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1 Overview

National air pollutant emission projections are used nationally and internationally to assess progress towards emission reduction targets and to provide input into future health and ecosystem impact modelling. The activities involved in estimating projections also provide a valuable contribution to establishing efficient and effective policies and measures, through the development of an understanding of sources, economic drivers and the effectiveness of technologies and controls.

There are a number of guidance documents available for estimating projected emissions of greenhouse gases (GHGs) (e.g. UNFCCC, 2004, 2016), and the European Commission's Directorate-General for Climate Action (DG CLIMA) has published comprehensive guidance on the development of GHG projection guidelines (DG CLIMA, 2012). For air pollutants, the original recommendations of the Clean Air for Europe programme (CAFE, 2006) and, more recently, the guidance published supporting development of the national air pollution control programme (EC, 2017; EC, 2019) are useful sources of information. An earlier EEA report also discusses methodological aspects of past GHG and air pollutant projection reporting (EEA, 2015).

This chapter has been compiled based on these documents and on information from a range of institutions. Where possible, additional documents have been identified and referenced, so that users can find more detailed information. The work of the expert panel on projections of the Task Force on Emission Inventories and Projections (TFEIP) of the United Nations Economic Commission for Europe (UNECE) has also informed the development of this chapter.

Projections are a tool to assess what might happen if countries take (or had taken) no action ('without measures' (WOM)), what might be achieved with actions that countries are committed to ('with existing measures' (WEM) or sometimes simply known as 'with measures' (WM)) and what else could be done ('with additional measures' (WAM)). These three scenarios should be assessed using the same set of exogenous economic projections. Projected estimates will therefore need to be able to reflect the impacts of relevant policies and measures to assess whether or not the policies in place are far reaching enough for emission targets to be met.

However, emission projections are inherently much less certain than the historical emission inventory, since they require additional assumptions about future growth in activity (e.g. production, transport, population) and technology uptake.

This chapter is designed to provide general guidance on projecting emissions to accompany national inventory reporting under the UNECE Convention on Long-range Transboundary Air Pollution (LRTAP Convention) (1), the EU's National Emission Ceilings (NEC) Directive (EU, 2016) and reporting of the national air pollution control programmes (Article 6 of the NEC Directive).

The material is intended both for countries establishing projected emission estimates for the first time and for countries with established projection approaches. This chapter covers:

- the terminology used in projections and projections reporting;
- the methods used to project emissions;
- guidance on tackling common problems associated with gathering appropriate data on emission factors and activities and ensuring consistency with historical emission inventories.

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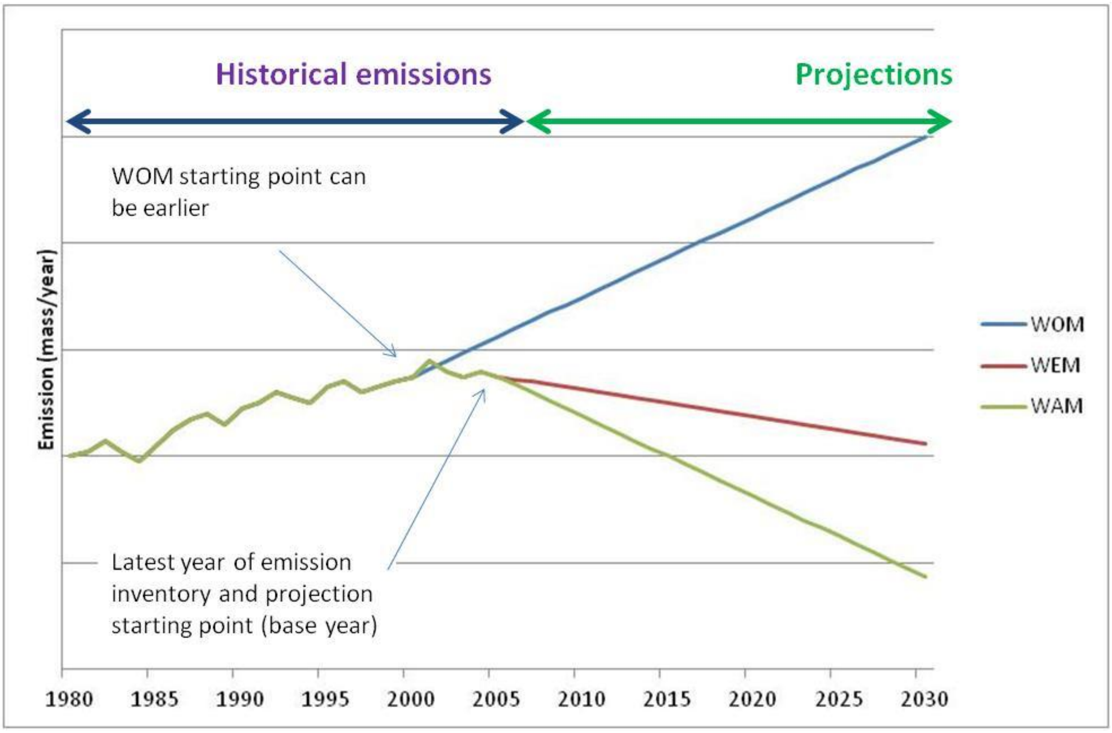
(1) Definitions concerning the reporting of projections under the LRTAP Convention are provided in UNECE (2014).

Sector-specific projection issues are described in Annex 1 of this chapter; detailed information on historical inventory compilation can be found in the sector-specific chapters of this Guidebook.

2 Terminology

Figure 2-1 illustrates the terminology used when projecting emissions. Most projections will include a number of different estimates (known as scenarios) comprising different combinations of assumptions. These assumptions will relate to changes in activity levels (e.g. economic growth or decline) and the impacts of new technologies, techniques and practices. These may have been introduced as local, national or international efforts (known as policies and measures (2)) designed to reduce emissions, ranging from emission controls for vehicles and industrial plants to incentives for cleaner fuels and technologies or changing behaviour.

Figure 2-1 Emission projections



The WOM scenario is not required for international emission projections reporting. Therefore, there are two scenarios (WM and WAM) that are commonly used for reporting projected pollutant emissions and emission reduction potentials and this terminology should be used where appropriate. This terminology is in line with that described in the guidelines for reporting emissions and projections data under the LRTAP Convention (UNECE, 2014) and, for GHGs, the EU Regulation on a mechanism for monitoring and reporting GHG emissions (EU, 2013) and the requirements for

(2) Policies and measures can be laws, agreements or incentives to address (reduce) certain polluting activities or to enforce or encourage abatement or clean technology. Measures can be interrelated, such as energy efficiency and emissions trading, where emission reductions can result from addressing both.

reporting of GHG projections to the United Nations Framework Convention on Climate Change (UNFCCC) as defined in a set of guidelines (UNFCCC, 2016).

When defining the three scenarios, it is important to consider which policies and measures to include. 'Planned' policies and measures are those that are not yet written into any formal legislation, 'adopted' policies and measures are those that have been agreed and written into legislation and 'implemented' policies and measures are those in relation to which action has been, or is being, taken, often over several years.

Without measures

A WOM projection excludes all policies and measures implemented, adopted or planned after the year chosen as the starting point for this projection (UNFCCC, 2016, paragraph 26). For example, in Figure 2-1, the starting year for the WOM scenario is 2000, even though the latest inventory year is much later than that. This scenario was formerly known as 'business as usual'.

With existing measures (WEM/WM)

A WEM (or WM) projection must encompass currently implemented and adopted policies and measures (UNFCCC, 2016, paragraph 26).

Implemented policies and measures are, in accordance with UNFCCC (2016, paragraph 11), those for which one or more of the following applies:

- national legislation is in force;
- one or more voluntary agreements have been established;
- financial resources have been allocated;
- human resources have been mobilised.

Adopted policies and measures are those for which an official government decision has been made and there is a clear commitment to proceed with implementation (UNFCCC, 2016, paragraph 11).

As identified in the reporting guidelines (see footnote ([1])) for emission projections, Member States (MSs) should provide a set of WEM/WM projections and, where relevant (i.e. where these projections are not compliant with the national emission reduction targets) a WAM projection.

With additional measures

WAM scenarios include planned policies and measures (UNFCCC, 2016, paragraph 26). Planned policies and measures are options that are under discussion and have a realistic chance of being adopted and implemented in future (UNFCCC, 2016, paragraph 11).

As with WEM scenarios, it is good practice for the starting point of WAM scenarios to be the most recent inventory year. However, officially, the starting point of the projections can be as old as the latest inventory year x – 3 (EU, 2016).

> **Note:** In some cases, other (and sometimes conflicting) terms and interpretations are used (e.g. 'business as usual' is sometimes used by countries to refer to the 'with existing measures' scenario). It is good practice when documenting scenarios to clearly refer to the WM and WAM scenario terminology to be clear on what the projection represents.

In addition to these three terms, the following terms are also sometimes used.

Maximum feasible reduction
Maximum feasible reduction is a variant on the WAM scenario that includes the furthest reaching action that can be achieved through all possible technical and non-technical measures. Sometimes, maximum feasible non-technical reduction (MFNTR) and maximum feasible technical reduction (MFTR) are presented separately.

MFNTR includes measures such as changes in economic drivers (e.g. fuel price rises) and measures aimed at fuel switching and behavioural change (e.g. awareness-raising). MFTR includes measures such as full application of abatement and control or the encouragement of new technologies.

Current reduction plans
A current reduction plan is not a scenario but a politically determined intention to reach a specific national emission reduction target (or 'emission ceiling'), as defined in the various protocols of the LRTAP Convention. It should include a strategy of how the reduction will be achieved. However, such an emission reduction target is not regarded as an emission projection. It may have originated from a particular scenario estimated at the time of setting targets, which has now been superseded.

Box 2-1 Cost-effectiveness

Cost-effectiveness is one type of policy tool used to prioritise actions. A tonne of a pollutant abated per unit cost is usually used as the basis on which decisions are made, but, strictly speaking, cost-effectiveness should be judged on an impact basis, such as health effects reduced per unit cost. To do this, the costs of implementing measures should be calculated along with the achieved reductions and these should be used to prioritise actions. The marginal cost curve in terms of a plot of total quantity of pollution avoided against the marginal cost of reduction (in unit currency/tonne) can form the basis for a consistent calculation of cost-effectiveness. A number of past studies have developed methods for assessing the costs of environmental protection measures that can be applied to emissions reduction estimates for particular measures. In some cases, regional considerations and health impact assessments may override the natural order of measures presented in any cost curve.

3 Planning

The first step is to undertake thorough planning of the processes involved. It is important to design a system that is flexible enough to deal with varying data sources. The following are some initial considerations:

- **Institutional arrangements:** these are the arrangements and processes between government and non-government organisations that enable continuous collection and reporting of sector-based data relevant for GHG and air pollutant inventories and projections. There are several models that can be used — the projections work can be centralised within a government department, ministry or agency or it can be spread across several government departments, ministries or agencies or external organisations. The most common approach is to have the projections work done within the team that compiled the historical emission inventories (as that team will already have a good technical understanding of emissions). However, complications can arise from the fact that historical emissions are considered technical work, and emission projections introduce political issues. Therefore, an environment agency might lead the compilation of the historical emissions, but it may be considered that emission projections should be the responsibility of the environment ministry.

- **Resources and expertise:** assessing a model to determine the institutional arrangements will need to consider where existing expertise and knowledge is placed within a given country and how much time it will take to compile emission projections and the resources available. From the outset, it is sensible to have a target for the resources needed to deliver emission projections to a good quality (including resources for continuous improvement). It is important to include resources for personnel outside the core inventory team, such as data providers.
- **Data:** the approach used for estimating emission projections is to combine the historical emissions inventory with information on how the existing emissions will change in future years.
- **Historical emissions inventory:** it is particularly difficult to show the impact of policies on future emissions if the historical inventory uses calculations that are too simple to allow these impacts to become visible. Therefore, the quality and detail of the existing historical emissions inventory is important and, often, it is the emission projections work that drives improvements in the historical inventory.
- **Projected data:** projected activity data (such as projected fuel combustion from power stations and the road transport sector) are often found in government strategies and plans. There is a large variation from country to country on the extent to which 'official' projections data are available. Without these data, it is necessary to make best estimates and draw on expert judgement. People are often reluctant to offer expert judgement because of the political nature of emission projections, but this is almost always required to ensure completeness in the emission projections. It is important to be open about the generally high levels of uncertainty in emission projections.

4 Institutional arrangements

The aim is not just to establish a 'home' for the projections work but to secure adequate resources and long-term inputs from other institutes/organisations.

There are many different organisations that are involved in emission projections, fulfilling different roles. Compared with compiling historical emission estimates, work on emission projections also needs to include input from policymakers. It is this need for technical knowledge and understanding about emissions combined with an understanding of policy issues that makes it particularly complicated to decide who should 'own' the emission projections work.

Box 3-1 Importance of establishing institutional arrangements

A common mistake is to underestimate the importance of setting up institutional arrangements. If these are not put in place, the resulting work on projections is often under-resourced, of poor quality (because enough data cannot be accessed) and inefficient (because it is not aligned with other relevant statistics, e.g. GHG emission projections). Furthermore, it can often be difficult to change institutional arrangements that are not delivering well.

Establishing effective institutional arrangements can take a long time. This investment is important, however, to ensure that the work on projections can continue and develop in the long term, not least because of the value they can bring for air pollutant action planning and decision-making on policies and measures.

