

AECC Technical Seminar
on Heavy-duty Engine Emissions
Thursday, 25 October 2007

Effects of planned legislation on transport emissions in Germany

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Overview



- **IFEU – short introduction**
- **TREMOD Model**
- **Air Quality and National Emission Ceilings**
- **Effect of Euro VI and Euro 5/6 on Particulate Matter and NO_x-Emissions in Germany**
- **Effect on urban emissions (NO_x and NO₂)**
- **Conclusions**

IFEU Company Profile



IFEU = Institute for Energy and Environmental Research Heidelberg, since 1978

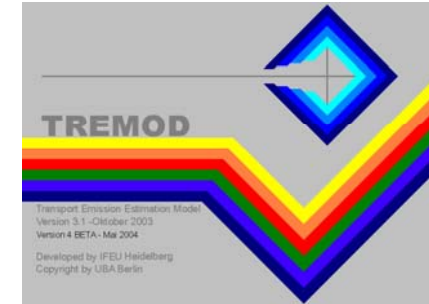
- Independent science
- organised as a private non profit company
- with about 40 scientists



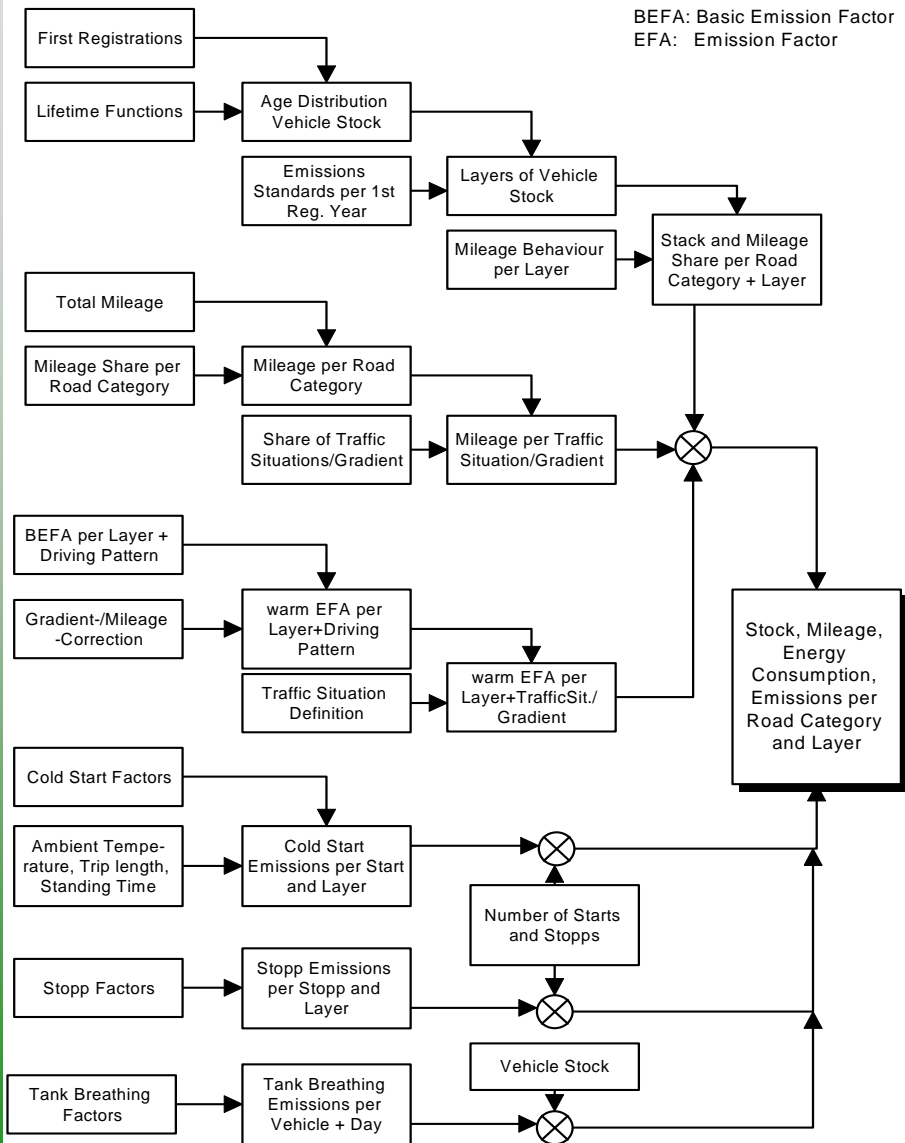
• **IFEU Topics**

- **Transport and Environment**
 - Life Cycle Assessment
 - Agriculture
 - Air pollution control
 - Waste management
 - Radioecology
 - Energy
- **IFEU Clients:** National and international associations, organisations and companies (e.g. World Bank, International Aluminium Association, Shell, Chevron-Sasol, European Commission, NGOs etc.)

- **TREMOD: Transport Emission MODel**
 - ▶ Developed by IFEU for and in close cooperation with the German Federal Environment Agency, Ministry of Transport, Association of Automobile Manufacturers and others (since 1993)
 - ▶ **Official database for emission reporting of the German Government**
- **Based on a range of European measurement programs:**
 - ▶ **Measurement of the driving patterns of vehicles**
 - Cycles recorded in real world traffic (car following method)
 - Weighted by traffic volume for a specific traffic situation
 - ▶ **Measurement at vehicles (emission behaviour)**
 - Vehicles grouped to different layers with comparable emission characteristics (vehicle types and sizes/ EURO stages, etc.)
 - Engine maps/ Real world cycles
 - Weighting according to fleet composition
 - ▶ **Harmonized with “Handbook of Emission Factors” (INFRAS Bern et al.)**



Emission Calculation in TREMOD



Modelling all relevant factors:

- driving behaviour,
- mileage,
- load factor,
- differentiated emission factors,..

Estimation of

- fuel consumption and
- exhaust and evaporative emissions (CO₂, CO, NO_x, NMHC, CH₄, benzene, SO₂, particulates, N₂O, NH₃).
- for all motorized passenger and goods vehicles.
- for Germany year by year from 1950 to 2030
- for various scenarios.

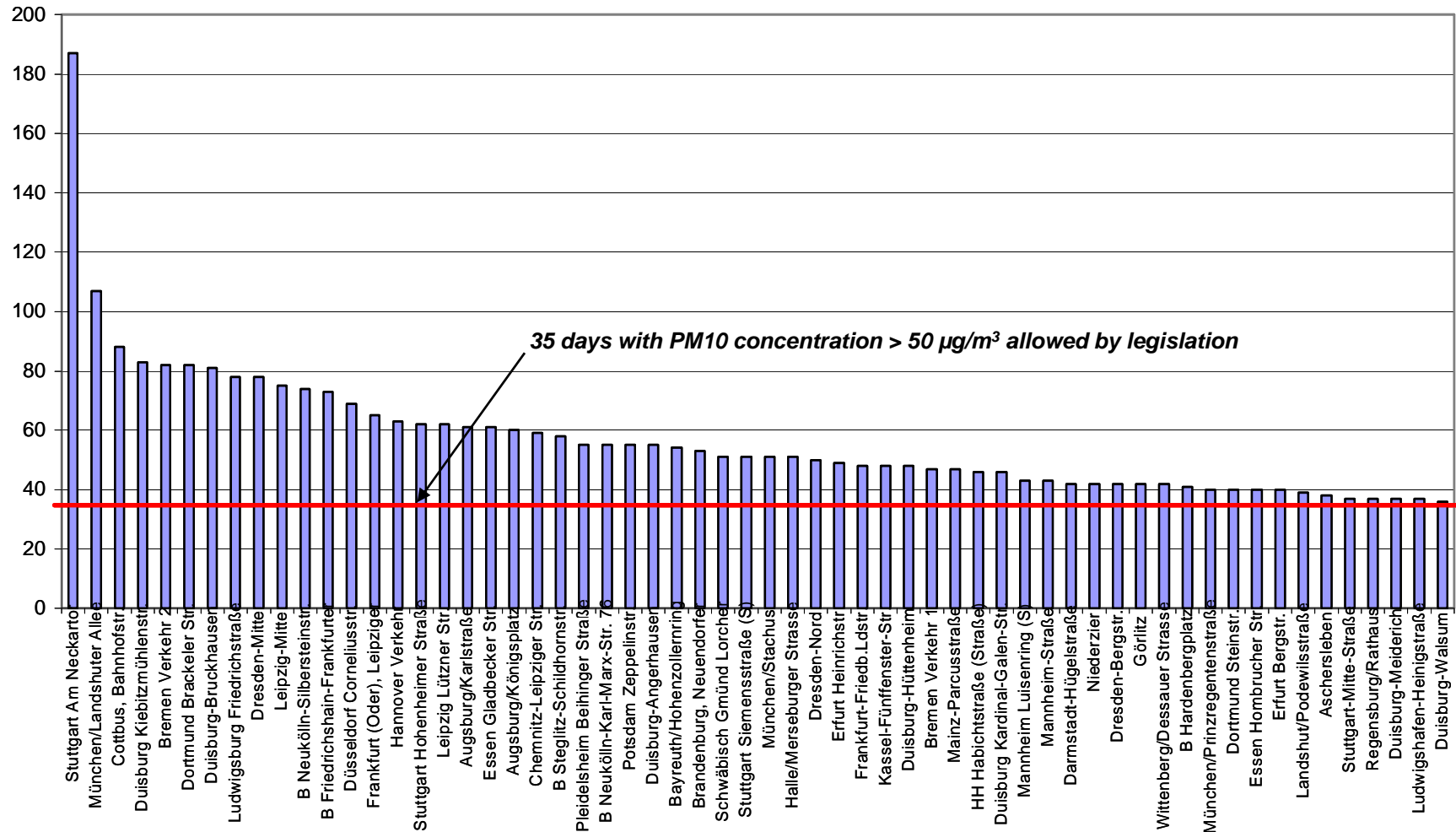
Situation in Germany

- Air Quality (PM₁₀ and NO₂)
- National Emission Ceilings (NEC)

Situation 2005 in Germany for PM10: Number of days > 50 µg/m³



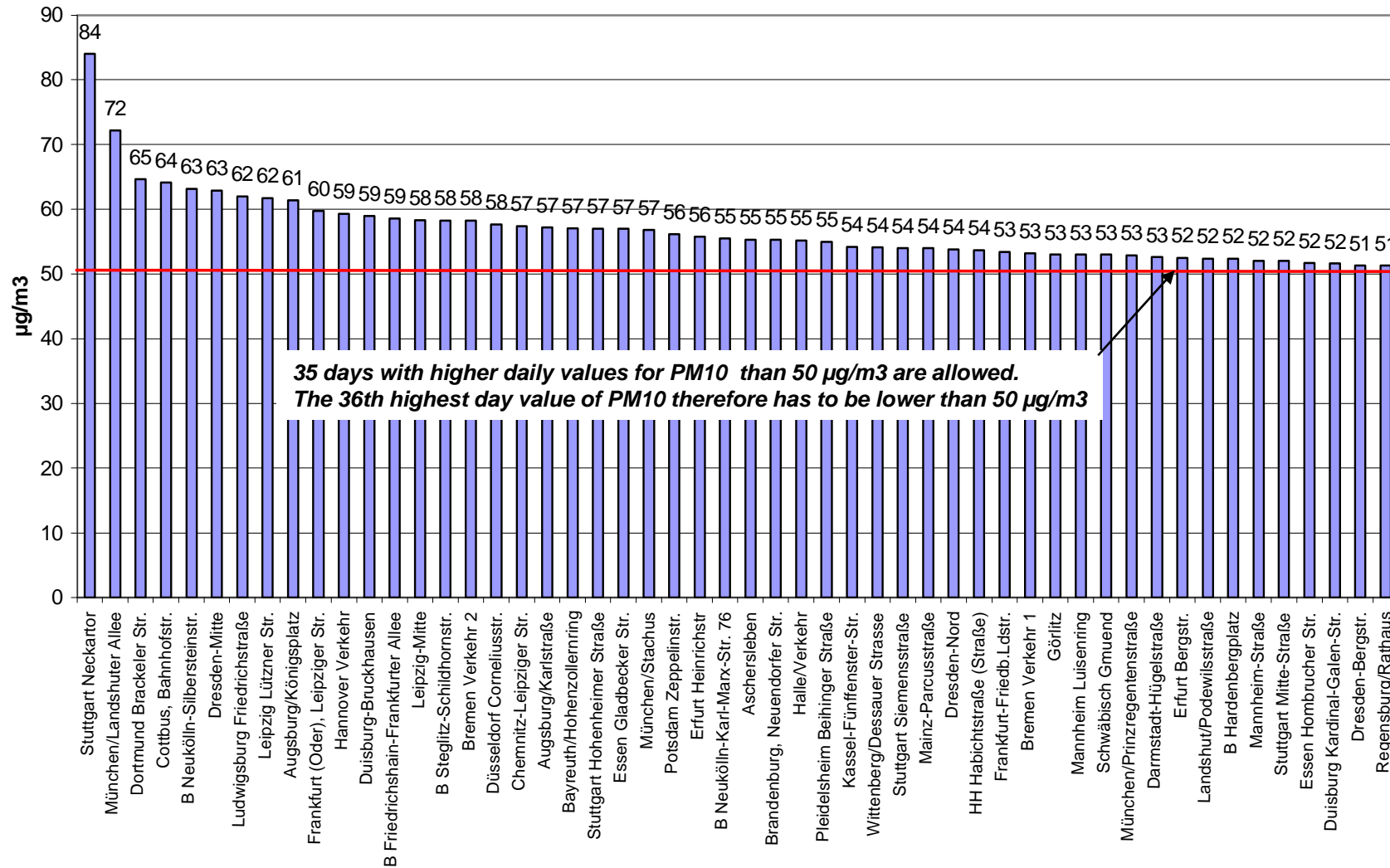
Situation 2005 in Germany for PM10: Number of days > 50 µg/m³



