

Ammonia Emissions from Vehicle Emissions Measurements



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Presentation Outline

1. Introduction

1.1. Ammonia Emissions

1.1. Vehicular Sources

2. Measurement Techniques

2.1. Remote Sensing

2.2. Point Sampling

3. Research Results

4. Conclusions

4.1. Relevance to Welsh Air Quality

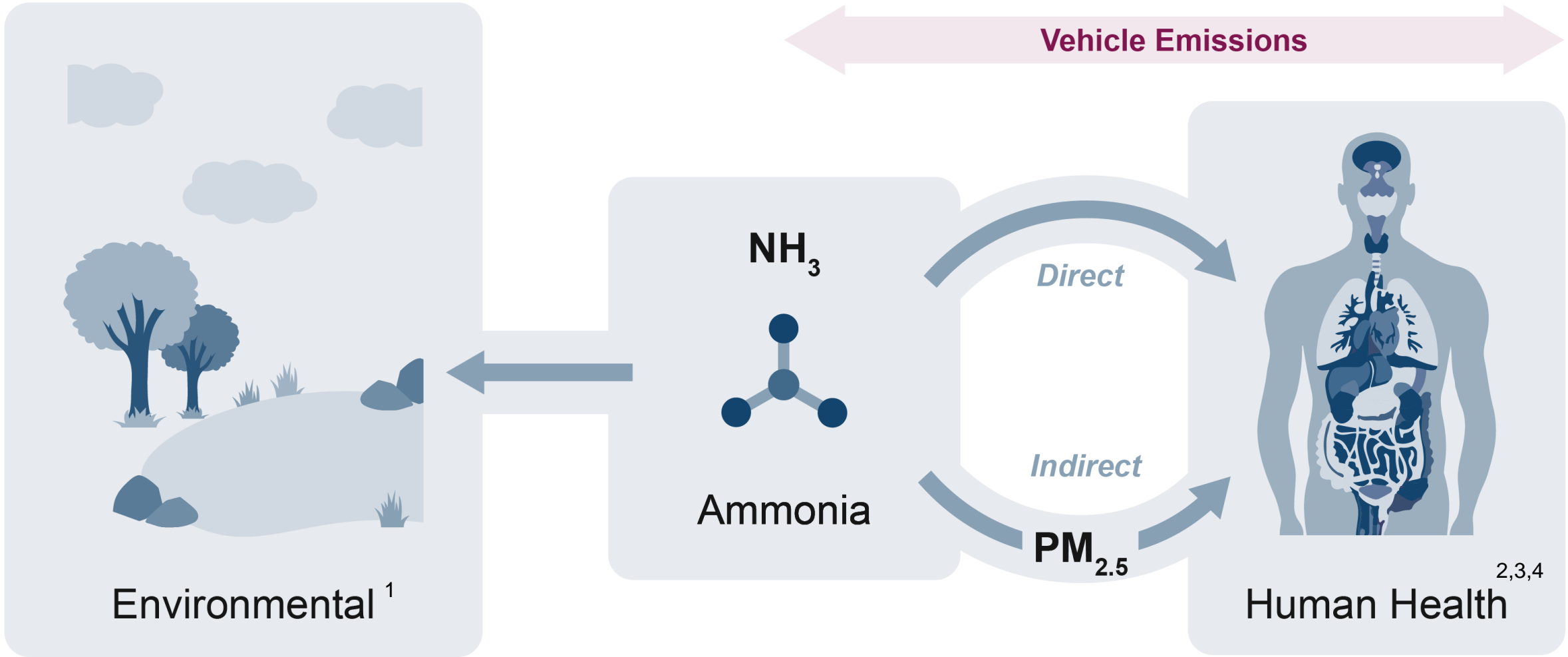
4.2. Future Work



1.

Introduction

Ammonia Emissions: Why are they important?



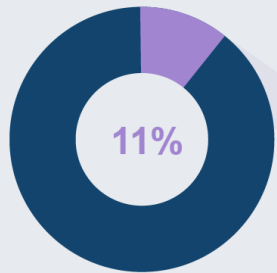
Ammonia Emissions: Where do they come from?

Total **UK** 2022 NH₃ emissions: **260 kT**⁵

Agriculture (87%)

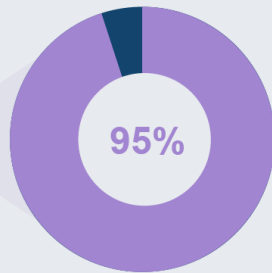
Road transport (2%)

Light-duty (96%)



Urban areas

Land area:
240,000 km²



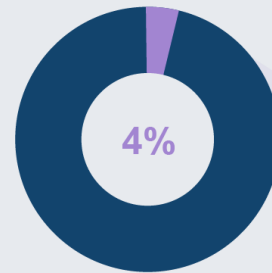
Population:
67.1 million

Total **Wales** 2022 NH₃ emissions: **23 kT**⁵

Agriculture (93%)

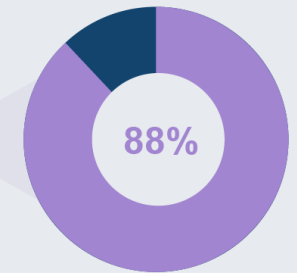
Road transport (1%)

Light-duty (95%)



Urban areas

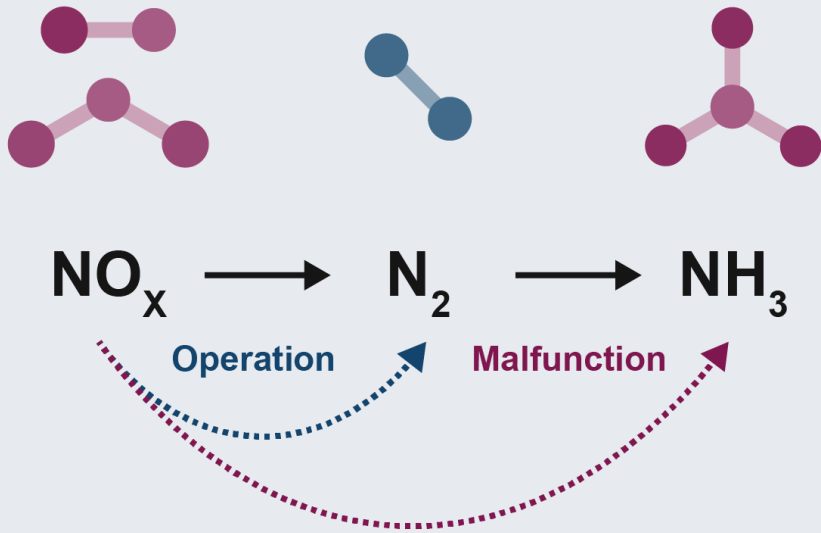
Land area:
21,000 km²



Population:
3.1 million

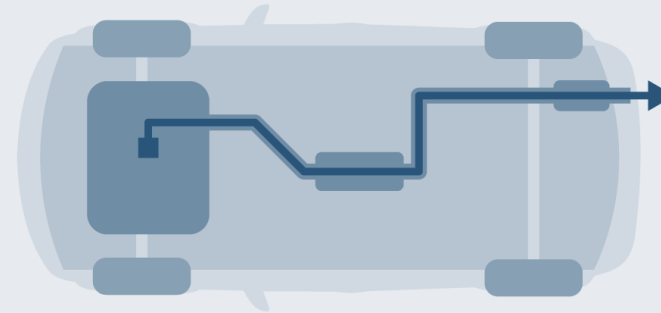
Vehicular Sources: Catalysis

NH_3 is not produced during combustion, it is a product of **NO_x reduction catalysis**



