Report

Development of CREAM Emissions Model Version 2

7 February 2025

Document Control

Document Title: Development of CREAM Emissions Model Version 2

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Revision History

01 07/02/2025

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Contents

Tables

Figures

1 Introduction

1.1 In February 2020, Air Quality Consultants Ltd. (AQC) published a report: 'Ammonia Emissions from Roads for Assessing Impacts on Nitrogen-sensitive Habitats'[1]. This highlighted the importance of including ammonia (NH_3) emissions from road traffic when assessing the effects of local roads on biodiversity. Prior to this, it was common for the effects of road traffic on nitrogen-sensitive habitats to be assessed solely based on emissions of nitrogen oxides (NOx).

1.2 At that time there were no readily available emissions factors for traffic-related NH_3 other than those in the EU Emissions Inventory Guidebook[2], which AQC's 2020 report showed were significant underestimates[3]. It was recognised that, without access to easy-to-use emissions factors, many air quality assessments would continue to omit the contribution of NH_3, potentially leading to a lack of protection for biodiversity. AQC thus combined the limited information available at that time to produce Version 1 of the 'Calculator for Road Emissions of AMmonia' (CREAM) model[4], which it made freely available for any organisation to use. In recognition of the significant uncertainties around this subject, CREAM V1 sought to err on the side of caution with respect to future-predictions, in particular the effect of degradation over time of three-way-catalysts and the use of internal combustion engines in hybrid vehicles.

1.3 Since the 2020 report[1] was published, there has been widespread acceptance that NH_3 should be included in air quality assessments of road traffic on biodiversity. The CREAM model has thus seen widespread use[5]. In the intervening period, the research community has also continued to gather information regarding NH_3 emissions from road vehicles[6]. The uptake of electric and hybrid vehicles has also accelerated significantly[7]. The CREAM model has therefore been updated to take account of this new information. This report describes the development of CREAM V2[8]. AQC is not paid to produce CREAM and so development of CREAM V2 has been protracted by other priorities.

1.4 It remains the case that CREAM is intended to facilitate the ready inclusion of traffic-related NH_3 into air quality modelling studies and, with this aim, it makes many pragmatic assumptions based on the information which has been reviewed. As more information becomes available, it will be possible to revise and refine these assumptions.

1.5 It is relevant to note that where there was previously some scepticism of there being any need to consider traffic-related NH_3 at all[9], subsequent attention has given this issue a much higher profile.

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[1] https://www.aqconsultants.co.uk/CMSPages/GetFile.aspx?guid=3aa4ec2e-ee4e-4908-bc7a-aeb0231b4b37

[2] https://www.eea.europa.eu/themes/air/air-pollution-sources-1/emep-eea-air-pollutant-emission-inventory-guidebook

[3] A conclusion which has since been reported by others[29].

[4] Available to download at: https://www.aqconsultants.co.uk/resources

[5] For example, it is integrated into the current version of the UK Air Pollution Assessment Service (UKAPAS) Government Digital Service.

[6] e.g. https://uk-air.defra.gov.uk/assets/documents/reports/cat09/2112201014_1272021_Exaust_Emissions_From_Road_Transport.pdf

[7] e.g. https://www.smmt.co.uk/2025/01/record-ev-market-share-but-weak-private-demand-frustrates-ambition/

[8] AKA 'double cream'. CREAM V1 was released as 'V1A' to allow for small future revisions. These revisions were not necessary (there is only one V1 of CREAM) and so 'V1A' is referred to as 'V1' in this report. Similarly CREAM V2 is released as V2A but since no revisions to V2 have yet been made, V2A is referred to as V2 in this report.

[9] For example, during the 2019 Examination in Public of the Wealden Local Plan, Natural England argued that emissions of NH_3 from road traffic should not be included in the assessment since this deviated from common practice.

This is potentially at the expense of action on other emissions sources. It remains the case that, in rural areas which are often of most interest when assessing air quality effects on biodiversity, traffic-related NH_3 emissions are usually small compared with those from agricultural sources. While it continues to make little sense to quantify the effects of road transport on biodiversity without including NH_3, there may often be much more significant local NH_3 emissions which might benefit from scrutiny. CREAM only calculates emissions from road traffic.

2 Emissions Data

Types of Data

2.1 In very broad terms, road transport emissions data might come from:

- laboratory dynamometer tests, where engines or whole vehicles are run on a bench or 'rolling road';
- Portable Emissions Measurement Systems (PEMS), where tested vehicles are driven on open roads;
- remote sensing studies, in which equipment is placed in a fixed position at the roadside and samples the plume of vehicles that pass; and
- pairing measurements of ambient concentrations with a dispersion-type model. This might be inverse dispersion modelling or forward-run modelling used to either infer, calibrate, or validate source emissions rates.

2.2 Details of each these methods are provided in previous AQC reports [10,1].

2.3 Characterising emissions of NH_3 presents significant challenges. Not only is NH_3 a challenging gas to measure using physical contact methods[11], but its emission from road vehicles can be sporadic. This has been shown effectively by Prebble *et al*. (2019)[12], who used remote sensing to measure emissions from Heavy Goods Vehicles (HGVs) equipped with Selective Catalytic Reduction (SCR) in California (Figure 1). A striking feature of Figure 1 is that the interquartile ranges (purple boxes) all lie so far below the means (black dots). This shows that the number of records is dominated by HGVs with very low (often essentially undetectable) emissions, with the mean affected by small numbers of high-emission vehicles. Measurements made on small numbers of vehicles might therefore not provide a good indication of fleet average emissions since, with small sample sizes, the mean becomes very sensitive to the precise set of vehicles sampled (i.e., there might be no high emitting vehicles in the sample, or lots of them, solely because of chance)[13].

2.4 PEMS studies are usually restricted to relatively few vehicles, but they do cover whole drive cycles. Remote sensing can capture emissions from many more vehicles, but measurements are made at fixed points on the road[14] and so might also not capture the full variability in emissions. Roadside ambient measurements are typically driven by very large numbers of vehicles[13], but are also constrained to reflect specific points on a road, and thus specific driving patterns.

2.5 In principle, combining data from more than one source can help minimise these uncertainties. For example, the weaknesses of remote sensing might be tested using PEMS data, and vice versa. In practice, however, such an approach is not straightforward. CREAM V1 took emissions data principally from remote sensing studies, albeit with a qualitative inclusion of some PEMS data. The remote sensing data were then combined with ambient measurements, using the ADMS-Roads dispersion model to ensure that the base-year concentration predictions matched the available measurements.

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[10] https://www.aqconsultants.co.uk/CMSPages/GetFile.aspx?guid=a13b63aa-02ff-4bf1-8bbb-aa0e86aad4dc

[11] e.g. https://www.sciencedirect.com/science/article/abs/pii/S1352231018308185

[12] Environ. Sci. Technol. 2019, 53, 14568−14576

[13] Even a relatively quiet road carries several million vehicles per year and several tens of thousands of HGVs. Emissions affecting roadside biodiversity are thus much more likely to comprise a 'typical' balance of high- and low-emitting vehicles.

[14] Usually at a slight incline.

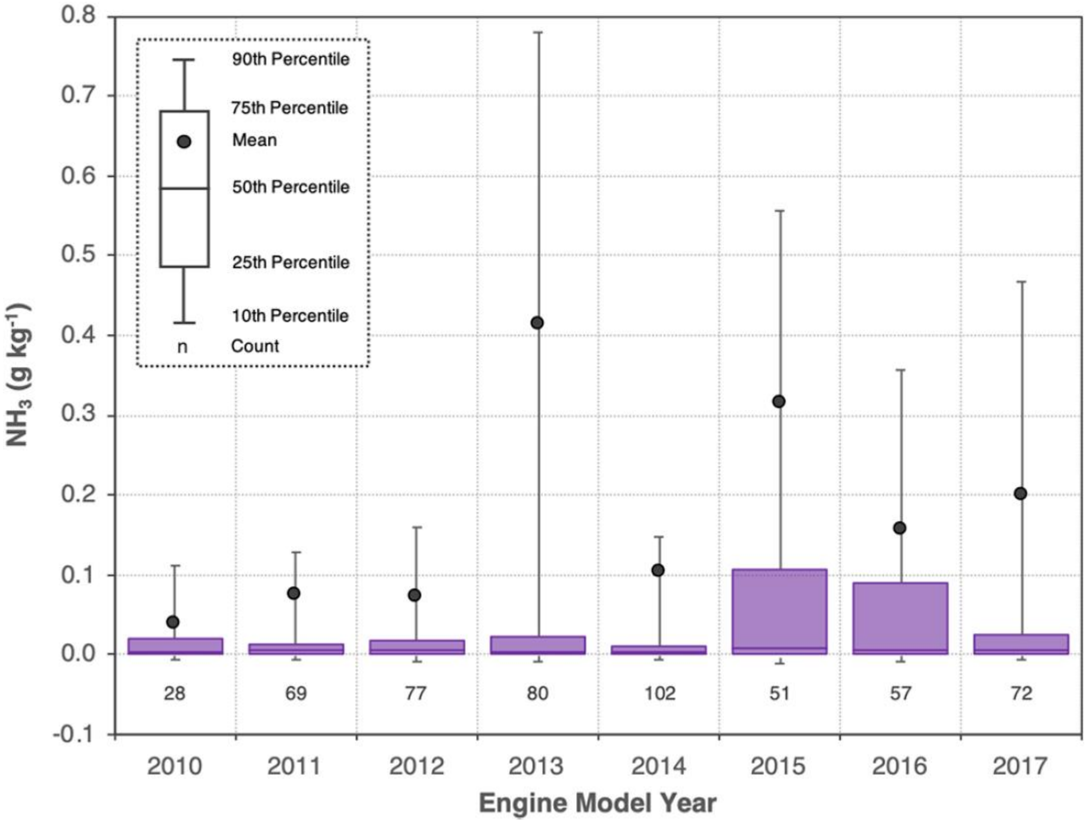

Figure 1: Distribution of Measured NH_3 Emissions by Engine Model Year for SCR-Equipped HGVs Measured in 2018 (Reproduced from Prebble et al., 2019[12])

2.6 On balance, given the known variability in NH_3 emissions from different vehicles, it is considered that remote sensing provides advantages over PEMS data for NH_3, since it can sample so many more vehicles, albeit at fewer points on a drive cycle. This update to CREAM has therefore continued to rely on remote sensing and ambient roadside measurements.

Petrol Cars

2.7 Petrol cars represent the most significant source of traffic-related NH_3 in the UK. At the time that CREAM V1 was prepared, it was understood that NH_3 emissions from newer petrol cars were lower than those from older models. What was not known was the extent to which this was driven by improvements to the vehicles and their catalysts (i.e. causing the newer vehicles to be emit less), and the extent to which it was caused by ageing of the catalysts (i.e. causing the older vehicles to emit more)[6]. Because of this uncertainty, and to avoid under-predicting NH_3 emissions in the future, CREAM V1 assumed that all observed between-model differences in emissions were caused by catalyst ageing (i.e. causing older vehicles to emit more than when they were new). Based on the assumption that the average age of the vehicle fleet would remain approximately constant over time, it was thus assumed that there would be no change over time to average NH_3 emissions per petrol car. CREAM V1 also took no account of the speed-dependence of emissions, since this information was unavailable.

Emissions from Petrol Cars by Speed and Vehicle Milage

2.8 The relative importance of technical improvements vs catalyst ageing was examined by Farren *et al*. (2021)[15]. They used 210,000 remote sensing measurements, collected at 37 sites across 14 regions of the UK between 2017 and 2020, to evaluate a range of factors affecting NH_3 emissions from petrol cars. This included separating out the effects of increased catalyst age from those of progressive European type approval emissions standards ('Euro standards'). They showed that while catalyst ageing does remove a sizeable proportion of the apparent benefits which appear from a simple comparison of different Euro standards, some of these benefits remain when comparing vehicles of the same mileage (using mileage as an indicator of catalyst ageing). While it would be inappropriate to predict future emissions for each Euro standard based solely on historic tests without taking account of vehicle ageing, Farren *et al*. (2021)[15] provide a mechanism for considering both Euro standard and vehicle ageing separately, with emissions also characterised by average vehicle speed. More recent work in this area[16,17] has identified broadly similar findings and the values from Farren *et al*. (2021)[15] are therefore considered suitable for use here.

2.9 Table 1 is reproduced from Farren *et al*. (2021)[15]. It predicts average emissions from different types of petrol cars as a function of average speed using the approach developed by Davison *et al*. (2020)[18]. Using total vehicle 'mileage'[19] as a measure of catalyst ageing, the same authors predict that average NH_3 emissions factors from Euro 3 and Euro 4 cars increase by around 35% over the first 100,000 km of a vehicle's life, while for Euro 5 cars this is 17% over the first 100,000 km. There were insufficient mileage data for Euro 6 cars to make the same assessment. Emissions were shown to increase with mileage at an approximately linear rate over the first 100,000 km, after which time the increases appear to be more gradual (Figure 2).

