optimising the available fixed route services

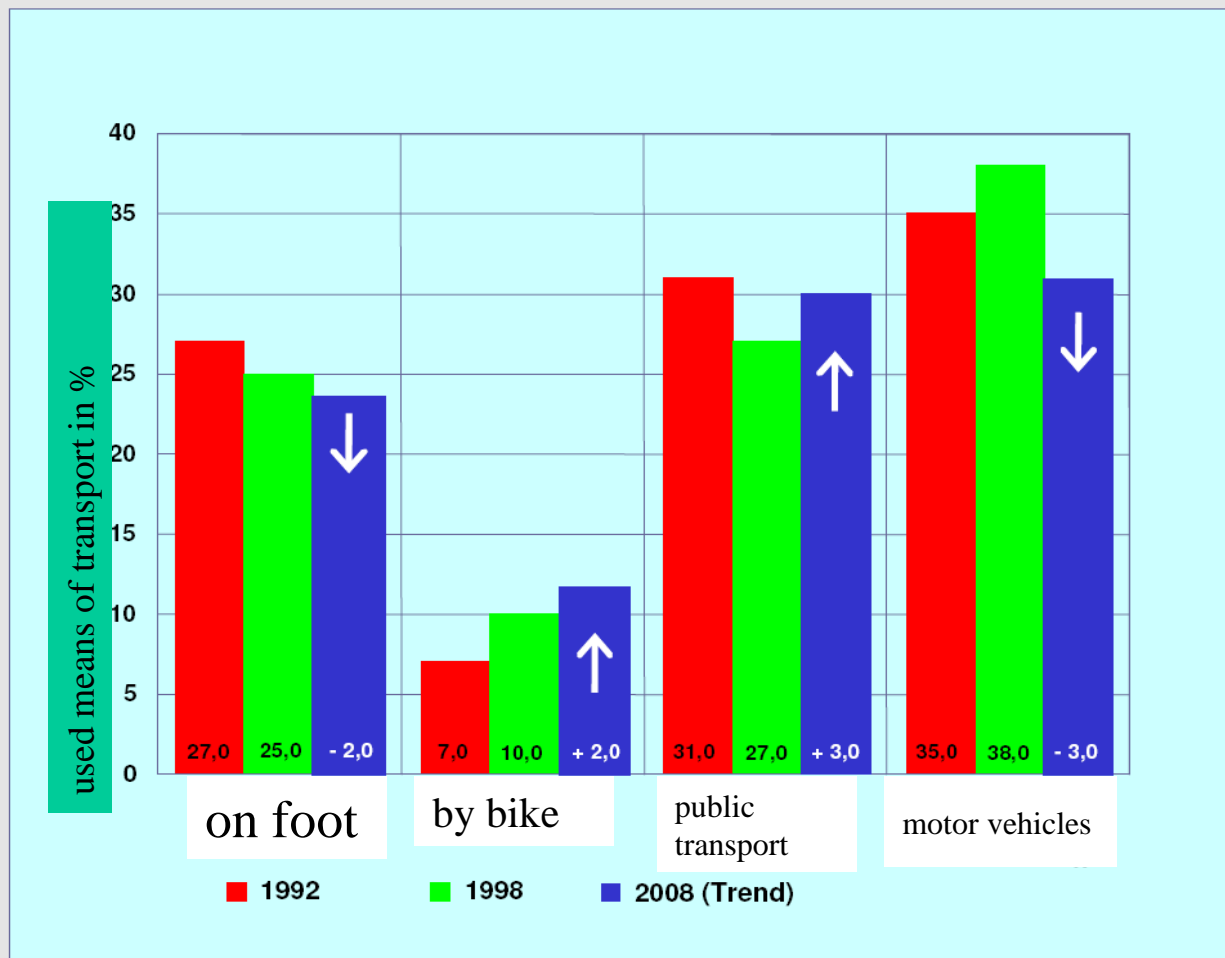
These are good ways of avoiding superfluous motor vehicle traffic and controlling air pollution, particularly in the densely populated inner city areas



Berlin's transport strategy

👉 **current trend in modal split**

Modal Split Development 1992 / 1998 / 2008



Quelle Diagramme: Senatsverwaltung für Stadtentwicklung*

* Stand 1998 (Letzte Haushaltsbefragung; neue Erhebung 2008)



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Example of comprehensive measures

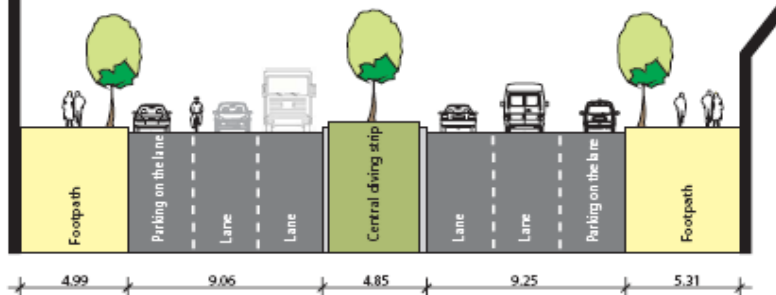
👉 redesigning road space



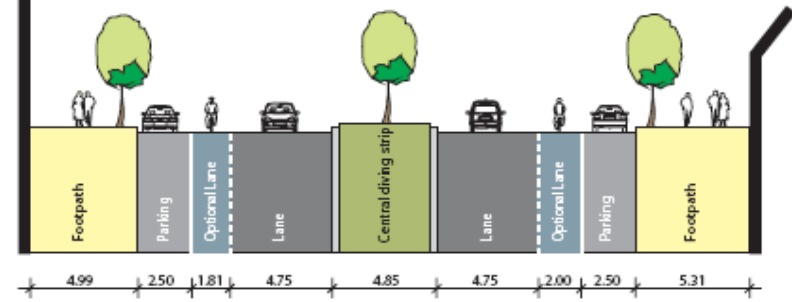
Example Prinzenallee

- removing one traffic lane
- set up separate lane for cyclists
- improve crossing for pedestrians
- planting of additional trees

before



after



Example of noise reduction measures

👉 redesigning road space

before

after

Sanierung Prenzlauer Promenade



- **separating tram tracks from motor traffic**
 - ↳ shortens travel time of public transport & makes it more attractive
- **set up noise absorbing lawn tracks**
 - ↳ also reduces re-suspension of road dust

