Scenario Modelling Tool - Extending NAEI projection baseline to 2050

Neil Passant, Anne Misra

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1. Introduction

The Scenario Modelling Tool (SMT) baseline emissions are based on the UK projections compiled as part of the National Atmospheric Emission Inventory (NAEI). The NAEI projections are compiled in line with the latest EMEP/EEA guidebook. They take, as their starting point, the latest available estimates of historical emissions (i.e. the year 2018 in the SMT) which are then extrapolated into the future taking into account forecasts of energy consumption (by BEIS), road traffic (from DfT), and other activity data, as well as assumptions about the impact of environmental policies and measures on emissions (see chapter 9 in IIR for detailed information about the NAEI projections).

The NAEI projections cover the time period up to 2030 in line with UK and international reporting requirement under the UK NECR and UN LRTAP Gothenburg Protocol (GP)[1]. Under both, the NECR and GP, the UK has agreed to reduce emissions of air pollutants (i.e. NOx, NMVOC, SOx, NH_3 and $PM_{2.5}$) in line with set emission reduction commitments by 2020 and 2030 (NECR only). The SMT however covers all years up to and including 2050. In the absence of NAEI baseline projections beyond 2030 emission are currently kept constant between 2031 and 2050 in the SMT.

This paper assesses the likelihood that these constant or flatlined emissions will correctly represent emissions between 2031 and 2050, using existing evidence.

To assess whether these flatlined emissions are a good or false representation of future emissions, compared to a fully modelled dataset out to 2050, one has to keep in mind that projected emissions are inherently uncertain, with some sources being more uncertain than others. Robust estimates of activity up to 2050 seem to be scarce, although this may simply be a reflection that the NAEI has not until now sought such data. Similarly, the latest 2019 EMEP/EEA guidebook does not usually contain emission factors (EF) covering new or future technologies, and industry is often unwilling or unable to provide information on emissions beyond a few years into the future. Thus, it is challenging to model emissions beyond 2030.

This paper focuses on groups of key stationary emission categories for NOx and $PM_{2.5}$ only (NFR 1A1a; NFR 1A1b/1A1c; NFR 1A2/1A4a/1A4c; NFR 1A4b; NFR 2A (PM only); NFR 2B-2I). Projected emissions of NOx and $PM_{2.5}$ for 2031 to 2050 have been provided for the transport sector (NFR 1A3) and as such are not covered in this paper again.

[1] Reporting projected emissions for 2040 and 2050 is voluntary.

2. Review of SMT, NAEI & EEP information

The SMT is currently based on the NAEI2018, i.e. the NAEI compiled in the year 2019, both for historic and projected emissions. The latest available NAEI is the NAEI2019, compiled in 2020. Any improvements or changes made in the NAEI2019 are not yet reflected within the SMT. This chapter provides a comparison of the data in the SMT and that in the NAEI2019, for the calendar years 2018 and 2030. While the focus of this paper is on NOx, $PM_{2.5}$ and to some extent SO_2, emission for all NECR pollutants have been provided for information.

NFR 1A1a

NFR 1A1a covers the electricity supply industry (ESI). Current emission estimates in SMT for the 2018 base year and 2030 are compared below with values from the latest versions of the historical and projected NAEI2019.

Table 2.1 Emissions of NOx, SOx, NMVOC, NH_3 and $PM_{2.5}$ for NFR 1A1a

	Emissions in ktonnes				
	NO_X	$PM_{2.5}$	NMVOC	SO_2	NH_3
2018:					
SMT	98.14	2.25	1.89	22.46	0.11
NAEI	85.77	1.72	1.68	20.58	0.13
2030:					
SMT	57.98	1.50	1.19	4.11	0.18
NAEI	51.94	1.05	0.96	3.48	0.20

Power stations are a significant source of NO_X, $PM_{2.5}$ & SO_2 but not of VOC or NH3. The figures in Table 2.1 illustrate one issue that will be referred to repeatedly in this note – that emission estimates even for the historical NAEI are uncertain and subject to change from year to year. In the case of the figures given for 2018, the SMT figures are based on the '2018' version of the NAEI, whereas those quoted above for the NAEI are from the '2019' version. These versions are referred to hereafter as NAEI18 and NAEI19. The figures for 2030 are, in the case of SMT, based on NAEI18 and the 2018 version of the 'EEP' energy projections by BEIS (EEP2018[2]), whereas the latest NAEI figures are based on NAEI19 and the more recent EEP2019[3] set of energy projections.

Historical emission estimates can change for a number of reasons but most importantly there can be changes to methodology or revisions to input data. In the case of power stations, input data will include emissions data reported to UK regulators, and fuel consumption given in UK energy statistics. The former are generally not revised but the latter often are. In the case of power stations, the NAEI methodology was also refined between the 2018 and 2019 versions, so the change in the 2018 figure between that in SMT and in the latest NAEI will be due to a combination of methodological change and data revision. There is one final reason for changes in 1A1a – emissions from one source were included in 1A1a in NAEI18 but moved to 1A2 for NAEI19. This is the principal cause why NO_X emissions are now lower for 1A1a in the NAEI than in SMT (but emissions from 1A2 are higher – see later section).