Situation 2005 in Germany for PM10: 36th highest day value



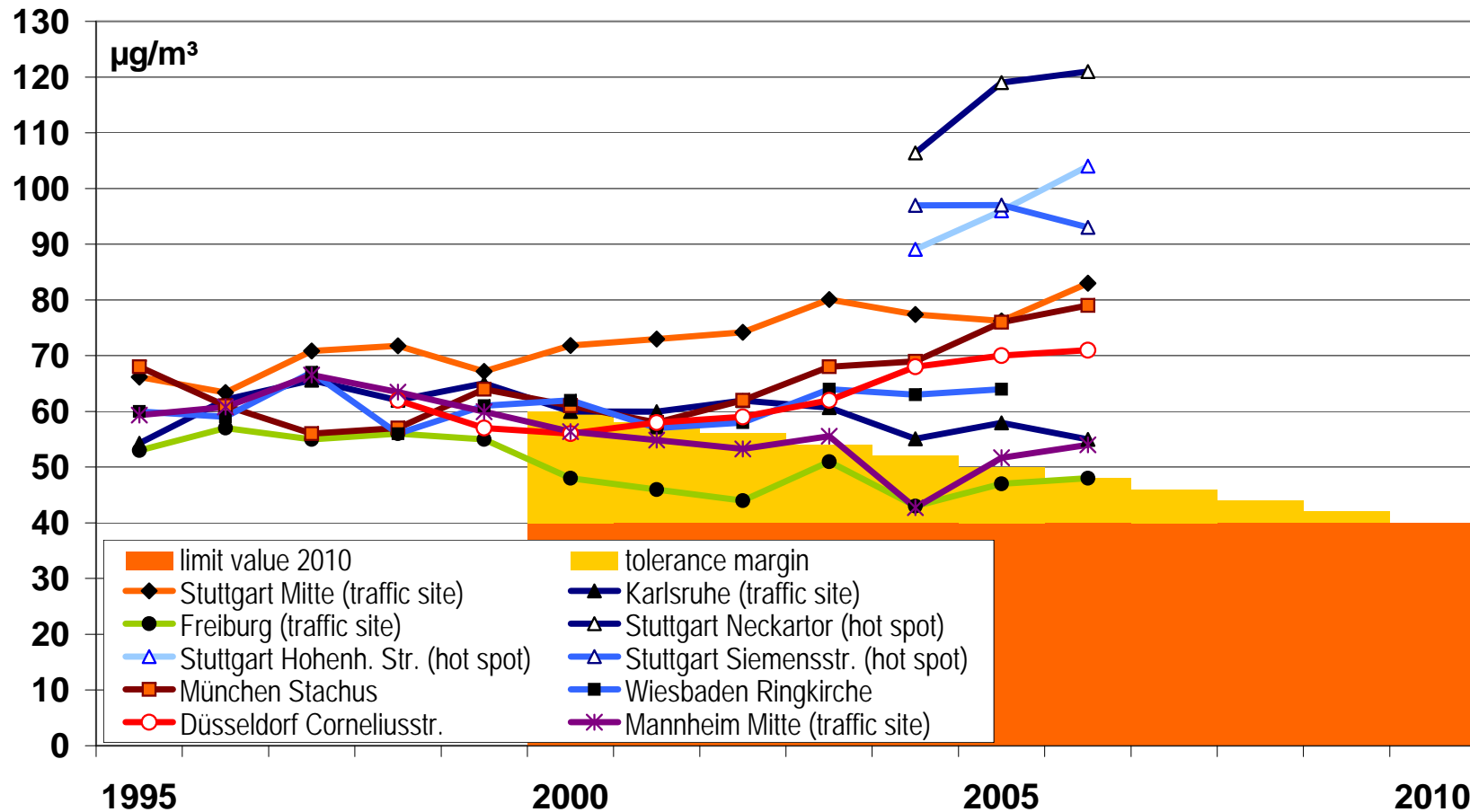
Situation 2005 in Germany for PM10: 36th highest day value



NO₂ Concentrations in Germany



NO₂ Concentrations at Traffic Sites in Germany



➔ Exceedance of future NO₂ air quality limit at many traffic sites in Germany.

Nitrogen Dioxide (NO₂) Ambient Air Concentrations in Germany 2005

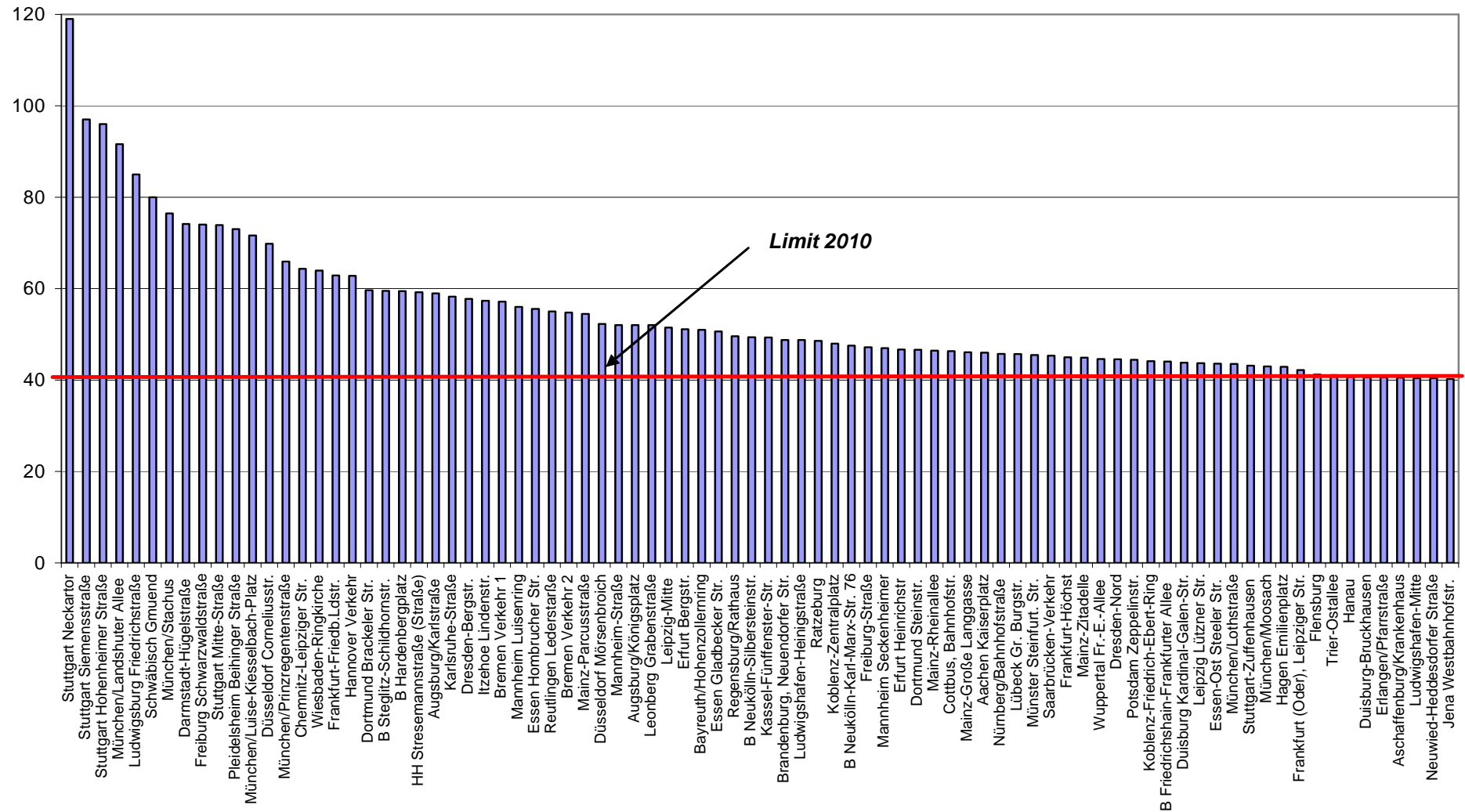
Introduction

TREMOD

Air Quality and NEC

PM and NO_x in Germany

Urban Emissions – NO_x and NO₂

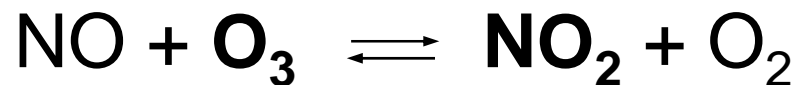


Causes for high NO₂ Concentrations



Explications for development of NO₂ concentrations in busy streets:

- 1. Increased primary NO₂ emissions** due to increased NO₂/NO_x ratio in the **exhaust** of Diesel cars equipped with **oxidation catalysts** and urban busses equipped with **continuous regenerating trap**
- 2. Increased ozone concentrations** and higher oxidation of NO (from vehicles) to NO₂



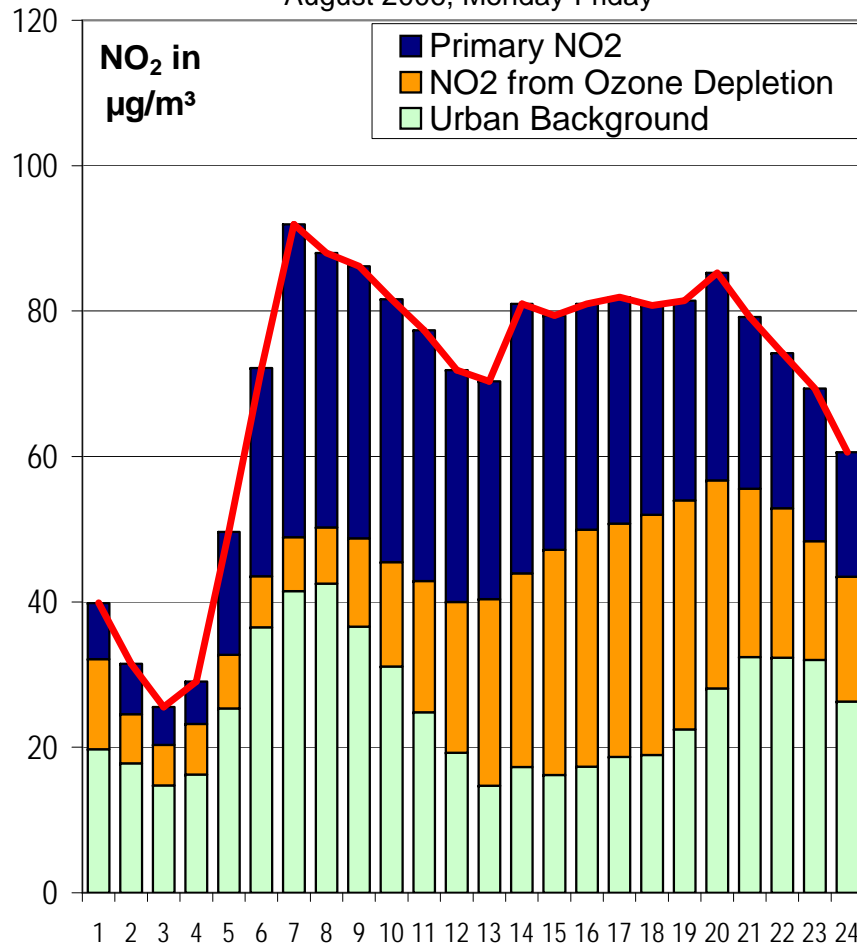
Shifted chemical balance of NO, NO₂ and ozone

Composition of NO₂ Concentrations in a Street



NO₂ Concentration in a Street (Stuttgart, Germany)

August 2006, Monday-Friday



➤ Strong variation of NO₂ concentrations in the course of a day.

➤ Varying contribution of

➤ **Urban Background,**

➤ **Ozone depletion in the street,**

➤ **Direct NO₂ emissions.**

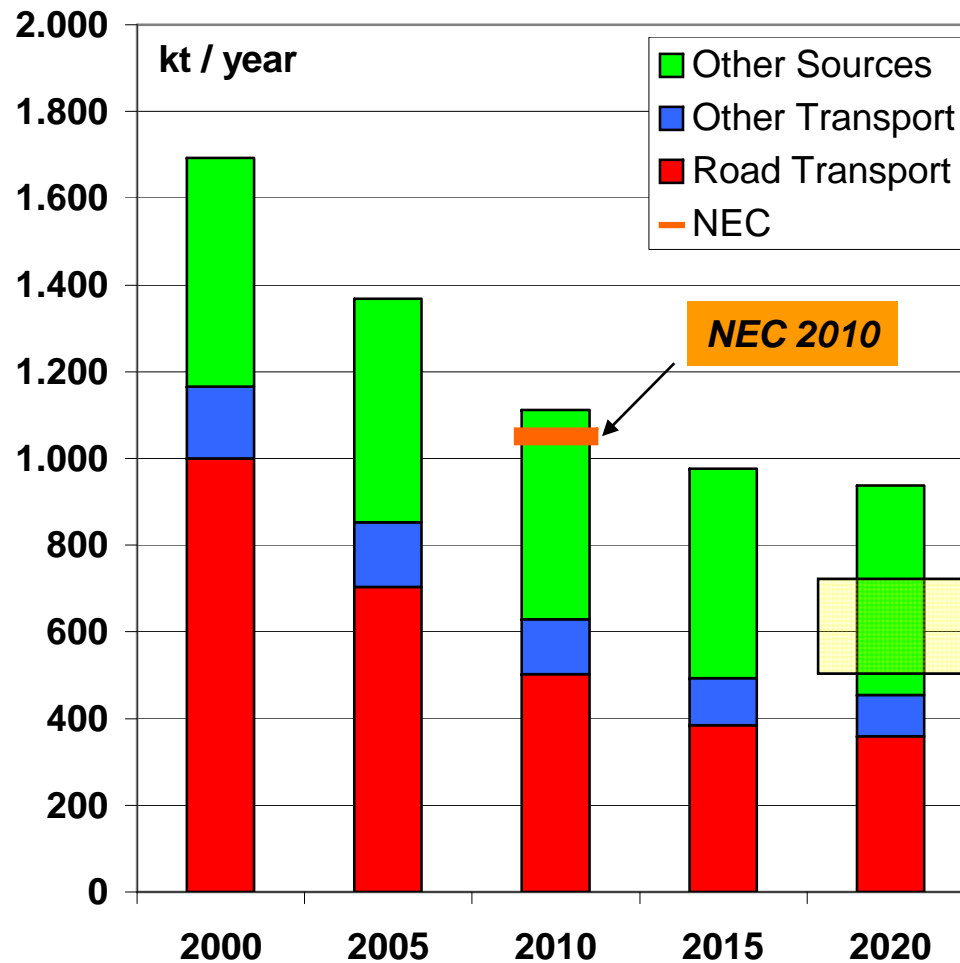
Considerable contribution of direct NO₂ emissions.

Share of different causes varies from site to site

NO_x Emissions and National Emissions Ceilings (NEC) in Germany



NO_x Emissions in Germany
(only NEC relevant emissions)



Quelle: Umweltbundesamt, 2006

- In the future, further decrease in NO_x emissions through regulations already in force/decided
- Additional measures are necessary to comply with the NEC in 2010.
- Preparation of National Programme
- ⇨ **Thematic strategy on air pollution** sets ambitious objectives for health and environment protection.
- ⇒ NEC Directive Revision: lower emission ceilings in 2020 (in discussion...)

