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Submitted to **Local Development Plan 2030 - Draft Plan Strategy Representations**
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SECTION A - DATA PROTECTION AND CONSENT

Please tick to confirm that you have read and understood the Council's Local Development Plan Privacy Notice.

I confirm that I have read and understood the Local Development Plan Privacy Notice and I give my consent for Antrim and Newtownabbey Borough Council to hold my personal data for the purposes outlined.:
Yes

SECTION B - CONTACT DETAILS

Please specify if you are responding as an individual, as an organisation, or as an agent acting on behalf of an individual, group or organisation?

Respondent Type:
Organisation

Please specify your contact details:

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Last name:
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Job Title (where relevant):

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What is your email address?

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NOARC21@MAIL.COM

Please Read Before Continuing. . .

SECTION C - REPRESENTATIONS

Do you consider the draft Plan Strategy to be SOUND or UNSOUND?

I consider it to be 'Unsound'

Unsound Representation

Please identify which section of the draft Plan Strategy you consider to be UNSOUND:

Paragraph Number in Document:

Policy Heading:
Waste Management and Disposal Facilites

Strategic Policy (SP) Paragraph Number:
10

Detailed Management Policy (DM) Paragraph Number:
Policy DM53;

Page Number In Document:
302

Proposal Map (If relevant state location):

Under which test(s) of soundness do you consider this to be UNSOUND:

P2 - Has the Council prepared its Preferred Options Paper and taken into account any representations made?, CE3 - Are there clear mechanisms for implementation and monitoring?

Please give details why you consider the draft Plan Strategy to be UNSOUND having regard to the test(s) you have identified above.

Unsound Justification:
DM53.2 - Fails to deal with the everyday requirement to meet the World Health Organization Guidelines on Air Quality which the council should adopt before all other considerations be it social or economical benefit. Therefore placing the health and well being of all residents at the forefront of the borough future development. No monitoring of air quality to any significant detail throughout the borough is currently in place. Therefore in the absence of current air quality levels how can a determination of adverse effect of any proposal. Adverse effect requires further definition including a measurement within the WHO guidelines.

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Modifications

If you consider the draft Plan Strategy to be 'UNSOUND', please provide details of what, if any, modifications do you think should be made to the section, policy or proposal which your representation relates to? What specific modifications do you think should be made in order to address your representation? Please briefly state how your proposed alternative would meet the requirements of the Sustainability Appraisal and other published assessments.

Modifications:
No proposal will be approved based on social and economic grounds if this detrimental on:

(a) Human health;
(b) In terms of air, water, noise or light pollution;
(c) On the historic environment and natural heritage assets; and
(d) On neighboring uses and the character and amenity of the surrounding area.

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clean-air-strategy-2019.pdf was uploaded

If you are seeking a modification to the draft Plan Strategy, please indicate how you would like your representation to be dealt with at Independent Examination:

Written Representation

Would you like to submit another representation?

No

BMJ

BMJ 2014;348:f7412 doi: 10.1136/bmj.f7412 (Published 21 January 2014)

RESEARCH

Long term exposure to ambient air pollution and incidence of acute coronary events: prospective cohort study and meta-analysis in 11 European cohorts from the ESCAPE Project

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Abstract

Objectives To study the effect of long term exposure to airborne pollutants on the incidence of acute coronary events in 11 cohorts participating in the European Study of Cohorts for Air Pollution Effects (ESCAPE).

Design Prospective cohort studies and meta-analysis of the results.

Setting Cohorts in Finland, Sweden, Denmark, Germany, and Italy.

Participants 100 166 people were enrolled from 1997 to 2007 and followed for an average of 11.5 years. Participants were free from previous coronary events at baseline.

Main outcome measures Modelled concentrations of particulate matter <2.5 µm ($PM_{2.5}$), 2.5-10 µm (PM_{coarse}), and <10 µm (PM_{10}) in aerodynamic diameter, soot ($PM_{2.5}$ absorbance), nitrogen oxides, and traffic exposure at the home address based on measurements of air pollution conducted in 2008-12. Cohort specific hazard ratios for incidence of acute coronary events (myocardial infarction and unstable angina) per fixed increments of the pollutants with adjustment for sociodemographic and lifestyle risk factors, and pooled random effects meta-analytic hazard ratios.

Results 5157 participants experienced incident events. A 5 µg/m^3 increase in estimated annual mean $PM_{2.5}$ was associated with a 13% increased risk of coronary events (hazard ratio 1.13, 95% confidence interval 0.98 to 1.30), and a 10 µg/m^3 increase in estimated annual mean PM_{10} was associated with a 12% increased risk of coronary events (1.12, 1.01 to 1.25) with no evidence of heterogeneity between cohorts. Positive associations were detected below the current annual European limit value of 25 µg/m^3 for $PM_{2.5}$ (1.18, 1.01 to 1.39, for 5 µg/m^3 increase in $PM_{2.5}$) and below 40 µg/m^3 for PM_{10} (1.12, 1.00 to 1.27, for 10 µg/m^3 increase in PM_{10}). Positive but non-significant associations were found with other pollutants.

Conclusions Long term exposure to particulate matter is associated with incidence of coronary events, and this association persists at levels of exposure below the current European limit values.

Introduction

According to the recent report on the Global Burden of Disease, throughout the world particulate air pollution is estimated to cause 3.1 million deaths a year and 22% of disability adjusted life years (DALY) due to ischaemic heart disease.[1] Several cohort studies have reported that long term exposure to air pollution is associated with mortality, in particular cardiovascular mortality.[2-13] The evidence of an effect on incidence of cardiovascular events—that is, acute myocardial infarction and unstable angina—is less consistent and requires further investigations.[12-15]

In the European Union the current annual limit for particulate matter <2.5 µm ($PM_{2.5}$) is 25 µg/m^3, which is far above that implemented in the United States (12 µg/m^3). One obstacle in the European standard setting process in the past had been that the available estimates of the exposure-response associations of particulate matter were primarily based on studies conducted in North America.[3-12] In response, the ESCAPE Study (European Study of Cohorts for Air Pollution Effects) was conducted between 2008 and 2012 to quantify the associations between exposures and health outcomes by using standardised methods for assessment of exposure and data from existing cohort studies.[16 17]

We estimated the association between long term exposure to particulate matter <2.5 µm ($PM_{2.5}$), 2.5-10 µm (coarse), <10 µm (PM_{10}) in aerodynamic diameter, soot ($PM_{2.5}$ absorbance), nitrogen oxides (NO_x and NO_2), and traffic indicators and the incidence of coronary events. We evaluated effect modification by several individual characteristics, and we investigated the exposure-response relations of the pollutants below selected thresholds.

Methods

Design and population

This study is an analysis of cohort data obtained by ESCAPE to investigate the long term effects of exposure to air pollution on human health in Europe and a meta-analysis of the cohort specific results. The present study included 11 European cohorts from five countries with information about incident cases of acute coronary events and the most important potential confounders. The cohorts were in Finland (FINRISK)[18]; Sweden (the Swedish National Study on Aging and Care in Kungsholmen (SNAC-K), the Screening Across the Lifespan Twin Study, (SALT), the 60 year olds study, and the Stockholm Diabetes Prevention Program study (SDPP))[19-22]; Denmark (the Danish Diet, Cancer and Health cohort study [DCH])[23]; Germany (the Heinz Nixdorf Recall Study (HNR), the Cooperative Health Research in the Augsburg Region (KORA))[24 25]; and Italy (the European Prospective Investigation into Cancer and Nutrition

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Extra material supplied by the author (see http://www.bmj.com/content/348/bmj.f7412?tab=related#webextra)

Appendix: Cohort details and noise assessment

Video on bmj.com (see also http://bmj.com/video)

Video abstract

in Turin (Epic-Turin), the International Study on Asthma and Allergies in Childhood in Turin and Rome (parents of representative samples of children participating in SIDRIA-Turin and SIDRIA-Rome)).[26 27] These were all centres included in the ESCAPE intensive monitoring programme for particulate matter and nitrogen oxides.[28 29] Table 1 shows specific settings, periods of recruitment, and person years at risk⇓. With the exception of the Italian cohorts, all the cohorts enrolled representative samples of the adult population for the age groups considered in the single studies. Additional information on each cohort is presented in the appendix.

Outcome definition

For nine out of 11 cohorts, information on coronary events was derived by record linkage procedures with hospital discharge and mortality registries. We selected international classification of diseases (ICD) codes for "acute myocardial infarction" or "other acute and sub-acute forms of ischemic heart disease" (ICD-9-CM codes: 410, 411; ICD-10 codes: I21, I23, I20.0, I24) in principal diagnoses of hospital discharges. We also considered as incident cases those people who died outside hospital from ischaemic heart diseases, according to the death certificates (ICD-9: 410-414; ICD-10: I20-I25) and had no evidence of hospital admission for ischaemic heart disease in the 28 days before death and no evidence of admission for any cause in the two days before death. To identify incident cases, we excluded those who had had an acute coronary event or cerebrovascular event previously (previous admission to hospital with principal or secondary diagnoses with ICD-9 codes 410, 411, 430, 431, 434, 436 and ICD-10 codes I21, I23, I20.0, I24, I61, I63, I64). The reference period to evaluate previous events varied across the cohorts, with the minimum of three years in the two SIDRIA cohorts and all lifelong history for the KORA cohort. For the HNR study, incident cases were adjudicated by an independent end point committee based on medical records.[24] For the KORA cohort, incident cases were determined by interview and medical history and validated through linkage with the myocardial infarction register.[25]

Exposure to air pollution

Exposure to air pollution in each area was estimated following a standard methods developed for the ESCAPE project and described elsewhere.[28 29] Briefly, for each area under study, particulate matter of varying sizes measured in μm (shown as subscript)—that is, PM_{10}, coarse PM, $PM_{2.5}$, and $PM_{2.5}$ absorbance (blackness of the $PM_{2.5}$ exposed filter, determined by measurement of light reflectance as a marker for soot and black carbon)—was measured in 20 sites, and nitrogen oxides were measured in 40 sites in three separate two week periods (to cover different seasons) over one year (between 2008 and 2011). For each site, results from the three measurements were averaged to estimate the annual average, with adjustment for temporal variation by using a centrally located background reference site, which was operated for a whole year.[30 31] By using several traffic and land use variables, we developed area specific land use regression (LUR) models to explain the spatial variation of each measured pollutant. These models were then used to estimate concentrations of air pollution at each participant's residential address. Geographical variables typically evaluated include altitude, population density, industrial land use, green space, and traffic flows variables.[30 31] In addition to concentrations of pollutants, we considered two traffic variables at the participant's residence: traffic intensity on the nearest road (vehicles/day) and traffic load on major roads in a 100 m buffer (vehicles×m/day), defined as the sum of traffic intensity on roads with >5000 vehicles/day multiplied by the length of those roads in a 100 m buffer. To validate the models, we used the leave one out cross validation method— that is, systematically subtracting each of the monitoring points from the model one by one, and then comparing the predicted value for each monitoring location with the measured level at the location without using this measurement in the development of the model.[30 31]

Covariates

All cohorts had a common set of potential confounders and effect modifiers at baseline: marital status (coded as single, married/living with partner, divorced/separated, widowed; for the SDPP cohort only the binary variable "living with partner" was available; for SIDRIA-Rome all participants were living as couples at baseline), education (primary school or less, up to secondary school or equivalent, university degree and more), occupation (employed, unemployed, homemaker/housewife, retired), smoking status (current, former, never), duration of smoking (years), smoking intensity (cigarettes/day), hypertension, and diabetes. Most cohorts had information on additional cardiovascular risk factors such as body mass index (BMI; coded as <25, 25-29, ≥30), physical activity (<1 hour/week, about 1 hour/week, >2 hours/week), alcohol consumption (never, 1-3 drinks/week, 3-6 drinks/week, >6 drinks/week), and three cohorts had information on use of drugs for hormone replacement therapy. Four of 11 cohorts had data on cholesterol concentrations. Ten of 11 cohorts had data on noise exposure, estimated at the residential addresses from European noise exposure assessment in 2007, and we used an eight class categorical variable of 5 dB of exposure from 45 dB to 75 dB and more (see appendix). Each cohort also used an area based socioeconomic status indicator because socioeconomic indicators at the area level are predictors of morbidity, access to care, and lifestyle risk factors in addition to individual socioeconomic characteristics.[32]

Statistical analyses

To evaluate the association between exposure to air pollution and incidence of coronary events we performed the analyses in two stages. Firstly, we analysed each cohort using a common protocol for confounders, outcomes, and statistical modelling. We used Cox proportional hazards regression models (hazard ratios) with age as the time scale. A script with statistical code was provided to all cohort specific analysts. The results were evaluated centrally at the Department of Epidemiology in Rome. Secondly, we carried out a random effects meta-analysis to pool results.[33] We calculated I^2 statistics and P values for χ^2 test from Cochran's Q to quantify the heterogeneity among studies.[34]

We first estimated hazard ratios adjusted for age, sex, and year of enrolment only (model 1), then adjusted for a common set of individual covariates (marital status, education, occupation, smoking status, smoking duration, and smoking intensity; model 2), and then adjusted for area based socioeconomic status indicators (model 3). When investigating the effects of traffic variables we also adjusted all models for background NO_2 levels. We estimated the effects of exposure to air pollution using fixed increments of pollutants (20 μg/m^3 for NO_x, 10 μg/m^3 for PM_{10} and NO_2, 5 μg/m^3 for $PM_{2.5}$ and PM_{coarse},10^{-5}/m for $PM_{2.5}$ absorbance).

We performed several sensitivity analyses to deal with potential sources of bias and to consider the confounding role of additional cardiovascular risk factors. Firstly, we adjusted for possible intermediate variables (diabetes, hypertension) available

in all the cohorts; then for physical activity, alcohol consumption, and BMI (available in eight cohorts); finally we added to previously mentioned factors the cholesterol concentration (available in four cohorts). We then analysed the role of living in low/high urbanised settings, of noise exposure, and of residential stability (restricting the analysis to those living at the same baseline address during the follow-up). We stratified the Cox model 3 for predictors that did not meet the proportionality hazard assumption. We analysed the influential role of the largest cohort by excluding the DCH study from the analysis. Finally, we evaluated the role of the performance of land use regression models, stratifying cohorts by cross validation R^2> or ≤60%.

To explore the effect of clustering by area of residence in the association between exposure and mortality—that is, residents in the same area usually share similar characteristics (socioeconomic status, health, access to services) and have similar environmental and air conditions—we performed a frailty model to measure the role each area played.[4]

We evaluated potential effect modification by adding to model 3 an interaction term of exposure and one effect modifier at a time (sex, educational level, smoking status, BMI, hypertension, and residence in low or high urbanised settings). We used the likelihood ratio test to compare the models with and without interaction terms. For age during follow-up, we estimated effect modification by adding an interaction term between exposure and a time dependent categorical variable indicating age group (<60, 60-74, >75).

To provide information about the health effects below specific threshold values (20, 30, and 40 μg/m^3 for PM_{10}, and 15, 20, and 25 μg/m^3 for $PM_{2.5}$), we studied the effect of fixed increments of $PM_{2.5}$ and PM_{10} among people with air pollution concentrations at residences only below these thresholds.

We used STATA software (versions 10, 11, and 12) for all the analyses, with the exception of frailty models for which we used R (www.r-project.org).

Results

Table 1 shows a summary description of the 11 European cohorts⇓. Table 2 shows individual characteristics of participants⇓ and table 3 their exposures to air pollution⇓. Additional characteristics of the participants are provided in table 4⇓. The enrolment period covered 15 years, and the average follow-up was 11.5 years. The participating cohorts varied in characteristics, availability of data on covariates, and levels of exposure. The proportion of participants included in the study ranged from 82.4% to 99.3% of the original cohorts (overall 93.1%), after exclusion of missing values on any of the covariates in model 3. There were no differences in exposure levels between included and excluded participants. Among 100 166 participants included in the study and followed for 1 154 386 person years, there were 5157 incident cases. The average $PM_{2.5}$ level at residence ranged from 7.3 μg/m^3 in Sweden (SD=1.3) to 31.0 μg/m^3 (SD=1.7) in northern Italy, and all other pollutants had similar patterns. All exposure models had good performance (R^2 ≥0.61), and the prediction ability of models for nitrogen dioxides (based on a larger number of measurements sites) was slightly higher than those of particulate models.

Table 5⇓ shows the pooled hazard ratios with 95% confidence intervals for incidence of coronary events for fixed increments of all pollutants. We observed the strongest association for PM_{10}. While in model 1 (adjusted for age, sex, and calendar period) all particulate matter indicators were strongly associated with incidence of coronary events, when we adjusted for marital status, education, occupation, smoking status, smoking duration, smoking intensity, and socioeconomic area indicator (model 3), only PM_{10} showed a significant association (hazard ratio 1.12, 95% confidence interval 1.01 to 1.25, for each 10 μg/m^3 increase). There was also an association for $PM_{2.5}$ (1.13, 0.98 to 1.30, for each 5 μg/m^3 increase) and for coarse particles, whereas only small positive associations were found for nitrogen oxides. There was no evidence of an effect of traffic variables. There was no evidence of statistical heterogeneity between the cohort specific effect estimates (I^2<5%). The figure⇓ shows the forest plots of 10 μg/m^3 PM_{10} and 5 μg/m^3 $PM_{2.5}$ increments (model 3).

Table 6⇓ shows the results of the sensitivity analyses for PM_{10} and $PM_{2.5}$ from the base model (model 3), reporting the number of cohorts and participants included in each analysis. Overall, there were only a few marginal changes in the effect estimates across the various models, and there was no evidence of heterogeneity among cohorts. When we considered diabetes and hypertension in the adjustment, the effect estimates for PM_{10} and for $PM_{2.5}$ were slightly lower (hazard ratio 1.11 (95% confidence interval 1.00 to 1.24) and 1.11 (0.96 to 1.28), respectively). When we considered physical activity, alcohol consumption, and BMI in the eight cohorts with available information, the association between particulate matter and incidence of coronary events remained stable. Adjustment for cholesterol in the four cohorts with this variable did not alter the results. Adjustment for location of residence (urban, suburban/rural) slightly increased the effect estimates. In 63 121 participants who did not change their address during the follow-up, the effect estimate of air pollution was higher than in the whole population (hazard ratio 1.16 (1.01 to 1.32) for 10 μg/m^3 PM_{10}, and 1.18 (0.98 to 1.42) for 5 μg/m^3 $PM_{2.5}$), possibly because of more accurate exposure assignment. Exclusion of the large DCH study did not influence the results. When we restricted the meta-analysis to nine cohorts with exposure models with high cross validation (R^2 >60) for PM_{10} and six cohorts for $PM_{2.5}$, we found stronger associations (hazard ratio 1.18 (1.05 to 1.33) for 10 μg/m^3 PM_{10}, and 1.35 (1.04 to 1.74) for 5 μg/m^3 $PM_{2.5}$). When we took individual and area level covariates into account, we found no evidence of clustering in the neighbourhoods (data not shown).

Effect modification by age showed stronger $PM_{2.5}$ effects for those aged 60-74 (hazard ratio 1.25, 95% confidence interval 1.03 to 1.51) and for those >75 (1.18, 0.85 to 1.64) than among those aged under 60 (0.91, 0.71 to 1.15), with P=0.11 for effect modification. For all other effect modifiers, the P value of effect modification was far from significant (≥0.22).

Table 7⇓ shows the results of the threshold analysis for $PM_{2.5}$ and PM_{10}. When we restricted the analysis to participants from nine cohorts exposed to $PM_{2.5}$ concentrations below the current European limit value (<25 μg/m^3), there was a 18% increased risk per 5 μg/m^3 increase in $PM_{2.5}$ (hazard ratio 1.18, 95% confidence interval 1.01 to 1.39). Similarly, for PM_{10} below the current European limit value (40 μg/m^3) there was a 12% increased risk per 10 μg/m^3 increase in PM_{10} (1.12, 1.00 to 1.27). The effect was present even at exposure levels <15 μg/m^3 for $PM_{2.5}$ and <20 μg/m^3 for PM_{10}. This result was not an artefact caused by cohort selection at different thresholds as it persisted when we the restricted analysis to the seven cohorts with data available in each threshold (table 7, right columns⇓).

Discussion

This European multicentre study found that long term exposure to particulate air pollution is associated with an increased risk

of first coronary events. For both particulate matter with diameter <10 μm and <2.5 μm (PM_{10} and $PM_{2.5}$), we found associations at levels below the current European limits. The results were substantially robust to adjustment for confounding and model specification.

Comparison with other studies

Our effect estimates are similar to or higher than those from two cohort studies from the US. For an increase of 10 μg/m^3 in $PM_{2.5}$, Miller and colleagues found a 21% (hazard ratio 1.21, 95% confidence interval 1.04 to 1.42) increased risk of first coronary heart disease in postmenopausal women, and a (non-significant) 6% higher risk of myocardial infarction.[9] In the US Nurses' Health Study,[11] there was an increased incidence of coronary heart disease for a 10 μg/m^3 increase in $PM_{2.5}$ (hazard ratio 1.11, 0.79 to 1.55) and for a 10 μg/m^3 increase in coarse particles (1.04, 0.82 to 1.32). In the UK, Atkinson and colleagues found a non-significant 1% (−2% to 5%) higher risk in incident myocardial infarction per 3 μg/m^3 increase in PM_{10}.[14] In the California Teachers Study, Lipsett and colleagues found no evidence of increased myocardial infarction incidence per 10μg/m^3 increments in $PM_{2.5}$ and PM_{10}.[12] The results are also in line with the evidence produced so far by studies on the short term effects of particulate matter on ischaemic heart disease.[35 36]

We found a suggestion of a higher risk associated with particulate exposure in participants aged over 60. Evidence on which age range is the most susceptible is mixed. Miller and colleagues found a higher risk in those aged >70 compared with <70,[9] while Gan and colleagues found higher risks in first admissions to hospital for coronary heart disease in both those aged <60 and 60-69 than those aged ≥70.[5]

We found an effect of $PM_{2.5}$ below 25, 20, and 15 μg/m^3, and our results highlight the possible harmful health effects of fine particles well below the current EU annual limit for $PM_{2.5}$. It is clear that generalisability of these findings to the entire European population is not straightforward because the cohorts are not representative of the European population. Besides the differences among the cohorts in age range and underlying risk profiles, however, we detected no heterogeneity in the effect estimates among the cohorts.

There are several possible mechanisms through which exposure to air pollution can affect the cardiovascular system, including systemic inflammation, systemic oxidative stress, thrombosis and coagulation, changes in blood pressure, progression of atherosclerosis, and reduced heart rate variability.[15] Most of this evidence comes from studies of short term exposures and short term responses of cardiovascular function. The pathways implicated provide plausible biological mechanisms based on repeated exacerbations of cardiovascular risk factors potentially leading to long term progression of coronary artery disease.[15 37]

It is unlikely that our findings are driven by an excess in coronary disease mortality because in these and some other cohorts participating in the ESCAPE project we could not find much evidence of an association between exposure to air pollution and mortality for ischaemic heart disease or myocardial infarction.[38]

Our main positive results for coronary events are for an association with particulate matter, and the evidence for other pollutants such as nitrogen oxides could be considered as suggestive based on the small positive estimates. Several predictor variables explained the spatial variation of PM_{10} and $PM_{2.5}$ in ESCAPE study areas,[30] including not only traffic variables but also population density, industrial sources, urban green, and altitude. Estimated PM_{10} at place of residence therefore represents not only traffic emissions. In contrast, the spatial variation in $PM_{2.5}$ absorbance was more exclusively explained by traffic variables. Our findings suggest that sources other than vehicular traffic can have an important role on the risk of acute ischaemic heart disease.

Strengths and weaknesses

In this first multicentre European study to investigate long term effects of air pollution on incidence of coronary events, we used a standardised approach for assessment of exposure with respect to measurements and modelling.[28-31] Both the measurements and the land use regression models were centrally validated, and data analyses were centrally planned and conducted in the same way in each cohort. The European locations captured in this project provide a wide range of exposures and mixtures that vary from north to south. Although the design of the study did not allow us to benefit from the large variability of pollutant exposure between cohorts, we took advantage of the exposure variation within cohorts. The use of existing cohorts, not designed for air pollution epidemiology, might be seen as a limitation of the ESCAPE project. Indeed, we were able to perform a planned meta-analysis and make the most of existing studies in an efficient way. Therefore, we consider these data the first systematic assessment of the impact of ambient particles on incident coronary artery disease in Europe, highlighting that the burden of disease might be underestimated when estimates of mortality are considered alone.[15 39]

The assessment of exposure was conducted in 2008-11, while the cohorts were enrolled over 15 years, starting in 1992. The use of modelled concentrations based on measurements taken long after the beginning of the study assumes that spatial contrasts were stable over time, an assumption that has been supported from observations in different settings.[40-42] In the ESCAPE project considerable effort was made to take this problem into account; when possible, we back-extrapolated air pollution concentrations.[17] Analyses of the association between back-extrapolated concentrations and incidence of coronary events made no important difference.

We collected individual data on many cardiovascular risk factors to deal with confounding. When we compared the results of the "base model" with a model containing additional cardiovascular risk factors, we obtained similar results. It should be noted that variables used to adjust for area level socioeconomic status were different from cohort to cohort, ranging from the percentage of low income inhabitants in a 5 km grid in KORA to a census block deprivation index in the Italian cohorts. We could not determine whether this might have affected the results, but general adjustment for area level socioeconomic indicators did not have much influence in cohort specific analyses. Data on the most relevant cardiovascular risk factors (smoking, diabetes or hypertension, BMI, physical activity) were available for almost all cohorts, therefore a strong bias in the effect estimates caused by confounding is unlikely. Nevertheless, we cannot rule out residual confounding by, for example, differences in diet. In addition, we observed evidence for effect modification, but even within this large multicentre study, the power to reliably detect effect modification is limited and therefore we selected a limited set of interactions to evaluate a priori.

All cohorts, with the exception of the DCH study, enrolled fewer than 10 000 participants, making the statistical power to detect effects of air pollution in single studies limited. The characteristics of participants were heterogeneous, with two cohorts having younger participants than the others. Younger age could be a reason for the smaller effects found in some of

the cohorts. Finally, in nine out of 11 cohorts outcomes were ascertained from routine administrative databases, which could have led to a less precise effect estimate from misclassification of the outcome.

When we included only the studies with the best exposure assessment models (performance of the land use regression leave-one-out cross validation R^2>60%), we found increased effect estimates. This could be because of reduced misclassification of exposure. The cohorts with validation R^2 ≤60%, however, had young participants and (in particular the Italian ones) had higher rates of smoking and a better exposure assessment might be not the only explanation.

Conclusions

Our study suggests an association between long term exposure to inhalable particulate matter and incidence of coronary events. These associations remained for exposure concentrations below the current European limits. The results of this study, together with other ESCAPE findings, support lowering of European limits for particulate air pollution to adequately protect public health.

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Contributors: GC contributed to the design, exposure assessment, data analyses, and drafted the manuscript; FF contributed to the design, provided local cohort data and drafted the manuscript; MS contributed to the design, statistical script, and data analyses; ZJA, RH contributed to the statistical script and data analysis; CB, FH, EM, JPen, APy, FR, and AT contributed to the data analyses; RB, GH contributed to the design, exposure assessment and statistical script; BC, UdF, RE, LF, MH, AH, KHJ, KL, PKEM, CGO, KO, NLP, JPek, CS, and VS provided local cohort data; CG contributed to exposure assessment and provided local cohort data; BH, ORN, GP, and PV contributed to the design and provided local cohort data; MK contributed to the exposure assessment and the data analyses; KTE, DH, TL, AR, WS, and KdH contributed to exposure assessment; GW and KW contributed to the statistical script; BB and APe contributed to the design and drafted the manuscript. All authors contributed to critical reading of and comments to the manuscript, interpretation of data and approved the final draft. GC is guarantor.

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Ethical approval: The original cohort studies were approved by appropriate institutional review boards complying with all relevant national, state, and local regulations.

Transparency statement: The lead author affirms that this manuscript is an honest, accurate, and transparent account of the study being reported; that no important aspects of the study have been omitted; and that any discrepancies from the study as planned have been explained.

Data sharing: meta-analytic data and statistical code are available from the corresponding author.

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What is already known on this topic

Ambient particulate matter air pollution is estimated to cause 3.1 million deaths worldwide per year, and 22% of DALYs (disability adjusted life years) from ischaemic heart disease

The association between long term exposure to air pollution and incidence of coronary events remains controversial

What this study adds

There is an association between outdoor particulate matter and incidence of acute coronary events, even for exposure levels below the current European limits

The burden of disease attributable to outdoor particulate matter might be underestimated if only estimates of mortality are considered

The results of this study support lowering of the EU limits for particulate matter air pollution

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Tables

Table 1| Summary description of 11 European cohorts from five countries contributing data to study long term exposure to ambient air pollution and incidence of acute coronary events

Variable	FINRISK	SNAC-K	SALT	60 year olds	SDPP	DCH	HNR	KORA	EPIC Turin	SIDRIA	
										Turin	Rome
No of participants	9995	2684	6084	3686	7723	35 693	4433	8301	7230	5137	9200
Person years at risk	105 060	16 256	51 756	39 978	106 995	464 055	34 941	84 595	91 490	56 366	102 894
% of original cohort	93.5	89.4	92.3	91.0	97.6	96.0	99.3	94.0	82.4	95.5	87.1
No of cases	212	200	204	165	181	3293	135	282	157	123	205
Study location	Turku and Helsinki (Finland)	Stockholm (Sweden)	Stockholm (Sweden)	Stockholm (Sweden)	Stockholm (Sweden)	Copenhagen (Denmark)	Ruhr Area (Germany)	Augsburg (Germany)	Turin (Italy)	Turin (Italy)	Rome (Italy)
Years of enrolment	1992, 1997, 2002, 2007	2001-04	1998-2002	1997-99	1992-98	1993-97	2000-03	1994-95, 1999-2001	1993-98	1999	1999

Table 2| Individual baseline characteristics from 11 European cohorts from five countries contributing data to study long term exposure to ambient air pollution and incidence of acute coronary events. Values are numbers (percentages) unless stated otherwise

Variable	FINRISK	SNAC-K	SALT	60 year olds	SDPP	DCH	HNR	KORA	EPIC Turin	SIDRIA	
										Turin	Rome
No of participants	9995 (100)	2684 (100)	6084 (100)	3686 (100)	7723 (100)	35 693 (100)	4433 (100)	8301 (100)	7230 (100)	5137 (100)	9200 (100)
Mean (SD) age (years)	48 (13)	74 (11)	59 (11)	60 (0)	47 (5)	57 (4)	59 (8)	49 (14)	50 (8)	44 (6)	44 (6)
Women	5460 (55)	1751 (65)	3557 (58)	1967 (53)	4721 (61)	19 302 (54)	2309 (52)	4275 (51)	3472 (48)	2677 (52)	4859 (53)
Marital status:											
Single	1601 (16)	397 (15)	835 (14)	170 (5)	1272 (16)*	2352 (7)	256 (6)	879 (11)	438 (6)	121 (2)	0 (0)
Married/living with partner	7009 (70)	1263 (47)	4103 (67)	2628 (71)	6451 (84)	24 673 (69)	3319 (75)	6292 (76)	6183 (86)	4897 (95)	9200 (100)
Divorced/separated	1051 (11)	362 (13)	678 (11)	630 (17)	—	6599 (18)	444 (10)	620 (7)	375 (5)	37 (1)	0 (0)
Widowed	334 (3)	662 (25)	468 (8)	258 (7)	—	2069 (6)	414 (9)	510 (6)	234 (3)	82 (2)	0 (0)
Education:											
Primary school or less	3029 (30)	705 (26)	1332 (22)	1030 (28)	1996 (26)	10 589 (30)	499 (11)	1024 (12)	3168 (44)	898 (17)†	4130 (45)
Secondary school	5217 (52)	1128 (42)	2606 (43)	1631 (44)	3453 (45)	16 943 (47)	2466 (56)	6200 (65)	3081 (43)	3668 (71)	3690 (40)
University degree and more	1749 (17)	851 (32)	2146 (35)	1025 (28)	2274 (29)	8161 (23)	1468 (33)	1077 (13)	981 (14)	571 (11)	1380 (15)
Occupational status:											
Employed/self employed	7092 (71)	2016 (75)	—	1881 (51)	7088 (92)	28 600 (80)	1859 (42)	4908 (59)	—	3727 (73)	6500 (71)
Unemployed	610 (6)	668 (25)‡	—	374 (10)	635 (8)‡	7093 (20)‡	630 (14)	272 (3)	—	349 (7)	393 (4)
Homemaker or housewife	351 (4)	—	—	290 (8)	—	—	1664 (38)	1188 (14)	—	1061 (21)	2307 (25)
Retired	1942 (19)	—	—	1141 (31)	—	—	280 (6)	1933 (23)	—	0 (0)	0 (0)
Smoking status:											
Current smoker	2603 (26)	394 (15)	1224 (20)	751 (20)	2022 (26)	12 793 (36)	1040 (23)	2162 (26)	1768 (24)	2117 (41)	3884 (42)
Former smoker	2808 (28)	927 (34)	2678 (44)	1429 (39)	2815 (36)	9944 (28)	1482 (33)	2517 (30)	2368 (33)	1085 (21)	2147 (23)
Never smoker	4584 (46)	1363 (51)	2182 (36)	1506 (41)	2886 (37)	12 956 (36)	1911 (43)	3622 (44)	3094 (43)	1935 (38)	3169 (34)
Mean (SD) years of smoking among ever smokers	15 (12)	30 (17)	—	26 (13)	20 (10)	29 (10)	36 (9)§	21 (13)	23 (10)	18 (8)	18 (7)
Mean (SD) No of cigarettes/day among current smokers	15 (9)	11 (8)	13 (8)	13 (7)	14 (7)	17 (10)	17 (12)	15 (11)	14 (9)	15 (9)	15 (9)

*All except married/living with partner.

†<6 years of schooling.

‡All except employed.

§Only among current smokers.

Table 3| Air pollution exposure at residential address of individuals from 11 European cohorts from five countries contributing data to study long term exposure to ambient air pollution and incidence of acute coronary events. Figures are means and 5-95th centile ranges, correlation coefficients between PM2.5 and other pollutants, and R^2 of models and their cross validation

Variable	FINRISK	SNAC-K	SALT	60 year olds	SDPP	DCH	HNR	KORA	EPIC Turin	SIDRIA Turin	SIDRIA Rome
Mean (5th-95th centile) annual air pollution (µg/m^3) at residence address											
PM_{10}	14 (10-20)	16 (6-29)	15 (7-21)	15 (7-21)	14 (6-17)	17 (14-20)	28 (25-32)	20 (16-24)	46 (39-52)	48 (41-54)	36 (31-47)
Coarse PM	7 (4-11)	8 (1-19)	7 (2-12)	7 (1-12)	6 (1-9)	6 (4-7)	10 (7-12)	6 (5-8)	16 (12-20)	17 (13-20)	17 (12-24)
$PM_{2.5}$	8 (6-9)	8 (6-10)	7 (5-9)	7 (5-9)	7 (5-8)	11 (10-13)	18 (17-20)	14 (13-15)	30 (27-33)	31 (29-34)	19 (17-23)
Absorbance $PM_{2.5}$,10^{-5}/m	0.9 (0.5-1.2)	0.8 (0.5-1.2)	0.6 (0.4-0.9)	0.6 (0.4-0.9)	0.5 (0.4-0.7)	1.2 (0.8-1.5)	1.6 (1.2-2.2)	1.7 (1.5-2.0)	3.1 (2.3-3.6)	3.2 (2.6-3.8)	2.7 (2.2-4.0)
NO_2	15 (9-24)	17 (9-25)	11 (7-20)	11 (6-20)	8 (6-11)	16 (8-30)	30 (23-39)	19 (14-26)	53 (34-68)	60 (42-77)	39 (26-56)
NO_x	24 (14-41)	33 (15-58)	19 (12-40)	19 (12-39)	14 (12-20)	27 (7-66)	51 (33-72)	33 (24-47)	96 (62-132)	107 (79-162)	82 (39-122)
Daily No of vehicles/day on nearest road	1670 (50-9011)	3726 (500-21828)	1454 (500-6000)	1455 (500-6300)	864 (500-2575)	2994 (200-16145)	-	1636 (500-8367)	3907 (0-23951)	4290 (0-24379)	2966 (500-15312)
Daily traffic load on major roads in 100 m buffer (thousand), (vehicles×meters/day)	633 (0-3711)	2307 (0-6572)	578 (0-3437)	521 (0-3048)	109 (0-986)	1274 (51-4719)	1017 (0-4302)	444 (0-2805)	466 (0-2340)	804 (0-4197)	1417 (0-6947)
Pearson correlations coefficients between $PM_{2.5}$ and:											
PM_{10}	0.67	0.70	0.49	0.50	0.31	0.74	0.90	0.42	0.62	0.56	0.92
Coarse PM	0.10	0.71	0.50	0.50	0.32	0.60	0.51	0.38	0.51	0.32	0.90
Absorbance $PM_{2.5}$	0.98	0.98	0.84	0.84	0.90	0.49	0.76	0.50	0.77	0.73	0.78
NO_2	0.41	0.82	0.60	0.61	0.61	0.57	0.63	0.45	0.72	0.67	0.69
R^2 of land use regression models and their leave one out cross validation											
PM_{10}	067-0.42	0.82-0.77	0.82-0.77	0.82-0.77	0.82-0.77	0.75-0.64	0.69-0.63	0.83-0.75	0.78-0.69	0.78-0.69	0.72-0.59
Coarse PM	0.61-0.33	0.72-0.65	0.72-0.65	0.72-0.65	0.72-0.65	0.71-0.54	0.66-0.57	0.81-0.79	0.65-0.58	0.65-0.58	0.70-0.57
$PM_{2.5}$	0.67-0.53	0.87-0.78	0.87-0.78	0.87-0.78	0.87-0.78	0.62-0.55	0.88-0.79	0.78-0.62	0.71-0.59	0.71-0.59	0.71-0.60
Absorbance $PM_{2.5}$	0.65-0.47	0.89-0.85	0.89-0.85	0.89-0.85	0.89-0.85	0.92-0.86	0.97-0.95	0.91-0.82	0.88-0.81	0.88-0.81	0.84-0.70
NO_2	0.83-0.75	0.82-0.78	0.82-0.78	0.82-0.78	0.82-0.78	0.88-0.83	0.89-0.84	0.86-0.67	0.78-0.70	0.78-0.70	0.87-0.76
NO_x	0.85-0.74	0.83-0.79	0.83-0.79	0.83-0.79	0.83-0.79	0.83-0.73	0.88-0.81	0.88-0.76	0.78-0.72	0.78-0.72	0.80-0.79

$PM_{2.5}$=particulate matter <2.5 µm; PM_{10}=particulate matter <10 µm; NO_2=nitrogen dioxide; NOx=nitrogen oxides.