Gasoline⁷

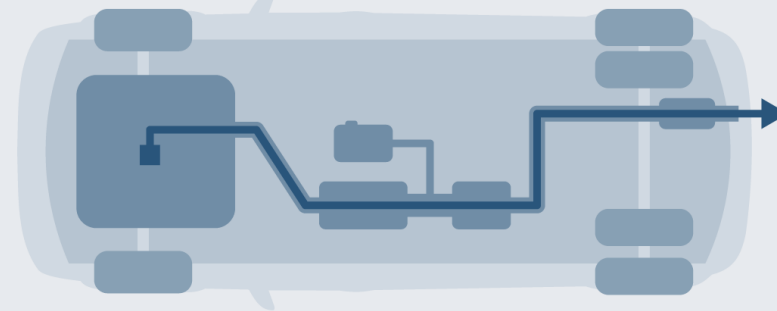
Three-way catalyst (TWC)



Light-duty vehicles
1980
(passenger cars)

Diesel⁷

Selective catalytic reduction (SCR)

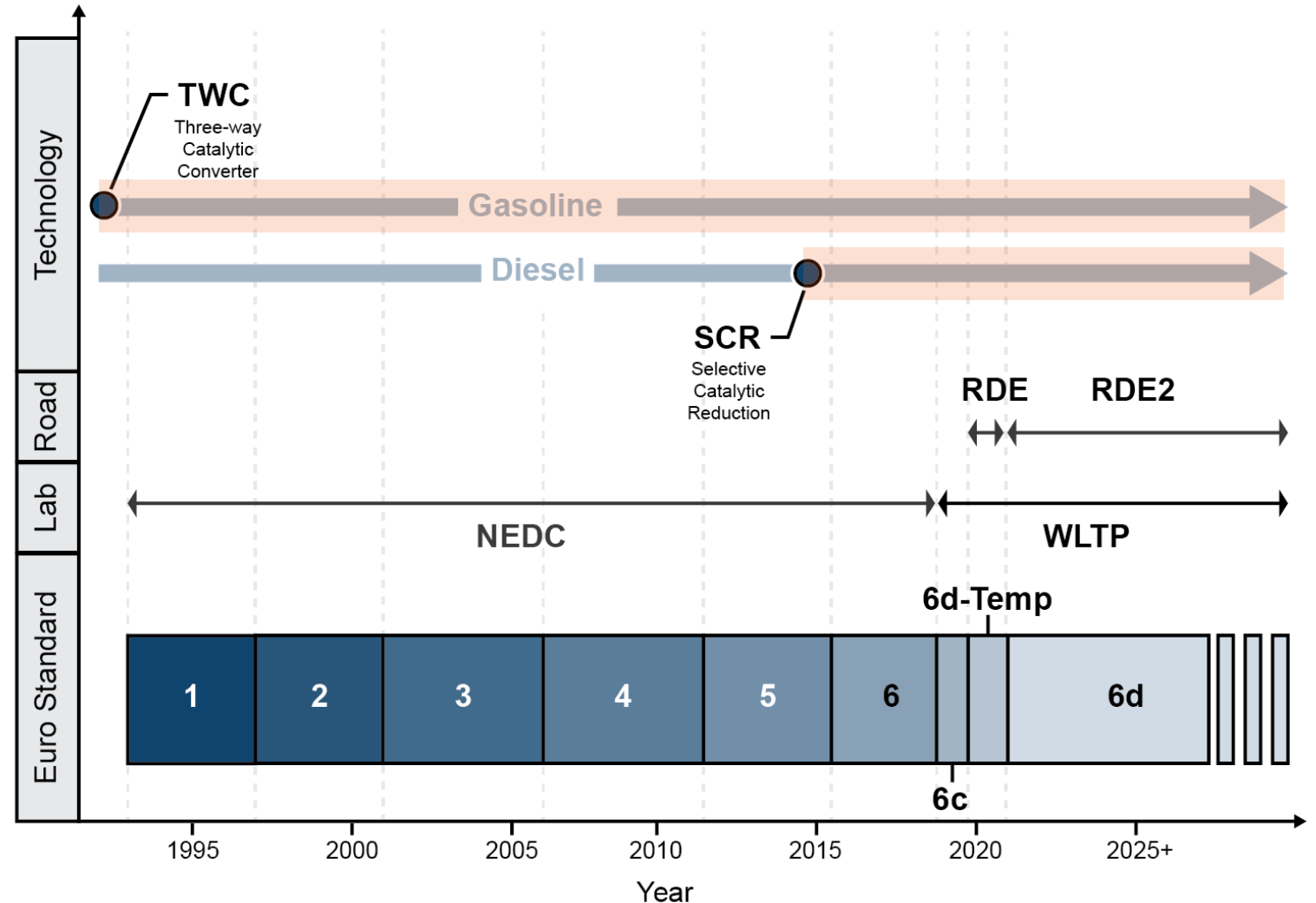


Heavy-duty vehicles
2010
Light-duty vehicles
2015

Vehicular Sources: Regulation

Euro Emission Standards ^{5,8}

- Increasingly stringent vehicle testing (laboratory and real-driving emissions RDE)
- Separate standards for light-duty (shown right) and heavy-duty vehicles
- Ammonia is currently **unregulated** for light-duty vehicles
- Light-duty vehicles account for 96% of vehicular NH₃ in the UK (95% in Wales)