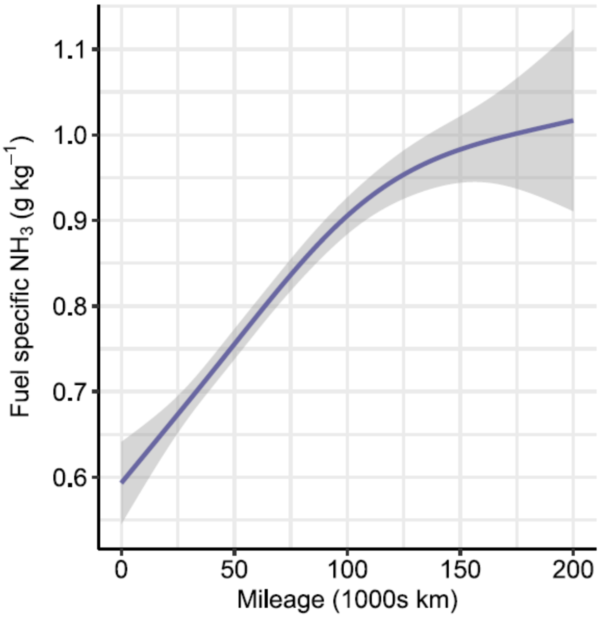

Figure 2: NH_3 Emissions as Function of Vehicle Milage for Petrol Cars (Reproduced from Figure 3 of Farren *et al*., 2021[15])

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[15] https://www.sciencedirect.com/science/article/pii/S2590162121000174
[16] https://www.sciencedirect.com/science/article/pii/S0160412023006037
[17] https://pubs.acs.org/doi/full/10.1021/acs.est.4c07907
[18] https://www.sciencedirect.com/science/article/pii/S0048969720332083
[19] The term mileage is used even when distances are measured in km.

Table 1: Average Emissions Factors for NH_3 (g/km) from Petrol Cars (Reproduced from Table S6 of Farren *et al.*, 2021[15])

Engine Size (L)	Speed (kph)	Euro 2	Euro 3	Euro 4	Euro 5	Euro 6
<1.4	[1,5]	0.51	0.25	0.31	0.23	0.17
<1.4	[5,10]	0.22	0.13	0.14	0.10	0.08
<1.4	[10,20]	0.13	0.08	0.09	0.06	0.05
<1.4	[20,40]	0.08	0.06	0.06	0.04	0.03
<1.4	[40,100]	0.06	0.05	0.05	0.03	0.02
1.4-2.0	[1,5]	0.60	0.31	0.40	0.35	0.30
1.4-2.0	[5,10]	0.24	0.16	0.17	0.14	0.12
1.4-2.0	[10,20]	0.14	0.11	0.10	0.08	0.07
1.4-2.0	[20,40]	0.09	0.07	0.06	0.05	0.04
1.4-2.0	[40,100]	0.07	0.06	0.05	0.04	0.03
>2.0	[1,5]	0.48	0.60	0.40	0.36	0.19
>2.0	[5,10]	0.23	0.25	0.17	0.14	0.09
>2.0	[10,20]	0.14	0.14	0.10	0.08	0.05
>2.0	[20,40]	0.09	0.09	0.07	0.05	0.04
>2.0	[40,100]	0.08	0.07	0.05	0.04	0.03

2.10 Defra's Emissions Factors Toolkit (EFT)[20], which is widely used to predict emissions of NOx, also takes account of lifetime degradation of vehicles. Prior to 2024, embedded within the EFT were cumulative milage predictions by vehicle type. However, these were very old, having first been published by the Transport Research Laboratory (TRL) in 2009. The 2024 update to the EFT (to EFT V12) replaced these with constant values, which do not change over time. For example, in EFT V12, emissions from Euro 2 petrol cars are uplifted substantially to take account of lifetime degradation, with this uplift not changing by year, however emissions from Euro 5 petrol cars are not uplifted to account for degradation, even when the assessment year is 2050.

2.11 In this respect, it was considered inappropriate to follow the EFT, since this would assume that vehicles do not degrade over time. However, the TRL forecasts (which were, for example, developed before it was known when Euro 6 would come into force) are considered too out of date to use. A basic vehicle ageing model has therefore been developed. This has been based on the Department for Transport's (DfT's) anonymised MOT data[21] (up to an including 2023), DfT's most recent published vehicle registration data[22], the National Travel Survey[23], and publications by the European

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[20] https://laqm.defra.gov.uk/air-quality/air-quality-assessment/emissions-factors-toolkit/

[21] https://www.data.gov.uk/dataset/e3939ef8-30c7-4ca8-9c7c-ad9475cc9b2f/anonymised_mot_test

[22] https://www.gov.uk/government/collections/vehicles-statistics

[23] https://www.gov.uk/government/statistics/national-travel-survey-2022/national-travel-survey-2022-factsheet-accessible

Automobile Manufacturers' Association (ACEA)[24] and Society of Motor Manufacturers and Traders (SMMT)[25,26]. Key assumptions are that:

- on average, petrol cars travel 6,200, 7,200, and 7,800 miles/yr (9,978, 11,587, and 12,553 km/yr) for small (<1400cc), medium (1400 to 2000cc), and large (>2000cc) vehicles respectively;
- the rate at which vehicles accumulate miles reduces with age (showing a 45% reduction in a vehicles first 8 years);
- on average, 95% of vehicles survive their first 5 years, and 77% survive 10 years with an accelerating decline thereafter. Vehicles no longer continue to accumulate mileage when they reach 20 years old. These survival rates are assumed to increase slightly with Euro standard and with vehicle engine size;
- a 'Euro 6+' category is used (i.e. Euro 6 + later standards). This encompasses all future Internal Combustion Engine (ICE) registrations regardless of Euro standard (and therefore aligns with the EFTV12 fleet data, which do not include post-Euro 6 standards and so effectively assumes that all future ICE registrations are Euro 6); and
- pre-2024 registrations are based on real data, while future registrations have been estimated based on historic trends. ICE registrations (which for these purposes include hybrids) are assumed to fall 60% by 2030 and by 99% by 2035. These dates are chosen to align with current policy expectations, but the registration values are simplistic estimates.

2.12 This vehicle ageing model is intended to provide indicative data to allow an approximation of the effects of vehicle ageing on NH_3 emissions. The precision of the model is at least commensurate with how it is used in CREAM, but it is not intended to provide a complete forecast of future vehicle use. While all of the assumptions are not set out in detail here, all the vehicle mileage data used in CREAM V2 are shown in Figure 3.

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[24] https://www.acea.auto/files/ACEA-Report-Vehicles-on-European-roads-.pdf

[25] https://www.smmt.co.uk/wp-content/uploads/SMMT-Sustainability-25th-Report-2024.pdf

[26] Owing to the volume of data in the DfT databases, a Large Language Model was used to interrogate the published data and subsequently to assist compiling the model. The assumptions and model predictions have been reviewed by the authors.

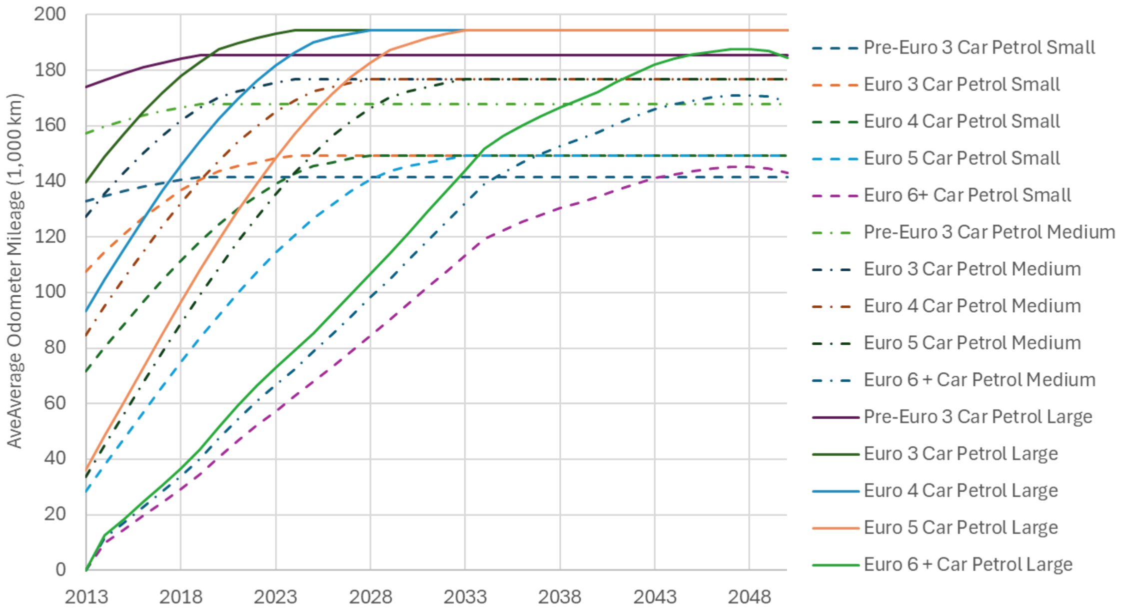

Figure 3: Average Odometer Mileage (in km) of Petrol Cars Assumed in Cream V2

2.13 The records in Table 1 do not reflect a fleet with zero mileage (i.e., they are not the starting point for the increases shown in Figure 2). The values in Table 1[27] were taken to align with the average assumed vehicle mileage in 2019. Up to a mileage of 100,000 km, emissions from pre-Euro 5 cars have been assumed to increase at a rate of 0.00035% per km (i.e. 35% over 100,000 km), while for Euro 5 and Euro 6 cars, the rate of change is assumed to be 0.00017% (17% over 100,000 km). At mileages between 100,000 km and 200,000 km, emissions from all types of petrol cars are assumed to increase following the trajectory shown in Figure 2, which has been approximately described here as:

$$a = -9.9278 \times 10^{-11} \times b^4 + 1.0423 \times 10^{-7} \times b^3 - 2.3761 \times 10^{-5} \times b^2 + 2.6522 \times 10^{-3} \times b$$

2.14 Where ‘a’ is the additional NH_3 emissions at mileage ‘b’ as a fraction of the emissions at 100,000 km, and ‘b’ is the additional mileage beyond 100,000 km (i.e. total mileage minus 100,000 km) in 1,000 km increments.

2.15 For example, if NH_3 emissions from a vehicle at 100,000 km are assumed to be 0.1 g/km, then emissions at 166,000 km would be 10% higher than this (the equation above gives a value of 10% at a value of 66,000 km for term ‘b’). Total emissions at 166,000 km would thus be 0.11 g/km.

2.16 Fleet average emissions are not the same thing as emissions from a fleet average vehicle. Fleet average vehicle mileage summarises a spectrum including both high and low mileage vehicles. Using fleet average statistics thus only provides a relatively crude approximation of calculating emissions from each individual vehicle separately. In practice, though, this limitation is common to many predictions of vehicle emissions and cannot practically be addressed here.

Cold Start Emissions from Petrol Cars

2.17 Cold petrol engines (i.e. during the period after start-up) are supplied with a fuel-rich air-fuel ratio which can promote the formation of NH_3. Farren *et al.* (2021)[15] used their data to approximate the additional cold-start NH_3 penalty, but cautioned that the average ambient temperature during their tests of cold engines was relatively warm (20°C) and that cold-start emissions might be higher when

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[27] Which were derived from tests carried out from 2017-2020 but not with equal sample numbers collected in each year.

the weather is cooler. Figure 4 summarises their results and shows how much more important cold starts are for NH_3 than for NOx from petrol cars[28]. Table 2 shows the relative increase that cold-start emissions cause over those of hot exhausts.

2.18 The proportion of cold engines on a road is location-specific and not, therefore, estimated in any of the activity data built into the EFT. The approach for CREAM V2 has been to allow users the option to specify the proportion of cold engines for each road link; it is expected that this will often be estimated based on location and proximity to likely trip-origin locations. Where users enter an assumed proportion of the fleet with cold engines on a given road link, the additional emissions have been calculated using the values in Table 2. No additional cold-start emissions are assumed for Euro 3 or earlier vehicles, and neither have the hot emissions been reduced despite Farren *et al*. (2021)[15] calculating lower emissions from Euro 3 vehicles when cold.

