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An Analysis of Future Urban Air Quality Compliance - Real Driving Emissions and ZEV Scenarios and their importance in designing cost effective responses to non-compliance

Presentation to FAIRMODE IAM Workshop on
Local Measures to Improve Air Quality and Health
Tallinn, 29 June 2018

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Contents

Introduction

Part 1

- The Urban Air Quality (UAQ) Extension Study builds on previous Concawe commissioned UAQ work*
- The five UAQ Extension study scenarios were informed by using actual Euro6 performance data provided by Ricardo – this presentation shows two scenarios
- Base case used was TSAP16 WPE2014 inputs, emissions and projections
- Full reports provide a comprehensive study write-up with EU-wide analysis.
- Extension Study includes case studies for 10 European cities:

  Antwerp, Berlin, Bratislava, Brussels, London,
  Madrid, Munich, Paris, Vienna, Warsaw

- This presentation will show compliance results for Munich and Paris and population exposure results for Munich.

Supporting Material

Part 2

- In addition, in the context of Urban IAM, a relevant hotspot analysis will be shown and a perspective on cost effectiveness is offered with some observations made on sources of uncertainty

(see Sources and Documentation slide for links)*

Comparison of Two Selected Scenarios from UAQ Extension Study

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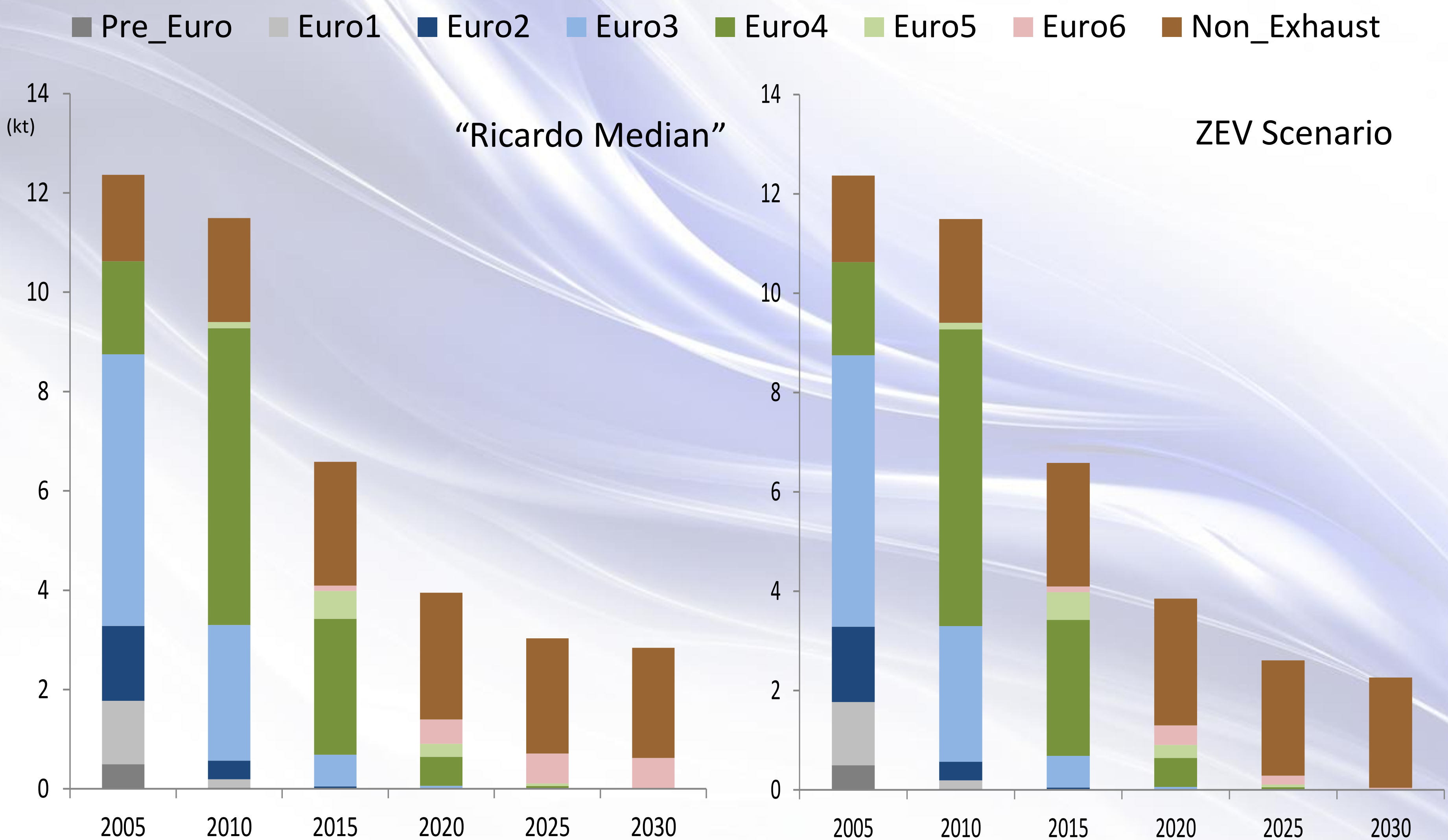
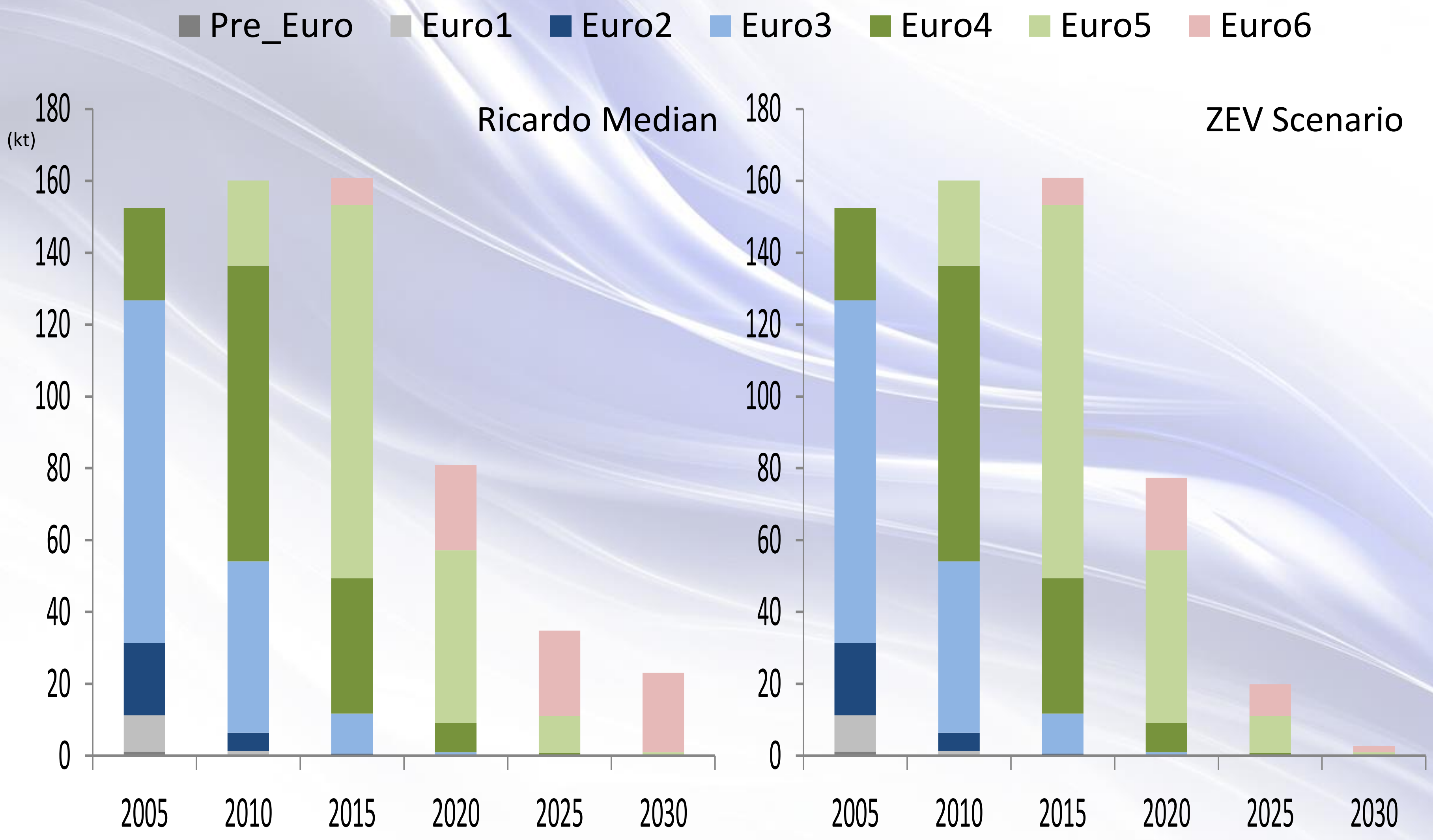
- **Scenario 1 - Ricardo Median**:
  - Assumes the median of the Ricardo Euro6 RDE data
- **Scenario 2 - ZEV Scenario**:
  - All Diesel PC registered after 2020 are replaced with zero exhaust emission vehicles undertaking the same activity

PM$_{2.5}$ Emissions by Scenario – Germany PCD Ricardo Median and ZEV post 2020



Note: Due to DPF, beyond 2020, non-exhaust emissions dominate transport PM emissions

NO_X Emissions by Scenario – Germany PCD Ricardo Median and ZEV post 2020



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Results: NO_2 Compliance

What is the impact of these emissions on ambient air quality limit compliance?