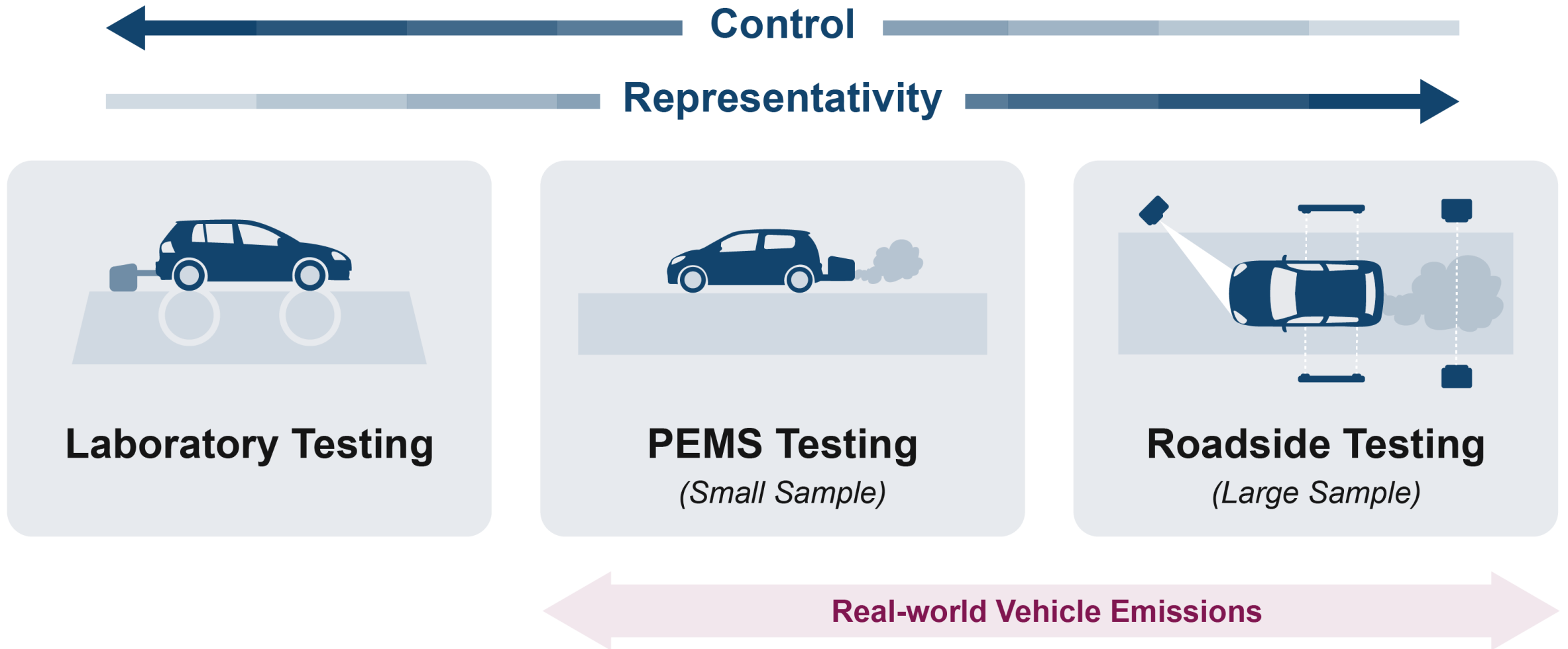




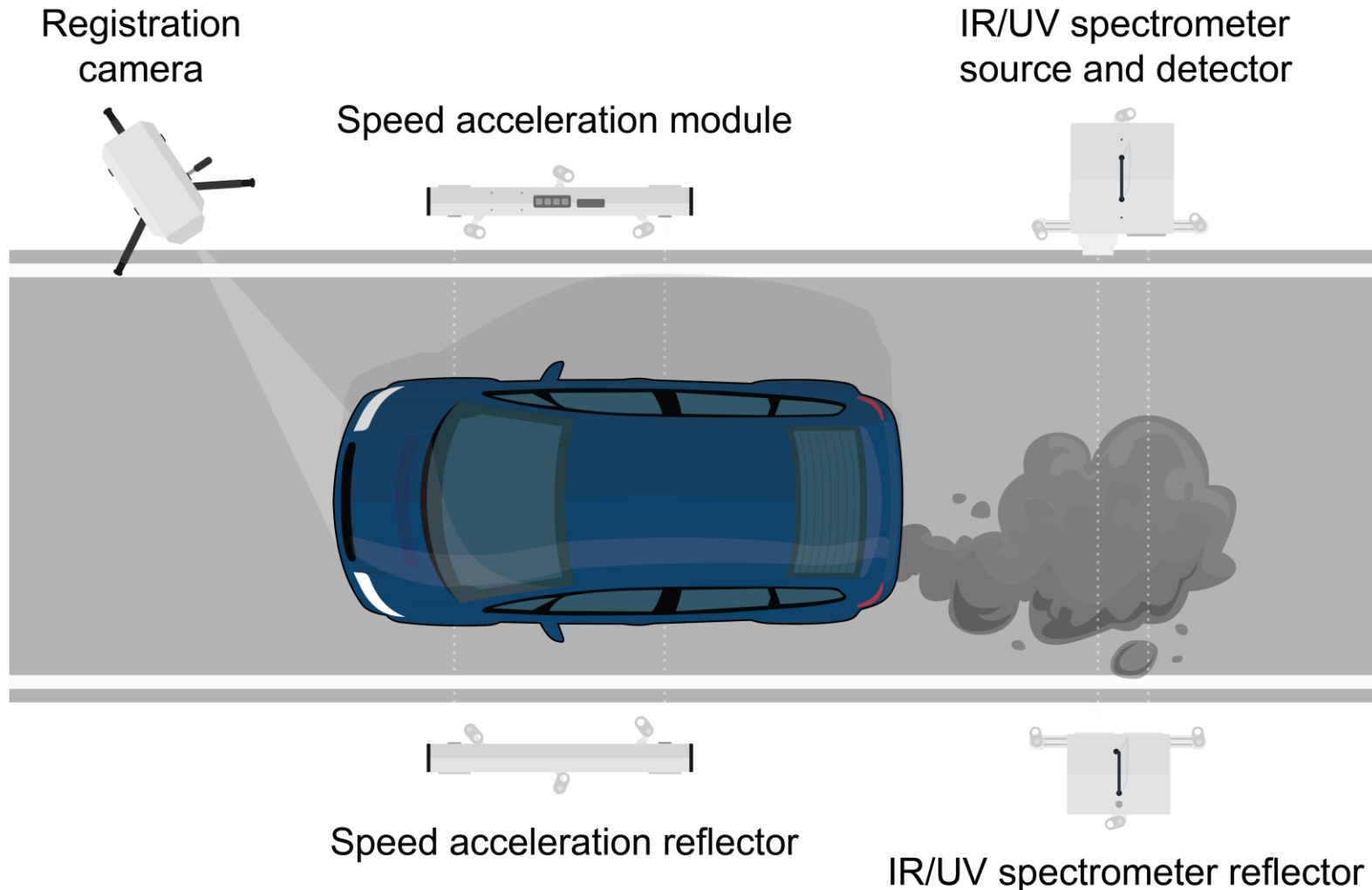
2.

**Measurement
Techniques**

Vehicle Emissions Measurements



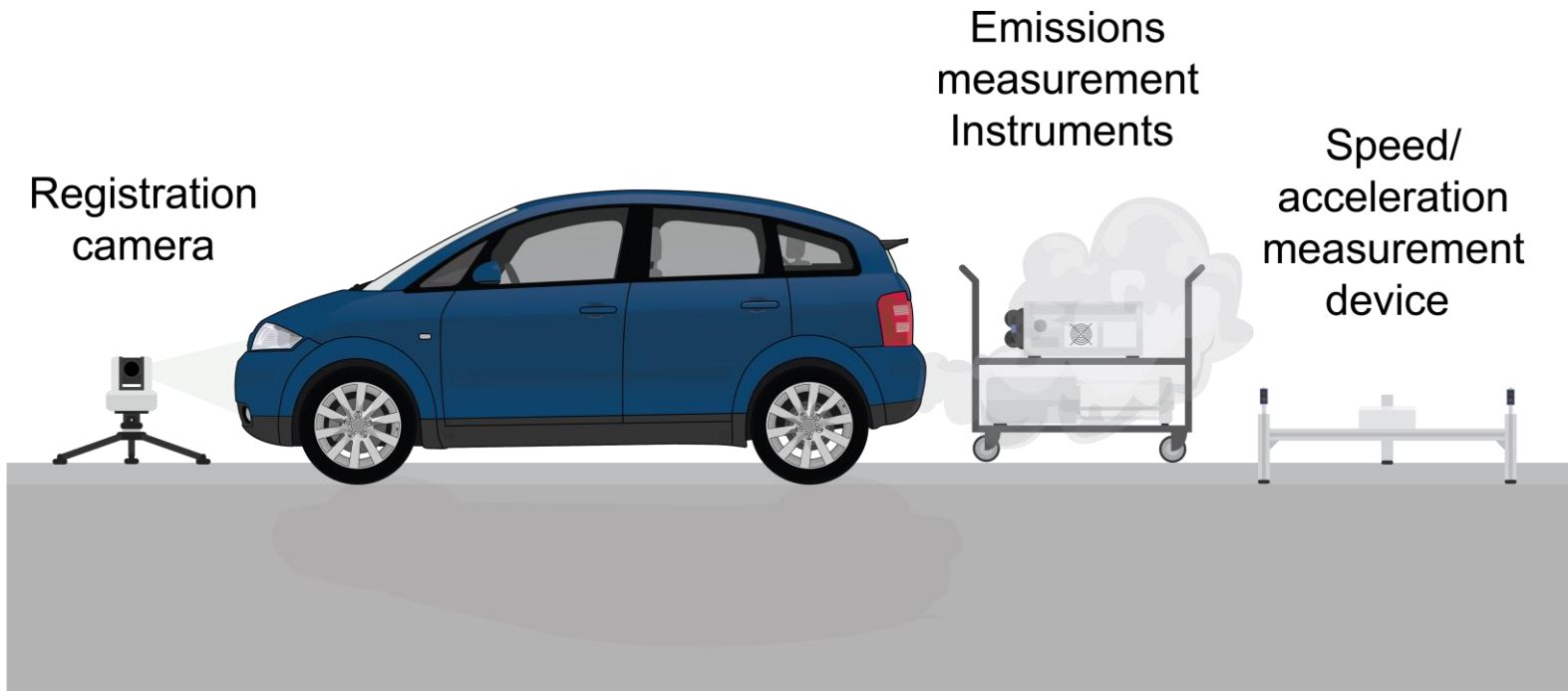
Remote Sensing



Technique Overview

- Cross-road IR and UV snapshot spectroscopy
- Full commercial system
- > 600,000 UK vehicle measurements available made 2012 – 2022
- Aggregate measurements to calculate NH_3 emission factors ($\text{g kg}^{-1} / \text{g km}^{-1}$)
- Opus RSD 4600/5000

Point Sampling



Technique Overview

- Continuous fast-response emissions measurements
- New and developing technique
- Robust linear regression to calculate NH_3 emission factors (g kg^{-1})
- Healthy Photon HT8600 NH_3 Analyser and Airyx ICAD NO_x Analyser



3.