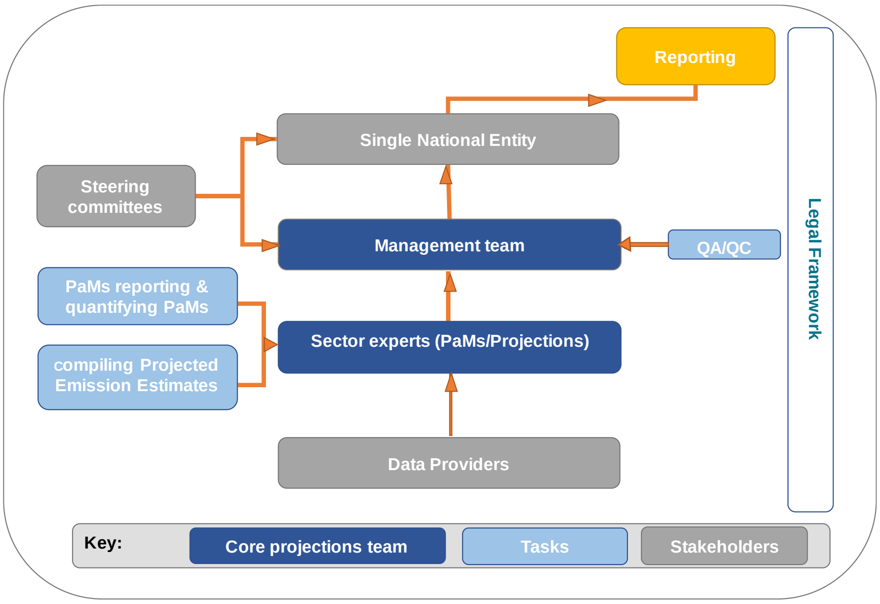
There are many different models that are used across MSs. Some countries have most of the work undertaken by the same team that compiled the historical emission inventory. Others have the projections work led and undertaken by their environment ministry, although the historical inventory might have been compiled by another party (e.g. the environment agency). However the responsibilities are arranged, it is of fundamental importance to have effective two-way links between the team doing the emission projections work and those providing policy and technical information to them.

4.1 General model for institutional arrangements

The detail of the institutional arrangements will need to be tailored to national circumstances and the existing set-up for the historical emission inventory and GHG emission projections should play a major part in establishing the model for emission projections.

Irrespective of whether the work is led within a ministry, a government agency, academia or an external organisation, there are several core functions that need to be set up within the model. An overview of these core functions and how they relate to each other is shown in Figure 4-1. This figure shows the key tasks involved, the stakeholders (data providers, steering committees and the single national entity, with the latter being ultimately responsible for reporting the air pollutant projections) and the core projections team, which comprises sector experts and the management committee, who, as a team, are responsible for coordinating the production of the estimates.

Figure 4-1 Core functions associated with air pollutant projections reporting



Note: PaMs, policies and measures; QA/QC, quality assurance and control.

4.2 Cross-cutting issues

GHG emission projections are likely to be more developed than air pollutant projections and this can bring substantial benefits to air pollutant work. In the same way that it is important to ensure consistency with the historical estimates, it is important to ensure consistency with the GHG projections. There are several dimensions to this:

- The data and assumptions used to underpin the air pollutant projections in the WM scenario should be consistent with the GHG emission projections. A specific aspect of this is taking into account the impact on air pollutant emissions of GHG-specific policies. Some will be simple to include, such as reduced fuel use resulting from improved fuel efficiencies in modern combustion equipment and better insulation in the residential sector. However, some will have rather more indirect consequences for air pollutants and possibly even negative impacts (e.g. fuel switching from gas to biomass).

- It is not just the WM emission projections that will need to be consistent with GHG projections; the data and assumptions that underpin new policy formation must also align with GHG projections. When considering ways of controlling future emissions of air pollutants, it is important to consider other co-benefits and potential trade-offs, for example the impact on GHG emissions.

- It is obvious that there is a need for extensive discussion and liaison between the teams compiling the GHG and air pollutant projections. If the work is being undertaken in different teams, or even by different ministries, efforts will be needed to ensure that the results are fully consistent.

In much the same way that the air pollutant projections need to be consistent with the GHG emission projections, it is also important to be consistent with sector plans and strategies in other government departments. This is usually ensured by securing the latest information from other ministries and departments and by understanding the data and assumptions that are included in sector plans and strategies. It will also be important to have a good understanding of current thinking in these ministries and departments, which may not be published in the public domain. In this way, it is possible to take a more joined up approach to decision-making.

4.3 Steering committee

As explained above, there are many different organisations directly or indirectly involved in compiling emission projections. It is therefore essential to have strong links across ministries to ensure access to data and expertise and, in particular, information on sector plans and strategies. There will be examples of policies and measures that provide benefits in one area but disbenefits in another. It is important to have a forum for openly discussing how departments, sometimes with different interests, can work together in a collaborative way.

An added benefit of this level of coordination and cooperation is that it allows peer review and discussion of improvements that are joined up across the different departments and policy areas. It is generally not possible to convince data providers in other government departments to improve the information that they are able to send to the inventory/projections team without this type of high-level cooperation to oversee activities and drive improvements.

4.4 Management team

In a similar way to that defined in best practice for historical emission inventories, roles need to be defined for managing the compilation of emission projections. This includes tasks such as:

- ensuring sector experts undertake their work to a given timetable and to agreed quality standards;

- compiling contributions from data providers and sector experts to create complete data sets on emission projections;

- putting in place and delivering a programme of quality assurance and control (QA/QC) (e.g. running quality checks as needed);

- designing and implementing a programme of continuous improvement — this may relate to improvements outside the sector experts/core projections compilation team.

The main difference from the tasks that are routinely done for the historical emission inventory is that there needs to be management of the input from policymakers. This will need to recognise that some decisions about policy implementation may be influenced by political decisions, rather than being completely based on technical information. For example, a government may decide to support the continued use of cal in the residential sector for reasons of fuel security and/or fuel poverty, even if there are clear environmental and cost benefits of supporting fuel switching.

4.5 Sector experts and data providers

The issues at stake for projections in relation to sector expertise and data provision are generally the same as those for historical emission inventories, the main differences being the addition of information that relates to future years and the need to incorporate information from policymakers.

4.5.1 Activity data

The more well-established activity data sets are usually available as estimates for future years. For example, it would be unusual for estimates of fuel use (in the form of national energy balance tables) and livestock numbers to be unavailable for future years. Similarly, population and gross domestic product (GDP) data are generally available for future years and can be used as surrogate data for estimating changes in other sectors. Further details on when the use of these indicators is reasonable is provided in the annexes.

The ease with which the impact on activity data of specific policies and measures can be quantified is very variable. Some policies will provide the information directly (e.g. improved fuel efficiency in power stations). Other policies and measures are more challenging (e.g. the modal shift from road vehicles to cycling that results from investment in making the road infrastructure safer for cyclists).

4.5.2 Emission factors

It is often challenging to estimate how emission factors may change in future years. There can be large step changes for some sources, such as power stations adding abatement equipment or improving the efficiency with which they are operated. Other emission factors will change gradually with time (e.g. nitrogen excretion from livestock). In many cases, there will be no data that are recognised as a 'formal' national data set. Where this is the case, expert judgement will be needed about whether the emission factor should be kept constant with time, increased or decreased with surrogate data or changed in some other way.

There is often a reluctance among experts to provide opinions that will be then used in national emission projections, because they may feel that this leaves them open to criticism. However, this is necessary to ensure a complete and more accurate emission projection. The important point to remember is that a national independent expert's estimate may well be the best information that is available. Their view will usually be better than using information from another country or international defaults. The key point is to interpret their views and convert that into something that is quantified so that it can be included in the projections.

5 Methodological choice

The starting point for developing projections should be the historical emission inventory. This gives confidence to the projections, as the inventory will have been developed following the sectoral guidance in the EMEP/EEA Guidebook and it is likely to have been subject to the LRTAP Convention/NEC Directive review process.

Ensuring that processes are in place is recommended to make it as easy as possible to update the projection calculations when new historical emission estimates become available. This can be achieved through the following activities:

Ensure the calculation spreadsheets for the projections refer to the data from the historical emission inventory. These spreadsheets can be constructed in such a way that, when new historical emissions data are added, there is no need for any significant reworking of the projection calculations (assuming that there is no change in the format of the historical data).

Identify clearly the years to which policies and measures are applicable and create automatic lookups to integrate them within the calculations. This ensures that rearranging timelines is not necessary when the base year of the projection estimates changes.

Arrange a brief (annual) review of projections input data at the same time as the historical inventory compilation. This ensures that the most recent version of the emission projections can be aligned with the most recent version of the historical emissions (even if the emission projections are themselves not reported under any international conventions or legislation).

Emission projections are, as with emission inventories, a function of activity data combined with an emission factor. However, with projections, a number of elements that make up the activity data and emission factors cannot be measured or counted and have to be estimated or modelled using assumptions about future activities, including behavioural or economic impacts and future emission factors.

5.1 Future activity

Future activity assumptions are based on a range of data sets, including projections of economic growth (GDP), industrial growth, population growth, changes in land use patterns and demand for transport. Energy models often combine these basic growth factors with energy price information to estimate energy demand by sector and fuel. These models can be used as a core data set as long as the assumptions underpinning them are consistent with national economic strategies, policies and measures.

It is key that there is consistency between national GHG emission projections and air pollutant emission projections and therefore the same official national activity projections should be used for both data sets.

5.2 Future emission factors

Future emission factors should reflect technological advances, environmental regulations, deterioration in operating conditions and any expected changes in fuel formulations. Rates of penetration of new technologies and/or controls are important in developing the right sectoral emission factors for any particular projection year.

It is good practice for a graded approach (3) to be used when projecting emissions, as indicated in Figure 5-1. Key categories (4) or sources where changes in technology or controls are expected to be significant should be estimated using grade 2 or 3 methods. When national models are used, they

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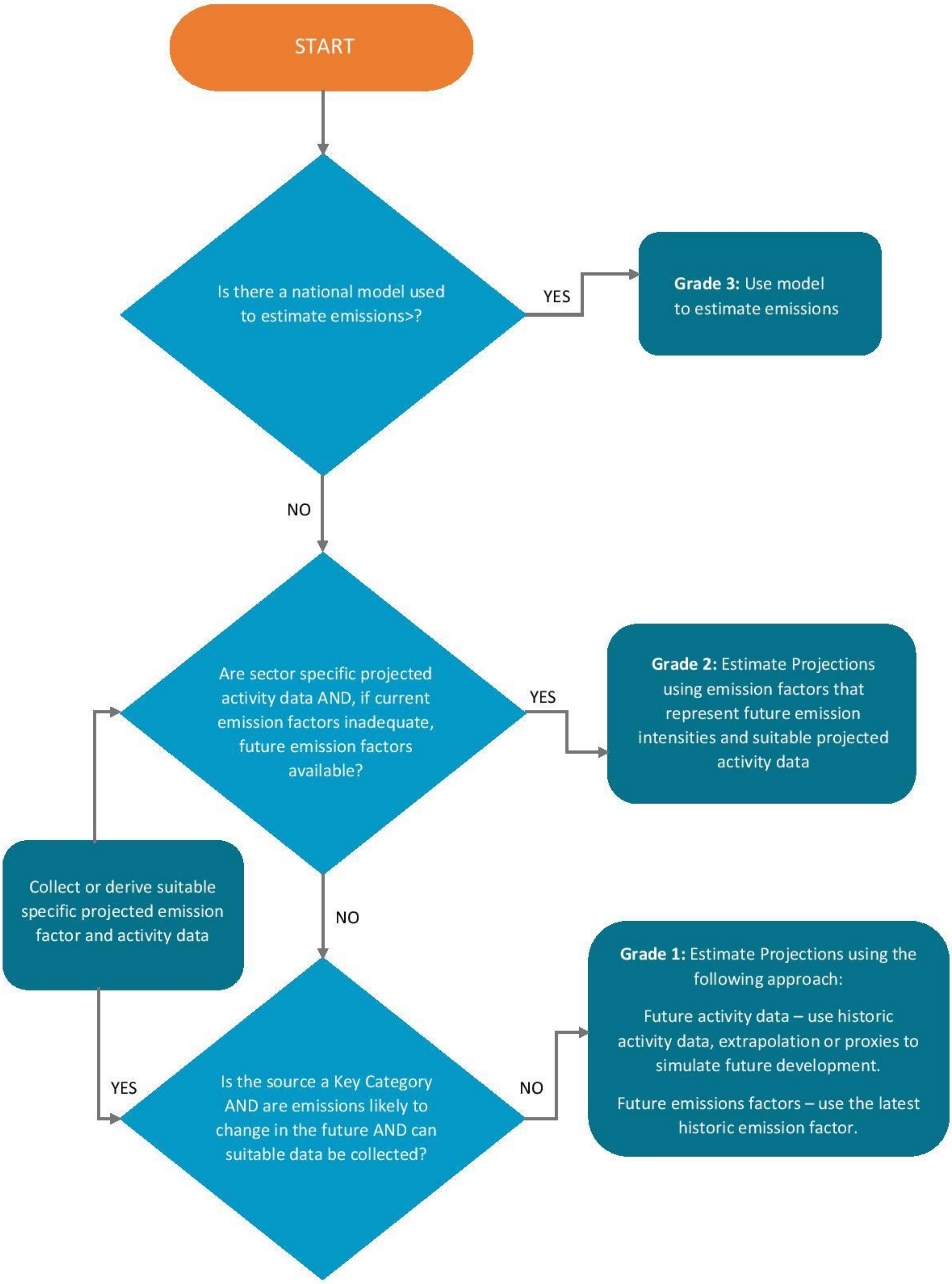
(3) With historical inventories, the different levels of sophistication are referred to as 'tiers'. For projections, the term 'grade' is used. This is consistent with the GHG projection terminology.