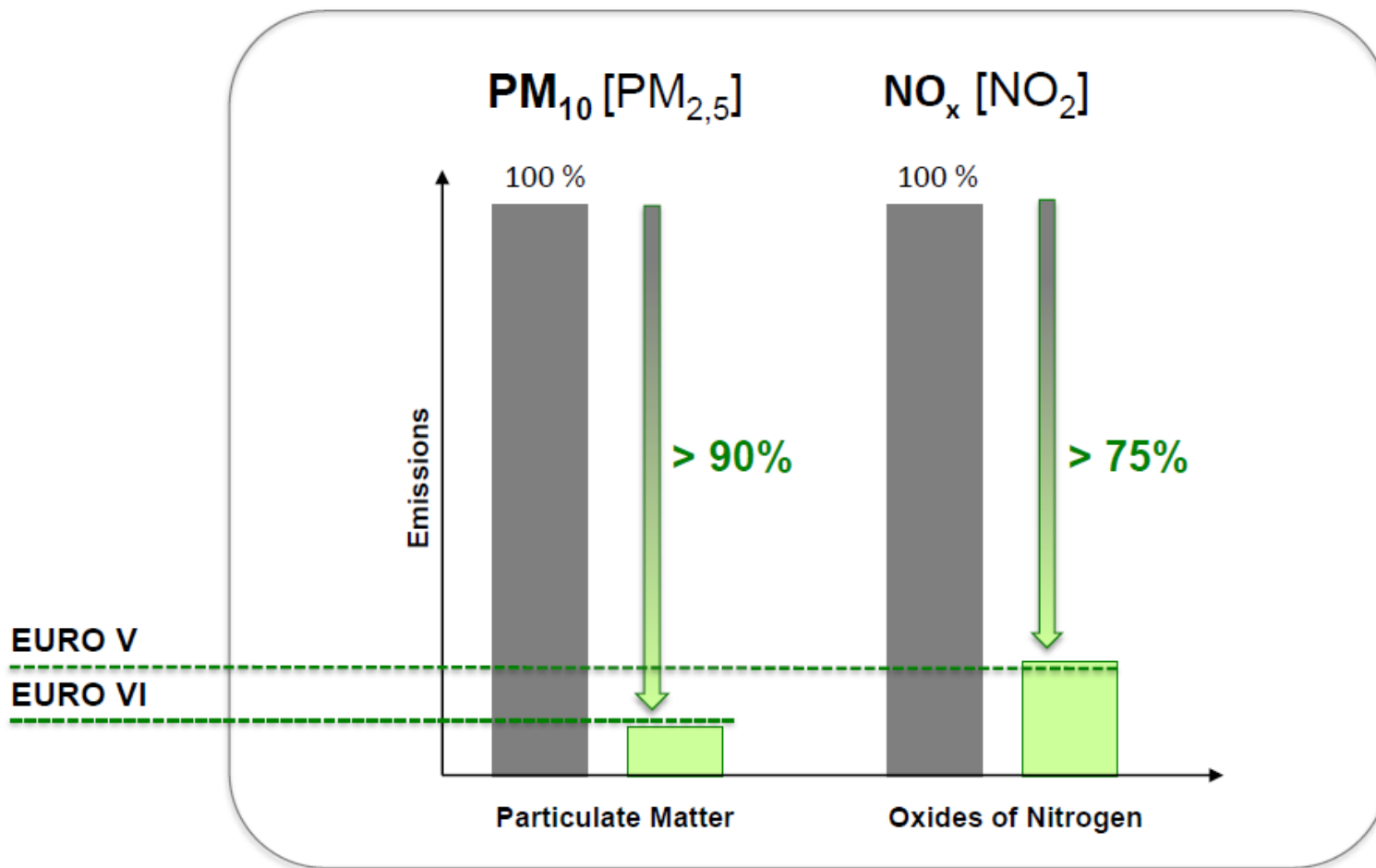


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Additional transport measures

- SCRT retrofit for public buses
- particulate filter for construction machines
- and as an option for the future,
 - SCRT retrofit for goods vehicles
 - Lez with a new light-blue sticker