**Research
Results**

Literature Summary

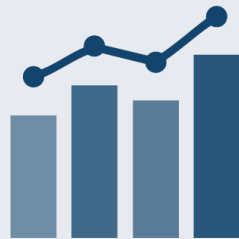
Vehicular ammonia is dominated by **Gasoline cars**⁹



Vehicular ammonia decreasing with new **catalyst technology**⁹



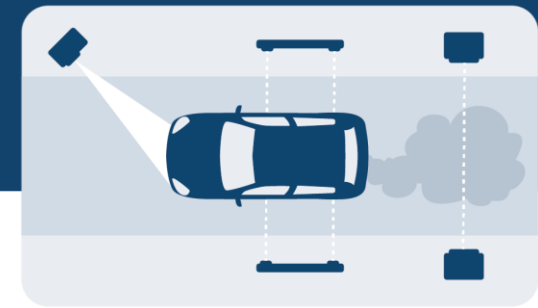
Vehicular ammonia **under-represented** in national inventories¹⁰



Vehicular ammonia contributes towards **PM_{2.5}** formation^{2,3,4}



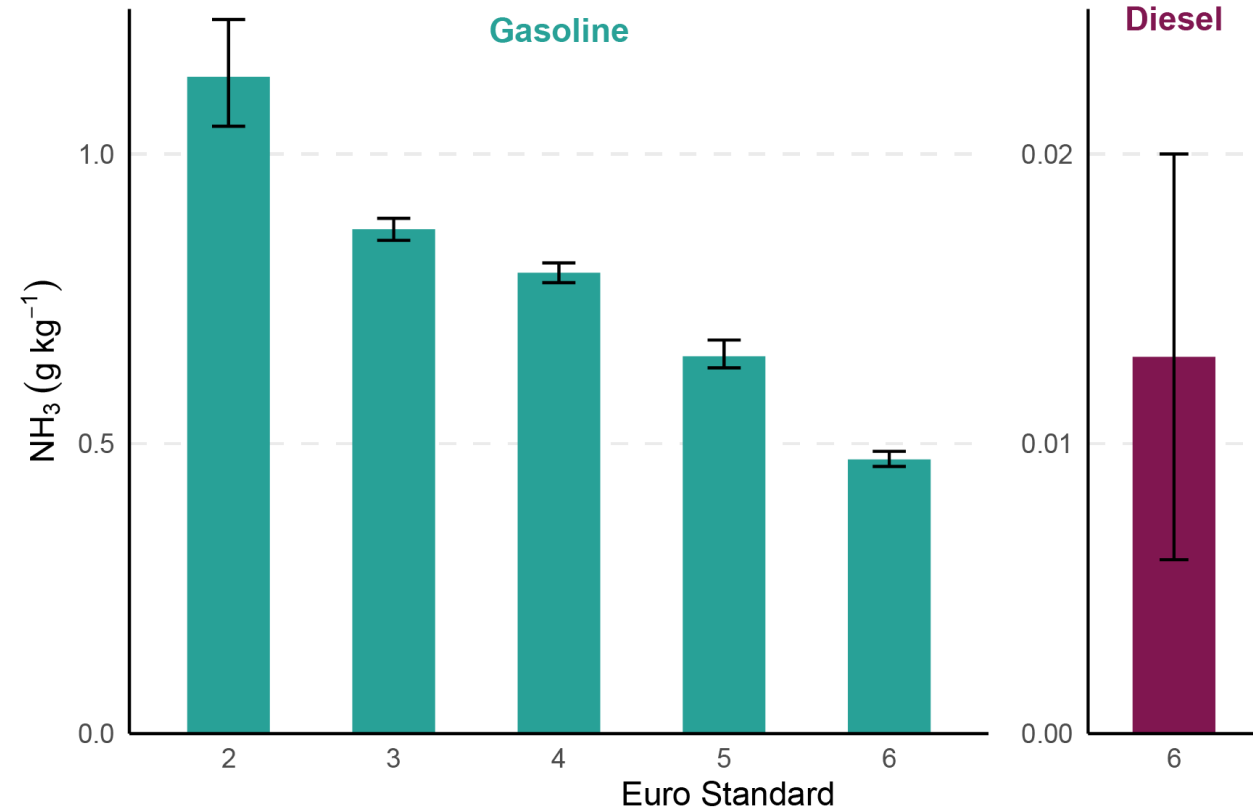
Remote Sensing I



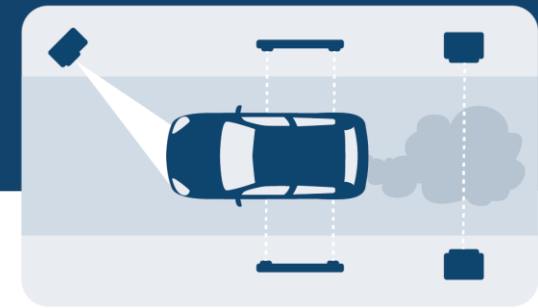
Underestimated Ammonia Emissions from Road Vehicles, N. J. Farren, J. Davison et al., *Environ. Sci. Tech.*, 2020

Results and Insight

- NH_3 emission factors reported for passenger cars (shown right)
- UK passenger car NH_3 emissions **2.6 x higher** than reported (NAEI)
- Increases to **17 x higher** in urban areas