[2] https://www.gov.uk/government/publications/updated-energy-and-emissions-projections-2018
[3] https://www.gov.uk/government/publications/updated-energy-and-emissions-projections-2019

Revisions to historical data matter for the projections as well. For stationary sources, we typically estimate the trend in emissions between the base year and the projection year i.e. whether emissions might increase by 10% say or decrease by 15% using data such as BEIS' EEP projections. If we change the base year estimate but use the same assumption about the trend, then the projected emissions will change as well. This is largely what we see for 1A1a – the base year emissions have changed, as have the 2030 estimates, but the trend between the two is similar in both the SMT and the latest NAEI figures. For example, for NO_X SMT has emissions decreasing by 41% between 2018 and 2030, whereas now the NAEI has a decrease of 39% over that period.

Note that our assumptions about trends can also change from year to year and sometimes these changes can be very significant. It just so happens that, in recent years, assumptions for 1A1a have been fairly stable. This reflects the BEIS EEP projections which have been fairly consistent in the past few years in predicting the closure of all coal-fired stations before 2030 but for use of natural gas to remain important and fairly constant. But the discussion above does show how even in a sector as well characterised as 1A1a, there can be significant changes even for historical data and estimates to 2030. Estimates to 2050 are likely to be far more uncertain.

EEP2018 only extended to 2030, whereas EEP2019 included projections to 2040. Currently, SMT assumes that emissions in 2031-2050 will remain unchanged from 2030 levels. EEP2019 can therefore be used to examine how likely it is that emissions will remain unchanged from 2030 to 2040. The main emission sources in 2030 are combustion of natural gas (important for NO_X), and various wastes and biofuels (important for NO_X, PM and SO_2). EEP2019 suggests that:

- natural gas consumption by the ESI will fall by 9% between 2030 and 2040.
- electricity generation from renewables will increase by 8% between 2030 and 2040.

So flat-lining emissions between 2030 and 2040 in SMT will overstate emissions for gas-fired power stations, and possibly underestimate emissions from renewable energy. The second statement is qualified because the EEP data we get only gives values for total renewables but does not distinguish between emissive types such as waste and biofuels and non-emissive types such as wind and hydro. For the NAEI projections this has led to us using a combination of EEP data and information from the National Grid's Future Energy Scenarios (FES) to estimate trends for each type of renewable energy. None of the FES scenarios seem to be BAU but we use the least ambitious (steady progression, SP) scenario as a guide to the possible make-up of the renewable generation for our projections to 2030, and this scenario can also be used to look at possible trends in 2030-2040. This scenario suggests that generation using wastes will remain relatively constant, whereas generation from biomass use will increase somewhat. The overall change in generation from wastes and biomass combined is a 9% increase between 2030 and 2040, compared with a growth in non-emissive renewables of 50%. So the evidence from EEP and FES together suggests a relatively small (~10%) decrease in use of natural gas between 2030 and 2040 and perhaps a relatively small (up to 10%) increase in use of biofuels and wastes. On that basis, it could be concluded that flat-lining emissions in SMT between 2030 and 2040 is not totally unrealistic, although that is perhaps more true for NO_X (where all fuels make important contributions) than for PM & SO_2 (where wastes and biofuels are more important sources).

FES can also be used as a guide to possible trends in 2040-2050, though as stated previously, all scenarios assume some level of effort towards reaching net zero so are not BAU. The SP scenario suggests that use of wastes and biofuels for electricity generation will decline by 11% between 2040 and 2050 and that use of natural gas will decrease by 10% (SP scenario has growth in wind and nuclear generation instead).

The preceding discussion summarises the figures that we have available and allows one to assess what a more up-to-date time-series for SMT might look like. However, it doesn't give much indication of the level of uncertainty. Planning and building power stations takes time and so there is probably limited uncertainty over which stations and which fuels will be needed to provide the UK with power for the next five or ten years. Uncertainty for 2050 however will be much higher. Some measure of this can perhaps be gained by looking at the various FES scenarios. These represent different levels of ambition levels towards reaching net zero, rather than representing different versions of BAU, but they do say something about the degree of flexibility with which the ESI can meet UK energy requirements in 2050. Some examples: the four FES scenarios suggest that fossil fuel stations in 2050 could vary between 0% and 20% of the installed capacity in 2050 (compared with ~40% in 2019) and that biomass capacity could be between 1% and 4% of the total. How much of that variation could occur in a BAU case is, however, not clear.

In summary therefore:

- Current best NAEI estimates for 2030 are lower than those used in SMT, so rolling from these higher SMT values for 2030 is conservative.
- EEP2019 suggests a ~10% decline in gas use between 2030 and 2040 and a ~10% increase in use of renewables. FES suggests a similar growth figure for wastes & biofuels. The net impact would probably be little change in NO_X emissions between 2030 and 2040 but small increases in emissions of PM and SO_2.
- FES suggests a ~10% decrease in use of both natural gas and waste/biofuels between 2040 and 2050, which would result in similar reductions in emissions of each pollutant in SMT.
- Overall impact of all these is that rolling data from the current SMT figure for 2030 is perhaps slightly conservative i.e. slightly overstates emissions when compared with updating SMT with the best currently available data.
- FES suggests that there is significant flexibility in how the ESI meets UK energy needs by 2050, but it is not clear how much of this flexibility exists within a BAU context.