Retrofit – Efficiency SCR + DPF® Systems



EURO V
EURO VI



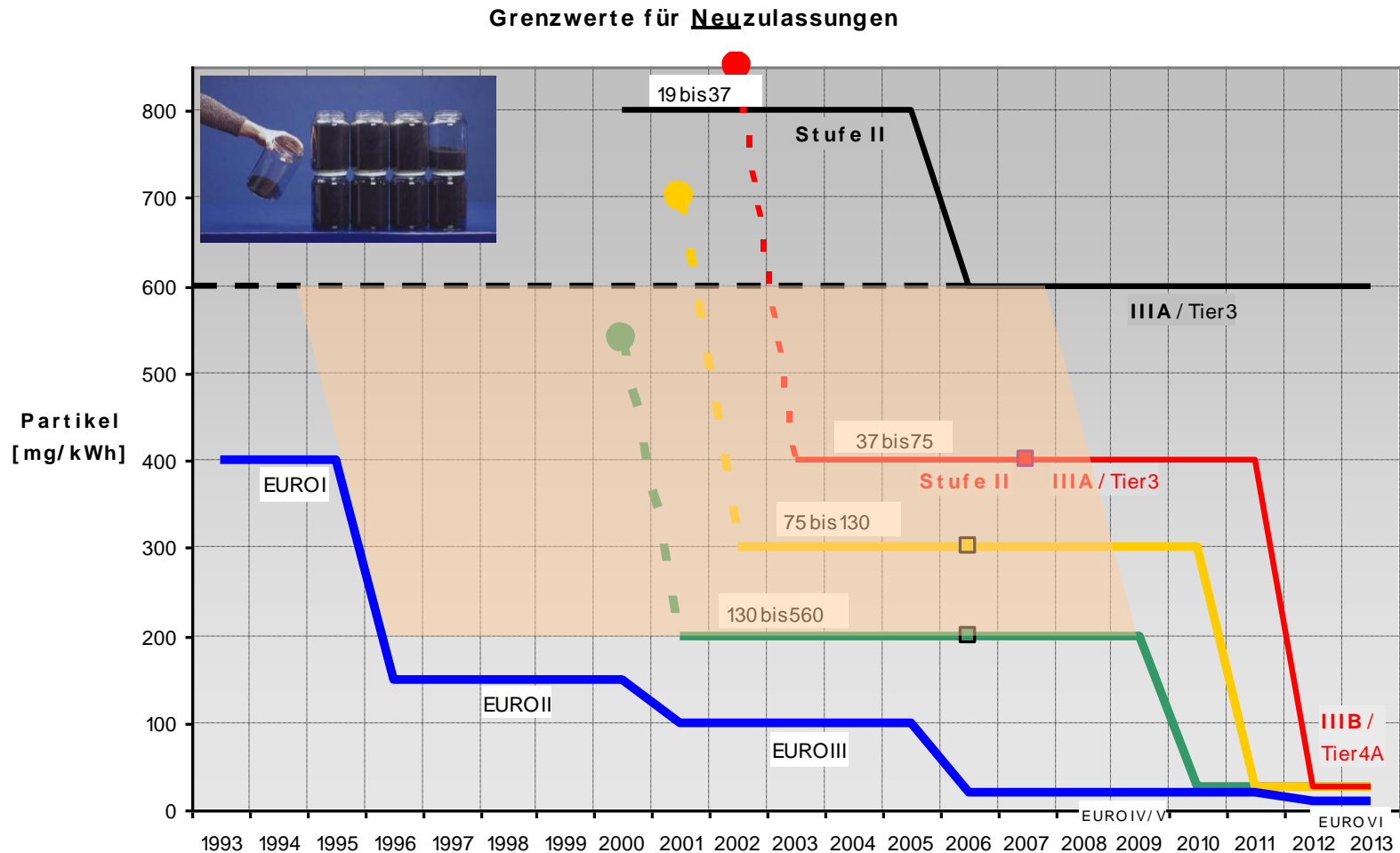
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ERECAL
Exhaust Retrofit Emission Control Alliance