Table 4| Additional baseline characteristics of study populations in analysis of long term exposure to ambient air pollution and incidence of acute coronary events. Values are numbers (percentages) unless stated otherwise

										SIDRIA	
	FINRISK	SNAC-K	SALT	60 year olds	SDPP	DCH	HNR	KORA	EPIC Turin	Turin	Rome
Area level socioeconomic indicators*:											
1 (lowest)	—	1429 (53)	1692 (28)	898 (24)	3024 (39)	—	—	—	963 (13)	1114 (22)	2332 (25)
2	—	1252 (47)	2643 (43)	924 (25)	1164 (15)	—	—	—	1404 (19)	1114 (22)	1802 (20)
3	—	3 (0)	242 (4)	938 (25)	2016 (26)	—	—	—	1342 (19)	944 (18)	1675 (18)
4	—	—	1507 (25)	926 (25)	1519 (20)	—	—	—	1662 (23)	1070 (21)	1684 (18)
5 (highest)	—	—	—	—	—	—	—	—	1859 (26)	895 (17)	1707 (19)
Mean (SD)	22 946 (5458)					1.9 (0.4)	12.6 (3.1)	28.1 (18.4)			
Mean (SD) BMI	26.3 (4.6)	25.6 (4.1)	28.5 (4.1)	26.8 (4.2)	25.7 (4.0)	26.0 (4.1)	27.8 (4.6)	27.1 (4.6)	25.3 (3.8)	—	—
BMI in classes:											
<25	4329 (43)	1209 (48)	1055 (18)	1349 (37)	3741 (49)	15 998 (45)	1201 (27)	2824 (34)	3691 (51)	—	—
25-29	3852 (39)	1004 (40)	3131 (52)	1633 (44)	2995 (39)	14 642 (41)	2025 (46)	3551 (43)	2779 (38)	—	—
>29	1811 (18)	302 (12)	1805 (30)	704 (19)	964 (13)	5026 (14)	1189 (27)	1852 (23)	761 (11)	—	—
Physical activity (hours/week):											
<1	1808 (18)	464 (20)	1575 (26)	2510 (69)	846 (11)	15 984 (45)	2263 (51)	3107 (37)	1660 (23)	—	—
~1	3322 (33)	686 (30)	3757 (62)	858 (24)	6273 (81)	19 709 (55)	490 (11)	3515 (42)	2032 (28)	—	—
>2	4839 (49)	1115 (49)	716 (12)	279 (8)	597 (8)	—	1667 (38)	1666 (20)	3538 (49)	—	—
Alcohol consumption (drinks/week):											
Never	1320 (13)	519 (19)	—	168 (5)	594 (8)	776 (2)	1015 (23)	3867 (47)	457 (6)	—	—
1-3	4566 (46)	634 (24)	—	771 (21)	2876 (38)	34 142 (98)†	1190 (27)	1212 (15)	201 (3)	—	—
3-6	3139 (32)	1236 (46)	—	1622 (44)	3873 (51)	—	2127 (49)	549 (7)	347 (5)	—	—
>6	824 (8)	288 (11)	—	1123 (30)	280 (4)	—		2662 (32)	6225 (86)	—	—
Diabetes mellitus:											
No	9546 (96)	2464 (92)	5833 (96)	3533 (96)	7597 (98)	34 943 (98)	3877 (87)	7940 (96)	7118 (98)	5111 (99)	9179 (100)
Yes	426 (4)	220 (8)	251 (4)	153 (4)	126 (2)	703 (2)	556 (13)	360 (4)	110 (2)	26 (1)	21 (0)
Hypertension:											
No	5877 (59)	902 (34)	4735 (78)	1770 (48)	5801 (76)	30 033 (84)	2002 (45)	5098 (62)	3629 (53)	5082 (99)	9124 (99)
Yes	4042 (41)	1762 (66)	1347 (22)	1915 (52)	1837 (24)	5625 (16)	2423 (55)	3190 (38)	3255 (47)	55 (1)	76 (1)
Mean (SD) serum cholesterol	211 (78)	—	—	231 (41)	—	—	231 (39)	229 (44)	—	—	—
Noise exposure at baseline address (dB):											
<45			123 (5)	84 (6)	—	126 (0)	721 (17)	466 (6)	44 (1)	62 (1)	—
45-49	1912 (23)‡	319 (12)	200 (8)	110 (7)	—	1838 (5)	989 (23)	1345 (16)	115 (2)	121 (2)	—
50-54	2040 (24)	799 (30)	524 (21)	292 (20)	—	9634 (27)	853 (20)	2946 (36)	87 (2)	103 (2)	—
55-59	1721 (21)	692 (26)	550 (23)	304 (21)	—	9560 (27)	565 (13)	1873 (23)	253 (5)	186 (4)	—
60-64	1181 (14)	627 (24)	435 (18)	291 (20)	—	7625 (21)	482 (11)	987 (12)	2419 (43)	2237 (44)	—
65-69	784 (9)	230 (9)	332 (14)	225 (15)	—	4600 (13)	462 (11)	478 (6)	1254 (22)	1133 (22)	—
70-74	714 (9)‡	0	237 (10)	143 (10)	—	2010 (6)	194 (5)	199 (2)	1369 (24)	1126 (22)	—
>74	—	—	43 (2)	30 (2)	—	294 (1)	40 (1)	3 (0)	136 (2)	156 (3)	—
Living in areas of low urbanisation:											
No	9086 (91)	2684 (100)	2763 (45)	1450 (39)	0 (0)	14 155 (40)	4433 (100)	3557 (43)	7230 (100)	5137 (100)	9200 (100)
Yes	909 (9)	0 (0)	3321 (55)	2236 (61)	7723 (100)	21 538 (60)	0 (0)	4744 (57)	0 (0)	0 (0)	0 (0)

*FINRISK: median income rate in 3 km area; SNAC-K: mean income in thirds at small neighbourhood level (Small Area for Market Statistics); SALT and SDPP: mean income in four categories at municipality level; 60 years: mean income in quarters at small neighbourhood level (Small Area for Market Statistics); DCH: mean income at municipality level (16 units with median population of 1500 inhabitants), per/100 000; HNR: unemployment rate at neighbourhood level; KORA: percentage of low income in 5 km grid; EPIC-Turin, SIDRIA-Turin, and SIDRIA-Rome: deprivation index, census block level (average 500 inhabitants).

Table 4 (continued)

										SIDRIA	
	FINRISK	SNAC-K	SALT	60 year olds	SDPP	DCH	HNR	KORA	EPIC Turin	Turin	Rome

†Any category of drinking.

‡First and last two classes are collapsed.

Table 5| Association between exposure to pollutants and incidence of coronary events. Results expressed per fixed increments

Exposure	Fixed increment	Cohorts	Participants	Pooled hazard ratios (95% CI)		
				Model 1*	Model 2†	Model 3‡
PM_{10} ($\mu g/m^3$)	10	11	100 166	1.15 (1.04 to 1.28)	1.12 (1.01 to 1.24)	1.12 (1.01 to 1.25)
Coarse PM ($\mu g/m^3$)	5	11	100 166	1.08 (1.00 to 1.17)	1.06 (0.98 to 1.14)	1.06 (0.98 to 1.15)
$PM_{2.5}$ ($\mu g/m^3$)	5	11	100 166	1.22 (1.04 to 1.44)	1.15 (1.00 to 1.32)	1.13 (0.98 to 1.30)
Absorbance $PM_{2.5}$ ($10^{-5}/m$)	1	11	100 166	1.18 (1.05 to 1.32)	1.10 (0.98 to 1.24)	1.10 (0.98 to 1.24)
NO_2 ($\mu g/m^3$)	10	11	100 166	1.04 (0.96 to 1.12)	1.03 (0.96 to 1.11)	1.03 (0.97 to 1.08)
NO_x ($\mu g/m^3$)	20	11	100 166	1.03 (1.00 to 1.07)	1.01 (0.98 to 1.05)	1.01 (0.98 to 1.05)
Traffic intensity on nearest road adjusted for background NO_2 (vehicles/day)§	5000	10	95 733	1.01 (0.98 to 1.04)	1.01 (0.98 to 1.04)	1.01 (0.98 to 1.04)
Traffic load on major roads in 100 m buffer adjusted for background NO_2 (vehicles×m/day)	4 000 000	11	100 166	1.02 (0.96 to 1.08)	1.00 (0.95 to 1.06)	1.00 (0.95 to 1.06)

*Adjusted for age (time variable), year of enrolment and sex

†As for model 1 plus adjusted for marital status, education, occupation, smoking status, smoking duration, and smoking intensity.

‡As for model 2 plus adjusted for socioeconomic area level variables.

§All cohorts except HNR study.[24]

Table 6| Incidence of coronary events, results from sensitivity analyses. Figures are pooled hazard ratios (and 95% CI) for 10 µg/m^3 PM10 and 5 µg/m^3 PM2.5, I^2 statistics, and P value for heterogeneity

Model	No of cohorts	No of participants*	Hazard ratio† (95% CI)	
			10 µg/m^3 PM_{10}	5 µg/m^3 $PM_{2.5}$
Base model (model 3)	11	100 166	1.12 (1.01 to 1.25)	1.13 (0.98 to 1.30)
Role of cardiovascular risk factors				
Intermediate variables: diabetes and hypertension:				
+ diabetes and hypertension	11	99 526	1.11 (1.00 to 1.24)	1.11 (0.96 to 1.28)
Physical activity, alcohol and BMI‡:				
Base model, on subset of participants with additional information	8	77 584	1.17 (1.04 to 1.33)	1.22 (1.03 to 1.44)
+ additional information	8	77 584	1.17 (1.04 to 1.33)	1.19 (1.01 to 1.42)
All cardiovascular risk factors (diabetes, hypertension, physical activity, alcohol, BMI, cholesterol)§:				
Base model, on subset of participants with additional information	4	25 625	1.19 (0.92 to 1.53)	1.28 (0.92 to 1.79)
+ additional information	4	25 625	1.20 (0.93 to 1.56)	1.29 (0.92 to 1.81)
Urban/suburban-rural residence location:				
Base model, on subset of participants with additional information	11	100 166	1.12 (1.01 to 1.25)	1.13 (0.98 to 1.39)
+ additional information	11	100 166	1.13 (1.02 to 1.26)	1.14 (0.99 to 1.31)
Noise¶:				
Base model, on subset of participants with noise information	9	73 840	1.14 (1.01 to 1.30)	1.16 (0.98 to 1.37)
+ noise variable	9	73 840	1.14 (1.01 to 1.31)	1.13 (0.95 to 1.36)
Change of address:**				
Base model, on subset of cohorts with change of address information	10	92 936	1.11 (0.99 to 1.23)	1.14 (0.98 to 1.33)
Participants who didn't change address during follow-up	10	63 121	1.16 (1.01 to 1.32)	1.18 (0.98 to 1.42)
Proportionality hazards (PH) assumption:				
Variables that do not meet PH put as strata	11	100 166	1.10 (0.99 to 1.23)	1.13 (0.98 to 1.30)
Exclusion of DCH Study				
Data after exclusion	10	64 473	1.12 (0.99 to 1.27)	1.09 (0.92 to 1.30)
Performance of land use regression model††:				
Leave one out cross validation R^2 >60%	—	—	1.18 (1.05 to 1.33)	1.35 (1.04 to 1.74)
Leave one out cross validation R^2 ≤60%	—	—	0.88 (0.68 to 1.12)	1.05 (0.89 to 1.25)

*Figures depend on number of cohorts included and on missing values of included variables

†Adjusted for age (time variable), year of enrolment, sex, marital status, education, occupation, smoking status, smoking duration, smoking intensity, and socioeconomic area level indicators.

‡Excludes SALT, SIDRIA-Turin, and SIDRIA-Rome.

§Includes FINRISK, 60 year olds, HNR, and KORA.

¶All cohorts except SDPP and SIDRIA-Rome.

**All cohorts except EPIC-Turin.

††For PM_{10}: nine cohorts, 80 971 participants (excludes FINRISK and SIDRIA-Rome). For $PM_{2.5}$: six cohorts, 42 906 participants (excludes FINRISK, DCH, EPIC-Turin, SIDRIA-Turin, and SIDRIA-Rome).

Table 7| **Results from random-effects meta-analyses for adjusted association between incidence of coronary events and exposure to PM10 and PM2.5 below various threshold values. Figures are pooled hazard ratios (95% CI) for 10 µg/m^3 PM10 and 5 µg/m^3 PM2.5, I^2 statistic, and P value for heterogeneity**

Exposure and threshold	Cohorts with exposure data available for respective threshold					Cohorts with exposure data available for all thresholds				
	No of cohorts	No of participants	HR* (95% CI)	I^2	P value	No of cohorts	No of participants	HR* (95% CI)	I^2	P value
PM_{10} (µg/m^3):										
Full range of exposure	—	—	—	—	—	7†	74 166	1.15 (1.02 to 1.30)	0	0.92
<20	7†	64 363	1.20 (1.01 to 1.41)	0	0.91	7†	64 363	1.20 (1.01 to 1.41)	0	0.91
<30	8‡	77 997	1.12 (0.98 to 1.27)	0	0.94	7†	74 019	1.12 (0.98 to 1.27)	0	0.91
<40	9§	86 222	1.12 (1.00 to 1.27)	0	0.48	7†	74 166	1.15 (1.02 to 1.30)	0	0.92
$PM_{2.5}$ (µg/m^3):										
Full range of exposure	—	—	—	—	—	7†	74 166	1.23 (1.04 to 1.46)	0	0.57
<15	7†	73 420	1.19 (1.00 to 1.42)	0	0.74	7†	73 420	1.19 (1.00 to 1.42)	0	0.74
<20	9§	85 216	1.17 (0.91 to 1.50)	30	0.18	7†	74 166	1.23 (1.04 to 1.46)	0	0.57
<25	9§	87 532	1.18 (1.01 to 1.39)	0	0.56	7†	74 166	1.23 (1.04 to 1.46)	0	0.57

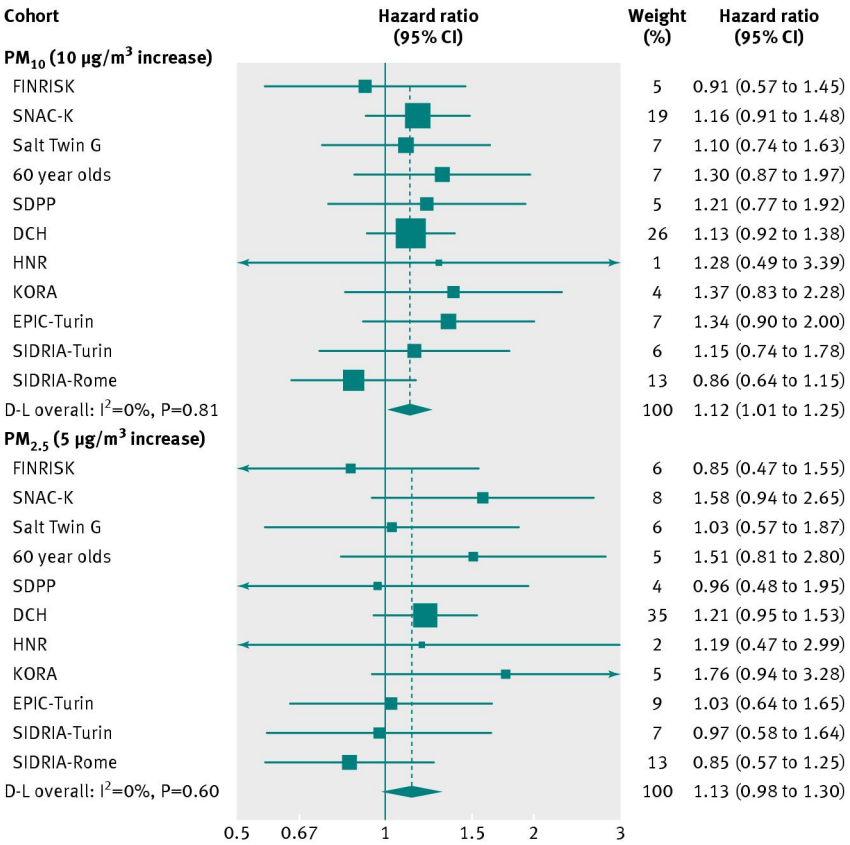
*Adjusted for age (time variable), year of enrolment, sex, marital status, education, occupation, smoking status, smoking duration, smoking intensity. and socioeconomic area level indicators

†All cohorts except Heinz Nixdorf Recall Study, EPIC-Turin, SIDRIA-Turin and SIDRIA-Rome.

‡All cohorts except EPIC-Turin, SIDRIA-Turin and SIDRIA-Rome.

§All cohorts except EPIC-Turin and SIDRIA-Turin.

Figure



Hazard ratios of incident coronary events per 10 µg/m^3 PM_{10} and 5 µg/m^3 $PM_{2.5}$. Cohort specific and meta-analytic results

Department
for Environment
Food & Rural Affairs

CLEAN AIR
STRATEGY **2019**

Contents

Foreword from the Secretary of State

At the most fundamental level, our health and prosperity depend on the health of the planet on which we live. From the air we breathe to the water we drink, the food we eat and the energy that powers our homes and businesses, we need to protect and sustain the health of the natural environment.

Nowhere is this more true than in the case of air quality. Air pollution is the top environmental risk to human health in the UK, and the fourth greatest threat to public health after cancer, heart disease and obesity. It makes us more susceptible to respiratory infections and other illnesses, and we estimate that the actions outlined in this document could cut the costs of air pollution to society by £1.7 billion every year by 2020, rising to £5.3 billion every year from 2030.

This Clean Air Strategy sets out the case for action and demonstrates this government's determination to improve our air quality. In some cases the goals that we have set are even more ambitious than EU requirements because we want to do all that we can to reduce people's exposure to toxic pollutants like nitrogen oxides, ammonia, particulate matter, non-methane volatile organic compounds and sulphur dioxide.

We often think of air pollution as a problem caused by road transport and industrial level burning of fossil fuels. These are two of the central sources of pollution, but industry and government have worked together to remedy many of the worst problems by incentivising the use of clean fuels and investing in new technology.
We have already secured a significant reduction in emissions since the 1970s. But now this trajectory has slowed.

Now we need to tackle other sources of air pollutants that damage human health and the environment. Air pollution can be caused by intensive agricultural food production, heating our homes or even cleaning with certain solvents.

We therefore need comprehensive action to safeguard our health.

For example, heating our homes with solid fuels makes a significant contribution to particulate matter - tiny particles that get into the lungs and blood and are transported around the body becoming lodged in the heart, brain and other organs. Like many other pollutants, particulate matter can have a short term impact over a single, highly polluted day or long-term impacts from low-level exposure over a long period of time. This strategy sets out our aim to reduce particulate matter emissions by 30% by 2020, and by 46% by 2030.

Ammonia emissions from agriculture are also increasing, and the widespread use of volatile organic compounds in many everyday cleaning and toiletry products poses a serious indoor exposure risk. Indeed, Public Health England attributed the 2014 smog in London, in part, to agricultural ammonia emissions.

Armed with increased awareness and improved scientific measurements, we must tackle these problems with a new goal that takes into account the World Health Organization's guidelines.
We plan to set out our ambitions in primary legislation, last updated by a Conservative government in the Clean Air Act 1993.
This strategy sets out new enforcement powers at a national and local level, across all sectors of society.

We will continue to work with the devolved administrations to deliver our international air quality commitments. This strategy is focused on tackling air pollution in England, but the United Kingdom has a shared goal to protect our natural heritage. This strategy highlights action being taken across the country, not just in England, but also in Northern Ireland, Scotland and Wales.

Leaving the EU marks a new chapter for the UK. We have an opportunity to set world-leading standards on everything from marine conservation to clean air strategies, and to set a gold standard for environmental protection. We will be able to set out a new direction for our environment, based on rigorous scientific research and underpinned by the legal principles that have done so much to improve our environment in the past. It is my profound hope that we will use the opportunity presented by leaving the EU to become a world leader in environmental excellence.

Rt Hon Michael Gove MP
Secretary of State for Environment, Food and Rural Affairs

Executive summary

This Clean Air Strategy shows how we will tackle all sources of air pollution, making our air healthier to breathe, protecting nature and boosting the economy.

This document builds on an extensive consultation process which indicated broad-based support for many of the actions we are proposing. There was also a range of constructive feedback and challenge that has enabled us to improve and extend our ambition even further in certain key areas. A document summarising the responses to the consultation is published alongside the strategy.

The final strategy sets out these proposals in detail and also indicates how devolved administrations intend to make their share of emissions reductions. It complements three other UK government strategies: the Industrial Strategy, the Clean Growth Strategy and the 25 Year Environment Plan.

Since the middle of the 20th century we have addressed many of the worst impacts of air pollution through regulatory frameworks, investment by industry in cleaner processes and a shift in the fuel mix towards cleaner forms of energy. However, exposure to the pollution still present in our atmosphere is one the UK's biggest public health challenges, shortening lifespans and damaging quality of life for many people. It also harms the natural environment, affecting our waterways, biodiversity and crop yields.

Clean air is essential for life, health, the environment and the economy. Government must act to tackle air pollution which shortens lives. We have already acted to reduce concentrations of nitrogen dioxide (NO_2) around roads from cars. But vehicles are not the only source of harmful emissions. Air pollution is a result of the way we currently generate power, heat our homes, produce food, manufacture consumer goods and power transport. Better, cleaner technologies and simple changes in behaviour will tackle the pollution that claims lives.

In the past, the priority was to tackle the biggest individual sources of pollution. As these major sources of emissions have decreased, the relative contribution of smaller and more diffuse sources of air pollution, like smaller industrial sites, product use, open fires in homes and spreading manure on farms, has increased. That requires new action.

We have already adopted **ambitious, legally-binding international targets to reduce emissions of five of the most damaging air pollutants** (fine particulate matter, ammonia, nitrogen oxides, sulphur dioxide, non-methane volatile organic compounds) by 2020 and 2030. We are now also proposing **tough new goals to cut public exposure to particulate matter pollution, as recommended by the World Health Organization.**

This Strategy sets out the comprehensive action that is required from across all parts of government and society to meet these goals. **New legislation will create a stronger and more coherent framework for action to tackle air pollution.** This will be underpinned by **new England-wide powers** to control major sources of air pollution, in line with the risk they pose to public health and the environment, **plus new local powers** to take action in areas with an air pollution problem. These will support the creation of **Clean Air Zones to lower emissions from all sources of air pollution**, backed up with clear enforcement mechanisms.

CHAPTER 1 - Understanding the problem

Air pollution comes from many sources. Pollutants can travel long distances and combine with each other to create different pollutants. Emissions from distant and local sources can build up into high local concentrations of pollution. The UK has set stringent targets to cut emissions by 2020 and 2030. The goal is to reduce the harm to human health from air pollution by half. A robust evidence base, backed by the most up to date science is essential to help us achieve this.

We are investing £10 million in improving our modelling, data and analytical tools to give a more precise picture of current air quality and the impact of policies on it in future.

We will increase transparency by bringing local and national monitoring data together into a single accessible portal for information on air quality monitoring and modelling, catalysing public engagement through citizen science.

CHAPTER 2 - Protecting the nation's health

Air quality is the largest environmental health risk in the UK. It shortens lives and contributes to chronic illness. Health can be affected both by short-term, high-pollution episodes and by long-term exposure to lower levels of pollution. There are small things we can all do that will make a big difference to emissions locally and nationally. Effective communication of health messages about air pollution and appropriate action can save lives and improve quality of life for many.

We will progressively cut public exposure to particulate matter pollution as suggested by the World Health Organization. We will set a new, ambitious, long-term target to reduce people's exposure to $PM_{2.5}$ and will publish evidence early in 2019 to examine what action would be needed to meet the WHO annual mean guideline limit of 10 µg/m^3.

By implementing the policies in this Strategy, we will reduce $PM_{2.5}$ concentrations across the UK, so that the number of people living in locations above the WHO guideline level of 10 µg/m^3 is reduced by 50% by 2025.

By taking action on air pollution we can help people live well for longer, as set out in the Department of Health and Social Care's recently published 'Prevention is Better than Cure' document, which sets the scene for the development of a prevention green paper.

We will provide a personal air quality messaging system to inform the public, particularly those who are vulnerable to air pollution, about the air quality forecast, providing clearer information on air pollution episodes and accessible health advice.

We will back these goals up with powers designed to enable targeted local action in areas with an air pollution problem.

We will work with media outlets to improve public access to the air quality forecast.

We will work to improve air quality by helping individuals and organisations understand how they could reduce their contribution to air pollution, showing how this can help them protect their families, colleagues and neighbours.

We have published updated appraisal tools and accompanying guidance to enable the health impacts of air pollution to be considered in every relevant policy decision that is made.[1]

We will equip health professionals to play a stronger role by working with the Medical Royal Colleges and the General Medical Council to embed air quality into the health professions' education and training. We will work with local authorities and directors of public health to equip and enable them to lead and inform local decision-making to improve air quality more effectively.

CHAPTER 3 - Protecting the environment

This strategy is a key part of delivering our 25 Year Environment Plan. Air pollution has direct impacts on the natural environment, contributing to climate change, reducing crop yields and polluting oceans. Cleaner air will directly benefit animals and habitats as well as creating a better environment for everyone to live, work and thrive in.

We will commit to a new target for the reduction of damaging deposition of reactive forms of nitrogen and review what longer term targets should be to further tackle the environmental impacts of air pollution.

We will monitor the impacts of air pollution on natural habitats and report annually so that we can chart progress as we reduce the harm air pollution does to the environment.

We will provide guidance for local authorities explaining how cumulative impacts of nitrogen deposition on natural habitats should be mitigated and assessed through the planning system.

CHAPTER 4 - Securing clean growth and innovation

This strategy contributes to the government's action on clean growth. Action to clean up the air will boost productivity and economic growth. We will make the UK a world leader in the development, use and export of goods and services focused on tackling air pollution.

We will maximise the advantages for UK industry from the global shift to clean growth – through leading the world in the development, manufacture and use of technologies, systems and services that tackle air pollution.

In partnership with UKRI, we will seek ways to support further investment in Clean Air innovation. For example, we have launched a joint research programme worth £19.6 million to promote the development of cleaner technologies and as part of this Innovate UK have run a £5 million Small Business Funding competition to promote and procure industry-led R&D.

Future electricity, heat and industrial policies will together improve air quality and tackle climate change. Phasing out coal-fired power stations, improving energy efficiency, and shifting to cleaner power sources will reduce emissions of air pollution as well as carbon dioxide. As we phase out oil and coal heating, we will ensure this transition improves air quality wherever possible and cost effective to do so.

Building on the framework established for bioenergy, we will seek to strengthen the collaboration between Defra and BEIS, so that we fairly and objectively articulate the trade-offs between energy and public health when developing strategies to meet air quality and carbon targets.

We will minimise the air quality impacts of the Renewable Heat Incentive Scheme and tackle non-compliance. For example, we have introduced new rules requiring all applicants to submit relevant permits and exemptions to evidence their compliance with all local and national environmental regulations, including air quality impacts. The government recently consulted on banning new RHI biomass applications installed in urban areas which are on the gas grid and introducing mandatory maintenance checks for those installations already accredited on the RHI and will be responding in due course.

We will consult on making coal to biomass conversions ineligible for future allocation rounds of the contracts for difference scheme.

CHAPTER 5 - Action to reduce emissions from transport

Transport is a significant source of emissions of air pollution. The immediate air quality challenge is to reduce emissions of nitrogen oxides in the areas where concentrations of these harmful gases currently exceed legal limits. The government has already committed more than £3.5 billion to tackle poor air quality through cleaner road transport and is working closely with local authorities and Local Economic Partnerships to make progress. Alongside this, the government is committed to cutting air pollution from all forms of transport.

We published Road to Zero, which sets our plans to end the sale of new conventional petrol and diesel cars and vans by 2040. We will position the UK as the best place in the world to develop, manufacture and use zero exhaust emissions vehicles and, during the transition, we will ensure that the cleanest conventional vehicles are driven on our roads.

In December we published a consultation on our strategy for the future of the UK Aviation sector, Aviation 2050. Our strategy shaping up the future of the maritime sector, Maritime 2050, will also be published soon, informed by a call for evidence held in March 2018.

New legislation will enable the Transport Secretary to compel manufacturers to recall vehicles and non-road mobile machinery for any failures in their emissions control system, and to take effective action against tampering with vehicle emissions control systems.

We will work with international partners to research and develop new standards for tyres and brakes to enable us to address toxic non-exhaust particulate emissions from vehicles which include micro plastics and can pollute air and water.

We will reduce emissions from rail and reduce passenger and worker exposure to air pollution. By the spring 2019, the rail industry will produce recommendations and a route map to phase out diesel-only trains by 2040.

By spring 2019, the government will publish guidelines to advise ports on how to develop effective and targeted Air Quality Strategies. The strategies will set out plans to reduce emissions across the ports and associated waterways, including both emissions from shore activities and visiting ships. Some ports like Southampton and London have already developed a strategy and are making progress. Following publication of the guidelines, ports within scope will be required to produce Air Quality Strategies by the end of 2019.

We have reviewed the policy on aviation-related emissions to improve air quality and have published the consultation on a new aviation strategy.

We are taking action to encourage the use of the cleanest modes of transport for freight and passengers, including active travel.

We are working with the Treasury to review current uses of red diesel and ensure its lower cost is not discouraging the transition to cleaner alternatives.

We will explore permitting approaches to reduce emissions from non-road mobile machinery, particularly in urban areas.

CHAPTER 6 - Action to reduce emissions at home

Many people are unaware that emissions in the home increase personal exposure to pollutants and contribute significantly to our overall national emissions. Burning wood and coal in open fires and stoves makes up 38% of the UK's primary emissions of fine particulate matter[2] ($PM_{2.5}$). Harmful sulphur dioxide (SO_2) is emitted by coal burned in open fires. Non-methane volatile organic compounds (NMVOCs) from a wide variety of chemicals that are found in carpets, upholstery, paint, cleaning, fragrance, and personal care products are another significant source of pollution.

We will legislate to prohibit the sale of the most polluting fuels.

We will ensure that only the cleanest stoves are available for sale by 2022.

We will make changes to existing smoke control legislation to make it easier to enforce.

We will give new powers to local authorities to take action in areas of high pollution.

We will work across government to look at opportunities to align our work on air quality, clean growth and fuel poverty in future policy design.

We will develop a dedicated communication campaign targeted at domestic burners, to improve awareness of the environmental and public health impacts of burning.

We will work with industry to identify an appropriate test standard for new solid fuels entering the market.

We will work with consumer groups, health organisations and industry to improve awareness of NMVOC build-up in the home, and the importance of effective ventilation to reduce exposure.

We will work with consumer groups, health organisations, industry and retailers to better inform consumers about the VOC content of everyday products. We will explore a range of options including the development of a voluntary labelling scheme for NMVOC containing products, and assess its potential effectiveness.

We will work with consumer groups, health organisations, industry and retailers to promote development of lower VOC-content products and to reduce emissions from this sector.

Alongside our actions on emissions of NMVOCs, we will consult on changes to Building Regulations standards for ventilation in homes and other buildings, to help reduce the harmful build-up of indoor air pollutants.

CHAPTER 7 - Action to reduce emissions from farming

The agriculture sector accounts for 88%[3] of UK emissions of ammonia, which is emitted during storage and spreading of manures and slurries and from the application of inorganic fertilisers. Ammonia damages sensitive natural habitats and contributes to particulate pollution in urban areas. Action by farmers can make a big difference to ammonia emissions. The government is already acting to help farmers by funding the necessary equipment.

We have provided a national code of good agricultural practice (COGAP) to reduce ammonia emissions.

We will require and support farmers to make investments in the farm infrastructure and equipment that will reduce emissions.

A future environmental land management system will fund targeted action to protect habitats impacted by ammonia.

We will continue to work with the agriculture sector to ensure the ammonia inventory reflects existing farming practice and the latest evidence on emissions.

We will regulate to reduce ammonia emissions from farming by requiring adoption of low emissions farming techniques.

We will extend environmental permitting to the dairy and intensive beef sectors.

We will regulate to minimise pollution from fertiliser use, seeking advice from an expert group on the optimal policy approach.

CHAPTER 8 - Action to reduce emissions from industry

Industrial processes, including energy generation to power our businesses and homes and the manufacture of goods and food, can all create pollution. For many decades, the UK has been at the forefront of reducing industrial pollution, and significant progress has already been made. We will continue to build on that progress by increasing standards to reflect international best practice.

We will maintain our longstanding policy of continuous improvement in relation to industrial emissions, building on existing good practice to deliver a stable and predictable regulatory environment for business as part of a world-leading clean green economy. This includes ensuring that there is a clear process for determining future UK Best Available Techniques for industrial emissions.

We will continue to work with industrial sectors to develop a series of ambitious sector roadmaps to make UK industry world leaders in clean technology and to secure further emissions reductions.

We will consider closing the regulatory gap between the current Ecodesign and medium combustion plant regulations to tackle emissions from plants in the 500kW to 1MW thermal input range. As legislation on medium combustion plants and generators comes into force, we will consider the case for tighter emissions standards on this source of emissions.

CHAPTER 9 - Leadership at all levels

Emissions from abroad, across the UK and local sources all contribute to the pollution that people and the environment are exposed to. Effective action is needed at all levels to clean up our air. This strategy sets out our commitment to cut our national emissions to reduce population exposure. As part of this we will make it easier to take action at local level. Alongside this, the UK will continue to play an active, leading role in international action to improve air quality.

We recently published draft clauses that set out how we will create a pioneering new system of green governance, establishing an Office for Environmental Protection, to ensure we succeed in leaving the environment in a better condition than we found it. The draft clauses also introduce a set of environmental principles that will be used to guide future government policy making and lead us toward a greener future; and place our 25 year environment plan on a statutory footing.

We will bring forward provisions on air quality in 2019. This will include an up to date legislative framework for tackling air pollution at national and local level, tying this into the development of the new environmental principles and governance framework to be outlined in the Environment Bill.

To drive and enable greater local action on air pollution, we will ensure responsibility sits at the right tier of local government and back this up with new powers as well as making existing powers easier to use. Neighbouring local authorities and other public bodies will work collectively to tackle air pollution.

Our international air quality commitments have been agreed at a UK level. However, air quality is a substantially devolved policy area. Scotland has already produced its own Air Quality Strategy, and Wales and Northern Ireland are currently in the process of drafting their own (further details of these are set out in Chapter 9).

The UK government will work in partnership with the governments of Scotland, Wales and Northern Ireland to develop a National Air Pollution Control Programme as required under the National Emissions Ceilings Directive for publication in 2019.

CHAPTER 10 - Progress towards our goals

Analysis shows that the actions set out in this strategy can meet our ambitious emissions reduction targets, if they are implemented with the necessary pace and determination.

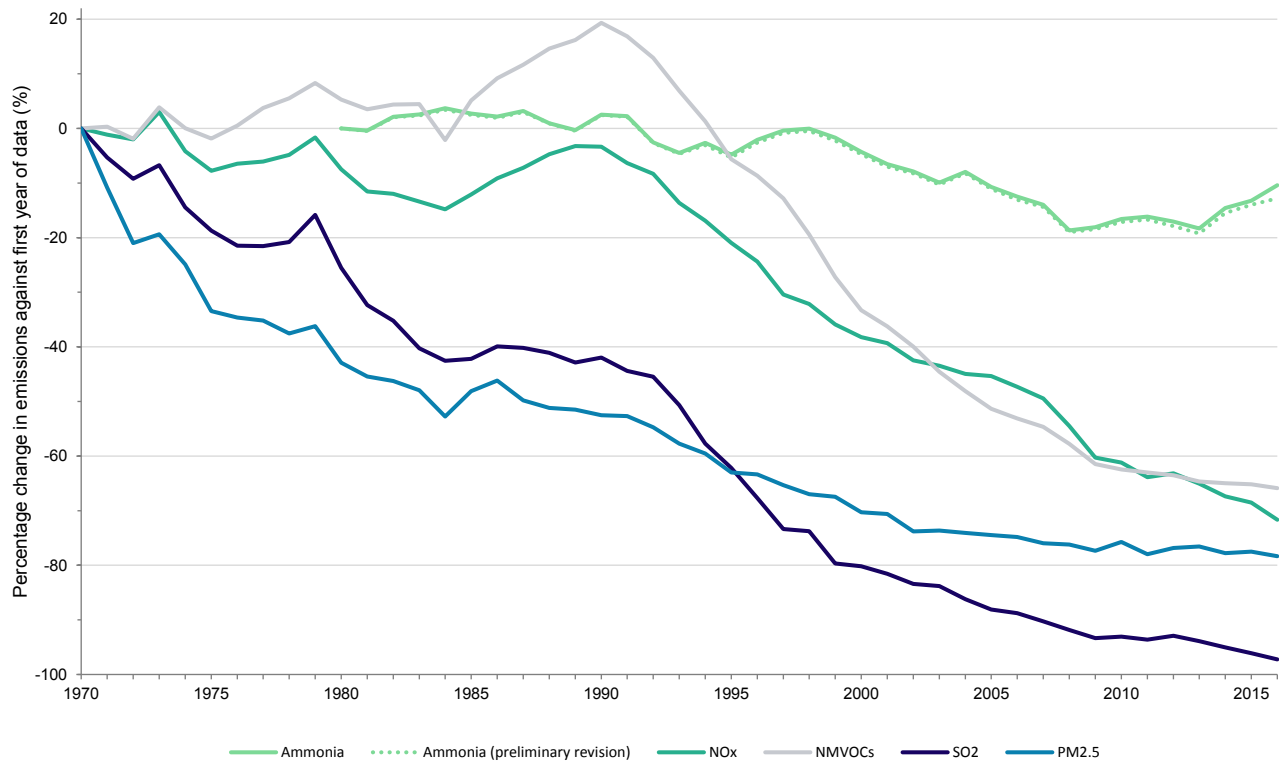
1. Understanding the problem

1.1 Background

Many substances can pollute the air. Some of these are very harmful and their sale and use is strictly regulated. Others are not immediately harmful, but are released in thousands or millions of tonnes per year nationally as by-products of transport, energy production, chemicals manufacture, domestic combustion and farming. When released into the air these substances have gradual but significant impacts on health and the environment. We maintain an award winning National Atmospheric Emissions Inventory (NAEI), to keep track of such emissions, which is updated annually.

Once released, air pollution is dispersed by the weather and can travel significant distances within and between countries. Pollutants mix and interact in the atmosphere, forming new compounds, and can be deposited on land and water. For example, sulphur dioxide emissions from coal burning power stations in the UK caused considerable “acid rain” damage in Scandinavia during the 1970s and 1980s. Dust frequently blows into the UK from as far away as the Sahara, and UK air quality can be affected by distant volcanoes. Pollution episodes in London and the southeast often arise when the weather transports pollution from continental Europe and elsewhere, exacerbating the impacts of our own urban pollution.

Change in emissions of air pollutants since 1970 (since 1980 for ammonia)[4]



Analysis by Rothamsted Research since the last inventory was published indicates a smaller rate of increase in agricultural ammonia emissions 2015-2016 than previously reported. The dotted line shows this indicative trend.