Scenarios for Particulates, NO_x and NO₂

A) Nationwide Emissions for Particulates and NO_x

- National Programm
- Additional Calculations for PM10 Inventory for Germany

B) Emission in Urban Areas for NO_x and NO₂

- Variation of share of Diesel cars
- Variation of implementation date for new Euro Stages

A) Nationwide Emissions of Road Transport in Germany



National programme for a reduction of the ozone concentration and to comply with emission ceilings

(Nationales Programm zur Verminderung der Ozonkonzentration und zur Einhaltung der Emissionshöchstmengen)

- Effect of Introduction of New Emission Standards on Emissions of **NO_x**, NMVOC, SO₂, CH₄

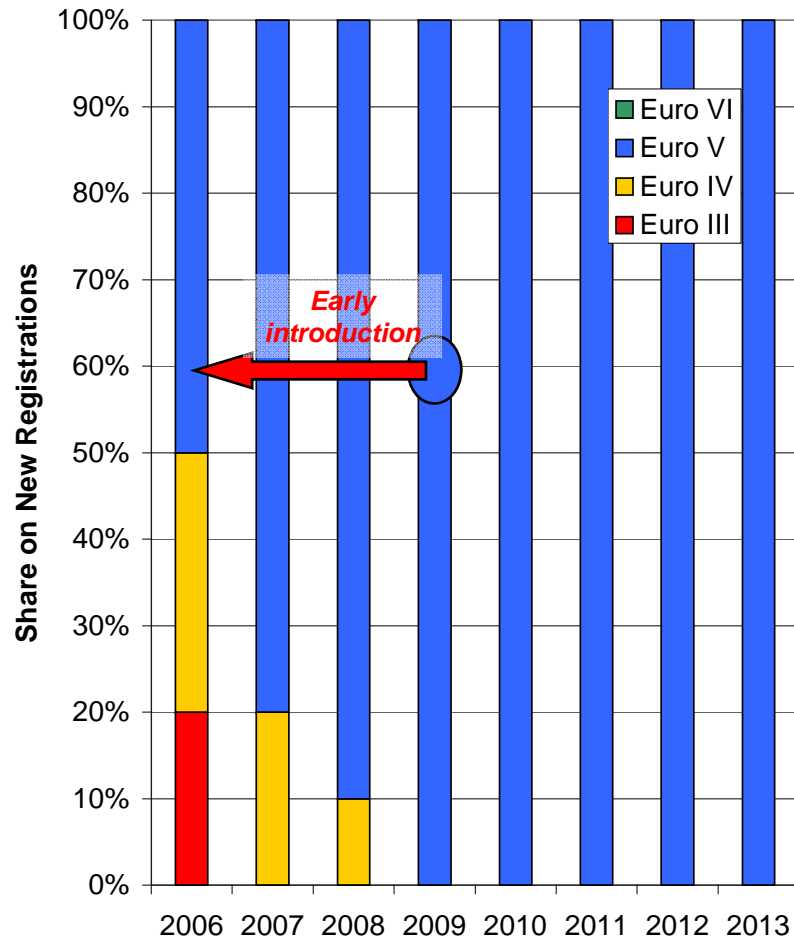
Inventory for PM10 and PM2.5 in Germany

- Effect of Introduction of New Emission Standards on Emissions of **PM10** and **PM2.5**

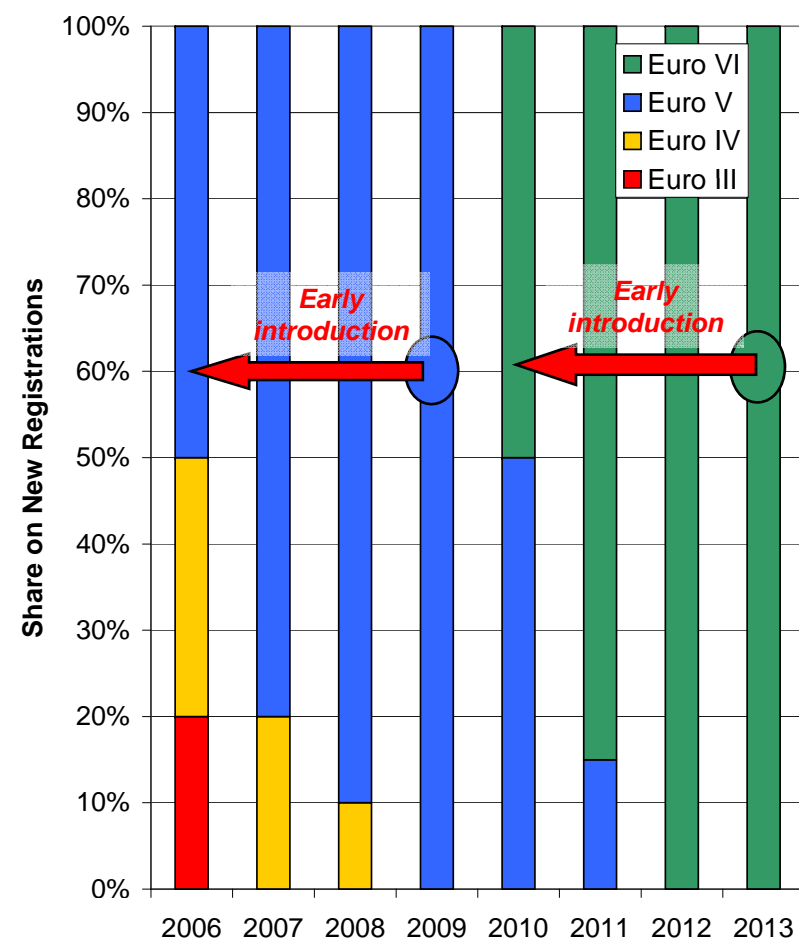
Share of Euro-Stages on New Registrations – Heavy Duty Vehicles



Share of Euro-Stages on New Registration - HDV
Scenario: Without Euro VI



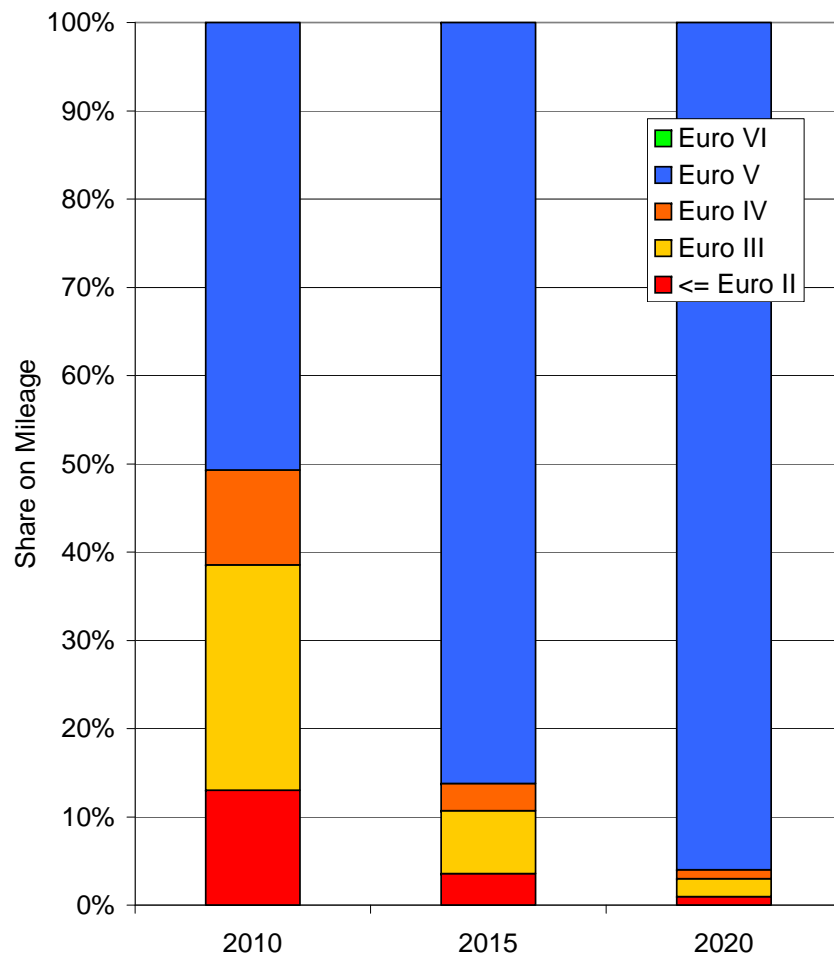
Share of Euro-Stages on New Registration - HDV
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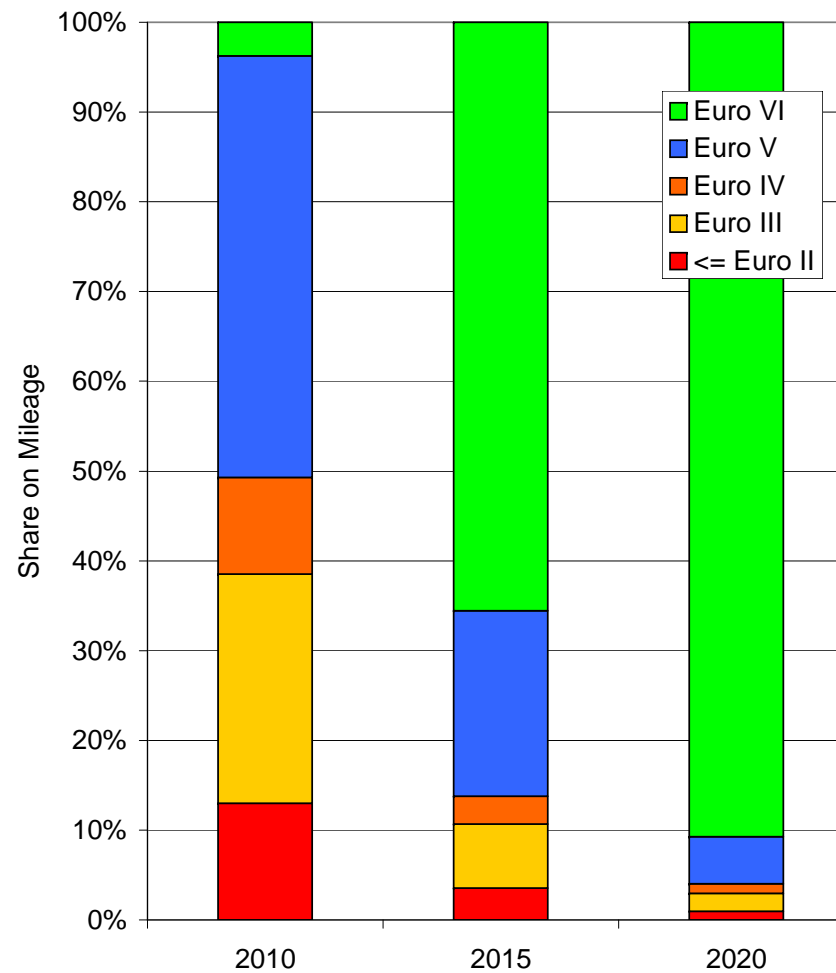
Share of Euro-Stages on mileage – Heavy Duty Vehicles



Share of Euro-Stages on Mileage - HDV
Scenario: Without Euro VI



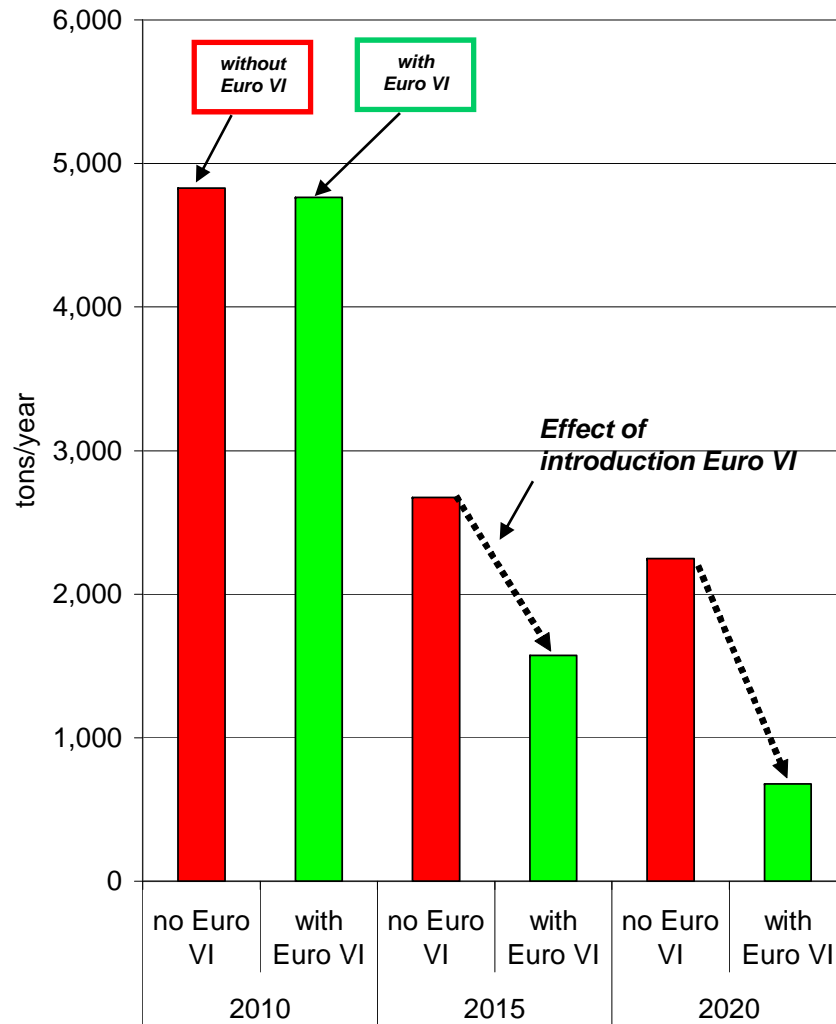
Share of Euro-Stages on Mileage - HDV
Scenario: With Euro VI