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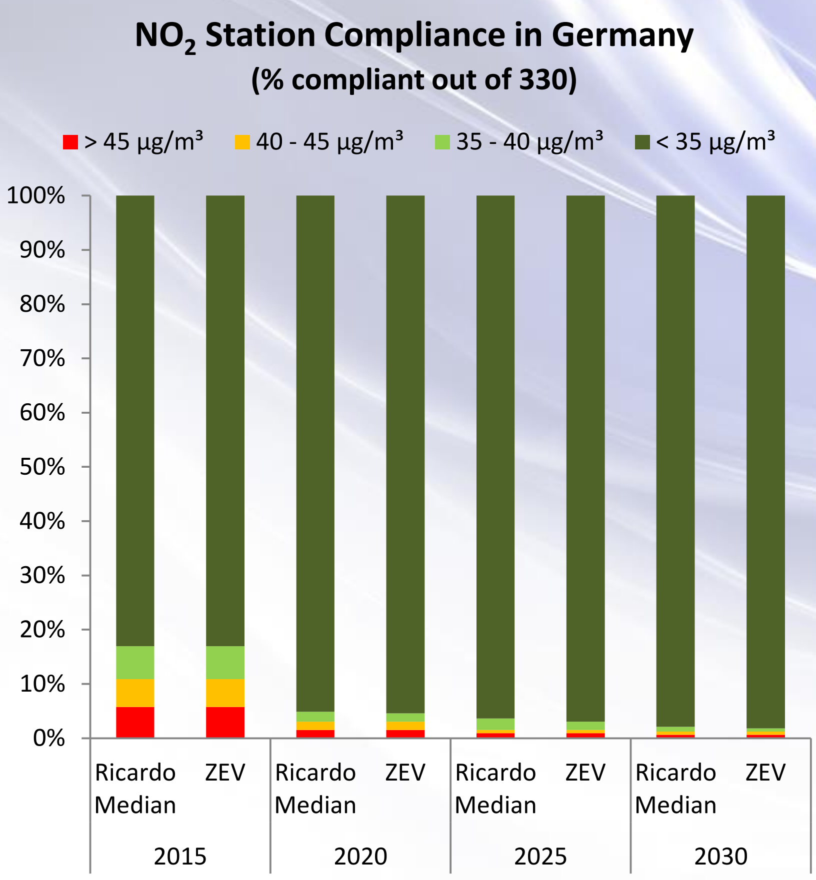
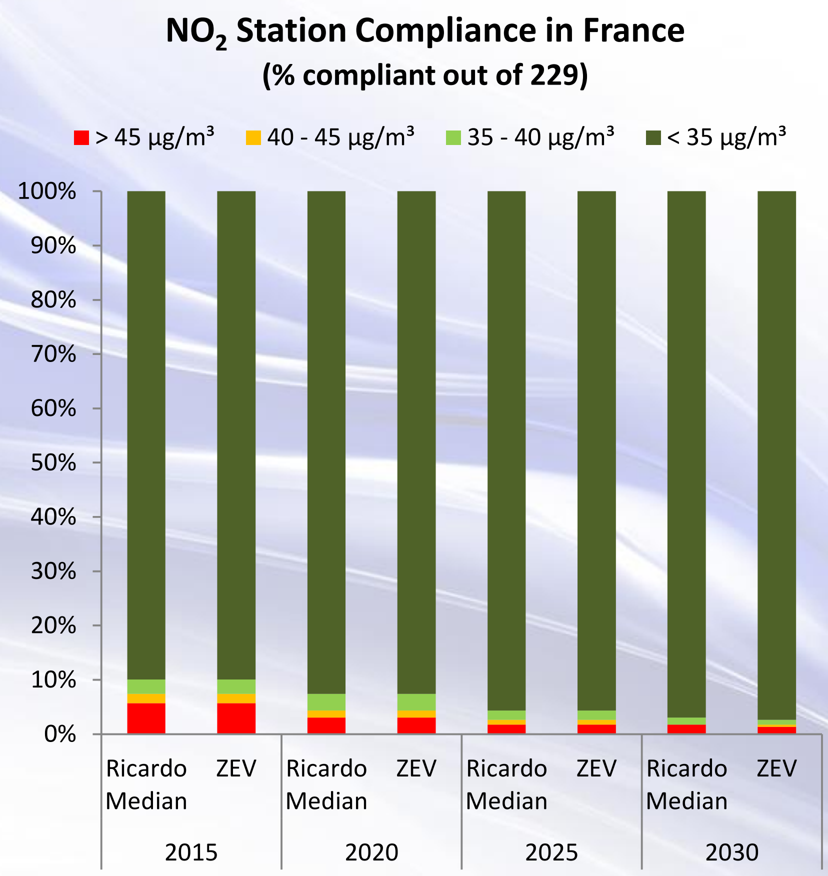
NO_2 station compliance in Germany and France: Ricardo Median and ZEV scenarios



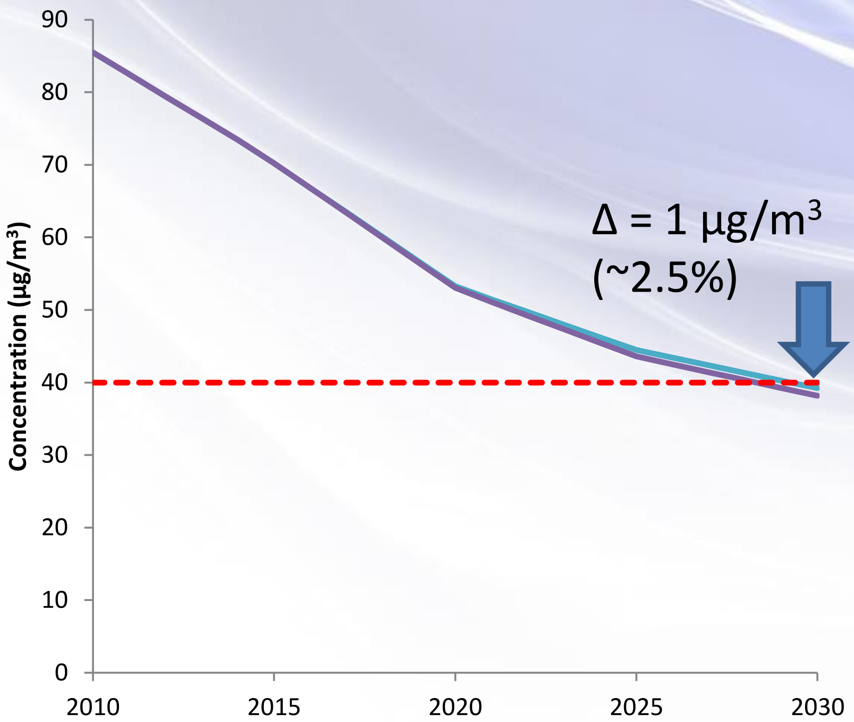


Negligible Air Quality Benefit of ZEV Scenario over Euro6d

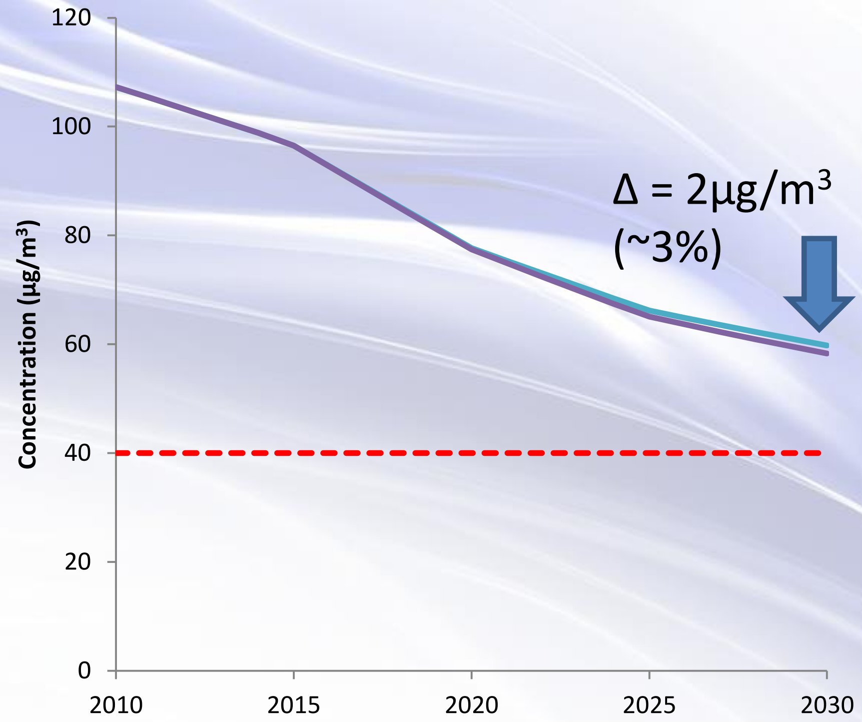
Key finding: Highest NO_2 measuring stations show near to zero response beyond Ricardo Median Scenario