NFR 1A1b / 1A1c

These NFR categories cover combustion at crude oil refineries (1A1b) and at a wide range of other energy industry facilities in 1A1c, including combustion at coke ovens, coal mines, oil & gas exploration and production facilities, oil & gas terminals, and gas compression facilities. Current emission estimates in SMT for the 2018 base year and 2030 are compared in Table 2.2 with values from the latest versions of the historical and projected NAEI2019.

Table 2.2 Emissions of NOx, SOx, NMVOC, NH_3 and $PM_{2.5}$ for NFR 1A1b/1A1c

	Emissions in ktonnes				
	NO_X	$PM_{2.5}$	NMVOC	SO_2	NH_3
2018:					
SMT	66.81	1.09	1.76	26.77	0.00
NAEI	68.57	1.36	1.71	26.60	0.00
2030:					
SMT	56.90	1.02	1.58	23.02	0.00
NAEI	63.50	0.91	1.51	25.66	0.00

These sectors are important sources of NO_X and SO_2 in particular. Most of the NO_X is emitted by offshore facilities involved in the production of crude oil and natural gas, with important contributions also from crude oil refineries. Refineries are the dominant source of SO_2 within the 1A1b/1A1c group.

Table 2.2 shows some significant changes in the latest NAEI compared with the earlier data used in SMT. Unlike in the case of 1A1a, described in the previous section, the 2018 base year figures are similar, and it is instead the trend between 2018 and 2030 that has changed most between the SMT data and that in the latest NAEI. For example, where SMT predicts decreases of 15% and 6% respectively for NO_X and $PM_{2.5}$, the latest NAEI suggests decreases of 7% and 33%. The emission totals in Table 2.2 are the sum of figures for some 30 or more source categories and so the reasons for these changes are complex, but include methodological changes to the NAEI and changes between EEP2018 and EEP2019. The figures show that both NO_x and SO_2 are currently underestimated in SMT compared with the latest data, whereas $PM_{2.5}$ is overestimated.

EEP2018 only extended to 2030, whereas EEP2019 included projections to 2040. EEP2019 forecasts for fuel use in the refinery sector are constant between 2030 and 2040, so consistent with the current approach in SMT. But the use of fuels by the offshore oil & gas industry is predicted to fall by 10% between 2030 and 2040. Projections of oil and gas production published by the Oil & Gas Authority in March 2019 assume that both oil production and gas production decline by 5% each year from 2024 onwards. This would imply that production of each commodity in 2050 was only 36% of the level in 2030, so the likelihood is that emissions from offshore oil & gas facilities would also be much lower by 2050.

NFR 1A2 / 1A4a / 1A4c

These NFR categories cover energy generation in the industrial, commercial, public, and agricultural sector. The NFRs actually cover both stationary combustion and combustion in mobile machinery and off-road vehicles, but the discussion here will be limited to stationary combustion where possible, which we will refer to hereafter as 'industrial-scale combustion'. Current emission estimates in SMT for the 2018 base year and 2030 are compared in Table 2.3 with values from the latest versions of the historical and projected NAEI.

Table 2.3 Emissions of NOx, SOx, NMVOC, NH_3 and $PM_{2.5}$ for NFR 1A2/1A4a/1A4c

	Emissions in ktonnes				
	NO_X	$PM_{2.5}$	NMVOC	SO_2	NH_3
2018:					
SMT	200.48	21.99	27.11	42.36	2.68
NAEI	220.02	23.49	27.79	45.42	0.53
2030:					
SMT	177.70	17.25	23.30	28.37	2.97
NAEI	193.24	21.43	24.89	40.38	0.61

Note the large change in NO_X emissions between the values in SMT and those in the latest datasets. This is partly due to the revised reporting of a source mentioned previously, this source being moved from 1A1a in the SMT dataset to 1A2 in the latest data. But there have also been important revisions to the NAEI methodology (affecting $PM_{2.5}$ in particular) and important changes to the projection assumptions (notably affecting SO_2). Compared with the latest data, SMT is underestimating all pollutants with the exception of NH_3.

EEP2019 provides information on trends in 2030-2040: it suggests that industrial fuel consumption will mostly increase. Consumption of natural gas, coal, gas oil & fuel oil are all predicted to be higher in 2040 than 2030, with only the consumption of biomass falling. The picture is similar for the 'services' sector in EEP2019 (i.e. commercial and public sectors) and the agricultural sector with either growth or constant levels of use of all fuels except biomass. Therefore, the flatlining of emissions in SMT after 2030 may actually be a further underestimation of emissions for this sector.

In one other respect, the current approach in SMT may overstate emissions. Both the SMT and latest NAEI projections are somewhat conservative. This is because the NAEI method for industrial-scale combustion, though improved in the latest NAEI, still cannot fully reflect the impact of regulation on the sector's emissions. This is due to a lack of suitable information (both on the activity data and emission factor side) and developing projections that fully reflect both historical regulation of large combustion plant (LCP) e.g. under IED, and planned measures such as regulation of medium combustion plant (MCPs) and specified generators is a challenging and intractable problem. The lack of data also means that we can't estimate the degree of how conservative the current figures might be – whether they are just marginally higher or whether the true emissions could be significantly lower than currently modelled. The recent improvement work does, however, suggest that most emissions within 1A2/1A4a/1A4c are from MCPs and small-sized plant, rather than the LCPs that are already well-regulated so the medium-term NAEI projections are less likely to be conservative, than those for the longer-term when regulation of MCPs will be fully implemented.

