Department for Environment Food & Rural Affairs

Air quality damage cost guidance

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1. Introduction

This damage cost guidance is designed for policy appraisers, to guide in assessing the air quality impacts of a policy.

The quality of the air can impact on human health, productivity, wellbeing and the environment. The mortality burden of the air pollution mixture (based on both $PM_{2.5}$ and NO_2) in the UK is an effect equivalent to 28,000 to 36,000 deaths at typical ages. Thus, it is important that impacts on air quality are appropriately factored into policy making.

There are various methodologies for air quality appraisal. There are the damage cost and the Impact-Pathway (I-PA) approaches, which are detailed further below. Alternatively, if a policy is expected to affect compliance, then the abatement cost approach may be most applicable. For more information on which approach is most suitable for you, please see https://www.gov.uk/guidance/air-quality-economic-analysis

The I-PA is the best practice approach to value changes in air quality. This approach uses atmospheric modelling to estimate the consequences of changes in the ambient concentrations of air pollutants for a range of outcomes.

Full I-PA can be resource and time intensive, requiring the estimation of emissions, dispersion, population exposure and outcomes. Damage costs have been developed to enable proportionate analysis when assessing relatively small impacts on air quality.

Damage costs are a set of impact values, defined per tonne of emission by pollutant, which are derived using the impact pathway approach. These values estimate the societal costs associated with a marginal change in pollutant emissions. They can be combined with forecasts of emission changes to provide an approximate valuation of the aggregate impacts of a policy.

The air quality damage costs have been updated after receiving advice from the Committee on the Medical Effects of Air Pollutants (COMEAP), which provides independent advice to the UK government on the impacts of air pollution. We have also incorporated advice from Public Health England (PHE) on the inclusion of additional morbidity impacts.

This guidance is intended to provide a clear understanding of how the updated 2019 damage costs should be applied in practice. The I-PA guidance document provides more detail on the methodology and how the damage costs have changed in this update. The remainder of the document has the following structure:

- Section 2: Damage costs
- Section 3: Applying the updated damage costs
- Section 4: Worked example
- Section 5: Updated damage costs

2. Damage costs

Damage costs are produced for five pollutants; nitrogen oxides (NOx), particular matter ($PM_{2.5}$), sulphur dioxide (SO_2), volatile organic compounds (VOCs) and ammonia (NH_3).

The table below sets out the latest damage cost values for air quality appraisal. The values shown below are national averages, a subset of the overall set of damage cost values, which can be found at the end of this guidance (see Table 3).

Table 1 - 2018 Damage Cost Values

Pollutant Emitted	2018 Damage Costs (£/t) National Averages (2017 prices) Latest figures
NO_x	**6,199**
SO_2	**6,273**
NH_3	**6,046**
VOC	**102**
$PM_{2.5}$	**105,836**

Damage costs are provided for a range of different sources for NOx and PM. In order to select the relevant damage costs for your policy, it is important to take into consideration various factors such as location, source of emissions, sector etc.

Part A sector damage costs

In the case of NOx and PM, there are also damage costs provided for Part A sector emissions. Part A processes refer to emissions from large industrial processes. These emissions are particularly variable, depending on the population affected and the size of the chimney. As such, these values allow for more bespoke analysis in those instances.

There are 9 different categories, and the relevant category can be determined using the matrix below (see Table 2). In order to identify the correct category, you will need to know the average population density and the height of the stack for the industrial installation.

Table 2 - Part A categories

Average population density (persons per km²)	Stack Height <= 50 m and all small points	Stack Height > 50, <= 100 m	Stack Height > 100 m
<= 250	**1**	**4**	**7**
> 250, <= 1000	**2**	**5**	**8**
> 1000	**3**	**6**	**9**

Activity damage costs

Activity damage costs are also available for NO_x and PM. These are damage costs associated with specific fuel types (e.g. coal, gas, biomass etc.) and rural urban classification (e.g. small urban, rural, inner conurbation etc.). If you require these activity costs, please contact us directly at igcb@defra.gov.uk

3. Applying the updated damage costs

Below is a step-by-step guide on how to apply damage costs. The next section outlines a worked example on how to apply damage costs. Defra has also provided an excel-based tool to help appraise air quality impacts.

Step 1: Identify and quantify reductions in emissions

The impact on emissions should be estimated on the basis of the change in activity at the source of emissions. The relationship between the activity and the pollution produced is known as the 'emissions factor'. For example, the emissions factor for road traffic is the amount of pollution produced per vehicle distance travelled. Estimates of emissions factors for different activities are developed by the National Atmospheric Emissions Inventory (NAEI). Their Emissions Factor Database is available here: www.naei.org.uk/emissions.