(4) A trend key category analysis will be particularly important for assessing key categories in projections (see the general guidance chapters in the EMEP/EEA Guidebook: Chapter 2, 'Key category analysis and methodological choice').

must incorporate underlying activity/energy data that are consistent with other relevant projected data sets and it must be ensured that relevant policies and measures are incorporated appropriately.

Figure 5-1 Decision tree showing the recommended approach for developing emission projections



5.2.1 Grade 3

Grade 3 projections use complex country-specific models to provide emission projections, taking account of a number of complex variables and parameters. However, these models must use input data that are consistent with national economic, energy and activity projections used elsewhere in the projected emission estimates. For example, a road traffic model needs to reconcile vehicle-kilometres and vehicle fuel efficiency with an energy model based on energy demand to provide a consistent national picture of vehicle emissions.

5.2.2 Grade 2

Grade 2 projections would be expected to take account of future activity changes for the sector based on national activity projections and, where appropriate (when measures are applied to a source), take account of future changes to emission factors. Expect to stratify your source category to apply the appropriate new technology or control factors to sub-sectors. This can be done by applying the detailed equations presented in sub-section 5.3, 'Formulae'.

5.2.3 Grade 1

Grade 1 projection methods can be applied to non-key categories and sources that are not expected to have future measures applied. Grade 1 projections will assume zero growth rates and use extrapolation techniques or proxies to predict future activity levels. A proxy is an indicative measure that does not have a direct causal relationship with the parameter or variable under consideration but which nevertheless provides an indicative measure. For this to be the case, the proxy must have a close correlation with the inferred value. Examples include projected population and GDP data. For emission factors for future years, it is likely that the latest year's historical emission factor will be used.

5.3 Formulae

The following general formula for projecting emissions for each source is based on projecting forward an existing historical emission inventory (5). The basic function can be used for both grade 1 and grade 2 methods and involves two key elements (the activity growth factor and the future emission factor) and will need to be applied in varying forms of complexity depending on the need to incorporate future technologies and controls.

The simplest form is:

$$E_n = \left(AD_s * GF_n\right) * (EF_n) \quad (1)$$

Future activity rate	Future emission factor

where:

E_n = the source emission calculated for the projected year n;

AD_s = the activity data for a historical year chosen as the starting year for the projection;

GF_n = the growth factor for the activity from the starting year to the projected year n;

(5) This ensures that the emission projection is consistent with the historic emissions inventory.

EF_n	=	the emission factor appropriate for the future emission rate of the source as a whole in year *n*.

When no changes are expected to the emission factor EFn or when the source is not a key category, EFn can be set to the latest historical emission factor. When a source responds to a simple global measure (e.g. a change in the sulphur content of the fuel), EFn can simply be applied to the whole sector. However, when a policy or measure applied to a source is complex and has an incremental effect on the overall sector's emission performance, or contains a number of different technologies or controls, the following equation will be needed to derive an appropriate national average factor (EFn) that takes account of the penetration of that technology or control:

$$EF_n = \frac{\sum_{t=1..p} EF_t * AD_t}{AD_n} \qquad (2)$$

where:

EF_n	=	the emission factor appropriate for the source as a whole in year *n*;
EF_t	=	the emission factor for a sub-set of the source using a specific technology or control;
AD_t	=	the projected activity data (consumption/production) for a particular technology or control within a source;
p	=	the total number of technologies;
AD_n	=	the projected activity for the whole source in year *n* (= $AD_s \times GF_n$).

$$AD_n = \sum_{t=1..p} AD_t$$

New activity sources will have to be treated separately. Section 5 of this chapter provides further information on the activities necessary to compile emission projections in this case.

In some complex detailed sectors, such as the power generation sector, there can be an interaction between the emission factors assumed for pollutant control technologies and the projected activity data. For example, in electricity generation, the underlying activity data may be future electricity demand. The energy production of the power sector must be consistent with the electricity demand and the efficiency of the future mix of power stations. However, the control measures applied (e.g. flue gas desulphurisation (FGD), selective catalytic reduction (SCR), carbon capture and storage) will affect the efficiency of the power stations and hence fuel consumption. Thus, the assumed mix of emission factors affects the fuel consumption data. In such cases for grade 3 methods, it will be important to use the assumed mix of abatement technologies as an input to the energy production model used to predict energy consumption in the sector.

5.4 Understanding available technologies

When considering grade 2 or 3 methods, the details of current technologies and controls and how this affects emission factors should be taken into account. Technology-specific emission factors can be found in the individual sectoral chapters of this Guidebook. However, emission factors for future technologies that have not been introduced may not yet be available. Suitable data may be available from national test measurement activities, indicated as limit levels in draft legislation, or from industry, from best available technique reference documents (BREFs) that provide details of possible technologies (6) or from the UNECE/LRTAP Convention Task Force on Techno-Economic Issues (TFTEI) (7).

Useful information on quantifying policies and measures may also be available through the activities of the Intergovernmental Panel on Climate Change Working Group II (i.e. on the implementation of the Effort Sharing Decision, policies and measures and projections) under the EU Climate Change Committee (8) and, more recently, in the EU's national air pollution control programme guidance (EC, 2019).

If no data are available, but the inventory expert believes that emission reductions will be achieved, expert judgement can be applied to derive an appropriate emission factor. The assumptions and data used to form this judgement should be well documented.

More details of sector-specific approaches are identified in the annexes.

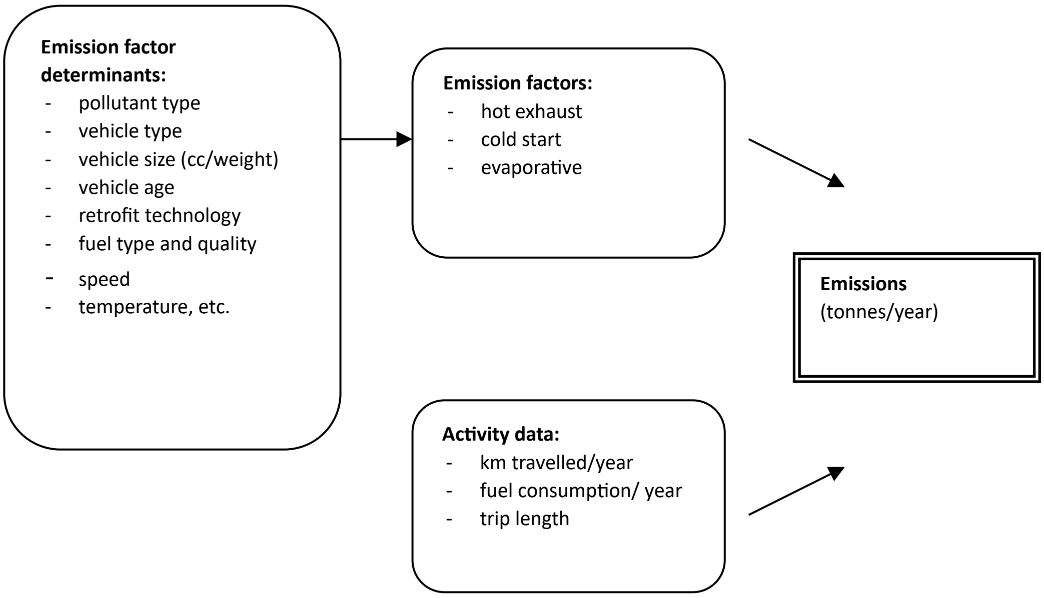
5.5 Stratification

Stratification involves breaking down a sector into its component sub-sectors and projecting emissions at this level of detail. There will be many cases in which historical emissions cannot be projected using simple growth factors and future emission factors because emission performance develops differently within the sub-sectors. Stratification helps to account for penetration of measures over a number of years by sub-dividing the sector into its components, so that a measure can be applied to the appropriate fraction of the sector's activity for each year of the projection. Two examples in which stratification is appropriate are shown in Box 5-1.

(6) http://eippcb.jrc.ec.europa.eu/reference/
(7) http://tftei.citepa.org/en/
(8) http://www.ipcc-wg2.org/

Box 5-1 Examples of stratification

Road transport: it is likely that a detailed model will be required to project emissions from this sector, as there are many variables that will affect future emissions. A schematic of the determinants is shown below:



Therefore, for this sector, it is not appropriate to adopt the simple methodology described in sub-section 5.3 above and emissions need to be broken down to a more detailed level in order to apply the appropriate emission factors and activity data.

Power generation — sulphur dioxide: when projecting emissions from the coal-fired power generation sector, plants must be stratified into FGD and non-FGD plants for each year that projections are being compiled, so that the appropriate emission reduction factor is applied for the fraction of fuel burned in FGD plants.

Stratification is required only in cases in which emission controls or new technologies are applied to sub-sectors.

5.6 Simplification

In many cases, the detail of future activity projections (e.g. employment, transport, energy use) will not be as comprehensive as underlying inventory data. For example, fuel types are often not broken down in as much detail (e.g. the increase/decrease in solid fuel provided in national projection data sets may be provided as a total and not broken down into coal, peat, etc.) or sectors are more highly aggregated (e.g. a projection for industry gas may not separate out all of the individual sectors within the inventory). In other cases, indicators rather than projected changes in activity may have to be used. Where appropriate, these more aggregated data sets can be used to derive growth factors (GFn) that can be applied to a number of individual sectors. Care should be taken to ensure that the growth factor is representative of the individual sector. An example of where simplification might or might not apply is shown in Box 5-2.

Box 5-2 Example of simplification

Historical inventory source/fuel combination:		GF_n:
domestic-coal	→	domestic-coal
colliery combustion-gas	→	industry-gas
lime production-gas	→	industry-gas
other industrial combustion-gas	→	industry-gas

In this example, the level of detail provided by the energy model is at an aggregated 'industry-gas' level. As there is no further breakdown to provide the detail necessary for the sectors in the historical inventory, the relevant inventory sectors will be projected using the 'industry-gas' growth rate.

5.7 Checks and controls: verification and quality assurance and control

The best practice principles for historical emission inventory compilation also apply for projections. Therefore, the resulting projections will need to be:

- **Transparent:** the guidelines for reporting emissions and projections data under the LRTAP Convention state that methodologies and assumptions for projections should be transparent and should allow for an independent review of data. This information should be provided in the projections chapter in informative inventory reports under the LRTAP Convention and will also be required for the EU's national air pollution control programme reporting. Parties annually submit national historical air pollutant inventories in both spreadsheet and report format (in the informative inventory report) under the LRTAP Convention. A template for the informative inventory report is provided on the Centre on Emission Inventories and Projections (CEIP) website (9). This contains a section on projections where the methodology needs to be included. However, no further information is provided. The following is a summary of the suggested structure for the projection methodology documentation:
    - Provide a general overview of the national policy framework. This would include policy priorities and their relationship to priorities set in other policy areas. Outline the institutional arrangements in place for compiling national air pollutant projections, including at the local and national levels, if relevant.
    - State the year of the historical inventory data (base year) and year of inventory report used as a starting point for the projections.
    - List the data providers for the projection calculations.
    - Provide general information on key exogenous assumptions and parameters used, such as economic growth and fuel price projections.
    - Comment on the extent of consistency with GHG emission projections, and where there are differences and why.
    - For each sector (energy, transport, industrial processes and product use, agriculture, waste), list the sources of input data, the methodology followed for projecting activity data and emission factors, the assumptions made and the completeness of the calculations.
    - Provide lists of the policies and measures incorporated, and in which scenarios (WM and WAM). This requires detailed consideration of progress made, likelihood of compliance and hence the need for additional policies and measures.

(9) http://www.ceip.at/ms/ceip_home1/ceip_home/reporting_instructions/annexes_to_guidelines/

   - Describe the sensitivity analysis undertaken, together with a brief explanation on which parameters were varied and how.

- **Accurate:** one significant challenge in compiling emission projections is that the availability of projected activity can be very limited, across all sources. The emission projections must be as accurate as possible, although in the context of the uncertainty of estimating future emissions this is somewhat different from the requirements of accuracy of estimating emissions that have occurred in the past.

  In the context of projections, accuracy involves checking that there are no errors in the application of assumptions, that they take account of the available information in a balanced, unbiased way and that they accurately reflect the current policy framework. The use of sector experts in the policy field is particularly important for applying sound assumptions if there is a lack of published data.

  Countries are also required to provide, where appropriate, a sensitivity analysis with the final projection results (NEC Directive, Annex IV, part 2). This provides an indication of how sensitive the emissions estimates are to variations in key assumptions or data sets.