Ricardo Median — ZEV Scenario — AQLV

Munich - Highest AQ Station



Paris - Highest AQ Station

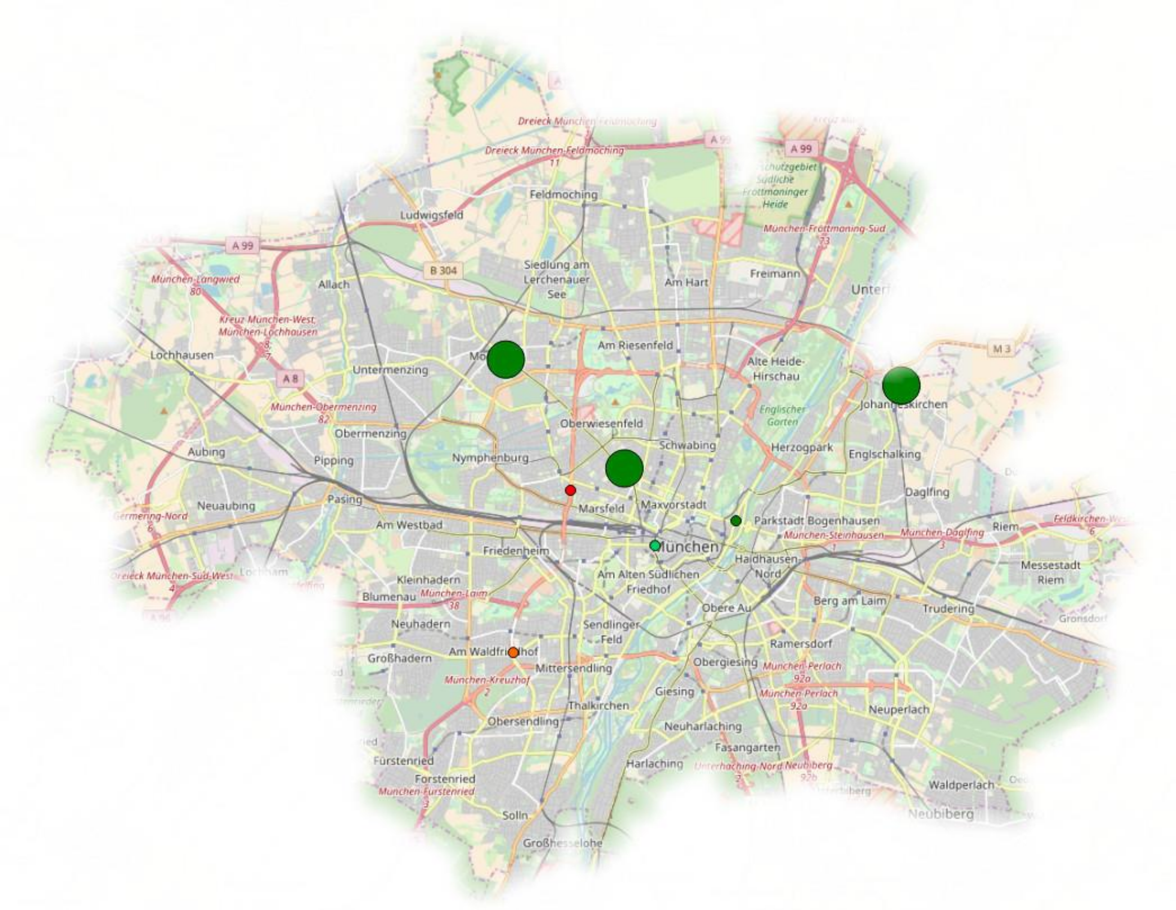


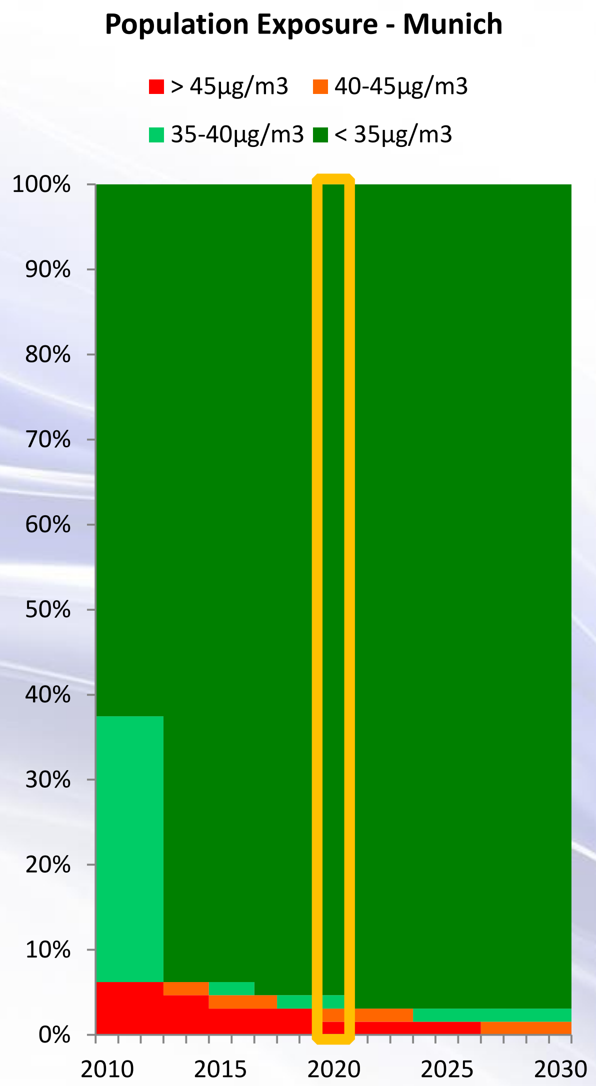
Results: Population Exposure

What is the relationship between compliance and population exposure?

Population Exposure (NO_2) EEA Methodology*

Munich 2020 (base case)





*"Exceedance of air quality standards in urban areas", EEA 20 October 2017
https://www.eea.europa.eu/data-and-maps/indicators/exceedance-of-air-quality-limit-3

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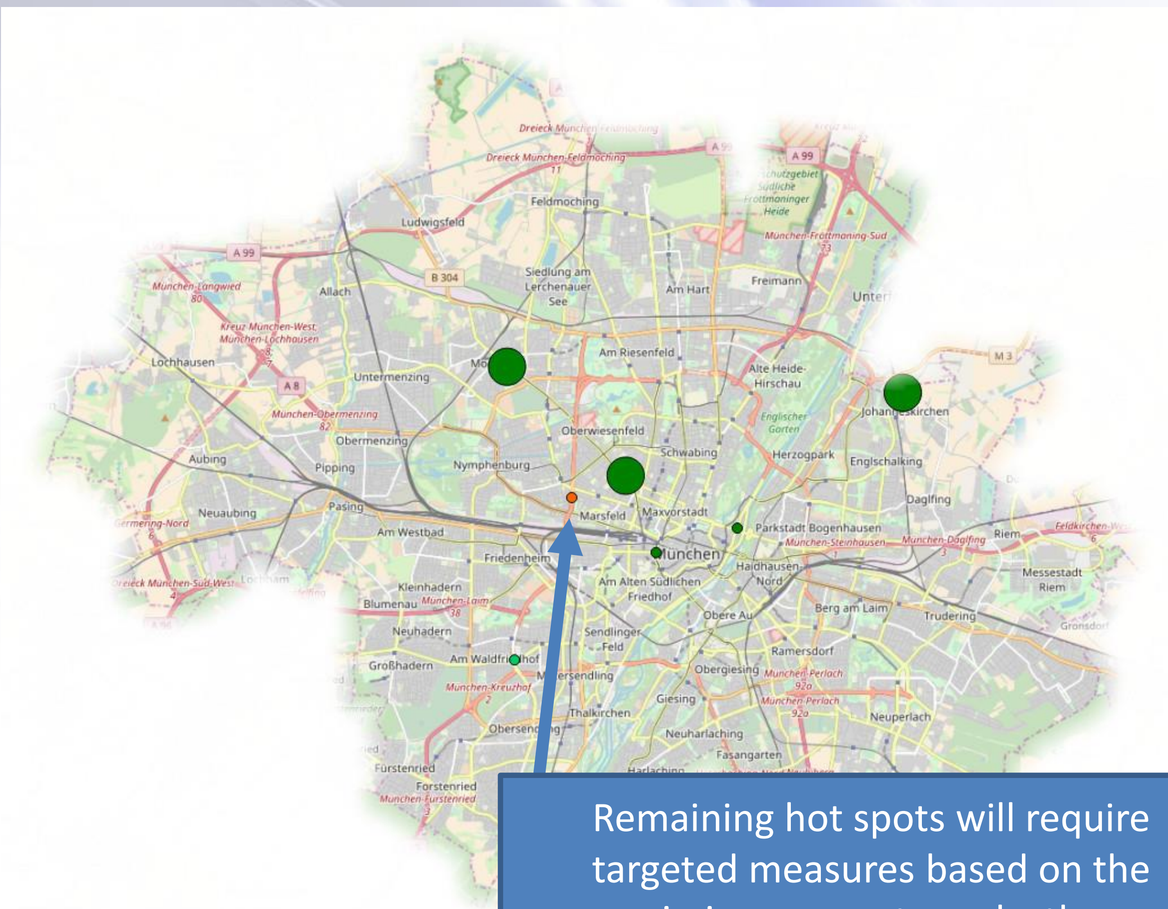
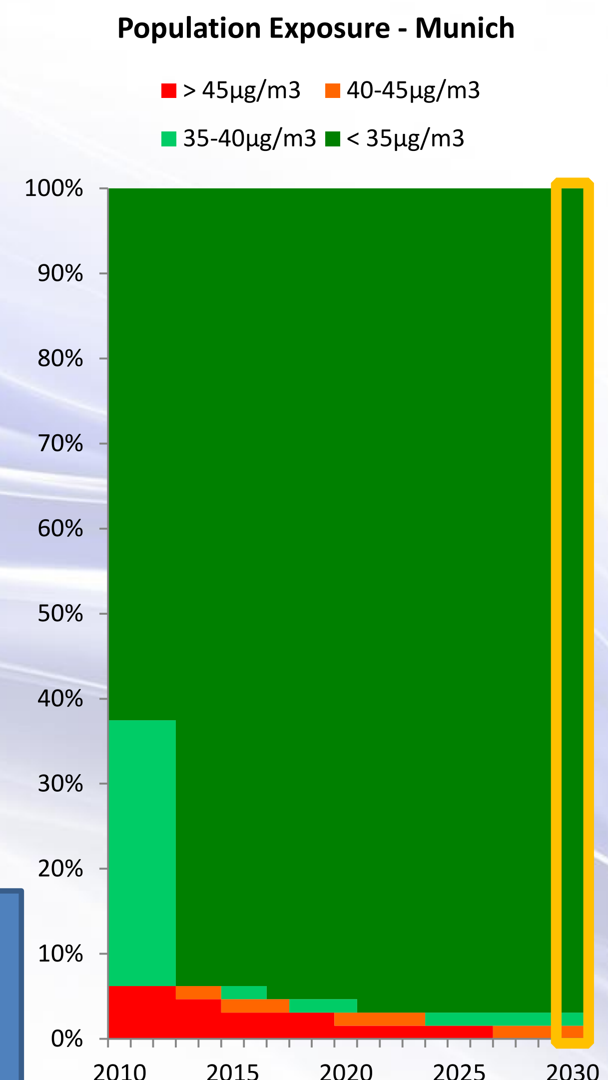
Population Exposure (NO_2) EEA Methodology

Munich 2030 (base case)



Remaining hot spots will require targeted measures based on the emission source to make them compliant



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UAQ Extension Study Key Findings

- In the natural turnover of the vehicle fleet, the significantly reduced NO_X emissions from correctly performing Euro 6d diesel passenger cars will be as effective as zero emission vehicles in helping cities become compliant with air quality standards.
- For NO_2, PM2.5 and PM10, no appreciable effect on air quality compliance or population exposure is observed between any of the modelled diesel passenger car scenarios or their replacement with equivalent zero emission vehicles.
- NO_2 compliance issues in traffic "hot-spots" persist until 2030 in a number of European cities under all modelled scenarios. It is unlikely that measures targeting new diesel cars will address this issue.
- In the case of particulates, modern passenger car emissions are largely independent of the drive-train given that mechanical abrasion (brake, road and tyre wear) is the most significant source.
- It is important to identify the actual emission sources contributing to each unique area of non-compliance to effectively address outstanding issues, for example, domestic heating or urban power generation in addition to road transport and other sources.

Part 2

Some Considerations for Urban Air Quality Integrated Assessment Modelling

Targeting Hotspot Measures

London traffic:
source apportionment example

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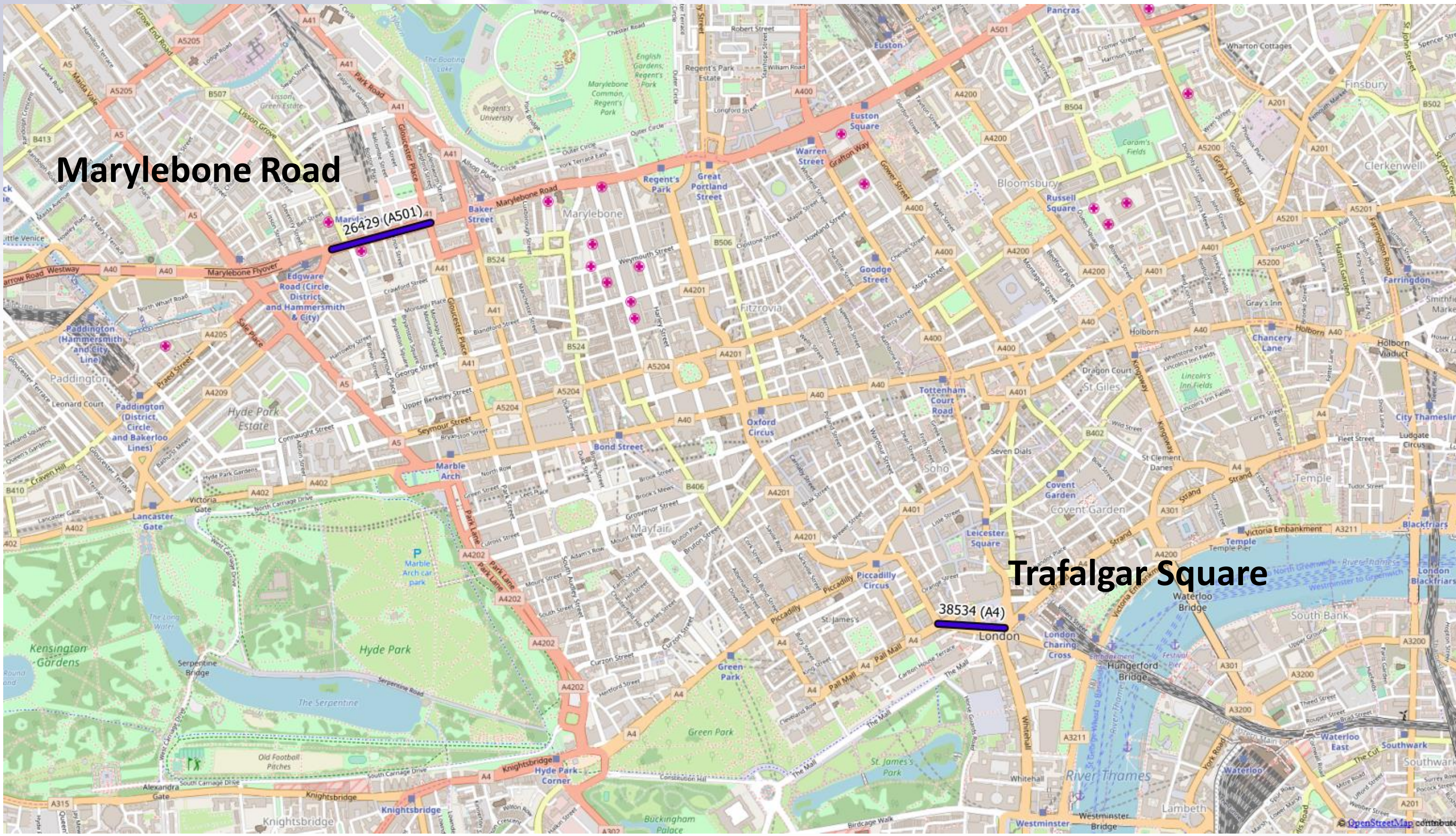
Two London "Hot Spot" Street Locations