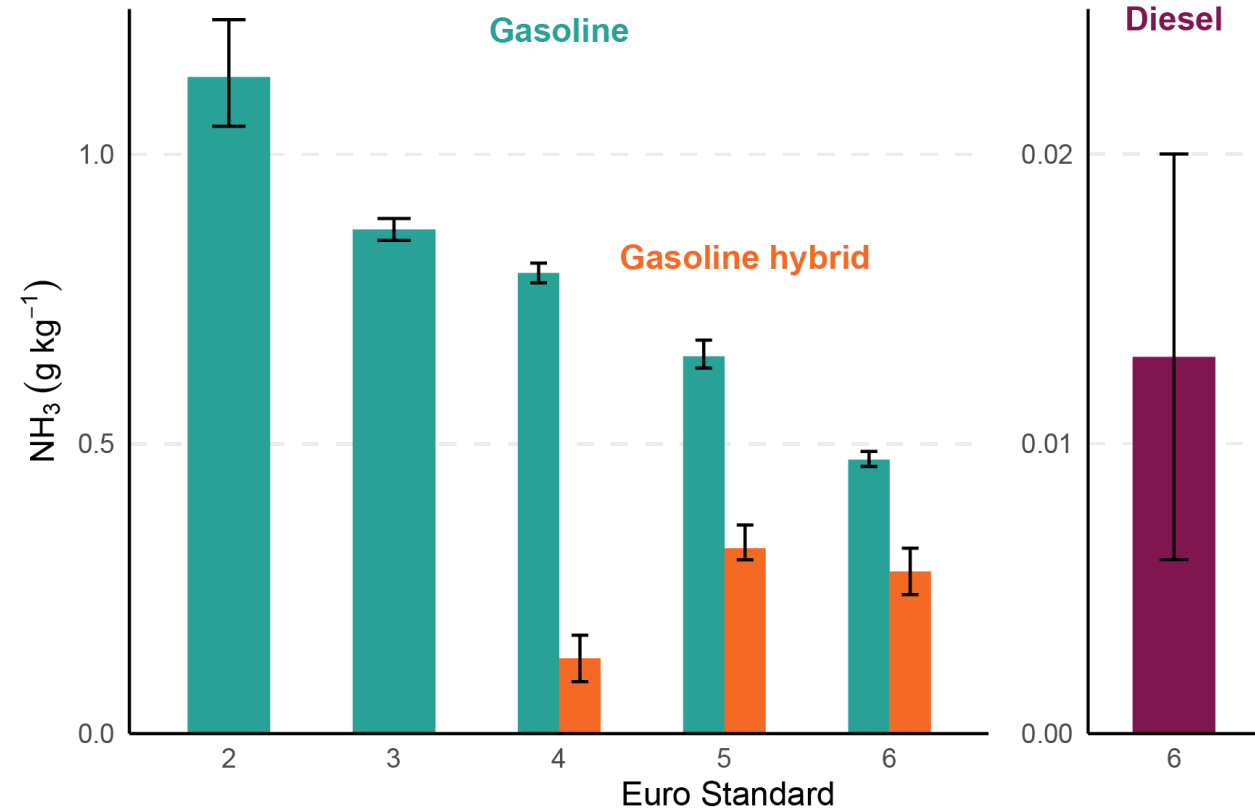
Remote Sensing II



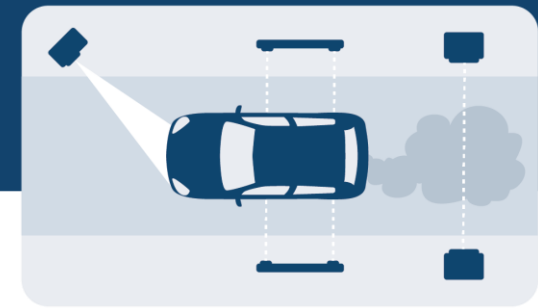
Characterisation of ammonia emissions from gasoline and gasoline hybrid passenger cars, N. J. Farren, J. Davison et al., *Atmos. Environ. X*, 2021

Results and Insight

- NH_3 emission factors reported for hybrid cars (shown right)



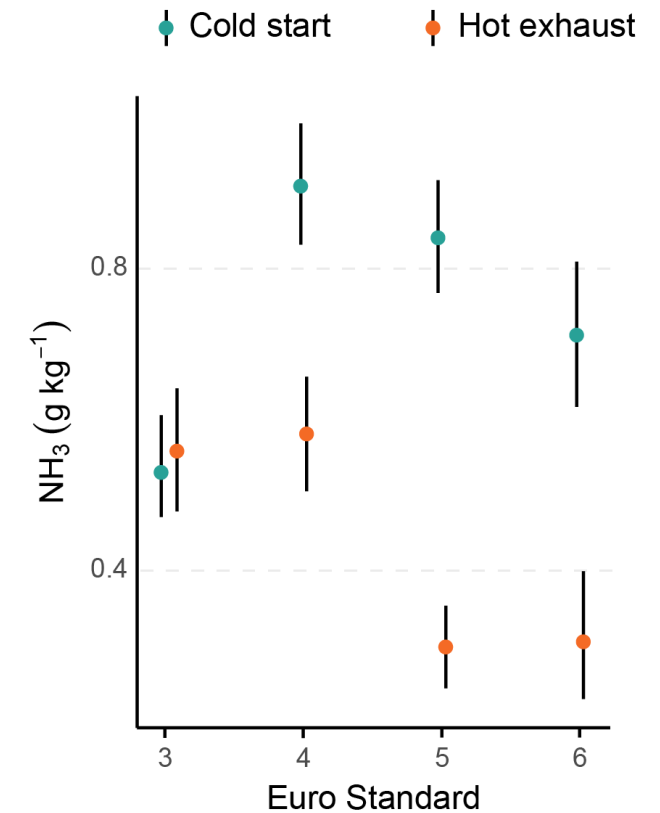
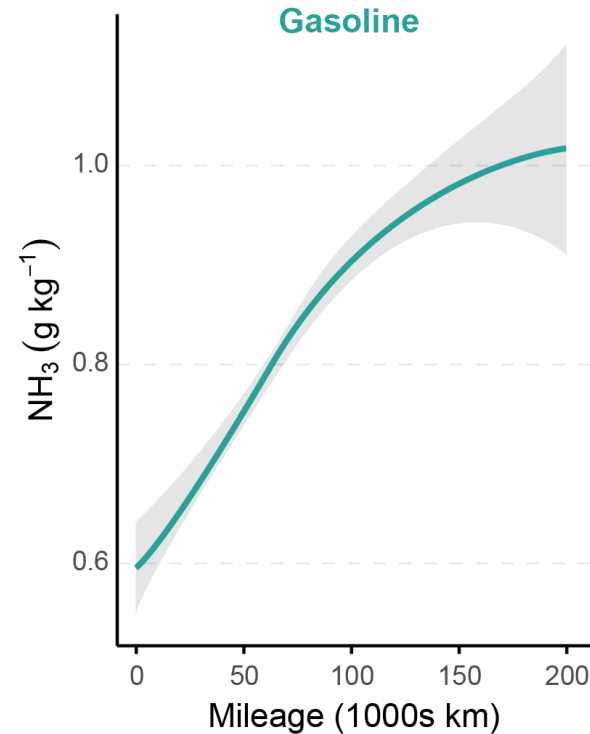
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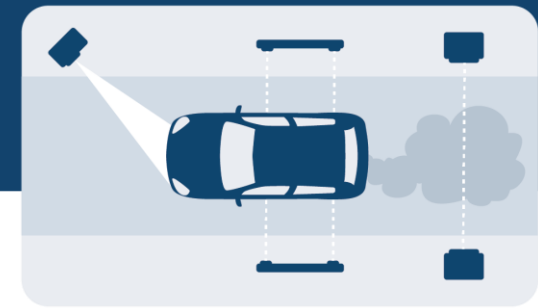
Characterisation of ammonia emissions from gasoline and gasoline hybrid passenger cars, N. J. Farren, J. Davison et al., *Atmos. Environ. X*, **2021**

Results and Insight

- NH_3 emission factors reported for hybrid cars (shown right)
- Increasing NH_3 emissions associated with increasing vehicle mileage
- Increasing NH_3 emissions associated with cold start