- **Consistent:** the emission projections should be (1) consistent with the historical inventory, (2) consistent between approaches for different pollutants and sectors, and (3) consistent with GHG emission projections. In some MSs, different teams compile the country's air pollutant emission projections and GHG emission projections, leading to inconsistencies in the activity forecasts used. When this is the case, MSs are strongly encouraged to share official activity forecasts with both their air pollutant and their GHG emission projection teams. In addition, meetings should be held between the air pollutant and GHG teams at regular intervals to ensure consistency of methods. For example, it is recommended that regular comparisons are undertaken at the sector level of the air pollution and GHG projection calculations to ensure consistency of assumptions about future drivers of emissions and activities.

- **Complete:** for all sectors for which historical emission estimates are produced, projections should also be produced. In some cases, it may be predicted that an activity may no longer take place and therefore the emissions would be estimated as zero, but this will need to be transparently explained in the accompanying report and emissions reported using the relevant notation key. If no country-specific forecasts are available, and the sector is not a key category, proxies can be used. Examples include national GDP and population forecasts. It is recommended that a comparison be made between the last year of the historical emission inventory and the first years of the projected emissions to identify any completeness issues. Details are provided in the sector-specific guidance at the end of this report to help projection compilers make decisions and improvements with regard to the completeness or reporting.
- **Comparable:** the emission projections should be comparable to other MSs' projections and should take into account the impact of all relevant policies and measures.

It is important to ensure that resulting emission projections have similar verification and QA/QC as those applied to the historical inventory. In addition to following the general guidance on good practice in Chapter 6, 'Inventory management, improvement and quality assurance/quality control', it is recommended that the checks and procedures listed below be pursued. Chapter A8 of Annex A of the GHG guidelines (DG CLIMA, 2012) also provides a comprehensive list of checks for further information. Additional information is available in DG CLIMA (2015).

- The energy-related emissions should be checked to ensure that energy consumption by fuel derived for the individual sectors in the projected emissions match the energy consumption used as input to the estimates. The overall energy balance used to derive the projected inventory should also be consistent with the energy balance from the input data.

- Compare projected trends in data (emissions or activity) with historical trends — if there are significant differences, then the compiler will need to explain why. This is based on a general observation that national emission/activity data tend to change gradually (although not always). The rationale for large step changes should be provided or methods should be revised to take out erroneous projected data or methods.
- It is good practice to reference all data sources within the spreadsheets/databases so that the input data are traceable and transparent.
- A check should be made to compare the emissions generated in the latest data set with previous projection versions. A designated checker should identify sources where there have been significant changes and satisfy themselves that the projections are correct and that the revisions are transparent.
- For a number of countries, national projections can be cross-checked against some international data sets. For example, the Price-Induced Market Equilibrium System (PRIMES) energy model ([10]) provides a centralised view on energy demand across Europe and the Greenhouse Gas — Air Pollution Interactions and Synergies (GAINS) model ([11]) provides projections for a number of pollutants and sectors.
- Check previous projections against results in the historical emission inventory; for example, how far off were projections for 2010 and 2015 compared with the historical inventory results and what were the sources of the differences? Note that projections are not considered predictions and therefore current inventories are not expected to match historical projections or vice versa unless all the assumptions that led to the projections became reality. This would be a very rare case. Nevertheless, the comparison with historical projections might give some clues on conceptual problems in the projected data.
- Check that the impact of all relevant policies and measures has been included.
- Check that assumptions have been reviewed by sector policy experts.
- Check that consistent assumptions are made between the country's air pollutant and GHG emission projections.

One further example is provided by the annual QA/QC procedure (including gap-filling procedures) performed annually by the EEA for reported GHG projections for the compilation of EU projections ([12]).

5.8 Changes in methodologies between the historical inventory and projections

An issue that sometimes arises is that the method for estimating the historical emissions is not detailed enough to reflect the impact of certain policies and measures. If the projections are estimated using a method that is different from (more detailed than) the historical emissions, then there can be a discontinuity in the time series. This 'detail' or 'discontinuity' issue often arises because the aims, and hence the focus, of the work on the historical emission inventory and on the projections are different. When historical emission inventories are compiled, effort will be spent on estimating the larger sources with more detailed methodologies. There is generally little

([10]) The PRIMES partial equilibrium model covers many European countries; see: http://www.e3mlab.eu/e3mlab/index.php?option=com_content&view=category&id=35%3Aprimes&Itemid=80&layout=default&lang=en

([11]) For more information on the GAINS model, see: http://www.iiasa.ac.at/web/home/research/researchPrograms/air/GAINS.html

([12]) See, for example: http://acm.eionet.europa.eu/reports/docs/ETCACM_TP_2015_11_QA_PROC.pdf prioritisation of one air pollutant over another in terms of the use of more detailed methodologies. The aim for historical emissions is to provide a generally good quality across all sources and all pollutants. Emissions inventories are reviewed in this way.

When the WM scenario is compiled, this approach is also broadly used, but it becomes necessary to represent the future impact of policies and measures, and this can result in a need to use very detailed methodologies for estimating emissions from specific sources. It is not necessarily the largest sources that are under the most scrutiny. Furthermore, some pollutants will be under intense scrutiny if they exceed emission reduction commitments, and others will attract less attention if they are shown to be easily complying with future commitments. This issue is even more exaggerated when additional policies and measures are considered. There will be intense scrutiny of selected sources, which may not be very well characterised in the historical inventory.

A simple solution would be to update the historical emission estimates when the projections are being compiled, to ensure that they can both use the more detailed method. But this is often not possible because the historical emissions have been 'released' as an official national data set. They will not be updated for another 12 months and it might not be possible to sufficiently postpone the development of the projections. Figure 5-2 Figure 5-3a-c illustrate examples of the different approaches. Figure 5-2 is an example that might arise when a simple method (tier 1) has been used for historical emission estimates, but a more detailed method (tier 2) has been used for projected emissions.

Figure 5-2 An example of a historical-projections discontinuity

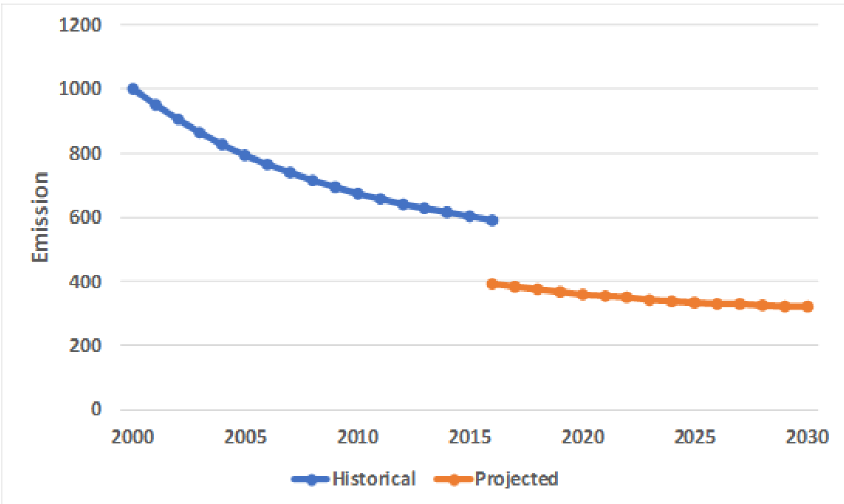
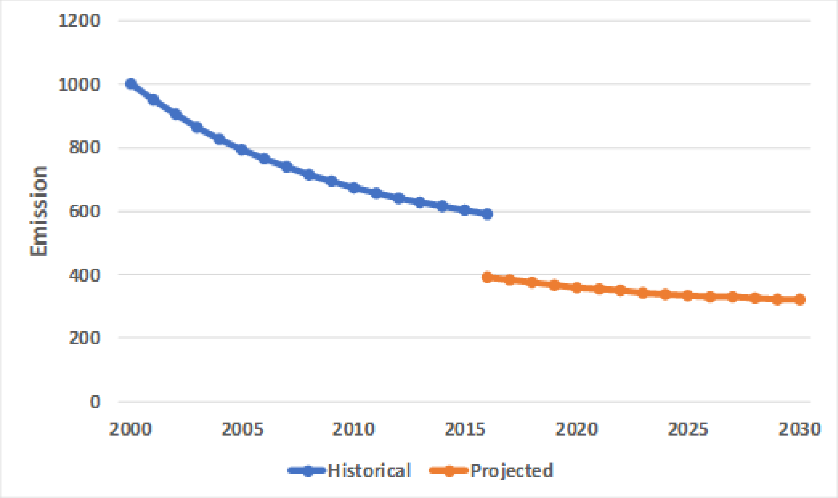


Figure 5-3 Options for addressing discontinuities

(a) Retaining the discontinuity

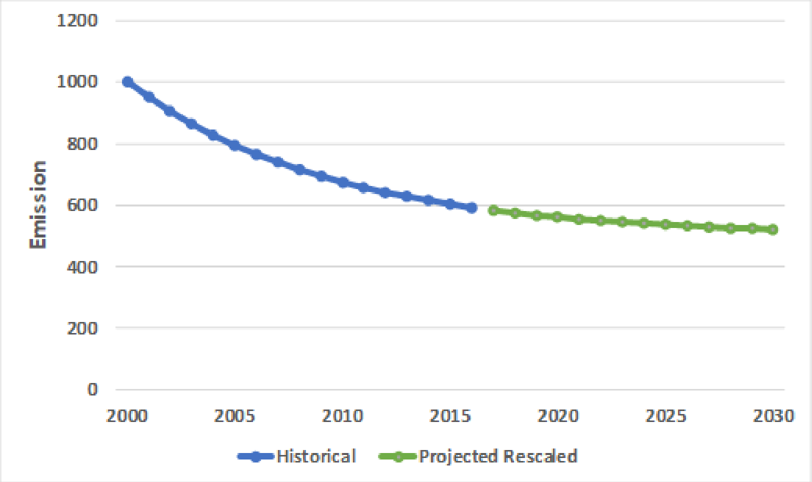
If the difference between the historical and projected data is small, then it is possible to retain the discontinuity.

This has the advantage of using the higher tier method for the projections, which is considered to be based on the best approach/methodology available.



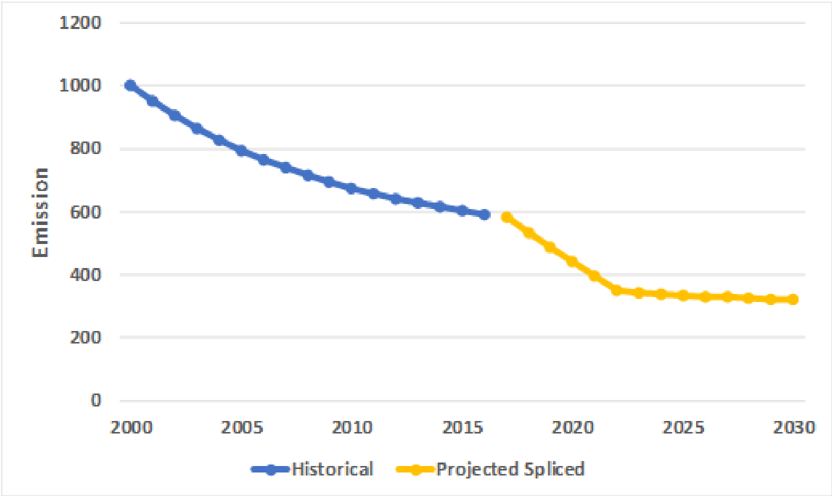
(b) Rescaling projected emission estimates

Rescaling the projected data to provide a good fit with the historical data removes the discontinuity. However, this does have the disadvantage that the projected emission estimates (which are considered to be based on a better method) have been altered to fit the historical data.



(c) Splicing historical and projected emission estimates

This is a compromise approach, in which the data sets are spliced and the projection estimates gradually transition from data that are rescaled to be consistent with the methodology used for the historical data to the higher tier method across a given period (in this case 5 years).



5.9 Dealing with gaps in projected data

For key categories, it is good practice to fill any projection gaps with national projected estimates through the development of new models or by accessing new data on national projections. When matching projected statistics (e.g. projections of fuel combustion and cement production in cement plants to match historical statistics) are unavailable, 'surrogate' projections (e.g. housing growth) can be used to help project future activity.

For non-key categories, when no appropriate data or surrogates are available for a source sector, it is good practice to assume that the projected value is the same as that for the latest historical year of the inventory. This approach can be applied to the activity data and/or the emission factors when no other data are available. When projected activity data are available only for particular years, data for intermediate years can be estimated using extrapolation.

Issues relating to non-disclosure may be encountered (at a sectoral or spatial level) that may impose barriers to acquiring data. As only highly aggregated output data are needed for reporting, signing of non-disclosure or confidentiality agreements or asking the data supplier to derive aggregated data sets may improve the accessibility of these data. It will be important that issues relating to this are identified and dealt with in consultation with the national statistical authority.

5.10 Data sources

The complexity of emission projections will depend on the level of data available in the country. As a minimum, for good practice, national government sources of data should be used for all key categories in preference to other national or international data sets. Key data sources are national energy models, which combine economic-based energy demand criteria with energy price information. These models often provide a number of different energy demand scenarios based on different economic and price elasticity criteria. When the data on energy demand projections can be aligned to sectors and fuels in the inventory, they can be used as growth factors for the activity data in the emission projections. Examples of data sets are provided below.

5.10.1 National sources

National projected emissions should aim to be consistent with other national activity projections (e.g. agricultural productivity, population growth, energy demand and supply, and industrial production). It is good practice to use these national data sets, where they exist, as a starting point for the projections. This is also important in order to remain consistent with the method used in projecting GHG emissions.