Sample of UK DEFRA NO_2 Source Attribution for London Hot Spots

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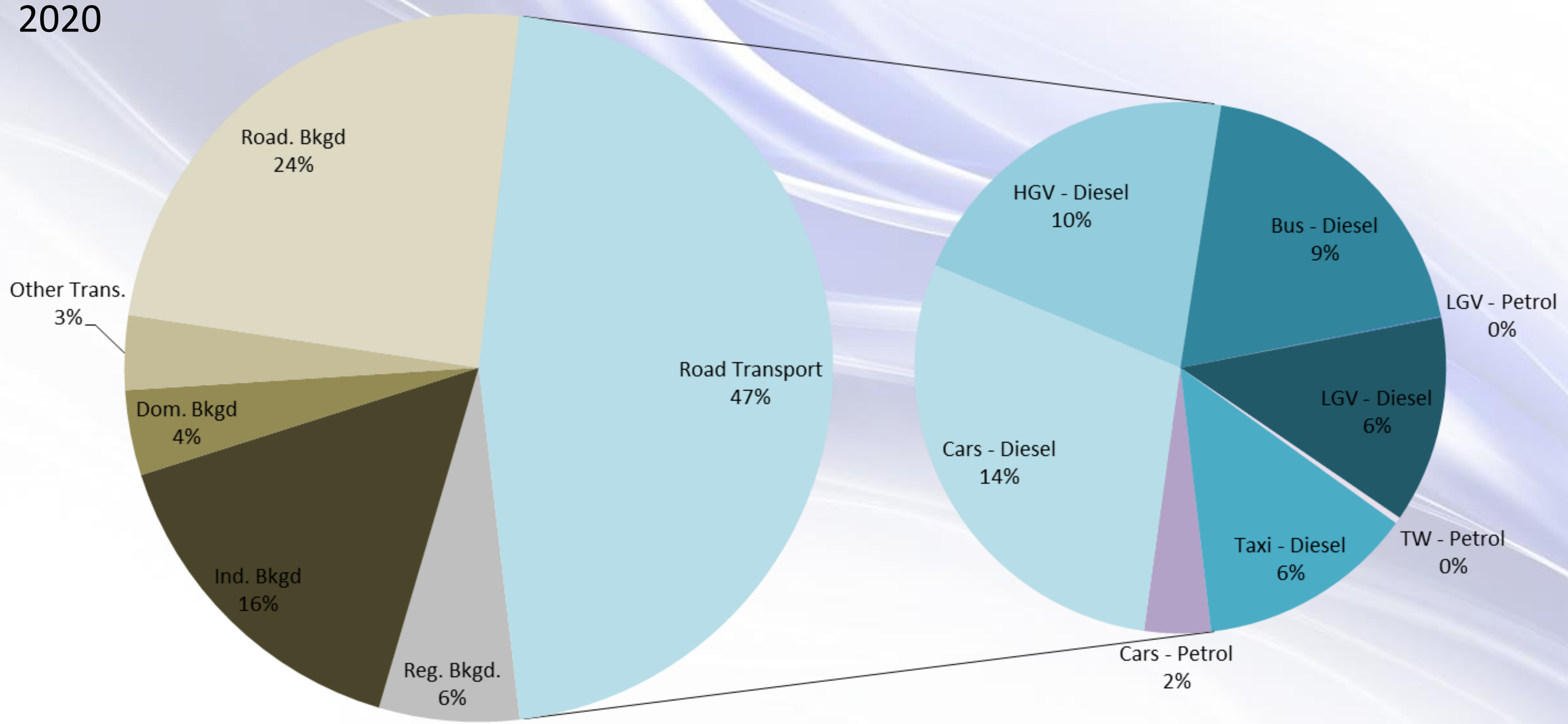
Marylebone Road – outside ULEZ

Road Census ID: 26429
Year: 2020

NO_2 = 71 μg/m³

Bus 9%
PCD 14%



Source: UK DEFRA RFI request 7900 "2015 NO_2 projections data (2013 reference year)"
https://uk-air.defra.gov.uk/library/no2ten/2015-no2-projections-from-2013-data

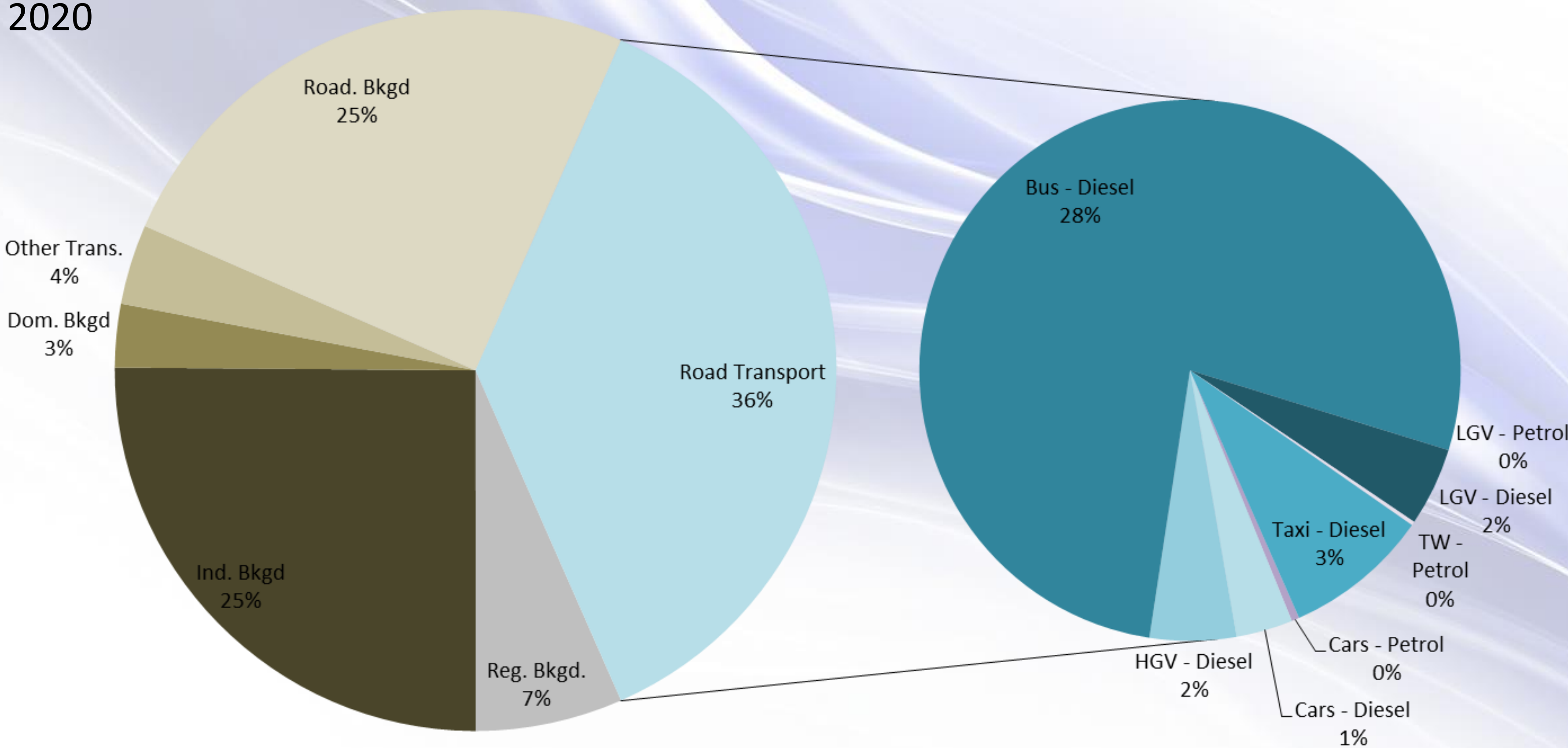
Sample of UK DEFRA NO_2 Source Attribution for London Hot Spots

Trafalgar Square – inside ULEZ

Road Census ID: 38534
Year: 2020

NO_2 =66 µg/m^3

Bus 28%
PCD 1%



Source: UK DEFRA RFI request 7900 "2015 NO_2 projections data (2013 reference year)"
https://uk-air.defra.gov.uk/library/no2ten/2015-no2-projections-from-2013-data