In order to monetise PM_{10} emissions, appraisers must adjust their PM_{10} emissions to $PM_{2.5}$, and then monetise those using the $PM_{2.5}$ damage costs. A list of adjustment factors for different sectors, based on the ratio between these emissions in the NAEI, is provided in Table 3.

Step 2: Identify which damage cost values to use

Depending on the nature of the policy a sector-specific damage cost may be available. For example, this may be a transport average for NOx, or an industry average for PM.

Step 3: Convert damage cost values to relevant base year prices

All the damage costs value presented in Table 3 are in 2017 prices. These need to be adjusted to the price base year for the policy/project appraisal (i.e. the year in which all costs and benefits are being accounted) to take into account inflation.

Step 4: Uplift damage costs by 2% year on year

This value now needs to be uplifted by 2% cumulatively per annum from 2017 to reflect the assumption that willingness to pay for health outcomes will rise in line with real per capita GDP growth. This is done by multiplying the damage cost with the 2% uplift factor to reflect the annual increase. A worked example of this is shown in the section below.

Step 5: Calculate benefits for each year

The adjusted damage costs, calculated in Step 4, can be used to calculate the benefits of a reduction in pollutant emitted for each year of the appraisal period. This calculation simply multiplies the expected reduction in emissions figures from Step 1 (in tonnes) by the adjusted damage cost figures in each year to calculate the annual benefit.

Step 6: Discount benefits across the period of the policy appraisal and calculate total present value

To calculate the present value of air pollution impacts the undiscounted value of impacts for each year (calculated in Step 5 above) is multiplied by the discount factor below, where 0.035 is the 3.5% discount rate (in line with HMT's Green Book guidance) and *t* is the number of years into the future that value is from the base year (year 0):

$$\text{Discount Factor} = \frac{1}{0.035^t}$$

$$\text{Present Value} = \text{Valued benefit} \times \text{Discount Factor}$$

The total present value is the sum of the present value of impacts in all appraisal years.

Step 7: Sensitivity analysis

In addition to the central damage cost estimates there are also low and high damage cost estimates that should be used for sensitivity analysis – see the Technical Appendix for an explanation of how these are calculated. Repeat Steps 3 – 6 using the high and low sensitivity damage cost values provided to generate present values of impacts for those sensitivities. It is worth noting that these sensitivity values do not account for all uncertainty. This is because the low and high sensitivities are based on the inclusion of different health impact pathways, and differences in the valuation of a life year, and not other sources of uncertainty.

Furthermore, there is also a potential overestimation of PM impacts through the damage costs. This is because air pollutants are typically emitted in mixtures, and so is there likely to be a degree of overlap between NO_x and PM. While the NO_x damage costs are adjusted for this, there is no such adjustment factor available for PM emissions. As such, the PM damage costs do not account for the potential confounding effect of other correlated pollutants.

Thus, using the PM damage costs, this overestimation should be recognised when reporting your results. For more information, please see section 6 of the Impact Pathway Guidance.

4. Worked example

Below is a worked example of how the impact of NO_2 can be calculated for a hypothetical policy measure.

The hypothetical policy

A measure aimed at improving the efficiency of vehicles is to be introduced. One of the expected benefits of implementing this measure is the reduction of NOx emissions as well as other pollutants (e.g. PM emissions). This measure is being assessed for 10 years, from 2019, and is expected to reduce emissions of NO_x by 12 tonnes per year until 2021 and 3 tonnes per year thereafter compared to a do nothing counterfactual scenario. The price base year for appraisal is 2018.

Step 1 – Identify and quantify reduction in emissions

The level of reduction that is expected in this hypothetical example is set out below.

Note: If you are quantifying the impacts of PM_{10}, ensure you convert your emissions to $PM_{2.5}$ using the conversion factors set out in Table 3 at the end of the document.

	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
NOx Emission Reductions (Tonnes)	12	12	12	3	3	3	3	3	3	3

Step 2 – Identify which damage cost values to use

	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
NOx Emission Reductions (Tonnes)	12	12	12	3	3	3	3	3	3	3
NOx Damage Costs (Road Transport)	£10,699	£10,699	£10,699	£10,699	£10,699	£10,699	£10,699	£10,699	£10,699	£10,699

Step 3 – Convert NOx damage costs to base year

The price base year for the appraisal is 2018 in this case, so the damage costs will need to be adjusted to the new price base, using GDP deflators[1]. Using the ratio of the index values for 2018 (113.88) and 2017 (112.17), and multiplying by the damage cost value, gives a rebased value of £10,863.