Emission Reduction – Particulate Matter Tailpipe – Germany



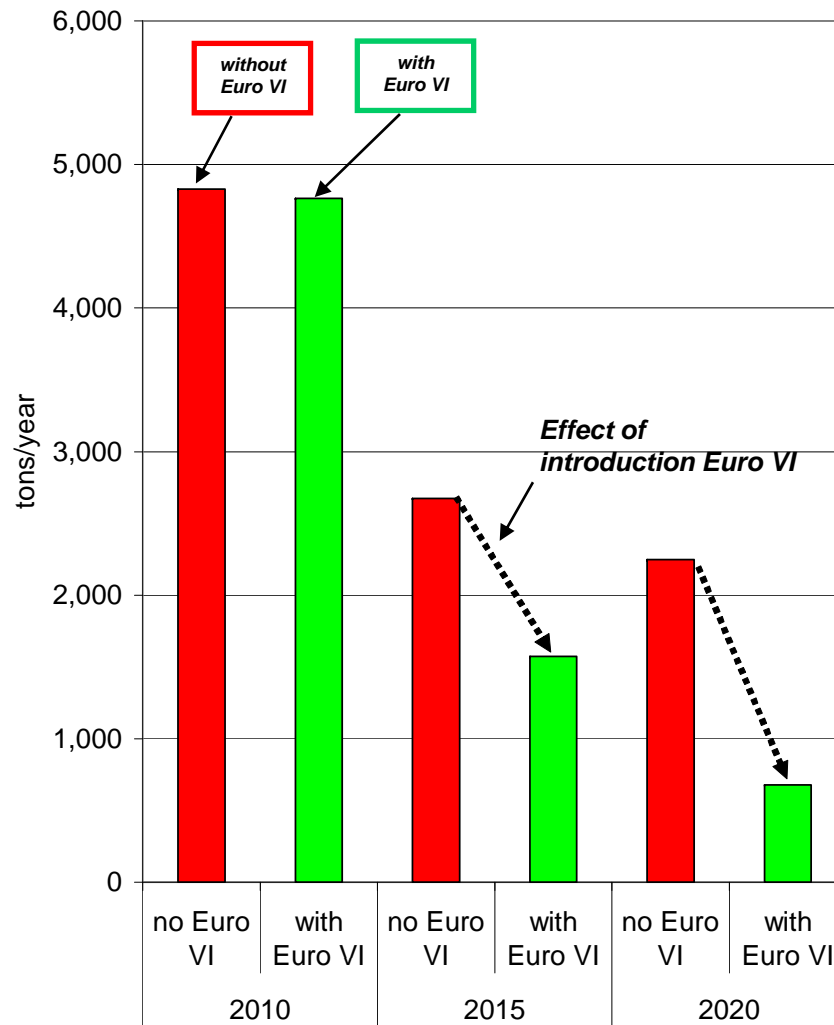
Particulate Matter - Heavy Duty Vehicles



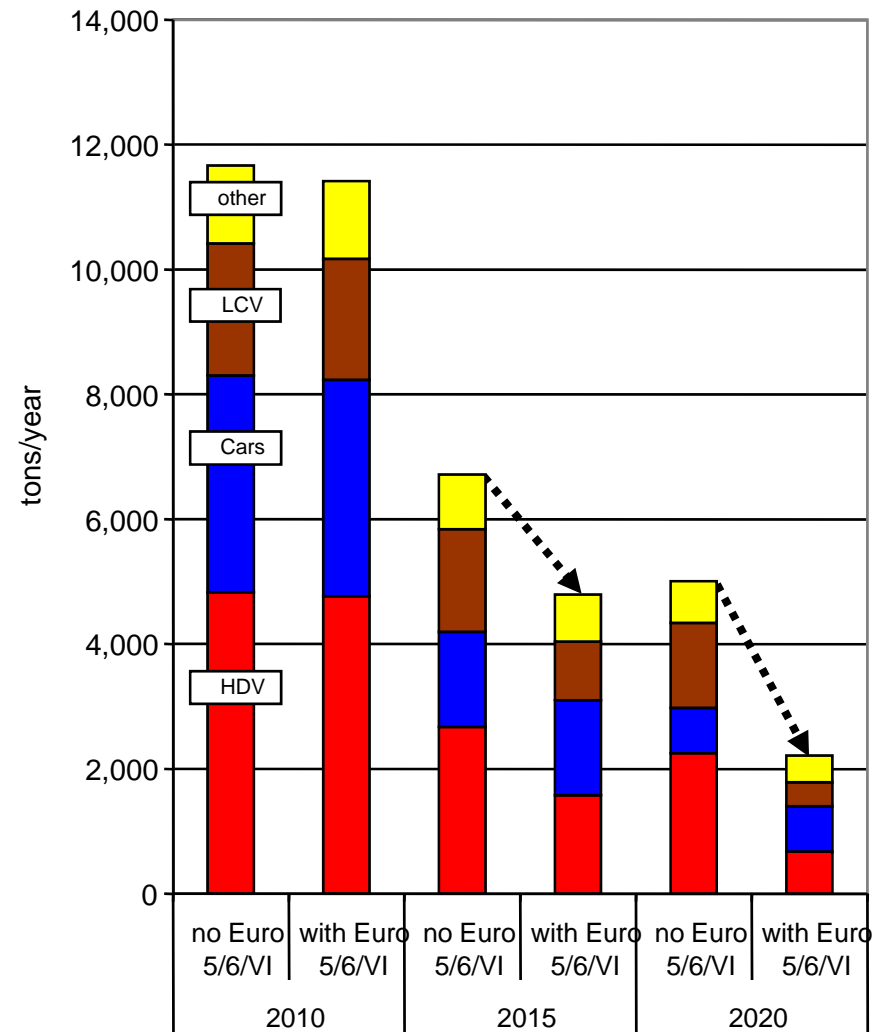
Emission Reduction – Particulate Matter Tailpipe – Germany



Particulate Matter - Heavy Duty Vehicles



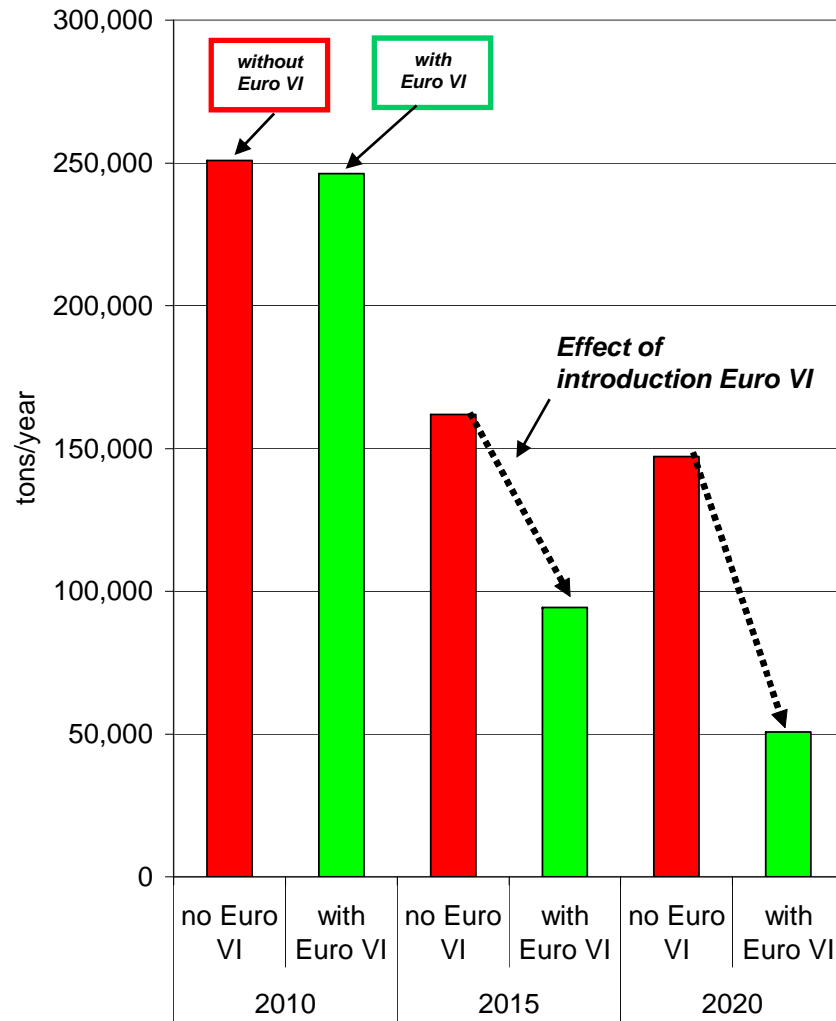
Particulate Matter - all vehicles



Emission Reduction – Nitrogen Oxides – Germany



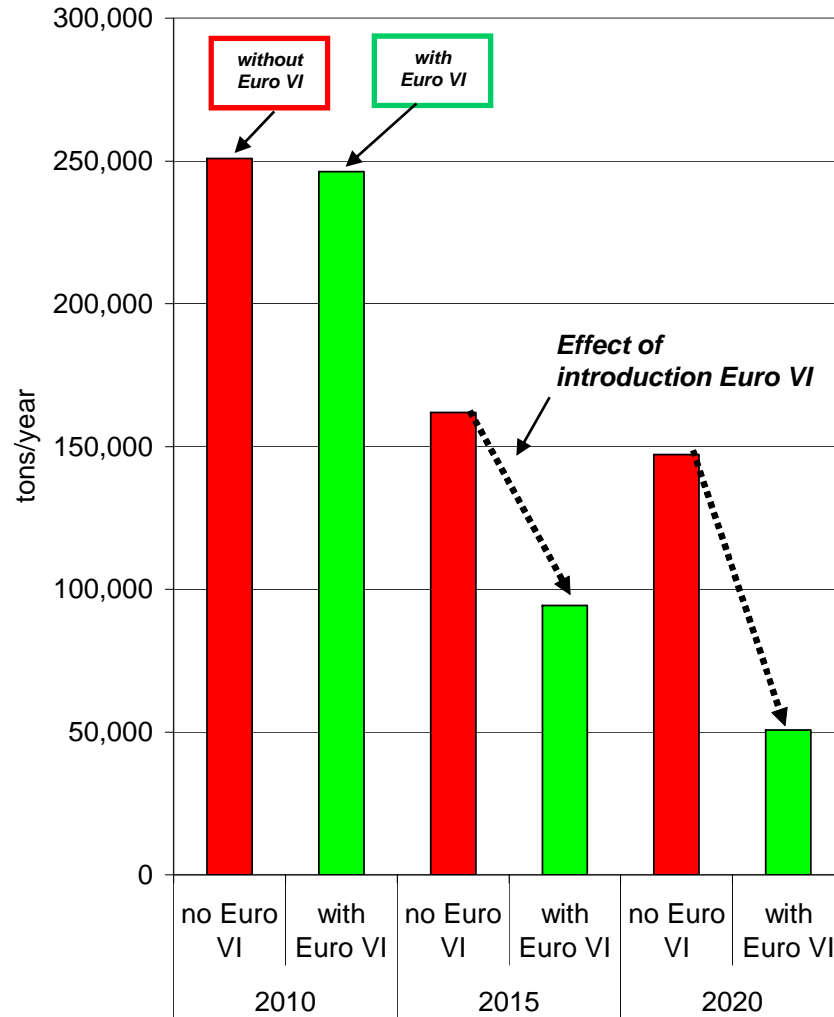
Nitrogen Oxide Emission - Heavy Duty Vehicles



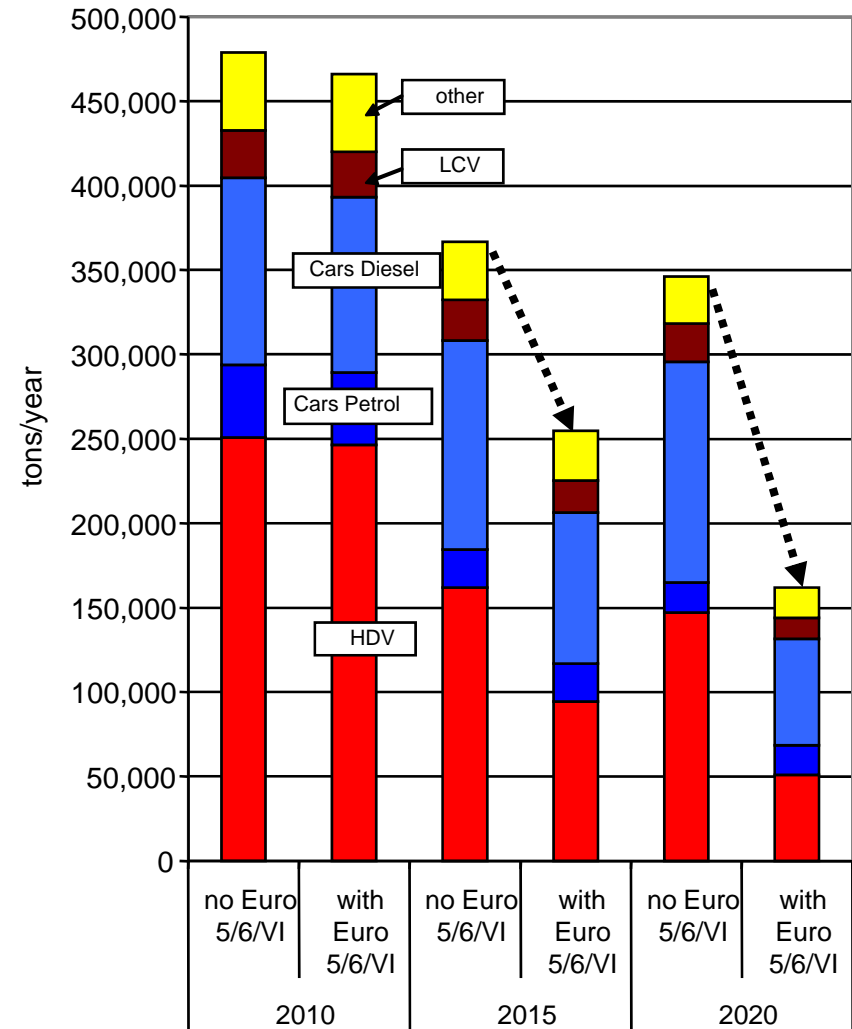
Emission Reduction – Nitrogen Oxides – Germany



Nitrogen Oxide Emission - Heavy Duty Vehicles



Nitrogen Oxide Emission - all vehicles



A) Nationwide Emission of Road Transport in Germany



Conclusions

Heavy Duty Vehicles

- Introduction of Euro VI leads to high reductions of NO_x and Particulates for Heavy Duty Vehicles
- The reduction will be effective if a relevant number of Euro VI-vehicles are used. In Germany high reductions are expected after 2015.
- Emission dependend road toll and the German Innovation Programm (subsidies for cleaner HDV) lead to an earlier introduction for HDV

Road Transport

- Higher Reduction of Particulate than of NO_x - Emissions
- High share of Diesel passenger cars and less reduction in emissions causes the less strong reduction of NO_x-Emissions
- **If assumed emission reductions (orientated on emission standards) will not be achieved, emission reductions will be lower**

B) NO_x and NO₂ emissions in urban areas



Effects of the introduction of new emission standards on NO_x and NO₂ Emissions from Road Vehicles in the years 2005, 2010 and 2015, Outlook 2020

- **Scenarios for the implementation of new emission standards**
 1. **Without** Euro 5/6 (PC/LCV) and Euro VI (HDV).
 2. **Regular implementation** of Euro 5/6/VI as demanded by legislation.
 3. **Early introduction** of Euro 5/6/VI into the vehicle market.