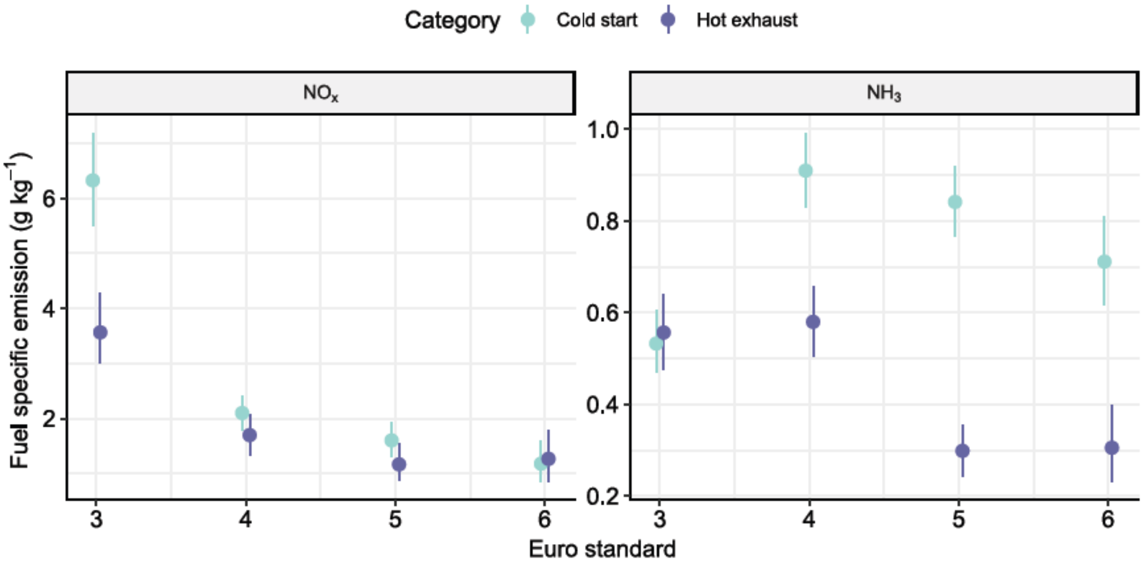

Figure 4: Emissions of NOx and NH_3 from Petrol Cars, Split by Whether Vehicles are Likely to have Hot or Cold Engines (Reproduced from Figure 4 of Farren *et al*., 2021[15])

Table 2: Ratio of Mean Cold-start to Mean Hot Exhaust Emissions from Petrol Cars (Calculated from Table S4 of Farren *et al*., 2021[15])

Euro Standard	Difference between Cold and Hot Emissions as % of Hot Emissions
Euro 3	-5%
Euro 4	57%
Euro 5	180%
Euro 6	129%

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[28] The cold-start penalty for NOx from diesel cars tends to be greater than for petrol cars, particularly when SCR is used.

Diesel Cars

2.19 As explained in AQC's 2020 report[1], diesel cars, even those with SCR, are a much less important source of NH_3 than petrol cars. CREAM V1 estimated average NH_3 emissions for different Euro standards of diesel cars, derived from early published remote sensing data. These were all a small fraction of those predicted from petrol cars. Farren *et al*. (2020)[29] used a similar method to the work described above for petrol cars to estimate NH_3 emissions from Euro 6 diesel cars. These are summarised in Table 3. They note that, from their remote sensing data (which is significantly larger than the dataset available when CREAM V1 was produced), pre-Euro 6 diesel cars effectively have zero NH_3 emissions.

2.20 CREAM V2 has thus used the emissions factors in Table 3 for Euro 6 diesel cars and assumed no NH_3 emissions from earlier model diesel cars.

Table 3: Mean NH_3 Emissions from Euro 6 Diesel Cars (Taken from Figure 3 of Farren *et al*., 2020[29])

Road Type	NH_3 (g/km)
Urban	0.000872
Rural	0.000945
Motorway	0.001180

Petrol Light Goods Vehicles (LGVs)

2.21 In terms of emissions per vehicle, petrol LGVs are likely to have appreciable NH_3 emissions. CREAM V1 assumed that petrol LGV emissions were slightly higher than those from petrol cars. However, the LGV fleet is dominated by diesel vehicles, with a rapidly increasing component of EVs. The relatively small numbers of petrol LGVs means that this is unlikely to be a significant source of total traffic emissions, meaning that the results of CREAM will not be sensitive to any small errors in the petrol LGV emissions rates. The approach in CREAM V2 has thus been to treat petrol LGVs as large petrol cars.

Diesel LGVs

2.22 It has not been possible to find any recent quantification of NH_3 emissions from diesel LGVs from remote sensing in peer-reviewed literature. However, the emissions reported by Farren *et al*. (2020[29] and 2021[15]) both use the method described by Davison *et al*. (2020)[18]. The 2022 PhD thesis of the lead author of that paper[30] includes NH_3 emissions estimates for Euro 6 diesel LGVs which were taken from the same remote sensing surveys. These are summarised in Table 4. As with diesel cars, it has been assumed that pre-Euro 6 vehicles have no NH_3 emissions.

Table 4: Mean NH_3 Emissions from Euro 6 LGVs (Taken from Table C.4 of Davison, 2022[30])

Road Type	NH_3 (g/km)
Urban	0.00388
Rural	0.00252
Motorway	0.00263

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[29] https://eprints.whiterose.ac.uk/169685/1/Ammonia_emissions.pdf

[30] New Approaches for Understanding Vehicle Emissions Using Remote Sensing – Jack Davison – Doctor of Philosophy – University of York Chemistry – August 2022.

Heavy Duty Vehicles (HDVs)

2.23 CREAM V1 included granular estimates for HDV emissions, separated by Euro standard and derived from the most recent remote sensing data published at that time. As highlighted by Figure 1, there are risks to using granular data to describe NH_3 emissions from HDVs given that the numbers of sampled vehicles tend to be much smaller than for passenger cars; dividing the sampled dataset into small subsets inevitably shows differences, but these might simply reflect chance, with high-emission vehicles captured during a particular survey just happening to be of a certain model type, but that then being presented as a systematic trend.

2.24 Prebble *et al*. (2019)[12] took remote sensing measurements from approximately 1,000 trucks in California during 2018. They reported mean emissions of 0.01 g/kg for trucks without SCR and of 0.18 g/kg for trucks with SCR. While the authors noted a tendency for greater NH_3 emissions from later model vehicles, corresponding with a greater requirement to reduce NOx emissions, this principally manifested as an increase in the number of vehicles emitting detectable levels of NH_3 (as demonstrated by the larger interquartile ranges – purple boxes – from 2015 in Figure 1, above) rather than increasing the mean values (i.e. the black dots in Figure 1). The narrowing of the interquartile range for 2017-model vehicles might indicate the increasing use of NH_3 slip catalysts, but this has not driven down the mean emissions for those vehicles.

2.25 Euro VI HDVs must conform to an NH_3 emissions limit of 10 ppm and typically include NH_3 slip catalysts. Despite this, previous work[1] has shown that average emissions from Euro VI HDVs can remain appreciable.

2.26 In the absence of more recent published data from the UK and to maximise the available dataset, CREAM V2 has used the mean NH_3 emissions from all vehicles reported by Prebble *et al*. (2019)[12] as summarised in Table 5. The 'with SCR' emissions rates have been applied to all Euro VI and 'Euro V SCR' vehicles while the 'without SCR' rates have been applied to all 'Euro V EGR' (Exhaust Gas Recirculation) and pre-Euro V vehicles. To generate emissions in g/km, the g/kg emissions rates have been combined with the average fuel use data generated previously[1] which are given in Table 6. The calculated emissions in g/km are given in Table 7.

Table 5: Mean NH_3 Emissions from HDVs (Taken from Prebble *et al*., 2019[12])

Vehicle Type	NH_3 (g/kg)
HDVs without SCR	0.01
HDVs with SCR	0.18

Table 6: Average Fuel Consumption Values for Commercial Vehicles (Taken from Table A1.2 of AQC, 2020[1])

Vehicle Size	Assumed Fuel Consumption (g/km)
HDVs <12te	153
HDVs >12te	243

Table 7: Assumed NH_3 emissions from HDVs

Vehicle Size	NH_3 (g/km)	
	Without SCR	With SCR
HDVs <12te	0.00153	0.0276
HDVs >12te	0.00243	0.0438

Motorcycles

2.27 As with CREAM V1, NH_3 emissions from motorcycles are assumed to be zero. There is evidence of NH_3 emissions from motorcycles[31], but not enough information to allow robust quantification in CREAM. As shown in Section 4, CREAM V2 predicts fleet total emissions with broad accuracy, and emissions from this small section of the fleet may therefore be compensated for by marginally higher assumed emissions from other sectors. In fleets with very high proportions of motorcycles, CREAM V2 may underestimate emissions, but in most practical use cases, the omission of motorcycles is unlikely to have a significant effect.

Hybrid Vehicles

2.28 CREAM V1 assumed that emissions from hybrid and plug-in hybrid cars would be the same as those from the equivalent conventional model. This was because there was insufficient information regarding the how often the ICE is used in such vehicles, as well as concerns regarding the relative contribution of cold-starts to trip-total NH_3 emissions. As well as resolving questions regarding the cold-start penalty, Farren *et al*. (2021)[15] used their remote sensing measurements to predict the percentage of time that hybrids spend in battery mode. They predict that, under average urban driving conditions, ordinary hybrid cars spend 29% of time using batteries for propulsion, with this increasing to 42% for plug-in hybrid cars. These statistics are specific to urban driving.

2.29 More recently, it has been estimated that plug-in hybrid cars in the UK do approximately 50% of their total milage using batteries[32,33]. This proportion varies by speed, since faster speeds require higher power and are also typically associated with longer journeys. Figure 5, which was produced by Ricardo for the DfT, shows that at speeds below 75 kph, batteries are used between 61% and 73% of the time, while at speeds above 110 kph, they are used less than 20% of the time. This might reasonably be expected to change in the future as battery technology improves, but there is no robust way to predict this.

2.30 Broadly equivalent values to those shown in Figure 5 are also included in EFT V12. CREAM V2 therefore uses the hybrid utility factors from EFT V12. These are set out in Table 8 (note that Figure 5 shows % of electrical driving while Table 8 shows % of ICE driving).

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[31] e.g. https://www.sciencedirect.com/science/article/pii/S2590162122000247

[32] Real-world usage of plug-in hybrid vehicles in Europe: A 2022 update on fuel consumption, electric driving, and CO2 emissions - International Council on Clean Transportation

[33] Speed-emission/energy consumption curves for ultra-low emission vehicles and non-fuel operating costs for all vehicles

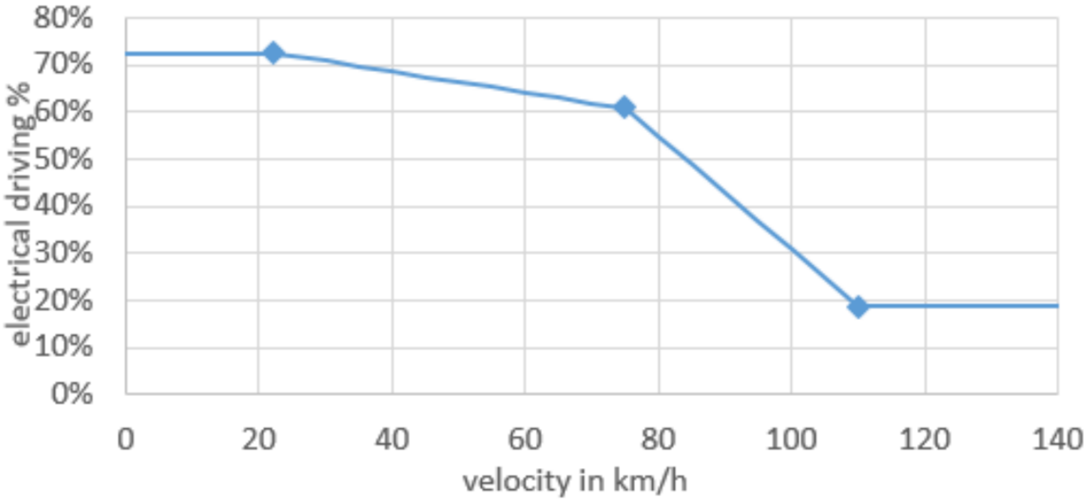

Figure 5: Share of Electrical Driving by Plug-in Hybrid Cars by Average Journey Speed[32]

Table 8: Share of ICE Driving of Hybrid Cars and LGVs Assumed in CREAM V2 (and EFT V12)

Vehicle Type	Speed (kph)		
	<50	50-80	>80
Petrol Hybrid Car	50%	70%	90%
Petrol Hybrid Plugin Car	10%	50%	90%
Diesel Hybrid Car	100%	100%	100%
Petrol Hybrid LGV	50%	70%	90%
Petrol Hybrid Plugin LGV	10%	50%	90%

Euro 7

2.31 It has not been possible to take account of any effect that the Euro 7 type approval emission standard might have on NH_3 emissions in the future. However, it is noted that before being removed from the standard, the proposed g/km emissions limit for passenger cars of 0.02 g/km would have been comfortably achieved by most current diesel vehicles (see Table 3) and only exceeded by a small amount by most petrol cars (see Table 1). It is unknown what effect the agreed emissions limit for HDVs of 85 mg/kWh on road (60 mg/kWh in the laboratory) will have in practice.