NFR 1A4b

This NFR category covers fuel use by the residential sector. Current emission estimates in SMT for the 2018 base year and 2030 are compared in Table 2.4 with values from the latest versions of the historical and projected NAEI.

Table 2.4 Emissions of NOx, SOx, NMVOC, NH_3 and $PM_{2.5}$ for NFR 1A4b

	Emissions in ktonnes				
	NO_X	$PM_{2.5}$	NMVOC	SO_2	NH_3
2018:					
SMT	35.16	46.81	48.76	40.72	2.49
NAEI	35.94	47.38	50.04	43.87	2.49
2030:					
SMT	32.64	41.06	46.84	15.49	2.94
NAEI	33.43	45.31	48.61	46.07	2.87

For the most part, the two sets of data are fairly similar, the main exception being the very different 2030 projection for SO_2. This is the result of changes made in the latest projections to address Regulations that will control the sales of certain solid fuels in England, but which may result in fuels with higher sulphur content being used in place of coal.

Recent work has resulted in new projections to 2050 being added to SMT and so we need not comment further on data on trends from 2031 to 2050. Note however that those new projections in SMT have to be consistent with the SMT data for 2018-2030 and so do not have the much higher figures for SO_2 that are seen in the latest NAEI.

NFR 1B

This NFR category is only a key source of VOC and, in line with the proposed scope for this task, is not discussed further. For information, current emission estimates in SMT for the base year and 2030 are compared in Table 2.5 with values from the latest versions of the historical and projected NAEI.

Table 2.5 Emissions of NOx, SOx, NMVOC, NH_3 and $PM_{2.5}$ for NFR 1B

	Emissions in ktonnes				
	NO_X	$PM_{2.5}$	NMVOC	SO_2	NH_3
2018:					
SMT	2.02	1.15	148.70	2.20	0.19
NAEI	2.29	1.14	129.69	8.85	0.19
2030:					
SMT	0.90	0.88	93.20	0.44	0.18
NAEI	0.90	0.88	79.67	7.52	0.18

NFR 2A

This NFR category covers process-related emissions from the minerals sector and from construction, but not process emissions from cement or lime kilns since those are included with combustion emissions from the kilns and reported in 1A2. Current emission estimates in SMT for the 2018 base year and 2030 are compared in Table 2.6 with values from the latest versions of the historical and projected NAEI.

Table 2.6 Emissions of NOx, SOx, NMVOC, NH_3 and $PM_{2.5}$ for NFR 2A

	Emissions in ktonnes				
	NO_X	$PM_{2.5}$	NMVOC	SO_2	NH_3
2018:					
SMT	0.00	5.91	1.01	5.99	0.53
NAEI	0.00	5.42	1.01	5.99	0.52
2030:					
SMT	0.00	5.18	1.27	7.69	0.61
NAEI	0.00	4.75	1.38	7.09	0.46

NFR 2A is only a significant source for $PM_{2.5}$ and SO_2 (and is a more significant source of PM_{10}). Both the SMT and latest NAEI data are very similar, with no revisions of note.

As with NAEI projections for 1A2/1A4a/1A4c, those for 2A are inherently somewhat conservative since NAEI methods cannot always take full account of regulation of sources. For example, the methods for construction and quarrying use the same factors for all years (from international inventory guidance), even though regulation of these sectors may have had some impact on emissions.

EEP2019 provides information on trends in 2030-2040 but is largely limited to projections related to fuel use i.e. the various sub-divisions of NFR 1A1. It does contain a timeseries of growth indices for various economic sectors including:

- Construction sector, predicted to grow by just 3% between 2030 and 2040.
- Mineral products sector, predicted to grow by 23% between 2030 and 2040.

The reason for the strong predicted growth for the mineral products sector is unclear and this is also a broad sector covering processes with varying emission characteristics. Thus 23% growth in mineral products need not mean 23% growth in emissions from the sector – it depends what parts of the sector are growing. But clearly there is the potential for the flatlining of emissions from 2030 onwards in SMT to underestimate emissions for NFR 2A.

We have no information on trends in 2040-2050.

NFR 2B-2I

These categories cover process-related emissions from industry (except the minerals sector and construction, covered in 2A) and use of products, including those that contain organic solvents. Current emission estimates in SMT for the 2018 base year and 2030 are compared in Table 2.7 with values from the latest versions of the historical and projected NAEI.