1.2 Air pollution: emissions, concentrations and exposure

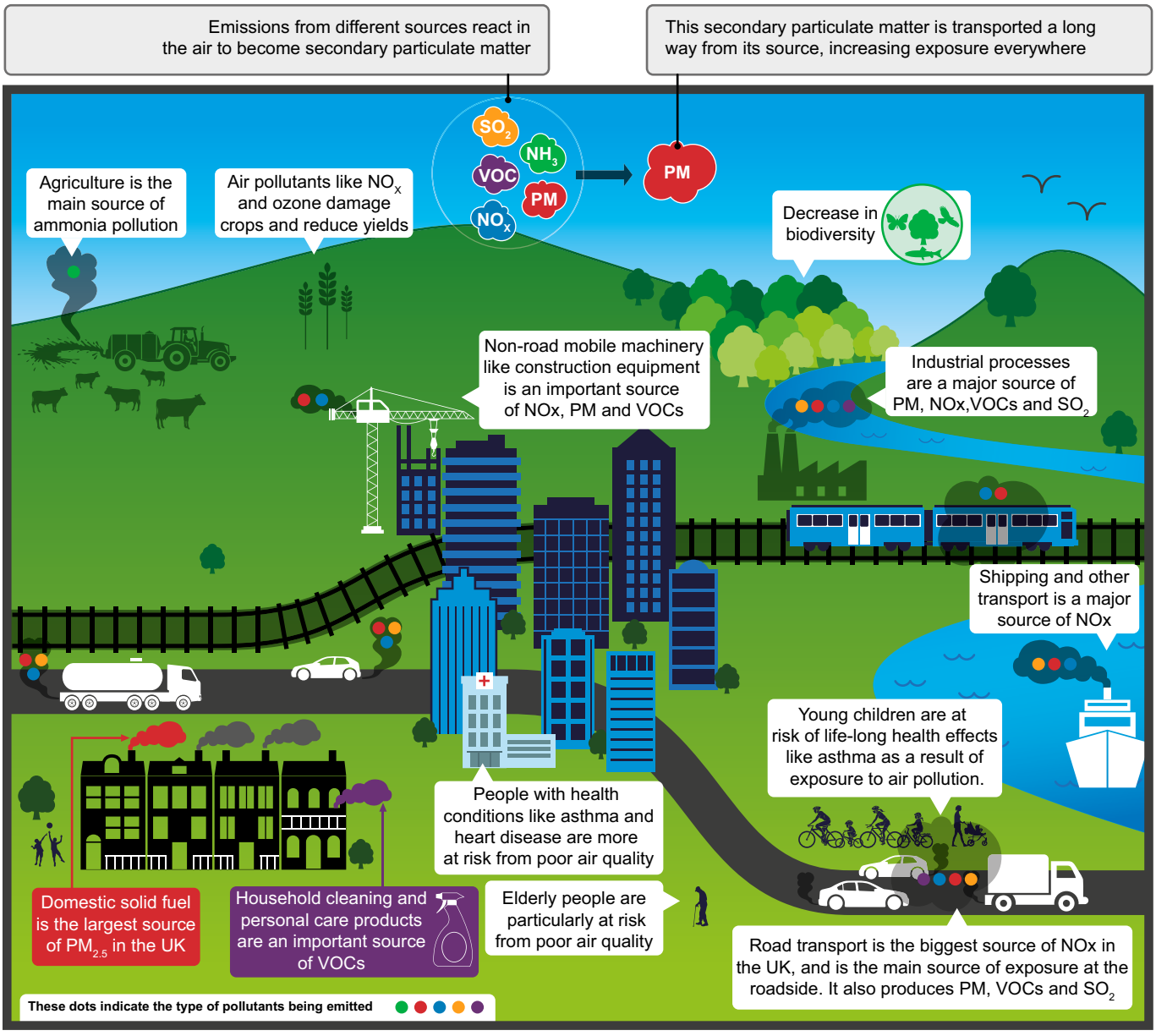
The impact of pollution depends on **how much** is emitted, **how harmful** it is and how it interacts with other substances in the air. It also depends on where it is emitted, its residence time in the atmosphere, and ultimately where it ends up and how sensitive the exposed population or environment is.

Vulnerable individuals and sensitive habitats are at particular risk. In monitoring and controlling pollutants we are concerned with the total volumes that are released (our national emissions).

These emissions contribute to **local concentrations** of pollutants, which occur where pollutants build up in significant quantities in particular locations, for example near busy roads, industrial installations or large intensive farming operations.

It is **exposure** to high concentrations of pollutants that is most likely to directly result in adverse impacts. These impacts are cumulative, so we need to think about reducing exposure at all stages of life, at home, when travelling, at school and at work.

The sources of air pollutants and their effects



Once emitted, pollutants can build up in the atmosphere contributing to **overall background** pollution. Background pollution can combine with local emissions to create localised high concentrations and exposure.

This is illustrated in the charts on page 25.

Ultimately, our emissions contribute to our neighbours' concentrations. **The aim of this strategy is to drive down the national emissions of pollutants, reducing background pollution, and minimising human exposure to harmful concentrations of pollution.**

1.3 What pollutants are we focusing on?

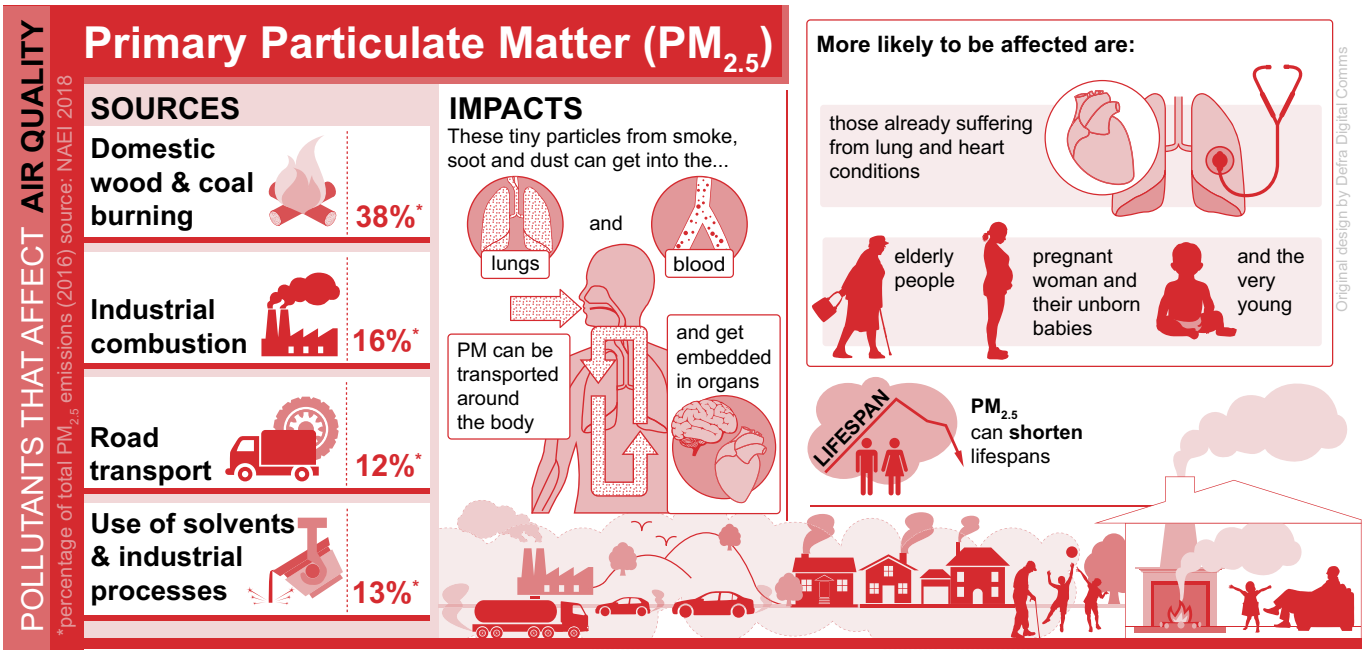
We have statutory obligations to keep concentrations of specified pollutants below certain levels.[5] The only area in which we are not currently meeting these limits, in common with many other countries in Europe[6], is in relation to roadside nitrogen dioxide concentrations. We also have national emission reduction commitments for overall UK emissions of five damaging air pollutants. These are:

- fine particulate matter ($PM_{2.5}$)
- ammonia (NH_3)
- nitrogen oxides (NOx)
- sulphur dioxide (SO_2)
- and non-methane volatile organic compounds (NMVOCs)

Our national emissions targets set ambitious reduction goals for 2010, 2020 and 2030. The UK has met the current targets since 2011.[7] By comparison, at least four EU countries (Austria, Croatia, Germany and Spain) were still in exceedance of their 2010-2019 NECD ceilings in 2016.[8] The more stringent targets that we have set for 2020 and 2030 aim to cut the harm to human health by half. **This strategy sets out existing policies and a programme of new actions that will help us meet these targets. Information about the individual pollutants and how they interact is set out on the following pages.**

Pollutants with ambient air quality standards in the UK.

- Nitrogen dioxide (NO_2) / NOx (vegetation)
- Particulate Matter (PM_{10})
- Fine Particulate Matter ($PM_{2.5}$)
- Ozone (O_3)
- Sulphur dioxide (SO_2)
- Benzene
- Lead (Pb)
- Carbon monoxide (CO)
- Benzo[a]pyrene (B[a]P)
- Nickel (Ni)
- Cadmium (Cd)
- Arsenic (As)
- 1,3-butadiene

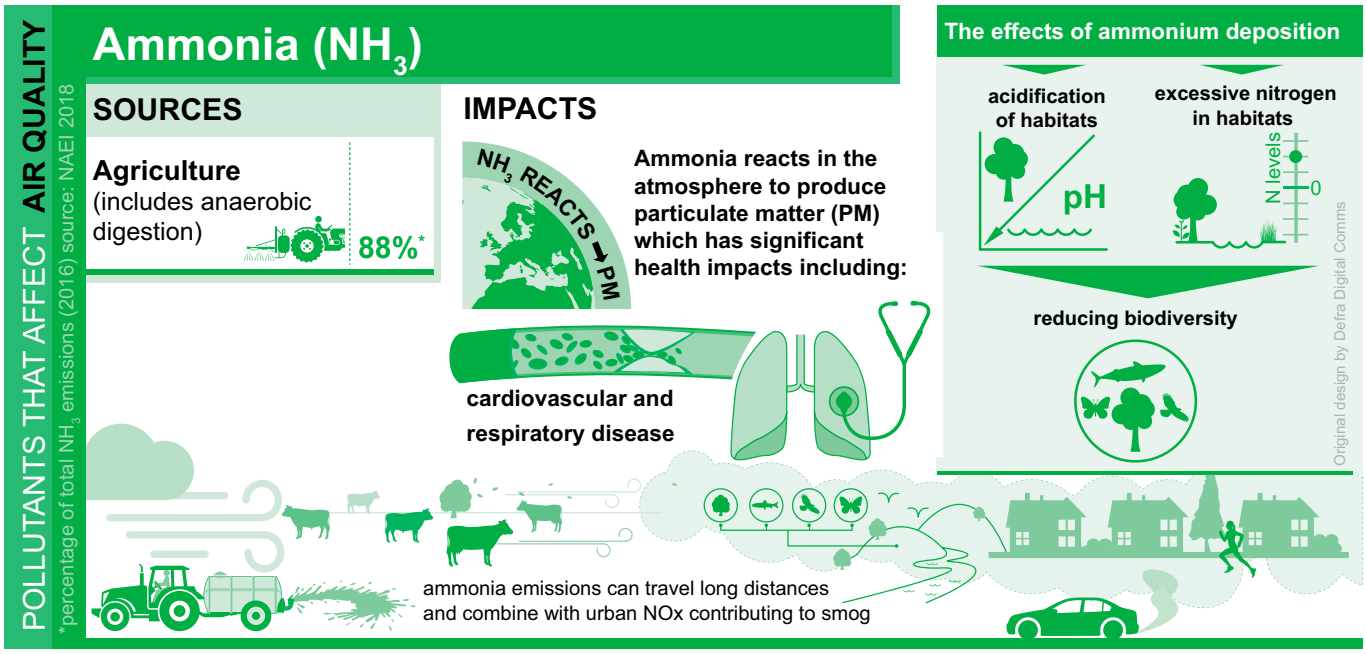


Particulate matter is everything in the air that isn't a gas, a suspension of particles which are solid, liquid or somewhere in between. It can come from natural sources such as pollen, sea spray and desert dust, and human made sources such as smoke from fires, soot from vehicle exhausts, dust from tyres and brakes, as well as emissions from industry. Particles emitted directly from these sources are called primary PM. Secondary PM is formed in the atmosphere through chemical reactions between other air pollutant gases such as nitrogen oxides (NO_x), ammonia (NH_3) and sulphur dioxide (SO_2). Particulates are classified according to size, either as PM_{10} (particles of ≤10μm (micrometres) diameter) or $PM_{2.5}$ (particles of ≤2.5μm diameter particles which are 200 times smaller than a grain of sand).

The distinction between PM and the other air pollutants considered here is somewhat artificial. PM is not a single pollutant; it is made up from a huge variety of chemical compounds and materials. Both PM and the gases that can form it travel large distances, so impacts may occur far from the original source. Around 15% of UK PM comes from naturally occurring sources, up to a third from other European countries and around half from UK human-made sources.

PM is formed of tiny particles that can get into the lungs and blood and be transported around the body, lodging in the heart, brain and other organs. PM affects health in two ways: by being toxic or by providing a surface for transporting toxic compounds to where they can do harm. PM can have short-term health impacts over a single day when concentrations are elevated, and long-term impacts from lower-level exposure over the life-course. Effects are amplified in vulnerable groups including young children, the elderly, and those suffering from breathing problems like asthma. The Department of Health and Social Care's independent Committee on the Medical Effects of Air Pollutants (COMEAP) quantified the long-term impacts of UK PM concentrations in terms of mortality as equivalent to 340,000 life years lost.[9]

38% of UK primary PM emissions come from burning wood and coal in domestic open fires and solid fuel stoves[10], 12% comes from road transport (e.g. fuel related emissions and tyre and brake wear)[11] and a further 13% comes from solvent use and industrial processes[12] (e.g. steel making, brick making, quarries, construction). Between 1970 and 2016 primary PM_{10} emissions fell by 73%, and primary $PM_{2.5}$ emissions fell by 78%. However, emissions of PM_{10} and $PM_{2.5}$ have been relatively stable since 2009.[13] Our aim is to reduce emissions of $PM_{2.5}$ against the 2005 baseline by 30% by 2020, and 46% by 2030.

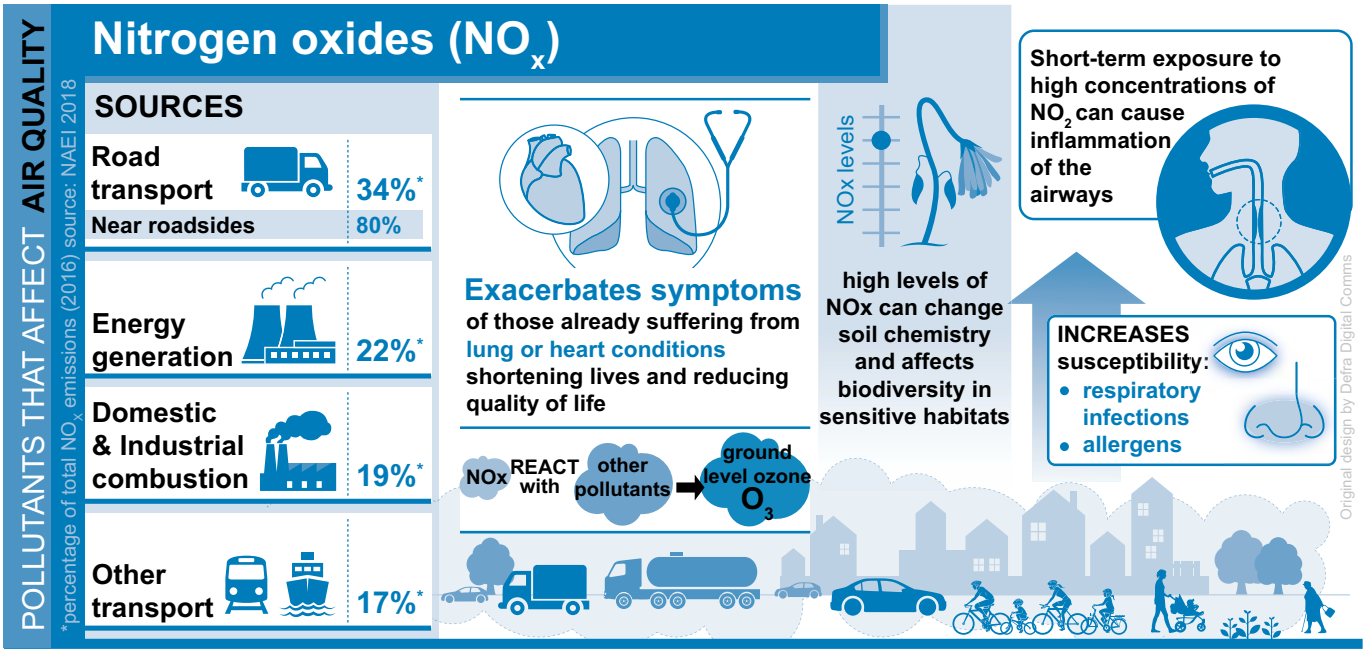


Ammonia is a gas that is emitted into the atmosphere and then either deposited back onto land or converted to secondary PM through reactions in the atmosphere. Agriculture is the dominant source of NH_3 emissions (88% in 2016). It is emitted during storage and spreading of manures, slurries and fertilisers. A further 4% of NH_3 emissions come from the waste sector. Remaining ammonia emissions are from a diffuse mix of sources including vehicles, human waste and industry.[14]

The main concerns resulting from ammonia emissions are the contribution to particulate matter and the human health effects described earlier. Ammonia is converted by mixing with nitrogen oxides and sulphur dioxide, producing ammonium compounds that turn into fine particulate matter. This PM is transported large distances and adds to the suspended background levels of particulates in the atmosphere. Public Health England attributed the 2014 smog in London in part to agricultural ammonia emissions.

NH_3 stays in the atmosphere for just a few hours as a gas but this extends to several days when converted to PM. In this form it can travel very long distances before being removed from the atmosphere by rain and snow and deposited to land. In this way ammonia can cause significant long-term harm to sensitive habitats, depositing more nitrogen onto soils and plants, and into freshwaters, than they can cope with. This has led to significant changes to plant communities, and also affects the animal species that depend on them.

Emissions of ammonia fell by 13% between 1980 and 2015. However, since then there has been an increase in emissions, largely as a result of fertiliser use.[15] Our aim is to reduce emissions of ammonia against the 2005 baseline by 8% by 2020 and 16% by 2030.

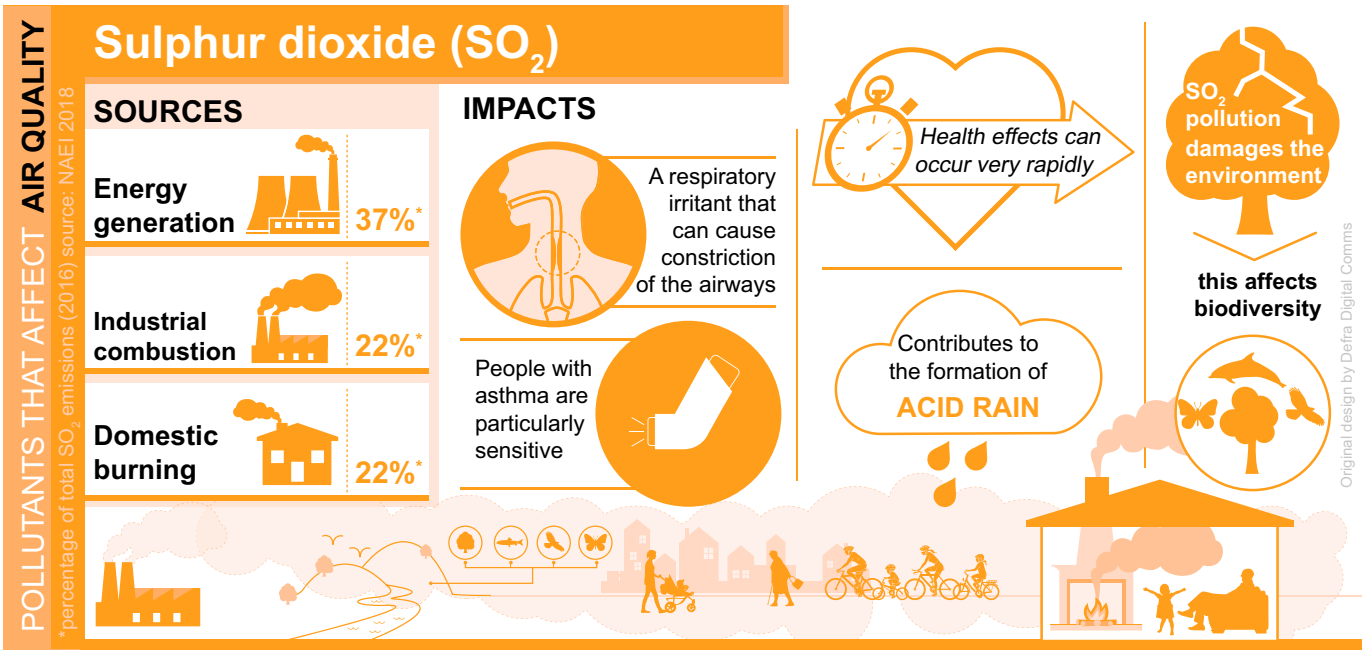


Nitrogen oxides (NOx) are a group of gases that are predominantly formed during the combustion of fossil fuels. The majority of NOx emitted as a result of combustion is in the form of nitric oxide (NO). When NO reacts with other gases present in the air, it can form nitrogen dioxide (NO_2), which is harmful to health. It is also important in the formation of ozone. NO coverts to NO_2 very quickly and vice versa. It is therefore usual scientific practice to refer to the two gases together as NOx. For reporting and measurement purposes, we report "NOx as NO_2" because of this very fast interconversion.

The main sources of NOx are road transport (34%), energy generation, for example power stations and refineries (22%), domestic and industrial combustion (19%) and 'other' transport such as rail and shipping (17%).[16] Our aim is to reduce emissions of nitrogen oxides against the 2005 baseline by 55% by 2020, increasing to 73% by 2030.

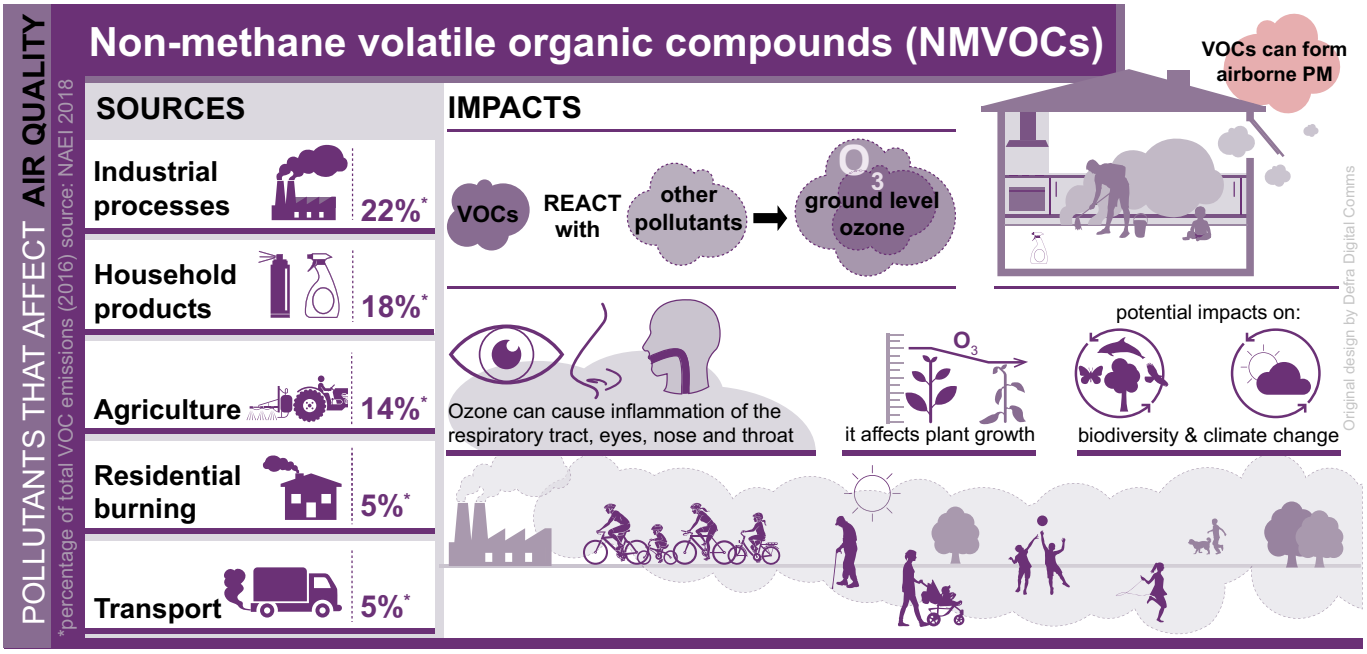
Short-term exposure to concentrations of NO_2 can cause inflammation of the airways and increase susceptibility to respiratory infections and to allergens. It exacerbates the symptoms of those who are already suffering from lung or heart conditions, shortening their lives.

NO_2 is emitted with other pollutants, particularly $PM_{2.5}$. The Committee on Medical Effects of Air Pollutants (COMEAP) has recently published a detailed study on the associations between long term exposure to NO_2 and mortality. While several studies report such associations, it is difficult to conclusively demonstrate that the effects observed are attributable to NO_2 alone. It is important to consider that in most cases, people are exposed to mixtures of pollutants at any one time, dependent on the local circumstances.



Sulphur dioxide is a corrosive, acidic gas which is harmful to health and combines with water vapour in the atmosphere to produce acid rain. SO_2 pollution episodes in ambient air are also associated with asthma and chronic bronchitis and can be a significant component of particulate matter. Sulphur in coal played a contributory key role in the health impacts of the London smog in 1952, where estimates of the resulting mortality range between 8,000 and 12,000 deaths. SO_2 emissions caused significant harm to forests and freshwater habitats in the Northern Hemisphere in the 1970s - 80s. Following concerted action to reduce SO_2 emissions, such episodes no longer occur in the UK.

Emissions of SO_2 are primarily from combustion of solid and liquid fuels and have reduced markedly with restrictions on the sulphur content of liquid fuels, as well as a shift away from a reliance on coal for energy generation. However, domestic coal burning can result in significant indoor exposure to SO_2. Our aim is to reduce emissions of sulphur dioxide against the 2005 baseline by 59% by 2020, increasing to 88% by 2030.



Non-methane volatile organic compounds (NMVOCs) are a very large group of organic compounds, which differ widely in their chemical composition but can display similar behaviour in the atmosphere. NMVOCs are emitted to air as combustion products, as vapour arising from petrol, solvents, air fresheners, cleaning products, perfumes and numerous other sources, often when products are used at work or in the home. The diversity of products and processes which emit NMVOCs is huge, covering not only industrial processes (22% of emissions), but also household products (18%), agriculture (14%), domestic burning and transport (5% each).[17]

In the outside atmosphere, NMVOCs react with other air pollutants in the presence of sunlight to produce ground level ozone (see below). NMVOC emissions can also form a significant component of indoor air pollution. Indoor reactions are different because ultraviolet light, the main driver of outdoor reactions, is absorbed by glass.

However, there are many other reactions which they can undergo to form other chemicals. A particularly important NMVOC is formaldehyde, which can be released from furniture, finishes and building materials, such as laminate flooring, kitchen cabinets and wood panels, and is also formed in chemical reactions in the air between other NMVOCs and chemicals generated from combustion processes, such as smoking, heating, cooking or candle burning. At low concentrations, exposure to formaldehyde can cause irritation to the eyes and upper airways, and is classified as a human carcinogen.

Other sources of NMVOCs include furnishing, carpets, and upholstery, products for cleaning and polishing, air fresheners, and personal care products, for example fragrance, deodorants, and hair styling products. Our aim is to reduce emissions of NMVOCs against the 2005 baseline by 32% by 2020, increasing to 39% by 2030.

Ozone (O_3)

Some pollutants are not directly emitted but formed in the air, such as ozone. Ozone is damaging to both human health and the environment. It is highly reactive, and will react with nitric oxide to form nitrogen dioxide. Modelling suggests that, as we reduce NO_2 concentrations in our towns and cities, we will need to consider how to address the increasing levels of ozone that might result. However, by tackling all sources of pollution, we will continue to reduce the formation of ozone across the whole of the UK. Ozone travels long distances and can reach high concentrations far from the original sources of pollution. It can cause inflammation of the respiratory tract, eyes, nose and throat. It can trigger asthma attacks and cause chest discomfort whilst breathing. It can also cause damage to crops.

1.4 Maintaining a strong evidence base

The atmosphere is a dynamic system in which many human-made and natural substances interact. To understand the total emissions of air pollutants and how these change over time the UK government produces and publishes national inventories of air pollutants each year, measuring and reporting according to agreed international guidelines. These inventories go back to 1970 and provide good evidence of changing trends in air pollution. They are drawn from a combination of sources, including:

- directly measured emissions
- data and our understanding of the activities that produce air pollution
- data and our knowledge of how these activities release pollutants to the atmosphere

We have a national air quality monitoring network consisting of 271[18] sites across the UK which measure ambient concentrations of various air pollutants. This network is operated by the Environment Agency on behalf of the UK government. Near real-time measurements from 170[19] monitoring sites is made available online and updated hourly.

It is not possible to monitor the air in every location, so modelling enables us to assess air quality in locations without monitoring stations. This helps us to understand how different sources contribute to local air pollution and provides a consistent framework for making future projections. We model the interaction between total emissions and the resulting local concentrations in order to better understand the impacts of air pollution in terms of human exposure to air pollution. We also make projections of the levels of emissions we expect to see in future, given current trends and regulations, looking forwards to 2030 in order to plan further action to reduce air pollution.

The Met Office makes daily short-term forecasts of air quality. These are produced early each morning for the current day and for the coming days. These forecasts are compared to monitoring information to ensure consistency of assessments.

We have a strong commitment to both transparency about the methods by which air quality assessments are made and the ease by which the public, industries, researchers and others can access air quality data. The National Atmospheric Emissions Inventory (NAEI) website contains detailed information on how air quality assessments are made[20], with easily accessible data on emissions of air pollutants available both via a web-based tool and as downloadable data files.[21]

In 2018 the UK won the international award for the most complete inventory at the annual task force for emissions inventories and projections (TFEIP) conference in Sofia, Bulgaria, ahead of more than 40 countries who report emissions data.

The dedicated UK-Air website[22] enables everyone to:

- understand how air quality affects their health and the environment[23]
- access data on local concentrations of air pollutants, including datasets on air quality trends and real-time air quality assessments[24]
- access short-term forecasts for air quality[25]
- explore the network of monitoring sites and access information on how these function[26]

We remain strongly committed to a process of continuously improving the evidence base on air quality in the UK and to ensuring this evidence is accessible and transparent to a wide range of audiences from academic experts and school children to health professionals and vulnerable individuals.

The national monitoring and modelling available through UK-AIR is designed to meet our international obligations. In addition to this, local authorities run their own monitoring networks and local models to support them meet their legal obligations at the local level. There is also increasing interest and opportunity for individuals to undertake their own monitoring, using a variety of 'citizen science' sensor equipment. These different data sources require careful interpretation due to variability in data quality, location and technology type. We are investing in methods to use sensor equipment reliably with a view to influencing modelling and monitoring programmes in the future.

Historically, the national and local data sources have been managed and published separately, reflecting their different intended uses. This has led to a fragmented data landscape which is not being used to its full potential. Information is needed at all scales because action is needed at all scales to address the air pollution challenges we face. We will, therefore, increase transparency by bringing local and national monitoring data together into a single accessible portal for information on air quality monitoring and modelling, catalysing public engagement and encouraging citizen science initiatives. The distinctions between the aims and quality of local and national monitoring data will be made clear.

This will help increase public engagement with air quality data, in addition to providing an improved infrastructure for more sophisticated air quality modelling, particularly in urban environments

Working closely with the government's existing Air Quality Expert Group that provides us with independent advice, we will develop a wider network of inter disciplinary collaborations with the research community to further improve our understanding of air pollution sources and impacts, and to encourage innovative approaches to the many technical challenges in making significant further improvements to our air quality.

UK Research Innovation (UKRI) has recently launched a new £19.6 million research programme to predict future air quality challenges, identify the most vulnerable groups in society, and improve new technologies and policies for reducing air pollution. The programme will be led by the Natural Environment Research Council (NERC) with the Met Office.[27]

1.5 Action to improve understanding of the problem and its solutions

- We are investing £10 million in improving our modelling, data and analytical tools to give a more precise picture of current and future air quality and the impact of policies to improve it. We will continue to collaborate closely with UKRI and the wider science and engineering community to deliver cost-effective and innovative solutions to reducing air pollution
- We will increase transparency by bringing local and national monitoring data together into a single accessible portal for information on air quality monitoring and modelling, catalysing public engagement through citizen science

2. Protecting the nation's health

2.1 Health evidence

Air pollution is a major public health risk ranking alongside cancer, heart disease and obesity.[28] It causes more harm than passive smoking. A review by the World Health Organization concluded that long-term exposure to air pollution reduces life expectancy by increasing the incidence of lung, heart and circulatory conditions.

The Department of Health and Social Care's advisory Committee on the Medical Effects of Air Pollutants (COMEAP) have recently estimated that long-term exposure to man-made air pollution in the UK has an annual impact on shortening lifespans, equivalent to 28,000 to 36,000 deaths.[29]

That is why we are taking action to accelerate the improvements to air quality that will reduce public exposure to air pollution, save lives and improve quality of life for current and future generations.

Conditions caused or exacerbated by air pollution include asthma, chronic bronchitis, chronic heart disease (CHD), and strokes. These conditions significantly reduce quality of life. They also mean that people are less able to work and need more medical care, resulting in higher social costs and burdens to the National Health Service.

Poor air quality can affect health at all stages of life. Those most affected are the young and old. In the womb, maternal exposure to air pollution can result in low birth weight, premature birth, stillbirth or organ damage. In children there is evidence of reduced lung capacity, while impacts in adulthood can include diabetes, heart disease and stroke. In old age, a life-time of exposure to air pollution can result in reduced life-expectancy and reduced wellbeing at end of life. There is also emerging evidence for a link between air pollution and an acceleration of the decline in cognitive function.

Public Health England (PHE), the independent body responsible for protecting the nation from public health hazards, has identified air pollution as a top priority for action.

Deprived communities are more likely to experience adverse health effects from poor air quality because they are more exposed to air pollution, for example, by being close to major roads.[30] They are less likely to live close to well-maintained green spaces associated with lower levels of air pollution, increased physical activity, and improved mental wellbeing.[31] However, air quality can also be poor in areas that are generally considered affluent, such as central London. This is reflected by the overall national distribution of air pollution with highest average levels in South East England and lowest in the North of England, Scotland, Wales, and Northern Ireland.[32]

Counting the costs of air pollution on health

In order to target action to tackle air pollution we need to understand the costs of the damage caused by emissions and the benefits of intervention. Our economic appraisal tools provide a monetary estimate of the health and environmental impact costs of each tonne of air pollutant still released into the atmosphere. Up to now, these estimates have mostly focused on the value that people place on living longer lives. This is a very important impact, but it's not the only factor: we also know that people have to live with the consequences of conditions brought on by air pollution and that emissions reductions could alleviate this day-to-day suffering. In the past, it has not been possible to quantify these impacts, but a big research effort is now advancing our understanding of these impacts. It is possible to estimate the impacts of air pollution on various conditions, including coronary heart disease, stroke, lung cancer and asthma.

Recent research commissioned by Public Health England has found that the health and social care costs of air pollution ($PM_{2.5}$ and NO_2) in England could reach £5.3 billion by 2035. This is a cumulative cost for diseases which have a strong association with air pollution: coronary heart disease; stroke; lung cancer; and childhood asthma.[33]

When diseases with weaker evidence of association are also added, including chronic obstructive pulmonary disease; diabetes, low birth weight, lung cancer, and dementia, the costs could reach £18.6 billion by 2035. When all diseases are included, air pollution is expected to cause 2.4 million new cases of disease in England between now and 2035. $PM_{2.5}$ alone could be responsible for around 350,000 cases of coronary heart disease and 44,000 cases of lung cancer in England over that time. Even small changes can make a big difference, just a 1μg/m^3 reduction in $PM_{2.5}$ concentrations this year could prevent 50,000 new cases of coronary heart disease and 9,000 new cases of asthma by 2035.[34]

The government supports a strong and growing evidence base on the effects of pollution through our two independent expert committees - the Department of Health and Social Care's advisory Committee on the Medical Effects of Air Pollutants (COMEAP) and Defra's Air Quality Expert Group (AQEG) that keep emerging evidence under regular review. We work closely with the health science community to further our understanding of the air quality impacts on the whole life cycle from before birth to death and also gain greater understanding on emerging areas of research. Public Health England is undertaking a feasibility study of a system to capture the health impacts resulting from air pollution across England.

Researching the link between air pollution and cardiovascular disease

British Heart Foundation and the University of Edinburgh

Since 2010, the British Heart Foundation has invested £3.2 million in research into how air pollution, especially fine and ultrafine particulate matter, can make existing heart conditions worse and increase the likelihood of a heart attack or stroke in vulnerable groups.

Research by the University of Edinburgh has shown how particulate matter contributes to cardiovascular disease. Senior Research Scientist Dr Mark Miller used harmless gold nanoparticles to mimic the ultrafine PM found in air pollution. These particles are of a similar size to the nanoparticles that are abundant in diesel exhaust. Volunteers breathed in these nanoparticles for 2 hours, which were then tracked through the body. Within 24 hours, a proportion of nanoparticles had crossed from the lungs into the bloodstream, where they were still detectable three months later. This demonstrates that the health risk from breathing PM could continue long after exposure.

Dr Miller's team also tested how the nanoparticles affected patients who were at high risk of stroke due to a build-up of fatty plaques inside their arteries. The researchers found that the gold nanoparticles accumulated within these plaques. While gold nanoparticles are harmless, if other particulates behaved in the same way it is likely that they would promote heart disease. These findings are hugely important in suggesting how PM from air pollution may cause heart attack or stroke and will help us to shape policies aimed at reducing the risk to people's cardiovascular health.

2.2 Health information

Effective communication of health messages about air pollution and appropriate action can save lives and improve quality of life for many. As we build our understanding of how poor air quality affects health in both the short and long term, it is important that we communicate the evidence in a transparent and accessible way.

Many of the everyday activities that create air pollution also increase personal exposure for ourselves and our families. For example, there is a common misconception that the air outside a car on a busy road is more polluted than inside. However, studies in London and other UK and European cities show that drivers and passengers inside vehicles are often exposed to significantly higher levels of air pollution than those walking or cycling along the same urban routes.[35] This is because cars can suck in emissions from surrounding vehicles, particularly those that are immediately ahead, and recirculate them within a confined space. Even when there is a lot of traffic, the evidence suggests that those cycling and walking often experience lower exposure to air pollution than those driving. Cycling and walking also creates less pollution and there are well understood health co-benefits from active travel, including greater fitness and improved mental health, as well as lower risk of obesity, heart disease and lung disease. In addition, active travel reduces traffic congestion, itself a major cause of air pollution. The government has published a cycling and walking investment strategy,[36] which identifies £1.2 billion across government available for investment in cycling and walking between 2016 and 2021. More detail on active travel is set out in Chapter 5 of this Strategy. Taking the scenic route and walking along quieter roads reduces exposure even further. Fewer cars on the road means less pollution for everyone.

Similarly, most people think that the air inside their home is cleaner than that outside. However, this is not always the case. Levels of air pollutants in the home can be significantly higher than those outside. For example, NMVOCs and particulates accumulate inside the more confined space in the home, through the multiple use of cleaning products, the installation of new carpets and furniture, and especially where wood burning stoves or open fires are regularly used. Simple actions, like burning cleaner fuels and opening windows to ventilate the home can make a big difference.

Children, the elderly and individuals with pre-existing cardio and respiratory conditions are particularly vulnerable to the effects of poor air quality, so it is important to provide clear and transparent information and air quality forecasts. Recent work to better understand public perceptions around air quality[37] has shown strong demand among certain groups for more information on air quality, with over a third of the general public calling for information on how to minimise their contribution and/or wanting to know more about how to protect themselves.

The government already provides information on local and national air quality. A multi-day air quality forecast service is available to the public on the government's UK-Air website. It provides up-to-date information on air pollution and has a postcode search facility to enable information to be provided at a local level. We will work with media outlets to improve public access to the air quality forecast and continue working with our technical partners to improve the accuracy and availability of localised air quality data and forecasts.

The government also provides health advice to support vulnerable individuals during episodes of poor air quality and we also work closely with a network of key health stakeholders to provide alerts during high pollution episodes. We will improve the quality and accessibility of our air quality information, especially for vulnerable groups and during high pollution episodes. We will also work in partnership with health organisations to review where improvements can be made to the Daily Air Quality Index (DAQI) and associated health advice.

The health impacts of poor air quality are not currently well represented in the health professions' education and training. We are working with the health community, including Medical Royal Colleges and other professional health bodies, to develop bespoke guidance material for doctors and other medical and care professionals. This will enable them to provide their patients with the most up-to-date advice on the health impacts of air pollution, and how to reduce their exposure. We will work with our partners in the medical and care community to distribute this material to health professionals, and to make air quality information available in doctors' surgeries and other healthcare settings.