3 Vehicle Fleet Data

3.1 The current and future vehicle fleet composition data used in CREAM V2 have been set to match those in EFT V12. EFT V12 contains forecasts, in terms of total vehicle-kilometres driven on different roads, for the uptake of different technologies such as plug-in hybrids and electric vehicles, and of the future proportions of different Euro standards. The forecasts in EFT V12 and CREAM V2 extend to 2050.

3.2 Euro 7 is not included in the fleet forecasts in EFT V12. The latest version of Euro 6 is therefore effectively the sum of current and any future standards.

3.3 Figure 6 shows an example of some of the vehicle composition forecasts contained in EFT V12 and CREAM V2. It shows how the proportion of electric cars is predicted to increase out to 2050. It is important to recognise that emissions are the result of car usage and not car registrations. It is to be expected that petrol and diesel cars will remain in use after the sale of new petrol and diesel cars ends. Notwithstanding this, the trajectory of EV usage outside London may be pessimistic given current policy expectations regarding the phase out of petrol and diesel cars. The implication of this is that future NH_3 emissions may be over-predicted by CREAM V2.

3.4 The trajectory of expected electric car use shown in Figure 6 is very different for Central, Inner, and Outer London than for the rest of the UK. This reflects a range of real differences between these areas that might affect EV uptake, but it is also caused by the forecasts coming from different sources (Transport for London rather than DfT). The implication of this difference is that NH_3 emissions from cars are predicted to fall much more rapidly within London than outside London.

3.5 There are also significant differences in the assumed trajectories for electric HGVs when comparing inside vs outside London. For example, in Central London in 2050, all rigid HGVs are predicted to be electric, while 99.8% of articulated HGVs are predicted to be electric. Outside of London, it is assumed that there will be no electric HGVs.

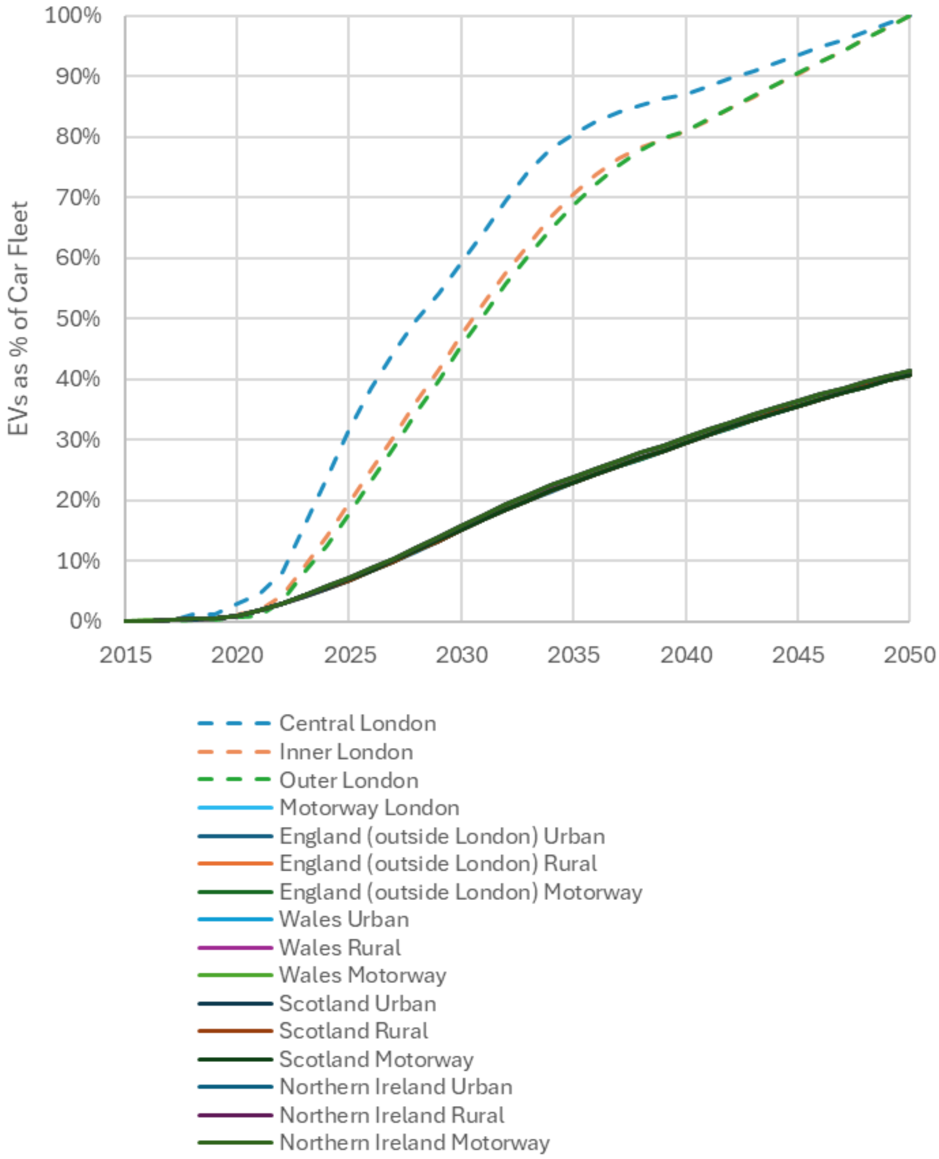

Figure 6: Example of Fleet Composition Data in EFT V12 and CREAM V2, Showing Electric Cars as a Proportion of the Car Fleet Between 2015 and 2050 by Region and Road Type (London shown by dashed lines)

4 Ambient Measurements

4.1 It is relatively rare for NH_3 to be measured at the roadside, and rarer still to have a dense network of paired roadside and background monitors using high-quality instrumentation. Development of CREAM V1 used measurements from a monitoring network operated by Wealden District Council (WDC) between summer 2014 and summer 2016. This network comprised six DEnuder for Long-Term Atmospheric ('DELTA') samplers[34,35] and 29 Adapted Low-cost Passive High Absorption ('ALPHA') samplers[36,37]. It also included 13 Automatic Traffic Counters (ATCs), measuring real-time traffic volumes concurrent with the air quality measurements. This represents the most comprehensive and detailed monitoring survey of roadside NH_3 that has been carried out[38], and the measurements obtained have been used to show a clear and quantifiable NH_3 signal from the road network (e.g. Figure 7).

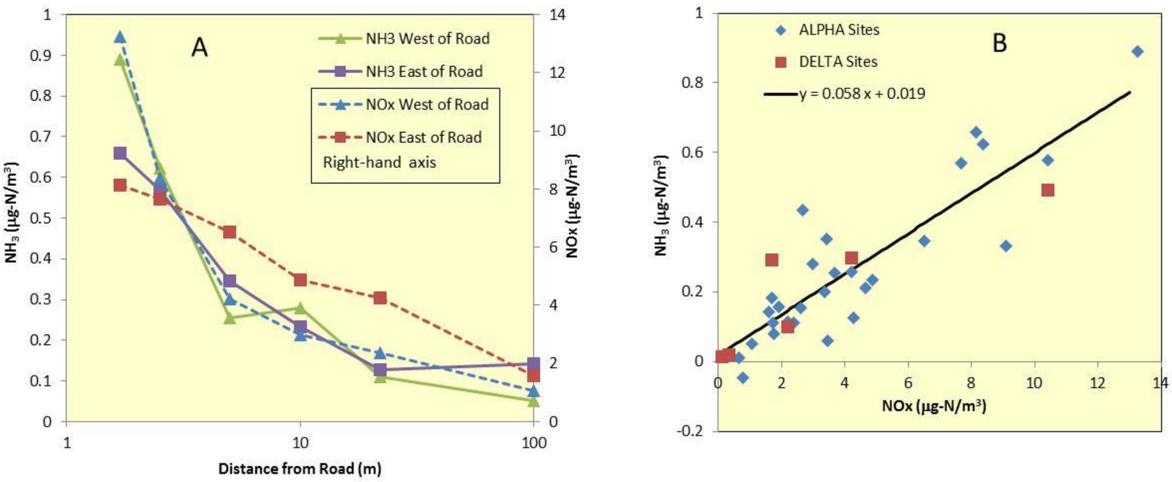

Figure 7: A: Two-year (2014-2016) average NH_3 and NOx concentrations along two transects running perpendicular to the A22 in East Sussex after subtracting measured background concentrations. B: Roadside increment of NH_3 vs roadside increment of NOx at all sites with co-located measurements, showing bivariate least squares regression line. Reproduced from Figure 5.11 of the Air Quality Expert Group (AQEG) Report on Exhaust Emissions from Road Transport (2021)[6]

4.2 The monitoring summarised in Figure 7, and used in CREAM V1, subsequently continued until the start of 2020; a small number of the sites were recommissioned in 2022, but data capture during 2022 was poor and no subsequent measurements have been published. Figure 8 shows the annual mean NH_3 concentrations measured over 5 years along the two transects running perpendicular to the A22. It highlights the influence of emissions from the road on annual mean concentrations in all years.

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[34] https://uk-air.defra.gov.uk/assets/documents/reports/cat09/2109211301_UKEAP_annual_report_2016.pdf

[35] These monitors, analysed in the same laboratory to the same quality assurance standards, also form the basis of Defra's National Ammonia Monitoring Network (NAMN), and Acid Gases and Aerosols Network (AGANet).

[36] https://www.researchgate.net/publication/10708796_Development_and_Types_of_Passive_Samplers_for_Monitoring_Atmospheric_NO2_and_NH3_Concentrations

[37] These monitors, analysed in the same laboratory to the same quality assurance standards, are also used in Defra's MAMN network.

[38] The network is described here: https://www.wealden.gov.uk/UploadedFiles/Ashdown-Forest-Air-Quality-Monitoring-and-Modelling-August-2018-Volume-1.pdf

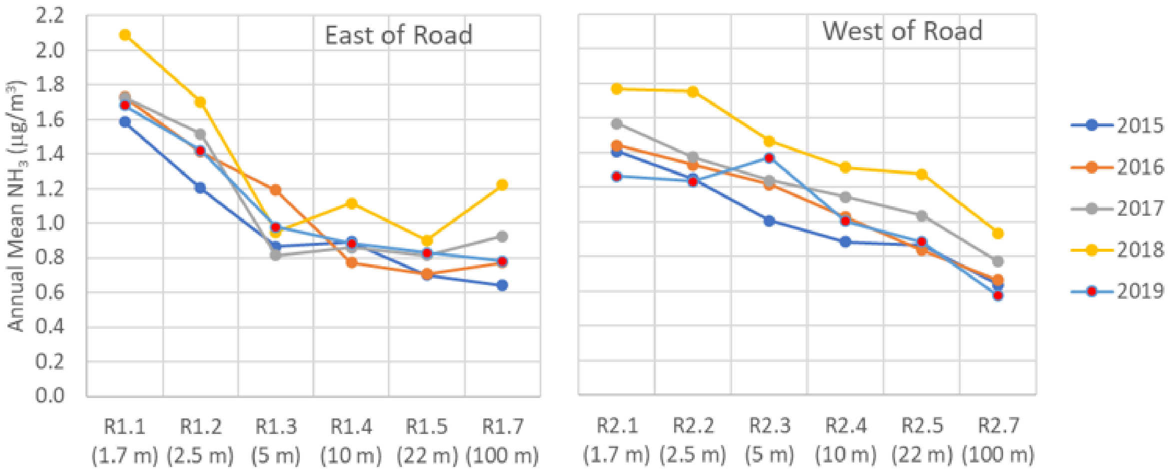

Figure 8: Annual Mean NH_3 Concentrations Measured Along Two Roadside Transects over Five Years (distances from kerb in parentheses)[39]

4.3 Figure 9(A) summarises the temporal trend in total measured NH_3 at all 35 monitors. Figure 9(B) shows the temporal trend in the local road increment of NH_3 at the 28 roadside monitors, derived by subtracting annual mean concentrations measured at nearby background monitors, operated as part of the study, from each annual mean roadside measurement.

4.4 The range in calculated road NH_3 increments in Figure 9, and the relatively short period of the survey, makes it difficult to discern temporal trends in the NH_3 road increments, but there is some suggestion of an overall increase in road-NH_3 during this period.

4.5 Prior to the development of CREAM V1, a common approach to predicting road-NH_3 was to infer it from road-NOx (often using the first set of measurements from the Wealden study). Figure 10 shows the calculated road-NH_3 to road-NOx ratios over 5 calendar years. Road-NOx concentrations at these monitoring sites fell only marginally over the 2015 to 2019 period (4% on average at the NOx monitors which were co-located with NH_3 monitors, although it should be noted that in most cases NOx was inferred from measured nitrogen dioxide (NO_2) using Defra's calculator[40] rather than measured directly). The road-NH_3 to road-NOx ratios therefore follow the same general temporal pattern as that for road-NH_3 in Figure 9, with a slight upward trend, although the change is small in context of the uncertainties inherent in this approach. The molar ratio of NH_3 to NOx has remained between 5% and 7%.