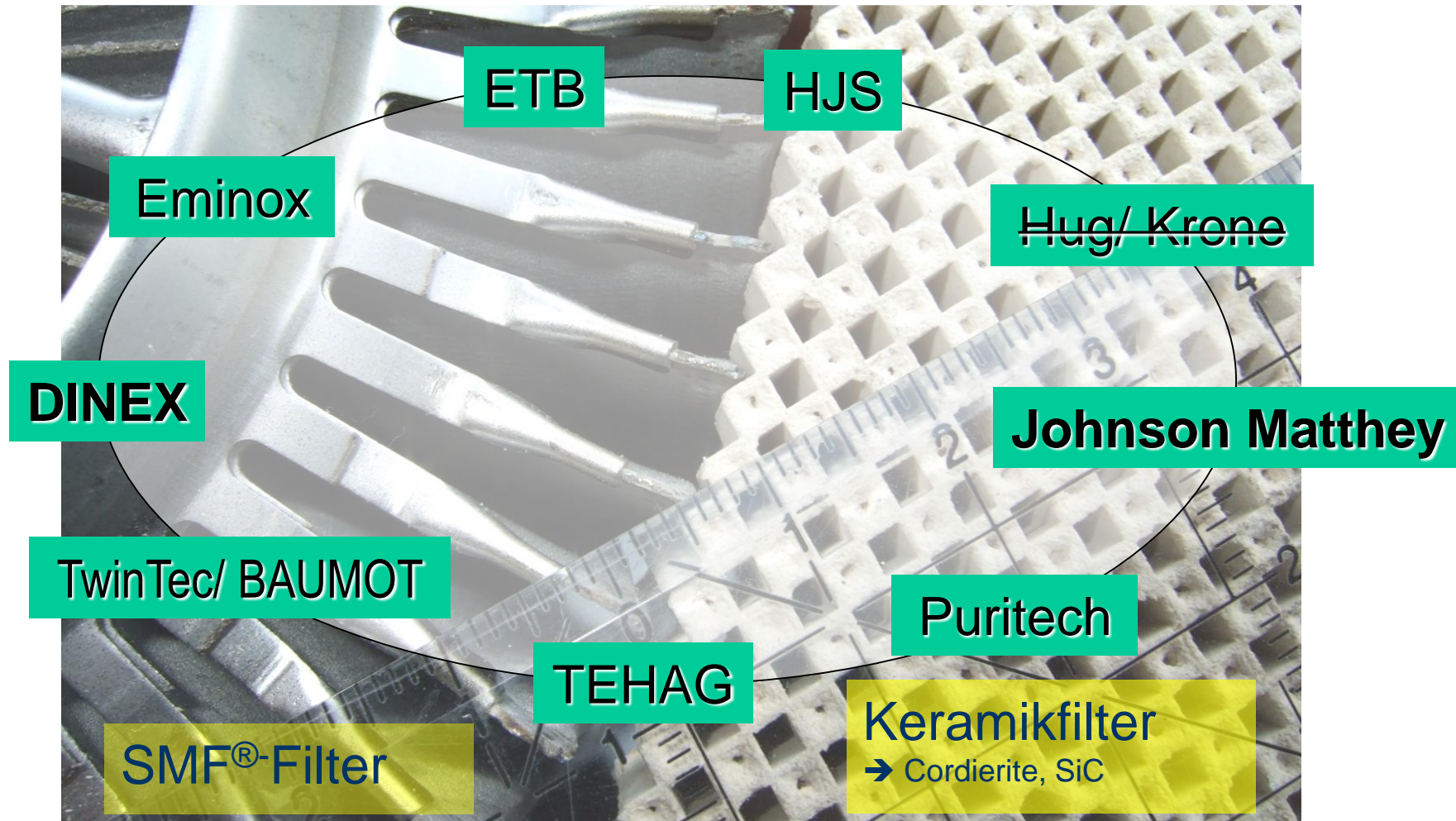
Retrofit is more cost-effective



PM standards for NRMM in comparison to HD vehicles



Participating DPF manufacturers





Regeneration principles installed, based on filter manufacturers' choice

- with additive (FBC)
- with additive + temporarily add-on electrical heating by alternator
- passive → catalytically coated filter (CRT principle)
- passive with catalytically coated filter + temporarily electrical regeneration “over night”
- external regeneration in oven

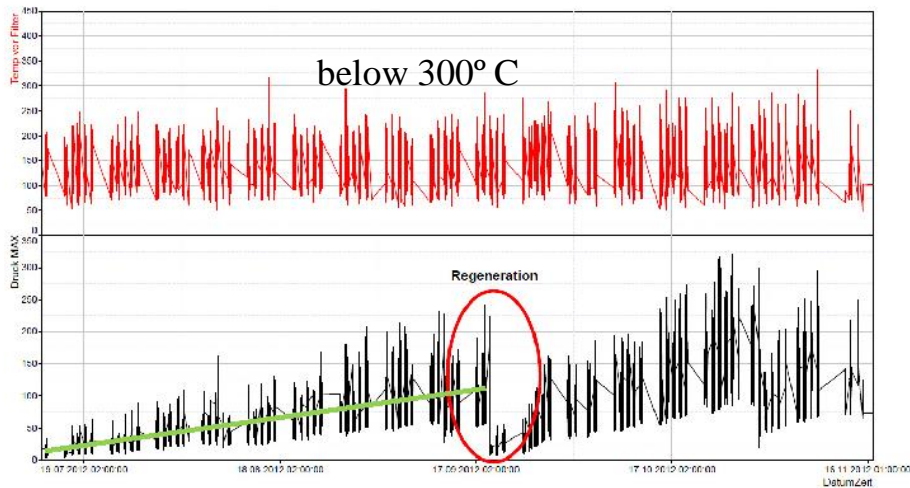
Two passive, catalytically coated filters (CRT principle)



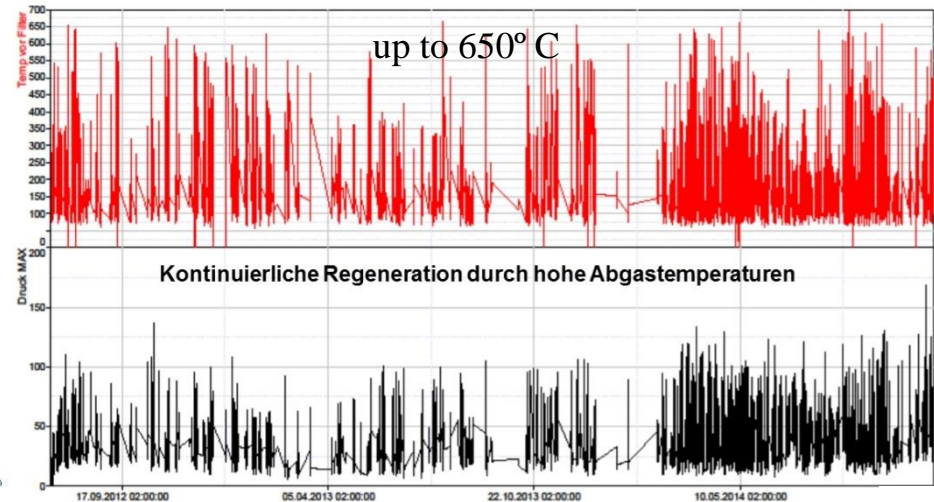
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HJS with additive + temporarily add-on electrical heating by alternator

Fz-Hersteller / Fz-Typ	Motor Typ / Leistung	Hubraum	Schadstoff-klasse	Filterfläche	Laufleistung am:	DPF-Typ
Yale / GDP30VX	Yanmar (4TNE92-NMH) / 31,2 KW	2,659 ltr.	Stufe III A	2,7 m² SMF	am 13.11.2014:601 Bn	SMF-AR



Fz-Hersteller / Fz-Typ	Motor Typ / Leistung	Hubraum	Schadstoff-klasse	Filterfläche	Laufleistung am:	DPF-Typ
Terex TL65	Deutz (D2011LD4) / 31,2 KW	3,109 ltr.	Stufe III A	1,8 m² SMF	n. bekannt	SMF-AR