Air Quality – how can we all do our bit?

On the go:

- if you can, make less use of your vehicle - try swapping your car/van for walking, cycling or taking public transport, particularly for short journeys. As well as reducing emissions, for most of us the health benefits of walking, cycling and 'active travel' far outweigh the risks of roadside exposure to air pollution
- turn off your engine when you're parked or waiting in traffic for long periods
- if you're changing your vehicle, switch to a less polluting model such as an electric vehicle

At home:

- reduce how much you burn in your home and garden, especially if you live in a built-up area
- if you choose to burn use the right fuel on an efficient and well-maintained appliance. See our advice leaflet here
- insulate your home so there is less of a need to heat and cool it, or turn your thermostat down
- group on-line purchases to reduce the number of deliveries needed

In addition, you can reduce your exposure by:

- opening your windows for ventilation when you clean, do DIY, smoke or do other activities that release pollutants directly into your home
- choosing quieter routes when walking or cycling

2.3 Providing decision makers with accurate data

The government is reviewing current evidence to provide recommendations for practical interventions to significantly reduce harm from air pollution from the wide range of sectors covered in this strategy. This builds on the Defra UK Plan for Tackling Roadside Nitrogen Dioxide Concentrations and the National Institute of Health and Care Excellence (NICE) air quality and health guidelines.[38] Additionally, the National Institute of Health Research will commission further research into action to reduce risks to public health from poor air quality. NICE is currently working on forthcoming guidance on indoor air quality.

Central and local government work closely together to provide support for local authority directors of public health to take action to tackle air pollution at local level and to inform how planning can avoid creating air pollution problems. In March 2017, Defra, PHE and the Local Government Association, jointly published an updated resource 'Air Quality: A briefing for directors of public health'. It provides information, case studies, guidance and communication tools for directors of public health and their teams.[39] This is being supported by a rolling programme of masterclasses with local health professionals to facilitate sharing of good practice and innovation on the ground.

2.4 Leading the way: reducing population exposure to $PM_{2.5}$

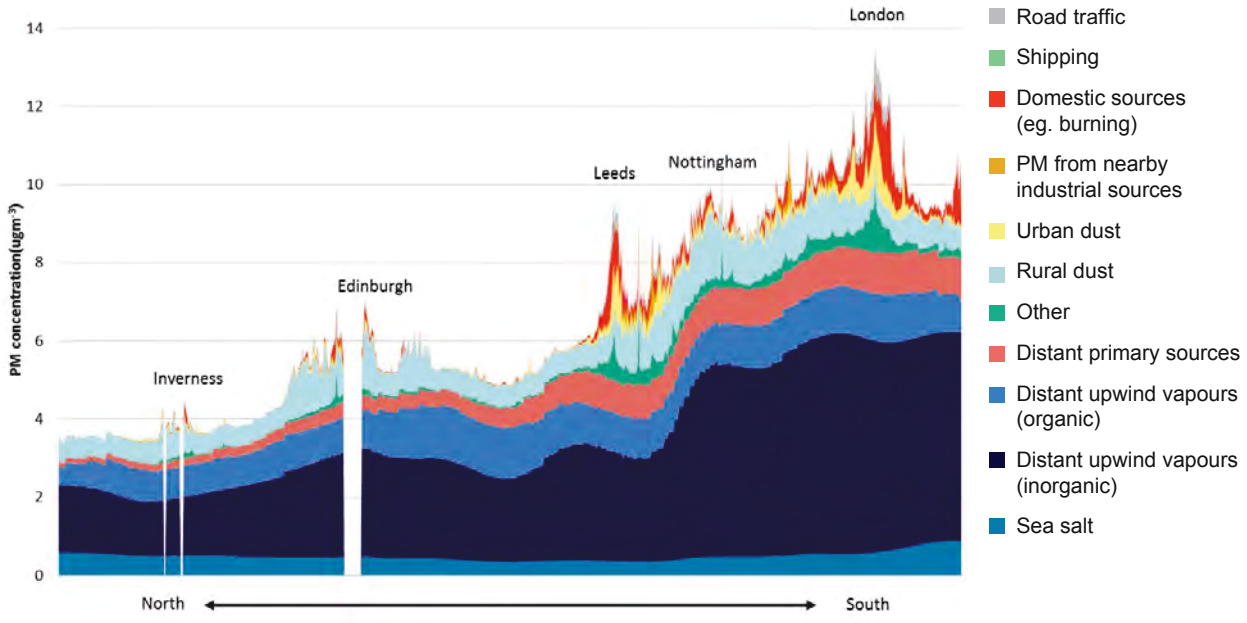
All ambitions to reduce average population exposure will deliver positive health benefits. **That is why we have already signed up to meet ambitious emissions ceilings by 2020 and 2030 and why we now want to go further by setting a new world-leading goal to reduce human exposure to $PM_{2.5}$.**

The UK sets air quality goals, informed by evidence from a range of sources. These include the World Health Organization (WHO) 2008 guidelines, recognised as the international benchmark for setting air quality standards.

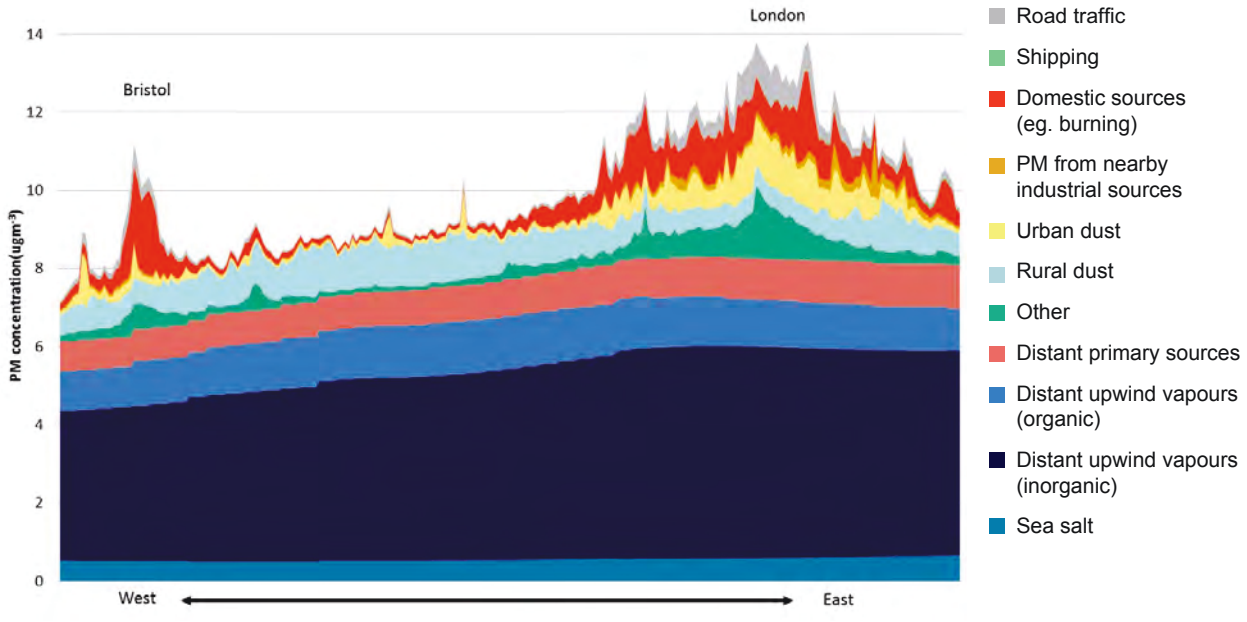
The UK's current objectives on $PM_{2.5}$ stem from EU legislation. We already meet the EU limit value of 25 µg/m^3 and are on track to meet a second stage limit of 20 µg/m^3 by 2020. In this we are ahead of several European countries who still have exceedances of these limits.

These images show how particulate matter from across the country can build up in the atmosphere as ‘background pollution’ and the role that this can play in combination with local sources in areas with a pollution challenge.

Annual mean $PM_{2.5}$ north to south transect across the UK for 2017 from PCM model



Annual mean $PM_{2.5}$ west to east transect across the UK for 2017 from PCM model



Like other pollutants, PM can travel large distances and it is a transboundary problem. Sometimes, depending on wind direction and other circumstances, around a third of the UK $PM_{2.5}$ levels (up to 50% on specific days) (more in South East England than other areas) are from sources outside of the UK (for example, continental Europe). This is why co-ordinated international action is required. PM also moves across the UK and emissions can build up in the atmosphere, far from the source of emissions. This strategy seeks to drive down emissions of PM across the UK and provide stronger powers to tackle it in local areas where there is a problem.

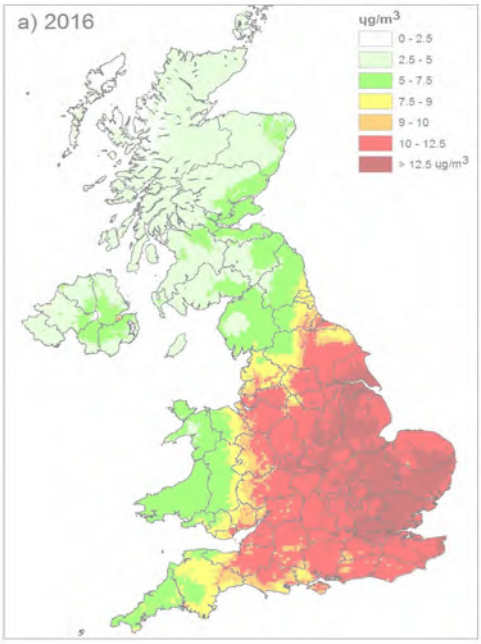
The WHO guidelines recommend an ultimate goal for concentrations of $PM_{2.5}$ of 10 µg/m^3. This is less than half the current EU limit and the WHO recognises that this represents a significant challenge. 92% of the global population currently live in areas that exceed this goal.[40] The WHO therefore recommend a step-by-step approach to achieve progressive reductions. Reflecting this, we will set a bold new goal to progressively cut public exposure to particulate matter pollution, as suggested by the WHO. **By implementing the policies in this Strategy, we will reduce $PM_{2.5}$ concentrations everywhere, so that the number of people living in locations above the WHO guideline level of 10 µg/m^3 is reduced by 50% by 2025, compared to our 2016 baseline. Areas above the 10 µg/m guideline limit in 2025 will have lower concentrations than today, and we will set out our plans to reduce $PM_{2.5}$ concentrations even further in due course.**

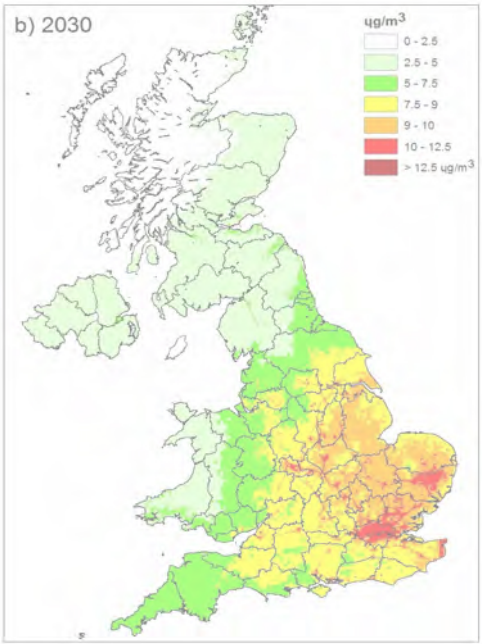
To support this we will publish evidence early in 2019 to examine what action would be needed to meet the WHO annual mean guideline limit of 10 µg/m^3 and use this to set a new, ambitious, long-term target to reduce people's exposure to PM 2.5 even further. **We will review our progress in 2022, setting out detailed interim objectives and reporting publically on our progress.** This will set a clear national ambition to drive down human exposure to $PM_{2.5}$ as rapidly as is feasible.

We will be bold in our ambition but practical in our approach, taking account of the different levels of challenge in different parts of the country (for example in major urban areas, where there are concentrations of industrial activity, traffic, transport networks and people) and the impact of transboundary air pollution which means that around one third of the PM in our atmosphere comes from abroad. **We will back these targets up with new powers designed to enable targeted local action in areas with an air pollution problem**.

We will engage with the devolved administrations to explore the potential to develop a shared UK-wide goal, recognising the work that the London Mayor and Scottish Government have already begun in this area. In achieving these targets, we can expect significant long-term reductions in acute and chronic diseases associated with air pollution.

These maps represent an interim output from recent analysis by Imperial College that shows concentrations of fine particulates ($PM_{2.5}$) in a) 2016 and b) how they will be reduced across the UK by 2030 by taking the action set out in this Strategy. Fine particulate concentrations will be reduced below the WHO guideline level of 10µg /m^3 across much of the country.





2.5 Actions to reduce people's exposure to air pollution

- We will reduce $PM_{2.5}$ levels in order to halve the number of people living in locations where concentrations of particulate matter are above 10µg/m^3 by 2025
- We will set a new, ambitious, long-term target to reduce people's exposure to $PM_{2.5}$ and will publish evidence early in 2019 to examine what action would be needed to meet the WHO annual mean guideline limit of 10 µg/m^3
- We will develop and deliver a personal air quality messaging system to inform the public, particularly those who are vulnerable to air pollution about the air quality forecast and provide clearer information on air pollution episodes and health advice
- We will back these goals up with powers designed to enable targeted local action in areas with an air pollution problem
- We will review our progress in 2022, and we will consider if we should have more challenging milestones towards WHO goals; the new independent statutory body that we are establishing to hold government to account on environmental objectives may, subject to consultation, have a role in the scrutiny of air quality policy and any other strategies relating to air quality
- We have published updated appraisal tools and accompanying guidance to enable the health impacts of air pollution to be considered in every relevant policy decision that is made[41]
- There is a need for straightforward, practical information so that people can reduce their own emissions for the benefit of themselves and their neighbours. We will work in partnership with a range of organisations to ensure this information is made available in a clear and accessible way
- We will work with health professionals to improve how advice and awareness about pollution can be delivered. We will use high quality behavioral research involving end users to underpin the delivery of clearer messages
- We will equip health professionals to play a stronger role by working with the Medical Royal Colleges and the General Medical Council to embed air quality into the health professions' education and training. We will work with local authorities and directors of public health to equip and enable them to lead and inform local decision-making to improve air quality more effectively
- By taking action on air pollution we can help people live well for longer, as set out in the Department of Health and Social Care's recently published 'Prevention is Better than Cure' document, which sets the scene for the development of a prevention green paper
- We will work with the NHS, hospitals, emergency departments, GPs and local authorities to gather better information on where, when and how patients report and are treated for air quality related health conditions, to help evaluate the effectiveness of actions to improve air quality. This will help meet the recommendations of the recent Chief Medical Officer report on all pollution[42]

3. Protecting the environment

3.1 Clean air and our environment

Human health and a thriving natural environment are concepts that go hand in hand and clean air is central to this vision. 19th century social reformers such as Octavia Hill promoted access to natural environments for city dwellers through a network of urban parks and green belt known as 'green lungs'. In the 20th century the idea of fresh air and exercise became synonymous with personal wellbeing. This Clean Air Strategy is part of a wider government vision for creating and maintaining thriving places where people can live, work, bring up families and enjoy their free time.

A Green Future: Our 25 Year Plan to Improve the Environment sets out the government's plans to secure clean air and water, protect our natural heritage, innovate to achieve clean growth and increase resource efficiency. This will provide benefits to both our environment and economy, and help us to keep our pledge to hand over our planet to the next generation in a better condition than we inherited it.

In the past, pollution was sometimes seen as a price we had to pay for progress, but that is outdated thinking. **We now know that clean, green and healthy environments in urban and rural areas are an essential component of progress, not a barrier to economic development.** We have set out our vision for a Green Brexit in which environmental standards are not only maintained but enhanced, and Chapter 9 of this strategy sets this in the context of our leadership role nationally and internationally.

In December we published draft Environment (Principles and Governance) clauses, which will be central to the new Environment Bill. The draft clauses set out how we will create a pioneering new system of green governance, establishing an Office for Environmental Protection, to ensure we succeed in leaving the environment in a better condition than we found it.

3.2 Impacts and improvements to date

Air pollution has direct impacts on the environment and is a factor in the poor conservation status of many of our protected sites. Over time, emissions of air pollutants have had negative impacts in plant and animal communities in many habitats. Reducing air pollution will reduce the pressure on natural habitats and animals and allow affected areas to start recovering.

Case study: tackling acid rain

UK sulphur dioxide emissions from coal burning power stations caused considerable "acid rain" damage in the UK and Scandinavia during the 1970s and 1980s. Sulphur dioxide (SO_2) is emitted to air from fossil fuel combustion at power plants and other industrial facilities along with mobile sources such as ships. When deposited from the atmosphere SO_2 damages vegetation, soils and watercourses. Acid deposition disrupts delicate nutrient balances and when it enters rivers and lakes can damage or kill fish, aquatic plants, invertebrates and trees.

The damage caused by acid rain demonstrated the transboundary nature of air pollution and prompted the agreement of the first international and prompted the agreement of the UNECE Convention on Long-range Transboundary Air Pollution in 1979, which established a common framework for transboundary cooperation on air pollution. Since then, significant reductions in sulphur emissions have been achieved, partially as a result of moving away from coal as a source of energy generation. Nature has slowly begun to recover, with sensitive species returning to large areas of the country. This success story shows us that appropriate action can make real, lasting environmental improvements.

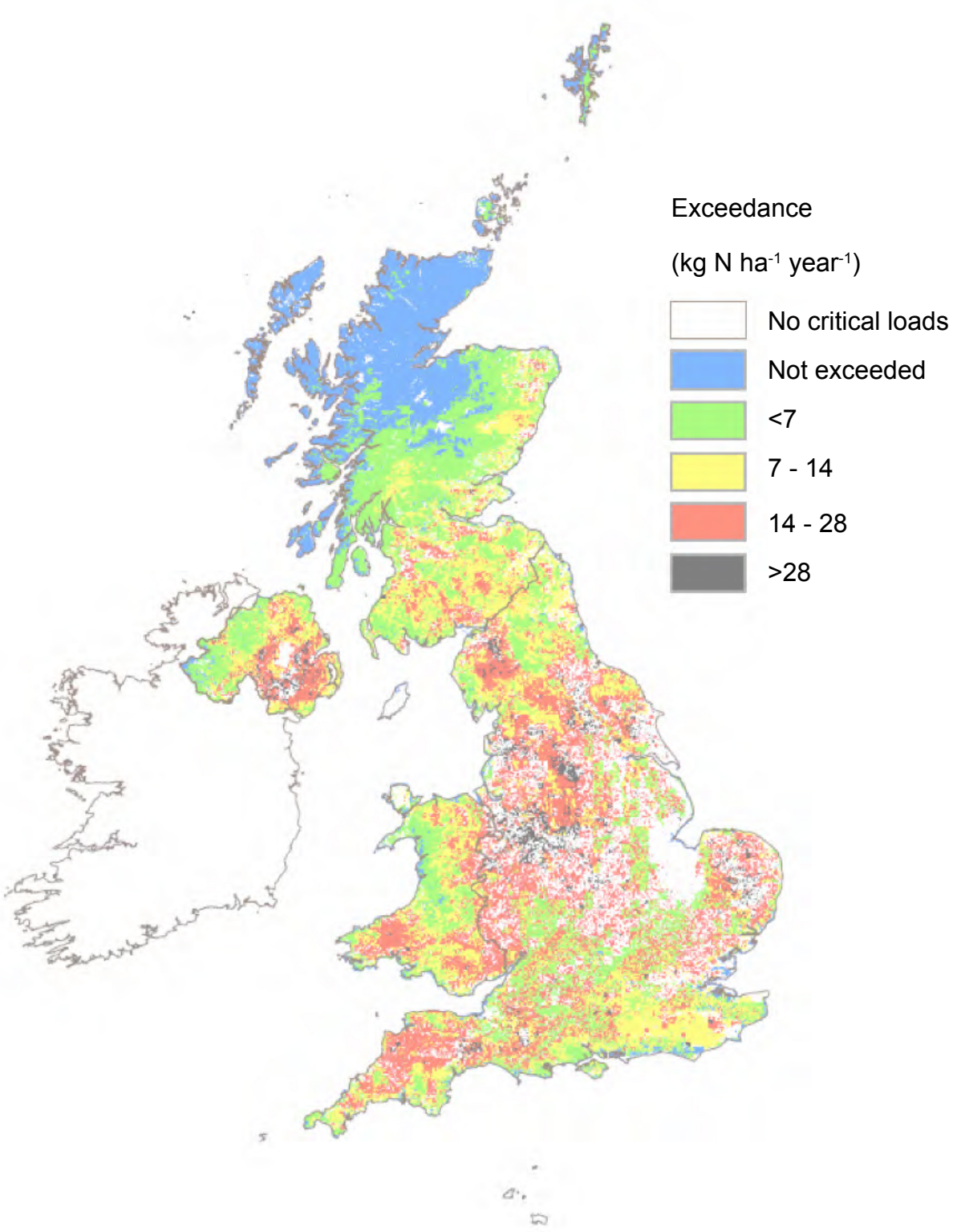
3.3 Effective nitrogen management

Nitrogen is a major component of fertiliser which is why it has an important role to play in food production. However, when excess atmospheric nitrogen spreads into the wider environment it can cause problems. Excess nitrogen from farming practices can be emitted to the air as ammonia (NH_3) and re-deposited onto soils and plants, and into freshwaters. Road transport and combustion are also significant sources, via emissions and subsequent deposition of oxides of nitrogen (NOx). NOx tends to dominate nitrogen deposition in urban areas and near major roads, whereas in rural areas NH_3 emissions from livestock production are the primary contributor. Whilst urban vegetation can have significant other benefits such as for noise pollution, the government's independent scientific advisory body on air pollution, the Air Quality Expert Group (AQEG) have found that urban vegetation is not a solution to the air quality problems at a city scale.[43] Nitrogen pollution can also cause the release of the potent greenhouse gas nitrous oxide (N_2O) to the atmosphere, contributing to climate change. Most nitrogen is deposited locally but some goes high into the atmosphere and can be transported long distances.

Some plants find reactive nitrogen toxic while others are squeezed out by tougher, nitrogen-loving, species. Most nitrogen-sensitive habitats across the UK receive more nitrogen than they can tolerate. More than two-thirds of our wild flower species, such as harebell and betony, are adapted to low-nutrient conditions and cannot survive in the overly-fertile conditions created by nitrogen deposition. Sensitive habitats have become colonised by more robust nitrogen-loving plants, such as the common nettle and cow parsley, with knock-on effects for other wildlife. There is evidence of population declines of certain species of butterflies and bees and other insects because the sensitive plants on which they depend are in decline or in poor condition.[44] [45]

The rare Cistus Forager moth is shown on a Pyramidal Orchid in Great Orme, Wales. Its larvae feed on Common Rockrose – the yellow flowers in the background. Both these plants require very low levels of nitrogen to grow.

The figure below shows that in 2015 62% of the area of sensitive habitat in the UK had more nitrogen deposition than it can cope with effectively.[46] This was a 13% improvement on 1996 levels but has shown no further positive change since 2009. Around 80% of Special Areas of Conservation in England by area are estimated to receive damaging amounts of atmospheric nitrogen. Once soil quality and the balance of species is changed, recovery is slow and costly to achieve.



3.4 Ground level ozone (O_3) - impacts on the environment

Ground level ozone (O_3) reduces plant growth, flowering and crop yields, affecting nature, agriculture, and horticulture. Damage to crops can include leaf damage that directly affects economic value particularly for spinach, lettuce and spring onions. It has been estimated that in a typical year in the UK, ozone reduces yields of wheat, potato and oilseed rape by 5%.[47]

The most effective way to tackle ozone is through concerted, international action on its main precursors including VOCs and NOx. Chapters 5 and 6 of this strategy set out actions we are taking on these pollutants and AQEG have been commissioned to provide advice on our approach to reducing emissions of VOCs across the UK.

Ozone-induced leaf injury on wheat

Green-winged Orchid, classified as near-threatened

3.5 Particulate matter (PM) - impacts on the environment

Much of our focus has been on the reduction of emissions from vehicle exhausts but friction during driving also generates fine particles from brakes, tyres and the road surface. They add to the concentrations of $PM_{2.5}$ and PM_{10} people are exposed to and also have an impact on the environment. In particular, abrasion of tyres and road paints produce tiny microplastic particles, which enter rivers and lakes mainly from road run-off and can eventually be deposited into the sea. Microplastic particles originate from many sources and their generation has increased in line with the global production of plastics (1.5m tonnes in 1950 to more than 300m tonnes in 2015).[48] Studies estimate that micro particles from tyres make up 5-10% of microplastics deposited in the oceans[49], with well documented impacts for marine wildlife and the food chain.

The government is investing £200,000 in research by the University of Plymouth to improve scientific understanding of how tiny particles of microplastics from car tyre friction on roads make their way into the sea through sewers. This Defra-funded research will close current gaps in the evidence; looking at how microplastics from a variety of sources end up in marine environment and what we can do to tackle this problem in the future. AQEG is also currently reviewing research into how particulates from tyres and brakes impact on air quality in order to inform advice to government.

Tackling other human-made pollutants

Human activity results in a range of pollution emissions to air and we are continuing to tackle these emissions as new evidence emerges.

Heavy metals accumulate in the environment, especially in lake and marine sediments, and are toxic to many species at low concentrations. Airborne lead (Pb) emissions have decreased by 98%[50] since 1990, achieved mainly by phasing out the widespread use of leaded petrol.

Work is continuing to reduce other pollutants. Levels of airborne nickel (Ni) can exceed health-based standards in some parts of the UK, particularly in the vicinity of steel processing plants. We are working with the regulators and industries to ensure emissions are lowered so that these standards are not exceeded.

Polycyclic aromatic hydrocarbons (PAH) are toxic, persistent[51] and accumulate through food chains[52], where they can affect animal reproduction, development and immune systems.[53] PAHs are released into the air by the incomplete burning of fuels, particularly solid fuels such as wood and coal. One specific PAH, benzo[a]pyrene (BaP) is a common component of combustion products and is a known carcinogen. Regulation has helped to decrease emissions of PAHs by 98% since 1990.[54] However, the use of wood as a domestic fuel has increased markedly over the last 20 years, and is calculated to produce 78% of total national BaP emissions.[55] Government action to tackle these emissions is outlined in Chapter 2.

3.6 Leadership to reduce environmental damage by air pollution

The UK has long recognised the importance of international coordinated action to reduce the environmental damage caused by air pollution. In 1987 the UK instigated the International Cooperative Programme on Effects of Air Pollution on Natural Vegetation and Crops.[56] This programme sets international standards to report the impacts of ozone, heavy metals and nitrogen, so that progress can be assessed across countries over time.

We also contribute to another of the International Cooperative Programmes (ICPs), on Modelling and Mapping of exceedances of damaging pollutants.[57] This programme models the amount of sulphur dioxide, oxides of nitrogen and ammonia deposited on land throughout the UK and the concentrations of these pollutants plants are exposed to annually. This work defines the impacts of air pollution emissions and the effect of emissions reductions. These programmes have become pivotal to an international requirement to report the monitoring of air quality impacts on terrestrial and freshwater ecosystems in the revised National Emissions Ceiling Directive. In June 2018 we reported on the location and methodologies for our monitoring networks[58] and in June 2019 we will report the first dataset which will inform action to protect the environment.

We are planning comprehensive action to control ammonia emissions from agriculture, detailed in Chapter 7 of this strategy. In line with these ammonia reduction plans we propose to reduce damaging deposition of reactive forms of nitrogen by 17% over England's protected[59] priority sensitive habitats by 2030 and review what longer term targets should be. **These measures are expected to protect an additional 200,000 hectares of natural habitat (an area the size of Warwickshire) from excessive nitrogen deposition.**

In addition to these regulatory controls we are taking action to improve the way that cumulative impact of nitrogen deposition on natural habitats is controlled. We will soon be providing guidance for local authorities explaining how cumulative impacts of nitrogen deposition on natural habitats should be mitigated and assessed through the planning system. Consistent application of this guidance will improve protection of important natural habitats while providing greater certainty for applicants to planning and permitting processes.

Case Study: focus on the Sherwood Shared Nitrogen Action Plan

Natural England's Shared Nitrogen Action Plan (SNAPS) pilots have been developed by bringing together local authorities, NGOs and agricultural and energy sector representatives to encourage shared responsibility for restoring habitats whilst maximising local economic benefits.

Sherwood Forest Focus Area has many air pollution sensitive habitats and species across its 11 Sites of Special Scientific Interest (SSSI). Air pollution sources in the area range from large farms and biomass and waste gas plants to main road traffic.

Local land owners and industries are working to develop innovative solutions to reduce emissions. Opportunities to use Countryside Stewardship & Productivity schemes are available to support actions such as installation of slurry covers and shelter belts along roadsides and around farmyards, together with advice on the impacts of fertiliser use. This will aid the recovery of over 1,500 hectares of SSSI.

Nottinghamshire County Council, Royal Society for the Protection of Birds, Nottinghamshire Wildlife Trust and Natural England have regular input on these plans to manage new emission sources to minimise the potential effects on protected habitats.

We will continue to work with the research community to make the best use of the available evidence and research to understand the mechanisms of ecosystem damage and recovery to underpin proportionate and targeted action. Defra is also working in partnership with stakeholders such as Plantlife and the National Farmers Union. They help us to understand how to improve farming practice and productivity. This has a variety of benefits including reduced greenhouse gas emissions through reduced fertiliser wastage and by achieving healthier soils, allowing communities to see other benefits such as reduced congestion and the services healthy ecosystems provide.

3.7 Action to reduce environmental damage from air pollution

- We will set a target for reduction of damaging deposition of reactive forms of nitrogen by 17% over England's protected[60] priority sensitive habitats by 2030 and review what longer term targets should be
- Our programme of actions to reduce ammonia emissions from agriculture is set out in Chapter 7
- Action to reduce emissions of the ozone precursors nitrogen oxides and volatile organic compound emissions, are set out in Chapters 5 and 6
- We will monitor the impacts of air pollution on natural habitats and report annually so that we can chart progress as we reduce the harm air pollution does to the environment
- We will publish guidance for local authorities explaining how cumulative impacts of nitrogen deposition on natural habitats should be mitigated and assessed through the planning system

Heather, Moss and Lichen are all sensitive to excess nitrogen. © Natural England/Peter Wakely

4. Securing clean growth and driving innovation

4.1 Clean growth

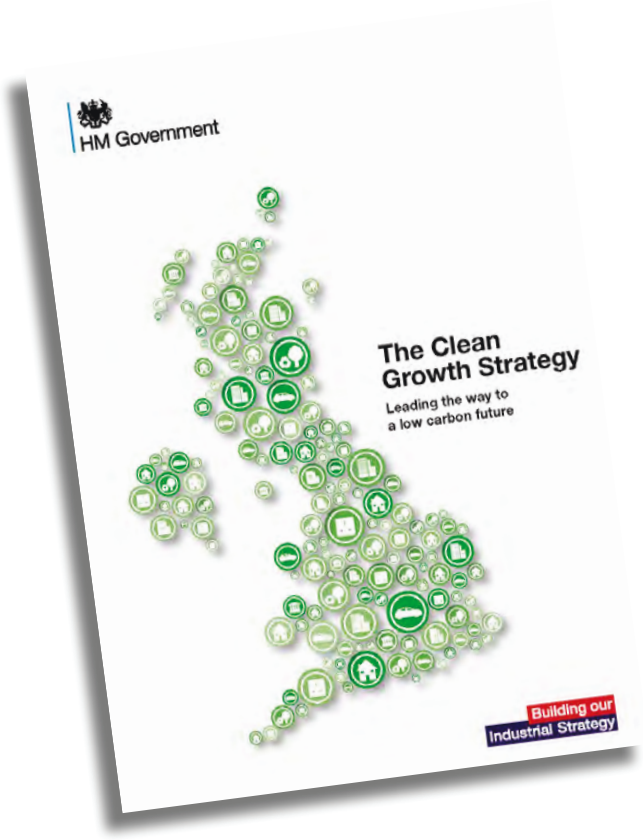
Clean growth means growing our national income whilst tackling air pollution, protecting the natural environment, and cutting greenhouse gas emissions. **It is about boosting productivity by improving air quality, using resources efficiently and making the shift to a low carbon economy.**

The government is taking action to accelerate clean growth on a number of fronts. The Clean Growth Strategy[61] is our plan for continuing to decarbonise the UK economy through the 2020s. A Green Future: Our 25 Year Plan to Improve the Environment, a sister document to the Clean Growth Strategy, provides another essential component, setting out our long-term plan for nature's recovery and good health. This Clean Air Strategy provides a comprehensive part of the picture, setting out actions to improve air quality to improve public health, protect the environment and boost the economy.

Cleaner air leads to increased productivity through improvements in public health, leading to reduced workplace absence, and through the creation of an environment that is appealing to businesses and the public alike. For example, particulate matter, nitrogen dioxide and ozone were estimated to be responsible for total productivity losses of up to £2.7 billion in 2012.[62]

There are significant opportunities for UK industries to become global leaders in clean, green technologies. The UK low carbon economy has the potential to deliver between £60 billion and £170 billion of export sales of goods and services by 2030.[63] By showing leadership and supporting the development of technologies and solutions that can clean up our air, we can achieve our air quality goals more quickly, as well as increase the UK's competitiveness and opportunities for trade as we leave the EU.

To help realise these opportunities, the Industrial Strategy[64] announced a Clean Growth Grand Challenge, focused on maximising the advantages for UK industry from the global shift to clean growth. As part of this, we want to make the UK a world leader in the goods and services focused on tackling air pollution, such as abatement technology, monitoring equipment and modelling skills.



4.2 Innovation

A variety of actions are needed to fill the gap between where we are now and what we want the quality of our air to be like in 10 years' time and beyond. Many technologies and solutions already exist to support the move towards a clean economy, for example, electric vehicles, increasingly energy-efficient products and abatement technologies. However, in some cases these readily available technologies and solutions to air quality challenges are not yet taken up at scale. In these cases, levers such as incentives, disincentives, behavioural change and regulation may help overcome barriers such as a lack of information or awareness, or access to finance.

Additionally, there are several sources of air pollution for which we do not yet have market-ready solutions available. Innovation can play a key role in both the development of novel solutions and improvements in the efficiency, cost or effectiveness of existing technologies. Through discussion with academics, industry and NGOs we have identified a number of priority areas where innovation funding will support us to achieve our air quality goals:

- particulate matter emissions from industrial combustion, tyre, brake and road wear, industrial processes and domestic burning
- zero or ultra-low emission heavy goods vehicles
- volatile organic compounds from industrial processes; and product formulation
- low and zero-emission options for non-road mobile machinery
- ammonia emissions from agriculture

A number of these areas can be investigated through existing avenues for innovation funding.[65] Many of the Industrial Strategy Challenge Fund[66] programmes also have objectives that are beneficial to air quality. In particular, the £90 million Transforming Food Production and the Transforming Construction Industrial Strategy Challenge Funds. We encourage innovators to pursue these.

UK Research and Innovation announced a £50 million pilot programme of loans for small and medium enterprises (SMEs) to be delivered to the end of 2019,[67] aiming to increase both the uptake of innovative technologies and the availability of testing grounds for innovators. The government is also taking action in a number of other relevant areas, including:

- spending nearly £1.5 billion supporting the take-up of ultra-low emission vehicles
- investing £2 million to support the uptake of e-cargo bikes in order to make last mile delivery more sustainable and to reduce vehicle emissions
- investing up to £246 million in the design, development and manufacture of electric batteries through the Faraday Challenge
- supporting new energy technologies, including £177 million to further reduce the cost of renewables such as offshore wind, and £265 million for smart electricity systems and storage
- launching a £19.6 million 'Clean Air: Analysis and Solutions' research programme, to be delivered in partnership with UKRI. The programme will drive innovation to solve air pollution problems, enable the development of novel technologies and promote a cleaner economy, as mentioned in chapter 3. As part of this programme, Innovate UK launched a £5 million Small Business Research Initiative Funding competition, looking to promote and procure industry-led R&D to tackle air pollution resulting from road vehicle brake and tyre wear, road surface wear, non-road mobile machinery used in construction and transport refrigeration units. The competition brief is available on the Innovate UK website

The Clean Growth Strategy also announced the formation of a Green Finance Taskforce to develop ambitious proposals to further accelerate investment that supports clean growth. One of the key themes in their report Accelerating Green Finance[68] focuses on how to improve capital availability to support the commercialisation of innovative clean technologies and solutions.

Case study: taking a joined-up approach to innovation

Industrial processes and power generation can contribute to air pollution, global warming and land contamination. EarthSave, a project funded by the Energy Catalyst, aims to both reduce the environmental impact and increase the performance efficiency of existing coal and anaerobic digestion plants, biomass boilers and industrial processes across many energy-intensive sectors.

The project aims to develop a prototype heat recovery system using a novel 'wet scrubbing' system. This could provide cooling, power generation and hot water services, whilst reducing air pollutants and carbon dioxide emissions.

Members of the research consortium have previously tested the 'wet scrubbing' system and found it reduced particulate matter emissions by up to 90% and nitrogen oxide emissions by over 80%. This is alongside carbon dioxide emission reductions of up to 20% and the production of clean water for recycling and use in the wet scrubbing system.

4.3 Tackling climate change and improving air quality

Many technologies and solutions support multiple aspects of clean growth. For example, the move towards electric vehicles supports both decarbonisation and air quality. However, there are some technologies which can create tension. For example, biomass burning can support decarbonisation but, without appropriate abatement, it will increase levels of air pollution, unless it involves a switch away from a dirtier fuel such as coal. This is particularly problematic when the burning takes place in or close to urban areas.

We will realise the opportunities for mitigating climate change and improving air quality together. For example, we will ensure industrial sector roadmaps for reducing air pollution are well aligned with those for decarbonisation. Where tensions exist, we will ensure that a balanced approach is taken which supports clean growth as a whole. In practice, this means integrating both air quality and climate change considerations into government policies such as energy and agriculture. It also means ensuring that innovation funds are focused jointly on air quality and decarbonisation wherever appropriate, so that we encourage the development of technologies and solutions with multiple benefits and avoid unintended consequences.

For example, the Renewable Heat Incentive (RHI) is a government subsidy scheme for eligible renewable heating technology, including biomass. The RHI has air quality requirements that participants using biomass are required to meet before they can claim support under the scheme. These air quality requirements set limits on the emissions of particulate matter (PM) and oxides of nitrogen (NOx). Participants are also required to use sustainable fuel that is listed on the emissions certificate of the accredited boiler. In order to ensure these criteria are being met, as of 1 October 2018, RHI rules place an annual obligation on all existing and new applicants to submit relevant permits and exemptions to evidence their compliance with all local and national environmental regulations, including those relating to air quality impacts.

In addition, we have introduced a number of measures to mitigate and minimise the air quality impact of RHI installations caused by non-compliance. This includes better data sharing between environmental regulators and piloting a cross-agency joint enforcement programme.

The government recently consulted on banning new RHI biomass applications installed in urban areas which are on the gas grid, as well as introducing mandatory maintenance checks for those installations already accredited on the RHI, and will be responding in due course. We are working across central and local government to ensure we are tackling air quality in a way which allows us to contribute to meeting our carbon targets, whilst not causing detriment to air quality.

In addition, we will consult on making coal to biomass conversions ineligible for future allocation rounds of the contracts for difference scheme.

Future electricity, heat and industrial policies will together improve air quality and tackle climate change. Phasing out coal-fired power stations, improving energy efficiency, and shifting to cleaner power sources will reduce emissions of air pollution, as well as carbon. As we phase out oil and coal heating, we will ensure this transition improves air quality wherever possible and cost-effective to do so. As part of our cross-departmental review into the role of biomass for heat and power, we have established a framework of principles and processes to ensure air quality is considered at the outset of policy development and appropriate tools and evidence are used to assess the impact on public health.