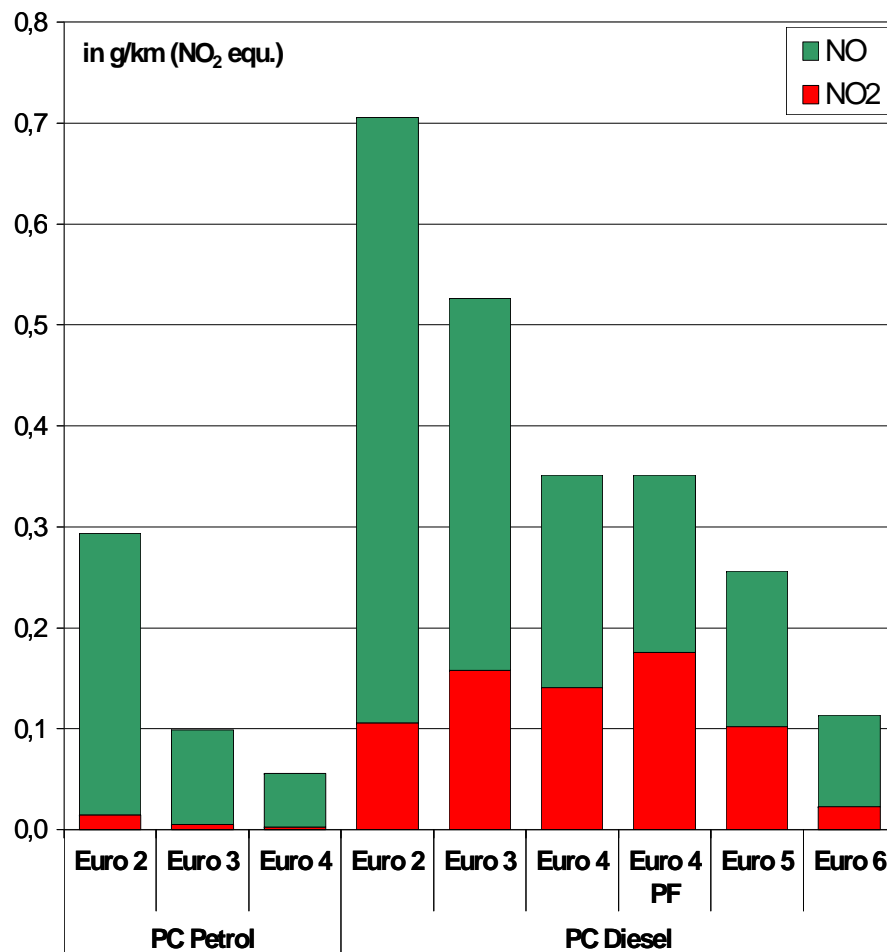
- **Different diesel shares on passenger car mileage**
 - a) Low diesel share (e.g. Switzerland or UK).
 - b) Medium diesel share (e.g. Germany).
 - c) High diesel share (e.g. France).

Source: IFEU Study for AECC - 2007

NO_x and NO₂ Emission Factors in Urban Situations



**NO₂ & NO Emission Factors for Passenger Cars
in Urban Situations**

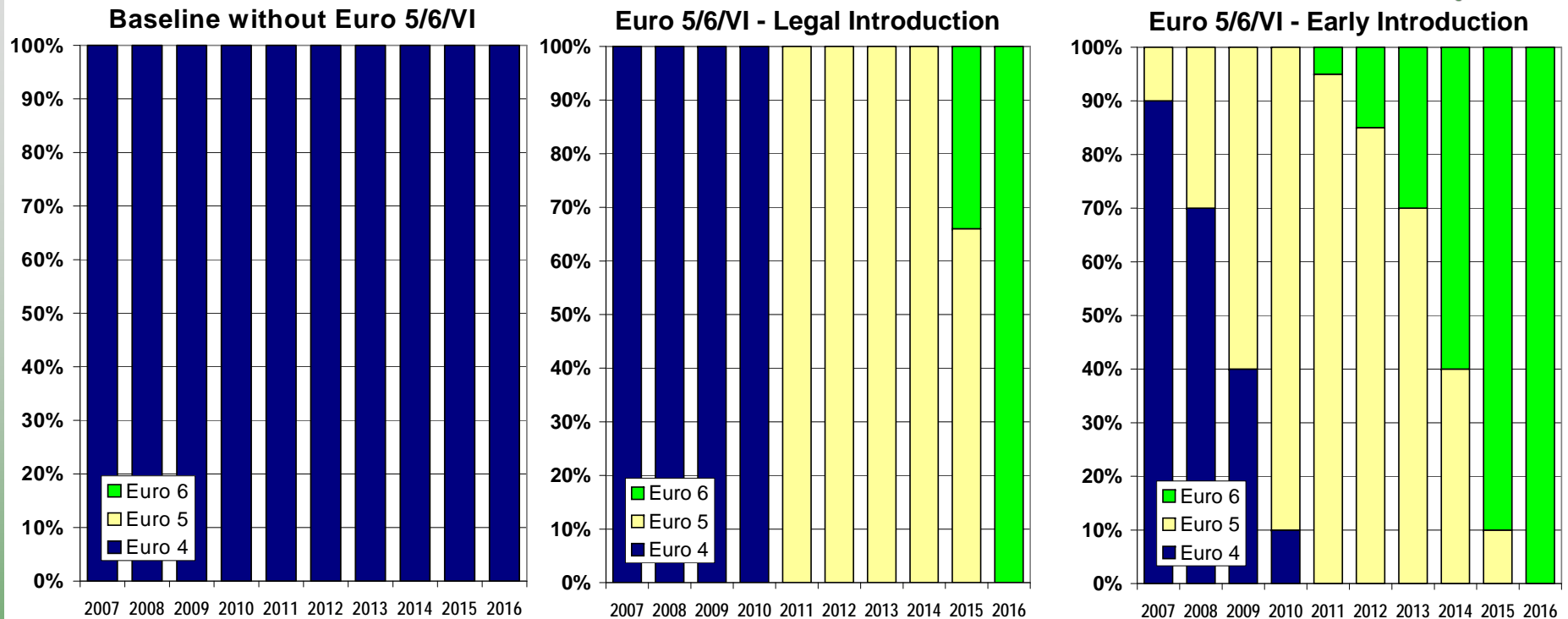


Source: IFEU for UM Baden-Württemberg 2007

NO ₂ /NO _x Ratios								
5%	5%	5%	15%	30%	40%	50%	40%	20%

- Emission factors for NO_x have been derived on the basis of Artemis and other projects and implemented in TREMOD (compatible with handbook)
- Emission factors of NO₂ have been derived on basis of a extensive literature research and additional data from different institutions

Introduction Periods for New Euro Stages of Passenger Cars



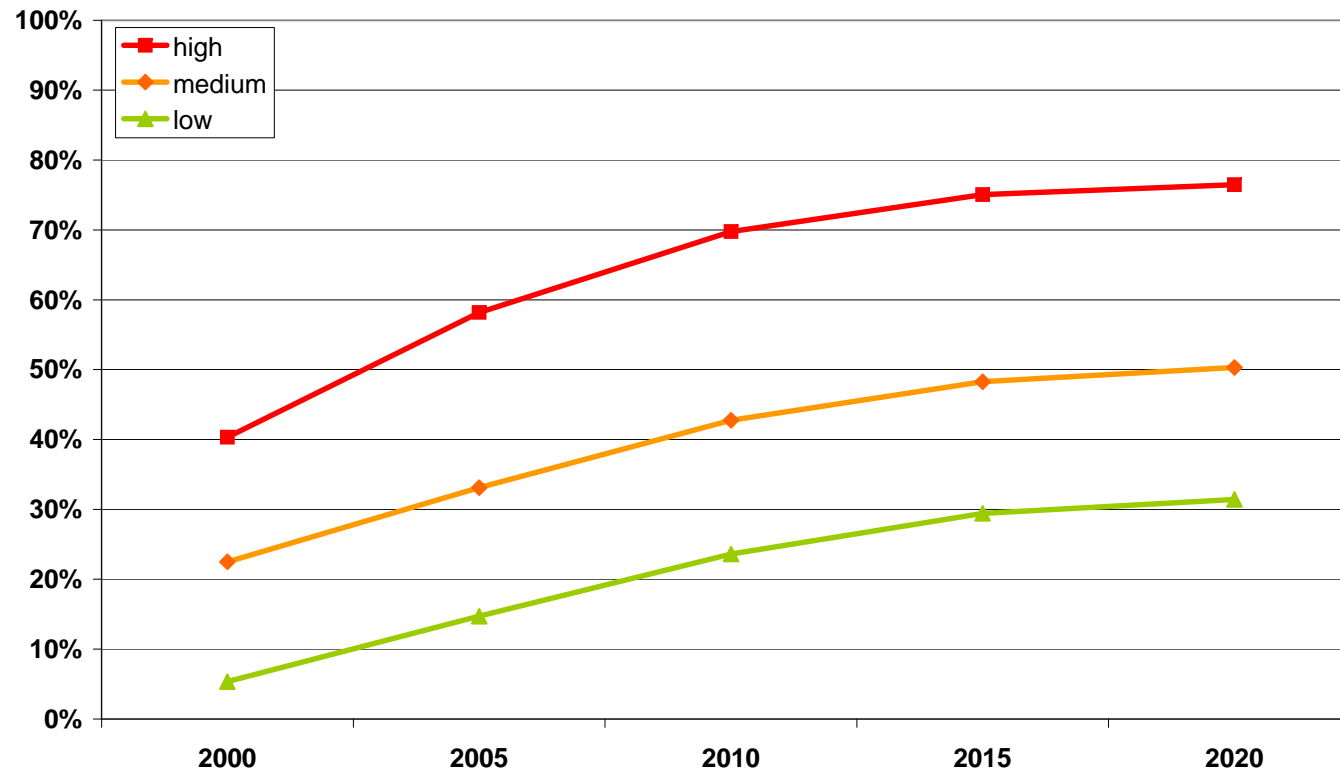
1. **Baseline:** Without new emission standards Euro 5/6/VI
2. **Euro 5/6/VI Regular Implementation:** Introduction of new Euro stages into the vehicle market exactly with the date demanded by legislation.
3. **Euro 5/6/VI Early Introduction:** Phased introduction of new Euro stages starting 3-4 years earlier than demanded by legislation.

Basic Assumptions for the Local Traffic in the Street



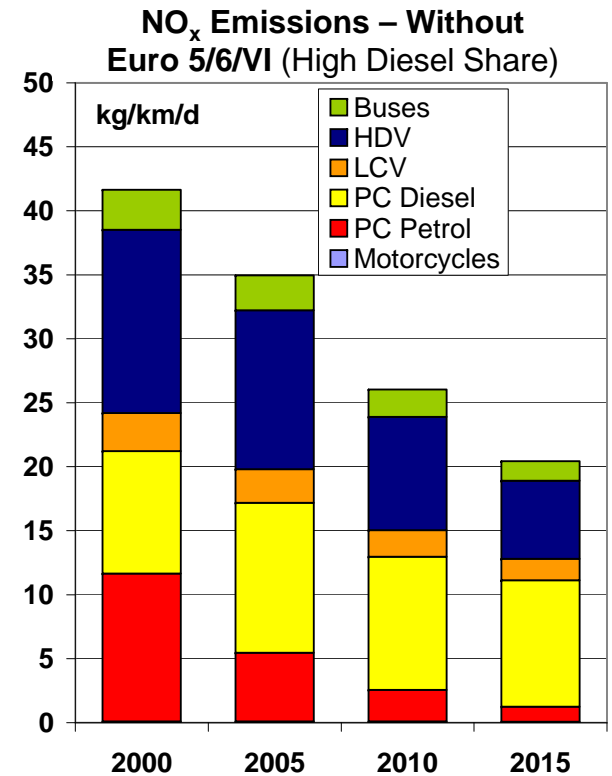
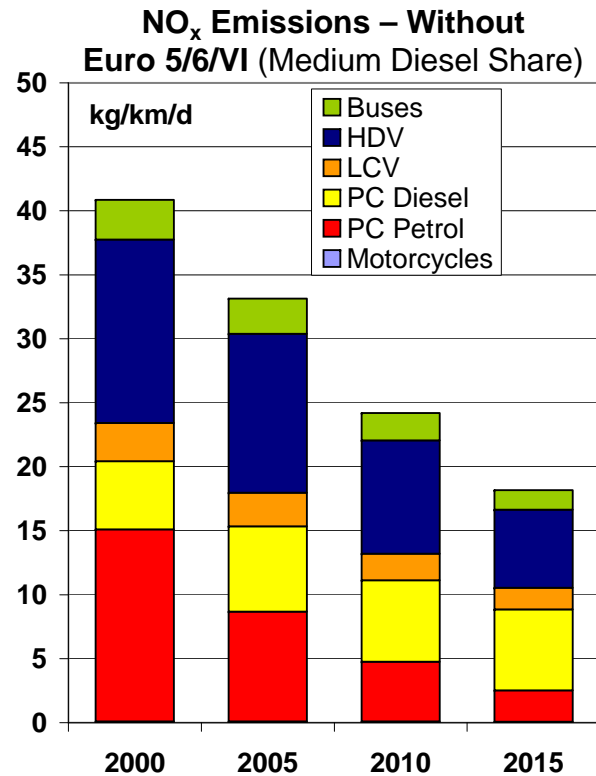
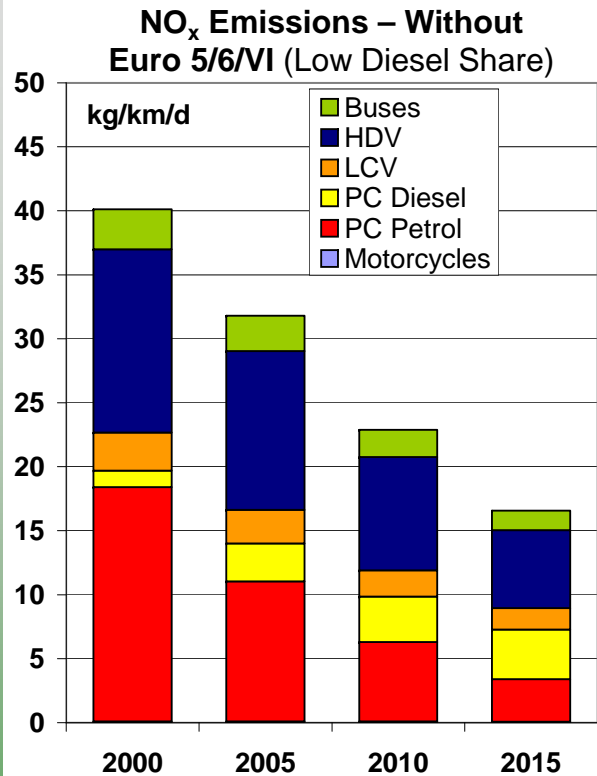
- 40'000 vehicles per day.
- 4.5 percent heavy-duty vehicles (trucks & buses).
- Low, medium and high diesel shares on mileage of passenger cars.