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[39] https://www.wealden.gov.uk/UploadedFiles/Ashdown-Forest-Monitoring-Main-Report-120521-2.pdf

[40] https://laqm.defra.gov.uk/air-quality/air-quality-assessment/nox-to-no2-calculator/

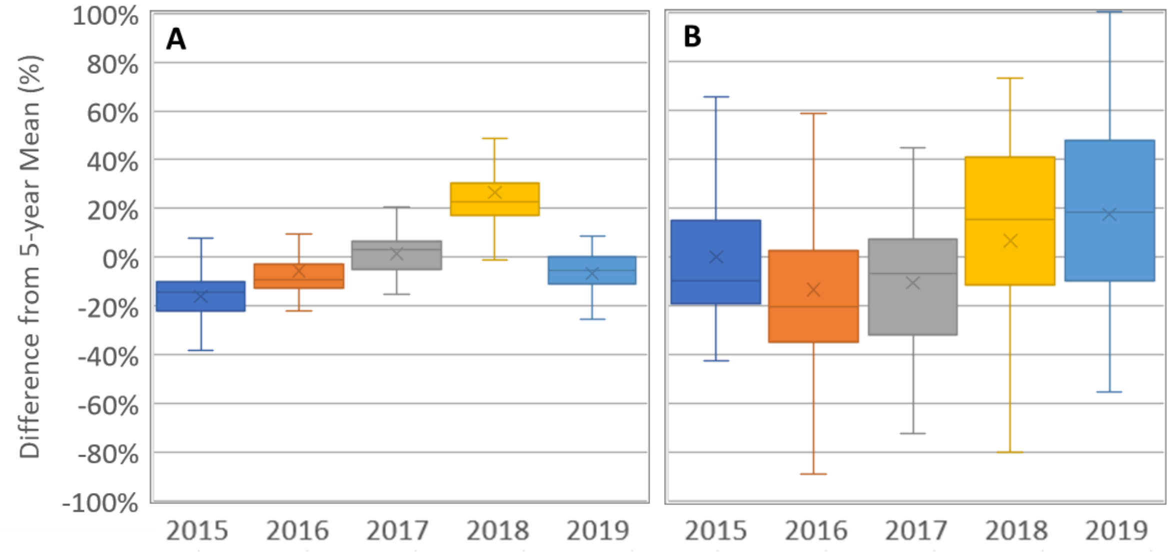

Figure 9: Relative change in annual mean NH_3 in Wealden over 5 Years, showing the difference between each annual mean measurement and the 5-year mean at that site: A) Total NH_3 at 35 monitoring sites, B) Local road-NH_3 at 28 roadside sites[39].

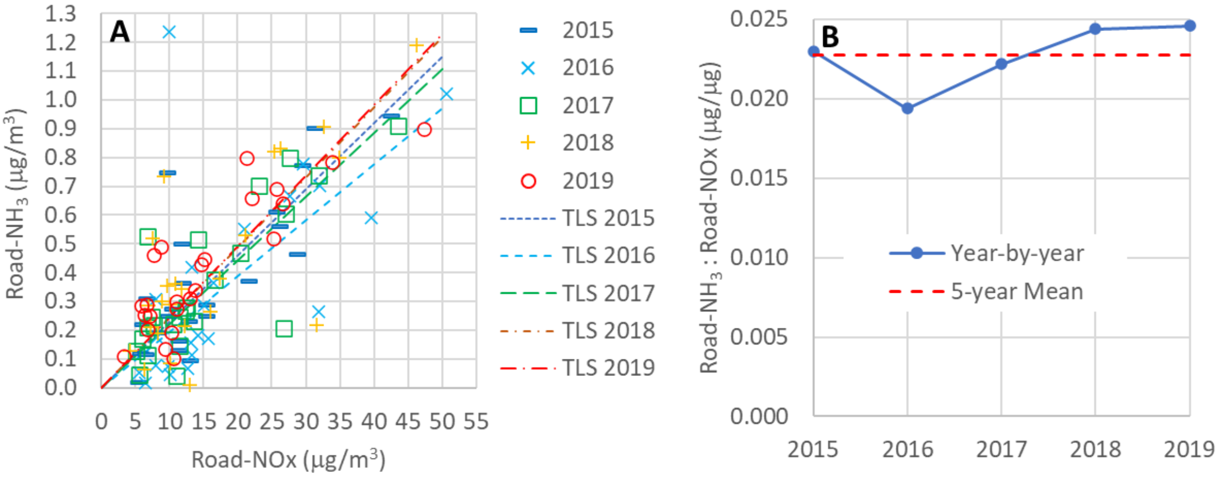

Figure 10: A) Annual mean road-NOx (as NO_2) vs road-NH_3 over 5 Years, also showing the Total Least Squares (TLS) regression line (forced through zero) for each year. B) Slope of total least squares regression lines by year and on average[39]

Use of Ambient Measurements in CREAM V2

4.6 WDC has allowed access to its concurrent NH_3 and road traffic measurements for the development of CREAM V2. The vehicle-specific emissions described in Section 2 have been combined with the fleet composition data described in Section 3 and the year-specific ATC traffic measurements described in Paragraph 4.1 to predict NH_3 emissions from each road which passes close to a monitoring site. Traffic volumes on roads included within the model network for which there are no ATC data (which are not alongside NH_3 monitors) have been adjusted from the values reported by AQC (2018)[38] based on the average changes recorded over the same period at the ATC sites.

4.7 These emissions have then been used within the ADMS-Roads V5 dispersion model to predict the local component of road-NH_3 concentrations at each monitoring site for comparison with the measurements. This is the same approach described in 2020 for the development of CREAM V1[1]. The ADMS model configuration is described in detail by AQC (2018)[38], and has been subject to independent academic peer-review[41].

4.8 The measurements have been considered as five separate sets of annual mean values (2015 to 2019 inclusive). For those monitoring sites[42] arranged over transects, the minimum measured concentration on that transect has been taken to represent the local background. For the other sites, the average measured concentration at all background monitors has been used. The total measurement minus the local background has then been taken to be road-NH_3.

4.9 Figure 11 shows the predicted vs measured road-NH_3 at all monitoring sites which were not used to define the local background values. Road traffic is not the only local source of NH_3 within the study area. NH_3 is also released from biogenic sources, the locations of which are unknown and can move. For example, animal activity can give rise to elevated local concentrations. Thus, while the measurements in Figure 11 are labelled as 'road-NH_3', there are almost certainly other local influences on them. To better focus on those sites with the clearest traffic signal, subsequent analyses has focused on those sites where the difference between the roadside and local background annual mean measurements is >0.3 µg/m³ and the predicted road-NH_3 prior to any model calibration is >0.15 µg/m³. These values were not defined in relation to any specific air quality standards or statistic but were based on a visual examination of the range of measurements at different site types. The retained sites, following this screening, are termed 'strong roadside sites'. The predicted vs measured road-NH_3 at the strong roadside sites is shown in Figure 12.

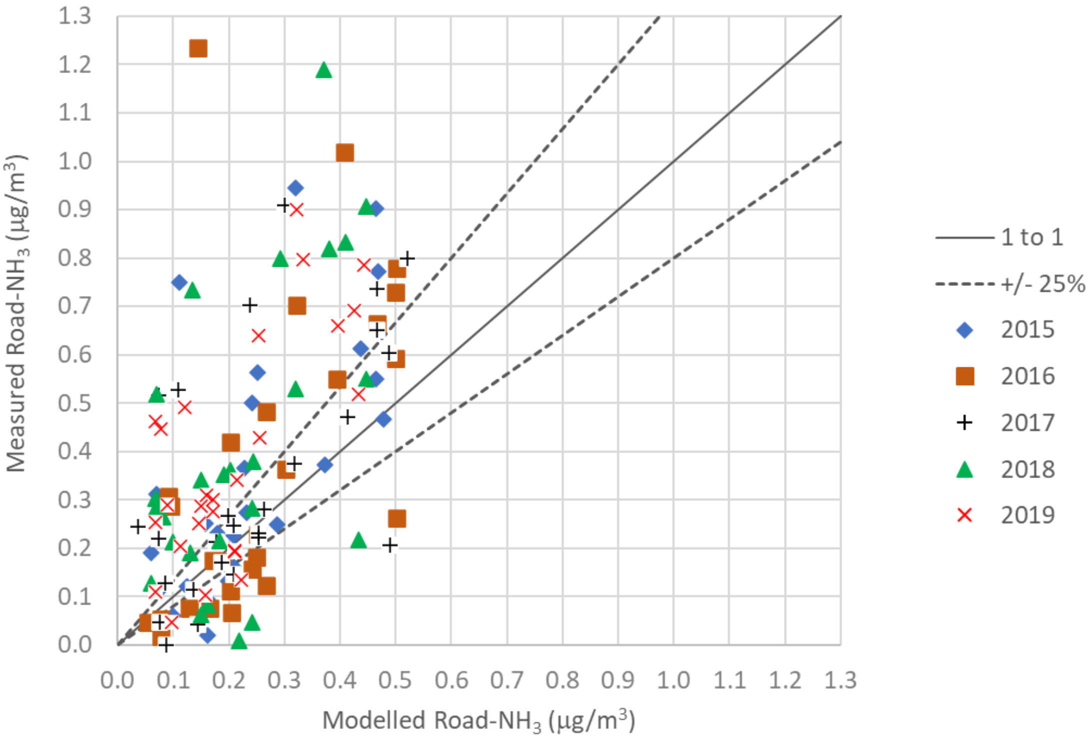

Figure 11: Measured vs Modelled Road-NH_3 over Five Years at all Sites

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[41] Sutton, M A., Tang, Y.S., and Braban, C. Risks from air pollution to the integrity of Ashdown Forest Special Area of Conservation. January 2019.

[42] https://www.wealden.gov.uk/UploadedFiles/Ashdown-Forest-Air-Quality-Monitoring-and-Modelling-August-2018-Volume-1.pdf

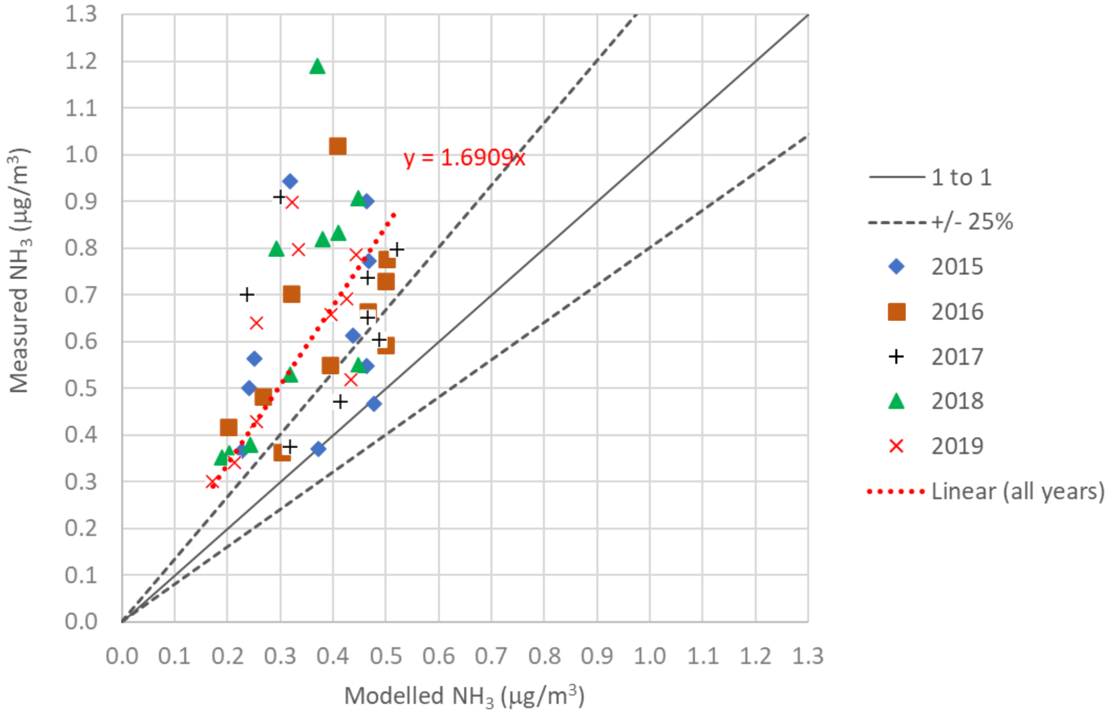

Figure 12: Measured vs Modelled Road-NH_3 over Five Years at Strong Roadside Sites

4.10 In principle, the measurements provide an opportunity to examine the temporal patterns and how these relate to individual components of the emissions model. For example, by adjusting features such as catalyst ageing effects, it would be possible to train the emissions so that the predicted concentrations change in time in near-perfect alignment with the temporal changes in the ambient measurements. It would also be possible to adjust the emissions in a granular way based on spatial differences. For example, the proportions of passenger cars measured on different roads are not all the same and the bias in the model alongside different roads is not the same; by applying vehicle-specific adjustments to the emissions, it would be possible to significantly improve the apparent fit of the model. This approach was not considered appropriate. In practice, the bias and scatter seen in Figure 12 might be caused by any number of reasons (including uncertainty in the individual measurements), and adjusting individual model components to achieve a perfect fit against individual measurements is equally likely to reduce the predictive power of CREAM V2 as to improve it.