The following organisations may be able to provide information:

- **statistical departments:** socio-economic projections data (economic growth, population, production/consumption);
- **government departments:** sector-specific data on activities and policies and measures should be gathered from the different government departments — available data sets could include agriculture activity and livestock, agricultural practices and emissions, traffic projections, and energy supply and demand;
- **regulators:** plant upgrade plans, emission limits and best available techniques (BREFs);
- **industry and industrial trade associations' views on growth and technological implementation:** it should be noted, however, that views could sometimes be political and resistant to change;
- **vehicle and engine manufacturers and regulators**.

Any policies and measures designed to meet national and international commitments for emission reductions (e.g. directives, protocols) should also be used as a key input to emission projections. These may provide assumptions about plant/vehicle replacement and implementation of new technologies and controls from the industry and regulators and include factors on penetration of technologies, population, economic and transport growth. Where possible, projections should also include assumptions about the impact of non-technical measures (e.g. low-emission zones and carbon trading) and indirect impacts of other policies and measures (e.g. air quality directives and climate change activities). These are complex elements to include in projected emission estimates. Where possible, assumptions on the impact of these measures on the activity rates and on the technologies used should be quantified and documented. If regulatory impact assessments are carried out, then these should include basic information about the likely impacts on emissions into the future.

Future emission factors should be based on measured data for in-service technologies and abatement. When this is not possible (e.g. for emerging technologies), future emission factors should be estimated using expert judgement or based on limit levels from regulators and industry.

More details of sector-specific approaches are identified in the annexes.

5.10.2 International sources

It is best practice to use national activity projections, as these will be more country specific and in line with the government's view on how things are likely to change in the future. However, international data sets can be used when national data are unavailable. These data sets may be able to provide projected activity data and/or emission factors and help with the comparability between countries; however, there may be a number of inconsistencies with national views. Examples include, but are not limited to, the following.

Activity data

- Projections of energy consumption/supply can be obtained from:
    - o the PRIMES model (http://www.e3mlab.eu/e3mlab/index.php?option=com_content&view=category&id=35%3Aprimes&Itemid=80&layout=default&lang=en);
    - o the Prospective Outlook on Long-term Energy Systems (POLES) model (http://www.enerdata.net/enerdatauk/solutions/energy-models/poles-model.php);

- the Market Allocation (MARKAL) and The Integrated MARKAL-EFOM System (TIMES) models (http://www.iea-etsap.org/web/tools.asp);
- the GAINS model (http://gains.iiasa.ac.at/models/);
- the EU Reference Scenario for 2016, which projects energy and transport trends in the EU up to 2050 (https://data.europa.eu/euodp/data/dataset/energy-modelling).

- Agricultural projections can be obtained from:
    - the Common Agricultural Policy Regionalised Impact (CAPRI) model (http://www.capri-model.org/dokuwiki/doku.php?id=start);
    - the Food and Agriculture Organization (FAO) ([13]);
    - FAO projections; however, data are available only for the EU as a whole and therefore country-specific knowledge would be required to refine the data for individual EU country use;
    - Scenar 2030 (https://ec.europa.eu/jrc/en/publication/eur-scientific-and-technical-research-reports/scenar-2030-pathways-european-agriculture-and-food-sector-beyond-2020);
    - the European Fertilizers Manufacturers Association ([14]);
    - the International Fertilizer Association ([15]);
    - Fertilizers Europe (https://www.fertilizerseurope.com/media/news/single/article/forecast-2017-2027).
- Transport projections can be obtained from:
    - the TREMOVE model (https://www.tmleuven.be/en/navigation/TREMOVE);
    - the Tools for Transport Forecasting and Scenario Testing (TRANS-TOOL) model (http://energy.jrc.ec.europa.eu/transtools/FTP.html);
    - the COPERT model (https://www.emisia.com/utilities/copert/);
    - Eurocontrol air traffic projections (https://www.eurocontrol.int/articles/forecasts);
    - International Civil Aviation Organization (ICAO) passenger and freight aviation forecasts ([16]).
- Solvent emission projections are available from:
    - the European Council of the Paint, Printing Ink and Artists' Colours Industry (CEPE) ([17]);
    - United Nations production statistics (http://unstats.un.org/UNSD/industry/ics_intro.asp).
- In addition to the above examples, the GAINS model (http://www.iiasa.ac.at/web/home/research/researchPrograms/air/GAINS.html) can be used to obtain country-specific activity projections for all sectors.

Emission factors

- Current and emerging technologies and their impact on emissions are available from:
    - the UNECE TFTEI, which provides detailed sector-specific data for industrial processes ([18]);

([13]) www.fao.org
([14]) www.efma.org
([15]) www.fertilizer.org
([16]) www.icao.int
([17]) www.cepe.org
([18]) http://tftei.citepa.org/en/

- the UNECE Task Force on Reactive Nitrogen (TFRN) ([19]);
- the European Agriculture Gaseous Emissions Inventory Researchers Network (EAGER) ([20]);
- BREFs and best available technique conclusions (http://eippcb.jrc.ec.europa.eu/reference/);
- the GAINS model (see above).

- Information on example penetration rates for different technologies is available from:
  - the GAINS model (see above).

More details of sector-specific approaches are identified in the annexes.

6 Sensitivities

Emission projections are always modelled or based on hypothetical expectations of future events. As a result of this, the sensitivities of that model also need to be understood and communicated.

Sensitivity analysis is the study of how the variation in the output of a model (numerical or otherwise) can be apportioned, qualitatively or quantitatively, to different sources of variation and of how the given model depends on the information fed into it (Saltelli et al., 2000). It quantifies the variation in model output that is caused by specific model inputs.

The sensitivities can be assessed by analysing the reaction of emission projections to changes in underlying input data, for example vehicle scrappage rates and economic growth. Sensitivity analysis should provide details of the most important parameters and the vulnerability of these parameters to change. This will give an expected range of likely future emissions for any particular scenario.

The goal of sensitivity analysis is to understand the quantitative sources of uncertainty in model calculations and to identify those sources that contribute the largest amount of uncertainty in a given outcome of interest.

The sensitivity analysis can be used to answer, for instance, the following questions:

What is the rank order of importance among the model inputs?

Are there two or more inputs to which the output has similar sensitivity or is it possible to clearly distinguish and discriminate between the inputs with respect to their importance?

Which inputs are most responsible for the highest and lowest emission estimates?

Is the model response appropriate?

The sensitivity analysis applied to emission projections could be applied to only some emission sources or to all of the activities included in the projections. The choice of an appropriate sensitivity analysis method depends on the objectives of the analysis, the characteristics of the model and other considerations, such as ease of implementation and resource availability to conduct the analysis (Frey et al., 2004). For example, when the objective of sensitivity analysis is to identify key categories of uncertainty and apportion variance in an output to individual inputs, the choice of

(19) http://www.clrtap-tfrn.org/
(20) http://www.eager.ch/

methods further depends on model characteristics. If a model is linear, correlation methods and regression analysis methods are appropriate. If the model is non-linear, analysis of variance (ANOVA) or other methods capable of dealing with interactions are better choices. When there are categorical inputs, classification and regression trees (CART; Breiman et al., 1984) may be more appropriate. When the objective of sensitivity analysis is to identify factors contributing to high emissions in order to develop control strategies, ANOVA and CART should be considered, as these methods can provide insight into conditions that lead to high emissions.

Further information on conducting a sensitivity analysis can be found at the EU Science Hub (https://ec.europa.eu/jrc/en/samo).

7 Steps to estimating emission projections

The following steps provide an outline of the activities necessary to compile emission projections.

Step 1: **Establish a starting point:** the starting point should ideally be the latest officially submitted inventory based on national statistics and an understanding of the current levels of technologies and controls included in the latest years of the emission estimates.

Step 2: **Identify important sources:** priorities for developing the detail and complexity of projections should be set based on a basic understanding of the important future sources. The list of priority sources should be established by looking at the key categories for the historical inventory (those that are large in the latest year and those that are showing signs of increasing; for example, aviation has seen a large increase in recent years and is likely to continue to increase into the future). This exercise should also involve an element of horizon scanning to identify possible future sources not currently in the inventory.

Step 3: **Initial trawl for projections data:** gather necessary activity projections from government departments (ensuring consistency with the GHG projections), regulators and information on policies and measures to create a basic emission projection. Use the data collection activity as an opportunity to build a cross-government working group (e.g. transport, agriculture, energy, industry trade and regulation) with an interest in the projection's outputs. Work with policymakers to quantify emission reductions for measures (so that this can be used as consistent input for projections). If there are gaps in government data for certain sectors, use other national data sets from industry and/or trade associations. Any possible new emission sources should be identified at this stage. It is good practice to consider the full scope of pollutants during this exercise so that the impacts of measures taken for one pollutant can be included in the projections for others. Where possible, air pollutant emission projections should be undertaken at the same time and have a methodology that is consistent with GHG emission projections.

Step 4: **Compile an initial WM/WEM projection:** make a first estimate of projections using the data gathered in the initial trawl and the methods presented above. All policies and measures (PaMs) that will have an impact on emissions, either positively or negatively, should be incorporated. Estimates may not initially be complete, with gaps in projection data for some sectors. Gaps in projection data should be addressed and circulated to the relevant government departments for comment. Initial projections should include a first-estimate WEM scenario (using, where possible, data provided on technologies and controls consistent with any implemented policies and measures).

PaMs can be implemented within projections only if enough information is available for their evaluation. When planning the approach to evaluating PaMs, the following points need to be considered:

- PaMs should be evaluated by sector experts within the framework of the projections national system, so that the data and baseline assumptions, etc., are compatible.
- For each PaM, sufficient information is required to enable them to be incorporated into the air pollutant projections transparently and without double counting.
- Checks are required to ensure consistency between assessments of strategies concerned with air pollution emission reductions and those concerned with energy efficiency and other measures, such as agriculture and industrial processes. These checks should be undertaken by doing a comparison of all assumed impacts across all of the different measures.
- The resulting emission projections in the WM scenario should be compared with future emission targets. If the targets are not met, additional PaMs that can be included in a WAM scenario need to be identified and developed.

The following steps outline the approach required for identifying and evaluating PaMs and incorporating their impacts into projections:

A. **Compile a longlist of WM PaMs** that either are in place already or have been agreed but are not yet fully implemented. These PaMs may be created for policy reasons other than air quality but have an indirect impact on air pollutant projections. This compilation is likely to require stakeholder input across a range of departments or organisations and will need to include international, national and potentially also local PaMs. For completeness, it must include PaMs that are likely to increase as well as decrease emissions.

B. **Compile detailed information on the impacts** expected from the WM PaMs.

   Collecting and refining the longlist of WM PaMs is likely to be an iterative process, as identifying if PaMs overlap is important. The impact of PaMs is not always simply additive, making it difficult to estimate the impact of multiple PaMs on an emission source. The general approach is to first undertake *ex post* assessments (reviewing the impacts of policies in historical years), to understand how effective policies have been in the past. This supports the design of new policies. *Ex ante* assessments (estimating what effects will occur as a result of a policy or action after policy implementation) can then be undertaken to quantify the expected future impact of the PaM.

   The data for each PaM should be listed within a consistent data set and any gaps should be highlighted. The relevant data to be collected include:

   - details from background information/studies used to define PaMs — information that was used to come up with an emission saving for the PaM should be prioritised;
   - assumptions on changes in technology (which will modify emission factors or emission factor parameters, e.g. energy efficiency improvements or liquefied petroleum gas (LPG) technology in vehicles);

- the penetration of the new technology (e.g. the number of LPG vehicles/quantity of fuel consumed);
- changes in activities, including reductions in polluting activities (e.g. driving) and increases in non-polluting activities (e.g. cycling);
- an end date when the PaM is expected to be delivered;
- an expected result (based on expert judgement).

C. **Use the information** on the PaMs emissions quantification when projecting the latest year of the historical emissions into future years. This can be done by altering the projected activity data or the projected emission factors or both from a simple forecast, depending on the details of the PaM(s) that have an impact on the source. For example, non-methane volatile organic compound (NMVOC) emissions from the use of solvent-containing products in the domestic sector might be expected to grow at exactly the same rate as population. However, the solvent content, and hence the NMVOC emission factor, might decrease with time as a result of EU-wide legislation. The extent to which this reduces emissions needs to be quantified as the impact of the PaM, and the projected emissions need to be calculated for inclusion in the overall NMVOC emission projections.

D. **Avoid double counting** by checking to see if multiple PaMs influence the same parameters. Parameters can be affected by several PaMs, but it is important to know if the effects on air pollutant projections can be simply added in cases in which PaMs interact with or counteract each other. Grouping and splitting PaMs appropriately can help remove double counting, reduce sensitivities and provide improved transparency to the projections. For example:

- When the effects of PaMs are simply additive (e.g. measures to reduce or change transport modes), the impacts could be combined and a total effect estimated.
- The separation of PaMs or components of PaMs to incorporate key variables that affect projections may be necessary if there are different sensitivities or when different possible outcomes of the PaM may have different effects on projections.
- Detailed QA/QC procedures can be undertaken to ensure accuracy in the implementation of the PaMs within the projections.