Sample of UK DEFRA NO_2 Source Attribution for London Hot Spots

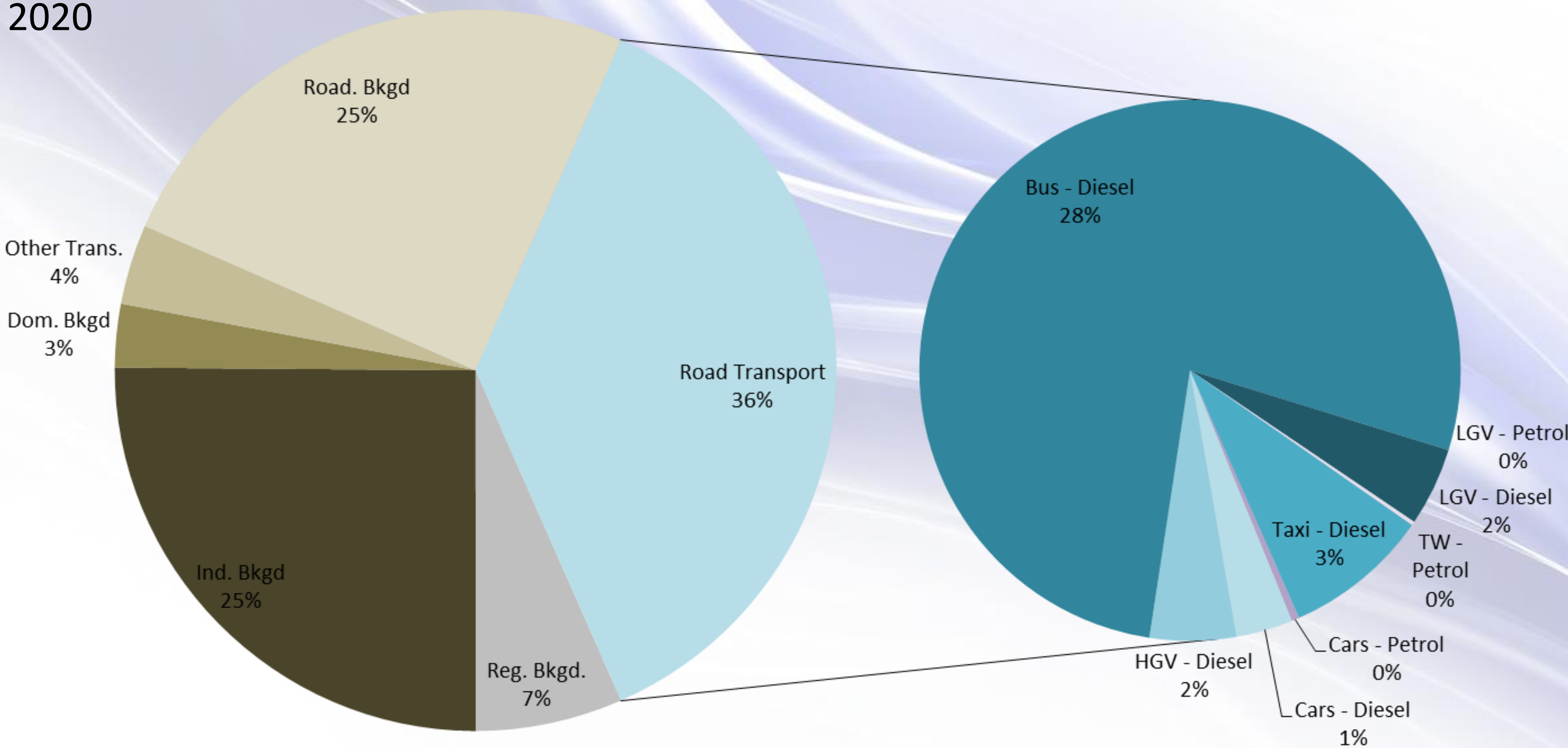
Trafalgar Square – inside ULEZ

Road Census ID: 38534
Year: 2020

NO_2 =66 µg/m^3

Source attribution highlights the most effective target

<u>Bus 28%</u>
PCD 1%



Source: UK DEFRA RFI request 7900 "2015 NO_2 projections data (2013 reference year)"
https://uk-air.defra.gov.uk/library/no2ten/2015-no2-projections-from-2013-data

Uncertainty considerations

Key issues for designing cost effective measures to protect health are subject to high uncertainty:

1. High concentration gradients
2. Total personal exposure variability
3. Uncertainty of health effects

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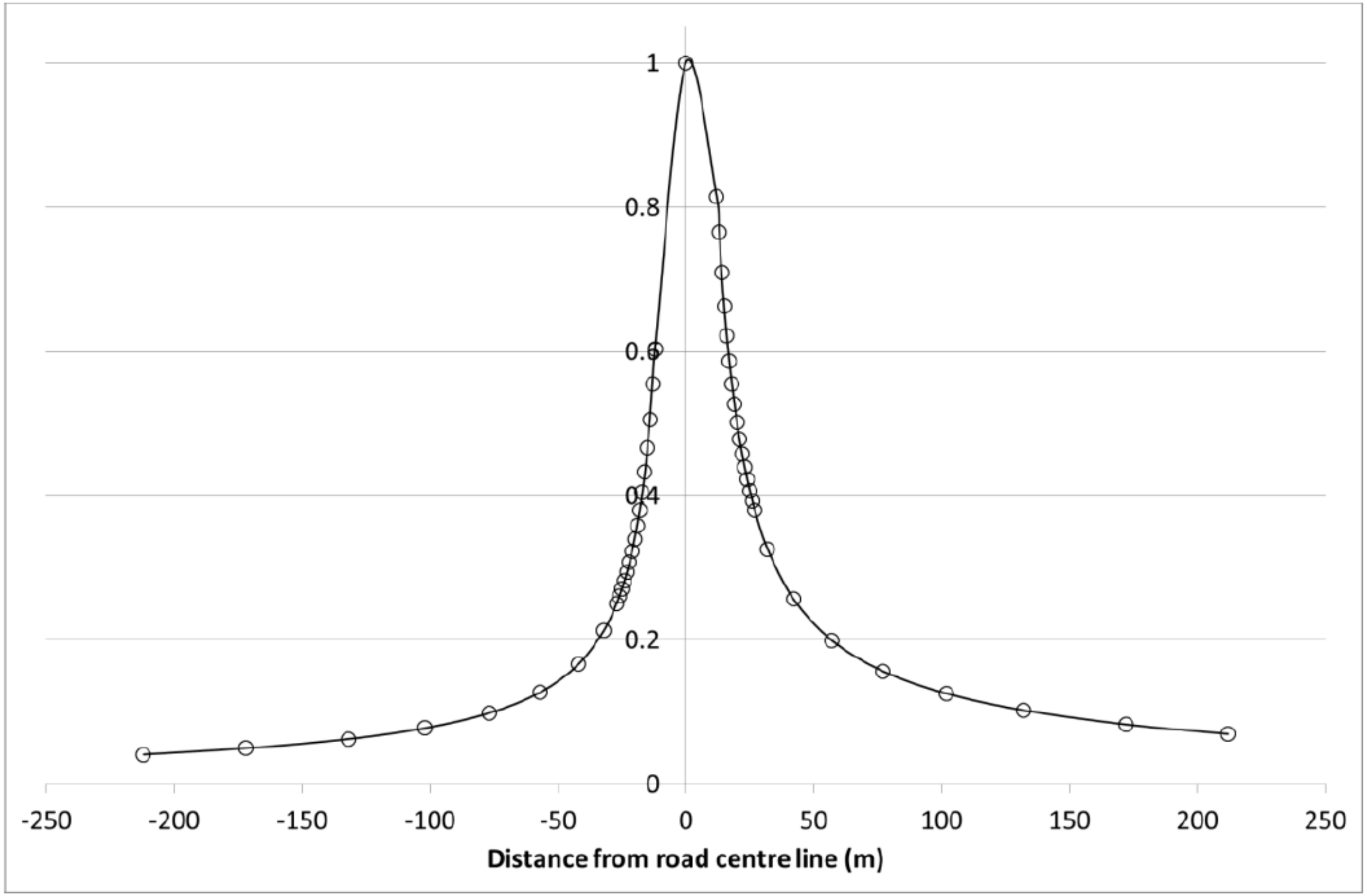
Uncertainty considerations

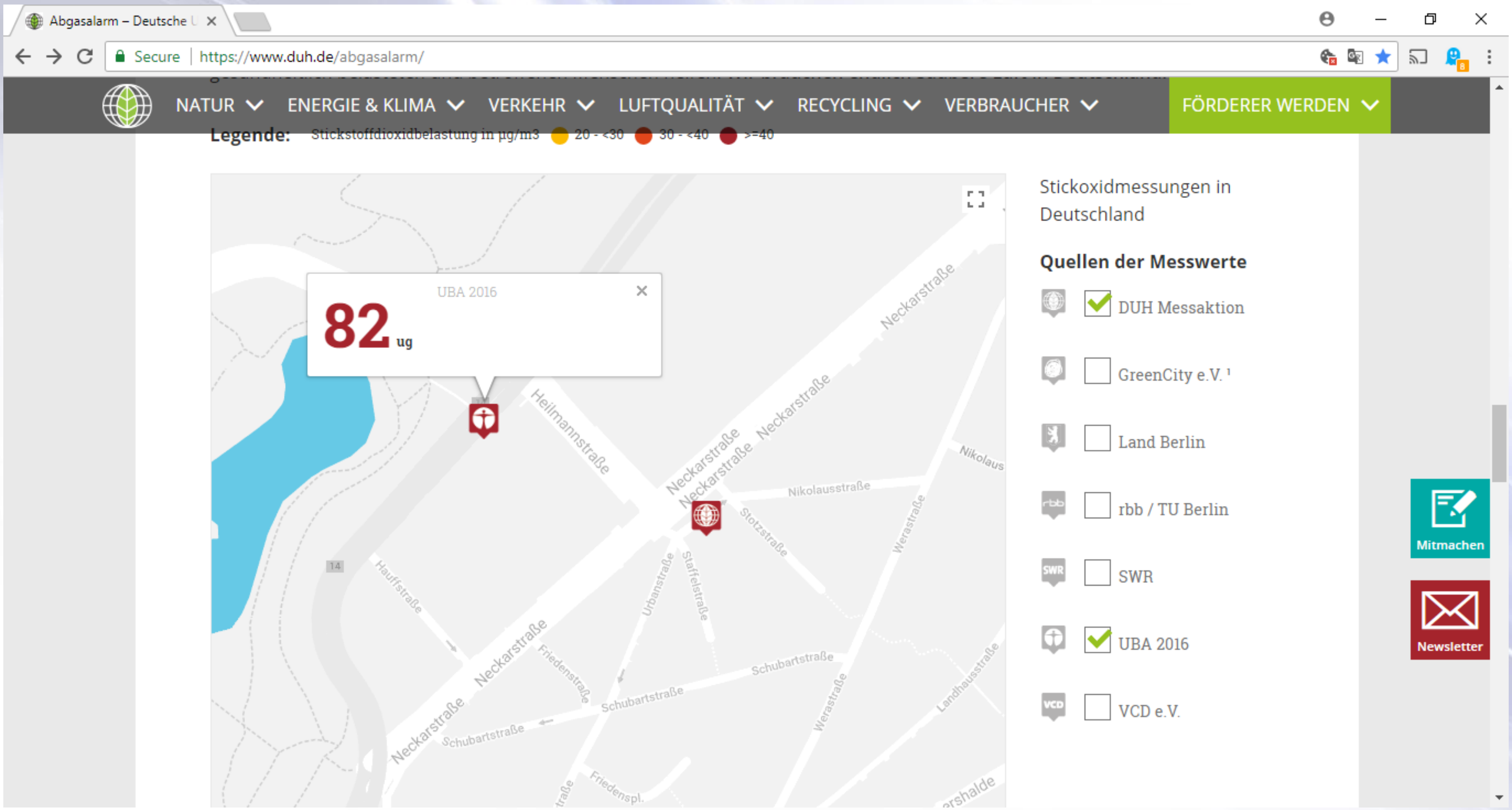
1. High concentration gradients

NO_2 Attenuation -vs- Distance from Single Road



Source: DEFRA Technical Report December 2015, Annex B, Figure B.2 – Example normalised concentration profile

Am Neckartor, Stuttgart – (UBA data)