Table 2.7 Emissions of NOx, SOx, NMVOC, NH_3 and $PM_{2.5}$ for NFR 2B-2I

	Emissions in ktonnes				
	NO_X	$PM_{2.5}$	NMVOC	SO_2	NH_3
2018:					
SMT	1.51	6.15	425.01	2.62	3.41
NAEI	5.46	8.52	443.44	11.31	3.42
2030:					
SMT	1.31	5.53	435.66	1.81	3.31
NAEI	4.24	6.94	444.94	9.05	3.72

Industrial processes are important sources of $PM_{2.5}$ and SO_2 and, combined with solvent use, the dominant source of NMVOC. The latest data for NO_X, $PM_{2.5}$ and SO_2 are significantly higher than those values in SMT, although the 2018 to 2030 trends are fairly similar. The higher figures in the latest data sets are mostly due to the inclusion of new estimates for paper production, although these estimates are highly uncertain and could be revised if further information becomes available. The NMVOC figures include a lot of differences in the detail, though totals are similar.

EEP2019 provides information on trends in 2030-2040 but is largely limited to projections related to fuel use i.e. the various sub-divisions of NFR 1A1. It does contain a time-series of growth indices for various economic sectors including:

- Chemical sector, no change between 2030 and 2040.
- Iron & steel sector, 15% decline between 2030 and 2040.
- Food & drink sector, 3% growth between 2030 and 2040.
- Non-ferrous metals, 15% decline between 2030 and 2040.
- Paper, printing & publishing, 14% decline between 2030 and 2040.
- Textiles, clothing, leather, footwear, 21% decline between 2030 and 2040.
- Other industries, growth by 8% between 2030 and 2040.

The estimates for 2B-2I cover a wide range of source-types but the declines predicted for sectors with significant emissions (metals, paper for example) and stagnation for chemicals and only small growth elsewhere suggests that flatlining emissions from 2030 onwards will overestimate emissions.

As with some other groups previously mentioned, NAEI projections tend to be somewhat conservative due either to use of methods that cannot fully reflect regulation, or a lack of data on the impact of regulation. Thus the 2030 emissions of NO_X, $PM_{2.5}$, SO_2 and NH_3 in particular could be too high, and the flatlining of emissions thereafter in SMT may also be conservative.

The very large emissions of NMVOC are mainly from whisky production and use of solvents in consumer products such as paint, aerosols & cosmetics. No regulations have been identified that would reduce emissions from these sources and indeed rising population means that emissions from consumer products are expected to continue to increase indefinitely. NMVOC emissions from industrial processes are often already well-regulated and the NAEI figures generally reflect this well so we think the flatlining of NMVOC emissions from 2030 onwards in SMT is not necessarily conservative and may actually underestimate emissions in 2050.

NFR 5

This NFR category is only a fairly small emission source of $PM_{2.5}$ and NH_3. However, in line with the proposed scope for this task, it is not discussed further. For information, current emission estimates in SMT for the 2018 base year and 2030 are compared in Table 2.8 with values from the latest versions of the historical and projected NAEI.

Table 2.8 Emissions of NOx, SOx, NMVOC, NH_3 and $PM_{2.5}$ for NFR 5

	Emissions in ktonnes				
	NO_X	$PM_{2.5}$	NMVOC	SO_2	NH_3
2018:					
SMT	1.44	3.57	6.58	0.59	8.20
NAEI	1.44	3.54	6.76	0.59	7.25
2030:					
SMT	1.44	3.66	6.15	0.60	8.59
NAEI	1.55	3.59	6.34	0.55	8.00

3. Overall Assessment of trends from 2030 onwards

Emissions can change over time due to changes in the level of the activity that causes the emission – such as changes in the quantity of fuel consumed, or changes in the production of some commodity. And emissions can change because of controls on the rate of emissions, for example the use of abatement to reduce emissions or changes to the way a fuel is burned, or a commodity produced, such that emissions are reduced. In other words, future emissions vary according to changes both in activity data and emission factors. Currently the NAEI produces emission projections to 2030 in line with international reporting under the NAEI contract, i.e. the NECR reduction commitments and before that the NECD. In the absence of readily available emission projections to 2050, the SMT has to date assumed that emissions can be flatlined beyond 2030. This was justified by the lack of information on both the likely changes in activity data, and changes in emission factors. And it is not unreasonable to assume little change in emission factors since these projections to 2050 represent a business as usual evolution of emissions, and there are likely to be few existing policies and measures that will deliver reductions after 2030 that can be quantified at this juncture. Much of the discussion in this paper therefore relates to the possibility of changes in activity levels between 2030 and 2050, and also the potential for existing projections to 2030 to be somewhat conservative already, due to the lack of data to fully model the impact of current policies and measures on emissions to 2030.

The NAEI projections rely heavily on the EEP published by BEIS each year. The latest version of this data sets covers the time period up to 2040 and contains population growth, GPD forecasts, projected fuel use across the economy as well as growth indices for certain industry sectors. Projected fuel data provide a good data source for modelling emissions from combustion/fuel related sources, ie the various sub-divisions of NFR 1A1, and NFR 1B. However, they are less reliable to accurately forecast projected emissions relating to certain industrial processes or the production and consumption of products (majority of emission reported within NFR2). Nonetheless, the latest EEP version does provide some information on how activity levels could change in the 2030-2040 decade, due to changes in activity/consumption/production. A few other datasets such as those from National Grid and OGA provide estimates of changes in activity to 2050. We suspect that many other projections may exist that could potentially be useful. Our existing projections work is based on use of EEP to ensure consistency with the projections reporting on the GHG side in line with international reporting requirements. Therefore, we do not normally need to seek other data, but in future, effort could be made to identify and collect other datasets which could complement EEP and be useful for extending projections for all sectors to 2050.