Step 5: Engage with policymakers and data providers: the initial WEM and, where applicable, WOM scenarios should be used to engage with policymakers and data providers and enhance the flow of information by illustrating the expected course of emissions and any uncoupling from economic projections. The approach taken should be well documented. It is useful to get national agreement on the most likely economic scenarios and PaMs that are to be included in the WEM scenario and how the implementation of these will be present in the projection estimates. Assessment and presentation of sensitivity in the projections will help to engage policymakers, stakeholders and data providers and help refine further improvement priorities. For further information on conducting a sensitivity analysis, see section 6, 'Sensitivities', of the present chapter.

Step 6: Iteratively improve the projections for important sources: following the preparation of initial projections, an idea of the most important sources will be clarified and an interest in correctly accounting for their future emissions will be established. These sectors can then be refined through the introduction of additional activity data (where appropriate), new studies and modelling, and more detailed stratification to ensure that estimates are representative of government expectations and actions. A picture of the expected emission reductions will begin to appear as more detailed information on PaMs is included and the country can begin to evaluate if the current level of action (PaMs) will achieve any planned reduction targets.

Step 7: **Develop a WAM scenario:** add additional options for emission reductions to the projections that could be considered to help meet established or planned targets. The WM scenario will show whether or not the existing PaMs are sufficient to meet emission reduction commitments (or achieve the required reductions in air pollutant concentrations). If they are not sufficient, then additional PaMs will be needed and a WAM scenario will have to be generated. The following provides a step-by-step guide to making projections with additional measures (i.e. to be reported as a WAM scenario):

A. Prioritise pollutants and key emission sources. Assess coherence with other plans and programmes. Identify which pollutants require additional PaMs. It will be apparent from the WM scenario which pollutants are predicted to achieve given emission reduction commitments. It should also be apparent which sources are likely to give the best options for additional PaMs.

B. Identify, evaluate, prioritise and select additional PaMs. Prepare a shortlist of PaMs with associated impacts on emissions that can be added to the WM scenario to give greater emission reductions. The quantification of emission reductions from these PaMs is undertaken in the same way as outlined in Chapter 6. The intention is to provide some choice for policymakers, so, while it is sensible to develop PaMs for a range of sources, the inventory compiler will need to liaise with the policymakers on the sectors that are likely to be targeted and may be instructed to investigate the impacts of specific PaMs. Policymakers may ask for the costs associated with the implementation of the different PaMs and the inventory compiler may have to provide some input into this process.

C. The policymakers will make decisions regarding the implementation of PaMs from the shortlist. The inventory compiler will need to check the overall impact (as it may not be simply additive). This information should be provided to the policymakers and discussions should be held about whether or not the chosen PaMs indicate that future emissions will comply with emission reduction commitments.

D. The inventory compiler then adds these additional PaMs to the WM scenario to generate the WAM scenario.

E. Monitor progress in implementation. The progress of the new PaM in delivering the target emission reductions will need to be monitored.

8 Continuous improvement

Continuous improvement is a fundamentally important component of all emission inventory work, and emission projections are no exception. Emission inventory managers will need to periodically review the quality of their emission projections, as indicated by assessing against the quality metrics explained in Chapter 5 ‘Uncertainties’.

The process for reviewing the quality of emission projections and planning improvements is broadly the same as that for historical emissions. However, for emission projections, there could also be improvements that may need to happen over very short timescales.

The policy landscape can change across relatively short periods of time and policymakers can 'switch' their interest from one policy area to another quickly. Therefore, ideally, the development of the projections needs to be able to respond to different policy needs quickly. It is sensible to periodically review the resources needed for this, because developing new scenarios and assessing the impacts of new PaMs will quickly become the majority of the emission projections work once the projections have been established as an effective policy tool with policymakers.

There are also longer term considerations that are similar to the issues encountered with historical emission inventories. Examples include the need for accessing better input data, especially to fill recognised gaps or weaknesses in the projections. This is challenging if there is a need to compile new data sets that have not been generated previously.

9 Guidance on documenting assumptions

The methodology and data sources used in compiling an emission projection scenario should be well documented. The methodology should include enough information to allow readers to understand the underlying assumptions and to reconstruct the calculations for each of the estimates included.

In addition to following Chapter 6, 'Inventory management, improvement and quality assurance/quality control', the following information should be included in projection-specific documentation:

- detailed data to aid transparency, including values and sources of activity data used, growth factors used, a list of the policies and measures that have been included, emission factors, details of grades, sector definitions, sector stratification and assumptions made in deriving future emission factors;
- a description of the methodology followed for each sector;
- information on the QA/QC undertaken;
- any major issues regarding the quality of input data, methods or processing and how they were addressed or are planned to be addressed;
- areas in which further improvements would be beneficial;
- contact information for obtaining the data sources, where applicable.

Documentation of estimation methods for projections should follow the general guidance in Chapter 6, 'Inventory management, improvement and quality assurance/quality control'. It is good practice to provide a description of the reasons for trends, revisions, policies and measures included, methods, data sources and assumptions as part of the inventory QA/QC documentation or as part of a national inventory report.

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11 Point of enquiry

Enquiries concerning this chapter should be directed to the relevant leader(s) of the TFEIP's expert panel on projections. Please refer to the TFEIP website (www.tfeip-secretariat.org/) for contact details of the current expert panel leaders.

Annexes

These annexes provide general guidance on the approach for estimating projections for the main sectors. There is a focus on the activity data needed and on identifying the most likely areas for development of specific future emission factors incorporating changes to technology, practices and abatement. Where available, specific technology emission factors and methodologies for estimating emissions are included in the sectoral volumes of this Guidebook. When technologies, controls or other changes are unlikely to affect emission factors, they can be kept the same as for the latest year of the inventory. The examples of projection tools and models given in these annexes refer mostly to work done by European countries.

These annexes are largely based on content from a European Commission Directorate-General for Environment funded study, (Ricardo, 2019) and are reproduced here with permission.

Annex 1 NFR 1A: combustion

A1.1 Introduction

Typically, historical emissions from stationary combustion sources are estimated by combining energy statistics with suitable emission factors. The Guidebook contains both tier 1 and tier 2 factors, typically given for solid, liquid, gaseous and biomass fuels (so there is not necessarily any distinction between, say, LPG and fuel oil). Countries may use tier 3 approaches based on site-specific emissions data. Projections can be made by replacing historical energy statistics with projections of energy use and combining those projections with emission factors, as is done for the historical inventory. The emission factors can be the same as those used to estimate historical emissions or, if combustion sources are likely to be controlled, can differ from historical factors to reflect changes in technology and/or abatement of emissions. The following sections describe the approach for projections in more detail.

Unlike in the case of carbon dioxide (CO_2), where emissions depend on the broad fuel type but are largely unaffected by the combustion technology, emissions of air pollutants are highly dependent on the nature of the combustion process: the technology used, the level of maintenance and/or the way in which the combustion device is used (e.g. for domestic grates) and the presence of any technologies to minimise or reduce emissions of pollutants such as nitrogen oxides (NO_x) or dust. Emissions can also depend on the exact characteristics of a fuel: for example, emissions of sulphur oxides (SO_x) from oils will depend on the sulphur content and this will vary far more than the carbon content. These issues mean that estimating emissions of air pollutants from combustion is much more complicated and difficult than for CO_2 and this is true for both projections and historical emissions. Historical emission estimates and projections may both, as a result, be far more uncertain than would be ideal. Projections should, as far as is practicable, be generated using methods that are consistent with the historical estimates and often this means that both will rely on simplistic assumptions and simple methods, as that is all that the data will allow.

A1.2 Understanding the factors that drive change

Before attempting projections, it is necessary to understand what circumstances, and what policies and measures (PaMs), might drive change in emissions in the future. Ideally, these factors will then all be reflected in the projections, although this is often quite difficult in practice. At the very least, emissions inventory compilers will need to identify all significant agents of change, even if these cannot all be included in projections.

PaMs should be easy to identify but care should be taken to ensure that the list of PaMs covers both policies that directly target air pollutants (e.g. the EU Industrial Emissions Directive (IED)) and policies that will affect emissions indirectly (e.g. through decarbonisation and measures to promote energy efficiency). Table A1-1 provides some of the key policies and regulations that may have an impact on air pollutant emissions arising from the energy sector. Please note, however, that this list is not exhaustive and items may be superseded following publication of this chapter.

National energy projections are expected to reflect most or all of the indirect measures, whereas the direct measures mostly need to be reflected through careful choice of emission factors used in the emission projections. In practice, it is often difficult to quantify the impact of direct PaMs. In most cases, the PaMs will cover only a part of the combustion sector and data may be lacking on the extent of that coverage. Measures such as the IED often set emission limit values (ELVs) that can be used in projections, although this is not always straightforward: ELVs may depend on the characteristics of the plant, such as capacity, and, if the types of plant present in a country are not known with certainty, then it is not certain what ELVs can be assumed.

Table A1-1 Summary of important EU legislation relevant to the energy industries sector

Description	Legislation	Parameters/variables
Industrial Emissions Directive	Directive 2010/75/EU replacing Directive 2008/1/EC	Emission factors, energy production, final energy consumption by sector by fuel type, fuel efficiency, share of different technologies
Medium Combustion Plant Directive	Directive (EU) 2015/2193	Boilers, engines and gas turbines ≥ 1 MW thermal input (not single household but may be used for centralised communal/district heating)
Directive on the reduction of national emissions of certain atmospheric pollutants	Directive 2001/81/EC and Directive (EU) 2016/2284	Emission reduction commitments for air pollutants
Ambient Air Quality Directives	Directive 2008/50/EC and Directive 2004/107/EC	New air quality objectives for $PM_{2.5}$ (fine particulate matter) including the limit value
Directive amending Emissions Trading Scheme to improve and extend the greenhouse gas emission allowance trading scheme of the Community	Directive 2009/29/EC	Electricity consumption, emission factors, final energy consumption by sector by fuel type, share of different forms of energy
Emissions Trading Scheme Directive	Directive 2009/29/EC amending Directive 2003/87/EC	Electricity consumption, emission factors, final energy consumption by sector by fuel type, share of different forms of energy, CO_2 price
Effort Sharing Decision and Effort Sharing Regulation	Decision No 406/2009/EC and Regulation (EU) 2018/842	Electricity consumption, final energy consumption by sector by fuel type, share of different forms of energy
Energy Performance of Buildings Directive	Directive (EU) 2018/844 amending Directive 2010/31/EU and Directive 2012/27/EU	Electricity consumption, emission factors, energy efficiency, final energy consumption by sector by fuel type
Directive on labelling and standard product information of the consumption of energy and other resources by energy related products (recast)	Directive 2010/30/EU	Electricity consumption, energy efficiency, final energy consumption by sector by fuel type, share of different forms of energy
Renewable Energy Directive (RED)	Directive 2009/28/EC	Consumption of renewable energy for cooling, consumption of renewable energy for heating, energy efficiency, final energy consumption by sector by fuel type, fuel specification, share of renewables in electricity generation
Directive on sulphur content in liquid fuels	Directive (EU) 2016/802	Sulphur content of certain liquid fuels

Directive on the geological storage of CO_2	Directive 2009/31/EC	Electricity consumption, emission factors, final energy consumption by sector by fuel type, share of different forms of energy
Directive on the ecodesign requirements for energy-using products (recast)	Directive 2009/125/EC	Electricity consumption, emission factors, energy efficiency, final energy consumption by sector by fuel type
Directive establishing a framework for the setting of ecodesign requirements for energy-using products	Directive 2008/28/EC	Electricity consumption, energy efficiency, final energy consumption by sector by fuel type
Directive on integrated pollution prevention and control (recast)	Directive 2010/75/EU	Emission factors
Directive on end-use efficiency and energy services	Directive 2006/32/EC	Electricity consumption, energy efficiency, final energy consumption by sector by fuel type
Directive on the ecodesign requirements for energy-using products	Directive 2005/32/EC	Electricity consumption, emission factors, energy efficiency, final energy consumption by sector by fuel type
Directive on the promotion of cogeneration	Directive 2004/8/EC	Electricity consumption, energy efficiency, final energy consumption by sector by fuel type
Directive on shifting the balance between modes of transport, in particular towards rail	Directive 2004/49/EC	Electricity consumption
Directive on energy labelling of household appliances (fridges and freezers)	Commission Directive 2003/66/EC	Electricity consumption, energy efficiency, final energy consumption by sector by fuel type
Directive concerning common rules for the internal market in natural gas	Directive 2003/55/EC	Electricity consumption, final energy consumption by sector by fuel type, share of different forms of energy
Directive on the taxation of energy products and electricity	Council Directive 2003/96/EC	Electricity consumption, final energy consumption by sector by fuel type, fuel price, share of different forms of energy
Directive on the internal electricity market	Directive 2003/54/EC	Electricity consumption, final energy consumption by sector by fuel type, share of different forms of energy
Directive on energy labelling of household appliances (air conditioners)	Commission Directive 2002/31/EC	Electricity consumption, energy efficiency, final energy consumption by sector by fuel type
Directive on energy labelling of household appliances (electric ovens)	Commission Directive 2002/40/EC	Electricity consumption, energy efficiency, final energy consumption by sector by fuel type
Directive on electricity production from renewable energy sources	Directive 2001/77/EC	Consumption of renewable energy for cooling, consumption of renewable energy for heating, share of renewables in electricity generation, share of renewables in energy production
Directive on energy efficiency requirements for ballasts for fluorescent lighting	Directive 2000/55/EC	Electricity consumption, energy efficiency, emission factors, final energy consumption by sector by fuel type
Regulation on energy-efficiency labelling for office equipment (recast)	Regulation (EC) No 106/2008	Electricity consumption, emission factors, energy efficiency, final energy consumption by sector by fuel type
Regulation on a Community energy efficiency labelling programme for office equipment	Regulation (EC) No 2422/2001	Electricity consumption, emission factors, energy efficiency, final energy consumption by sector by fuel type
Regulation on a Community eco-management and audit scheme	Regulation (EC) No 761/2001	Energy efficiency, final energy consumption by sector by fuel type
Ecodesign requirements for simple set-top boxes	Directive 2005/32/EC and Commission Regulation (EC) No 107/2009	Electricity consumption, emission factors, energy efficiency, final energy consumption by sector by fuel type
Ecodesign requirements for standby and off mode electric power consumption	Directive 2005/32/EC and Commission Regulation (EC) No 1275/2008	
Ecodesign requirements for non-directional household lamp	Directive 2005/32/EC and Commission Regulation (EC) No 244/2009	

Ecodesign requirements for fluorescent lamps	Directive 2005/32/EC and Commission Regulation (EC) No 245/2009	
Ecodesign requirements for external power supplies	Directive 2005/32/EC and Commission Regulation (EC) No 278/2009	
Ecodesign requirements for electric motors	Directive 2005/32/EC and Commission Regulation (EC) No 640/2009	
Ecodesign requirements for circulators	Directive 2005/32/EC and Commission Regulation (EC) No 641/2009	
Ecodesign requirements for televisions	Directive 2005/32/EC and Commission Regulation (EC) No 642/2009	
Ecodesign requirements for freezers and refrigerators	Directive 2005/32/EC and Commission Regulation (EC) No 643/2009	
Council Decision on energy-efficiency labelling programmes for office equipment	Directive 2006/1005/EC	Electricity consumption, emission factors, energy efficiency, final energy consumption by sector by fuel type

Note: MW, megawatt; PM, particulate matter$_{\text{(particle diameter size)}}$.