Diesel Share on Passenger Cars Mileage



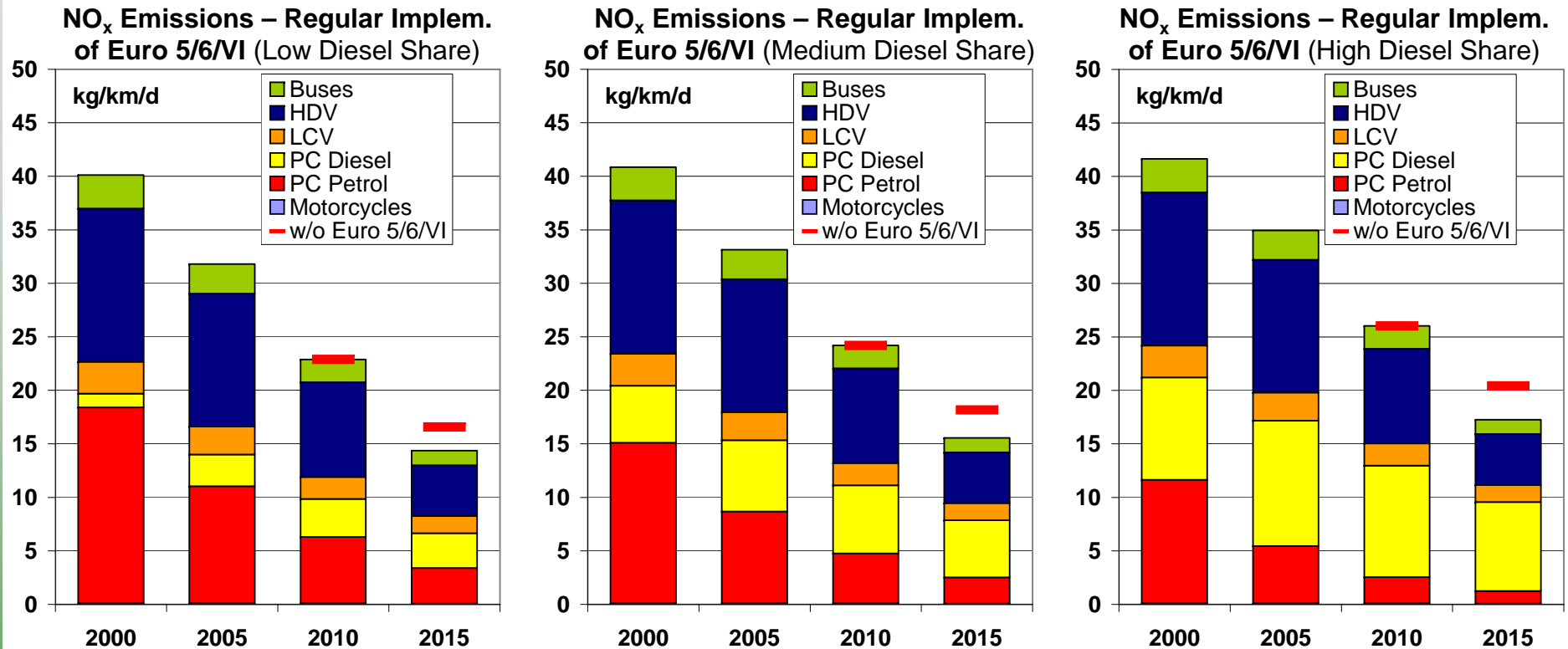
Source: Exemplary data for countries with different diesel share

Future NO_x Emissions – Without Euro 5/6/VI



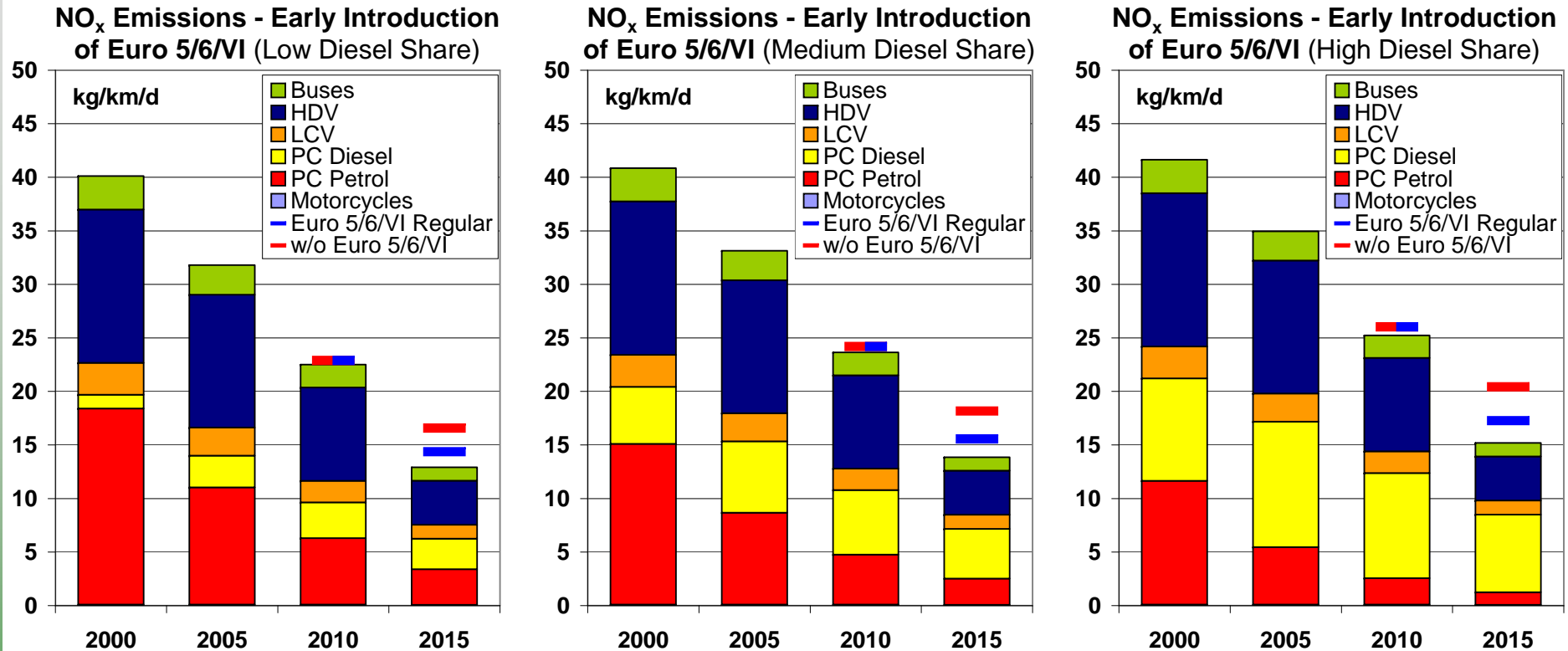
- Future decrease of NO_x emissions in all scenarios.
- Higher diesel share = Higher level of NO_x emissions.

Future NO_x Emissions – Euro 5/6/VI Regular Implementation



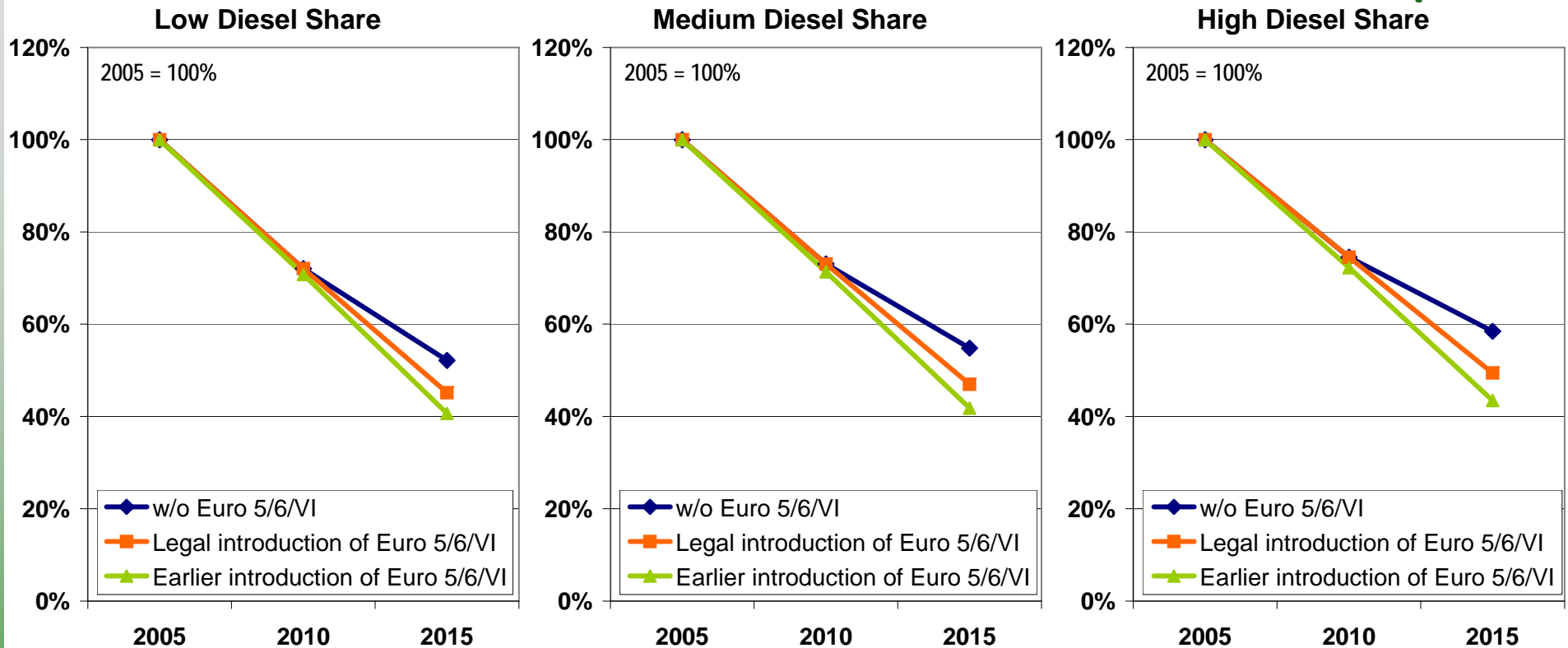
- Future decrease of NO_x emissions in all scenarios.
- Higher diesel share = Higher level of NO_x emissions.
- Regular implementation of Euro 5/6/VI reduces NO_x emissions in 2015 additionally by about 13-15%.

Future NO_x Emissions – Euro 5/6/VI Early Introduction



- Future decrease of NO_x emissions in all scenarios.
- Higher diesel share = Higher level of NO_x emissions.
- Regular implementation of Euro 5/6/VI reduces NO_x emissions in 2015 additionally by about 13-15%.
- Early introduction increases additional NO_x reduction in 2015 to 22-26%.

Future NO_x Emissions compared to 2005



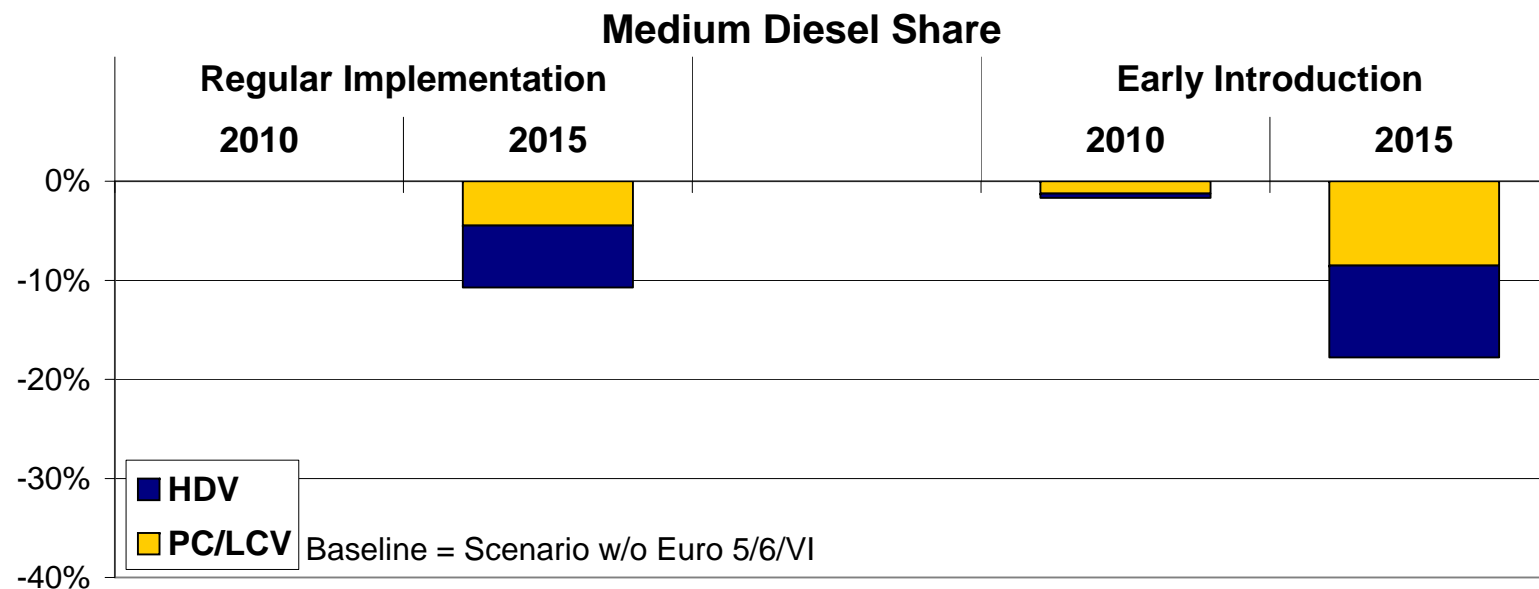
- *Without Euro 5/6/VI:* Reduction of NO_x emissions 2005-2015 ca. 42-48%.
- *Regular implementation of Euro 5/6/VI:* Increase of NO_x emission reduction 2005-2015 to 50-55%.
- *Early introduction of Euro 5/6/VI:* NO_x emission reduction 2005-2015 increased to 57-59%.