As previously discussed, the existing 2030 projections are somewhat conservative, particularly for NFR 1A2, 1A4a, 1A4c and parts of NFR 2. This is because of limitations in methods and data and these problems are often fairly intractable. Projections will probably always be conservative to some extent because the default approach is always to assume no reduction in emission factors unless we have evidence to suggest otherwise. It is unlikely that we will ever have a perfect knowledge of all things that will cause factors to reduce over time. In theory, the default approach could also lead to underestimation – since we could also be missing evidence that emission factors could increase. However, we believe it is reasonable to assume that factors will decrease over time more often than they will increase so overall the lack of sound evidence should mean conservative forecasts.

Table 3.1 indicates how likely we think that the flatlined emissions in SMT are over and/or underestimating emissions in 2031 to 2050. The assessment in Table 3.1 is split into two distinct time periods, 2031 to 2040 and 2041 to 2050 to account for the fact that the uncertainty of projected emissions estimated increases the further they are in the future. Given the availability of EEP data up to 2040, we consider the assessments for 2031-2040 are slightly less uncertainty than the assessments for 2041 to 2050. As already mentioned, we think it is important to start investigating the availability of projections to 2050. But as an interim measure, it might be the most sensible approach to vary emissions to 2040 in line with available activity data but then keep emissions constant from 2040 onwards.

Table 3.1 Summary of how likely flatlined emissions for 2031 to 2050 are an over and/or underestimation of expected emissions by main NFR code (red indicated an over/underestimation of expected future emissions, green represent a sensible representation of expected future emissions) with arrows indicating if emissions are more likely to be too high (down arrow), more likely to be too low (up arrow), or potentially too high or too low (both arrows) . Information is provided for non-RT sources.

NFR Code	Covering	NOx		$PM_{2.5}$		Comment on trend and uncertainty
		2031 - 2040	2041 - 2050	2031 - 2040	2041- 2050	
1A1a	Electricity supply industry	↑↓	↓	↑↓	↓	EEP has projections to 2040, National Grid Future Energy Forecasts provide data up to 2050. Projected fuel mix varies significantly across the different FES scenarios, in particular the contribution of fossil fuels to the overall fuel mix.
1A1b/c	Other energy industries (refineries, oil & gas production etc.)	↓	↓	↓	↓	EEP has projections to 2040 which suggest declining fuel use in oil & gas sector but unchanged consumption at refineries. Oil and Gas Authority (OGA) have projected oil & gas production to 2050, with production decreasing significantly over time but less certain if emissions will follow the exact same trend.
1A2/1A4a/1A4c	Industrial-scale combustion: industrial / public / commercial / agricultural sectors	↑↓	↑↓	↑↓	↑↓	EEP has projections to 2040 which suggest growth in fuel use in all these sectors. However, projections are conservative since NAEI methods cannot fully reflect impact of regulation. Unclear how conservative estimates are so unclear if 'better' projections would be higher or lower than current SMT ones.
1A3a,c,d,e	Off-road transport					Little to no information available on future fuel mix or demand for off road machineries in particular. We currently use the EEP growth rate indices for high level industry sectors to estimate the demand. Demand will remain high in line with construction projects. Technology of off-road mobile machineries is expected improve and as such reducing emissions but in absence of activity data it is not possible to model.

NFR Code	Covering	NOx		$PM_{2.5}$		Comment on trend and uncertainty
		2031 - 2040	2041 - 2050	2031 - 2040	2041- 2050	
1A4b	Residential combustion		↑↓	↑	↑↓	SMT updated with projections to 2050 though these are still consistent with the NAEI18 and EEP2018. Methodology changes in NAEI19 & EEP2019 would alter emissions somewhat. Trends in 2040 -2050 are more uncertain due to lack of data.
1B	Fugitive emissions from fuels					Minor NO_X / $PM_{2.5}$ source. Not reviewed in detail but latest NAEI figures are similar to those in SMT.
2A	Mineral processes and construction			↑	↑↓	NO_X emissions trivial. EEP suggests strong growth to 2040. Projections are, however, inherently somewhat conservative due to use of constant factors.
2B-2I	Other industrial processes and product use	↓	↓	↓	↓	Little to no information available for specific industrial processes although EEP provides top level industry growth indices out to 2040 which mostly predict declining output in key sectors. Projections are also inherently somewhat conservative.
5	Waste	↑	↑	↑	↑	Not reviewed in detail but latest NAEI figures are similar to those in SMT. Emissions from at least some of the NO_X / $PM_{2.5}$ sources in NFR5 could be expected to increase with a growing population (e.g. cremation), although this could be partly balanced by reductions due to increased control of emissions.
6A	Other (included in National Total for Entire Territory)					The sector contains various very small emission sources such as emissions from pets (predominately dogs, cats and horses), infant nappies, wild bird etc) with no meaningful impact on total emissions.

4. Sensitivity Assessment of Projections

The discussion so far has largely been limited to examining what alternative information we have related to emissions to 2040 and 2050 and how this differs from the flatlining in SMT. We have commented on some uncertainties such as the inherent conservativeness of the existing NAEI projections to 2030, but here we give some thought to the wider uncertainties.