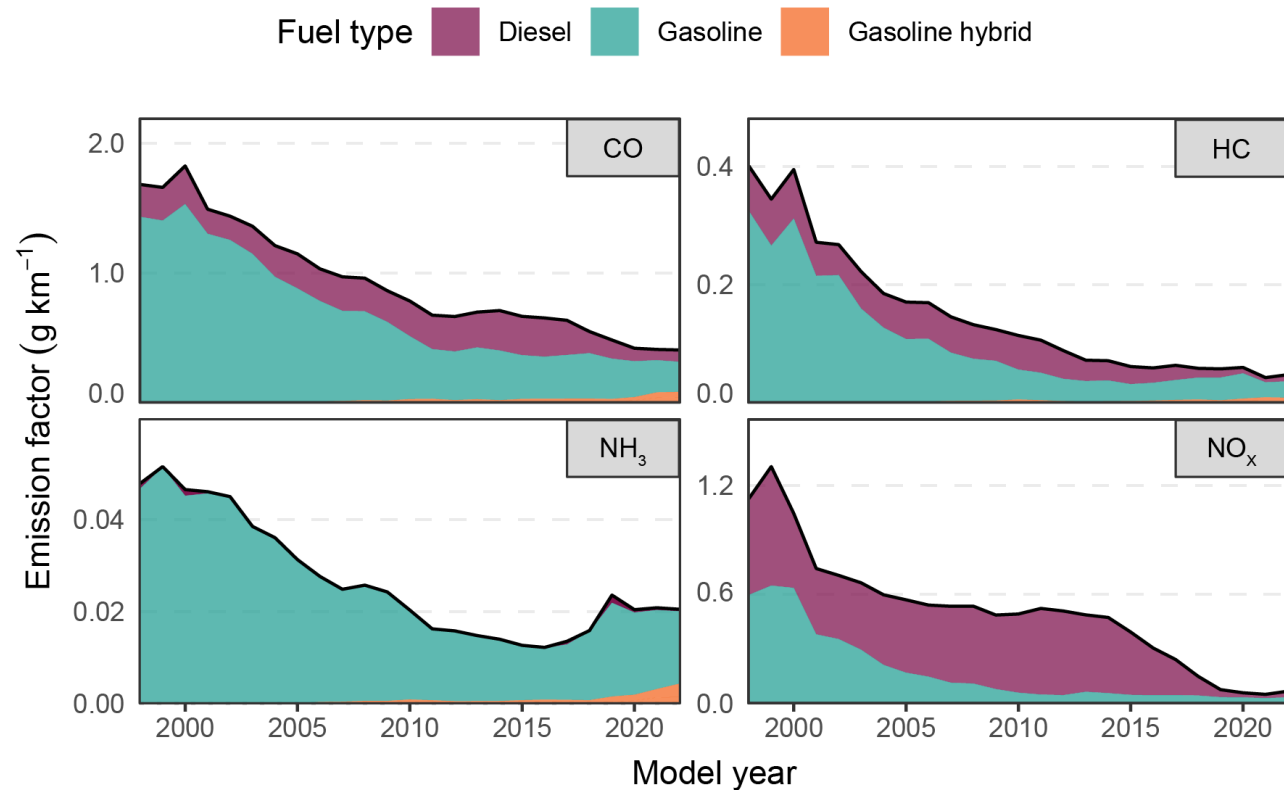
Remote Sensing III



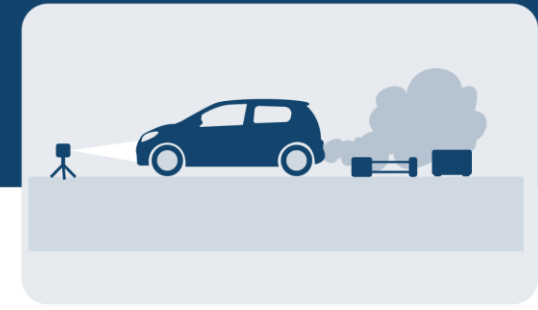
The impact on passenger car emissions associated with the promotion and demise of diesel fuel, S. Wilson, N. J. Farren, et al., *Environ. Int.*

Results and Insight

- Average passenger car NH_3 emission factor increases from 2015
- Dominated by the gasoline and gasoline hybrid car contribution
- Result of changes in the vehicle fleet composition (move away from diesel)



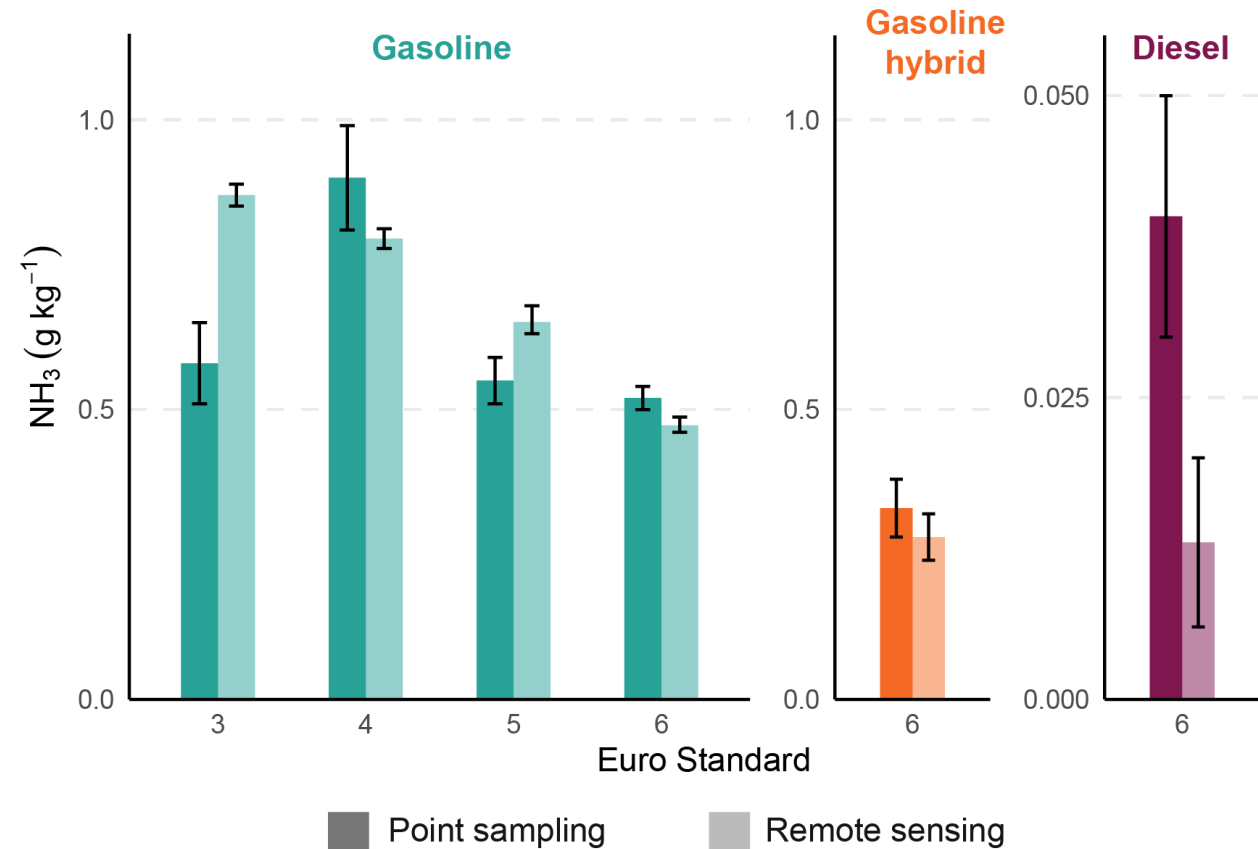
Point Sampling



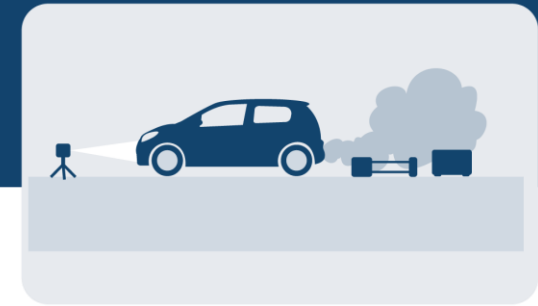
An Ambient Measurement Technique for Vehicle Emission Quantification and Concentration Source Apportionment, N. J. Farren, S. Wilson, et al., *Environ. Sci. Tech.*, 2024

Results and Insight

- First point sampling NH_3 vehicle emissions measurements (UK)
- NH_3 emission factors reported for passenger cars (shown right)