Contribution of PC/LCV and HDV to Emission Reduction

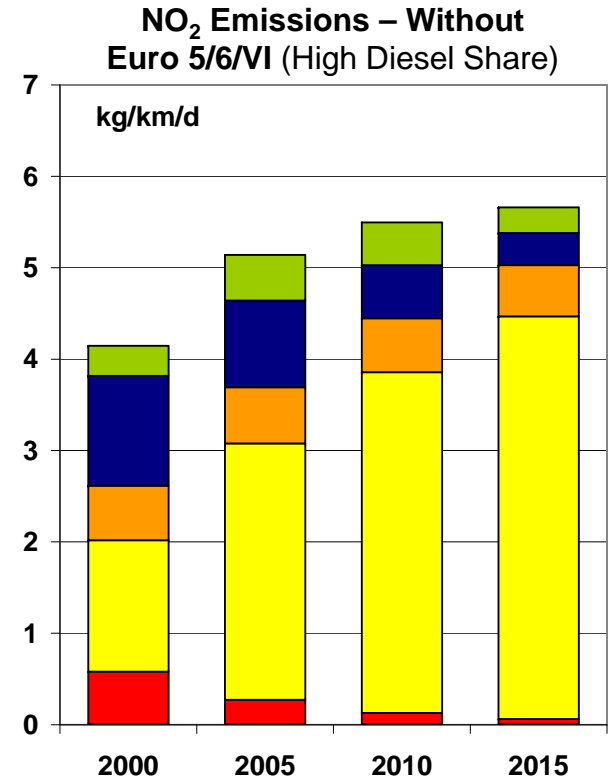
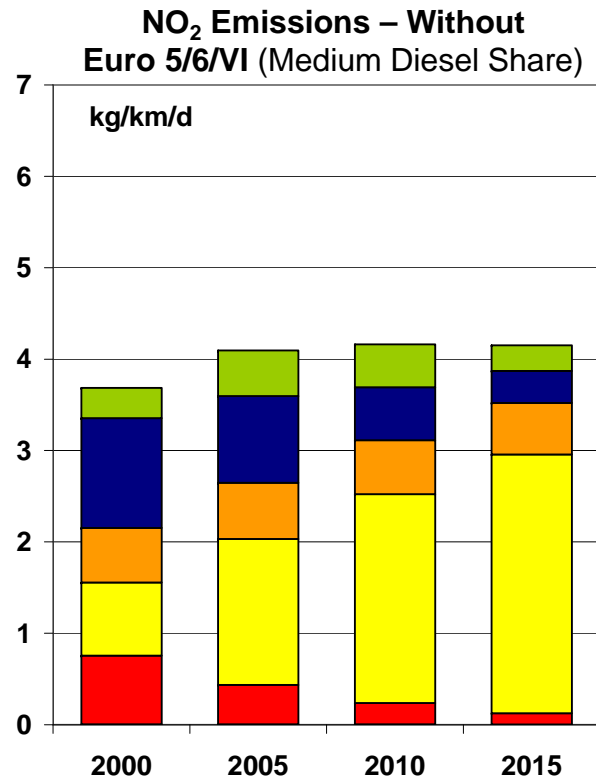
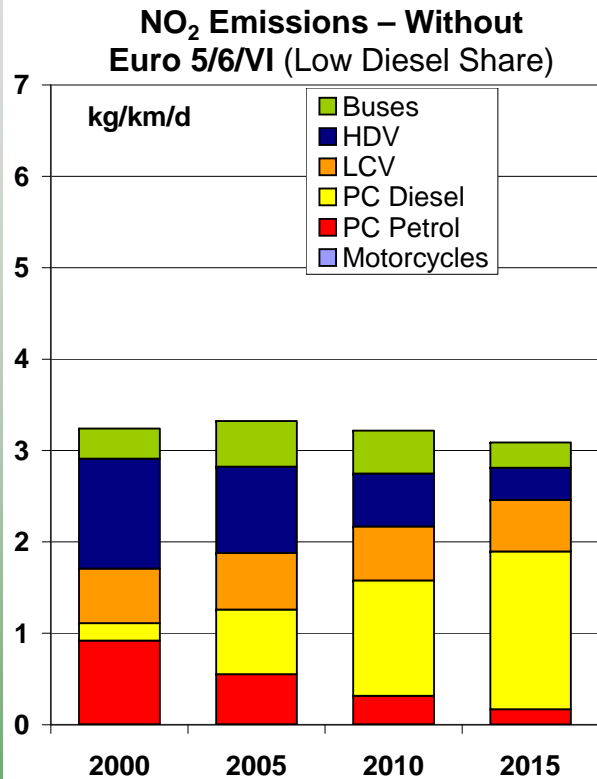


NO_x Emission Reduction

compared to Scenario without Euro 5/6/VI

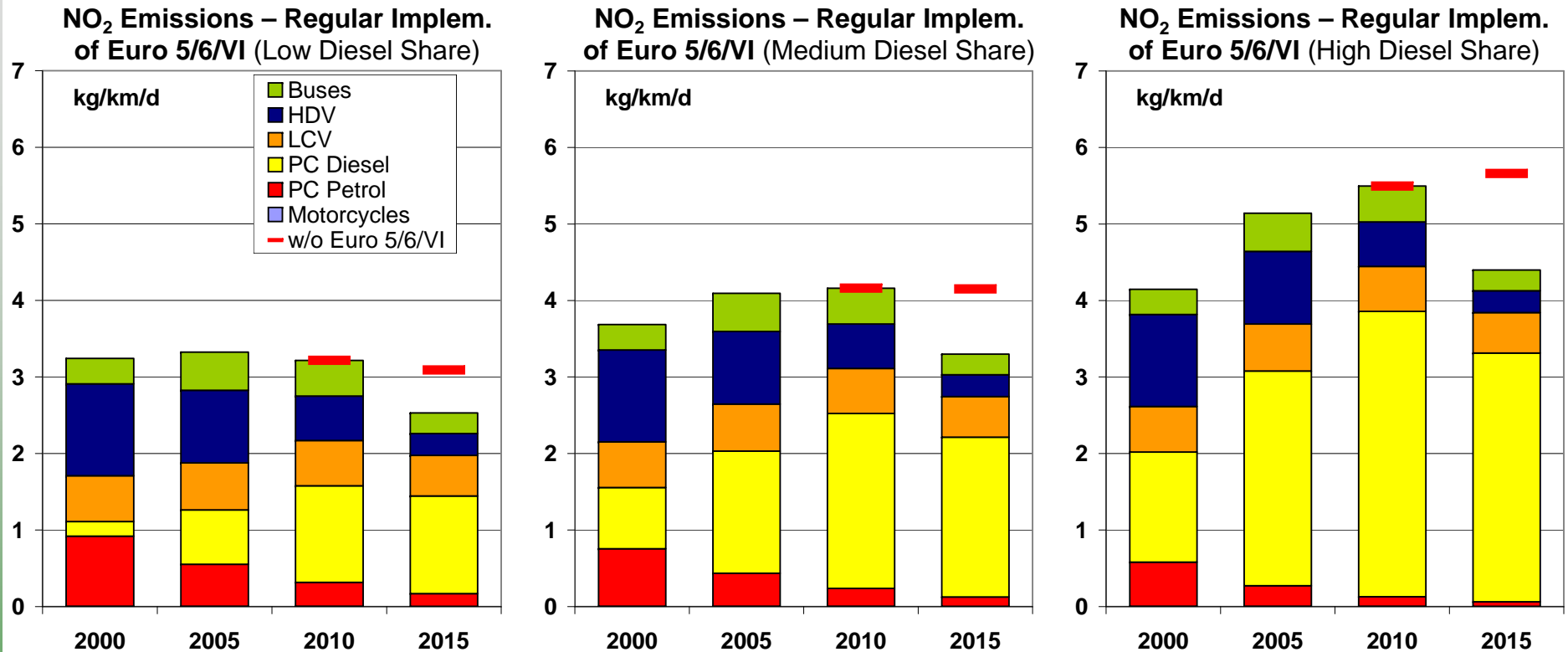


Future NO₂ Emissions – Without Euro 5/6/VI



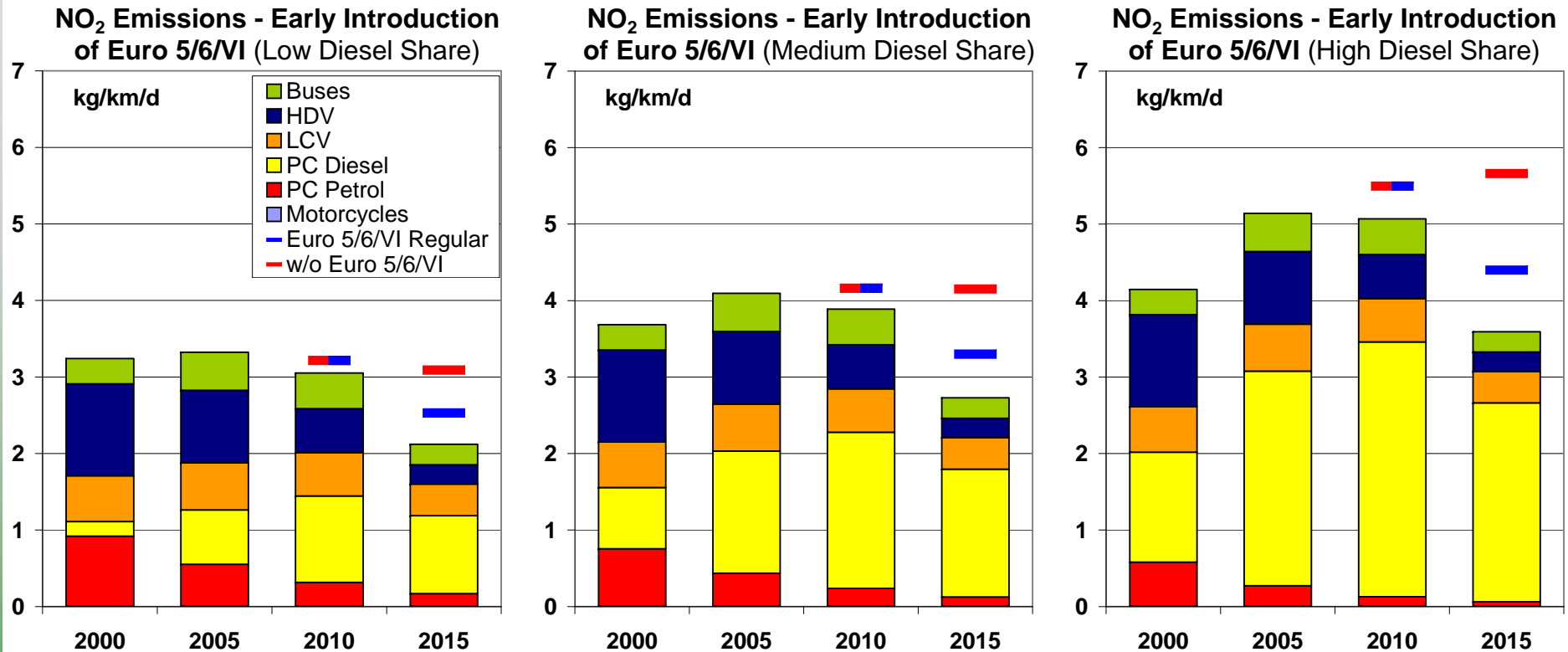
- Low diesel share: Slight decrease of total NO₂ emissions until 2015.
- Higher diesel share: Future increase of NO₂ emissions.

Future NO₂ Emissions – Euro 5/6/VI Regular Implementation



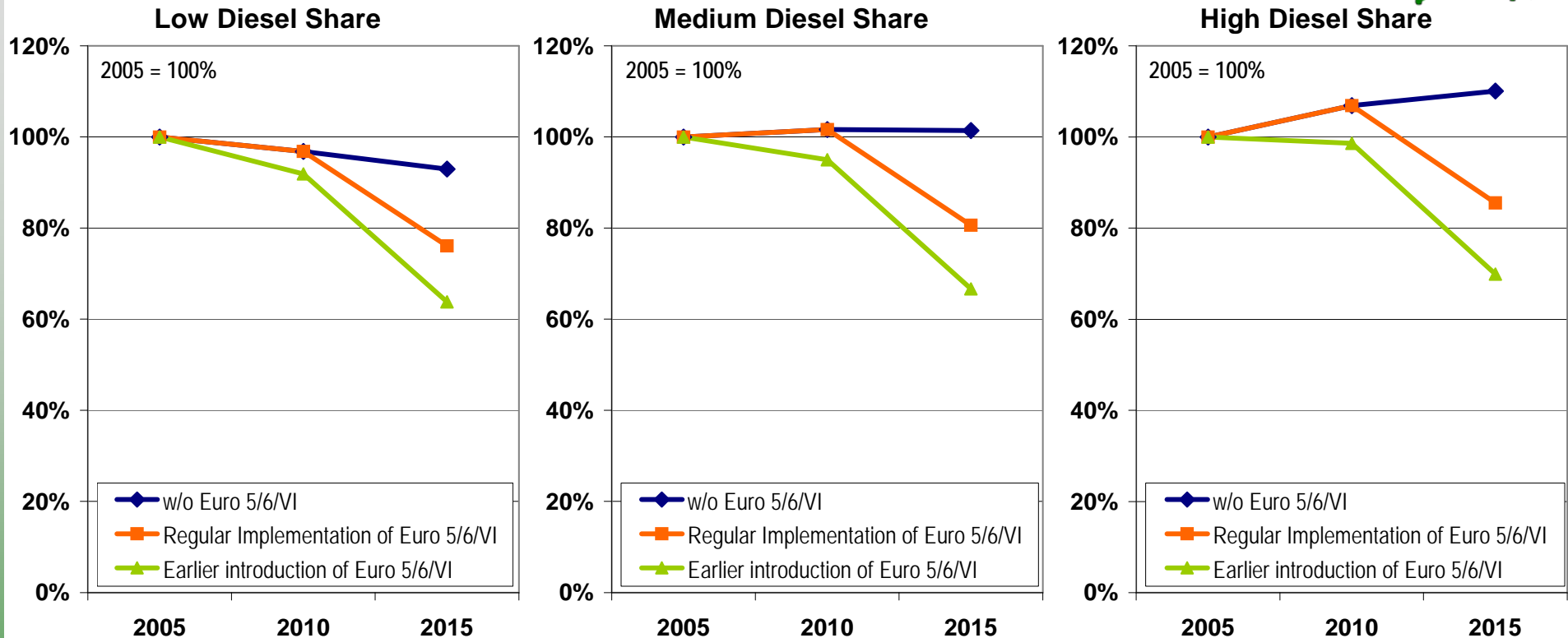
- Low diesel share: Slight decrease of total NO₂ emissions until 2015.
- Higher diesel share: Future increase of NO₂ emissions.
- Regular Implementation of Euro 5/6/VI: NO₂ emission reduction after 2010.

Future NO₂ Emissions – Euro 5/6/VI Early Introduction



- Low diesel share: Slight decrease of total NO₂ emissions until 2015.
- Higher diesel share: Future increase of NO₂ emissions.
- Regular Implementation of Euro 5/6/VI: NO₂ emission reduction after 2010.
- Early introduction: Slight NO₂ emission reduction already in 2010.