While PaMs may be important, there may be other circumstances that affect emissions; for example, declining use of a particular fuel as a domestic energy source or changes in the use of particular types of combustion devices may occur because of the personal decisions of the public and the natural replacement of old and inefficient devices and may be completely unrelated to any policy or measure. These types of changes are likely to be important for domestic combustion (and for small non-domestic combustion sources) but can be very difficult to quantify or estimate.

A1.2.1 Activity data projections

Emission projections will need to be structured in the same way as historical estimates; it is therefore good practice to generate projected activity data for at least the same level of detail as in the historical inventory.

It may be that energy projections are not available at that level of detail, in which case it might be necessary to calculate future fuel use at a more aggregated level (e.g. all industry) before disaggregating into NFR categories 1A2a, 1A2b, etc., or whatever structure is used in the historical inventory. In some cases, it may be useful to disaggregate even further for projections; for example, in cases in which an inventory category covers both regulated and unregulated sources, it may be useful to generate separate activity data projections for the two types of source.

Ideally, official national energy projections should be used as the starting point for emission projections for stationary combustion sources. The Guidebook suggests projections from the International Energy Agency and from the PRIMES model as alternatives, should national projections not be available. Finally, ‘economic (e.g. production, income) and demographic (e.g. population, households) data sets’ can be used, but are best avoided for key categories.

Energy projections may be available only at a relatively low level of resolution, for example predicting only total energy use by sector and not energy use by fuel type. Additional modelling would then be needed to ensure that emission projections reflect fuel use and potential fuel switching. Similarly, fuel use may be projected only at the level of broad sectors (e.g. industry) and consideration will then need to be given to splitting that sector-level fuel use into more detailed sub-sectors in those cases in which this has a large impact on emissions (e.g. separating gas oil used in stationary industrial plants from gas oil used in mobile machinery/off-road vehicles used in industry). If energy projections are available only at an aggregated level and projections of industrial production are available at a higher level of detail, then using the latter to further disaggregate the energy projections may be a useful approach.

As well as forecasting how much fuel will be used, it is also necessary to consider how that fuel will be burned (i.e. what technologies will be used). For example, will gas be burnt in steam-raising boilers, gas turbines, engines, etc.? The technology will affect emission rates for many pollutants and so will need to be considered when selecting emission factors. However, technology and energy conversion efficiency are also relevant for energy forecasters and so the national energy projections may be underpinned by various assumptions or data on the nature of combustion plants in the future (particularly for power stations and other very large combustion plants). Thus, it is important to investigate if the energy projections may also tell you something about the sites and technologies in use in the future and thus help in the selection of emission factors.

A1.2.2 Emission factors

It is good practice to use comparable methodologies for both historical and projected emission estimates (i.e. factors derived using comparable methods and assumptions). So, for example, if Guidebook tier 1 emission factors are used for base-year historical emission estimates for a given source, it would be advisable to use the same tier 1 emission factors for projected emissions to ensure consistency in methodologies. Ideally, emission factors for projections will reflect technological changes and environmental regulations, but this is also true for historical factors and, if insufficient information is available to do this for historical factors, then it is also unlikely that it will be possible for projected factors. Use of different tiered methods would produce projections that are not consistent with the historical inventory and would perhaps lead to step changes between the historical and projected emissions that reflected methodological differences rather than, say, changes in environmental regulation of sources. If new information is collected that allows higher tier methods to be used for projections, it is likely that those same higher tier methods could then also be applied to the historical baseline, and so historical estimates should be updated at the same time, wherever possible.

Most countries will adopt tier 1 or tier 2 methods for most or even all estimates of historical emissions from stationary combustion, often using Guidebook factors. Tier 3 methods may be possible for sectors such as power generation, petroleum refineries or other sectors characterised by larger plants that typically will provide emissions data to regulators.

Plants used by the manufacturing industries, public sector and commercial sector range from the very small to the very large and therefore are not all regulated in the same way. This usually makes it difficult to estimate emissions, except by using relatively simple approaches, and it complicates projections as well. In comparison, projections for the energy industries and for the residential sector are generally somewhat easier, at least in theory. Most of the former are likely to be large and regulated and can be modelled individually in emission projections, whereas, for the latter, all of the sources are small and not regulated individually, and effort can be concentrated on modelling the gradual changes in the appliance stock over time. Some further discussion of all the sectors is given in the following sections.

A1.3 NFR 1A1: energy industries

Most, if not all, countries have power stations (NFR category 1A1a); some may also have petroleum refineries (NFR category 1A1b) and other energy producers such as oil and gas production installations or coke ovens (NFR category 1A1c). In all of these cases, the sectors are characterised by a relatively small number of large installations. The processes will probably all be regulated and historical emissions data may therefore be available, in which case countries may use a tier 3 method for the historical emissions. Even if these data are not available, the regulation of these sources implies that a lot of site-specific data may be readily available perhaps including ELVs that the plant operator must meet or other environmental requirements, such as fuel quality requirements, and the emission minimisation strategies that the operator already employs to meet those requirements.

If this information is available or can be collected for all sites (or at least for a representative number), this can help to generate a baseline from which emissions can be projected.

Ideally, future emissions should be modelled based on energy projections on a site-by-site basis, at least for the most significant sites. National energy projections may already be available at the site level for some or all installations or, if there are only a few sites, these could be estimated from the national energy projections. In cases where it is not possible or feasible to generate energy projections at the level of individual sites, compilers should still aim to include as much detail (stratification) as is required to adequately model future emissions, for example separating out fuel use for groups of plants that are or will be regulated in different ways or which use or will use different technologies. Compilers will need to also consider if any large existing plants are likely to be closed or if new plants are being built or are planned.

Once future activity levels have been estimated, compilers will need to establish what future emission factors are appropriate for each site or group of sites. These future factors will obviously need to reflect the fuel used and type of plant but should also reflect any abatement measures, including both technological measures and measures related to fuel quality. Regulators and operators may have agreed on upgrades to meet the requirements of regulations and/or set ELVs and other standards that have to be met. If not, then the standards set in the regulations themselves should be assumed to be met (e.g. ELVs in the IED).

The ELVs set in the IED and similar pieces of legislation are expressed as concentrations in waste gases. These are not directly useful for inventory compilers who need an emission factor per unit of fuel consumed. However, for combustion activities, waste gas concentrations can be converted into emission factors (see Annex E to the EMEP/EEA Guidebook, Chapter 1A1). Chapter '*1A1 Energy industries*' provides factors equivalent to various best available technique standards for power stations (Table 6-1 of that chapter lists factors for particulate matter, NO_x and sulphur dioxide (SO_2)) and refineries (Table 6-2 of that chapter lists factors for SO_2, NO_x, carbon monoxide (CO) and particulate matter) and gives an estimated factor for SO_2 from coke ovens. Emission factors equivalent to other concentration levels and for other pollutants can be inferred from the Guidebook values in those two tables or calculated using information in Annex E of chapter '*1A1 Energy industries*' and United States Environmental Protection Agency Method 19. Note that the relationship between concentration and factor is dependent on the reference conditions for the concentration (such as the oxygen level).

The Guidebook also suggests an alternative approach to determining emission factors for abated power plants as part of the tier 2 approach for NFR category 1A1a. This requires an unabated emission factor and an abatement efficiency. In some cases, this approach may be preferred, particularly if the nature of future abatement can be established with some certainty (e.g. if operators have already committed to a particular approach) and if that abatement option is likely to reduce emissions significantly below any ELV. However, some caution should be exercised when using the approach: abatement efficiencies quoted for planned systems may assume optimal operation of the system, whereas, in reality, the performance of the system may be less good.

A1.4 NFR 1A2: manufacturing industries and construction

Emission sources covered by NFR categories 1A2a-f and 1A2gviii (as well as 1A4ai and 1A4ci, see sub-section A1.6) will range from small space-heating plants that might be only slightly larger than domestic combustion appliances to plants that are well in excess of 50 megawatt thermal (MWth). This causes inventory compilers several difficulties, which are expected to be common to all countries to some extent, such as:

- It covers a large number of sites/plants, so that it is practically impossible to collect data on all or to model all individual plants and therefore assumptions must be made about the operation of many or all of the plants.
- A wide range of combustion technologies are in use, which may be poorly understood by the inventory compiler, leading to difficulty in applying tier 2-type factors.
- There are different regulatory regimes for different types and sizes of plants and some plants are not regulated at all, so modelling future emissions is complicated. In most countries, it is likely that national energy statistics give only sectoral fuel use and do not give any information on the projected fuel used by specific groups of regulated sites (e.g. there will probably be no energy projections that relate only to large (> 50 MWth) combustion plants). Regulators should collect data on large combustion plants and MSs are required to develop databases of all medium combustion plants (1-50 MWth): these data may allow the quantities of fuels used in large, medium and small plants to be estimated, at least for the historical inventory. The data could also be used to generate projections of future fuel consumption in regulated plants, although this will be more uncertain.
- As a result of the large number of sites, there is a poor understanding of the extent and nature of abatement in place in the base year, which again hampers the use of tier 2 methods for the historical inventory and makes it difficult to assess the different impacts that future regulations may have.
- Similarly, there is a poor understanding of the impact of plant closures, new plants and replacement plants. As with any plant, combustion appliances have a finite life and, even in the absence of regulation, gradual replacement of older plants is likely to change emissions.

These difficulties are considerable and, for many countries, will lead to a tier 1 method being adopted for all combustion in NFR category 1A2 (and categories 1A4ai and 1A4ci, see sub-section A1.6). Should a country collect detailed data on combustion plants, the Guidebook provides tier 2 factors for various types of industrial furnaces and kilns in chapter '*1A2 Combustion in manufacturing industries and construction*' and a limited range of tier 2 factors for conventional combustion plants in the '*1A1 Energy industries*' and '*1A4 Small combustion*' chapters (which can also be applied to industrial plants). A tier 2 historical inventory is a minimum pre-requisite for reliable projections; otherwise, the same tier 1 factors will need to be used for both historical and projected emission estimates. For most countries, a full tier 2 method covering all of the relevant parts of NFR categories 1A2 and 1A4 will be very challenging, so it may be best to begin by identifying those parts of categories 1A2 and 1A4 for which it is relatively easy to introduce a tier 2 or higher method. This is likely to include some or all of the following:

- blast furnaces (see Table 3-7 in the Guidebook, Chapter 1A2);
- sinter plants (see Table 3-8 in the Guidebook, Chapter 1A2);
- primary non-ferrous metals production (see Tables 3-12, 3-14 and 3-16 in the Guidebook, Chapter 1A2);
- lime kilns (see Table 3-23 in the Guidebook, Chapter 1A2);
- cement kilns (see Table 3-24 in the Guidebook, Chapter 1A2);
- large (> 50 MWth) combustion plants (see Tables 3-9 to 3-20 in the Guidebook, Chapter 1A1).

Within EU MSs, these are all IED Chapter II-regulated activities (some, including cement and lime kilns, are regulated if above a capacity threshold). In addition, site-specific emissions data may be available for many sites falling within these categories, such that tier 3 methods could then be used for the historical inventory. The types of processes listed are also those that are most likely to be regulated and to have to comply with ELVs and other requirements (and, thus, sophisticated projections are more desirable in any case, compared with smaller plants that may largely be unregulated). Depending on the situation within a country, additional groups of sites might be included as being relatively easy to treat using a tier 2 methodology.