4.11 The approach which has been taken is simply to adjust all emissions by the average bias at all strong roadside sites in all years. This is shown by the trend line in Figure 12, which is derived using Ordinary Least Squares (OLS) regression with the trend line forced through zero. Apart from including multiple years, this is effectively the same approach that many local authorities take when verifying modelled NO_2 concentrations for reporting to Defra. The trend line in Figure 12 combines an assessment of the model performance in each consecutive year (e.g. predictions using 2019 traffic data and 2019 emissions factors are compared with 2019 measurements) without applying any weighting to one year vs another. While the model performance in 2019 is arguably more relevant than that in 2015, its ability to predict trends over time is also clearly important. All emissions, from all sources, have therefore been multiplied by 1.6909. Figure 13 to Figure 15 show how the model performs following this adjustment in terms of both road-NH_3 and total NH_3[43]. These data are also summarised in Table 9.

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[43] Total NH_3 has been calculated by adding to the predicted road-NH_3, the local background values described in Paragraph 4.8

4.12 Table 9 shows that the OLS regression line for each individual year varies over time, with a tendency for the model to over-predict on average at the start of this period and to under-predict in more recent years. However, Figure 13 to Figure 15 show a more nuanced picture, with site-specific under- and over-predictions occurring in all years. During 2016, 2017 and 2019, all of the adjusted total NH_3 predictions at strong roadside sites are within 25% of the measurements (see Figure 14). For 2015, the model over-predicts by more than 25% at two sites and underpredicts by more than 25% at one site. In 2018 it under-predicts by more than 25% at one site.

4.13 Over the 2015 to 2019 period, CREAM V2 predicts a gradual reduction in average emissions, while the inference from the measurements (see Figure 7B, above) is that road-NH_3 increased on average. However, on the basis of the performance of the model at individual sites, there is sufficient basis to conclude that CREAM V2 performed acceptably in all years. Given the uncertainty in the measured trend in Figure 7B (and the unknown influence of non-road sources), it is reasonable to conclude that CREAM V2 provides a suitable representation of temporal trends in NH_3 emissions based on current knowledge.

4.14 The overall model performance is relatively good given the constraints to measuring road-NH_3 and predicting its emissions.

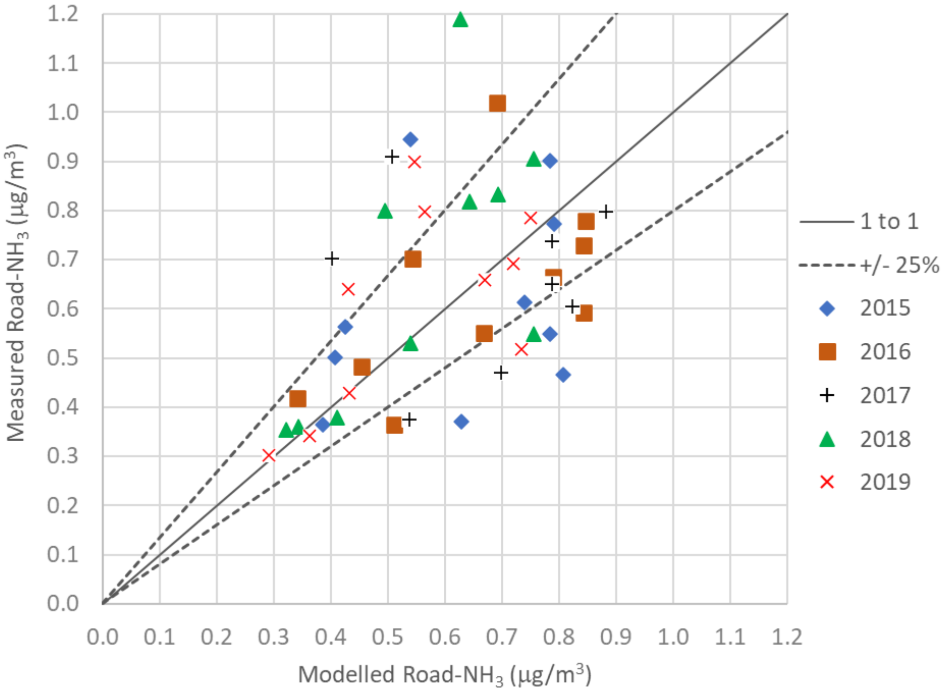

Figure 13: Measured vs Modelled Road-NH_3 over Five Years at Strong Roadside Sites Following Calibration

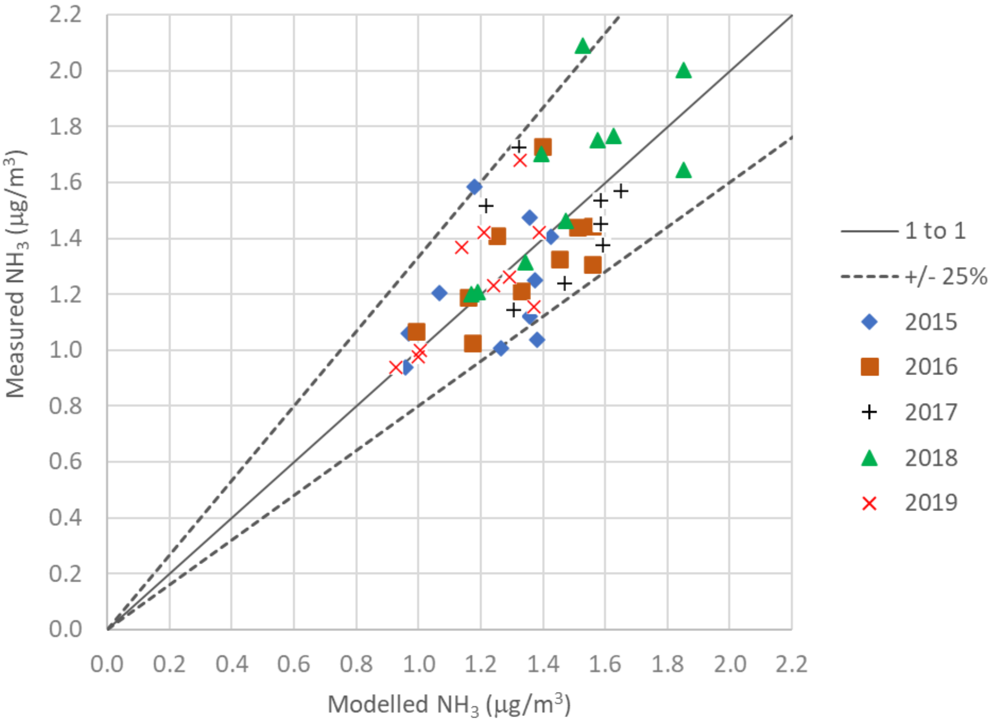

Figure 14: Measured vs Modelled Total NH_3 over Five Years at Strong Roadside Sites following Calibration

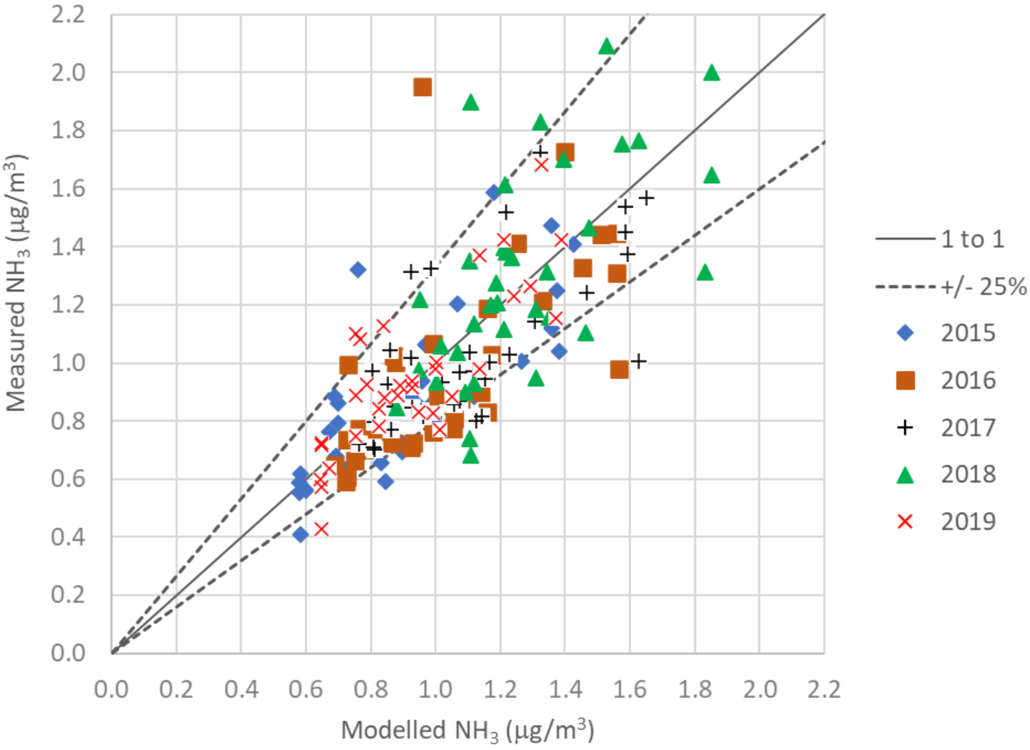

Figure 15: Measured vs Modelled Total NH_3 over Five Years at All Monitoring Sites following Calibration

Table 9: Performance of Adjusted Model in Each Year and on Aggregate

	2015	2016	2017	2018	2019	All
Road-NH_3 at Strong Roadside Sites						
OLS best fit line (y=x)	0.92	0.94	0.92	1.20	1.08	1.00
Correlation Coefficient	0.31	0.58	0.05	0.60	0.62	0.45
RMSE[44]	0.21	0.16	0.23	0.23	0.16	0.20
Fractional Bias	-0.04	-0.04	-0.03	0.18	0.10	0.04
% sites >25%	30%	20%	38%	10%	10%	21%
% sites <25%	10%	10%	25%	20%	30%	19%
% sites within 25%	60%	70%	38%	70%	60%	60%
Total NH_3 at Strong Roadside Sites						
OLS best fit line (y=x)	0.97	0.98	0.97	1.07	1.05	1.01
Correlation Coefficient	0.37	0.63	0.07	0.71	0.72	0.69
RMSE44	0.21	0.16	0.23	0.23	0.16	0.20
Fractional Bias	-0.02	-0.02	-0.02	0.07	0.05	0.02
% sites >25%	20%	0%	0%	0%	0%	4%
% sites <25%	10%	0%	0%	10%	0%	4%
% sites within 25%	70%	100%	100%	90%	100%	92%
Total NH_3 at All Sites						
OLS best fit line (y=x)	0.95	0.93	0.93	1.02	1.02	1.01
Correlation Coefficient	0.77	0.66	0.70	0.45	0.81	0.75
RMSE44	0.19	0.26	0.22	0.28	0.16	0.23
Fractional Bias	-0.04	-0.06	-0.06	0.02	0.02	-0.02
% sites >25%	20%	23%	9%	14%	6%	14%
% sites <25%	6%	6%	6%	9%	9%	7%
% sites within 25%	74%	71%	86%	77%	85%	79%

4.15 The emissions data underpinning CREAM V2 include significant speed-dependence for petrol cars, with much higher emissions predicted at very low speeds. The speed bands (see Table 1) are 1-5 kph, 5-10 kph, 10-20 kph, 20-40 kph, and >40 kph. Most Ashdown Forest monitoring sites were beside roads with average speeds greater than 40 kph. The Ashdown Forest ADMS model includes many links with slow assumed speeds (e.g. 20 kph), but these are not alongside the monitoring sites. In practice, most of the road links of interest with respect to impacts on designated nature conservation sites are expected to also have average link speeds >40 kph and thus match the roads for which CREAM has been calibrated. With respect to annual averages, it is rare to model average link speeds <10 kph.

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[44] Root Mean Square Error.

4.16 For consistency, the calibration factor defined above has been applied to all speed bands, but recognising the very large differences between assumed emissions at very low speeds and those >40 kph (e.g. emissions for speeds <5 kph in Table 1 are up to 10 times those >40 kph), CREAM V2 has been set to apply a minimum speed of 10 kph. Notwithstanding this, users should take care when selecting any speeds <=40 kph, since the model is not well calibrated in these cases.