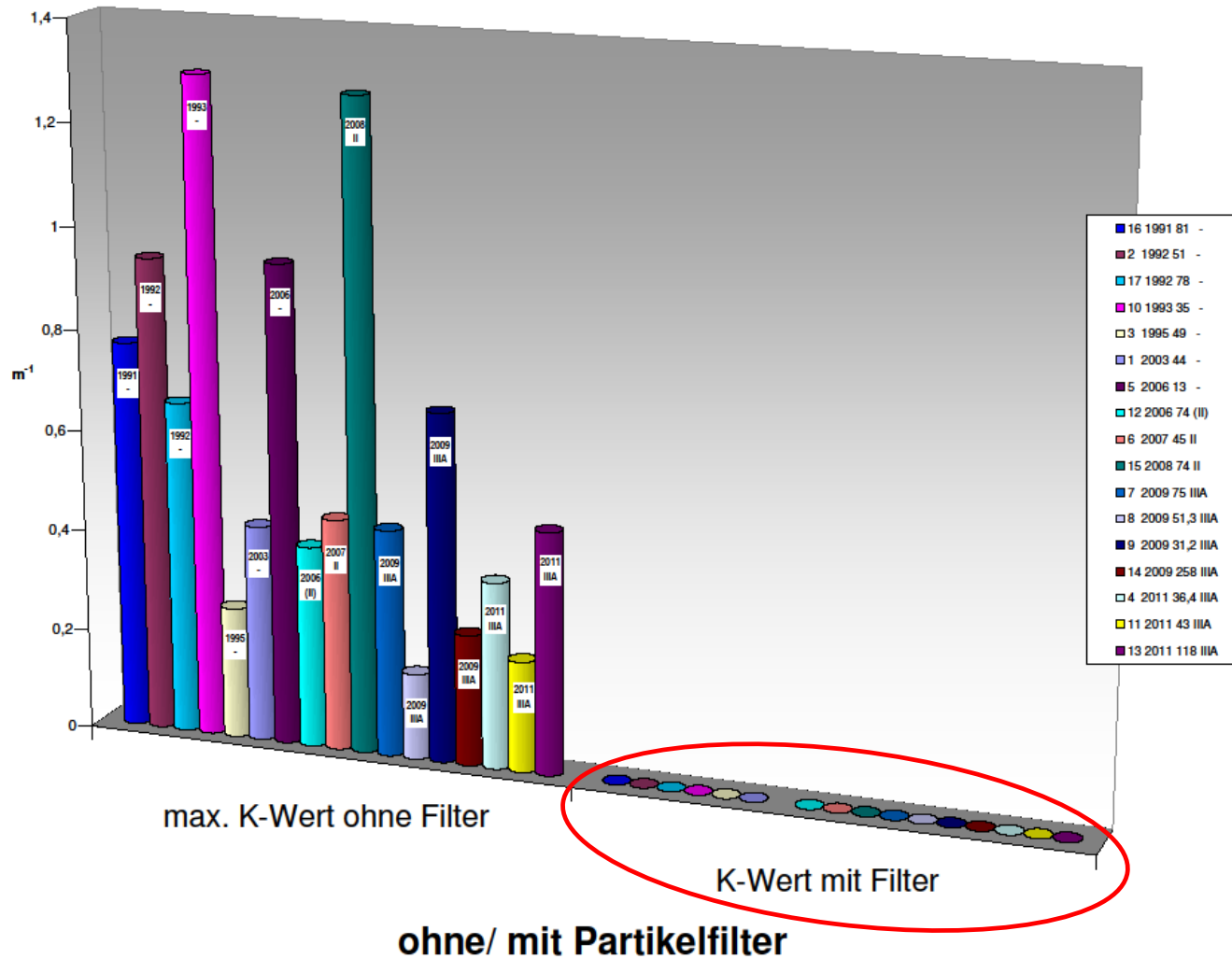


937 h



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Opazität nach Baujahr



Final results

- Not every vehicle can be refitted, because there may be no space for the refit, or the conversion is not cost-effective
- Malfunction only occurred when the DPF was assembled inadequately or the regeneration technology had not been adjusted.
- After the installation of the DPF the soot values had dropped near the detection limit in all tests.
- Use low-ash oil and the cleaning intervals will be at 1,000-2,500h. A professional cleaning including transport costs ca. 400 €
- IN ORDER TO REFIT SUCCESSFULLY YOU NEED A COMPETENT AND RELIABLE PARTNER, (DPF-Producer + a company that assembles filters) who sometimes says “NO” to cheap, passive regenerative filters

Every machine could then emit as few particles as these retrofitted vehicles



Thank you!