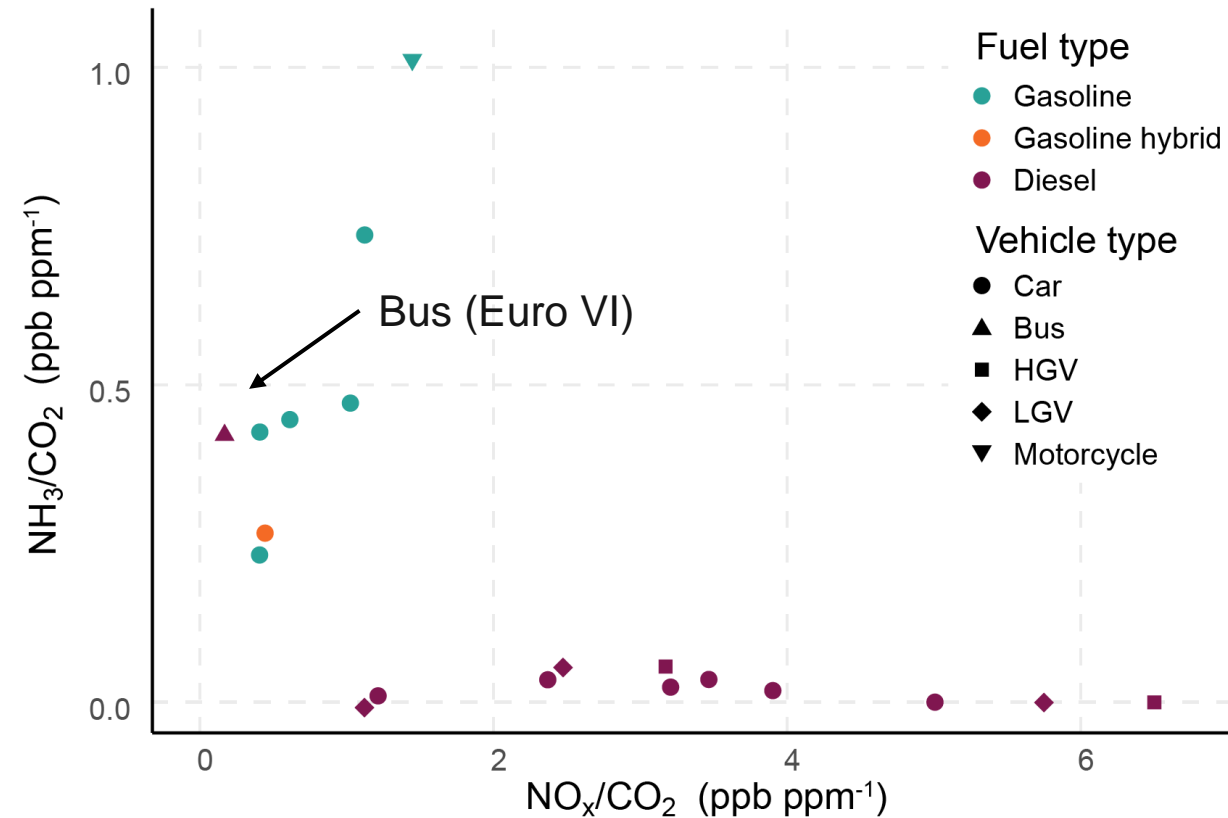
Point Sampling



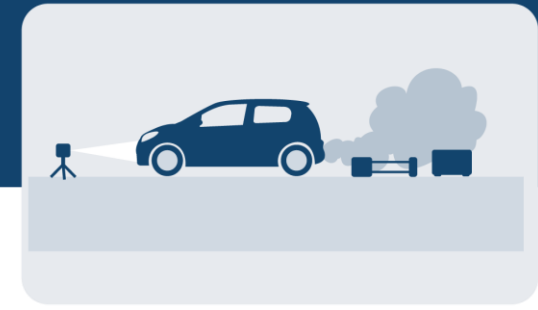
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Results and Insight

- First point sampling NH_3 vehicle emissions measurements (UK)
- NH_3 emission factors reported for passenger cars (shown right)
- High measured NH_3 emissions from buses



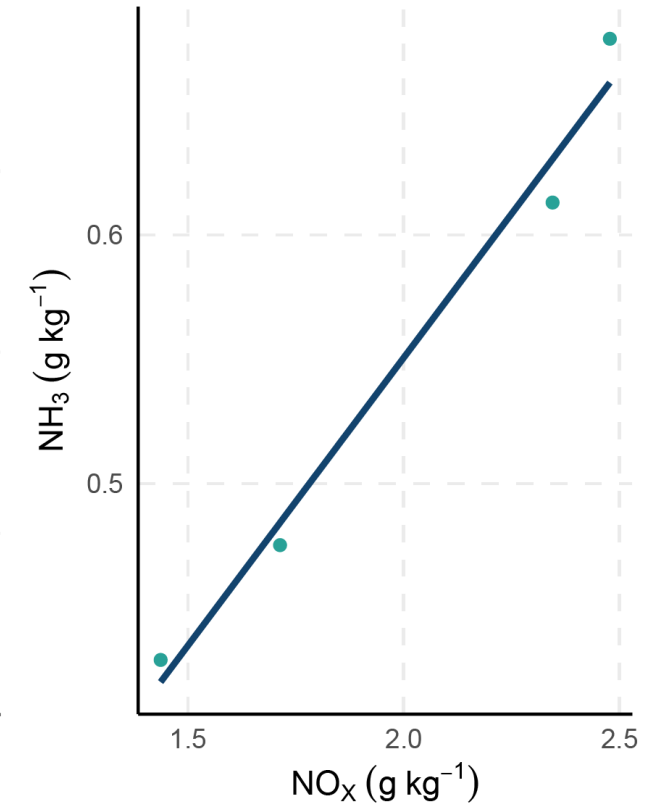
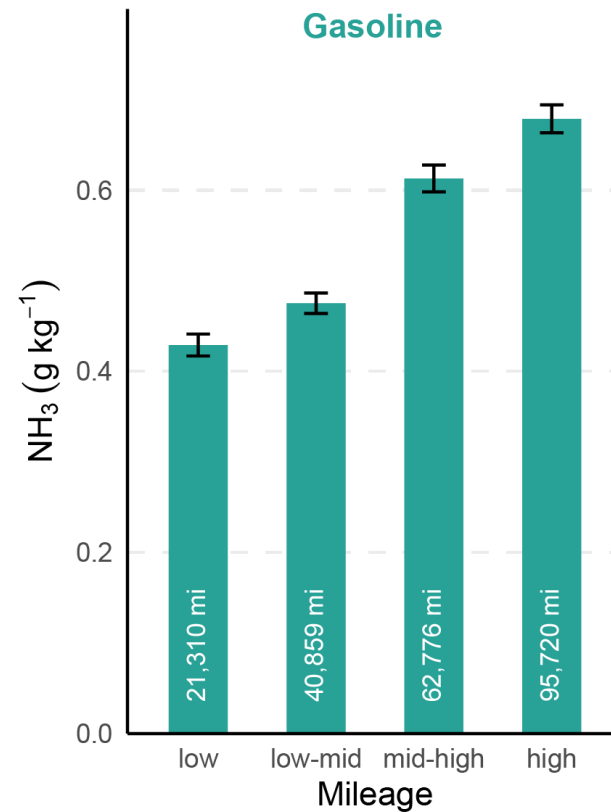
Point Sampling



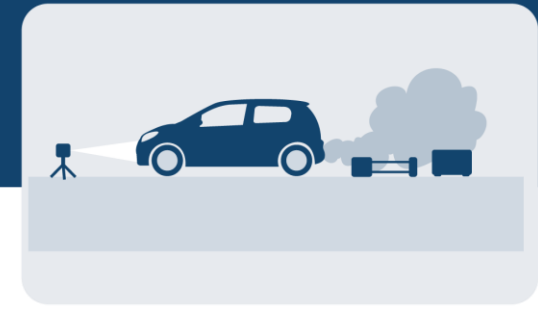
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Results and Insight