4.17 The model calibration has not taken any specific account of cold starts. While most of the WDC monitoring sites were alongside 'through' routes, there are a variety of recreational parking areas in the area, as well as nearby towns and businesses. The road vehicle fleet will therefore inevitably include some vehicles with cold engines. This means that CREAM V2 has been calibrated to allow for some element of cold start emissions; to an extent that it represents 'typical' road conditions. It is, therefore, only necessary to take account of additional cold-start emissions if there is a particular reason to expect an atypically high percentage of cold engines in the fleet.

4.18 Figure 10, above, presents the ratio of road-NH_3 to road-NOx. While it would be straightforward to run both CREAM V2 and EFT V12 for the same traffic datasets to derive equivalent emissions ratios, doing so would misleading. This is because it is very common for predictions made using the EFT to require uplifting following comparison against local measurements (this was also found to be the case for the Wealden study). Roadside NH_3 monitoring is much less common than roadside NO_2 monitoring, meaning that similar local comparisons will not usually be possible for modelling using CREAM. The intention of the calibration presented above is that local verification of CREAM, while occasionally helpful, is unnecessary. Therefore, a direct comparison of CREAM vs EFT outputs would not be comparing like-for-like data; it would first be necessary to take account of any local uplifts to be applied to the EFT-based outputs, which might vary by location.

5 Model Demonstration

5.1 Figure 16 shows how CREAM V2 predicts traffic-related NH_3 emissions to change over time from a typical rural road in England using a basic fleet split and 5% HDVs[45]. It also shows the predictions of CREAM V1. Predictions made using CREAM V1 for years after 2030 are shown as a dashed line; CREAM V1 does not extend beyond 2030 and so it is common for its 2030 predictions to be applied to subsequent assessment years. Predictions made using CREAM V2 for years prior to 2021 are also shown as dashed lines, since it is unlikely that most users would wish to predict emissions prior to this year.

5.2 The upward trajectory in CREAM V1 up to 2030 is to be expected given the deliberately conservative assumptions which underpins it. Similarly, the downward trajectory for CREAM V2 is also to be expected given the assumed reductions over time in emissions from petrol vehicles (even after accounting for vehicle age) and the updated assumptions regarding electrification of the vehicle fleet.

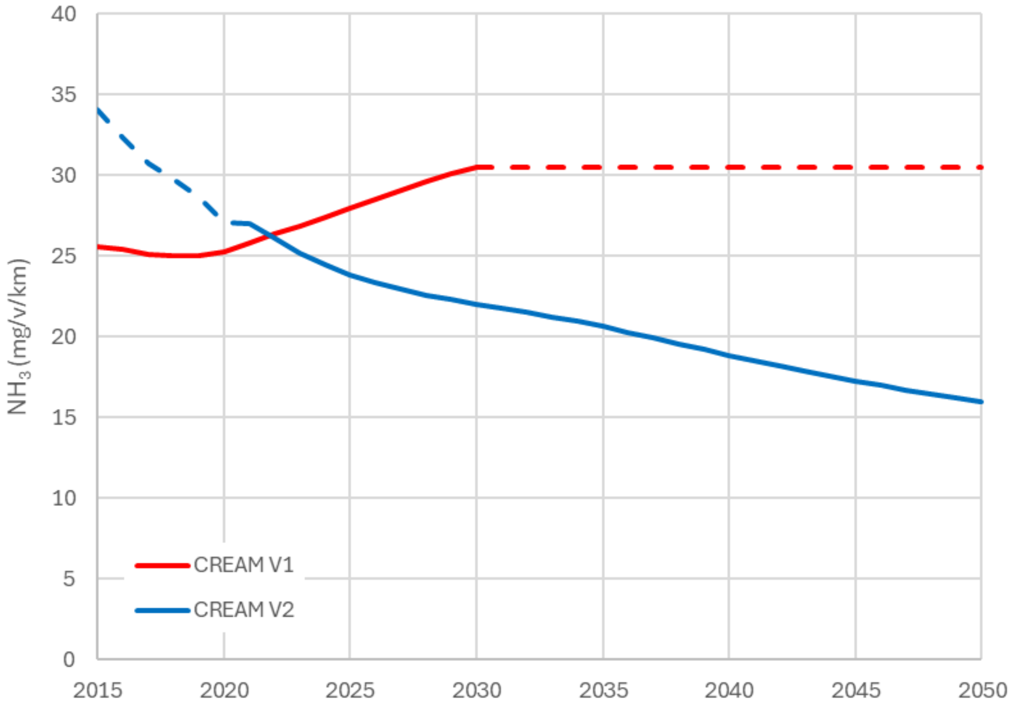

Figure 16: Fleet-averaged NH_3 Emissions for a Rural (England not London) Road with 0% Cold Starts, 5% HDV and Speed of 50 kph using CREAM V1 and CREAM V2

5.3 Both models have been calibrated against the same monitoring sites, but CREAM V2 includes measurements for additional years (2015 to 2019, vs 2014 to 2016 for CREAM V1). CREAM V2 also matches year-specific traffic flows with year-specific concentration measurements, while CREAM V1 was based on a single 2-year period. As is shown in Figure 9, above, average measured road-NH_3 increased between 2016 and 2019. Reconciling this with the forecast reduction in the underlying

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[45] Emissions in this section are presented as mg/v/km. CREAM generates results in g/km/s to align with the inputs of common dispersion models, while inputs to CREAM are typically numbers of vehicles per day. Emissions in mg/v/km can be derived from CREAM easily, for example by setting the traffic flow to 1,000 vehicles per day and multiplying the g/km/s values by 86,400.

emissions and activity data has resulted in CREAM V2 predicting higher emissions than CREAM V1 for years prior to 2021.

5.4 Figure 17 shows the predicted evolution over time of emissions from different sections of the passenger car fleet. Average emissions from all cars (red line) are predicted to reduce considerably, which is mainly driven by the expected transition to fully electric cars. Emissions from petrol cars (including hybrids - as shown by the dark blue line) are predicted to fall significantly to 2030 and then reduce more slowly. Emissions from conventional (non-hybrid) petrol cars are predicted to reduce until 2029 and then to increase. These two patterns reflect the interplay between the transition to Euro 6, the expected uptake of hybrid vehicles, and the assumed increase in average vehicle age/mileage of Euro 6 vehicles. The predicted increase to emissions from diesel cars over this period has a relatively trivial effect on the overall trend.

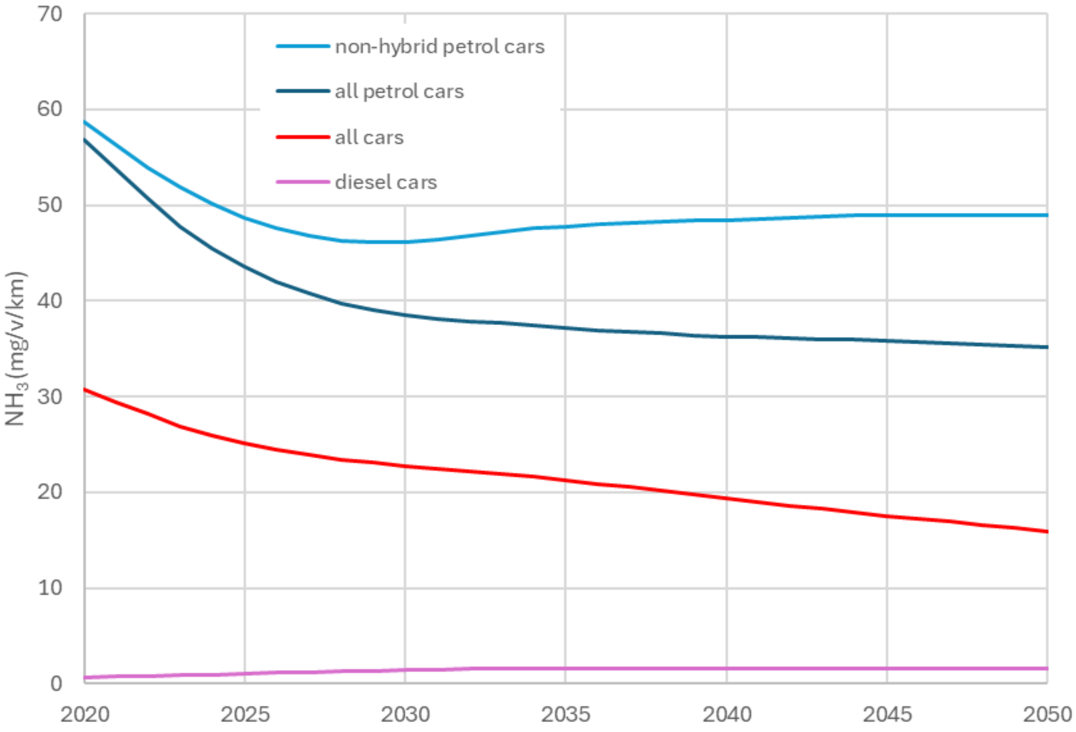

Figure 17: NH_3 Emissions from Different Sections of the Passenger Car Fleet over Time (on a Rural (England not London) Road with 0% Cold Starts) Using CREAM V2

5.5 Figure 18 shows how emissions from a nominal vehicle fleet (on a rural (England not London) road with 0% Cold Starts and 5% HDV) vary by speed. As explained in Section 2, CREAM V2 does not use speed-emission curves, but is based on speed bands. The picture shown in Figure 18 is also influenced by the hybrid utility factors given in Table 8, above. For example, emissions at 100 kph are predicted to be greater than those at 45 kph since more hybrid vehicles are assumed to use their internal combustion engine at 100 kph. This effect increases over time as the uptake of hybrids increases.

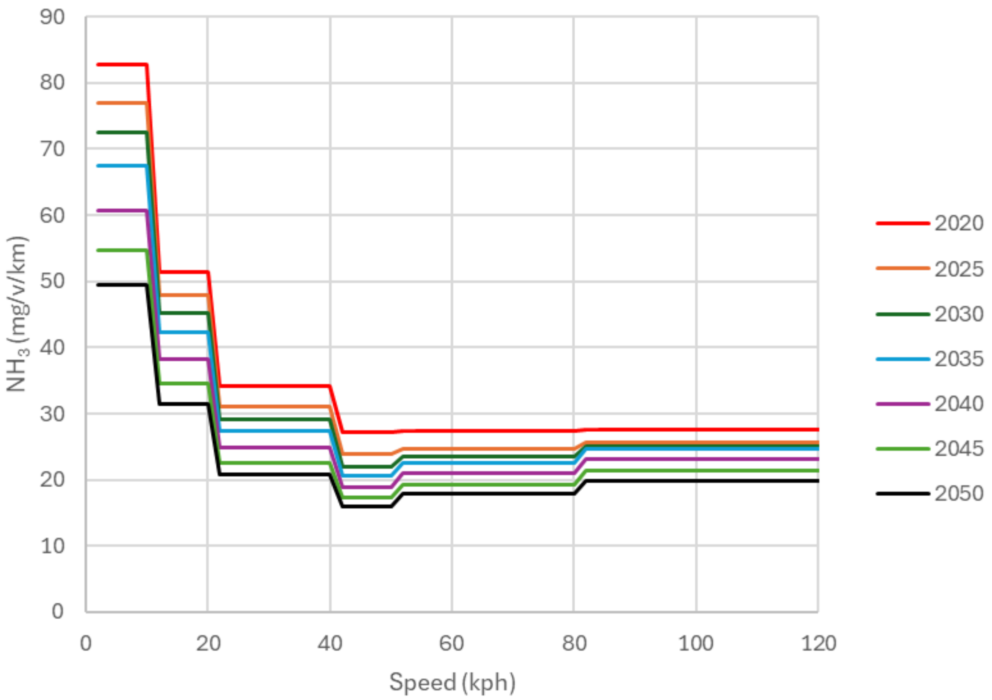

Figure 18: Fleet-averaged NH_3 Emissions by Average Speed, for a Rural (England not London) Road with 0% Cold Starts, and 5% HDV

5.6 Figure 19 shows how emissions from a nominal vehicle fleet (on a rural (England not London) road with 0% Cold Starts and an average speed of 50 kph) vary as the total HDV percentage increases. Notwithstanding that emissions from passenger cars dominate emissions from most roads, on an individual vehicle basis, they remain lower than those from Euro VI HDVs (i.e. petrol cars are so important because of their high numbers when compared with the number of HDVs on most roads). This means that calculated emissions increase in line with the percentage of HDVs, with this effect getting larger over time as emissions HDVs increase (with full transition to Euro VI to 2025 but no allowance for electric HGVs outside London) while those from cars and vans reduce (with transition to Euro 6, hybrids, and electric vehicles).