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030/9025-2390

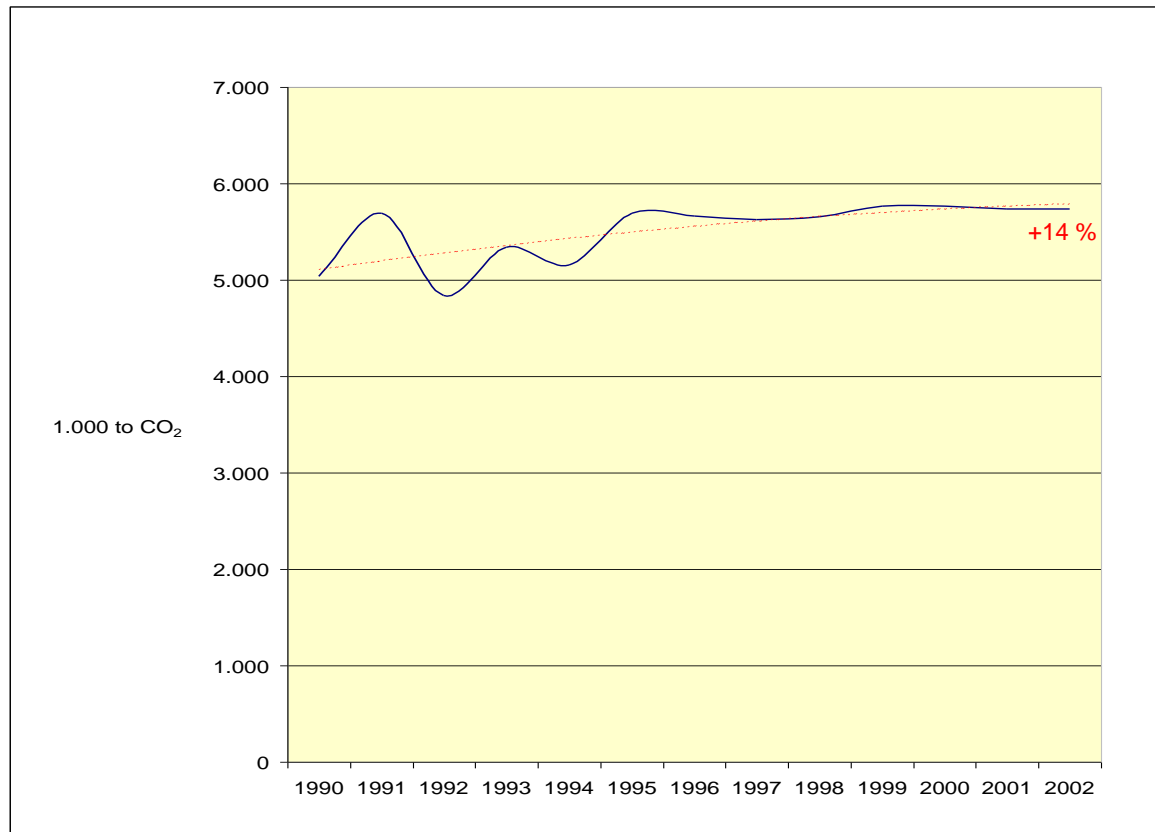
www.berlin.de/baumaschinen-partikelfilter



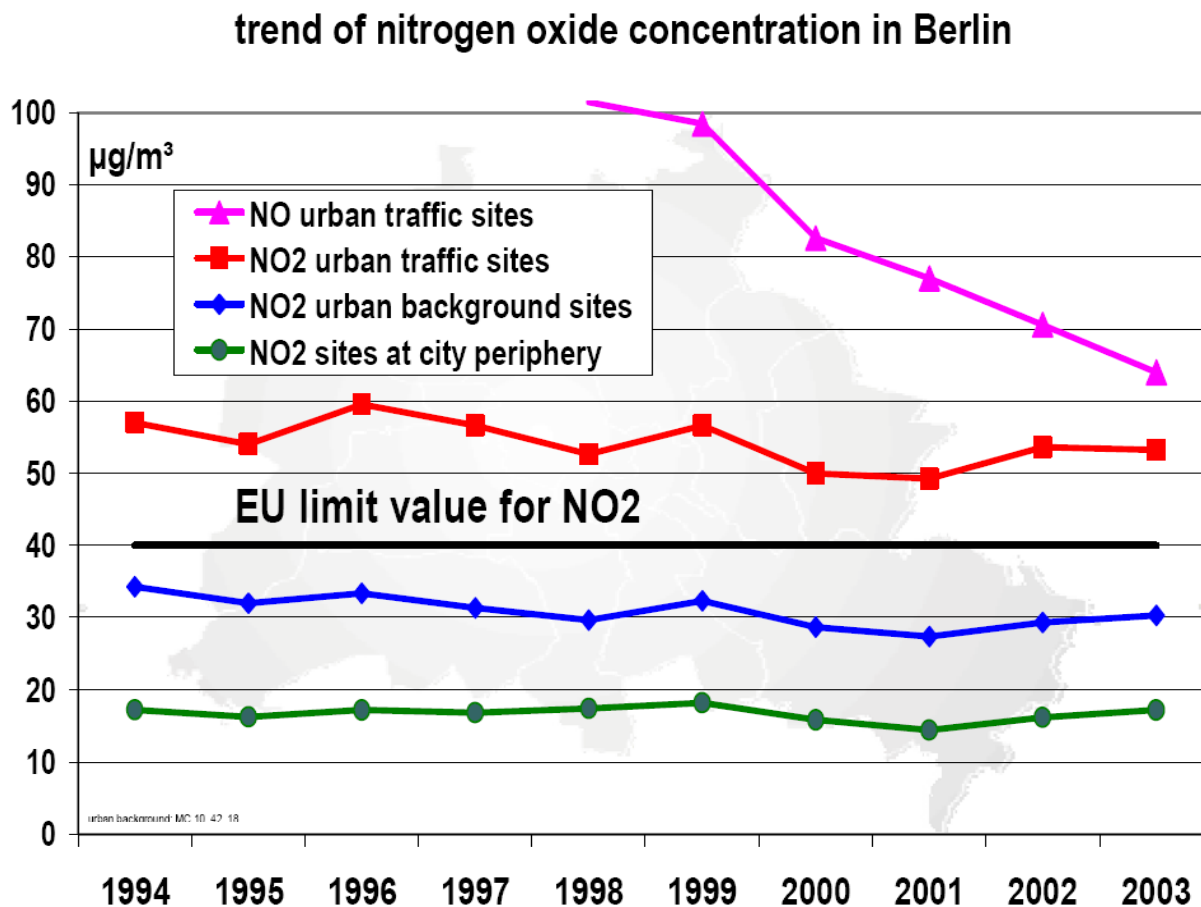
AQM 2016
مؤتمر القاهرة الدولي لإدارة تلوث الهواء و الضوضاء