This approach is supported by the Climate Change Committee Report on Biomass published on 15 November 2018, which highlighted the need to consider air quality implications of bioenergy policies. The report advises government not support the use of biomass for heat in urban areas for this reason.

Building on the framework established for bioenergy, we will seek to strengthen the collaboration between Defra and BEIS, so that we fairly and objectively articulate the trade-offs between energy and public health when developing strategies to meet air quality and carbon targets.

Case study: low emissions refrigeration

Sainsbury's has become the first company in the world to introduce a refrigerated delivery truck cooled by a liquid nitrogen powered engine, which will eliminate all emissions associated with refrigeration. Supplied by cooling technology specialists Dearman and its partners, the zero-emission cooling unit replaces the traditional diesel engine used to chill the vehicle and will significantly cut emissions.

Traditionally many refrigerated trucks require two diesel engines, one to power the vehicle and one for the refrigeration unit. The new system harnesses the rapid expansion of liquid nitrogen to deliver zero-emission power and cooling. Dearman believes that a more sustainable solution for refrigeration may soon be widely adopted on Britain's roads.

Dearman have said that during the three-month trial, 37kg of nitrogen oxides and 2kg of particulate matter were saved with a single truck, compared to a similar diesel system.

David Rivington, Director of special projects at Dearman, said; "There was a clear gap in the market for an affordable, zero-emission alternative". Nick Davies, Head of Logistics for Sainsbury's, said: "As one of Britain's biggest retailers we really recognise the importance of reducing emissions, which is why we're working hard to cut carbon emissions by 30% between 2005 and 2020."

Government provided funding through InnovateUK to support the development of the liquid nitrogen transport refrigeration engine - see https://gtr.ukri.org/projects?ref=101561

4.4 Actions to drive clean growth and innovation

- We will maximise the advantages for UK industry from the global shift to clean growth – through leading the world in the development, manufacture and use of technologies, systems and services that tackle air pollution.
- In partnership with UKRI, we will seek ways to support further investment in Clean Air innovation. For example, we have launched a joint research programme worth £19.6 million to promote the development of cleaner technologies and as part of this Innovate UK have run a £5 million Small Business Funding competition to promote and procure industry-led R&D.
- Future electricity, heat and industrial policies will together improve air quality and tackle climate change. Phasing out coal-fired power stations, improving energy efficiency, and shifting to cleaner power sources will reduce emissions of air pollution as well as carbon dioxide. As we phase out oil and coal heating, we will ensure this transition improves air quality wherever possible and cost effective to do so.
- Building on the framework established for bioenergy, we will seek to strengthen the collaboration between Defra and BEIS, so that we fairly and objectively articulate the trade-offs between energy and public health when developing strategies to meet air quality and carbon targets.
- We will minimise the air quality impacts of the Renewable Heat Incentive Scheme and tackle non-compliance. For example, we have introduced new rules requiring all applicants to submit relevant permits and exemptions to evidence their compliance with all local and national environmental regulations, including air quality impacts. The government recently consulted on banning new RHI biomass applications installed in urban areas which are on the gas grid and introducing mandatory maintenance checks for those installations already accredited on the RHI and will be responding in due course.
- We will consult on making coal to biomass conversions ineligible for future allocation rounds of the contracts for difference scheme. across the UK.

5. Action to reduce emissions from transport

5.1 Transport's importance for clean air

An efficient transport system is an essential part of modern life and a healthy economy. Average levels of nitrogen dioxide at the roadside are at their lowest level since the government first started to collect these statistics. Emissions of nitrogen oxides fell by 27% between 2010 and 2016 and are also at their lowest level since records began. However road transport, domestic shipping, aviation and rail are responsible for a significant proportion of air pollutant emissions: 50% of nitrogen oxides, 16% $PM_{2.5}$ and 5% of NMVOCs.[69]

Transport therefore has a key role to play in reducing emissions and meeting the government's objectives on the environment and public health. Emissions from road transport have been in the spotlight because of their impact on local air quality, but government is committed to cutting air pollution from all forms of transport. In 2017, the government published the UK plan for tackling roadside nitrogen dioxide concentrations, supported by more than £3.5 billion for air quality and cleaner transport.

5.2 Setting strategic direction for transport

The Clean Growth Strategy published in 2017 sets out measures which will reduce both CO_2 emissions and air pollutant emissions from the transport sector. These include supporting a move to lower emission road vehicles and more active forms of travel (walking and cycling); and by accelerating the shift of freight from road to rail.

Delivering the significant air pollutant emission reductions we require demands transformational change for our transport network and how we use it. The tools and technologies that will help achieve this are becoming available. Many deliver broader benefits as well as improving air quality, such as greater energy security and reduced congestion. The Industrial Strategy, published in 2017, set the 'Future of Mobility' Grand Challenge for the UK to become a world leader in the way people, goods and services move. The Challenge is supported by the £2.4 billion Transforming Cities Fund which aims to invest in new local transport infrastructure to boost productivity by improving public and sustainable transport connectivity.

In July we published the Road to Zero - setting out our approach to reducing exhaust emissions from road transport and complementing the Clean Air Strategy.

In this Clean Air Strategy we are also setting out ambitious plans to drive down emissions in each major transport sector.

5.3 Road transport

5.3.1 Action to date

Exhaust emissions

Our most immediate air quality challenge is to bring roadside concentrations of nitrogen oxides within legal limits in the shortest possible time. Road transport is responsible for some 80% of NOx concentrations at the roadside.

The UK Plan for Tackling Roadside Nitrogen Dioxide Concentrations, published in 2017 and supplemented in 2018, identifies those local authorities in England which have been directed to develop plans to bring roadside concentrations of nitrogen dioxide within legal limits in the shortest possible time. It also sets out the measures that the Mayor of London and Devolved Administrations are taking forward.

The government is providing extensive guidance for the local authorities required to develop local plans, including the Clean Air Zone Framework for England published in 2017, and is supporting them individually as they develop their plans. This includes committing a £275 million Implementation Fund to enable local authorities to take the necessary action to improve air quality, and a £220 million Clean Air Fund to help them to minimise the impact of their local plans on individuals and businesses.

In July 2018, we published our plan for the transition to zero emission road transport - the Road to Zero. Our mission is to put the UK at the forefront of the design and manufacturing of zero emission vehicles, and for all new cars and vans to be effectively zero emission by 2040. As set out in the UK Plan for Tackling Roadside Nitrogen Dioxide Concentrations, we will end the sale of new conventional petrol and diesel cars and vans by 2040. By then, we expect the majority of new cars and vans sold to be 100% zero emission and all new cars and vans to have significant zero emission capability. By 2050 we want almost every car and van to be zero emission. 2040 is an ambitious but achievable target and we believe it is a key part of the answer to our long term transport air quality and greenhouse gas issues.

We want to see at least 50%, and as many as 70%, of new car sales and up to 40% of new van sales being ultra low emission by 2030. We expect this transition to be industry and consumer led, supported in the coming years by the measures set out in the Road to Zero. We will review progress towards our ambitions by 2025.

Along with the £1.5 billion we are already investing to support the take-up of ultra low emission vehicles (between 2015 and 2021), the measures in our Road to Zero strategy add up to one of the most comprehensive support packages in the world for zero emission vehicles and their associated infrastructure.

Progress towards our mission has already started. There are more than 168,000 ultra low emission vehicles and around 15,000 public chargepoints across the UK (including more than 1,500 rapid chargers). More than 15,000 people are employed in the low emission vehicle sector and 1 in every 8 zero emission cars bought in Europe in 2017 was built in the UK.

We have also laid new regulations that enhance our existing powers concerning the sale of new vehicles with a prohibited defeat device, which came into force on 1 July 2018. These cover cars, vans, motorcycles, tractors and non-road mobile machinery.

For buses, we have already provided £119 million for the purchase of low emission vehicles and £27 million for retrofitting of existing bus fleets. In 2016, DfT announced a further £100 million, provided between 2017/18 and 2020/21. £11.1 million was awarded in August 2017 for new low emission buses via the Low Emission Bus Scheme. £40 million was awarded in February 2018 for retrofitting buses through the Clean Bus Technology Fund. The remaining funding, around £48 million, has formed the Ultra-Low Emission Bus Scheme, with winners due to be announced in January 2019.

Since 1 April 2014 all operators of HGVs at or above 12 tonnes gross weight using UK roads have been required to pay the HGV Road User Levy. From February 2019, HGVs that do not meet the latest Euro VI emissions standards will pay 20% more. Euro VI HGVs will receive a 10% reduction in the amount they pay. This is designed to incentivise a move to cleaner fleets, and therefore increasingly improve our air quality.

We are also considering the impact that road infrastructure has on air pollution. The Road Investment Strategy (RIS) includes a £100 million designated fund for work to tackle air quality concerns associated with existing and new road infrastructure. Under the Road Investment Strategy (RIS1), Highways England is taking a number of steps to improve air quality on the Strategic Road Network including:

- delivering the £100 million Air Quality Fund (2015-2021) which supports work to identify if there are viable options that could be introduced to bring forward compliance with legal air quality limits on the Highways England network in the shortest possible time
- working with local authorities as they develop options for achieving the statutory NO_2 limit values in the shortest time possible and
- ensuring that 95% of the network will have a chargepoint for electric vehicles every 20 miles

5.3.2 Taking Further Action

Non-exhaust emissions

Particulate emissions from non-exhaust sources are a result of the friction required for braking and maintaining traction on the road, which are essential for road safety. However, these particles are harmful to human health and the environment – and a source of microplastics in our oceans. The proportion of total emissions from non-exhaust sources has increased because of action to reduce emissions from other sources, including vehicle exhaust emission standards.

We published a call for evidence on tyre and brake wear which closed in September 2018 and are currently analysing the responses received. We will use these responses and the recommendations from the ongoing review on these emissions sources by the Air Quality Expert Group to inform future policies to address them.

In the meantime, we will continue to work with international partners seeking to develop new international regulations for particulate emissions from tyres and brakes through the United Nations Economic Commission for Europe, as well as with other international initiatives.

5.4 Maritime

The government is committed to driving down emissions from ships and reducing the impact of emissions from the maritime sector on the environment and public health. In 2016, domestic shipping (ships that start and end their journey in the UK) accounted for 10% of the UK's total domestic NOx emissions, 2% of $PM_{2.5}$ and 7% of SO_2.[70]

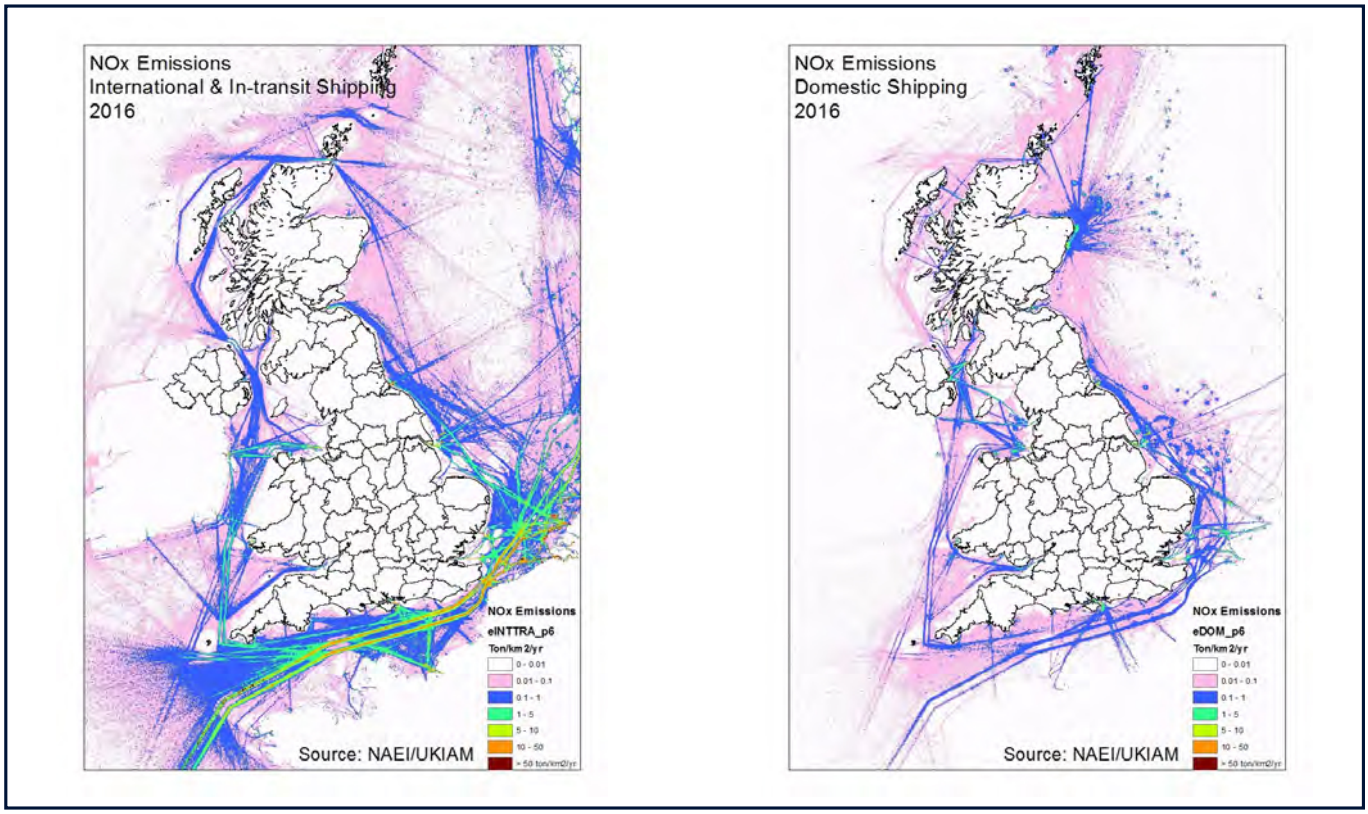
But the absolute numbers above (reflecting 2016 data in the National Air Emissions Inventory, (NAEI)) do not present the full picture, as they only focus on domestic emissions. It must be recognised that emissions from international shipping (ships calling at UK ports which come from or are going to international destinations) and shipping in transit through UK waters are much larger than emissions from domestic shipping. A recent analysis carried out by Imperial College, using Automated Identification System (AIS) data from the Ricardo report on The Review Methodology on Shipping Emissions, showed that, in 2016, NOx emissions from international shipping and shipping in transit were three and six times higher respectively, than from domestic shipping during the same year (see table 1 and figure 1 below).[71] [72]

Table 1

NOx Emissions from Shipping 2016 (Kt/year)	
Domestic	75
International	233
In Transit	433

The figures in Table 1 are for total emissions within the map area in Figure 1, and exclude naval activities. They were generated by Imperial College based on the AIS data.

Figure 1: Shows the modelled contributions of NOx emissions from shipping and the geographical location of these emissions. This analysis was carried out by Imperial College based on AIS data.



Where present, international and transit shipping contributes to local air pollution around ports, and we are undertaking further work to understand this impact in more detail. Globally, it is estimated that nearly 70% of ship emissions occur within 400km of the coast but within European waters there is greater proximity of emissions to the coast. An estimated 89% of North Sea ship emissions are within 50 nautical miles of the coast and 97% are within 100 nautical miles.[73] [74]

5.4.1 Action to date

To date, the UK's main priority in tackling ship emissions has been exerting influence at an international level. We have played a leading role in negotiating international limits to pollutant emissions from shipping, e.g. through the North Sea Emissions Control Area (ECA) where a sulphur cap of 0.1% was introduced in 2015 (a ten-fold reduction from the 1% limit introduced in 2010). The International Maritime Organisation (IMO) has recently agreed a 0.5% sulphur limit for global shipping outside ECAs from 2020, a reduction of three percentage points from the current limit. The IMO has also agreed to the introduction of a NO_x emissions control area for the North Sea from 2021 which will reduce the limit on NO_x emissions from new ships operating in this area by around three-quarters. To put this into context, the limit for cars is 0.001% (which is the lowest detectable amount). So, the 0.1% used in the ECA is 100 times more, and the 0.5% is 500 times more than the limit imposed in fuel for road vehicles.

The IMO has also agreed to the introduction of a NOx emissions control area for the North Sea from 2021 which will reduce the limit on NOx emissions from new ships operating in this area by around three-quarters.

The UK has been at the forefront of pushing for an ambitious strategy to reduce greenhouse gases (GHGs) from shipping at the IMO, where in April member states committed to phasing out GHG emissions from shipping as soon as possible in this century and by at least 50% by 2050. This sends a very clear message that a switch to zero emission technologies is now imminent, and will deliver benefits for air quality.

Attention has now shifted towards implementation of the Initial Strategy. In October 2018 the IMO agreed a programme of follow-up actions to 2023. This has a particular focus on progressing short-term measures which can deliver GHG reductions by 2023, while starting work on mid- and long-term measures to deliver the 2050 ambition. Effective implementation of the Initial Strategy will provide greater certainty for industry and allow it to make the shift to low and zero emissions in a smoother transition that is more cost effective in the long-term.

5.4.2 Maritime 2050 and the Clean Maritime Plan

We are currently developing a long-term UK maritime strategy, Maritime 2050, planned to be published in early 2019. This strategy will set out our vision for the sector over the coming decades.

The environment is a key theme of our Maritime 2050 strategy to ensure that any short term solutions to reduce pollutant emissions are not dealt with in isolation and are underpinned by a holistic, longer-term plan.

Following on from the Maritime 2050 strategy, we will work with stakeholders to develop a Clean Maritime Plan by Spring 2019.

This plan will set out a number of domestic policies to reduce greenhouse gases and pollutant emissions from shipping in parallel (in addition to the policies listed below), while maximising the potential economic benefit for the UK from global transition to zero emission shipping.

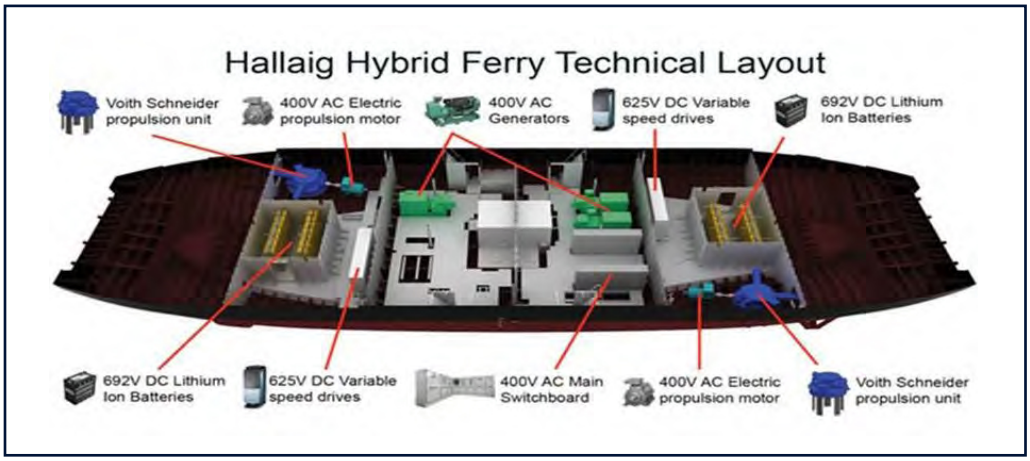
We have now introduced a new government-led Clean Maritime Council to bring together different parts of the maritime sector to drive uptake of cleaner technologies and greener fuels.

The Minister for Maritime, Nusrat Ghani, opened the first meeting of the Clean Maritime Council on 15 October. Alongside government officials, the Council is comprised of 14 thought leaders from industry, academia and the third sector.[75] It will meet quarterly, to help plot the route to zero emissions for the UK maritime sector. One of its first activities will be to assist in the development of the UK Clean Maritime Plan, to be published in Spring 2019.

Members of the Clean Maritime Council at their first meeting in October 2018.

The Clean Maritime Council will have a vital role in devising a national strategy with the triple aims of:

- improving air quality on and around our waterways, ports and shipping lanes
- reducing greenhouse gas emissions from the maritime sector and
- delivering clean growth opportunities from green shipping for the UK



5.4.3. Taking further action on shipping

- By Spring 2019, we will publish a Call for Evidence to explore options for standardising environmental regulations for vessels operating domestically within the UK, including inland waterways. Our aim is to collect a body of evidence that will allow us to understand more clearly the extent of emissions from vessels which do not currently fall within the remit of environmental regulations, which are currently mainly based on UK implementation of international conventions

  In delivering this Call for Evidence we will engage across government departments, governmental agencies, and local and navigation authorities to ensure that any proposed intervention does not overlap, replicate, or conflict with any existing or proposed policies regarding inland waterways, river or canal craft

- By Spring 2019 - we will consult on options for extending the current Emissions Control Areas (ECAs) in UK waters. These options will aim to extend the limits on SOx, and NOx emissions - currently in force in the Baltic and North Sea area (see para 5.4.1 above) – to the Irish Sea area thus covering the extent of UK territorial waters and allowing ports to operate on a level playing field

- By Spring 2019, the government will publish guidelines to advise ports on how to develop effective and targeted Air Quality Strategies. The strategies will set out plans to reduce emissions across the ports and associated waterways, including both emissions from shore activities and visiting` ships. Some ports like Southampton and London have already developed a strategy and are making progress. Following the publication of these guidelines, ports within scope will be required to produce Air Quality Strategies by the end of 2019

  The strategies and plans must be able to reduce emissions while allowing trade to grow and ports to be competitive, in doing so these will be integrated with other policy areas for ports where relevant

  Before their publication, the government will engage with key stakeholders and relevant government departments to make sure the guidelines are evidence based and flexible enough to cater for the specific characteristics of each port. These plans will be reviewed periodically to establish if the measures implemented are effective or further government action is required

5.5 Rail

Rail transport is generally considered to be a cleaner form of transport which makes a relatively small contribution to poor air quality (4% of NOx emissions and 1% of $PM_{2.5}$ emissions,[76] nationally) with overall emissions both less per passenger mile and tonne per km for freight when compared to other transport modes. It is clear, however, that more can and should be done to drive down emissions and improve air quality throughout the whole rail sector, not least as rail emissions have risen overall in absolute terms.

5.5.1 Action to date

Government has asked the industry to set up a taskforce that will look at how to decarbonise the rail industry and improve air quality through reducing harmful emissions produced by the rail industry. The approach of this task force will be holistic and examine the industry in the wider sense by not only considering energy sources for powering trains, but also Network Rail infrastructure such as stations.

As part of this, government has also challenged the taskforce to set out how the industry will meet the ambition of removing all diesel only trains by 2040 (encompassing both freight and passenger traction). This will be both stretching and challenging (particularly given that rolling stock often has a lifespan of over 30 years) and will require embracing new technologies and innovative ideas, potentially pursuing the use of alternative energy sources such as hydrogen and batteries. The industry task force will report back shortly.

There is a substantial amount of activity already taking place, both by government and by industry, as well as through partnerships, to make early progress on reducing emissions. For example:

- In October, Innovate UK launched First of a Kind 2, a competition with £3.5 million government funding to bring innovative ideas to the railway for decarbonisation and passenger experience in stations. Solutions for decarbonisation have a direct impact on emissions, while improving passenger experience can encourage modal shift to rail
- Porterbrook Leasing Company has entered into an agreement with the University of Birmingham to convert one of their electrical units into a hydrogen powered train. Development work has recently commenced and there are plans for the train to undertake testing and demonstration runs in Summer 2019. It is planned that the train will retain the ability to operate across existing electric routes and with the addition of a hydrogen fuel-cell it is planned that it will also be capable of operating in self-powered mode, without the need for diesel engines
- Northern will be reporting back in early 2019 on their preferred option for an alternative fuel for the Windermere line
- As a mechanism to support the rail decarbonisation challenge, industry through the Rail Safety and Standards Board (RSSB) is making £1 million of funding available for feasibility studies and demonstrator projects to solve the challenges of decarbonisation specific to high speed passenger trains, freight and wider infrastructure implications such as energy storage and distribution. RSSB is also co-funding a £1 million+ Knowledge Transfer Partnership (KTP) call, jointly funded by InnovateUK. Both competitions were launched on 30 October 2018. Separately to this, RSSB are also looking at setting up an industry led strategy on air quality.
- Since 2017, the new Bi-Mode Class 800 – Intercity Express trains have been replacing Class 43 trains, delivering a reduction in emissions by complying with latest emission standards and by switching to electric mode where lines and stations are electrified
- There are examples of lower emission alternatives in use on the rail network, for example, in Birmingham there are light rail and tram alternatives which are helping to improve local air quality
- There are also bi-mode rail freight locomotives in service, including the new Class 88s which provide an environmental benefit as they are predominantly designed for electric mode but retain the ability to use diesel on non-electrified lines
- After poor air quality issues were identified at Birmingham New Street, industry introduced measures including reduced idling time to reduce air pollution
- We have introduced progressively more stringent emission standards to drive down emissions from new rail engines since 1999 and have started implementation of Stage 5

standards, which will be introduced in 2020 and require a reduction in PM and NOx emissions of over 90% compared with a pre-1999 train

- We have set carbon reduction targets for all rail franchises to reduce their greenhouse gas emissions. Franchisees may replace older diesel trains with new trains or retro fit diesel and hybrid systems to existing trains, that are compliant with the latest emission limits.

Electrification

Passengers expect high quality rail services and we are committed to electrification where it delivers passenger benefits and value for money, but we will also take advantage of state of the art new technology to improve journeys.

New technologies and state of the art trains mean that we can improve journeys for passengers, such as improving journey times, without carrying out electrification works along the whole of these routes.

As battery technologies improve we would expect to see diesel engines replaced by electrical energy storage systems capable of providing power to trains between electrified sections of the network.

5.5.2 Taking further action to reduce emissions from rail

- We are developing the evidence and testing alternatives to conventional fuels. In particular we are looking at the viability of using alternative fuels including hydrogen fuel cells through research conducted by the Transport Systems Catapult project (amongst others). This technology is being developed for use in the UK within the next few years

- Government will work closely with the decarbonisation task force and industry in early 2019 to develop a range of measures to tackle decarbonisation and air quality within the wider rail industry including in stations

- We will develop options to reduce emissions from freight informed by the National Infrastructure Commission's Freight Study, among other sources

- Government is sponsoring the independent assessment of air quality at enclosed stations to identify if there is a widespread problem. This assessment will be completed in early 2019 and will suggest a range of measures that could be undertaken in order to improve air quality in stations

- The Department for Transport is actively considering what else might be necessary to build the evidence base of Rail's impact on air quality. For example, it is aiming to commission research in early 2019 that will look at air quality on diesel trains and alongside their routes

- Rolling stock companies are starting to trial solutions which allow battery operation in and out of stations and in urban areas

- HS2 stations will have individual station plans developed that will include measures that aim to reduce the impacts and effects of traffic and transport movements

5.6 Aviation

Aircraft contribute to air pollution while in the air, during take-off and on the ground. The biggest domestic impact of aircraft is during take-off and landing (1% of total NOx and SO_2 national emissions).[77] In addition, airports are large, complex sites with a range of emission sources and so can be of concern for local air quality. They also generate significant land journeys by passengers, workers and freight transport.

5.6.1 Action to date

The government works to improve international standards on emissions from aircraft and to challenge airports and local authorities (as appropriate) to improve local air quality.

The industry is taking action to cut airport-related emissions by operating aircraft more efficiently, introducing new lower emission technologies and practices, reducing vehicle emissions within the airport boundary, and improving public transport links to airports.

The government published a consultation on a new aviation strategy, Aviation 2050, on 17 December 2018 which includes consideration of air pollutant emissions from flight and non-flight sources associated with airport operations and passenger travel, and contains a separate section on surface access to airports and reducing car travel.

In addition the Aviation Strategy considers action on a broad range of air quality issues including:

- how air quality information is communicated to residents dwelling nearby major airports
- potential requirements and guidance for airports to produce air quality plans
- what sort of oversight major airports might need for air quality issues
- how to support the development and deployment of cleaner fuel technologies for aviation

5.6.2 Taking further action

- Over the coming months the government plans to work with the aviation industry, the general aviation community, businesses in the wider economy, business groups community groups, environmental groups, and passenger representatives to develop a series of clear plans and roadmaps for how it intends to make the vision for Aviation 2050 a reality

5.7 Reducing emissions by modal shift

We remain committed to encouraging transport users to choose lower emission modes of travel for their journeys where possible. This might include utilising the rail network to move freight across the UK rather than roads, or walking, cycling or public transport instead of a car.

5.7.1 Freight

Over three times as much freight is moved by road as by rail and water combined; so we recognise that in the short to-medium term it would not be possible for that traffic to be accommodated on other modes. Nonetheless, our freight mode-shift grants[78] help remove in excess of 800,000 lorry journeys a year from Britain's roads.

Taking further action to reduce freight emissions, we will support industry research into:

- rail freight emissions and air quality to enable better comparisons with HGV emissions, to understand how a shift from road to rail can best be used to deliver a reduction in emissions of air pollutants
- developing and deploying cost-effective options for shifting more freight from road to rail, including low emission rail freight for delivery into urban areas with zero emission last mile deliveries

In Control Period 5 (2014-2019), Government is investing £235 million in the Strategic Freight Network (SFN) – a ring-fenced fund to improve the capacity and capability of the rail network for freight. This fund is supporting projects and enhancements where there is the opportunity for more freight to be transported by rail.

Currently in delivery through this programme is the Felixstowe branch capacity scheme, where £60 million of government and private investment will enable more trains to serve the Port of Felixstowe.

We will continue to work with Network Rail and the freight industry to develop a programme of potential investments for freight enhancements in Control Period 6 (2019-2024).

There is also an opportunity for reducing emissions from specific major construction projects through mode-shift. For example HS2 Ltd is committed to moving as much material by rail as is reasonably practicable, with its contractors committed to considering sustainable transport as part of their construction logistics strategies. This ensures that contractors must consider rail and waterborne delivery methods before they resort to moving material by road.

5.7.2 Active Travel

Encouraging an increase in cycling and walking for short journeys delivers a reduction in traffic congestion and emissions from road transport, as well as health benefits from more active lifestyles.

Our Cycling and Walking Investment Strategy identifies £1.2 billion available for investment in cycling and walking from 2016-21 to double the level of cycling by 2025 and to reverse the decline in walking. This has included investing £101 million through the Cycle City Ambition programme to improve and expand cycle routes between the city centres, local communities, and key employment and retail sites in eight cities to get more people cycling, as well as £80 million to support local projects including training and resources to make cycling and walking safer and more convenient. In addition, local councils and metro mayors have allocated an additional £700 million[79] to safe infrastructure and other Active Travel projects since the Cycling and Walking Investment Strategy was published. The result is that almost £2 billion is being invested in this area over this Parliament.

Since the Cycling and Walking Investment Strategy was launched government has identified additional funding which will help support the delivery of the Strategy. This includes a proportion of the £2.4 billion Transforming Cities Fund to improve local transport links like cycling and walking improvements to make it easier to travel between city centres and suburbs, and a proportion of the £220m of capital and revenue funding available through the Clean Air Fund.

Since 2010 the government has also provided £34 million to train operating companies for new and improved cycle facilities at stations to make it easier and more convenient for people to get to and from the station by bike. Over 22,000 new cycle parking spaces at stations have been added as a result of these projects, more than tripling the number of cycle parking spaces at stations across England. In the same period, cycle trips to stations have increased by nearly 40%.

Further to this, in September 2018 the Prime Minister announced a £2 million e-cargo bike fund to support the purchase of e-cargo bikes at the Zero Emissions Vehicle Summit.

5.7.3 Public Transport

As well as providing vital connection for communities and workplaces, public transport can also have great benefits for reducing emissions. Journeys taken by rail and bus not only take cars off the road, they also reduce congestion.

Buses

In 2017, we introduced the Bus Services Act which includes a range of measures to improve bus services through franchising and better partnership working. We have also announced the £2.4 billion Transforming Cities Fund, which will drive productivity through improving public transport connectivity in some of England's largest cities. It aims to tackle congestion through increased public transport in major cities, which will have an impact on exhaust and non-exhaust emissions. £840 million has already been allocated to the six mayoral combined authorities on a devolved basis and a Call for Proposals for access to the remaining £840 million of funding was launched for non-mayoral city

regions on 13 March 2018. Local bus services were identified as a key element of the bidding process, with DfT looking for local authorities to work with local transport providers to create improved user experiences for bus passengers and drive growth on those improved services.

Since 2010/11 we have approved investment of over £450 million in major local transport schemes to improve bus-based infrastructure and improve local services. This includes support for schemes in Bath, Birmingham, Blackburn, Bristol, Leeds, Lincoln, Luton, Manchester, Oxford, Portsmouth, Rochdale, South Yorkshire, Tees Valley, Wolverhampton and York.

Government also pays around £200 million a year in Bus Service Operator Grant (BSOG) directly to bus operators in England outside London. BSOG keeps fares 3% lower, service levels 6.7% higher and patronage 4.4% higher. £43 million a year is given directly to local authorities through this mechanism to support local tendered bus services.

Rail

Modal shift to rail can help to reduce road traffic congestion and emissions. The government has been working closely with the railway industry to reduce their emissions. Franchising has encouraged an increase in both the length of trains and the frequency of services to encourage passengers to travel by rail.

HS2 will increase capacity on our networks, which will help to meet current demand as well as encouraging modal shift, by putting more trains with more seats onto the network. The services will be much faster, reducing journey times on a number of intensively-used routes; e.g. Leeds to London journey times will reduce from 2 hours 11 mins to 1 hour 21 mins. These journey time reductions will attract those who would have previously travelled by car, or in the case of longer-distance markets like London-Glasgow, by plane.

An important part of encouraging people to utilise the rail network instead of private vehicles is making rail journeys more accessible for those with disabilities. One of the projects funded in 2017/18 through the first round of the First of a Kind competition was the development of an app designed to make rail travel more accessible for wheelchair users. The app is currently being trialled by a number of train operating companies and a full roll-out is planned for 2019.

As part of our Inclusive Transport Strategy, published in July 2018, the government has continued to fund the Access for All programme first launched in 2006. The programme has invested more than £500 million to provide step free accessible routes at around 200 stations and smaller scale access improvements at more than 1500. Now 75% of passenger journeys are via accessible stations, compared with 50% in 2005. In July the government announced £300 million of new funding to extend the programme until at least 2024.

5.8 Non-Road Mobile Machinery

Non-road mobile machinery (NRMM) covers a wide range of machinery which moves or is intended to move (whether self-propelled or not) and contains a combustion engine. It includes agricultural machinery, construction equipment, non-sea faring boats, watercraft and a range of industrial equipment such as off road trucks, road resurfacing machines and mobile crushers, as well as transport refrigeration units (TRUs) and smaller household machinery such as lawn mowers and generators.

The sector is responsible for emissions of NOx, PM, SO_2 and VOCs. Emissions of SO_2 are controlled by setting the maximum sulphur content of the fuel, with the remaining key pollutants being subject to regulations setting the maximum emissions levels - which are enforced at the point where the engine (or the product into which the engine is installed) is placed on the market in the UK. We are currently implementing more stringent emission standards which will be consistently applied across the wide range of engines used in NRMM from 2019 and drive a reduction in emissions with the turnover of the NRMM fleet. We recognise that emission standards have delivered significant reductions in air pollution from NRMM and envisage they will continue to be reviewed periodically to ensure they reflect what is technically achievable.

Use of red diesel in NRMM

Most NRMM uses red diesel, which has a significantly lower tax rate than road diesel and accounts for 15% of total diesel use in the UK, often in urban areas where it contributes to air pollution (for example, in London NRMM makes up 7% of NOx emissions). The reduced tax rate has a cost of nearly £2.5 billion per annum to the Treasury.

In May 2018, HM Treasury and Defra jointly published a call for evidence into red diesel use, on whether red diesel for NRMM discourages the purchase of cleaner alternatives. Red diesel for agricultural use was out of scope, as were use in fishing vessels, home heating and other static units. In several sectors (for example transport refrigeration, construction machinery, airport ground equipment) lower emission machinery is becoming available, but we are aware that it may not suit all applications, and that other sectors do not yet have viable alternatives to machinery with diesel engines. We are developing options for encouraging a transition to cleaner technologies and will announce next steps in Spring 2019.

5.8.1 Taking further action to tackle emissions from NRMM

Having considered the state of art, stakeholder responses and options available to reduce emissions from NRMM, we have decided to:

- In the first instance, explore the use of environmental permitting for significant NRMM sources where appropriate, to ensure consistent approaches are applied across England to regulate emissions
- Introduce new legislation to enable the Transport Secretary to compel manufacturers to recall NRMM for any failures in their emissions control system, to ensure the more stringent standards deliver a reduction in emissions in the real world
- Where certain types of NRMM pose a risk to air quality only in specific locations, we will work with industry and local bodies to identify local solutions
- Keep under review the need to make tampering with an NRMM emissions control system a legal offence, recognising that such systems will increasingly be required to meet the emission standards

6. Action to reduce emissions at home

6.1 Emissions at home

Up to now the public debate about air pollution has been focused on outdoor sources of air pollution. In recent years, this has been concentrated particularly on emissions from cars and other vehicles. **One aim of this strategy is to raise awareness of the breadth of everyday activities that contribute to air pollution.** Many of these activities take place in and around the home. This is important because, alongside our strong commitment to meeting our legally binding targets to reduce the amount of pollution in our atmosphere, the government's priority is to minimise human exposure to air pollution.

The principal forms of indoor air pollution are particulate matter (PM) and Non-Methane Volatile Organic Compounds (NMVOCs). PM is produced by many forms of cooking and home heating, most notably from combustion in open fires and stoves. NMVOCs are emitted by a wide variety of chemicals that are found in carpets, upholstery, paint, cleaning, fragrance, and personal care products. Sulphur dioxide (SO_2) is emitted by coal burned in open fires.

Indoor air pollution both increases personal exposure and contributes to our overall national emissions as most of these indoor emissions end up in the atmosphere. There are simple, practical steps that we can all take to reduce our exposure such as ensuring homes are adequately ventilated, and making informed choices about the products we use.

These indoor emissions can have a significant impact for some people and add to everyone's incremental exposure over the life course. Studies have found that as much as 90% of the day is spent indoors where the levels of some air pollutants are often far higher than outside.[80] Awareness of the exposure that takes place in the home is currently very low. **The government's objective is to raise awareness of the potential impacts of air pollution at home and ensure that consumers are armed with reliable information enabling them to make informed choices to protect themselves, their families and their neighbours.**

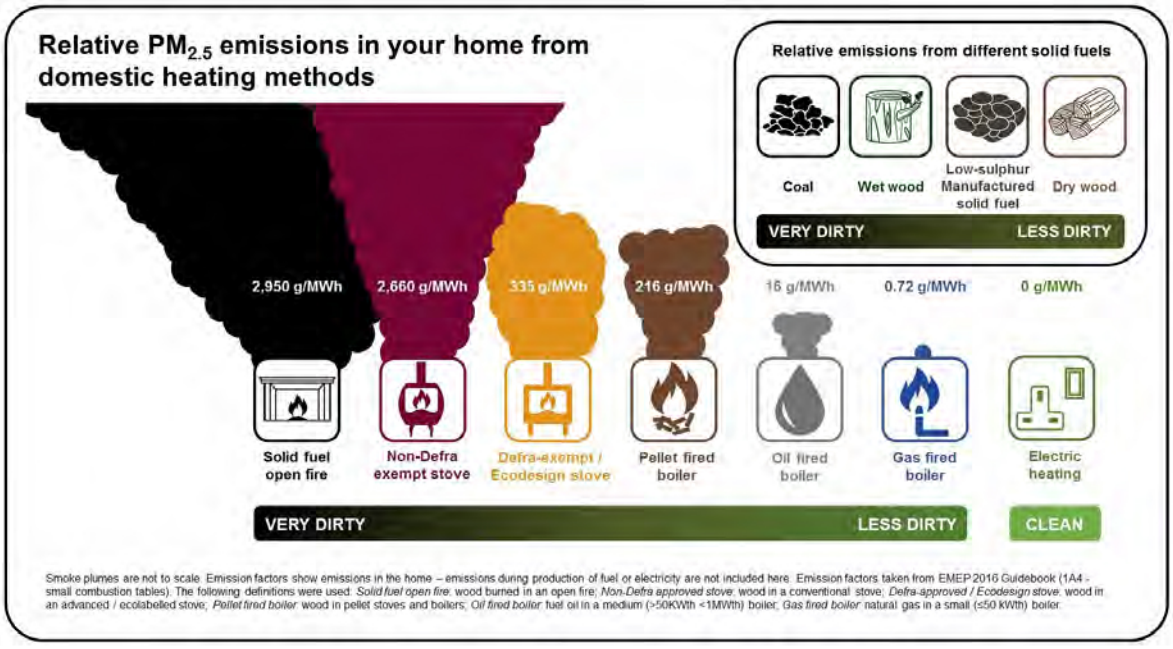
6.2 Domestic burning

Open fires and wood-burning stoves have risen in popularity over recent years. They are now an additional form of heating for many households in both urban and rural areas; for a minority they may be the sole heat source. In addition, we have seen the growth of biomass boilers for home heating. This increase in burning solid fuels in our homes is having an impact on our air quality and now makes up the single largest contributor to our national PM emissions at 38%.[81] This compares with industrial combustion (16%) and road transport (12%). What people burn and the appliance they use will have a significant impact on emissions. A recent report by King's College London,[82] measuring local concentrations, found that wood burning accounts for up to 31% of the urban derived $PM_{2.5}$ in London. This change in behaviour means that the boundaries of smoke control areas (where it is illegal to allow smoke emissions from the chimney of your building) that were established in the 1950s, no longer necessarily align with those areas with high levels of domestic burning. Whilst this legislation is still helpful to reduce the impact of burning in those areas, a more widespread solution is needed.