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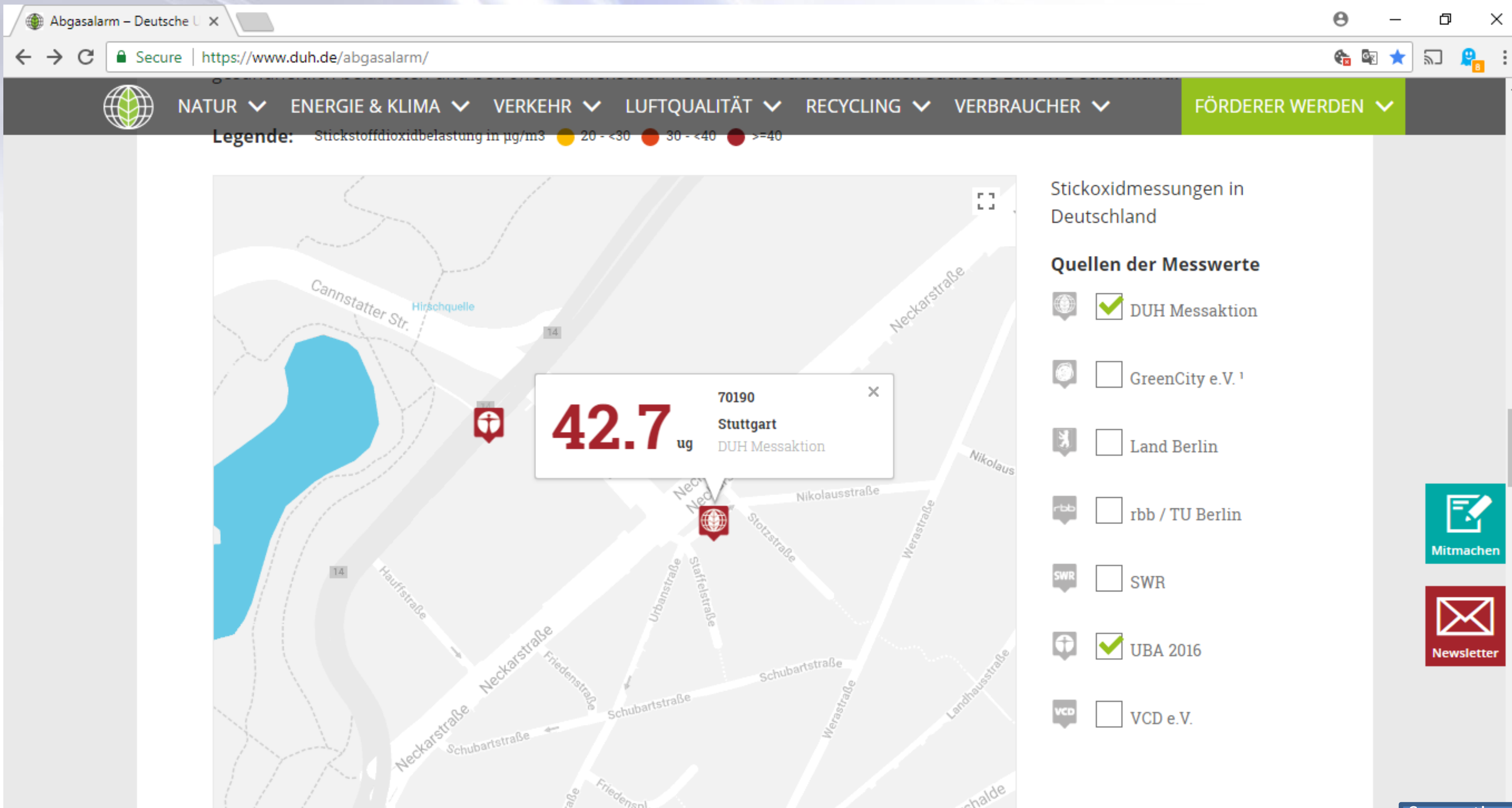
Parallel Road at ~ 100m: Neckarstrasse (DUH data)



Supporting Material

Uncertainty considerations

2. Total personal exposure variability

Black carbon exposure of London commuters
Exposure variability by route choice

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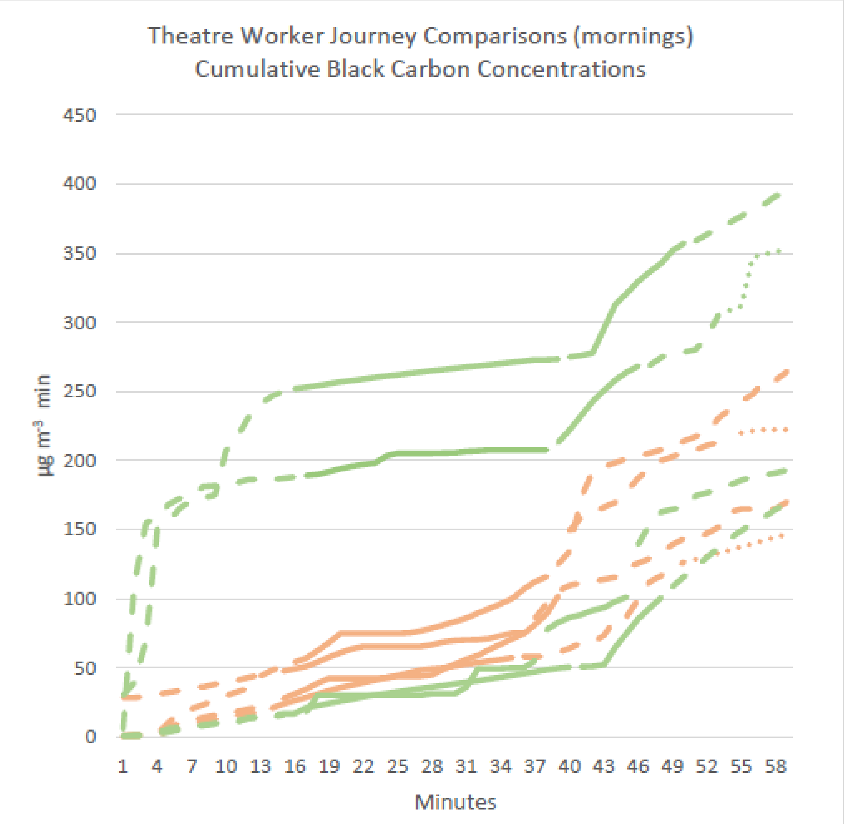
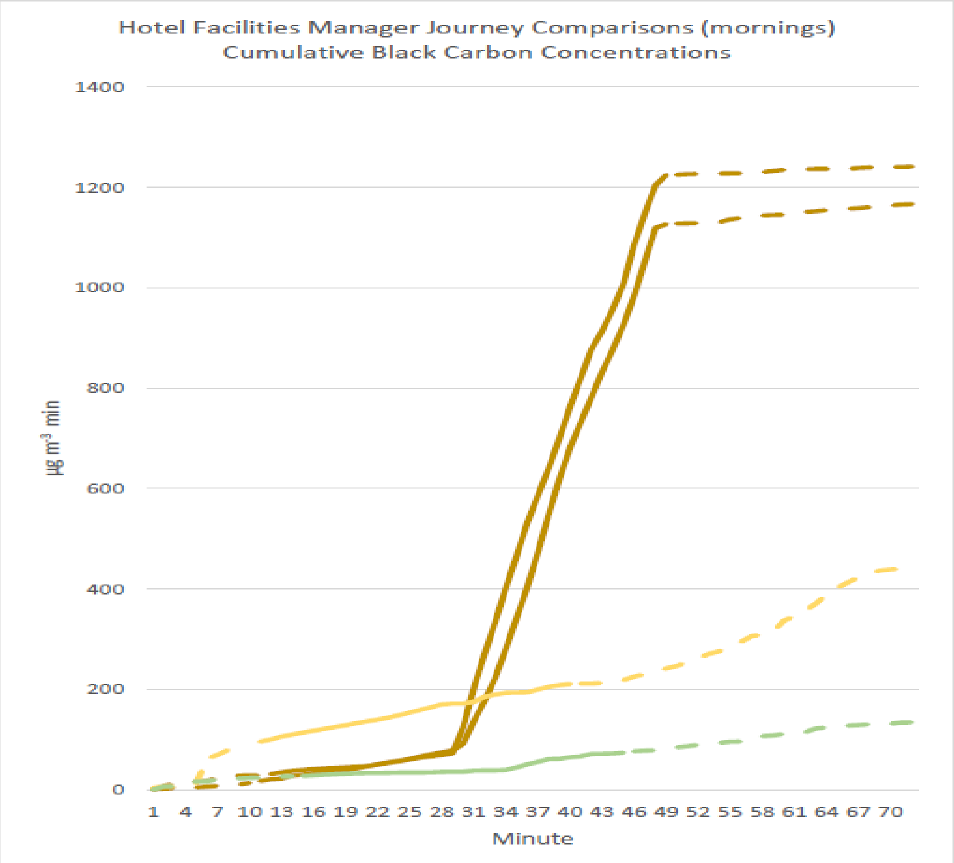
Commuters varied routes over two weeks; dotted = walks, solid = trains/tubes

Figure 1 Theatre Worker Week 1 Vs Week 2 journey comparisons



Key:
- Hither Green > Aldwych (Train) (morning) (week 1)
- Hither Green > Aldwych (Train + Underground) (morning) (week 2)

Figure 9 Hotel FM journey comparisons



Key:
- Bakerloo line Harlesden to Charing Cross
- Overground line Harlesden to Euston / Walk (busy route)
- Overground line Harlesden to Euston / Walk (quiet route)

https://thenorthbank.london/wp-content/uploads/2018/03/Personal-Exposure-and-Air-Quality-in-Northbank-Final-1.pdf

Black carbon exposure of London commuters
Route choice is free!

Personal Exposure and Air Quality in Northbank
A detailed study on commuter exposure for Northbank Business Improvement District
by King's College London
July 2017

Section 7. Recommendations (extract)
…
A recent study into long-term trends of PM2.5 particulate in London by King's found that roadside PM2.5 concentrations had fallen by around 25% between 2010 and 2015 (King's College London, 2017). This is the result of all policies aimed at reducing urban particulate concentrations.

By contrast, volunteers in this study were able to achieve reductions in excess of this in their daily commutes, mostly without incurring any extra cost.
…

https://thenorthbank.london/making-progress/clean-air/

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Uncertainty considerations

3. Uncertainty of health effects

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REVIHAAP Question C4 on NO_2

Question C4

Based on currently available health evidence, what NO_2 metrics, health outcomes and concentration–response functions can be used for health impact assessment?

Answer (edited)

…

Cohort studies also show relationships between long-term exposure to NO_2 and mortality, but not all are sufficiently robust for use in a core health impact assessment. Therefore, the effect of long-term exposure to NO_2 on all-cause mortality is recommended for sensitivity analysis only. Concentration–response functions from cohort studies with effect estimates for NO_2 that were adjusted for at least PM mass should be used. In the same way, cardiovascular mortality could also be included in a sensitivity analysis, due to the uncertainty about a mechanistic understanding of cardiovascular effects.

…

Page 117,
REVIHAAP Project: Technical Report, WHO/Europe, 2013

Supporting Material

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COMEAP's Interim advice to DEFRA, 24 July 2015

…

"A coefficient of 1.025 (1.01–1.04) is recommended. However, you should note that the group intends to run a new meta-analysis to obtain an updated coefficient for use in its own calculations. When included in an assessment which also includes assessment of health impacts on the basis of PM2.5, a reduction of this coefficient by up to 33% is proposed to take account of possible overestimation due to double counting of effects associated with PM. However, there will also be a need to consider possible overestimation of effects calculated on the basis of single-pollutant model estimates of associations with PM2.5. The group is not in a position at this stage to say what this additional overestimate is likely to be."