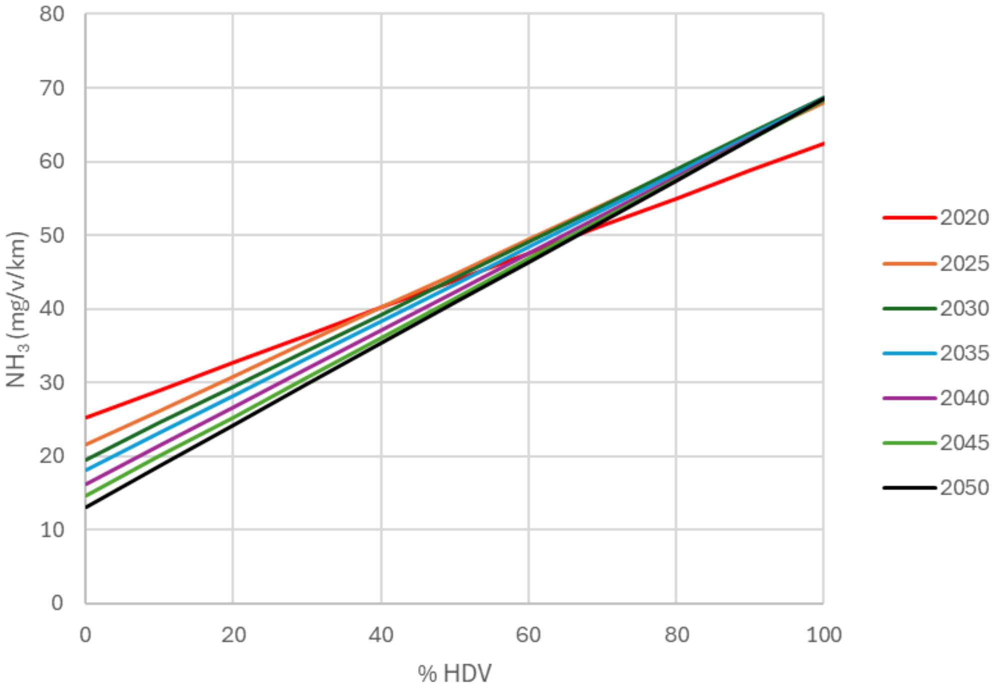

Figure 19: Fleet-averaged NH_3 Emissions by HDV Percentage, for a Rural (England not London) Road with 0% Cold Starts, and an Average Speed of 50 kph

5.7 Figure 20 shows how emissions vary in relation to the input assumptions on cold starts. In all years, increasing the proportion of cold starts increases the assumed emissions, but the precise trajectory changes over time as the composition of the vehicle fleet changes.

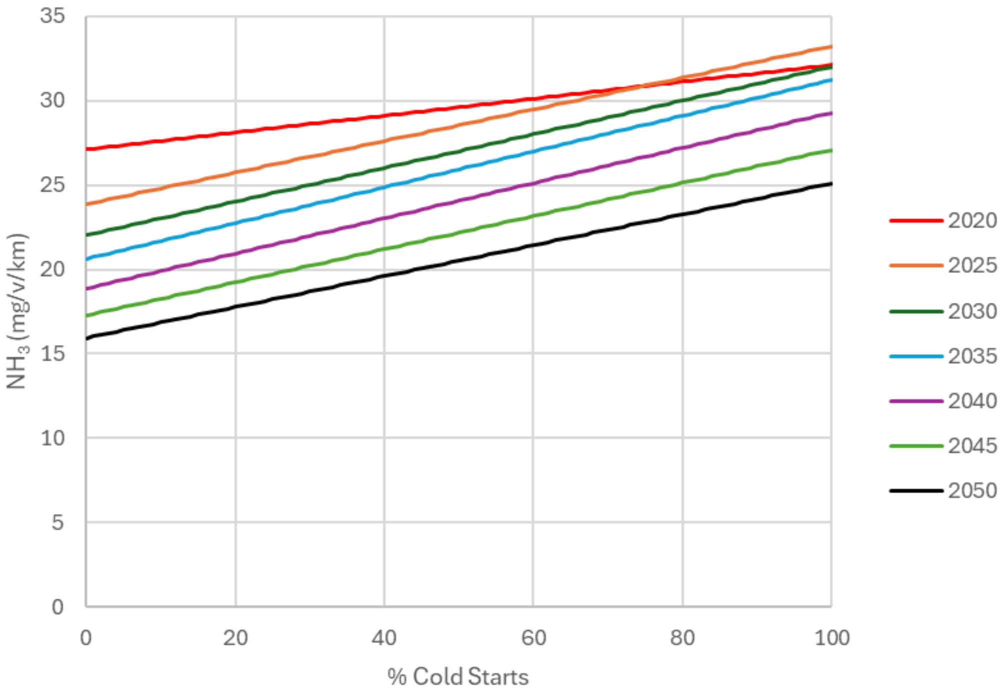

Figure 20: Fleet-averaged NH_3 Emissions by Percentage of Cold Starts, for a Rural (England not London) Road with 5% HDV, and an Average Speed of 50 kph

5.8 Figure 21 shows the assumed trajectory of emissions over time from a nominal fleet (with 5% HDV, an average speed of 50 kph, and 0% cold starts) in different parts of the UK and different types of roads. The highest predictions in 2020 are for areas with the greatest proportion of petrol cars (Outer London and Urban England). For other areas outside London, the proportion of petrol cars is lower in 2020 because of greater use of diesel cars, while for other areas within London, it is lower because of the importance of electric cars. Predicted emissions from roads in all areas outside of London, and from motorways in London, decline at similar rates out to 2050. Within London, the patterns are different, reflecting the very different assumptions made in EFT V12 regarding the uptake of electric vehicles, which are described in Section 3, above.

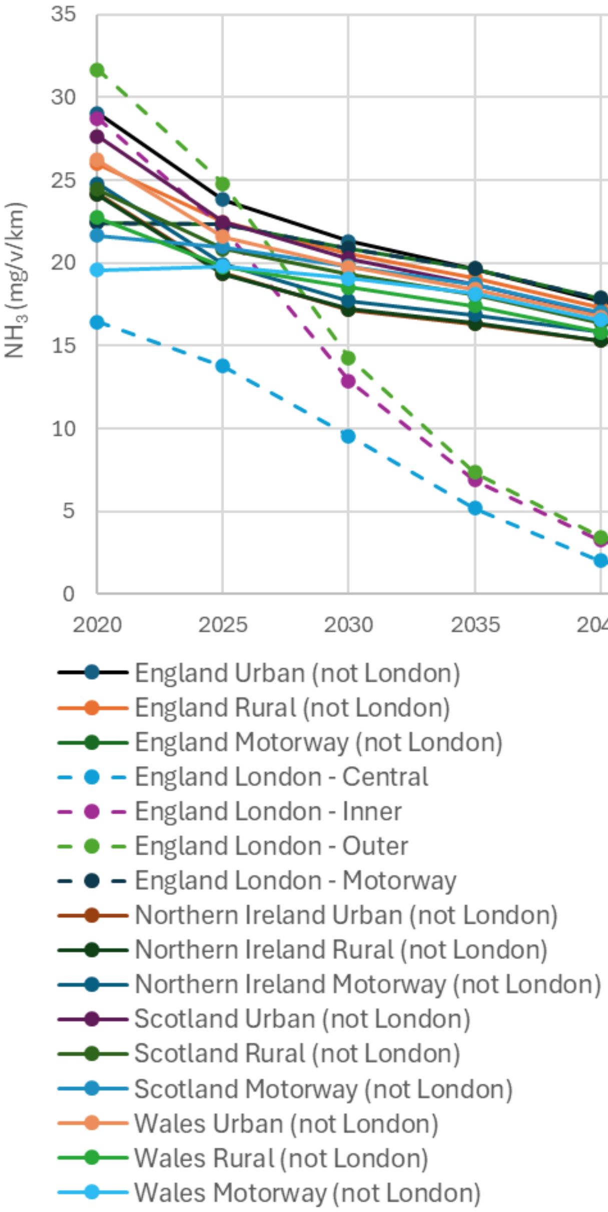

Figure 21: Fleet-averaged NH_3 Emissions by Region and Road Type, for a Road with 5% HDV, 0% Cold Starts, and an Average Speed of 50 kph (London shown by dashed lines)

6 Summary and Conclusions

6.1 In 2020, AQC highlighted the importance of including NH_3 emissions from road traffic when assessing the effects of local roads on biodiversity. Prior to this, it was common for the effects of road traffic on nitrogen-sensitive habitats to be assessed solely based on emissions of NOx. At that time there were no suitable emissions factors for traffic-related NH_3 that could readily be used in air quality assessments. AQC thus combined the limited information available at that time to produce CREAM V1.

6.2 Since 2020, information on NH_3 emissions from road vehicles, and the utility of electric propulsion, has continued to emerge. The CREAM model has therefore been updated to take account of this new information. This report has described the development of CREAM V2.

6.3 The most significant differences between CREAM V1 and CREAM V2 are:

- the approaches taken in CREAM V1 reflected the significant uncertainties in predicting NH_3 emissions from petrol vehicles at the time, in particular the effect of degradation over time of three-way-catalysts. CREAM V1 thus sought to err on the side of caution with respect to future-predictions. New information is now available on the individual impacts of tightening Euro standards vs catalyst ageing, and this has been used to calculate revised emission factors. The impacts of cold starts on emissions from petrol vehicles have also been estimated;
- revised emission factors for diesel vehicles have also been incorporated. These are based information on emissions by Euro type and road type for diesel cars and LGVs, while the updated factors for diesel HDVs are based on Euro type, fuel consumption (based on vehicle weight) and whether SCR is fitted;
- new information on time spent in battery vs ICE mode has allowed revision to the emissions factors for hybrid cars, which were previously assumed to emit at the same rate as the equivalent conventional model in CREAM V1;
- CREAM V1 used same vehicle fleet assumptions as Defra's EFT V 9.0. CREAM V2 uses the same fleet assumptions as EFT V12.1;
- CREAM V1 did not include any speed dependence of emissions. CREAM V2 uses average speed to calculate emissions from petrol vehicles, as well as the ICE usage rates in hybrid vehicles.
- as with CREAM V1, CREAM V2 has been calibrated against ambient measurements using predictions made with ADMS-Roads. In most cases, this negates the requirement to verify model outputs against local measurements (although in those cases where roadside NH_3 measurements are available, local verification may still be helpful[46]). The same monitoring network has been used for both versions of CREAM, but CREAM V2 takes account of measurements made over five separate years.

6.4 The main effect of these changes is that CREAM V2 now predicts significant reductions over time in traffic-related NH_3 from most fleet mixes. This contrasts with CREAM V1, which was deliberately precautionary and therefore predicted increases over time.

6.5 It remains the case that CREAM is intended to facilitate the ready inclusion of traffic-related NH_3 into air quality modelling studies and, with this aim, it makes pragmatic assumptions based on the

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[46] If this is done, AQC would be grateful for details of the local verification, which might assist future updates to CREAM.

information which has been reviewed. As more information becomes available, it will be possible to revise and refine these assumptions.

6.6 Since the development of CREAM V1, the issue of traffic-related NH_3 has achieved a much higher profile, potentially at the expense of action on other NH_3 emissions sources. While it continues to make little sense to quantify the effects of road transport on biodiversity without including traffic-related NH_3, there may often be much more significant local NH_3 emissions which might benefit from scrutiny. CREAM only calculates emissions from road traffic.

7 Glossary

ACEA	European Automobile Manufacturers' Association
ADMS-Roads	Atmospheric Dispersion Modelling System model for Roads
AGANet	Acid Gases and Aerosols Network
ALPHA	Adapted Low-cost Passive High Absorption
AQEG	Air Quality Expert Group
AQC	Air Quality Consultants
ATC	Automatic Traffic Counters
CREAM	Calculator for Road Emissions of Ammonia
Defra	Department for Environment, Food and Rural Affairs
DELTA	DEnuder for Long-Term Atmospheric
DfT	Department for Transport
EFT	Emissions Factors Toolkit
EGR	Exhaust Gas Recirculation
HDV	Heavy Duty Vehicles (> 3.5 tonnes)
HGV	Heavy Goods Vehicle
ICE	Internal Combustion Engine
kph	Kilometres Per hour
LGV	Light Goods Vehicle
$\mu g/m^3$	Microgrammes per cubic metre
NAEI	National Atmospheric Emissions Inventory
NAMN	National Ammonia Monitoring Network
NH_3	Ammonia
NO	Nitric oxide
NO_2	Nitrogen dioxide
NOx	Nitrogen oxides (taken to be NO_2 + NO)
OLS	Ordinary Least Squares
PEMS	Portable Emissions Measurement Systems
RMSE	Root Mean Square Error

SCR	Selective Catalytic Reduction
SMMT	Society of Motor Manufacturers and Traders
TfL	Transport for London
TRL	Transport Research Laboratory
WDC	Wealden District Council

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