While emissions from domestic burning and other sources have reduced significantly since the 1950s, the evidence on the adverse health impacts from air pollution has also grown during that time, showing that, even at today's lower levels, significant harm can be caused. We are more aware of the impacts of indoor air pollution and how it can affect people with open fires and stoves in their homes. We also have a better understanding of how pollution travels through the atmosphere, meaning that pollution emitted in one area can have an effect far away. It is therefore more appropriate to consider a nationwide approach to reduce the impact of domestic burning on air quality and the health of all citizens.

6.3 Reducing the impact of domestic burning

Not all forms of domestic burning are equally polluting. The appliance (for example, stove or fireplace), how well it is used and maintained, and what fuels are burnt in it, all make a big difference to how much pollution is produced. Significant air quality benefits can be realised through a new efficient appliance as compared with an old stove or open fire. There are simple steps that households can take to limit emissions both indoors and out. Using cleaner fuels, in a cleaner appliance which is installed by a competent person, knowing how to operate it efficiently, and ensuring that chimneys are regularly swept, will all make a big difference. Defra has developed simple guidance for all local authorities to share with residents on these simple steps.



6.3.1 New powers for local government

Smoke control areas are specific areas, designated by local councils, where it is illegal to allow smoke emissions from the chimney of your building. In these areas you can only burn authorised fuels or use an appliance (e.g. a stove) which has been exempted for use in the area. They remain an important mechanism by which to reduce local emissions from burning. Local authorities have advised that awareness of, and compliance with, smoke control area legislation is low and that few people make the link between domestic burning and air pollution. Some retailers are working to raise awareness (at point of sale) of the requirements. In addition, some local authorities are raising awareness of smoke control areas and re-assessing their boundaries. However, they have told us that smoke control areas can be hard to enforce.

In future, we will focus on a nationwide approach to smoke control which can be built upon as appropriate by local authorities. Through the new Environment Bill we will make changes to make smoke control legislation easier to enforce. In addition, we will explore powers for Local Authorities to go further in areas of high pollution, for example, we will continue to explore how we can give Local Authorities powers to increase the rate of upgrades of inefficient and polluting heating appliances. We will also consider what additional, stronger local powers would be effective to further reduce pollution from domestic burning where there is a clear case that action needs to be taken to protect human health. We will improve and develop new guidance on when existing local and national powers should be used in times of high air pollution.

6.3.2 Ensuring only the very cleanest stoves can be bought and installed

In 2022 the new EU Ecodesign regulations[83] will come into force, which will mean that all new stoves will need to meet agreed emissions standards, regardless of where they are used. This will raise the standard of appliances across the whole country.

These emission limit requirements for solid fuel appliances will need to be coupled with an effective approach to testing. Measuring emissions of particulate matter from wood stoves is a recognised challenge and Defra is working with industry sectors and test houses to review different methods for testing stove emissions to determine what test methods are most reliable.

6.3.3 Ensuring only the cleanest fuels are available for sale

We will legislate to prohibit the sale of the most polluting fuels. In August 2018, government issued a consultation on cleaner domestic burning of solid fuels and wood. The purpose was to identify appropriate action on wood which would enable people who buy wood in large quantities and season it at home to continue to do so, but to reduce the sale of wood that has not been seasoned or dried, which is highly polluting when burned. In addition, we wished to understand the impact of phasing out the sale of the most polluting mineral fuels, such as bituminous house coal or high-sulphur manufactured solid fuels. We will be taking the evidence and views submitted to develop a final proposal for legislative changes.

High sulphur content fuels are harmful to human health and the environment. They also cause damage to stoves and chimneys. At present the sulphur content of solid fuels is limited to 2% in smoke control areas but not elsewhere. It is hard for consumers to identify at point of sale whether a product is high sulphur or not. Government intends to extend this 2% sulphur limit nationwide to ensure that consumers are protected against cheaper, dirtier alternatives.

In addition, new fuels are now entering the market made from a variety of wastes and recycled products. The government wishes to encourage innovation, but it is essential that all products are safe to use and that consumers understand what they are buying. Government will work with industry to identify an appropriate test standard for new solid fuels entering the market.

Call for evidence and consultation on cleaner domestic burning

In response to our Call for Evidence, we received evidence from a wide range of respondents, some of whom called for a total ban on domestic burning, primarily due to personal experience of nuisance or health impacts. Others felt that there should be no restrictions at all or were concerned about the impact on those in fuel poverty.

Some suggested that more should be done to help inform consumers; many are unaware of the impacts of burning waste or cheaper fuels, and some unscrupulous suppliers market wood as seasoned, when it is not. Many chimney sweeps highlighted the point that how a stove is used can have a significant impact on emissions.

We consulted on the cleaner domestic burning of solid fuels and wood between August and October 2018. The proposals in this more detailed consultation included:

- restrictions on the sale of wet wood for domestic burning so that it can only be purchased in volumes over a specified cut-off point
- applying sulphur standards and smoke emission limits to all solid fuels
- phasing out the sale of bituminous or traditional house coal

We are currently analysing the consultation responses, and intend to publish our formal response to this consultation in early 2019.

6.3.4 Voluntary industry initiatives

The stove, fuel and chimney sweep industries have been proactive in recognising the benefits to them and their customers from promoting those fuels, stoves and actions which will reduce air quality impacts. This is making it easier for consumers to understand the benefits of cleaner fuels, appliances and chimneys.

Woodsure's 'Ready to Burn' scheme, backed by government, enables consumers to easily recognise which wood is dry, and ready to take home and burn, instead of wood which is wet and must be seasoned for up to 2 years prior to burning. This can reduce emissions by 50% and in some cases is better value for money.

Case study particulate matter – 'Ready to Burn'

Particulate matter (PM) emissions are increasing, which has a significant impact on human health. It is widely recognised that domestic wood burning is the primary single contributor, accounting for 34% of $PM_{2.5}$ emissions in 2016.[84]

Defra met fuel industry representatives in January 2017 to discuss and identify ways to reduce emissions from wood fuel. This led to the wood fuel industry launching the 'Ready to Burn' scheme in September 2017. It aims to raise consumer awareness and educate wood-burning stove owners about the importance of burning clean, dry, quality logs to help reduce air pollution.

The scheme sets a benchmark for logs and other wood fuels in the UK to help consumers to identify wood that has been carefully chosen and is 'Ready to Burn' for the benefit of their appliance and the environment. The initiative is being led by Woodsure, the UK's only wood fuel quality assurance scheme, and supported by Defra. Suppliers signing up to the scheme provide a guarantee that the fuel they sell as 'Ready to Burn' has a moisture content of 20% or less, meaning that it can be burned without the need for further drying out. To date, over 50 UK suppliers have signed up to the scheme including the UK's largest suppliers of wood fuel alongside small and medium fuel producers.

A 1kg freshly cut log can contain around a pint of water. Burning off all that water takes a lot of energy from the fire and creates a lot of smoke!

The Stove Industry Alliance has introduced its Ecodesign Ready brand ahead of the implementation of the ecodesign provisions due to be introduced in 2022. This shows consumers which stoves are already compliant with the key components of the new legislation and therefore can have up to 90% lower emissions than an open fire or old stove.

We have worked with chimney sweep organisations to provide advice to chimney sweeps and householders. They have developed an informative website and guide which provides clear advice on how to save money and reduce pollution by following certain simple rules.

We are working with industry bodies such as HETAS[85] and the Stove Industry Alliance[86] on a dedicated campaign to inform retailers of Ready to Burn and Ecodesign Ready, providing free point of sale information for consumers and technical bulletins for industry and trade. This is alongside updated training and work with education providers to ensure that stove retailers and installers understand their role in educating the consumer on the benefits of buying the right stove and using an accredited installer, using the correct fuels, and ensuring regular servicing/ chimney sweeping. Together, these actions can safeguard consumers and will have a big impact on the level of emissions from domestic burning.

The way in which we use our stoves can have a big impact on air quality and how long the chimney and stove will last. A local professional sweep can help consumers get it right, ensuring that they get the most from their stoves and provide advice on optimum operation. This can help save money and avoid chimney fires. It is recommended that a chimney is swept twice a year.

6.4 Biomass

Around 2% of households burning biomass have biomass boilers to heat their homes. In general the air quality impacts of these installations are much lower than open fires and stoves, although they could have local impacts. However, like stoves, the emissions can vary depending upon the quality of the installation, the fuel used and how it is maintained. Government will raise awareness of these factors through working with industry and developing clear guidance for local authorities, regulators and households to reduce the air quality impacts from biomass installations. In addition, as set out in chapter 4, we are committed to reducing the air quality impacts of the Renewable Heat Incentive.

6.5 Actions to reduce emissions from domestic burning

- We will legislate to prohibit sale of the most polluting fuels
- We will ensure that only the cleanest stoves are available for sale by 2022
- We will make changes to existing smoke control legislation to make it easier to enforce
- We will give new powers to local authorities to take action in areas of high pollution
- We will work across government to look at opportunities to align our work on air quality, clean growth and fuel poverty in future policy design
- We will develop a dedicated communications campaign targeted at domestic burners, to improve awareness of the environmental impact of their actions
- We will work with industry to identify an appropriate test standard for new solid fuels entering the market

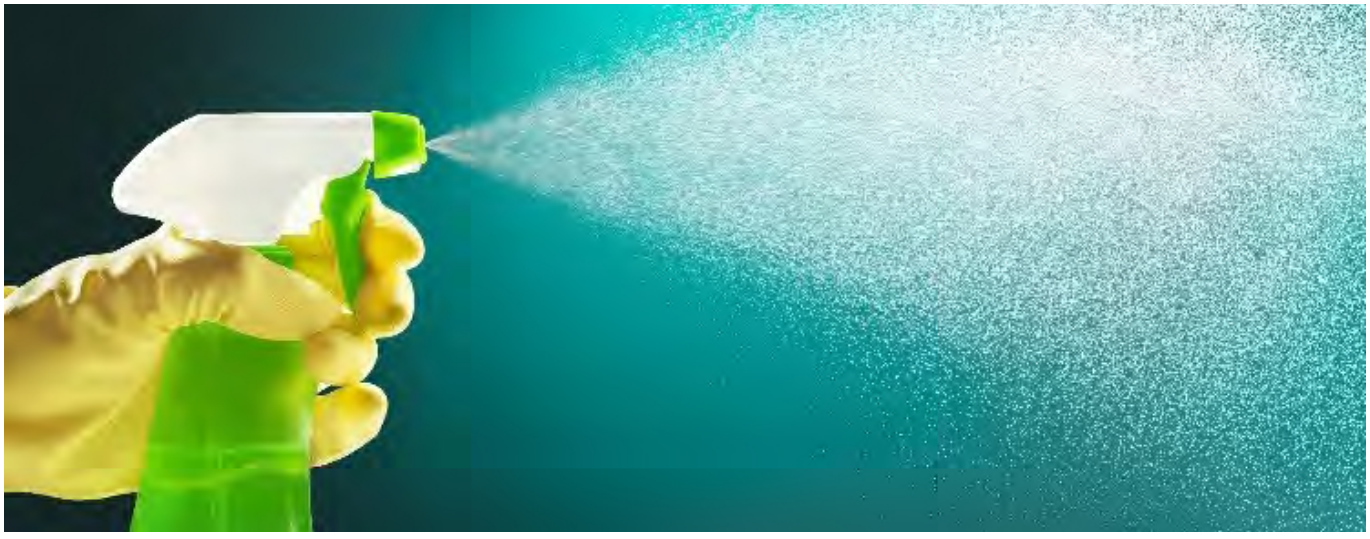
6.6 Non-methane volatile organic compounds (NMVOCs)

Volatile organic compounds (VOCs) are chemicals which evaporate into the air at room temperature. They are emitted from many sources, including production processes, household chemicals, solvent use and different kinds of combustion. Non-methane volatile organic compounds (NMVOCs) are VOCs with the exclusion of methane (natural gas). Methane is already subject to emission controls as a greenhouse gas, so we have not duplicated these in our national emissions ceilings.

Fossil fuels produce NMVOCs either directly as products (for example, vapour from petrol) or indirectly as by-products (for example, vehicle exhaust gas). NMVOCs are also commonly found in paints, carpeting, furniture, adhesives, cleaning products, personal care products and a range of other building and interior materials. If a product has a strong smell, there is a good chance it contains NMVOCs.

In the past most NMVOC emissions came primarily from larger point sources such as refineries and fuel pipelines. However, as these have become increasingly well-regulated, the scientific community is becoming more aware of the significant proportion that arise from diffuse sources, such as the use of products in the home. Many NMVOCs have low levels of toxicity in isolation but may react to form chemicals which are much more harmful.

When products containing NMVOCs are used, concentrations within the home can often exceed ambient outdoor concentrations, particularly if ventilation is poor. How well a home is ventilated is down to a mixture of occupant behaviour, the ventilation system provided, and the natural leakiness of the home. We therefore encourage people to regularly ventilate their homes. Indoor concentrations of NMVOCs also contribute to the overall level of UK NMVOC emissions.



NMVOCs outdoors

Outdoors, NMVOCs react with other pollutants in the air in the presence of sunlight to cause ground level ozone and particulates. Ozone can cause short term physical symptoms such as inflammation of the mouth, eyes, nose, throat and lungs, in addition to causing damage to ecosystems. Industrial NMVOC emissions are subject to a range of controls. By requiring producers and users to apply for environmental permits, we limit VOC emissions from a wide range of industrial solvent activities, including printing, surface cleaning, vehicle coating, dry cleaning and the manufacture of footwear and pharmaceutical products. These set strict emission limits and can require reductions in emissions over time. These permits require regulated businesses to use the Best Available Techniques as agreed by industry, regulators, health and environmental groups.

VOC emissions into the atmosphere from petrol during storage, distribution to service stations, and refuelling of petrol cars at service stations are controlled via the requirement to install petrol vapour recovery systems. Since the early 1990s, standards on VOC emissions from new cars sold in Europe have been in place, requiring the fitting of three-way catalysts to all new petrol cars to significantly reduce emissions of CO, NOx and VOCs. A significant reduction of VOC emissions has been achieved by systems to collect fuel vapour from petrol pumps as vehicles are refuelled – the systems suck up vapours which would otherwise evaporate into the atmosphere. This is why petrol stations no longer smell as strongly of fuel as they used to.

The VOC content of paint products is limited through the Paints Regulations to minimise VOC emissions during use. There may be opportunities to improve awareness and enforcement of these limits, especially in sectors where they are under-recognised.

There is also a range of emerging approaches and alternatives that may reduce VOC emissions further over time. These include replacement of solvent-based adhesives with alternatives, including solid or reactive adhesives which do not release solvents, or with water-based adhesives which generally contain much lower concentrations of VOCs. These will not be suitable for all applications, but there is scope for wider take-up.

Abatement techniques are already applied in certain sectors and could potentially be taken up more widely. There are also emerging opportunities for switching to low or no VOC alternatives to existing products and processes. For example, new agrochemicals products have been developed with lower solvent contents. There are also emerging VOC-free dry cleaning options, including wet cleaning and CO_2, although none of these are yet as effective as the most commonly used solvent, perchloroethylene, and they can be more expensive.

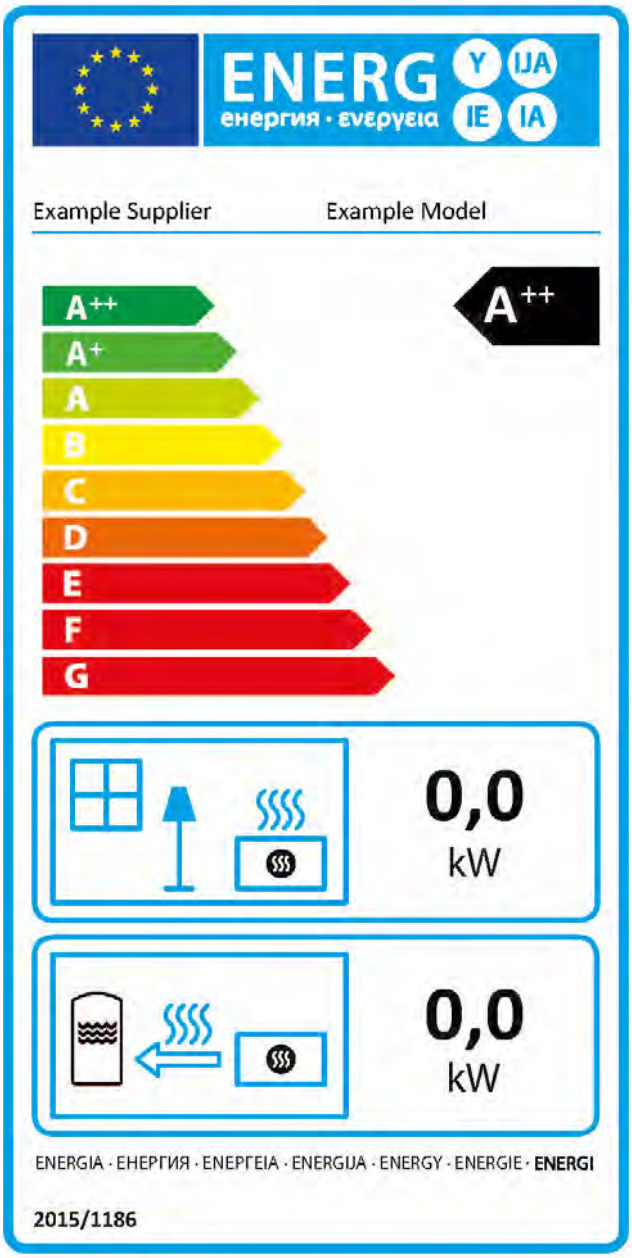
6.6.1 Reducing exposure to NMVOCs at home

Indoors, while NMVOCs do not react with sunlight in the same way as they do outdoors, they do still react in the air to form other chemicals. For example, many fragrances in common household and personal care products include limonene and alpha pinene (responsible for citrus and pine scents). These have a low level of toxicity, but once released into the air indoors they can react to form new chemicals. These include harmful substances such as formaldehyde, a well understood secondary product of fragrance chemicals.

There are a number of practical ways to reduce indoor air pollution from VOCs, which can be as simple as switching to lower VOC alternatives, such as unperfumed cleaning products, and ensuring that homes are well ventilated to avoid an accumulation of emissions from multiple sources.

Alongside our action on emission sources of NMVOCs, we also recognise the importance of ventilation in reducing the build-up of harmful levels of air pollution within homes. As part of the forthcoming review of the energy efficiency standards in the Building Regulations, as announced in the Clean Growth Strategy, the Ministry of Housing, Communities and Local Government will consult on changes to standards in Part F of the Building Regulations relating to ventilation in homes and other buildings. The consultation is due to take place in spring 2019.

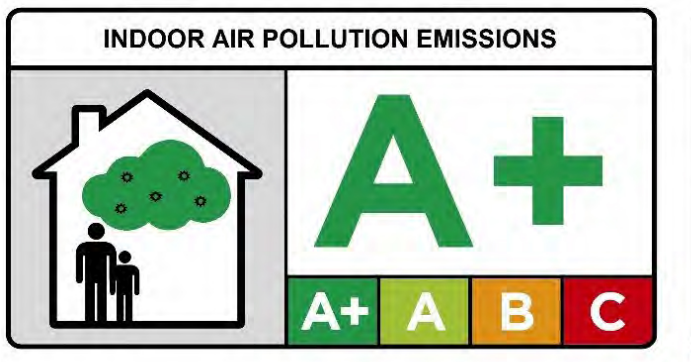
EU energy label, with “traffic light”-style colour scale.

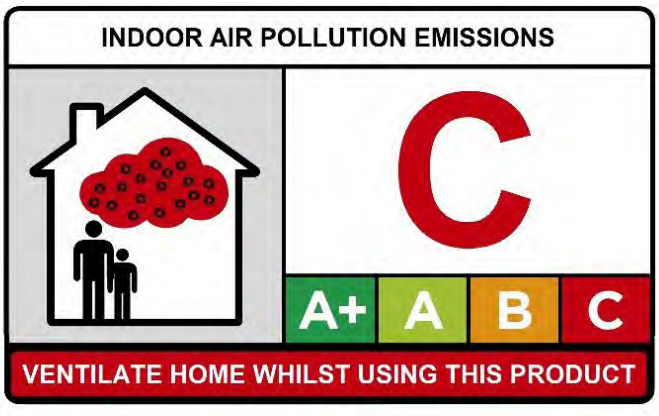


Currently, with the exception of the Paints Regulations, there are few provisions limiting the VOC content of products used in the home. We will improve understanding of exposure to VOCs within the home, working with industry, academia and health organisations. Recognising the impact of high-VOC products, both in the home and once ventilated outdoors, we would like a wider range of low-VOC alternatives to many household products. Many products contain VOCs to enable their function, for example, propellant in aerosol cans, but many other products contain VOCs as an added extra, for example, fragrance in soap. The government will work with industry on how best to enable consumers to make informed choices about what they use in their homes, and to switch to low-VOC content products wherever possible. Options include the development of a voluntary labelling scheme for NMVOC-containing products; example mock-ups of these labels are given below. There are a wide range of labelling schemes across Europe, including traffic-light labeling for the nutritional content of food in the UK, EU-wide energy labelling and indoor air quality labels in several countries, including France and Denmark.

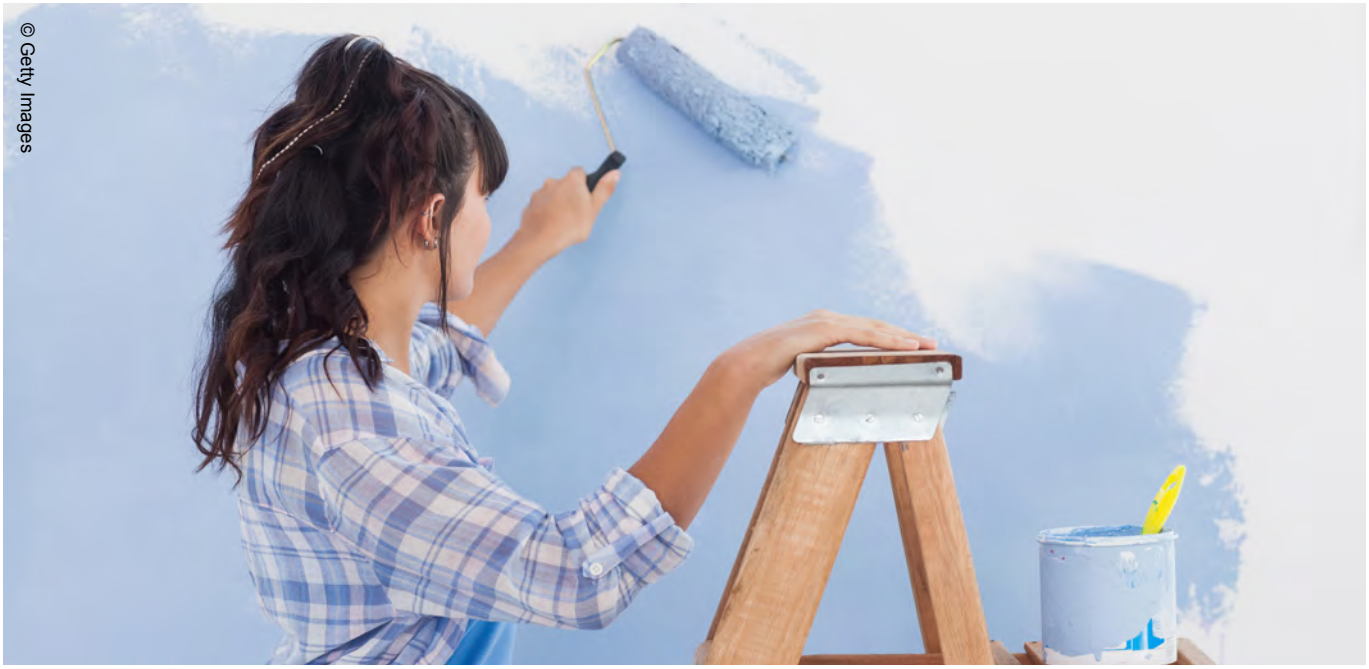
The science about the impacts of indoor use of products containing VOCs is developing rapidly. The government will work with industry to take account of this emerging evidence base. We want to develop voluntary approaches wherever possible and will look at regulation where necessary.

Danish indoor air quality label for furniture.





Mock-up of NVMOC product labels – adapted from French labels



6.6.2 Actions to reduce emissions of NMVOCs in the home

- We will work with consumer groups, health organisations and industry to plan an extensive public engagement campaign, to raise awareness of NMVOC build-up in the home, and the impact that purchasing choices have on indoor air quality
- We will explore a range of options including the development of a voluntary labelling scheme for NMVOC-containing products, and assess its potential effectiveness
- We will work with consumer groups, health organisations, industry and retailers to promote development of lower VOC-content products and drive reformulation, to reduce emissions from this sector
- Alongside our actions on emissions of NMVOCs, we will consult on changes to Building Regulations standards for ventilation in homes and other buildings, to help reduce the harmful build-up of indoor air pollutants

7. Action to reduce emissions from farming

7.1 Agriculture and air quality

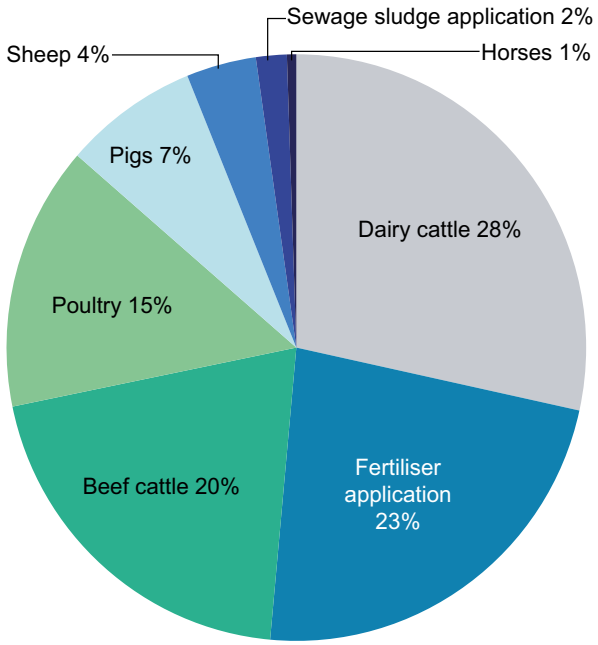
Agriculture is at the heart of our rural communities, producing high quality food and creating and maintaining the beautiful landscapes we all enjoy. Farming has a role to play in protecting our environment by keeping our air and rivers clean, improving our soils, and providing habitats for our wildlife. As set out in the 25 Year Environment Plan, we will support farmers and land managers to provide public goods and enable them to meet rules to control pollution.

Ammonia is emitted during storage, land-spreading and deposition of manures and slurries, and from application of inorganic fertilisers. The agriculture sector is the main source of ammonia, accounting for 88% of UK emissions in 2016.[87] Ammonia reacts with nitrogen oxides and sulphur dioxide to form secondary particulate matter which significantly impacts on human health. Most notably, ammonia contributes to smogs in urban areas. Ammonia also damages sensitive habitats as described in Chapter 3.

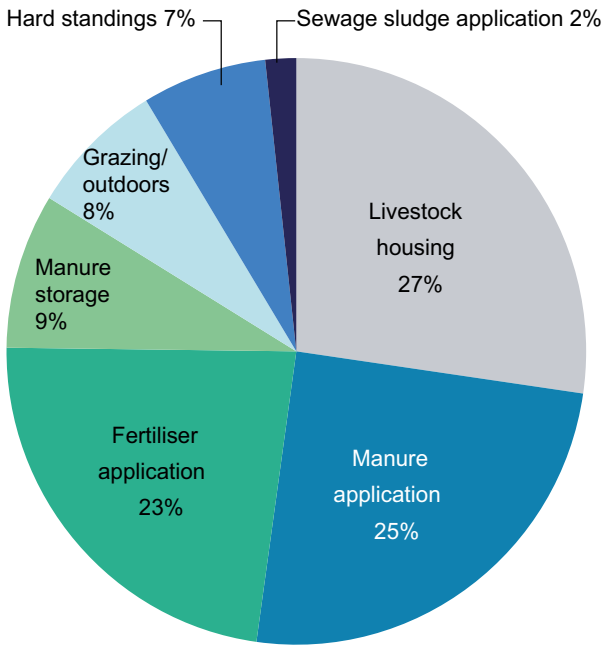
Agriculture also accounts for around 51%[88] of methane emissions and 14%[89] of NMVOC emissions. These contribute to ozone formation, which can cause harm to human health and to key agricultural crops and flowering plants as detailed in Chapter 3. In a typical year, ozone damage is estimated to reduce yields of wheat, potato and oilseed rape by around 5%[90] in the UK. Ozone also damages horticultural crops such as spinach, lettuce and spring onions. Many of the farm practices that can be used to reduce ammonia emissions also reduce emissions of NMVOCs.

The pie charts (right) give a breakdown of agricultural ammonia emissions by source. Cattle farming, particularly dairy farming, accounts for a substantial proportion of ammonia emissions whereas extensively grazed livestock, which are not housed, make a small contribution to ammonia emissions.

UK agricultural ammonia emissions (2016) by livestock and fertiliser category



UK agricultural ammonia emissions (2016) by management category



7.2 Existing regulation and policies affecting ammonia emissions

A number of existing frameworks are in place to limit ammonia emissions from agriculture. Intensive pig and poultry farms are point sources of ammonia emissions and those over a certain size are regulated under the Environmental Permitting Regulations in England. Operators of intensive farms over specified thresholds must hold an environmental permit which requires adoption of Best Available Techniques for their production processes to reduce emissions to air, water and land. The use of these techniques reduces emissions from these facilities by around 30%. At present, around 1,290 English pig and poultry farms hold permits. The planning regime plays an important role in protecting habitats that are sensitive to nitrogen deposition from sources of ammonia emissions, such as animal houses and slurry stores. Policies such as Farming Rules for Water, the Nitrates Regulations and measures within existing agri-environment and farm advice schemes also help to reduce ammonia emissions.

7.3 Reducing Ammonia Emissions

Farmers can take practical action to reduce ammonia emissions.

Key measures to control ammonia emissions from farming

- covering slurry and digestate stores or using slurry bags
- using low emissions techniques for spreading slurries and digestate on land (for example, by injection, trailing shoe or trailing hose)
- incorporating manures into bare soils within 12 hours of spreading
- washing down animal collection points soon after use
- ensuring that levels of protein in livestock diets are well matched to nutritional needs
- switching from urea based fertilisers to ammonium nitrate, which has lower emissions, injecting or incorporating urea into soil or applying it alongside a urease inhibitor

The sources of ammonia emissions (such as slurries, manures) also cause nitrate and phosphate pollution to our surface waters and groundwaters. Across England and Wales, agriculture is estimated to account for up to 60% of nitrate losses to the water environment, and also nationally, 25% phosphate, of 75% sediment loadings in rivers,[91] and 80% of nitrate pollution to groundwaters.[92] These actions to reduce ammonia emissions will help to improve nitrogen use efficiency, which can improve water quality and reduce greenhouse gas emissions. Some of these practices will also save farmers money on inorganic fertilisers.

Widespread implementation of these kinds of measures across the farming sector is expected to reduce ammonia emissions in line with our 2030 targets. In addition to these measures, there is a need for specific localised action on ammonia to help deliver our nature objectives.

7.3.1 Learning from international experience

Action in other European countries has already effectively reduced ammonia emissions in this way.

Netherlands

The Netherlands reduced ammonia emissions by 64% between 1990 to 2016[93] through actions including:

- regulating to ensure manure is applied using low-emission spreading equipment
- regulating to ensure slurry stores are covered
- funding for manure banks to supply arable farms with excess manure and reduce over-application on livestock farms
- providing financial support for a voluntary industry strategy to develop and install low-emission animal housing
- regulating to ensure that all new housing since 2007 meets low-emission criteria; suitable housing is recognised by the government through a certification scheme
- providing grants for research into innovative manure management techniques and subsidies, and tax breaks to support investment in the new technologies
- establishing farmer networks for knowledge transfer and peer-to-peer support

The overall improvement in nutrient management in the Netherlands has been estimated to cost €500 million annually, but resulted in annual societal benefits of €900-3,700 million, including €150 million in fertiliser savings for farmers.[94]

Denmark

Denmark reduced ammonia emissions by 40%[95] between 1990 and 2016 through actions including:

- regulating to ensure manure is applied using low-emission spreading equipment (band spreaders or injection), and spreading in winter is limited to certain crops
- regulating to ensure slurry stores are covered
- regulating to ensure solid manure must be incorporated into bare soil within 6 hours
- permitting most farms, requiring a fertiliser plan and adherence to nitrogen application limits; small farms do not require a permit, but are incentivised to create a fertiliser plan by a tax relief on mineral fertiliser
- allocating the majority of their EU funded rural development programme to tackling pollution
- setting nitrogen limits at up to 18% below the economic optimum level; this was raised in 2015 to the economic optimum level
- limiting the amount of mineral fertiliser available for purchase; all purchases are recorded automatically on a farm's online fertiliser plan

7.3.2 Current action

The government is already acting to help farmers to reduce ammonia emissions. The focus of action so far has been on enabling farmers to invest in the equipment that will help to achieve this objective. As a first step, we provided practical help for farmers through the Farming Ammonia Reduction Grant Scheme which funded slurry store covers and on-farm advice. Funding has been made available through the Countryside Productivity Scheme to help farmers purchase manure management equipment including low-emission spreaders, and through the Countryside Stewardship Scheme for slurry tank and lagoon covers for farmers in priority water catchments.

We are also working with farming organisations to increase the uptake of best practice and signpost available grant funding for low emissions farm equipment and infrastructure through a number of routes. We supported industry action led by the Campaign for the Farmed Environment which has run workshops on reducing ammonia emissions and improving nutrient use efficiency. We are also delivering a £3 million programme of support to farmers over a 3 year period. This has started with demonstration events showcasing low-emission spreading equipment and providing advice on other practical mitigation methods, such as slurry and manure storage, housing, animal feed and fertiliser use. Practical help to reduce ammonia emissions is now available to farmers in high priority water catchment areas through their Catchment Sensitive Farming officer.

We developed a national advisory code of good agricultural practice (COGAP) to reduce ammonia emissions in collaboration with farming organisations, which was published in July 2018. We will explore whether the code could form the basis of a clean air standard within a wider gold standard for farmers.

7.4 Cutting ammonia emissions from farming

More still needs to be done to reduce emissions of ammonia in line with our targets. To achieve this, we will introduce clear, proportionate regulations.

In future, financial support for the farming sector will be focused on delivering improvements to the environment, including air quality and protection of the habitats impacted by it. For most farmers, changing practice to reduce emissions will incur some costs. Therefore, we will require and support farmers to make investments in the farm infrastructure and equipment that will reduce emissions.

A future environmental land management system will fund targeted action to protect habitats impacted by poor air quality. Achievement of our 2030 air quality targets will reduce the pressure of emissions on semi-natural habitats. However, despite projected improvements, some vulnerable habitats will still be exposed to nitrogen deposition and atmospheric levels of ammonia that are greater than they can tolerate. Natural England is currently examining options to improve the effectiveness of incentive schemes for mitigating ammonia emissions to air and protecting natural ecosystems. In addition, we have commissioned further work to investigate how these habitats might be protected most effectively through new environmental land management schemes.

7.4.1 Improving the evidence base

The UK's ammonia inventory compares favourably to those compiled in other countries and UK academics have actively shaped the guidance used internationally for compiling agricultural emissions inventories. A lot of work is being done by farming organisations and advisers to improve uptake of best practice to reduce ammonia emissions. We will continue to work with the agriculture sector to ensure the ammonia inventory reflects existing farming practice and the latest evidence on emissions.

7.4.2 We will regulate to reduce ammonia emissions from farming

We will:

1. Introduce rules on specific emissions-reducing practices including

- a requirement to take action to reduce emissions from urea-based fertilisers. We will consult on this policy in 2019 with a view to introducing legislation in the shortest possible timeframe
- a requirement for all solid manure and solid digestate spread to bare land (other than that managed in a no-till system) to be incorporated rapidly (within 12 hours) with legislation to be introduced in the shortest possible timeframe
- a requirement to spread slurries and digestate using low-emission spreading equipment (trailing shoe or trailing hose or injection) by 2025. We will also consider options for phasing in this requirement so that those spreading digestate or large volumes of slurry may be required to adopt the practice at an earlier date
- a requirement for slurry and digestate stores to be covered by 2027. We will consider options for phasing in this requirement so that those producing or storing digestate or large volumes of slurry may be required to adopt the practice at an earlier date.
- mandatory design standards for new intensive poultry, pig and beef livestock housing and for dairy housing. The standards will be designed in collaboration with industry experts and will include design features to improve animal health and welfare and minimise environmental pollution to air (including greenhouse gas emissions), water and land as far as practicable

We will consult on each policy as quickly as possible to provide farmers, farm suppliers and farm service providers with certainty on the investments needed. In order to promote innovation and provide flexibility, wherever possible, we will seek to design a regulatory approach that enables adoption of alternative proven and verifiable techniques for achieving equivalent or greater emissions reductions.

2. Regulate to minimise pollution from organic and inorganic fertiliser use

The 25 Year Environment Plan sets out our commitment to work with farmers to improve fertiliser use efficiency. The plan states that we will "put in place a robust framework to limit inputs of nitrogen-rich fertilisers such as manures, slurries and chemicals to economically efficient levels backed up by clear rules, advice and, where appropriate, financial support".

Given the impact of fertilisers (including organic fertilisers such as manures and digestates) on air and water quality and on greenhouse gas (GHG) emissions, we propose that an integrated approach, considering all these impacts, should be taken in developing future policy.

We will task an expert group including agricultural policy experts, agronomists, scientists and economists to make recommendations on the optimal form of regulation to minimise pollution from fertiliser use. The recommendations should prioritise the use of organic fertilisers, limiting ammonia emissions, GHG emissions and water pollution and protecting sensitive habitats at least in line with government commitments.