	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
NOx Emission Reductions (Tonnes)	12	12	12	3	3	3	3	3	3	3
NOx Damage Costs (Road Transport)	£10,699	£10,699	£10,699	£10,699	£10,699	£10,699	£10,699	£10,699	£10,699	£10,699
Damage Costs Rebased to 2018	£10,863	£10,863	£10,863	£10,863	£10,863	£10,863	£10,863	£10,863	£10,863	£10,863

Step 4 – Uplift damage costs by 2% to reflect higher willingness to pay for health

The damage costs are then uplifted by 2% annually. In the example below, the appraisal period starts in 2019, while the damage costs are set in 2017. Therefore, the damage

[1]WebTAG Data Book (Nov 2018)
(https://www.gov.uk/government/publications/tag-data-book)

costs should first be uplifted to 2019, and then subsequently uplifted annually thereafter. This is equivalent to multiplying the rebased damage costs by the uplift factors in the table below.

	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
NOx Emission Reductions (Tonnes)	12	12	12	3	3	3	3	3	3	3
NOx Damage Costs (Road Transport)	£10,699	£10,699	£10,699	£10,699	£10,699	£10,699	£10,699	£10,699	£10,699	£10,699
Damage Costs Rebased to 2018	£10,863	£10,863	£10,863	£10,863	£10,863	£10,863	£10,863	£10,863	£10,863	£10,863
Uplift Factors	1.04	1.06	1.08	1.10	1.13	1.15	1.17	1.20	1.22	1.24
Damage Costs Uplifted*	£11,302	£11,528	£11,758	£11,993	£12,233	£12,478	£12,727	£12,982	£13,242	£13,506

*** Figures shown are rounded, but exact values used in calculation**

Step 5 – Calculate benefits for each year

The uplifted damage cost values below are then multiplied by the emission values for the corresponding years.

	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
NOx Emission Reductions (Tonnes)	12	12	12	3	3	3	3	3	3	3
Damage Costs Rebased to 2018	£10,863	£10,863	£10,863	£10,863	£10,863	£10,863	£10,863	£10,863	£10,863	£10,863
Damage Costs Uplifted	£11,302	£11,528	£11,758	£11,993	£12,233	£12,478	£12,727	£12,982	£13,242	£13,506
Total Benefits	£135,619	£138,332	£141,098	£35,980	£36,700	£37,434	£38,182	£38,946	£39,725	£40,519

Step 6 – Discount benefits across the period of the policy appraisal and calculate total present value

The table below shows the present values for the hypothetical policy scenario. The central estimate of the total present value of air quality impacts can then be calculated as the sum of present values across the appraisal period. For this policy measure the central estimate of the present value is £618,513 over the ten year appraisal period.

	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
NOx Emission Reductions (Tonnes)	12	12	12	3	3	3	3	3	3	3
Damage Costs Uplifted	£11,302	£11,528	£11,758	£11,993	£12,233	£12,478	£12,727	£12,982	£13,242	£13,506
Total Benefit	£135,619	£138,332	£141,098	£35,980	£36,700	£37,434	£38,182	£38,946	£39,725	£40,519
Total Discounted Benefit	£135,619	£133,654	£131,717	£32,452	£31,982	£31,518	£31,061	£30,611	£30,168	£29.730
Total Present Value Benefit	**£618,513**									

Step 7 – Sensitivity analysis

The table below shows how the net present value is calculated for the high sensitivity damage cost values. For the same policy measure, the high estimate of the present value is £1,602,786. The same should also be repeated for the low sensitivity.

	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
NOx Emission Reductions (Tonnes)	12	12	12	3	3	3	3	3	3	3
NOx Damage Costs (Road Transport)	£40,986	£40,986	£40,986	£40,986	£40,986	£40,986	£40,986	£40,986	£40,986	£40,986
Damage Costs Rebased to 2018	£41,520	£41,520	£41,520	£41,520	£41,520	£41,520	£41,520	£41,520	£41,520	£41,520
Damage Costs Uplifted	£43,198	£44,062	£44,943	£45,842	£46,758	£47,694	£48,648	£49,620	£50,613	£51,625
Total Benefit	£518,371	£528,739	£539,313	£137,525	£140,275	£143,081	£145,943	£148,861	£151,839	£154,875
Total Discounted Benefit	£518,371	£510,859	£503,455	£124,040	£122,242	£120,470	£118,724	£117,004	£115,308	£113,637
Total Present Value Benefit	**£2,364,109**									

5. Updated 2018 damage costs

Table 3 below presents the updated set of damage cost values, alongside the low and high sensitivities. The final column also displays the conversion factor required to estimate impacts of PM_{10} emissions.