Future NO₂ Emissions compared to 2005

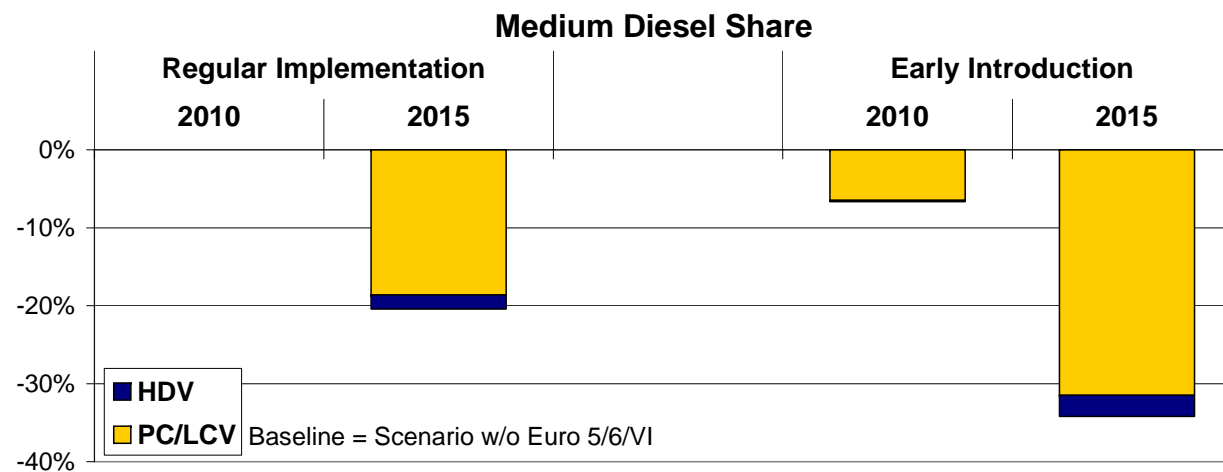


- *Without Euro 5/6/VI:* Small NO₂ emission reduction 2005-2015 in scenario with low diesel share. However, NO₂ increase in case of higher diesel share.
- *Regular implementation of Euro 5/6/VI:* No effect on NO₂ emissions in 2010. NO₂ emission reduction 2005-2015 of 14-24%.
- *Early introduction of Euro 5/6/VI:* NO₂ emission reduction 2005-2010 of 0-8% and 2005-2015 of 30-36%.

Contribution of PC/LCV and HDV to Emission Reduction



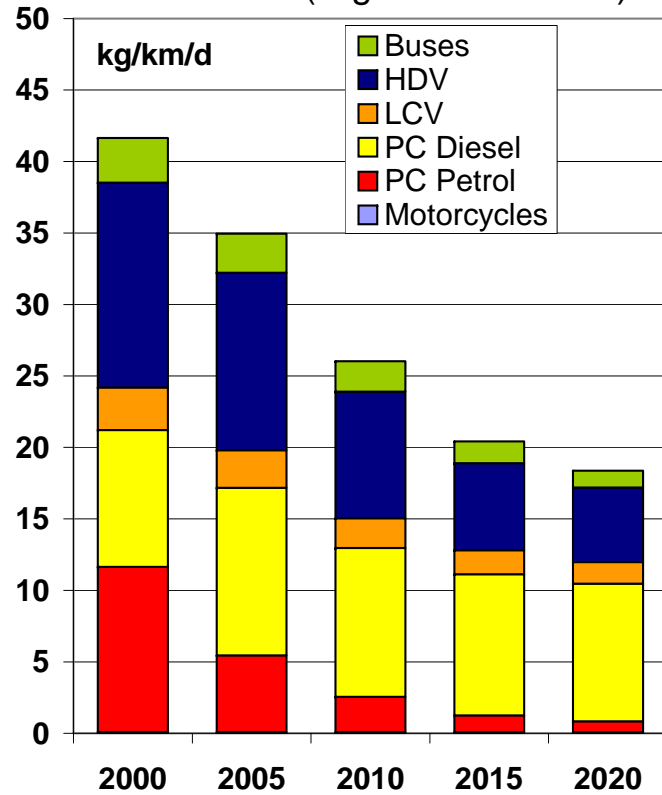
NO₂ Emission Reduction compared to Scenario without Euro 5/6/VI



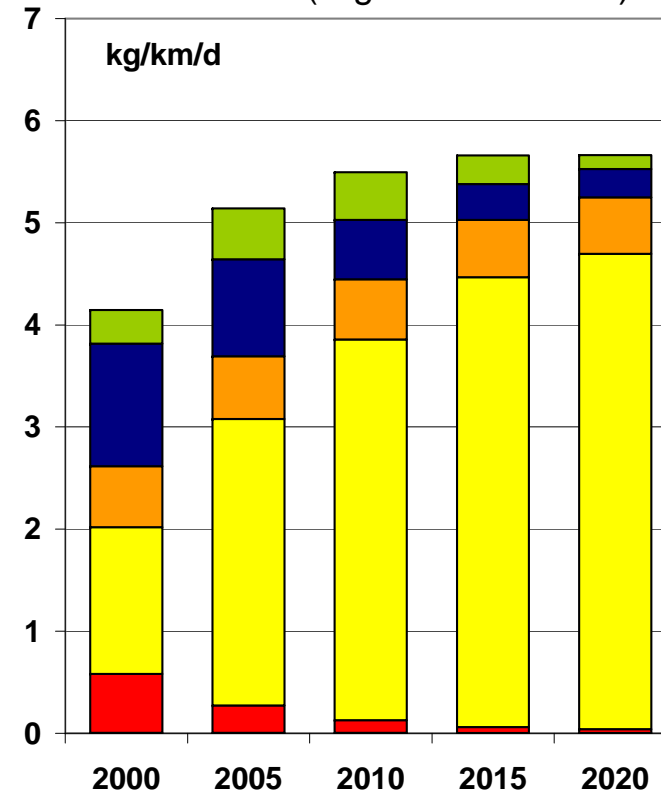
Outlook 2020



NO_x Emissions – Without Euro 5/6/VI (High Diesel Share)



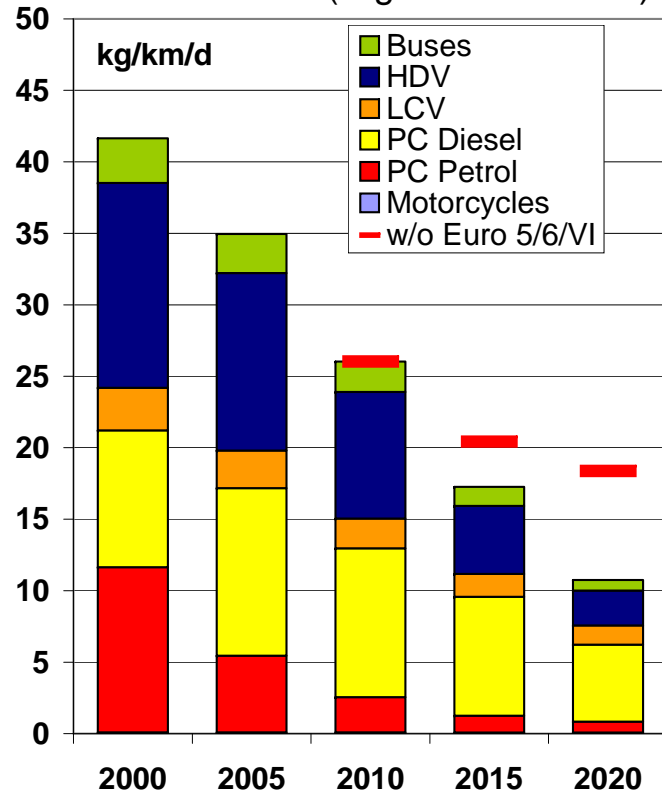
NO₂ Emissions – Without Euro 5/6/VI (High Diesel Share)



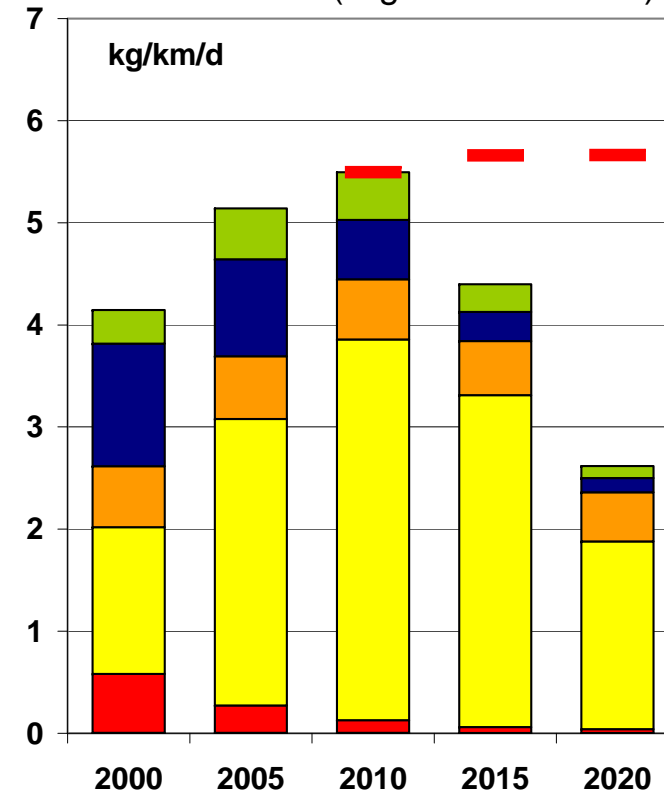
Outlook 2020



NO_x Emissions – Regular Implementation of Euro 5/6/VI (High Diesel Share)



NO₂ Emissions – Regular Implementation of Euro 5/6/VI (High Diesel Share)

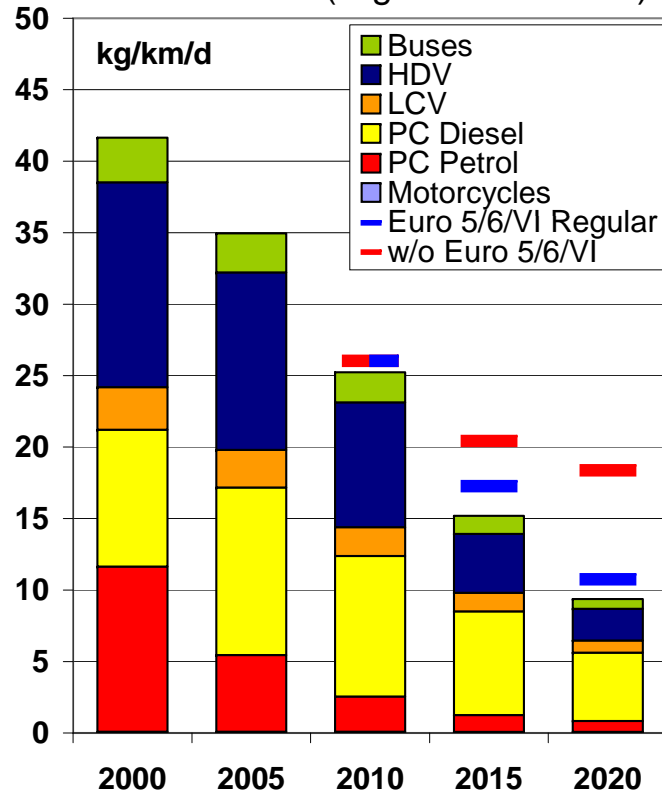


- Further decrease of NO_x and NO₂ emissions after 2015 in scenarios with Euro 5/6/VI.
- Low reliability of calculated NO₂ emissions for 2020 due to uncertainties regarding applied emission reduction technologies for PC/LCV Euro 6.

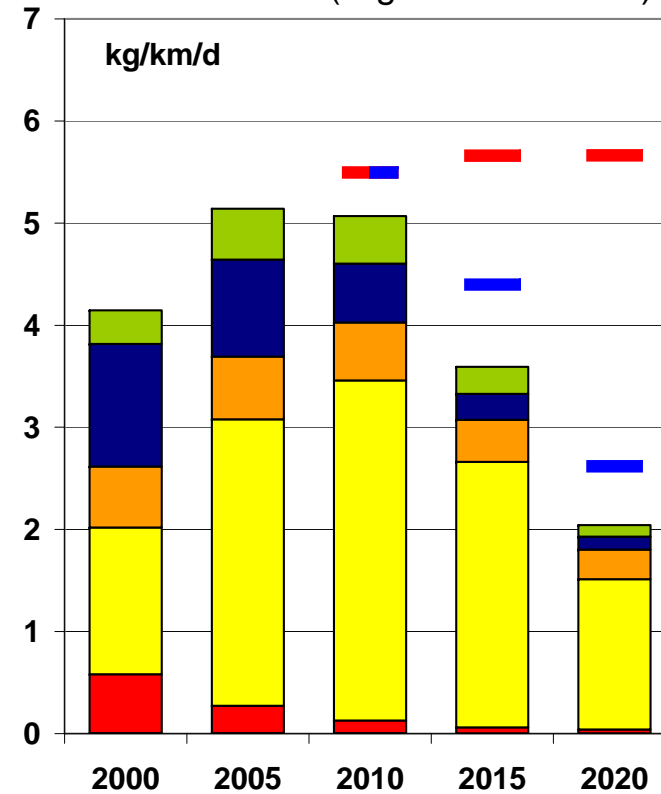
Outlook 2020



NO_x Emissions – Early Introduction of Euro 5/6/VI (High Diesel Share)



NO₂ Emissions – Early Introduction of Euro 5/6/VI (High Diesel Share)



- Further decrease of NO_x and NO₂ emissions after 2015 in scenarios with Euro 5/6/VI.
- Low reliability of calculated NO₂ emissions for 2020 due to uncertainties regarding applied emission reduction technologies for PC/LCV Euro 6.

Conclusions



- Decrease of NO_x emissions in all scenarios between 2005 and 2015, similar contribution from HDV and from PC/LCV.
- Strong increase of NO₂ emissions from Diesel PC leads to increase or only low reduction of NO₂ emissions from urban traffic until 2010.
- After 2010 decrease of NO₂ emissions of Diesel PC only with implementation of Euro 5/6. Early introduction of these Euro stages increases NO₂ emission reduction.
- ➔ Reduction of NO₂ emissions from urban traffic only with reduction of NO₂ emissions from passenger cars by implementing Euro 5/6.
- ➔ Early introduction of Euro 5/6/VI would help to comply with European NO₂ air quality limits.
- ➔ ⚡ If assumed emission reductions (orientated on emission standards) will not be achieved, emission reductions will be lower

Thank you for your attention

For further information, please contact:

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