…

This Interim advice equates to an adjusted mid range Hazard Ratio of 1.016 per 10µg/m^3

US EPA *Policy Assessment for the Review of the Primary National Ambient Air Quality Standards for Oxides of Nitrogen*, April 2017

"…

Staff Conclusions

Staff has reached the conclusion that the available scientific evidence, in combination with the available information from quantitative analyses, supports the adequacy of the public health protection provided by the current primary NO_2 standards. Staff further reaches the conclusion that it is appropriate to consider retaining the current standards, without revision, in this review. In light of this conclusion, we have not identified potential alternative standards for consideration in this PA. **In its review of the draft PA, CASAC agreed with these conclusions, stating that it "concurs with the EPA that the current scientific literature does not support a revision to the primary NAAQS for nitrogen dioxide".**

Supporting Material

https://www.epa.gov/naaqs/nitrogen-dioxide-no2-primary-standards-policy-assessments-current-review

Current US EPA Annual Mean NAAQS NO_2 = 53pbb = 53 x 1.88 = **100 µg/m3**

https://www.epa.gov/criteria-air-pollutants/naaqs-table

Question to consider?:

What would the EU NO_2 Compliance picture look like
if the US Annual Mean NAAQS standard was applied?

COMEAP's refined advice to DEFRA, 14 July 2017

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…

"For interventions which primarily target emissions of NOx, use 25-55% of the statistical association obtained from population studies. This is, in our judgement, the likely extent to which this association represents effects causally related to NO_2. This is more uncertain than assessing traffic pollutants as a mixture."

…

Source:

Annex A – Refined COMEAP recommendations letter,
UK Plan for tackling roadside nitrogen dioxide concentrations,
Technical report, July 2017

This refined advice equates to a mid range Hazard Ratio of 1.0092 per 10µg/m^3 i.e. ~40% decrease and it made the central cost benefit case negative.

Supporting Material

Note the size of the change relative to the modelled concentration difference between scenarios

The full COMEAP Report on NO_2 and Health Impacts is expected imminently and it is anticipated to formalise the Committee's advice and opinion on the topic.

The Atkinson et al 2018 paper continues to note the weak NO_2 all cause mortality evidence and recommends a move to "prediction intervals" for burden calculations.

Supporting Material

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Conclusions and closing remarks

- The UAQ Extension study modelled ZEV scenario offers no compliance benefit over an anticipated and properly performing Euro6 scenario
- Using a London example, the extensive modelling work by DEFRA highlights the importance of ‘source attribution’ in designing effective local responses to address ‘hotspots’
- The open availability of data is essential to facilitate wider analysis
- Uncertainties in concentration modelling are potentially of very small impact in comparison to uncertainties in exposure estimation, hazard ratio estimates and cost benefit methodologies
- Integrated Assessment Modelling can provide vital support to air quality policy decisions
- Cost effective policy decisions need to be based on sound data and methods in order to maximise protection of public health

Thank you for your attention – Any questions welcome!

Sources and Documentation

EEA AQ dataportal for monitoring data:

https://www.eea.europa.eu/themes/air/dc

IIASA GAINS for emissions data

COPERT 4v11 for emission factors

TREMOVE for vehicle stock and activity

Concawe in house traffic emissions model

Full details of methodology and results published

UAQ Study Report, March 2016:

https://www.concawe.eu/publication/urban-air-quality-study-report-no-1116/

UAQ Study: extension 1, April 2018:

https://www.concawe.eu/publication/comparison-real-driving-emissions-euro-6-diesel-passenger-cars-zero-emission-vehicles-impact-urban-air-quality-compliance-urban-air-quality-study-extension/

Relevant EU Legislation:

http://ec.europa.eu/environment/air/quality/existing_leg.htm

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Ricardo derived NOx Conformity Factors

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A Comparison of Real Driving Emissions from Euro 6 Diesel Passenger Cars with Zero Emission Vehicles and their Impact on Urban Air Quality Compliance

Table 1 Conformity factors for diesel passenger cars derived from the Ricardo study – Nitrogen Oxides (NO_x)[4]

	Euro 6b Pre-2015	Euro 6b Post-2015	Euro 6c	Euro 6d (temp)
Minimum NO_x	1.13	0.20	0.25	0.23
Maximum NO_x	17.25	5.35	3.65	1.29
Mean NO_x	6.70	2.19	1.43	0.73
Median NO_x	5.41	1.90	1.21	0.76

UAQ Study: extension 1, April 2018, Table 1 from "(Ricardo, 2018) Expectations for Actual Euro 6 Vehicle Emissions. RD18-000697-2"
https://www.concawe.eu/wp-content/uploads/2018/04/RD18-000697-2-CONCAWE_Expectations_for_Actual_Euro_6_Vehicle_Emissions.pdf

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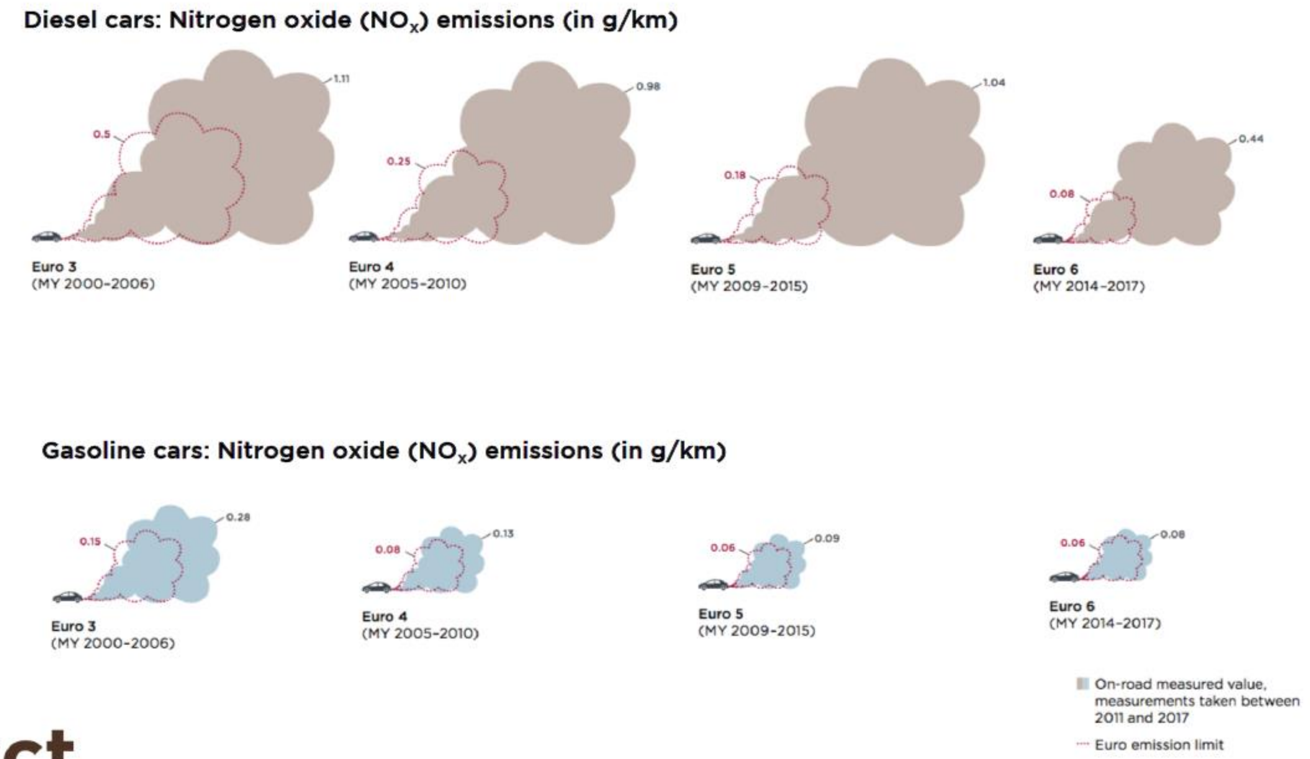
Back-up

ICCT/CONOX view of NOx EF

The importance of enforcement: NO_x emissions from diesel cars in Europe have not decreased as expected



icct
THE INTERNATIONAL COUNCIL ON CLEAN TRANSPORTATION

Source: NOx emissions from remote-sensing across European cities, CONOX project (ICCT, IVL, BAFU)
ICCT pocket book

"*Pathways for a post-Euro 6 regulation for LDV*" Yoann Bernard, Jan Dornoff, 6 March 2018

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COPERT 4 to 5 revisions: Examples for France

TABLE 4-1: AVERAGE NO_x EMISSION FACTOR BY VEHICLE CATEGORY, THE LATEST COPERT 5 VERSION COMPARED TO COPERT 4 USED FOR THE TSAP IMPACT ASSESSMENT. EXAMPLES FOR FRANCE.

	Fuel	Emission standards	Emission factor in mg NO_x per km	Ratio of new to emission factor compared to the 2013 TSAP assessment
Cars	Diesel	Euro 4	680	1.11
		Euro 5	815	1.16
		Euro 6a,b	540	2.00
		Euro 6d	124	1.11
Cars	Gasoline	Euro 1	355	0.80
		Euro 2	180	0.71
		Euro 3	75	0.67
		Euro 4	40	0.62
		Euro 5	23	0.44
		Euro 6	25	0.52
Heavy duty trucks	Diesel	Euro VI	250	0.61

Source: IIASA Clean Air Outlook Report,
PROGRESS TOWARDS THE ACHIEVEMENT OF THE EU'S AIR QUALITY AND EMISSIONS OBJECTIVES,
IIASA, June 11, 2018, 2017