Table 3 - Updated full set of damage costs

Pollutant Emitted	Central Damage Cost (£/t)	Low – High damage cost sensitivity range (£/t)		$PM_{2.5}/PM_{10}$ Conversion Factor
		Low sensitivity	High sensitivity	
National				
NO_x	6,199	634	23,153	
SO_2	6,273	1,491	17,861	
NH_3	6,046	1,133	18,867	
VOC	102	55	205	
$PM_{2.5}$	105,836	22,588	327,928	0.642
PM Part A Sector				
$PM_{2.5}$ Part A Category 1	8,666	2,473	25,060	0.659
$PM_{2.5}$ Part A Category 2	37,087	8,350	113,161	0.659
$PM_{2.5}$ Part A Category 3	81,059	17,444	249,465	0.659
$PM_{2.5}$ Part A Category 4	2,989	1,299	7,462	0.659
$PM_{2.5}$ Part A Category 5	6,392	2,002	18,013	0.659
$PM_{2.5}$ Part A Category 6	9,708	2,688	28,293	0.659
$PM_{2.5}$ Part A Category 7	2,557	1,209	6,125	0.659
$PM_{2.5}$ Part A Category 8	3,355	1,374	8,598	0.659
$PM_{2.5}$ Part A Category 9	4,223	1,554	11,289	0.659
PM Source Sector				
$PM_{2.5}$ Industry (area)	95,847	20,679	308,503	0.534
$PM_{2.5}$ Commercial	63,797	13,636	183,869	0.977
$PM_{2.5}$ Domestic	85,753	18,171	247,526	0.977
$PM_{2.5}$ Solvents	194,078	41,485	692,660	0.366
$PM_{2.5}$ Road Transport	203,331	42,713	625,927	0.673
$PM_{2.5}$ Aircraft	194,269	40,571	560,317	1
$PM_{2.5}$ Offroad	153,487	32,181	446,162	0.943
$PM_{2.5}$ Rail	163,413	34,240	476,129	0.929
$PM_{2.5}$ Ships	33,739	7,443	97,124	0.947
$PM_{2.5}$ Waste	162,082	34,067	484,553	0.789
$PM_{2.5}$ Agriculture	46,442	11,732	192,401	0.218
$PM_{2.5}$ Other	251,877	52,538	738,774	0.894

$PM_{2.5}$ Road Transport Central London	1,111,831	230,582	3,430,456	0.673
$PM_{2.5}$ Road Transport Inner London	1,132,776	234,913	3,495,112	0.673
$PM_{2.5}$ Road Transport Outer London	602,201	125,195	1,857,233	0.673
$PM_{2.5}$ Road Transport Inner Conurbation	420,523	87,626	1,296,397	0.673
$PM_{2.5}$ Road Transport Outer Conurbation	250,221	52,409	770,676	0.673
$PM_{2.5}$ Road Transport Urban Big	305,377	63,815	940,942	0.673
$PM_{2.5}$ Road Transport Urban Large	247,045	51,753	760,871	0.673
$PM_{2.5}$ Road Transport Urban Medium	203,359	42,719	626,014	0.673
$PM_{2.5}$ Road Transport Urban Small	152,694	32,242	469,611	0.673
$PM_{2.5}$ Road Transport Rural	69,745	15,089	213,548	0.673
NO_x Part A Sector				
NO_x Part A Category 1	1,690	287	5,375	
NO_x Part A Category 2	2,701	365	9,362	
NO_x Part A Category 3	4,829	529	17,753	
NO_x Part A Category 4	1,625	282	5,119	
NO_x Part A Category 5	1,903	304	6,215	
NO_x Part A Category 6	2,576	355	8,871	
NO_x Part A Category 7	1,599	280	5,017	
NO_x Part A Category 8	1,665	285	5,277	
NO_x Part A Category 9	1,749	292	5,609	
NO_x Source Sector				
NO_x Industry (area)	5,671	593	21,070	
NO_x Commercial	13,307	1,180	51,177	
NO_x Domestic	13,950	1,229	53,711	
NO_x Road Transport	10,699	980	40,896	
NO_x Aircraft	11,672	1,054	44,732	
NO_x Offroad	8,656	823	32,841	
NO_x Rail	9,009	850	34,230	
NO_x Ships	2,506	350	8,592	
NO_x Waste	6,766	677	25,391	
NO_x Other	7,426	728	27,990	
NO_x Road Transport Central London	57,517	4,576	225,472	
NO_x Road Transport Inner London	58,967	4,688	231,189	

NO_x Road Transport Outer London	31,326	2,564	122,215	
NO_x Road Transport Inner Conurbation	22,005	1,848	85,468	
NO_x Road Transport Outer Conurbation	13,200	1,172	50,754	
NO_x Road Transport Urban Big	16,010	1,388	61,834	
NO_x Road Transport Urban Large	12,994	1,156	49,940	
NO_x Road Transport Urban Medium	10,844	991	41,465	
NO_x Road Transport Urban Small	8,343	798	31,605	
NO_x Road Transport Rural	4,191	480	15,237	