3. Extension of environmental permitting to dairy and intensive beef farms by 2025

Ammonia emissions arising from dairy cattle accounted for around 28%[96] of UK agricultural ammonia emissions in 2016 and emissions from beef farms accounted for around 20%[97] of UK agricultural ammonia emissions. Cattle farming as a whole accounts for 54% of UK agricultural GHG emissions (dairy farming for 19%[98] and beef farming for 35%).[99] Agriculture was the largest sector responsible for significant pollution events to water in 2016 and the dairy sector was responsible for more water pollution incidents than other agricultural sub-sectors between 2013-2016.[100]

However, unlike the pig and poultry sectors, ammonia emissions from dairy and intensive beef farms are not currently regulated. Given their contribution to ammonia emissions and other pollutants, we will work with the industry to agree appropriate emission limits and Best Available Technique (BAT) documents for limiting pollution from these sectors.

The livestock housing standards (see above) will be based on the BAT documents developed in collaboration with industry.

7.5 Action to reduce emissions from farming

- we have provided a national code of good agricultural practice (COGAP) to reduce ammonia emissions
- we will regulate to reduce ammonia emissions from farming by requiring adoption of low emissions farming techniques
- we will extend environmental permitting to the dairy and intensive beef sectors
- we will regulate to minimise pollution from fertiliser use, seeking advice from an expert group on the optimal policy approach
- we will require and support farmers to make investments in the farm infrastructure and equipment that will reduce emissions
- we propose that a future environmental land management system should fund targeted action to protect habitats impacted by ammonia
- we will continue to work with the agriculture sector to ensure the ammonia inventory reflects existing farming practice and the latest evidence on emissions

7.6 Ammonia emissions from anaerobic digestion

Anaerobic digestion (AD) is an effective treatment for organic waste which produces renewable fuel, heat or energy and a nutrient rich by-product, digestate, which can be used as a fertiliser. AD also helps to avoid greenhouse gas emissions associated with manure storage and waste disposal to landfill.

As well as these positive impacts on the environment, ammonia emissions released during the AD process and during the storage and spreading of digestate account for around 3% of UK ammonia emissions.[101] Over recent years the AD industry, and the ammonia emissions associated with it, have grown rapidly in response to incentives to encourage the use of renewable heat and energy. We expect the AD industry to continue to grow in scale while these incentives are offered.

Ammonia emissions from digestate can be reduced by covering stores and using low-emission spreading equipment. Many AD facilities are subject to environmental permits requiring digestate stores to be covered which helps to reduce ammonia emissions. Digestate can give rise to more ammonia emissions than the fertilisers it is likely to replace. The spreading of digestate accounts for the majority of emissions from AD, and it is therefore important that it is spread in accordance with good practice guidance.

As noted in Section 7.4 we will introduce a requirement to store digestate in covered stores by 2027 at the latest and a requirement to spread digestate using low-emission spreading equipment (trailing shoe and trailing hose or injection) by 2025 at the latest. We will consider options bringing in these requirements at an earlier date for digestate than for slurries in view of the fact that it is a more potent source of ammonia emissions. We will also consider whether the earlier requirement should be imposed only on digestate from facilities coming into operation after a specified date.

8. Action to reduce emissions from industry

8.1 Industry and air quality

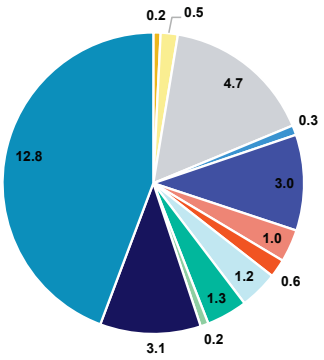
Industrial processes, including energy generation to power our businesses and homes, and the manufacture of goods and food can all create pollution. These processes are carefully managed to avoid potentially significant impacts on our health and environment and this has already made a significant contribution to reductions in air pollution. However, emissions from industrial sources still contribute to background levels of pollution throughout the UK. Reducing these emissions further, alongside action on other sources, will have a direct impact on the concentration of air pollutants in those places where people live and work.

Chapter 4 notes that businesses can increase productivity and achieve air quality improvements by harnessing the opportunities for innovation and investment in clean growth. The government's Industrial Strategy: Building a Britain Fit for the Future[102] and Clean Growth Strategy,[103] set out how we will maximise the advantages for UK industry of the global shift to clean growth.

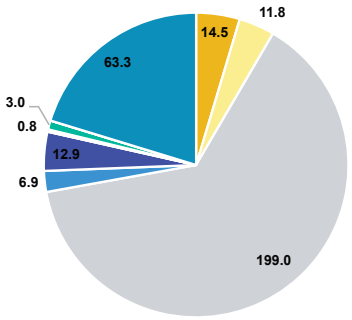
A sectoral breakdown of the UK's industrial emissions of air pollutants

The following charts show the contribution of individual sectors to the UK's total industrial emissions for 2016. Source: NAEI (2018)

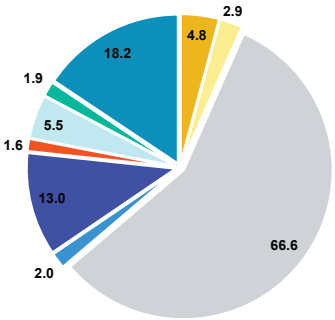
$PM_{2.5}$ Emissions From Industrial Sources (kt)



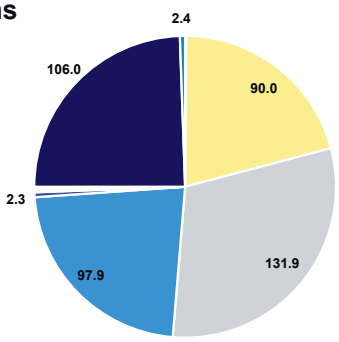
NO_x Emissions from Industrial Sources (kt)



SO_2 Emissions from Industrial Sources (kt)



NMVOC Emissions From Industrial Sources (kt)*



* Sectors with total emissions of less than 2 kt are not labelled

- Cement and lime production
- Food and drink
- Non-ferrous metal production
- Pulp paper and wood production
- Other industrial combustion
- Solvent and other product use
- Chemical industry
- Iron and steel manufacturing
- Energy industry
- Mining and quarrying
- Glass production
- Other manufacturing

8.2 A strong existing framework

The UK has been at the forefront of reducing industrial pollution, using a proportionate framework of regulation to require industry to improve their environmental performance, and industry has responded with investment and innovation to meet these standards. For example, we have set limits on the emission of NOx from power stations, reduced the amount of sulphur allowed in liquid fuels and redesigned fuel pumps to recover petrol vapour. Industry will need to continue to progressively drive down emissions of all pollutants, looking at more diffuse sources such as product use, as well as the larger point sources of emissions.

The UK introduced an integrated approach to controlling pollution to air, water and land as a result of the 1990 Environment Act, as well as the concept of Best Available Techniques. These approaches have subsequently been adopted and applied across the EU through the Industrial Emissions Directive, which sets challenging industry standards for the most polluting industries.

Best available techniques

The Industrial Emissions Directive (IED) aims to prevent and reduce harmful industrial emissions across the EU, while promoting the use of techniques that reduce pollutant emissions and that are energy and resource efficient.

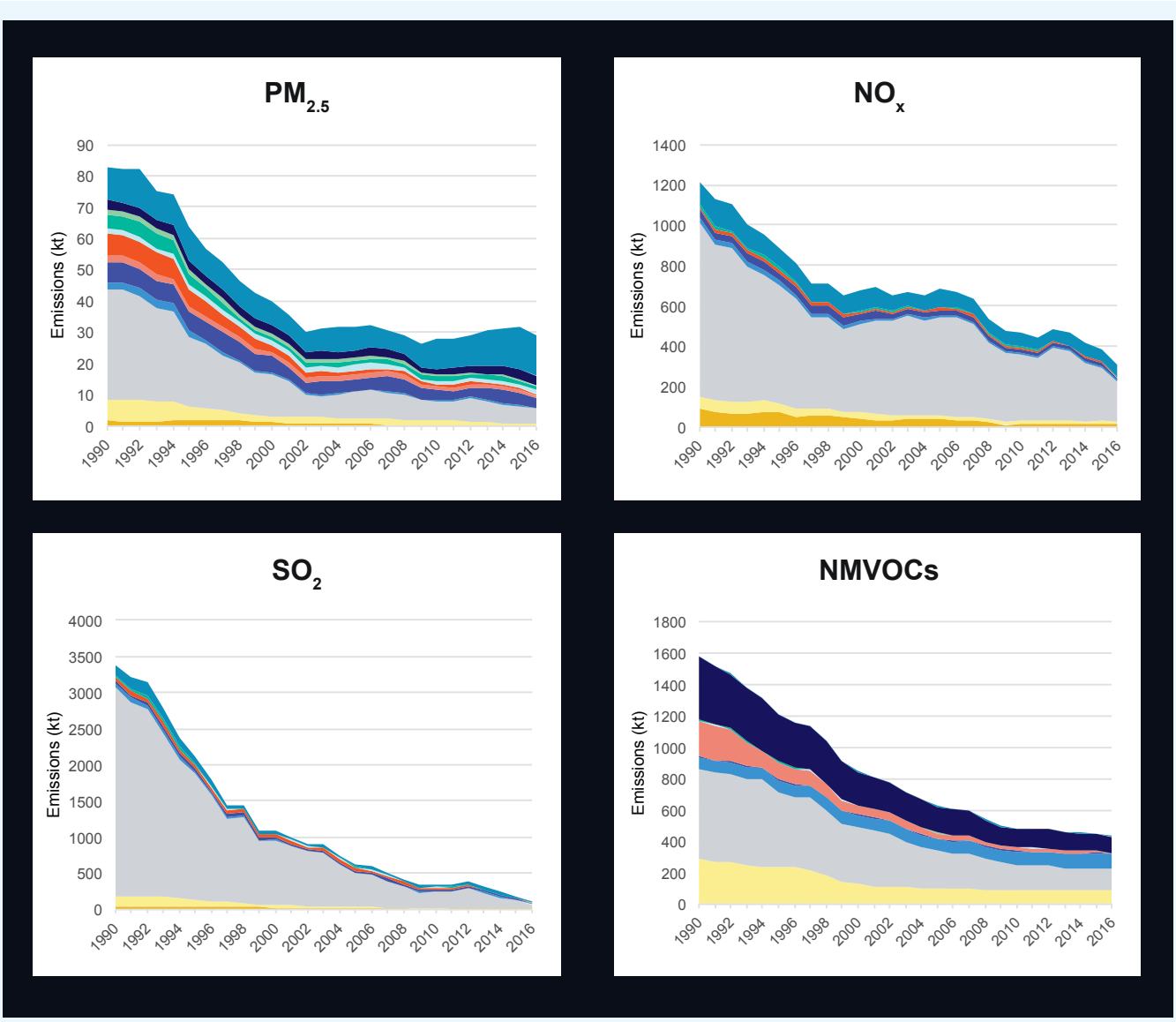
Larger industrial facilities undertaking specific types of activity are required to use Best Available Techniques (BAT) to reduce emissions to air, water and land. BAT means the available techniques which are the best for preventing or minimising emissions and impacts on the environment. ‘Techniques’ include both the technology used and the way your installation is designed, built, maintained, operated and decommissioned.

The European Commission produces BAT reference documents (BREFs). For example, there’s a BREF for intensive agriculture which contains BAT for housing for pig rearing units and a BREF for the textiles industry which contains BAT for selecting materials for textile manufacture. BREFs include BAT conclusion documents that contain emission limits associated with BAT, which must be complied with.

The UK is committed to maintaining high standards and good practice and will continue to apply the existing successful model of integrated pollution control as we exit the EU. As a direct result of these actions, the level of pollution from industry has decreased significantly over recent decades.

Industrial emissions trends

Since 1990, industrial emissions of nitrogen oxides to air have reduced by 74%, emissions of sulphur dioxide have reduced by 97% and emissions of volatile organic compounds have reduced by 73%. However, industrial emissions are still responsible for a significant proportion of total UK emissions - 35% of nitrogen oxides, 65% of sulphur dioxides, 27% of particulate matter and 53% of volatile organic compounds in 2016.[104] Estimates of projected emissions to 2030 suggest further action is required from the industrial sector if we are to meet our emission reduction targets.



The Industrial Emissions Directive is mainly focused on the most polluting activities. Emissions from smaller plants used by industry, as well as from offices, large buildings, schools and hospitals will also need to be controlled, if we are to make further progress in cutting air pollution. That is why we introduced legislation in January 2018 to reduce emissions from a significant and previously unregulated source of air pollution: medium-sized combustion plants and generators[105] and we will keep this sector under review.

8.3 A commitment to continuous improvement

We recognise the importance of maintaining policy stability for industry in order to send a clear, long-term signal, to provide the certainty they need to make investment decisions. Many of these businesses have long-term plans and investment cycles, so any changes to the regulatory framework need to be signalled well in advance. That is why we are making clear our long-term commitment to the existing successful model of integrated pollution control and maintaining continuity of our legislation on industrial emissions as we leave the EU. The EU Withdrawal Act 2018 ensures that existing EU environmental law will continue to have effect in UK law, including the Industrial Emissions Directive and BAT Conclusion Implementing Decisions made under it. This provides businesses and stakeholders with maximum certainty as we leave the EU.
We will ensure there is a clear process for determining future BAT Conclusions for UK industrial emissions that broadly maintains a consistent approach with the Industrial Emissions Directive. This would be developed with the devolved administrations and regulators across the UK. We will ensure this helps deliver our overall commitment of improving the environment within a generation.

In order to meet our challenging 2030 targets and to maintain our ambitious industrial emissions policy, we will look to all sectors to make appropriate contributions, recognising both their efforts to date and the potential to do more. And, while tackling big point sources of emissions remains a priority, we will also need to address increasingly diffuse sources of emissions in order to reduce background levels of pollution.

Working in close collaboration with industry we will explore further opportunities for emissions reductions by developing a series of sector roadmaps to set ambitious, achievable standards aimed at making UK industry world leaders in clean technology. The roadmaps will identify where additional measures can be implemented within industrial sectors, focusing on the most polluting industries and those with the greatest potential to drive improvements in air quality.

We held a series of successful workshops in the summer of 2018 with the most significant polluting industrial sectors; including energy, refineries, iron and steel, manufacturing, solvents, chemicals, and other industrial sectors such as cement production. Through this, we have begun to explore the emissions reduction contributions from industry to date, the potential to make further commitments to improving air quality, and the technical and financial feasibility of doing so. We will build on this success by driving forward a programme of work to deliver the roadmaps from 2020.

With respect to the emissions from medium combustion plants and generators, we acknowledge that the legislation introduced in early 2018 is still in the early days of implementation. We will therefore gather and assess evidence and consider whether additional measures are required to further reduce emissions from these plant. This will include the need to close the regulatory gap between current ecodesign and medium combustion plant regulations; and the need or otherwise to exempt generators used for research and development.

As part of the Environment Bill we are looking to strengthen local authority powers with respect to air quality. We will also review existing guidance to support effective emission controls at smaller industrial sites and aim to review the current local authority permitting system, including fees and charges.

Diesel generators © John Henderson at Environment Agency

8.4 Action to tackle emissions from industry

- We will maintain our longstanding policy of continuous improvement in relation to industrial emissions, building on existing good practice to deliver a stable and predictable regulatory environment for business as part of a world-leading clean green economy. This means that we will maintain the existing successful model of integrated pollution control as we leave the EU.
- We will strive to improve the current framework to make it work better for both the environment, the public and UK industry by:
    - Working with industry to develop a series of ambitious sector roadmaps to make UK industry world leaders in clean technology and to secure further emissions reductions from industry by 2030 and beyond
    - Ensuring there is a clear process for determining future UK Best Available Techniques for industrial sectors. The future UK BAT regime will continue to endorse the collaborative approach of the current system
    - Reviewing existing guidance to support effective emission controls at smaller industrial sites and consider whether further action is needed to strengthen the current regulatory framework. This will include a review of the current local authority permitting system, including fees and charges
    - Considering the case for tighter emissions standards on emissions from medium combustion plants and generators
    - Considering closing the regulatory gap between the current ecodesign and medium combustion plant regulations to tackle emissions from plants in the 500kW to 1MW thermal input range while being mindful of the impact on small and medium-sized businesses
    - Considering the need to exempt generators used for research and development from emissions control

9. Leadership at all levels

9.1 International leadership on clean air

Air pollution does not stop at national borders and we know that emissions produced across the country, the continent and the globe can all impact on air quality in the UK. Similarly, the emissions we produce in the UK can have health and environmental impacts on our neighbours. As one of the original signatories to the 1979 UNECE Convention on Long-range Transboundary Air Pollution, the UK has long been at the forefront of international action to tackle transboundary air pollution, and formal ratification of the three most recently amended Convention Protocols in the coming months will signal our ongoing commitment to its objectives.

Under this UN Convention, the UK supports international programmes to drive forward scientific understanding of air pollution emissions and their impacts, and engages constructively to agree ambitious standards and emission reduction commitments that encourage action across the Northern Hemisphere and serve as a model for a global response. As we work towards our 2020 and 2030 emission reduction commitments, the Convention will continue to be the cornerstone of the UK's international engagement on air quality. It will be a key forum for cooperation on long term and cross-cutting challenges, for example action to tackle short-lived climate pollutants. The UK will also continue to support bodies such as UN Environment and the World Health Organization in raising the issue of transboundary air pollution up the global agenda.

The action we are taking to develop and implement policies to achieve our ambitious 2020 and 2030 commitments sits alongside similar action in other countries. We will continue to actively engage with our neighbours, sharing experience and best practice. We will continue to be reliable partners, willing allies and close friends with countries in Europe and around the world, as we work to achieve cleaner air for all of our citizens.

9.2 National leadership on clean air

This government is committed to be the first generation to leave the environment in a better state than we inherited it. One of our top environmental priorities is to drive down overall emissions of air pollutants and reduce human exposure to local concentrations of pollutants. This strategy sets out next steps to achieve our challenging national emissions reduction targets. These were made legally binding in February 2018. In April 2019 we will publish our initial National Air Pollution Control Programme. This will set out how the actions in the Clean Air Strategy will enable the UK to meet its statutory commitments. We will continue to monitor and report on air quality across the UK within this internationally recognised framework.

In addition to these existing commitments, we want to go even further to address the main impacts of poor air quality on people's health and the environment. As outlined earlier in the strategy, we have set a new target to reduce damaging deposition of reactive forms of nitrogen and we are committing to halve the number of people living in areas above the WHO guideline limits on $PM_{2.5}$ by 2025. Building on this, we will also set a new, ambitious, long-term target to reduce people's exposure to $PM_{2.5}$ and will publish evidence early in 2019 to examine what action would be needed to meet the WHO annual mean guideline limit of 10µg/m^3.

9.2.1 Securing a green Brexit

Leaving the EU means we will take back control of environmental legislation. This presents a unique opportunity to design policies to drive environmental improvement that are specifically tailored to the needs of our country. Our vision is for a green Brexit in which environmental standards are not only maintained, but also enhanced. The EU Withdrawal Bill will ensure existing EU environmental law

continues to have effect in UK law after we leave the EU, providing businesses and stakeholders with maximum certainty.

Currently, emission reduction commitments in the UK are overseen by the European Commission, which has powers to take action to enforce compliance. They are also overseen by the UNECE Convention Committee and will continue to be in future.

The government recognises that some of the scrutiny and enforcement mechanisms currently provided by the EU institutions in respect of EU environmental law and policy, including in relation to air quality, will no longer apply to the UK once we leave the EU. The government has therefore committed to the establishment of a new, independent statutory body to hold government to account including through legal proceedings if necessary on environmental legislation following EU exit and on the development of a new policy statement on environmental principles. In December we published draft Environment (Principles and Governance) clauses, which will be central to the new Environment Bill . The draft clauses set out how we will create a pioneering new system of green governance, establishing an Office for Environmental Protection, to ensure we succeed in leaving the environment in a better condition than we found it. The draft clauses also introduce a set of environmental principles that will be used to guide future government policy making and lead us toward a greener future; and place our 25 year environment plan on a statutory footing.

9.2.2 The legislative framework & national action

The UK government will introduce new legislation outlining a strengthened, up to date legislative framework for tackling air pollution. This framework will be underpinned by England-wide action to control major sources of air pollution, in line with the risk they pose to public health and the environment, plus new local powers to take action in areas with an air pollution problem.

New clean air legislation will:

- enable the Transport Secretary to compel manufacturers to recall vehicles and non-road mobile machinery for any failures in their emissions control system, and to take effective action against tampering with vehicle emissions control systems
- we will review, and if necessary amend, the existing legislative framework to ensure that the UK has the flexibility to address concerns in relation to pollution from the maritime sector; this review will necessarily consider both current technologies and pollutants, and the implications of technological change such as innovative fuels or coatings that may raise new challenges
- **strengthen, simplify and update the legislative framework that applies at the local level** in order to both enable and drive further reductions in local concentrations of air pollution. This includes updates to both the Local Air Quality Management framework and the Smoke Control Area framework (further details in section 9.2.3)

In addition, as set out earlier in this document, **we will legislate to ensure that major sources of air pollution are subject to proportionate controls that reflect the risk they pose to public health and the environment**. This will strengthen powers at both national and local level. We will take England-wide action to:

- prohibit the sale of polluting fuels and inefficient stoves for domestic use
- limit emissions of ammonia from farming
- consider the case for setting tighter emission controls for biomass installations to reduce PM pollution from energy generation
- close the regulatory gap to apply limits to medium combustion plants between 500kw - 1MW and consider the case for increasing stringency of limits for plants above 1MW while being mindful of the impact on small and medium-sized businesses
- explore the use of environmental permitting for sectors with significant NRMM emissions where appropriate, to ensure consistent approaches are applied across England to regulate emissions
- consider further the need to exempt generators used for research and development from emission controls

9.2.3 The local government framework

Local government has been the main agent for cleaning up local air since before the first Clean Air Act of 1956. This Clean Air Strategy sets out the case for tackling air pollution from activities which form an essential part of 21st century life. The impacts of air pollution and the action required to address it are highly relevant to local government priorities: health, housing, transport, education, local economics, greenspace and quality of life. As air quality continues to improve, the focus on local hotspots will continue to increase and local action will remain essential.

Local government structures have evolved in recent decades and vary across the country. Across the 353 local authorities in England, there are two-tier district and county authorities, as well as single-tier unitary authorities, plus metropolitan and London boroughs. Combined authority mayors elected in 2017 in six regions have budgets, powers and responsibilities delegated by national government to enable groups of local councils to collaborate and make decisions across boundaries. Public health and transport decisions are made at upper or regional level, as are strategic decisions on investment, growth, job creation and home building. These policies can drive real change in improving local air; however, policy responsibility for local air quality has sat at district level in two-tier authorities.

242 local authorities in England have one or more Air Quality Management Areas (AQMAs). These are designated where local air quality monitoring identifies a problem. Once an AQMA is in place, the local authority is expected to produce a plan to tackle the issue. There are 610 AQMAs in England and some were declared as long ago as 2001. Fewer than 200 AQMAs have been revoked suggesting that problems once identified may not be being resolved.[106]

Furthermore, this current framework does not effectively encourage all local authorities to work collaboratively across departmental or structural boundaries, or take a total emissions approach to tackling local air quality.

In summary, the current legislative framework has not driven sufficient action at a local level. In the Environment Bill, associated secondary legislation and statutory guidance, we will outline proposals that will address this. Options under consideration are:

- **ensuring accountability sits at the right tier** of the local government structure
- shifting the focus towards prevention, **promoting greater action to avoid exceedances**, rather than tackling air pollution only when limits are surpassed
- creating the **concept of a 'lead authority'** with requirements on neighbouring local authorities and other public bodies to work collectively to tackle air pollution
- requiring local authorities to create an action plan to **reduce population exposure during Air Pollution Episodes** to protect public health
- enabling greater local action on $PM_{2.5}$ by **updating the Smoke Control Area (SCA) framework**
- enabling greater local action by **improving guidance on the use of existing local powers, strengthening these powers** where necessary and introducing **new powers**
- developing **clear, effective guidance** on how AQMAs, SCAs and Clean Air Zones (CAZs) interrelate and how they can be used by local government to tackle air pollution

Under the current framework, local authorities produce plans to tackle air pollution when local air quality monitoring has identified concentration exceedances against maximum limits. Compliance with maximum limits however does not incentivise prevention. New legislation therefore will **seek to shift this focus towards prevention**. This will enable early action to be taken by local authorities to avoid exceedances against future targets set by national government. This new approach will be instrumental for the government to achieve its objective of improving public health and the environment.

The introduction of a **'lead authority' for air quality** will ensure responsibility to tackle air pollution sits at the correct level of local government. The lead authority will coordinate action to improve air quality and ensure compliance with the air quality objectives set by national government. This will involve using the levers available to them to reduce emissions and public exposure.

We will also seek to enable strong collaborative action, ensuring that neighbouring local authorities and other relevant bodies work alongside the lead authority, supporting each

other in achieving compliance with air quality objectives. In the Environment Bill, we will seek to underpin this approach through new duties and powers where necessary that will produce an effective framework for tackling transboundary pollution.

This will result **in all bodies taking effective, collaborative action** to deliver air quality objectives.

During Air Pollution Episodes, the lives of vulnerable people can be severely affected, with loss of life is not uncommon. Under this new framework, lead authorities for air quality will be enabled to **take action to reduce population exposure during Air Pollution Episodes (APEs)**, focusing in particular on protecting the most vulnerable. We are considering the best mechanism for enabling local authorities to take effective action to reduce public exposure to air pollution during high pollution episodes, including via legislative means. We will consult on this proposal as we develop the policy.

We will **enable greater local action by simplifying and updating the Smoke Control Area framework**. The current Smoke Control Area framework is difficult to enforce and out of date. We will bring it into the 21st century with more flexible, proportionate enforcement powers. This will enable local authorities to enforce the law more effectively, tackling a key source of harmful $PM_{2.5}$ emissions. The designation of Smoke Control Areas will also be made easier.

Local authorities have long had specific legal powers to tackle local air pollution, including to tackle exceedances under the local or national assessment regimes. They also have long-standing powers to tackle emissions from domestic chimneys and industrial sources. Alongside these specific obligations, strategic decisions on transport, planning and public health taken by local government all contribute to the quality of the air that people breathe in local communities. However we recognise that improvements are needed. Therefore, **we will give local government new legal powers to tackle $PM_{2.5}$ emissions from burning**.

We will also ensure that **existing powers for local government can be more easily used**. Specifically:

- we will continue to take forward modernisation of the existing anti-idling guidance for local authorities over the coming months. We will engage with local authorities on whether further changes to the legislation are necessary
- we are reviewing recommendations made within the recent Task and Finish Group on Taxi and private hire vehicle licensing; they include ways in which taxi and PHV legislation could be reformed. A government response to the report will be issued in due course
- we will improve guidance on the use of existing powers to tackle industrial emissions where these are contributing to a current or future expected exceedance of air quality objectives.
- develop **clear, effective guidance** on how AQMAs, SCAs and Clean Air Zones (CAZs) interrelate and how they can be used by local government to tackle air pollution.

In addition, we will enable greater local action on air quality by:

- **consulting on transformative changes to the LAQM guidance**, focusing on aligning the guidance to drive local action in accordance with the new framework set out in the Environment Bill
- **encouraging greater public transparency about local air quality to empower local citizens** and the air quality decision-makers in their local communities
- **continuing to work with MHCLG to strengthen the planning practice guidance** on air quality to ensure planning decisions help to drive improvements in air quality
- **facilitating the sharing of best practice and knowledge** between local authorities through webinars and other digital media

The actions set out in this section require greater action at a local level, but also make local action easier and less burdensome. **Where cost recovery is permitted and available, we will look to support local government to ensure it is able to fully cover their costs.**

9.2.4 Local government tackling NO_2 hotpots around roads

The most immediate and urgent air quality challenge faced by local authorities is to tackle the problem of NO_2 concentrations around roads. This is most acute in towns and cities which should be healthy places to live, work and relax. The UK Plan for Tackling Roadside Nitrogen Dioxide Concentrations ('The NO_2 plan') published in July 2017 sets out Government's approach to working with local authorities to bring forward compliance with NO_2 limits. This work is supported by the Clean Air Zone (CAZ) framework which sets out principles for local government to define an area where targeted action is taken to improve air quality, and resources are prioritised and coordinated in order to shape the urban environment in a way that delivers improved health benefits and supports economic growth.

As set out in the NO_2 plan and the supplement to the plan published in October 2018, 36 local authorities have been directed to produce local plans to reduce NO_2 levels in the shortest time possible, which includes benchmarking proposals against the possible introduction of a charging Clean Air Zone, where this is appropriate. It should be noted that the UK government believes that if a local authority can identify measures other than charging zones that are at least as effective at reducing NO2, those measures should be preferred as long as the local authority can demonstrate that this will deliver compliance as quickly as a charging Clean Air Zone. The supplement also set out that 10 local authorities have been directed to immediately implement measures identified to bring forward compliance with legal NO_2 limits, including bus retrofit and traffic signal improvements.

Clean Air Zones can be both charging and non-charging, and the CAZ framework is a useful guide for all local authorities, not just those identified in the NO_2 plan, to help address all sources of pollution, including particulate matter, to reduce public exposure using a range of measures appropriate to the particular location.

The CAZ framework offers a creative, total emissions tool for local authorities to clean up local air, but awareness of its potential is low. We will look to the local authorities taking accelerated action under the NO_2 Plan to help other local authorities learn from their activities when taking action to tackle wider pollutants.

Government funding and support to tackle NO_2 exceedances

The NO_2 Plan announced £255 million for 28 local authorities to accelerate their air quality plans to achieve legal compliance in the shortest possible time. A further £220 million was announced in the November 2017 Budget for a new Clean Air Fund (CAF) available to local authorities to support individuals and businesses impacted by local plans to improve air quality. In November 2017 Government consulted on measures that could be funded through the CAF, and could include helping people switching to sustainable forms of transport or supporting take up of low and zero-emission vehicles. In total, the government has committed £3.5 billion for tackling poor air quality and promoting cleaner transport.

The Joint Air Quality Unit provides those local authorities taking action on NO_2 exceedances with comprehensive technical support and guidance specifically for the development and implementation of local plans and measures to improve air quality. Each local authority has a dedicated account manager who supports co-ordination and communication with the relevant local authorities, and keeps track of progress. We provide guidance and workshop style support, and signpost to funding streams across government.

9.2.5 Local leadership to improve air quality

We know good work is taking place across the country at local level. For example:

- the county-wide Surrey Air Alliance will deliver a programme to primary and secondary schools across Surrey to raise awareness about the impacts of air quality, encourage behaviour change and reduce idling outside schools
- City of Bradford Council has been leading work in collaboration with other West Yorkshire local authorities and Public Health England to develop a regional Low Emissions Strategy; it includes measures to tackle transport emissions to deliver significant and rapid improvements, encouraging update of ULEVs, including development of air quality and planning technical guidance and a low emissions procurement guide
- the Sussex Air Quality Partnership will deliver a targeted schools and businesses campaign to reduce idling, increase walking and cycling and reduce emissions from plant
- London Boroughs of Hackney, Islington and Tower Hamlets have established a Zero Emissions Network, with over 1,100 residents and businesses committing to cleaner air
- Leicester City Council and London Borough of Islington are both making it easier for residents to understand and comply with Smoke Control Area rules by consolidating all their Smoke Control Areas
- Westminster City Council worked with a hard-to-reach group of businesses to provide concrete advice on what actions they can take to reduce their air quality impact, this resulted in being nominated for a Transport Award

We want these types of good practice to showcase what is possible and what can be achieved when local government shows commitment and leadership to tackle air pollution.

We will continue to support local government to build on the good practice demonstrated by many local authorities and ensure that the long-standing framework for local action on air pollution remains robust and relevant.

9.3 Leading by example - air quality and government operations

Achieving our legally binding emissions targets will require action across society, and it is the UK government's ambition to lead by example. With the wider environment in mind, our commitment to improving air quality extends to improving how we are running our buildings and estates, as well as the sustainable procurement of vehicles, services and cleaning products through our Greening Government Commitments and Government Buying Standards.

Case study: PHE/NHS England Sustainable Development Unit (SDU)

Health related travel makes up over 3% of all road miles. In 2017, the Sustainable Development Unit (SDU) for Public Health England and NHS England published the Health Outcomes Transport Tool (HOTT). This tool helps NHS organisations measure the impact their travel has in environmental, financial and health terms, allowing valuation of improvements in these same terms. HOTT measures impacts (such as air and noise pollution, road traffic incidents and greenhouse gases) and sources (such as staff commute, patient and visitor travel, fleet and supply chain travel). Manchester University NHS Foundation Trust recently used HOTT to provide evidence that their work on sustainable travel had avoided over £870K in economic costs. This tool is designed to be used by a wide range of health organisations and their supply chains, and has the potential to be adopted on a much wider scale.

Defra is already encouraging sustainable travel among employees by developing a Sustainable Travel Plan. The plan sets out to reduce air miles and private car miles, encourage active travel with bike schemes, provide incentives to cycle and walk to meetings, and remove the need to travel by encouraging remote working.

The Government Buying Standards for vehicle procurement published in December 2017, together with the Government Fleet Commitment, announced in the 2017 Budget, demonstrated our ambition to accelerate a move to zero or ultra-low exhaust emission vehicles, thus improving our health and quality of life by making the air cleaner in our towns and cities. There are plans to go much further on incorporating air quality emissions into sustainable procurement across government.

In England, 3.5% of all road miles travelled are health-related. The NHS Long Term Plan included a commitment to reduce air pollutant emissions, by 20% by 2023/24. At least 90% of the NHS fleet will use low-emissions engines (including 25% ultra low emissions) by 2028, and primary heating from coal and oil fuel at NHS sites will be fully phased out.

9.3.1 Action to improve coverage of air quality in the greening government commitments

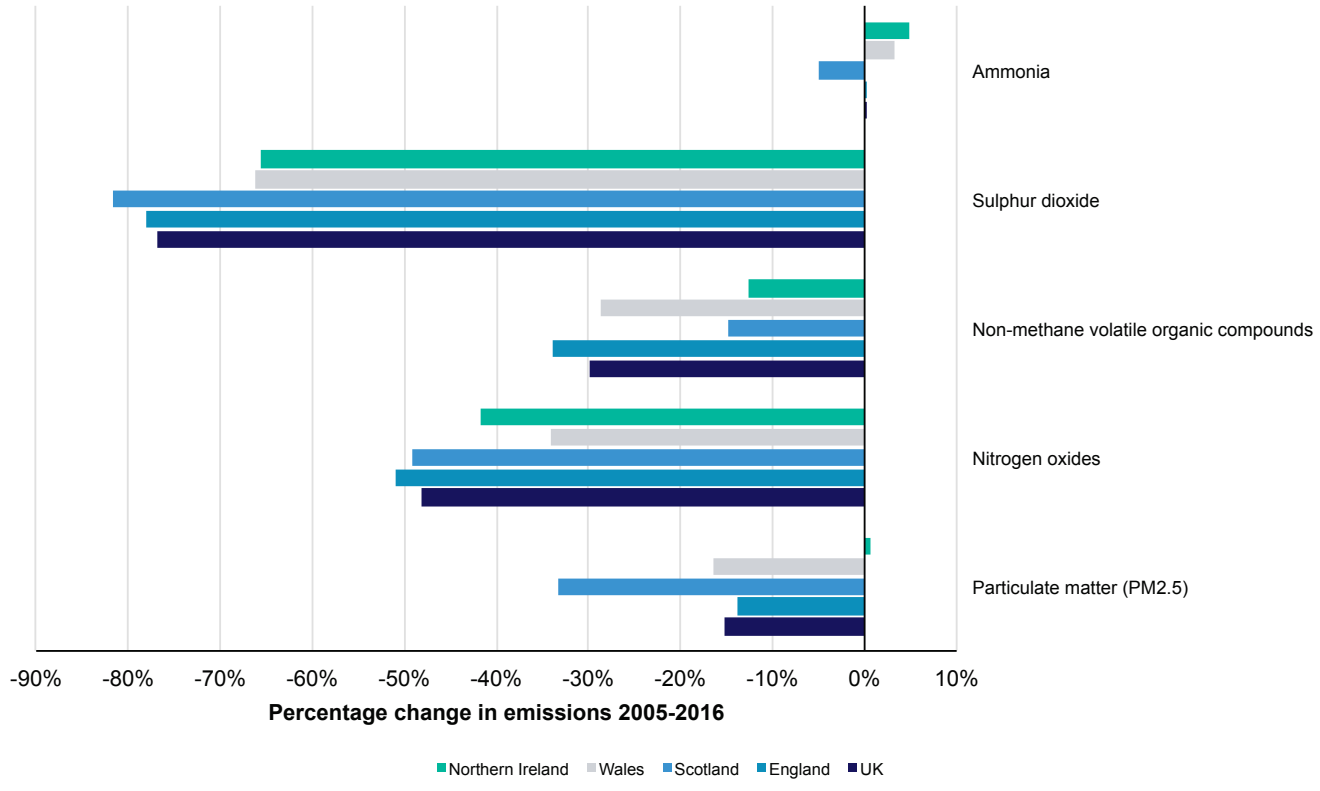
- The government will be taking further robust action to reduce emissions across the government estate. For example, we will ensure 25% of the central government fleet will be ultra low emission by 2022 and we want 100% of the central government car fleet to be ultra low emission by 2030
- The Environment Agency are evaluating the use of more stringent emissions requirements from their suppliers under their Next Generation Supplier Arrangements (NGSA)
- While government departments already report greenhouse gas emissions from their estate and operations under the Greening Government Commitments, we intend to extend this to reporting and achieving reductions of air pollutant emissions

9.4 Action on clean air across the UK

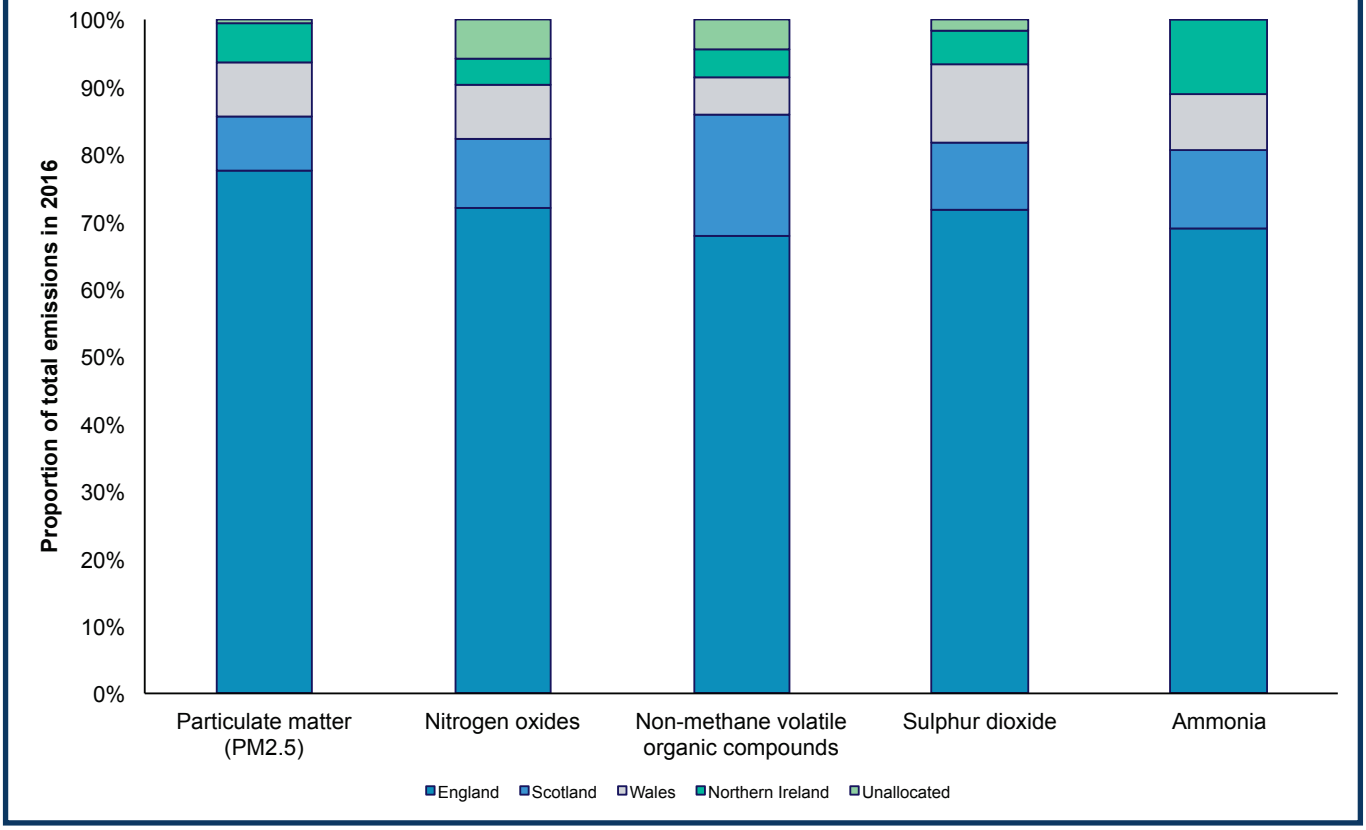
Our international emission reduction commitments, under the National Emission Ceilings Directive and Gothenburg Protocol under the Convention, have been agreed at a UK level. The UK government annually prepares a national atmospheric emissions inventory in line with internationally recognised standards and is required to report on their achievement. Nevertheless, air quality is a devolved policy area: Scotland, Northern Ireland, and Wales lead on policy within their own territories. Given the transboundary nature of air pollution, close partnership-working between the nations of the UK is essential. The UK government and the devolved administrations are working together to manage transboundary air pollution and improve air quality right across the UK.