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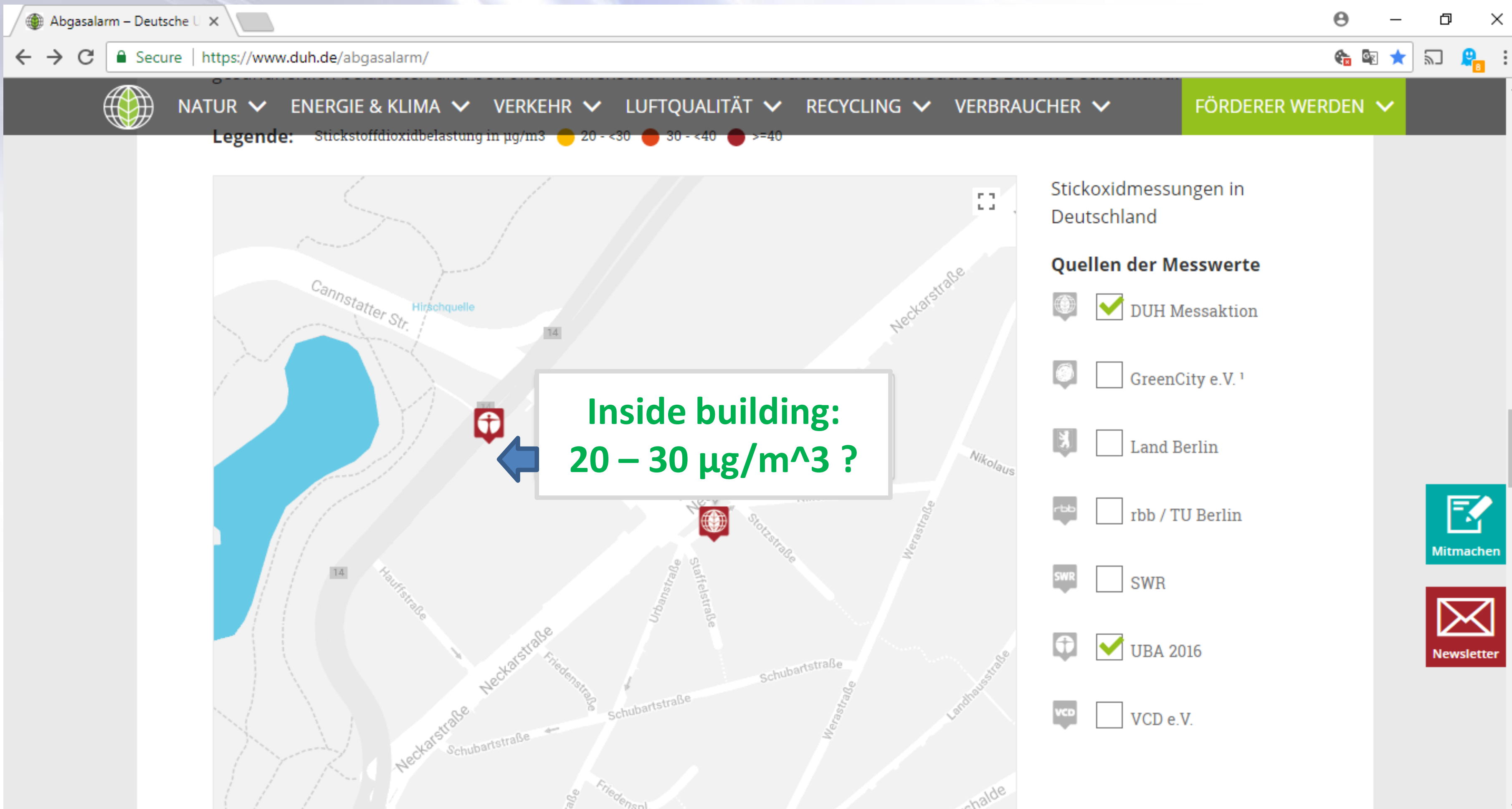
Stuttgart District Court Indoors?*

(* value verbally reported at AAQD Fitness Check Stakeholder workshop, 18 June 2018)



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REVIHAAP Table 10
NO_2 Pollutant Outcome Pairs

Notes:

First column is for "central analysis"

Bottom row is outcome "All cause mortality"

Italics are used to signify "most uncertainty"

Table 10. Recommended pollutant outcome pairs by health impact assessment context and ranked by uncertainty

NO_2 per se, central analysis (d(i)) – that is, a likely effect of NO_2	NO_2 per se, sensitivity analysis (d(ii)) – that is, a possible effect of NO_2 additional to the effect of PM	NO_2 per se, sensitivity analysis, "what if either NO_2 or a PM metric" (d(iii)) (compare, but do not add)	Crude substitute for a PM effect, if PM data unavailable (d(iv))	Marker for traffic (with caveats)[a] (better metric of primary PM than PM mass) (also (d(iv))
Respiratory hospital admissions (short term), adjusted coefficient preferable	NA	NA	*Respiratory hospital admissions (short term), single-pollutant model*	Respiratory hospital admissions (short term),[b] single-pollutant model
NA	*Cardiovascular admissions, adjusted coefficient*	NA	*Cardiovascular admissions, single-pollutant model*	Cardiovascular admissions, single-pollutant model
All-cause mortality (short term), adjusted coefficient preferable	NA	NA	*All-cause mortality (short term), single-pollutant model (but may not be additional to effects of long-term exposure)*	All-cause mortality (short-term), single-pollutant model (but may not be additional to effects of long-term exposure)
Bronchitic symptoms in asthmatic children (long term, year to year variations), adjusted coefficient	NA	NA	[NO_2 independent of several other PM metrics Bronchitic symptoms in asthmatic children could be used as a marker for organic carbon, but might not be a marker for diesel.]	Bronchitic symptoms in asthmatic children (long term, yearly variation element), single-pollutant models
NA	[Adjusted coefficients unavailable for asthma incidence and/or prevalence studies]	*Asthma prevalence from within city studies, single-pollutant models*	*Asthma prevalence from within city studies, single-pollutant models*	Asthma prevalence within city, single-pollutant models
NA	*All-cause mortality (long term), adjusted coefficients*	*All-cause mortality (long-term), single-pollutant models*	*All-cause mortality (long term), single-pollutant models*	All-cause mortality (long term), single-pollutant models

[a] The ratio of NO_2 to primary PM is changing over time.

[b] It might be possible to use a model adjusted for $PM_{2.5}$, if examining the traffic pollution element is done separately from PM, in general.

Note. The following notations and conventions are used in this table: bold underline: least uncertainty; underline: some increased degree of uncertainty; italics: most uncertainty, increased difficulty in controlling for confounding, fewer studies, less supporting clinical or toxicological evidence; plain (straight, non-italic) text: traffic marker not on same scale of uncertainty as NO_2 per se; small font italics: rough substitute for PM, not on same scale of uncertainty as NO_2 per se, but uncertain; text in square brackets: notes; NA: not applicable.

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DEFRA's updated NO_2 Plan CBA based on COMEAP's refined advice

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Change from positive to negative NPV of NO_2 plans based on COMEAP 14 July 2017:

UK Plan for tackling roadside nitrogen dioxide concentrations
Technical report
July 2017
https://www.gov.uk/government/publications/air-quality-plan-for-nitrogen-dioxide-no2-in-uk-2017

Table 3.8: Summary of the economic impacts of the CAZ scenario

Impacts	Low	Central	High	Comments
Health impact	£2.8m	£400m	£2,400m	The net monetised impact of the change in NO_x emissions resulting from the CAZ scenario. The uncertainty range is based on the range of coefficients linking NO_2 and mortality set out in Section 4.2.5.
Government impact	-£410m	-£250m	-£230m	The cost to government of setting up and administering the CAZs over the ten-year period. The uncertainty range is based on the Green Book guidance for optimism bias for a non-standard civil engineering project (Section 4.2.11).
Public impact	-£2,000m	-£1,200m	-£500m	The net of the costs of lost welfare and asset value with the benefits in traffic flows. The uncertainty range is based on removing and doubling the welfare impacts (Section 4.2.7) only (loss of asset value and benefits in traffic flows remain constant across the range presented).
Greenhouse gas emissions impact	£7.7m	£15m	£23m	The net monetised impact of the change in CO_2e emissions. The uncertainty range is based on government's carbon price range (Section 4.2.12).
Economic growth impact		Positive and negative impacts		Positive impacts through improved air quality and higher new vehicle purchases. Negative impacts through increased costs to businesses.
Overall NPV	-£1,800m	**-£1,100m**	+£1,000m	*This uncertainty range is based on the overarching uncertainty in the cost-benefit analysis (Section 4.1.2). This is not the sum of all of the uncertainties set out in Section 4 or those above but instead represents the highest and lowest NPVs generated by the individual sensitivities run on the cost-benefit analysis. This is consistent with the advice from the cost-benefit analysis uncertainty panel.*

Note: All monetised impacts are present values, discounted to 2017 prices, appraised over 2018-30. Positive values indicate a benefit.
All monetised impacts are rounded to the nearest two significant figures, totals may therefore not sum to the total of the rounded figures.

The overall net present value (NPV) of the measures in the central CAZ scenario is -£1.1 billion, within the range of -£1.8 billion to +£1 billion.

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CASAC Advice to EPA Integrated Science Assessment

US EPA CASAC Policy Assessment:

- Based on "Integrated Science Assessment for Oxides of Nitrogen –Health Criteria, January 2016" 109 pages of current references
- Committee Chair:
  - Dr. Elizabeth A. (Lianne) Sheppard, Professor of Biostatistics and Professor and Assistant Chair of Environmental & Occupational Health Sciences, School of Public Health, University of Washington
- 22 December 2016 Meeting, Four page cover letter to Administrator:
  - Page 1, Para 2: *"Overall, the CASAC finds that the Draft PA provides an appropriate summary of the science and technical information for the review of the primary National Ambient Air Quality Standards (NAAQS) for nitrogen dioxide (NO_2). **The CASAC concurs with the EPA that the current scientific literature does not support a revision to the primary NAAQS for nitrogen dioxide.** The CASAC has additional comments and recommendations on improving the PA. With the completion of the recommended revisions outlined below and in the consensus responses, the PA will serve its intended purpose **and another CASAC review of the document is not needed.**"*
  - Page 3, para 3: *"The **key research areas include multipollutant exposure and epidemiology to attempt to distinguish the contribution of NO2 exposure to human health risk**, identification and evaluation of additional health effect endpoints (e.g., multiple asthma phenotypes, cardiovascular disease, premature mortality), implications of effects for adversity and clinically significant outcomes, improved mechanistic understanding of modes of action, ongoing need for meta-analysis of existing and new studies, temporal and spatial variability in NO_2 concentration, and better characterization of at-risk populations.*
- 59 page report including appendices and committee member comments

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Atkinson et al 2018

Long-term Concentrations of Nitrogen Dioxide and Mortality: A Meta-analysis of Cohort Studies
Atkinson, Richard., W.a; Butland, Barbara., K.a; Anderson, H., Ross.a,b; Maynard, Robert., L.c

Background:

Concentrations of outdoor nitrogen dioxide (NO_2) have been associated with increased mortality. Hazard ratios (HRs) from cohort studies are used to assess population health impact and burden. We undertook meta-analyses to derive concentration–response functions suitable for such evaluations and assessed their sensitivity to study selection based upon cohort characteristics.

Methods:

We searched online databases and existing reviews for cohort studies published to October 2016 that reported HRs for NO_2 and mortality. We calculated meta-analytic summary estimates using fixed/random-effects models.

Results:

We identified 48 articles analyzing 28 cohorts. Meta-analysis of HRs found positive associations between NO_2 and all cause (1.02 [95% confidence interval (CI): 1.01, 1.03]; prediction interval [PI]: [0.99, 1.06] per 10 μg/m^3 increment in NO_2), cardiovascular (1.03 [95% CI: 1.02, 1.05]; PI: [0.98, 1.08]), respiratory (1.03 [95% CI: 1.01, 1.05]; PI: [0.97, 1.10]), and lung cancer mortality (1.05 [95% CI: 1.02, 1.08]; PI: [0.94, 1.17]) with evidence of substantial heterogeneity between studies. In subgroup analysis, summary HRs varied by age at cohort entry, spatial resolution of pollution estimates, and adjustment for smoking and body mass index at the individual level; for some subgroups, the HR was close to unity, with lower confidence limits below 1.

Conclusions:

Given the many uncertainties inherent in the assessment of this evidence base and the sensitivity of health impact calculations to small changes in the magnitude of the HRs, calculation of the impact on health of policies to reduce long-term exposure to NO_2 should use prediction intervals and report ranges of impact rather than focusing upon point estimates.

https://journals.lww.com/epidem/Fulltext/2018/07000/Long_term_Concentrations_of_Nitrogen_Dioxide_and.2.aspx

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