Volker Schlickum, engineer, Berlin

Traffic

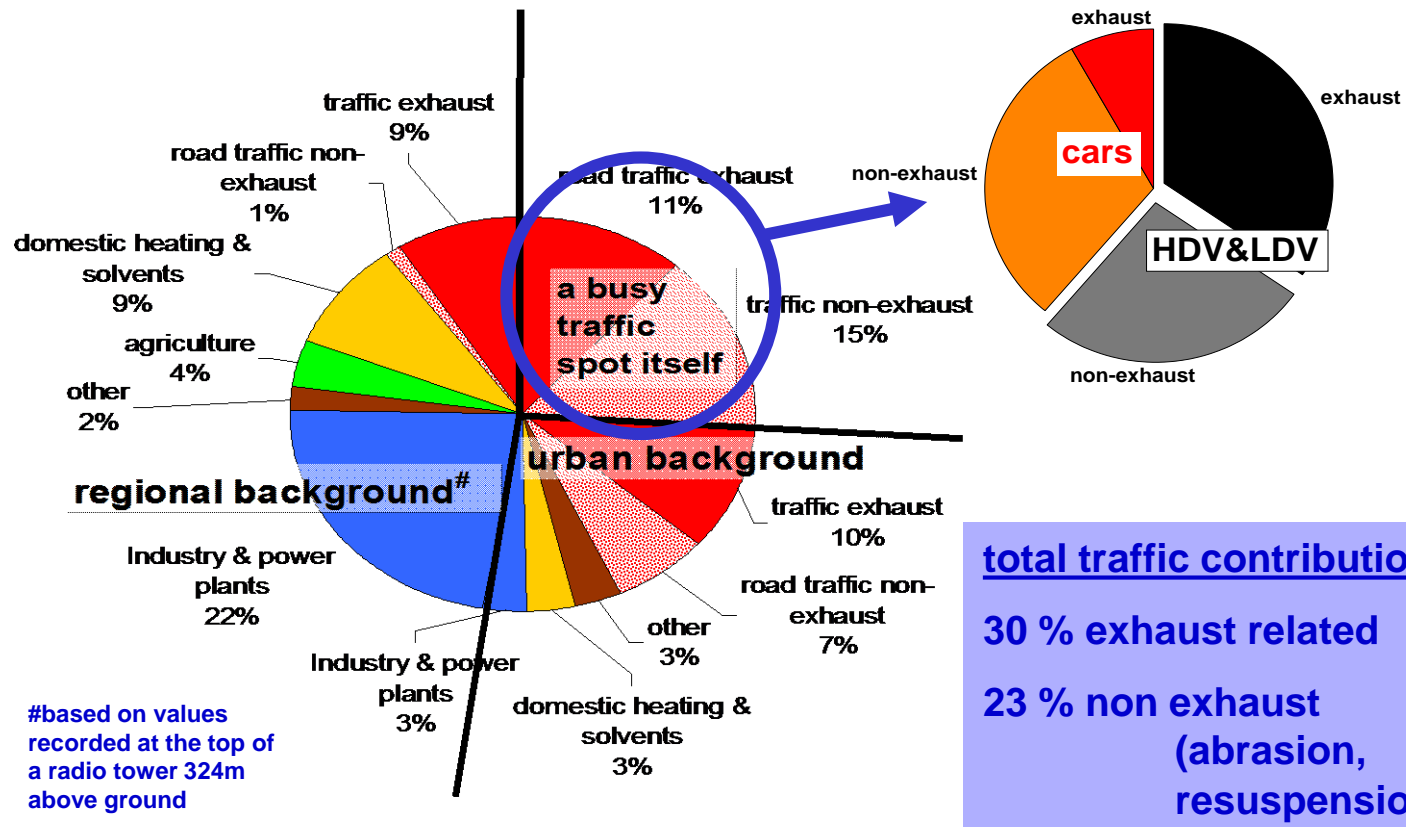


Long-term trend of NO₂ and NO in Berlin



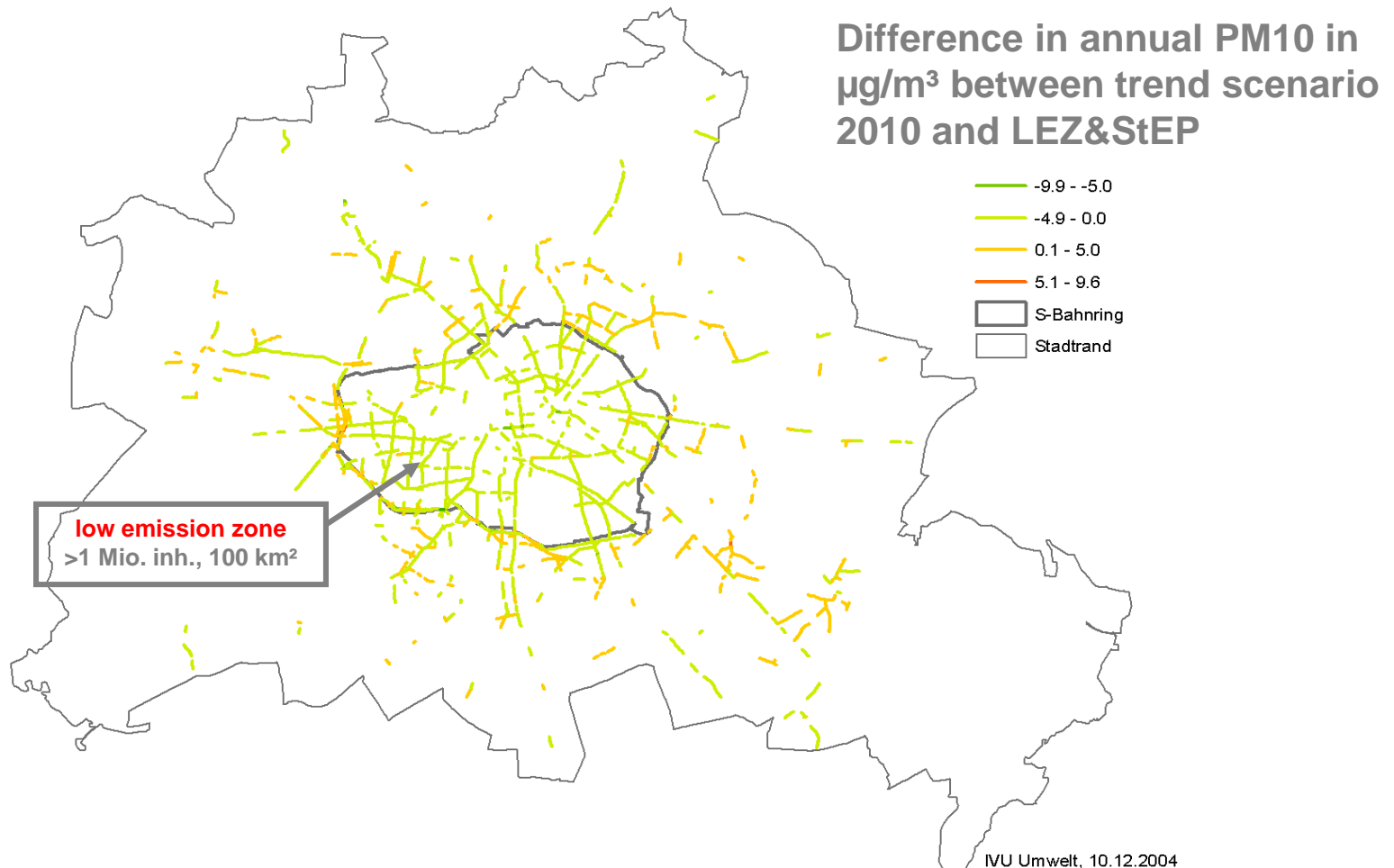
Source attribution by monitoring

☞ Sectors contributing to total **PM10** at a busy traffic spot in Berlin....



LEZ & “StEP” scenario 2010

☞ **PM10** reduction beyond the trend scenario 2010



Air Pollution Control Plan

☞ **Core measure: low emission zone**

traffic restriction for high emitting vehicles in the central city area

☞ **stage I: 2008,**
Diesel vehicles require at least **EURO II**

☞ **stage II: 2010,**
Diesel vehicles require at least **EURO III & particle trap**
gasoline vehicles need at least **EURO I**

☞ scrutiny in 2006, whether **retrofit** with particle trap could be required already in stage I

☹ **still needed...**

☞ national **labelling** scheme for **clean vehicles**
☞ **Federal Government**

☞ **economic incentives**, in particular for clean (or retrofitted) vans and lorries
☞ **Federal Government**





www2.senstadt.verwalt-berlin.de/index_en.shtml

Entry Requirements and marking ordinance

👉 Consequences

Clean air plan Berlin 2005:

- **Stage I** from 2008: at least Euro II for Diesel-Veh.
 - 4% of all cars und 30% of HDV
- **Stage II** from 2010:
 - for Diesel-veh.: at least Euro III + Particulate trap
 - 5% of all cars und 30% of HDV
 - for Petrol veh.: at least Euro I

After resolution of marking ordinance (KennzVO):