- First point sampling NH_3 vehicle emissions measurements (UK)
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- High measured NH_3 emissions from buses
- Increasing NH_3 emissions with increasing mileage



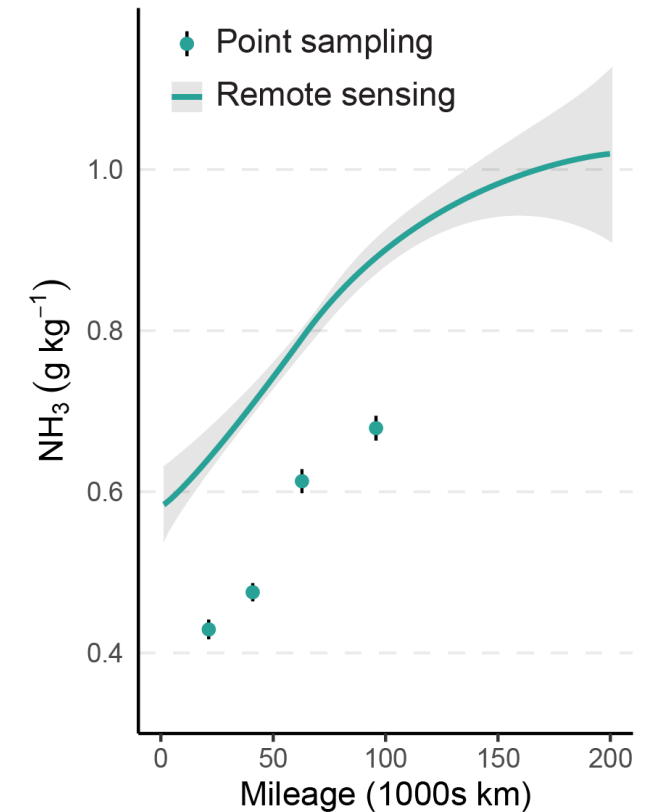
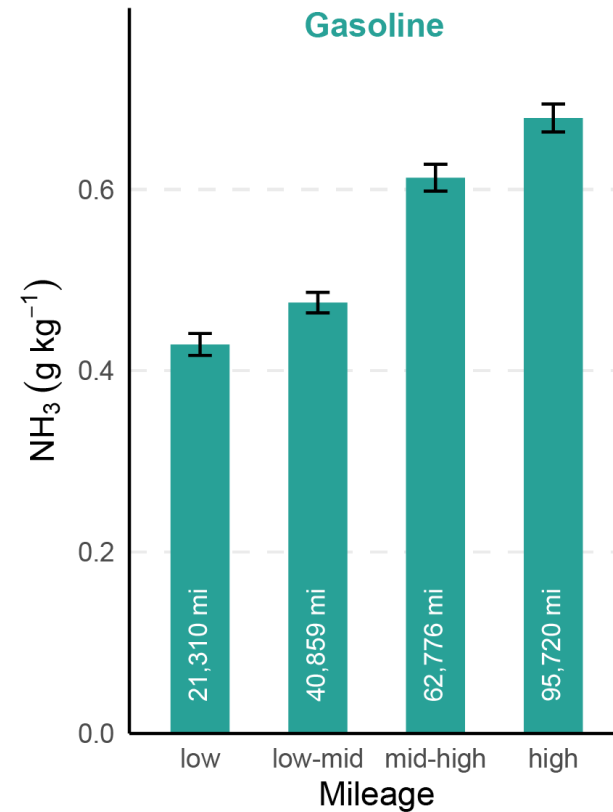
Point Sampling



An Ambient Measurement Technique for Vehicle Emission Quantification and Concentration Source Apportionment, N. J. Farren, S. Wilson, et al., *Environ. Sci. Tech.*, 2024

Results and Insight

- First point sampling NH_3 vehicle emissions measurements (UK)
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4.

Conclusions

Relevance to Welsh Air Quality

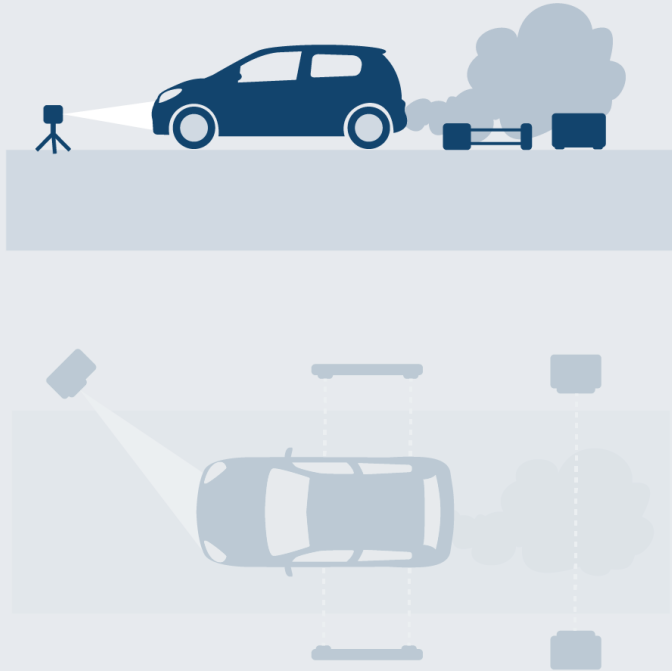


Key Points ¹¹

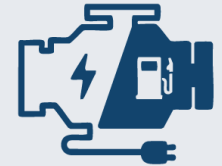
- Share of gasoline/gasoline hybrid vehicles is increasing steadily
- Ammonia emissions from these vehicles will likely increase over time
- To continue improving air quality vehicular ammonia must be considered

Future Work

Real-world NH_3 vehicle emission measurements (**point sampling**)



Focus on **gasoline hybrid** passenger cars (ageing)



Monitor diesel **SCR systems** (HGV + LGV)



Explore impacts of NH_3 on **urban air quality**



Ammonia Emissions from Vehicle Emissions Measurements



Thank you!

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Welsh Air Quality Seminar

28th November 2024

References

1. Ammonia: emission, atmospheric transport and deposition, W. A. Asman et al., *New Phytol.*, **1998**, 139 (1)
2. The need for ammonia abatement with respect to secondary PM reductions in Europe, J. W. Erisman et al., *Environ. Pollut.*, **2004**, 129 (1)
3. Rapid growth of new atmospheric particles by nitric acid and ammonia condensation, M. Wang et al. *Nature*, **2020**, 581 (7807)
4. Fossil Fuel Combustion-Related Emissions Dominate Atmospheric Ammonia Sources during Severe Haze Episodes: Evidence from ¹⁵N-Stable Isotope in Size-Resolved Aerosol Ammonium, Y. Pan, *Environ. Sci. Tech.*, **2016**, 50 (15)
5. UK National Atmospheric Emissions Inventory, <https://naei.energysecurity.gov.uk/air-pollutants/ammonia>, Accessed: 2024-11-02
6. UK Office for National Statistics: Towns and cities, characteristics of built-up areas, <https://www.ons.gov.uk>, Accessed: 2024-11-02
7. Controlling automotive exhaust emissions: Successes and underlying science, M.V. Twigg, *Phil. Trans. R. Soc. A*, **2005**, 363
8. European Commission, Automotive Industry, https://single-market-economy.ec.europa.eu/sectors/automotive-industry_en, Accessed: 2024-11-02
9. Trends in on-road vehicle emissions of ammonia, A. J. Kean et al., *Atmos. Environ.*, **2009**, 43 (8)
10. Vehicle Emissions as an Important Urban Ammonia Source in the United States and China, K. Sun et al., *Environ. Sci. Tech.*, **2016**, 51 (4)
11. Department for Transport Vehicle Statistics, <https://www.gov.uk/government/collections/vehicles-statistics>, Accessed: 2024-11-11