Each administration faces different challenges in reducing emissions. Therefore different approaches are required across the UK to meet these challenges and address the specific sources of pollution and emission patterns. The chart below show the relative change of air pollutant emissions for England, Northern Ireland, Scotland and Wales as compared to the overall UK change, and the proportion of UK emissions that each nation produced in 2015.

Relative change of air pollutant emissions for England, Northern Ireland, Scotland and Wales



Proportion of UK emissions that each nation produced in 2016



The following sections set out a summary of air quality data for each country of the UK and showcase actions taken already, which have led to considerable improvements.

9.5 Action to tackle air pollution in Northern Ireland

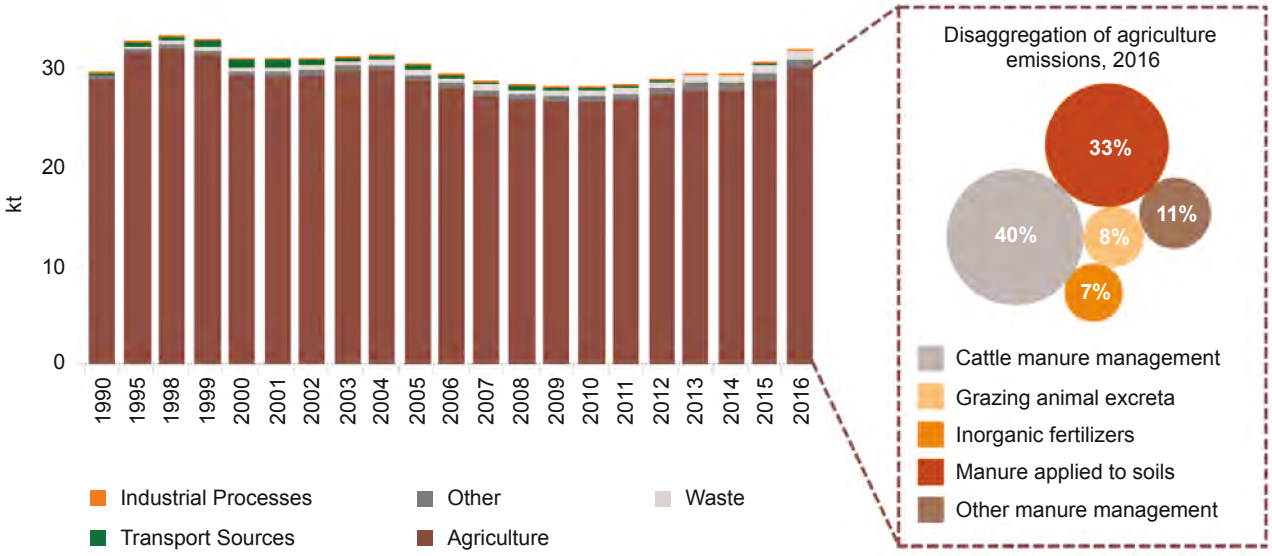
Air pollution in Northern Ireland is dominated by three main sources: nitrogen oxides from road traffic emissions, in particular those from diesel vehicles; particulate matter from residential burning of solid fuels, in particular coal; and ammonia emissions from agricultural activities such as manure storage, handling and spreading.

Northern Ireland has largely seen reductions in emissions in recent years similar to those for the UK as a whole for nitrogen oxides, sulphur dioxide and volatile organic compounds. Emissions of ammonia and particulate matter have reduced at a slower rate in Northern Ireland than for the UK as a whole and emissions of these pollutants in Northern Ireland represent a significant proportion of the UK total. For ammonia, this reflects the nature of land use in Northern Ireland, and the relative importance of the agricultural sector to the Northern Ireland economy while in the case of particulate matter, this reflects the higher prevalence of solid fuel heating in the domestic sector compared to the rest of the UK.

Northern Ireland's geography and maritime position ensure it has a steady supply of good air; however, NO_2 pollution from road traffic is a significant problem,with the proportion of journeys made by public transport and active travel being fairly stable over time. However, generally concentrations of nitrogen dioxide have been falling in recent years and except for Belfast, Northern Ireland is compliant with the limit values for nitrogen dioxide concentrations set out by the Air Quality Directive. Further action to reduce these concentrations was announced in the UK plan for tackling nitrogen dioxide concentrations. Between 1994 and 2017 there has been a 37% decrease in the annual mean concentration.

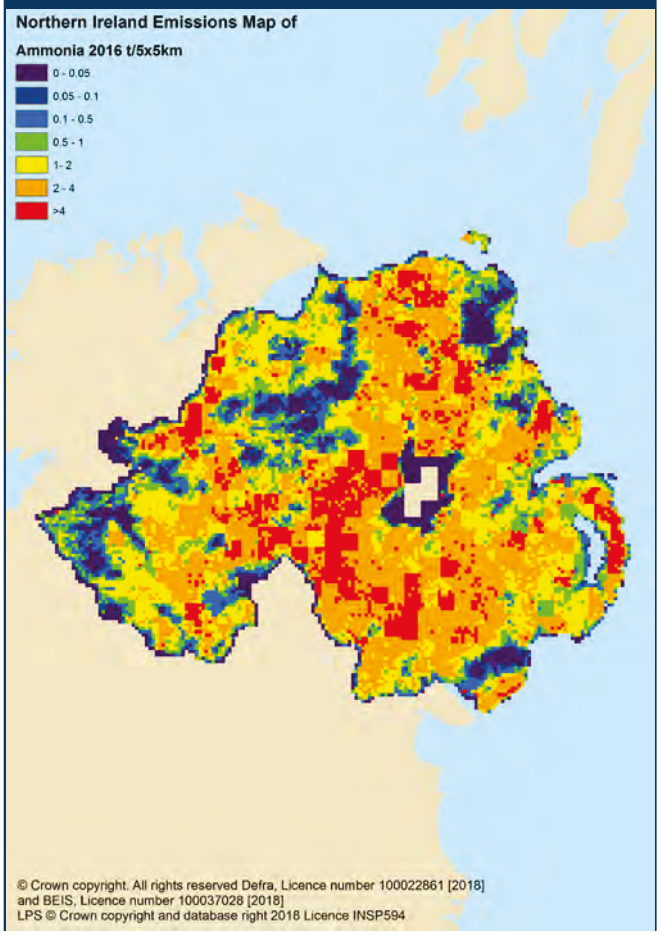
The Northern Ireland Department of Agriculture, Environment and Rural Affairs (DAERA), in partnership with the Department for Infrastructure, recognises the contribution of emissions of nitrogen oxides from road transport to non-compliance in Belfast with the limit value and suggests a number of initiatives that have been taken forward to address this including investment in infrastructure and public transport.

Ammonia emissions in Northern Ireland by sector, 1990 - 2016



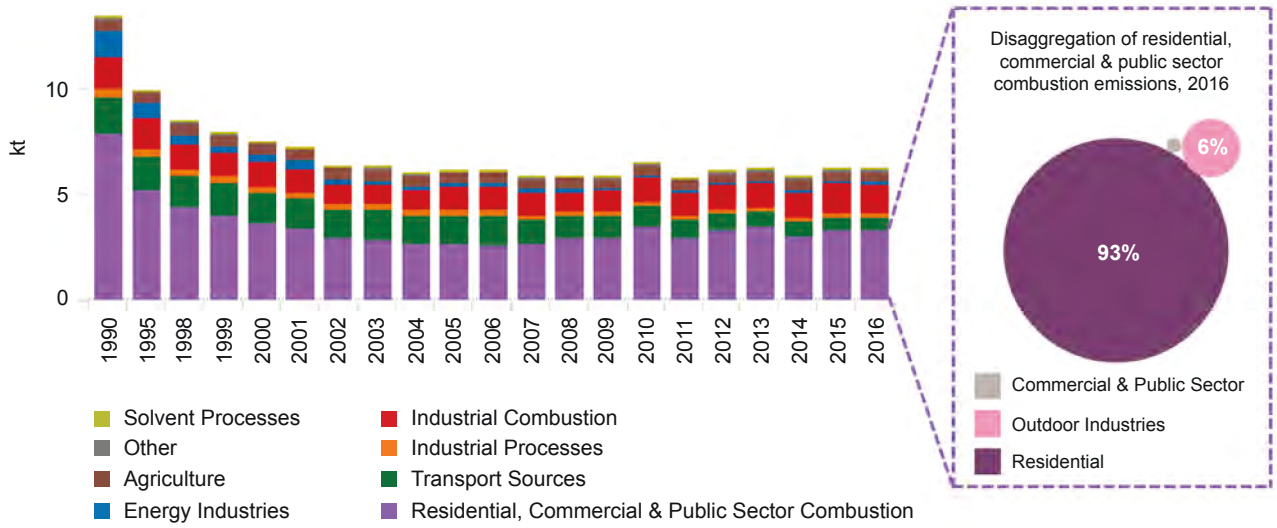
The trend in ammonia emissions for Northern Ireland by sector is shown in the figure above; which shows that a large proportion of ammonia emissions come from manure management and manure applied to soils. Emissions of ammonia in Northern Ireland have increased by 5% since 2005. An increase in the cattle population in the last few years (a 6% increase between June 2014 and June 2017, although cattle numbers are down compared with 2005),[107] a large increase in the pig population since 2005 (60% increase between June 2005 and June 2016),[108] along with spreading of animal manure to agricultural soils and the influence of changing agricultural systems are responsible for the increase in ammonia emissions. The spatial distribution of emissions in Northern Ireland is determined by the distribution of farms across the administration.

Ammonia emissions map for Northern Ireland, 2016

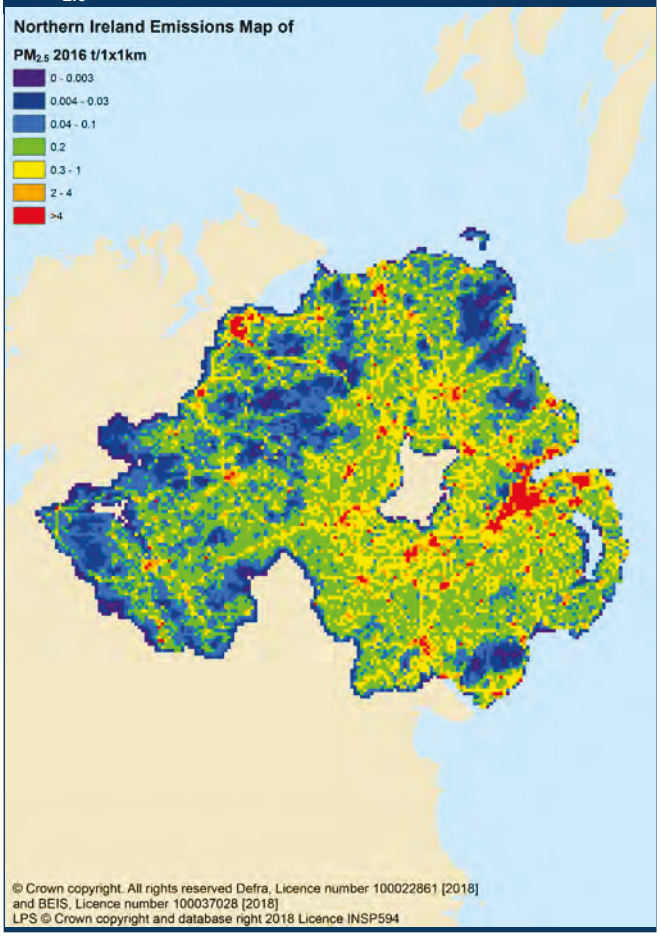


The trend in particulate matter (PM_{10}) emissions for Northern Ireland by sector is shown in the figure below; which shows that PM_{10} emissions have a number of sources, but residential combustion activity contributes a large proportion of emissions in Northern Ireland.

$PM_{2.5}$ emissions in Northern Ireland, 1990 to 2016



$PM_{2.5}$ Emissions in Northern Ireland, 2016



Similar to the rest of the UK, the use of wood-burning stoves in residential homes is on the rise in Northern Ireland. Domestic combustion is a particular issue for Northern Ireland due to the relatively high proportion of homes that do not have gas or electrical heating. At least 66% of households in the 2011 census did not have gas or electric central heating; the majority of these households have oil-based central heating. This represents a much larger proportion of the population dependent on solid fuels or oil for their heating needs compared to England (at least 9% of households), Scotland (at least 10% of households), and Wales (at least 14% of households). However, efforts continue in Northern Ireland to increase the availability of natural gas with two significant gas extension projects underway, one of which is to receive financial support from the NI Executive. The spatial distribution of emissions in Northern Ireland is determined by the distribution of the population (domestic combustion).

9.5.1 Northern Ireland's plans for cleaner air

A specific Air Quality Strategy for Northern Ireland is in preparation.

The strategy will look at air pollution on a sectoral basis, focusing on pollution from road traffic, household emissions and agricultural activities. It will put forward policy proposals for reducing air pollution from each of these sectors. It also looks at the existing Local Air Quality Management (LAQM) system to see how it should be improved, and makes recommendations regarding raising awareness of air pollution and its impacts, and how communication may be used to promote behaviour change. Following consultation, the Strategy will be finalised and published.

The Northern Ireland Executive's draft Programme for Government contains an indicator on air quality (monitored levels of nitrogen dioxide). The indicator has a delivery plan that sets out a range of measures, including those focusing on transport, which are aimed at reducing congestion and promoting modal shift away from private car use. Measures contained in the Programme for Government Delivery Plan for the air quality indicator will also come on line in the future.

Northern Ireland is signed up to the UK Air Quality Strategy. The Department for Agriculture, Environment and Rural Affairs (DAERA) funds local authorities to enable them to monitor air quality, declare Air Quality Management Areas, and produce Action Plans to deal with air pollution.

Belfast Rapid Transit (BRT), which operates under the brand name Glider, commenced operations on 3 September 2018. BRT is a £90 million investment by the Department for Infrastructure, which has brought a new kind of high quality public transport system to Belfast. BRT is a key element in the delivery of a step-change in the quality of public transport in Belfast and is one of the key supporting drivers for regeneration throughout the city, providing high quality access to, and linkages between jobs, hospitals, schools and colleges across the city. One of the main aims of BRT is to contribute to a reduction in the number of short journeys made by car in the city and therefore lead to an improvement in air quality.

A Northern Ireland Expert Working Group on Sustainable Agricultural Land Management has examined the issue of ammonia in an annex to their original Strategy. This group had membership from across the spectrum of stakeholders with an interest in land, including farmers, the environment sector, the supply chain and government. Its report on ammonia is entitled Making Ammonia Visible. The report made a number of key recommendations to government and farmers: a partnership approach to address ammonia; improved communication and education on ammonia; scientific research to address significant evidence gaps; adoption of guiding principles for planning applications; the implementation of ammonia mitigation measures on farms, including an end to the use of both splashplates for slurry-spreading and non-stablised urea fertiliser; and the establishment of an Agri Emissions Partnership.

DAERA has established a Project Board which is working with stakeholders on Ammonia to develop and implement a DAERA Action Plan on Ammonia. This action plan will set out an approach which aims to:

- achieve tangible and sustained reductions in ammonia emissions from Northern Ireland farms
- reduce the impact of ammonia via nitrogen deposition on nature and habitats, and in particular, designated sites
- respond to each of the recommendations of the Expert Working Group in their Ammonia Annex
- encourage uptake of on-farm ammonia mitigation measures
- highlight the impact of ammonia on human health, while noting the relevant uncertainties

DAERA has also commissioned research into pollution from solid fuel burning and is working with district councils to examine emissions from domestic combustion sources, particularly from solid fuel burning.

9.6 Action to tackle air pollution in Scotland

In November 2015, the Scottish Government published Cleaner Air for Scotland – The Road to a Healthier Future (CAFS),[109] Scotland's first separate air quality strategy. CAFS sets out in detail how Scotland intends to deliver further air quality improvements over the coming years.

CAFS sets out a national approach to improving air quality. The strategy contains 40 key actions within six policy areas – transport, health, climate change, legislation, placemaking and communications. CAFS also introduces two important new policy initiatives, the National Modelling Framework (NMF) and the National Low Emission Framework (NLEF).

The NMF promotes a standard approach to evaluating and assessing air quality, providing evidence to support the actions and decision making process around land use and traffic management to improve local air quality. The NMF consists of two elements, a local modelling approach and a regional modelling approach. The local approach involves building detailed air quality and traffic models for Scotland's four largest cities – Aberdeen, Dundee, Edinburgh and Glasgow. The regional approach draws on air quality modelling methodology adopted in the Netherlands and reflects the fact that land use and transport planning decisions made across local authority boundaries can have implications for local air quality. The regional approach is focused on the strategic development planning authority areas surrounding the four cities.

The outputs from the NMF will be used to inform the NLEF. This is designed to enable local authorities to appraise, justify the business case for, and implement a range of transport related policy interventions to improve local air quality.

Since CAFS was published, Scotland's first Low Emission Zone (LEZ) has already been introduced in Glasgow. It initially sets phased targets for Euro VI compliance for local buses, and upon full implementation in December 2022 will require all vehicle types to be fully compliant. Further LEZs are expected to be in place in Aberdeen, Dundee and Edinburgh by 2020, and in all remaining local Air Quality Management Areas by 2023, where appraisal suggests such an approach would be appropriate.

The most recent CAFS annual progress report[110] was published in August 2018 and summarises progress on delivering the actions.

In its 2018/19 Programme for Government, the Scottish Government announced that a comprehensive review of CAFS will be undertaken and completed by the end of 2019. Scotland has largely seen reductions in emissions of the five NECD pollutants in recent years that are similar to those for the UK as a whole.

9.7 Clean air Wales

The Welsh Government is committed to building healthier communities and better environments. Clean air has a central role in creating the right conditions for better health, well-being and greater physical activity in Wales. In September 2017, the Welsh Government published their national strategy: 'Prosperity for All'.[111] This document sets out a cross-government commitment to reducing emissions and delivering vital improvements in air quality through planning, infrastructure, regulation, and health communication measures.[112]

The Welsh Government provides the strategic direction for air policy in Wales, which is framed within a complex set of regulatory and operational responsibilities.

The Welsh Government has recently strengthened their own legislative framework through the Well-being of Future Generations (Wales) Act 2015 (WFG Act) and the Environment (Wales) Act 2016,[113] which sets a legal target for reducing emissions of greenhouse gases by a minimum of 80% by 2050 and places a duty on the Welsh Ministers to set a series of interim targets (for 2020, 2030 and 2040) and carbon budgets. These budgets will set limits on the total amount of emissions of greenhouse gases emitted in Wales over a 5 year period and act as stepping stones to ensure regular progress is being made towards the long term target.

In December 2018, the Welsh Government set their interim targets and first two carbon budgets in legislation, providing clarity and certainty to help drive investment. The Welsh Government will also set out how they are going to achieve their first carbon budget through policies and proposals by the end of March 2019. This will inform their Low Carbon Delivery Plan. These actions will cover key sectors such as energy, buildings, agriculture and land use, industry and business, waste and transport.

Air pollution often originates from similar activities that contribute to climate change and there are many co-benefits that can be realised through actions such as promoting low-carbon vehicles, renewable sources of energy and planting trees. In delivering the Low Carbon Delivery Plan, the Welsh Government will look to maximise the opportunities from the transition to a low carbon economy, which not only brings opportunities around clean growth, quality jobs and global market advantages, but also has wider benefits of enhanced places to live and work, with clean air and water and improved health outcomes.

The WFG Act has also established average population exposure to nitrogen dioxide as one of the Welsh Government national indicators which are used to measure progress towards well-being goals in Wales. Regulations made under the WFG Act require public services boards to consider air quality when carrying out their statutory assessments of local well-being under the Act.

The Environment (Wales) Act 2016 sets out the "sustainable management of natural resources" (SMNR). SMNR means using natural resources in a way and at a rate that promotes the achievement of the objective to maintain and enhance the resilience of ecosystems and the benefits they provide, and that, in doing so, meets the needs of present generations without compromising the ability of future generations to meet their needs. The definition of "natural resources" includes air. The Act sets out a framework for the delivery of SMNR, which includes a statutory evidence base: The State of Natural Resources Report published by Natural Resources Wales in 2016,[114] and a statutory Natural Resources Policy which was published in August 2017.[115] The Natural Resources Policy sets out the challenges and opportunities for managing Wales' natural resources sustainably, which includes reducing pollution levels in air and enhancing air quality. Actions for air quality include taking practical steps to improve air quality across Wales, not just in the most polluted hotspots but across Wales. This will require a mix of action to address pollution from traffic and other sources and to improve the ability of the natural environment to reduce public exposure to air pollution through intelligent tree planting and better access to green infrastructure.

Clean Air Wales Programme

In order to be effective in tackling air quality pollution, it is essential to take a cross-government approach.

To achieve this, the Welsh Government established a cross-government Clean Air Wales Programme during summer 2018 to reduce the burden of poor air quality on human health and the natural environment. In the nearer term, it will support delivery of actions required to comply with our European and domestic legislative air quality obligations.

This programme will consider evidence and develop and implement actions required across government departments including environment, health, education, decarbonisation, transport, local government, planning, agriculture and industry to achieve clean air for Wales.

For example, in order to reduce atmospheric ammonia and fine particulate matter emissions, the National Emissions Ceiling Directive requires National Air Pollution Control Programmes to include measures applicable to the agricultural sector. Such measures should be cost-effective and based on specific information and data, taking account of scientific progress and previous measures undertaken by Member States. There is a requirement for a National Action Programme to be published by March 2019.

Draft guidance and reporting format for the National Air Pollution Control Programme required under the Directive is currently being assessed. Member States must establish a national advisory code of good agricultural practice to control ammonia emissions, taking into account the UNECE Framework Code for Good Agricultural Practice for Reducing Ammonia Emissions of 2014, which covers at least the following items:

- nitrogen management, taking into account the whole nitrogen cycle
- livestock feeding strategies
- low-emission manure spreading techniques
- low-emission manure storage systems
- low-emission animal housing systems
- possibilities for limiting ammonia emissions from the use of mineral fertilisers

The Welsh Government is currently assessing how their existing Code of Good Agricultural Practice addresses these requirements and what action is required to comply with the requirements of the Directive.

The principles of Basic Measures were consulted upon as part of the Consultation on the SMNR, which ended in 2017. A Welsh Government working group has been established to consider the need for Basic Measures. The outcome of this work will inform future Clean Air Wales Programme actions.

A key future action for the Programme is the development of a Clean Air Plan for Wales, which the Welsh Government intends to consult on and publish in 2019. The Clean Air Plan for Wales will include of range of measures to support our aspirations for clean air, including:

- identifying key pollutants and their effects on public health and the natural environment in Wales. These will include noise and legally binding targets to reduce emissions of the most damaging pollutants under the National Emissions Ceiling Directive (fine particulate matter, ammonia, nitrogen oxides, sulphur dioxide, non-methane volatile, ozone) by 2020 and 2030
- measures to achieve compliance with the European and domestic legislative requirements
- actions across a range of Welsh Government departments and sectors to achieve clean air in Wales. For example, environment, transport, planning, agriculture and industry
- proposed communications, engagement and education to encourage behavioural change to support air quality improvements
- proposed improvements to local authority reporting on air quality issues in their areas and their plans to deal with them

The Programme will build on existing cross-government work to reduce air pollution. For example, in December 2018 the Welsh Government published Planning Policy Wales (PPW). This is the Welsh Government's main planning policy document, which has been completely restructured and rewritten in the context of the Well-being of Future Generations Act.

Air quality and soundscape are addressed in the new PPW as a key component of the natural and built environment, placing the issues on an equal footing with other objectives such as housing, transport and economic development. PPW recognises the importance of air quality and appropriate soundscapes to the health and well-being of people and the environment. It is expected that the new PPW will ensure long-term approaches are taken to prevent creation of new problems or worsening of existing issues. It will also seek to encourage integrated solutions which aim to reduce average levels of airborne pollution. The Welsh Government will produce further guidance for local planning authorities, specifically on air quality and soundscape, within this National Assembly for Wales term.

Between 25 April and 19 June 2018, the Welsh Government consulted on a Clean Air Zone Framework for Wales. This provides guidance to local authorities[116] who are considering options to address local air quality issues. It describes what a clean air zone is, under what circumstances it may be applied and the key considerations for local authorities who wish to establish one. The reasons for reducing airborne pollution, through a clean air zone, may be to address the need to reduce emissions to within legal limits, but most importantly, to bring about improvements in the environment and to deliver better health for all. The final version of the Framework will be published, and issued to local authorities, in early 2019.

Between 25 April and 19 June 2018, the Welsh Government published a consultation on the Welsh Government supplemental plan to the UK plan for tackling roadside nitrogen dioxide concentrations 2017 (WGSP). The plan set out actions the Welsh Government would take and is taking to ensure compliance within the shortest possible time with the limit values for nitrogen dioxide (NO2) laid down by the Air Quality Standards (Wales) Regulations 2010.

The Welsh Government's ability to take action in relation to air quality is limited to taking steps that fall within the scope of its devolved competence. This includes the implementation of local measures where nitrogen dioxide limit exceedances exist on discrete stretches of the motorway and trunk road network, using its powers as highway authority. Where a local authority is responsible for a relevant stretch of road, the Welsh Government has the power to direct the authority to take action. Outside this, the Welsh Government engages with the UK government on relevant matters that are not within its devolved competence, such as vehicle specification standards, vehicle exercise duty, fuel duty, and the enforcement of Euro emission standards.

The Welsh Government is committed to legal compliance. However, the focus of the plan is taking action to improve the air quality for everyone in Wales for the health improvements that this will deliver and because it's the right thing to do.

In accordance with a High Court undertaking, the Welsh Government published an interim supplemental WGSP in July. In addition, between 21 September and 2 November, the Welsh Government published a consultation on likely measures to reduce nitrogen dioxide levels in the shortest possible time at teach of the Welsh Government managed motorway and trunk road locations where nitrogen dioxide levels are above legal limits. The consultation was a culmination of a number of activities that have been undertaken by Welsh ministers since summer 2017 to establish what measures may be most effective and can feasibly be implemented on the Welsh Government motorway and truck road network. The Welsh Government published their final WGSP on 29 November 2018.

The Welsh Government has committed £20 million for an Air Quality Fund through to 2021 to help accelerate compliance with nitrogen dioxide limits and improve air quality in Wales.

This will be used to provide ongoing support, guidance and finance, enabling Welsh Local Authorities who are non compliant with nitrogen dioxide limits to develop and implement plans and take action to achieve compliance in the soonest possible time.

The Welsh Government also issued new statutory policy guidance to local authorities in Wales in June 2017, which ensures that the ways of working enshrined in the WFG Act are applied fully in local authorities' air quality management work. The new guidance stresses the need for transport and planning departments in local authorities to work collaboratively with air quality teams if local air quality management is to succeed. This statutory guidance recognises schools and active travel routes, amongst others, as "sensitive receptor locations".

Addressing air quality in Wales is an urgent issue and local authorities are crucial to achieving the development of a broad range of solutions. The Welsh Government has invited proposals for collaborative projects to improve the quality of the urban and rural built environment and access to green infrastructure under its Enabling Natural Resources and Well-Being in Wales 2019-2023 grant scheme. This grant scheme includes both revenue and capital funding, and may be used to trial and implement innovative new approaches to improving air quality and soundscapes.

10. Progress towards our clean air goals

10.1 Our commitments to improving air quality

The UK has signed up to a number of high-profile international agreements to improve air quality. This is because we recognise that reducing air pollution not only benefits our own citizens, but emissions can travel long distances and impact human and environmental health around the world. Our commitments relate to total emissions[117] and local concentrations[118] of pollutants.

The UK is compliant with the concentration limit values set out in legislation, except for NO_2 where we face a significant challenge along with many other EU countries. We have therefore produced an air quality plan for nitrogen dioxide,[119] which will ensure compliance with NO_2 limit values as quickly as possible. We are currently compliant with our ceilings for total emissions for all pollutants. However, we need to ensure that we continue to reduce the total amount of air pollution we produce to both protect the health of the nation and remain compliant with our statutory commitments.

The table below, presents our 2005 baseline emissions of 5 key pollutants and our commitments to reductions by 2020 and 2030.[120]

	2005 baseline (kt)	Reduction required by 2020	Reduction required by 2030	2020 ceiling (kt)	2030 ceiling (kt)
NOx	1,714	55%	73%	771	463
SO_2	773	59%	88%	317	93
NMVOCs	1,042	32%	39%	709	636
$PM_{2.5}$	127	30%	46%	89	69
NH_3	288	8%	16%	265	242

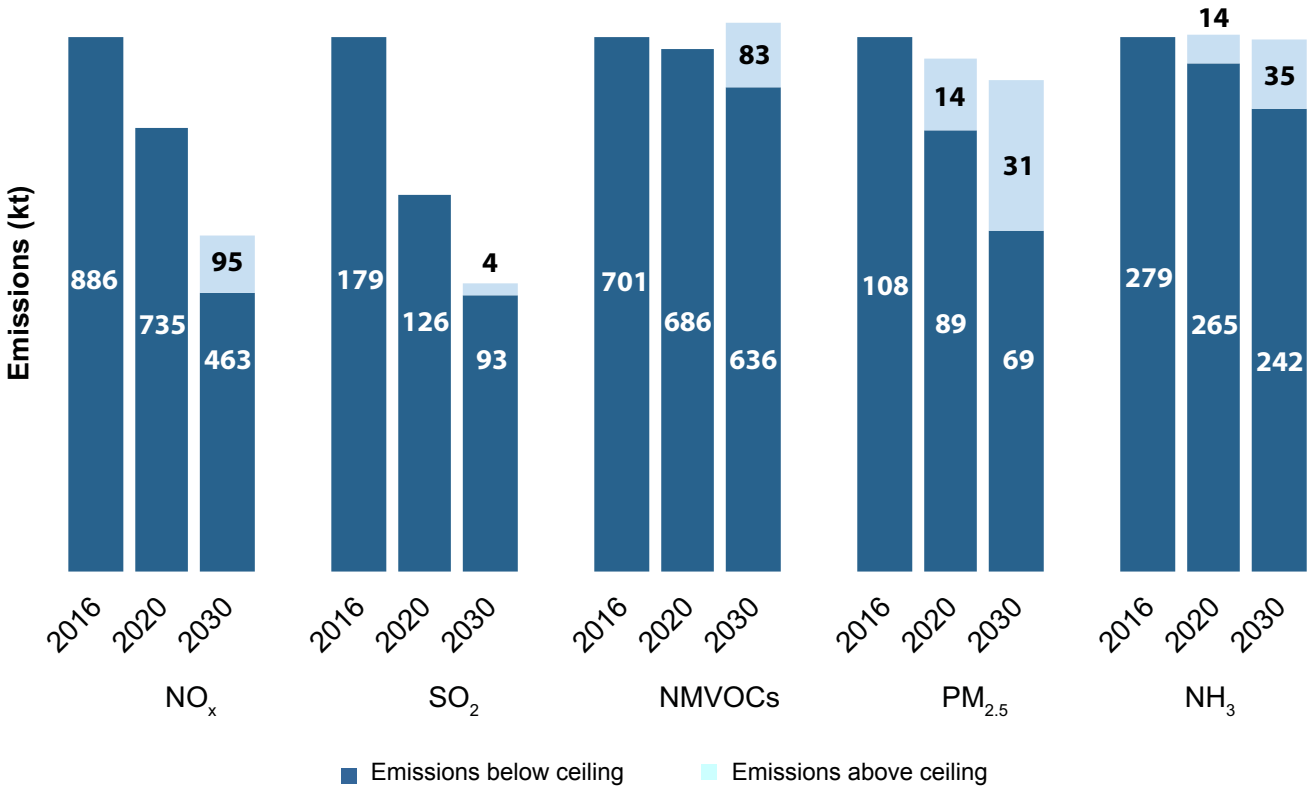
10.2 How far will existing action get us?

Measuring our progress towards emission ceilings requires an understanding of future emissions of air pollution based on our best estimates about the likely impacts of our regulatory measures and other actions already in place. Emission projections are produced by Ricardo Energy & Environment on behalf of Defra and are published via the EIONET data repository.[121]

Projections are constructed by using our knowledge and some informed assumptions about how activities that produce air pollution are likely to change over time (for example, the levels and types of industrial production) and how much pollution each activity would produce (for example, the amount of pollution produced per unit of industrial production). These projections are consistent with projections for other government policy priorities, such as those developed for BEIS on future energy use.

The figure below, presents our actual emissions in 2016 and our projected 2020 and 2030 emissions before the new policies and commitments set out in this strategy are taken into account. It shows whether these projections are above or below our emissions ceilings. The total height of each bar (i.e., light blue plus dark blue areas) are current and projected total emissions for each pollutant. The dark blue segments of each bar represent emissions that are up to our ceilings and the light blue segments represent emissions above our ceilings. Where a bar has no light blue segment we are already on track to deliver emissions reductions that will meet a particular emissions ceiling.

Current and projected emissions of 5 key pollutants
Total bar heights are BAU projections, light blue areas are distances above NECD ceilings



This figure shows that, without the new policies and commitments set out in this strategy, we would be likely to breach our emissions ceilings for $PM_{2.5}$ and NH_3 in 2020 and all five of our emissions ceilings in 2030. Following a path of no action will have a significant long-term impact on the health of our nation. Our latest set of appraisal tools[122] indicate that the population health impacts of not delivering on our emission reductions could be around £1.7bn per annum by 2020 and £5.3bn per annum by 2030.

10.3 Action to meet our emissions ceilings

As discussed in previous chapters, air pollution is produced from a wide range of sources and we have identified a suite of policies across different sectors to reduce our overall emissions. These build on existing policies, such as eco design for domestic stoves and the Medium Combustion Plant Directive. The table below presents how our proposed suite of policies will go further to abate emissions to close the gap to our emissions ceilings.

Table showing the impact of Clean Air Strategy policies

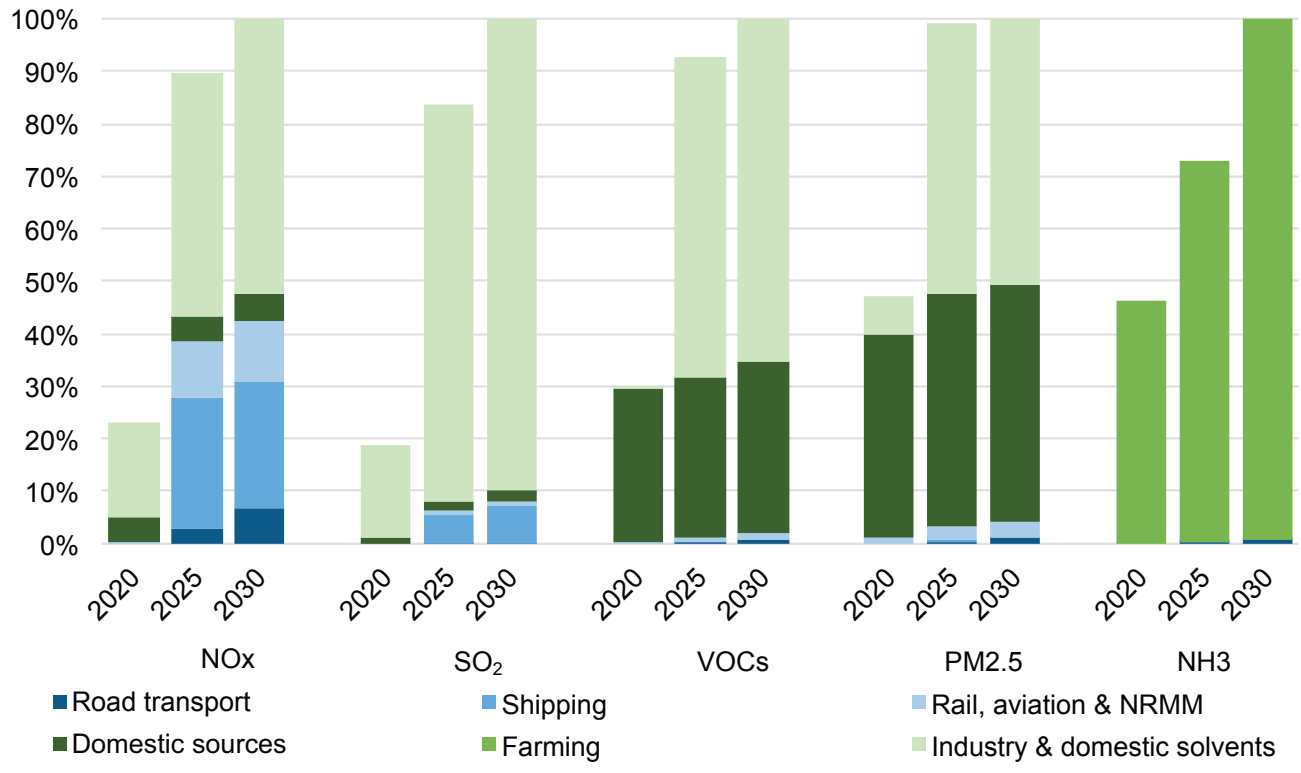
	2020 gap to ceiling (kt)	2020 CAS impact (kt)	2030 gap to ceiling (kt)	2030 CAS impact (kt)
NOx	-36	Around 10	95	75 to 150
SO_2	-190	Around 5	4	35 to 55
NMVOCs	-23	Around 20	83	50 to 95
$PM_{2.5}$	14	Around 15	31	25 to 40
NH_3	14	Around 25	35	Up to 65

Negative gaps to ceilings indicate BAU is below ceiling

The table indicates that we are likely to be above our emission ceilings for $PM_{2.5}$ and NH_3 in 2020 and all 5 pollutants in 2030 if we take no action. Our analysis indicates that we should be able to meet all of our emission ceilings with the policies set out in this document.

We have also analysed the abatement potential at sector level. The chart below, presents our initial assessment of abatement by broad sector.

Contribution to abatement by broad sector



The chart indicates how our policies will look for emission reductions across all sectors. For NOx there is significant potential for abatement in the non-road transport and industrial sectors. For NMVOCs the largest opportunities are associated with industrial processes and domestic burning & solvent use. For $PM_{2.5}$ we need to look for reductions in the domestic burning and industrial sectors. Reductions in NH_3 emissions are almost all driven by action in the farming sector.

In conclusion, we believe that the commitments set out in the preceding chapters will enable us to meet all of our emissions ceilings in 2020 and 2030.

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This publication is available at www.gov.uk/government/publications

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