Uncertainty in projections to 2050 will depend on uncertainties in three areas:

- Firstly, uncertainty in the underlying inventory methods. Emission estimates are calculated using emission factors and models that can be revised. In many cases, the same approach is appropriate across the entire timeseries so any revision will affect both the base year and emissions in future. Sources that were once considered trivial might become more significant due to changes in the methods, or big source may become less important. Revisions of this kind are often individually small but not always, and revisions can sometimes have a dramatic impact on inventories. For example, NMVOC emission estimates have in recent years been added for agriculture and for coal mining and these significantly increased historical emission totals. Many of the estimation methods used in the NAEI are subject to considerable uncertainty and there is a high chance of future revisions in methods.
- Secondly, there is uncertainty over trends in activity. The NAEI projections rely heavily on activity trends that are derived from EEP. Though there tends to be relatively small differences between each successive version of EEP, over a longer period there can be large differences. For example, EEP versions from some years ago assumed significant quantities of coal being burnt in power stations even in 2030, whereas EEP now assumes all coal-fired stations close before 2030. The EEP dataset we get is just a set of best estimates, but the assumptions and data used to generate EEP are all uncertain. The changes over the years in EEP show how the best estimates have changed over time but overall uncertainty will be greater still. BEIS do not routinely provide any quantification of uncertainty, although they have occasionally provided alternative scenarios in the past (which will be unlikely to represent the full range of possible futures). Uncertainty in activity trends are likely to increase, the further into the future one of trying to forecast, and projections for 2050 are likely to be very uncertain.
- Thirdly, there is uncertainty over trends in emission factors. The NAEI projections are inherently quite conservative in this area and likely to overestimate emission factors even in 2030. There is also uncertainty over these trends – the level of impact that regulation will have. The conservativeness and uncertainty also apply to 2050, however because SMT baseline is based on business as usual forecasts, we suspect that there is often not that much more uncertainty in 2050 than in 2030 (at least compared with the uncertainty related to activity levels). This is because there aren't many policies and measures currently planned that would be expected to have significant impacts on emission factors in the 2030s and 2040s, so the assumption that factors will remain constant after 2030 is likely to be a reasonable default approach.

Table 4.1 and Table 4.2 show how NAEI projections for 2030 have changed over the past seven submissions. Some of the changes seen are due to changes in methodology e.g. the step-change for PM2.5 from 1A4 between the 2013 and 2014 submissions and the addition of NOx emissions for the various sub-divisions of NFR3 from the 2016 submission onwards. Other fluctuations may reflect changes in EEP over time – for example, the changes in NOX from 1A2 are at least partly due to that. Recent submissions have incorporated improvements to the projections to make them less conservative, although the changes are generally small enough that it does show up clearly in the national totals. It is also worth noting that Table 4.1 and Table 4.2 present data at a highly aggregated level (as internationally reported) and therefore aggregate a lot of changes that would be seen in the detail. The tabulated data though do give some idea of the changes that can occur over a period of years and from that provide some sense of the uncertainty even when projecting only to 2030.

Table 4.1 Summary of projected 2030 NOx emissions submitted between 2013 (naei2013 baseline) and 2021 (NAEI2019 baseline)

	Projected emissions in 2030 (ktonnes)						
	NOx						
NFR Code	**2013 BL**	**2014 BL**	**2015BL**	**2016 BL**	**2017 BL**	**2018 BL**	**2019 BL**
1A1	115.02	137.99	122.14	121.61	130.59	116.17	115.44
1A2	136.33	158.57	144.81	127.95	128.52	129.24	143.97
1A3b	169.12	113.24	113.35	116.22	107.20	79.54	83.76
1A3bi	120.23	71.14	67.87	66.71	63.55	52.02	55.16
1A3bii	38.26	31.12	37.82	42.05	36.93	21.27	21.87
1A3biii	10.33	10.68	7.17	6.93	6.26	6.12	6.60
1A3biv	0.31	0.30	0.49	0.53	0.46	0.12	0.13
1A3bv	NA	NA	NA	NA	NA	NA	NA
1A3bvi	NA	NA	NA	NA	NA	NA	NA
1A3bvii	NA	NA	NA	NA	NA	NA	NA
1A3a,c,d,e	81.65	70.63	69.16	103.77	100.91	106.76	101.37
1A4	58.86	65.58	62.73	72.58	77.35	81.67	82.70
1A5	19.84	14.61	14.39	11.14	11.67	12.83	14.09
1B	1.39	1.40	1.38	1.55	1.51	0.90	0.90
2A,B,C,H,I,J,K,L	1.82	1.89	1.85	1.21	1.58	1.27	4.20
2D,2G	NA	NA	NA	0.04	0.04	0.05	0.04
3B	NA	NE	NE	1.59	1.51	1.56	1.50
3B1a	NA	NE	NE	0.19	0.20	0.19	0.20
3B1b	NA	NE	NE	1.00	0.93	0.93	0.90
3B2	NA	NE	NE	0.02	0.02	0.02	0.02
3B3	NA	NE	NE	0.18	0.17	0.19	0.19
3B4a	NA	NE	NE	NO	NO	NO	NO
3B4d	NA	NE	NE	0.00	0.00	0.00	0.00
3B4e	NA	NE	NE	0.03	0.02	0.02	0.02
3B4f	NA	NE	NE	0.00	IE	IE	IE
3B4g	NA	NE	NE	0.17	0.18	0.19	0.18
3B4h	NA	NE	NE	0.00	0.00	0.00	0.00
3D	NA	NE	NE	5.49	24.90	24.61	30.89
3F,I	NA	NE	NE	0.00	NA	NA	NA
5	1.50	1.39	1.35	1.45	1.55	1.44	1.55
6A	0.16	0.14	0.14	0.15	0.38	0.38	0.37
TOTAL	**585.70**	**565.45**	**531.31**	**564.73**	**587.72**	**556.41**	**580.79**