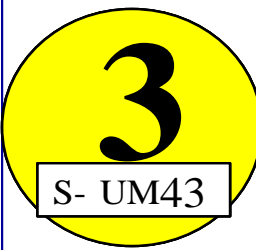
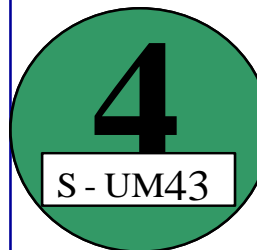

- Stage I from 2008: pollution group 2 
 - stricter for old petrol cars: at least Euro 1
 - **weaker** for diesel veh.: Euro 1 Diesel retrofitted with trap are allowed (still more particles than Euro 2 without filter)
- Stage II from 2010: pollution group 4 
 - **weaker**: Euro 1 petrol cars with catalyst allowed (more NO2)
 - **weaker**: trap efficiency 30/50(65)% instead **40/90%** (car/HDV)



Marking ordinance for low emitting vehicles

Resolution of the Bundesrates (against Berlin), adopted by federal government:

☞ 4 pollution groups; the **worst without sticker**

Sticker:				
Requirement for Diesel Veh. petrol cars	Euro 1, for particels Euro 2,	Euro 2, for particels Euro 3,	Euro 3, for particles Euro 4, Euro 1	Euro 4, for particels Euro 5, Euro 1,
Ban of Diesel veh. before year of manufacture	1992	1996	2000	2005
Particulate trap retrofitting: Efficiency >	only Euro 1 PKW: > 30% LKW: > 50%	only Euro 2 PKW: > 30% LKW: > 50%	only Euro 3 PKW: > 30% LKW: > 65 %	only Euro 4 PKW: > 30% LKW: > 65 %



Road sign

First proposal of the
federal government



Beginn eines Verkehrsverbots zur Verminderung
schädlicher Luftverunreinigungen in einer Zone

Recommendation to the EU:
Promote a harmonized, non-
discriminating road sign.

Proposal of Berlin

„Zeichen 270.1



Now accepted by the
Bundesrat and the
federal government; still
to be notified by the
CEMT