Table 4.2 Summary of projected 2030 $PM_{2.5}$ emissions submitted between 2015 (naei2013 baseline) and 2021 (NAEI2019 baseline)

	Projected emissions in 2030 (ktonnes)						
	$PM_{2.5}$						
NFR Code	**2013 BL**	**2014 BL**	**2015 BL**	**2016 BL**	**2017 BL**	**2018 BL**	**2019 BL**
1A1	2.47	2.04	1.96	2.56	3.17	2.56	1.96
1A2	11.86	12.96	18.25	16.54	16.04	14.78	18.97
1A3b	10.58	10.42	10.33	10.50	9.88	10.11	10.94
1A3bi	0.61	0.61	0.52	0.77	0.70	0.73	0.79
1A3bii	0.23	0.13	0.09	0.12	0.10	0.16	0.16
1A3biii	0.10	0.11	0.12	0.13	0.12	0.12	0.13
1A3biv	0.01	0.01	0.01	0.03	0.02	0.02	0.03
1A3bv	NA	NA	NA	NA	NA	NA	NA
1A3bvi	6.39	6.34	6.36	6.26	5.91	6.01	6.53
1A3bvii	3.24	3.22	3.22	3.20	3.03	3.07	3.31
1A3a,c,d,e	2.81	2.13	2.10	2.54	2.62	2.21	2.29
1A4	26.78	47.07	44.77	44.26	43.43	43.49	47.77
1A5	0.52	0.23	0.23	0.19	0.19	0.20	0.22
1B	0.49	1.21	1.17	1.05	1.03	0.88	0.88
2A,B,C,H,I,J,K,L	7.64	7.98	7.98	8.65	8.52	8.91	10.04
2D,2G	1.84	1.97	2.29	5.08	1.79	1.80	1.65
3B	1.82	2.94	3.14	3.50	2.00	2.03	2.00
3B1a	0.19	0.64	1.32	0.73	0.57	0.56	0.61
3B1b	0.23	0.44	0.98	1.40	0.73	0.71	0.71
3B2	NA	0.17	0.17	0.67	0.03	0.03	0.03
3B3	0.26	0.29	0.03	0.03	0.02	0.03	0.03
3B4a	NA	NO	NO	NO	NO	NO	NO
3B4d	NA	0.00	0.00	0.00	0.00	0.00	0.00
3B4e	NA	0.04	0.04	0.04	0.01	0.01	0.01
3B4f	NA	NA	NA	NA	IE	IE	IE
3B4g	1.15	1.36	0.61	0.63	0.64	0.68	0.61
3B4h	NA	0.00	0.00	0.00	0.00	0.00	0.00
3D	NA	0.65	0.63	0.64	0.75	0.76	0.74
3F,I	0.31	NA	NA	NA	NA	NA	NA
5	2.02	2.11	1.73	3.81	3.76	3.66	3.59
6A	2.27	2.14	2.14	0.10	0.03	0.03	0.03
TOTAL	**71.40**	**93.86**	**96.72**	**99.42**	**93.20**	**91.42**	**101.08**

5. Conclusions and recommendations

The historical values for 2018 and projections to 2030 in SMT sometimes differ significantly to what is in the latest NAEI datasets. Therefore, to ensure the emission results in the SMT are consistent with the latest evidence and science, it is advisable to update the underlying NAEI dataset with the latest version if and when it becomes available, for both the historic and projected data.

Emission projections are updated and improved each year, driven by improvements and/or changes in the underlying historic NAEI, by updates in the EEP and other projections, and the collection of new data on changes to emission factors in future. Currently, we do not routinely collect data that explicitly address emissions as far into the future as 2050. However, the revisions and improvements made to historical data and projections to 2030 do also have implications for emission estimates for 2050.

We currently collect activity data projections that tend to be available for N + 20 years (N being the latest calendar year). So, for example, the latest EEP data extends to 2040. Currently there is very little information available to project beyond 2040. With increasing need to model emissions out to 2050, we advise that it is essential to start collecting an evidence base that could be used in SMT and which could help ensure consistency across government forecasting tools. The priority here is the collection of detailed activity data projections, to complement data in EEP and the DfT projections already used in the NAEI projections. In particular, good projections for non-energy sources are needed. We believe that suitable projections out to 2050 or beyond may already be available but not yet accessible to us.

We also recommend further research into future changes in emission factors, for instance due to the use of improved technologies over time. Care would need to be taken that these future factors were still business as usual, however, and just represented reductions that occur in the absence of further policies and measures.