However, for both the historical inventory and the projections, it would be necessary to separate out the fuel used at sites where a tier 2 method was to be used, so that the fuel used at the remaining sites (where a tier 1 method was to be used) could be calculated by the difference using national energy statistics. Therefore, either the national energy projections would need to separately consider the fuel used at the 'tier 2' sites or this would need to be estimated from the wider energy projections. Historical fuel use might be available in energy statistics or could perhaps be derived using data sets such as the EU Emissions Trading System.

Projections for the tier 2 sectors could then be made in a similar way as for the energy industries: characterisation of current abatement strategies and identification of future requirements and derivation of suitable emission factors to model the impact of those requirements on emissions.

A1.5 NFR 1A3: transport

When compiling projections, it is necessary to understand what circumstances, and what PaMs might drive changes in emissions in the future. Table A1-2 lists some of the key policies and regulations that may have an impact on air pollutant emissions arising from the transport sector. Please note, however, that this list is not exhaustive and items may be superseded following publication of the chapter. Some of these policies (e.g. Euro 5 and Euro 6 regulations for road vehicles) will affect emissions directly and others may have an indirect effect, so care should be taken when considering the impact of these measures.

Table A1-2 Summary of important EU legislation relevant to the transport sector

Description	Legislation	Parameters/variables
	Cross-cutting	
Renewable Energy Directive (RED)	Directive 2009/28/EC	Energy efficiency, final energy consumption by sector by fuel type, fuel specification, share of biofuels in transport, share of renewables in electricity generation
Directive on the taxation of energy products and electricity	Council Directive 2003/96/EC	Electricity consumption, final energy consumption by sector by fuel type, fuel price, share of different forms of energy
Emissions Trading Scheme Directive	Directive 2009/29/EC amending Directive 2003/87/EC	Electricity consumption, emission factors, energy efficiency, final energy consumption by sector by fuel type, share of different forms of energy
Directive on the reduction of national emissions of certain atmospheric pollutants	Directive 2001/81/EC and Directive (EU) 2016/2284	Emission reduction commitments for air pollutants
Effort Sharing Decision and Effort Sharing Regulation	Decision No 406/2009/EC and Regulation (EU) 2018/842	Electricity consumption, final energy consumption by sector by fuel type, share of different forms of energy
Ambient Air Quality Directives	Directive 2008/50/EC and Directive 2004/107/EC	New air quality objectives for $PM_{2.5}$ (fine particulate matter) including the limit value
	Transport	
Fuel Quality Directive	Directive 2009/30/EC	Emission factors, fuel specification
Directive on Stage II petrol vapour recovery	Directive 2009/126/EC	Emission factors for vehicle refuelling
Directive on the deployment of alternative fuels infrastructure	Directive 2014/94/EU	
Regulations on CO_2 from cars and vans	Regulations (EC) 443/2009, (EU) No 510/2011, (EU) No 397/2013, (EU) No 333/2014, (EU) No 253/2014, 2013/128/EU, (EU) No 396/2013 and (EU) No 114/2013	Emission factors, fuel efficiency

Regulation on CO_2 emissions and fuel consumption of heavy-duty vehicles	Commission Regulation (EU) 2017/2400	Fuel efficiency
Regulation on Euro 5 and Euro 6	Regulation (EC) No 715/2007	Emission factors
Regulation on Euro 6 RDE for light-duty vehicles	Commission Regulation (EU) 2017/1151 (Worldwide Harmonised Light Vehicles Test Procedure, contains RDE 1-3) and Commission Regulation (EU) 2018/1832 (contains RDE 4)	Emission factors
Regulation on Euro VI for heavy-duty vehicles	Regulation (EC) No 595/2009	Emission factors
Directive on the labelling of new passenger cars	Directive 1999/94/EC	Fuel efficiency
Regulation on the labelling of tyres	Regulation (EC) No 1222/2009	Emission factors, fuel efficiency
Directive on the promotion of clean and energy efficient road transport vehicles	Directive 2009/33/EC	Fuel specification
Eurovignette Directive on the charging of heavy goods vehicles for the use of certain infrastructures	Directive 1999/62/EC as modified by Directive 2006/38/EC and Directive 2011/76/EU	Share of freight transport per mode
Regulation on the approval and market surveillance of motor vehicles and trailers	Regulation (EU) 2018/858 amending Regulations (EC) No 715/2007 and (EC) No 595/2009 and repealing Directive 2007/46/EC	
Regulation on the approval and market surveillance of two- or three-wheel vehicles and quadricycles, and the related implementing regulation	Regulation (EU) No 168/2013 (Euro 4 and Euro 5)	
ACEA agreement: voluntary agreement to reduce specific CO_2 emissions from cars	1999/125/EC	Emission factors, fuel efficiency
Directive on measures to be taken against air pollution by emissions from motor vehicles	Directive 98/69/EC	Evaporative emission factors for gasoline vehicles
Mobile Air Conditioning Directive (hydrofluorocarbon emissions from air conditioning in motor vehicles)	Directive 2006/40/EC	Fuel efficiency, fuel use per transport mode, share of gases in personal cars
IMO International Convention for the Prevention of Pollution from Ships (MARPOL) Annex VI to limit the sulphur content of fuels used by ships. Includes NO_x Technical Code limiting NO_x emissions from new engines	Implemented through Council Directive 1999/32/EC, which was subsequently amended by Directive 2005/32/EC and Directive 2012/33/EU	Emission factors in emission control areas, outside emission control areas, at berth in EU ports
IMO Energy Efficiency Design Index for ships		Energy efficiency of new ships over 400 gross tonnage
Directive on sulphur content in liquid fuels	Directive (EU) 2016/802	Sulphur content of certain liquid fuels
Directives on emissions from non-road mobile machinery	Directive 97/68/EC subsequently amended by Directive 2002/88/EC, Directive 2004/26/EC, Directive 2006/105/EC, Directive 2010/26/EU, Directive 2011/88/EU and Directive 2012/46/EU	Emission factors
Regulation on requirements relating to gaseous and particulate pollutant emission limits and type-approval for internal combustion engines for non-road mobile machinery	Regulation (EU) 2016/1628	Emission factors
Regulation on the approval and market surveillance of	Regulation (EU) No 2013/167	

agricultural and forestry vehicles, and all related implemented and delegated acts		
Directive on recreational craft and personal watercraft	Directive 2013/53/EU	
Amending Directive 2003/87/EC to include aviation activities in the scheme for GHG emission allowance	Directive 2008/101/EC	Final energy consumption by sector by fuel type, shares of different forms of energy
Directive establishing a single European railway area	Directive 2012/34/EU	Electricity consumption, fuel switch in transport, fuel use per transport mode, kilometres driven per transport mode, modal shift in transport
Directive on the interoperability of the rail system within the Community (recast)	Directive 2008/57/EC	Electricity consumption, fuel switch in transport, fuel use per transport mode, kilometres driven per transport mode, modal shift in transport
Regulations establishing the second Marco Polo programme	Regulation 1692/2006 and Regulation 1382/2003	Electricity consumption, fuel switch in transport, fuel use per transport mode, kilometres driven per transport mode, modal shift in transport
Regulation on shifting the balance between modes of transport, in particular towards rail	Regulation (EU) 2016/796 repealing Regulation (EC) No 881/2004	Electricity consumption, fuel switch in transport, fuel use per transport mode, kilometres driven per transport mode, modal shift in transport
Integrated European railway area (second and third railway packages)	COM(2002)18 final	Electricity consumption, fuel switch in transport, fuel use per transport mode, kilometres driven per transport mode, modal shift in transport, share of different forms of energy

Note: ACEA, European Automobile Manufacturers Association; IMO, International Maritime Organization; RDE, real driving emissions.

A1.5.1 NFR 1A3a: aviation

Emissions from take-off and landing for both domestic and international flights must be included in national totals. The main consideration for an MS to estimate future emissions from aviation is the anticipated change in aircraft activities in that country. At the most basic level, this can be based on aviation forecasts in terms of numbers of departures and arrivals at national airports. However, MSs should also consider future changes in the aircraft fleet serving airports in the country, which would lead to a change in emission factors when using a tier 2 or tier 3 approach and changes in operational practices (e.g. time-in-mode during landing, take-off, etc.) when using a tier 3 approach. This information may be available from transport ministries or from airport authorities and airlines. In this respect, consideration should be given to any planned airport expansions and changes in aircraft types using them. Emission factors are available in the Guidebook for different types of aircraft and different modes of operation.

A1.5.2 NFR 1A3b: road transport

Road transport is a key source category for many MSs, so inventories require a tier 3 methodology to estimate emissions wherever possible, using detailed activity data and emission factors for different vehicle types. Ideally, the same tier 3 approach should underpin projections for this sector and therefore be based on best estimates on activities at a detailed level.

Future vehicle fleet turnover and composition

Unlike the data for the historical inventory, which can come from national transport statistics and vehicle registration sources, the emissions inventory team may not normally have access to information on projections. Valuable insight can be gained by analysing historical information on vehicle registrations to determine average lifetimes and mileage, which can be used to predict turnover in the fleet for future years, although care should be taken to consider the recent situation and the situations in the future that might differ from the past. Vehicle lifetimes, vehicle purchasing behaviour and usage patterns, such as how mileage changes with vehicle age or accumulated mileage typical of the past, might change in the future.

A fleet turnover model can be used to predict the number of vehicles in future years and the breakdown in the fleet by vehicle age, fuel and technology type, and Euro emission standard (and the stage of Euro 6 in the case of passenger cars and light-duty vehicles, as defined by the emission factors given in the COPERT 5 model for example, reflecting the performance of vehicles before and after compliance with EU Real Driving Emissions (RDE) limits). The model can be based on estimates of new vehicle sales and assumed lifetimes or survival rates, which determine how long existing and new vehicles remain in the fleet. Such a fleet turnover model should ideally be linked with a transport activity growth model. For instance, if the growth of activity of cars (in passenger-kilometres) in the future is limited, then the new vehicles that will be required to be registered will be less than a counterfactual case in which the activity growth would be higher.

There are several ways of interpreting vehicle registration data to make the desired fleet projections, depending on the level of detail available.

Average age distribution and vehicle survival rates

By examining vehicle registration data for recent years, it ought to be possible to determine the average age distribution of vehicles in the fleet and the distribution of Euro emission classifications. The age distribution in any particular year will be influenced by fluctuations in new vehicle sales in previous years, as well as vehicle lifetime/survival rates. A stock flow model should be used to analyse the age distribution of vehicles in different years and used to predict the distribution in future years according to new vehicle sales projections.

If sufficient licensing data are available, one approach might be to look at new vehicle sales or registrations for historical years and the age distribution of a current year. From this, it would be possible to determine how survival rates of vehicles change with age. For example, if 500 000 cars were registered new in 2010 and 400 000 5-year-old cars were still registered in 2015, then a survival rate of 80 % would be implied for 5-year-old cars. Survival rates should be determined like this, referenced to several previous years to determine a pattern of survival rates with vehicle age averaged over several years. Such a survival rate profile could then be applied to predictions of new vehicle sales to determine the age distribution of the fleet in future years and, based on matching the year of registration to Euro standards, the mix of Euro standards and alternative-fuelled vehicles in the fleet can be determined, while at the same time considering potential differences from alternative fuels usage (see the sub-section 'Consideration of future policies and measures').

The MS will need to consider the sales of imported second-hand cars into the country. This could be significant for some countries. These will not be accounted for in manufacturers' new car sales data and care will need to be taken to check with licensing authorities how these are accounted for in vehicle registration data. Ideally, there will be a record of the second-hand car's Euro emission classification when it is registered in the country.

Sources of vehicle data

Vehicle registration data should be available from the transport ministry or statistics bureau in the MS, but other data sets are available by country from:

- Eurostat (e.g. https://ec.europa.eu/eurostat/web/transport/data/database);

- the EEA (e.g. on the average age of cars by country at: https://www.eea.europa.eu/data-and-maps/daviz/average-age-of-road-vehicles-6#tab-chart_1);
- the European Automobile Manufacturers Association (ACEA) (e.g. on the average age of cars by country at: https://www.acea.be/statistics/tag/category/average-vehicle-age); these data differ significantly from the data from the EEA (above);
- the International Council on Clean Transportation's European vehicle market statistics pocketbook (https://www.theicct.org/publications/european-vehicle-market-statistics-20182019), which gives the number of new registrations each year up to 2017 by fuel type, technology and other vehicle parameters for passenger cars and light commercial vehicles.

Other studies have provided analyses of vehicle lifetimes (e.g. a report by Ricardo on the age distribution of cars at their end of life is available at: https://ec.europa.eu/clima/sites/clima/files/transport/vehicles/docs/ldv_mileage_improvement_en.pdf).

These sources may not all provide consistent data on an MS because of different data collection methods used, so wherever possible vehicle registration data held by the MS or from sources such as Eurostat should be used, otherwise some expert judgement may be necessary to determine which other data sets to use.

The 'TRACCS' database provides statistics on the population of cars, disaggregated by fuel and age recorded for each MS. The statistics cover the years up to 2010, but they are useful to allow calculations (by the EU MSs) with regard to the assessment of the average car lifetimes/survival rates (see https://traccs.emisia.com/download.php).

Overall new vehicle sales projections

Future evolution of the fleet of vehicles needs to consider the trend in the overall new vehicle sales (the overall quantities of new vehicles sold and of imported second-hand vehicles) and the type of technologies and fuels that penetrate the market. New vehicle sales and second-hand imports will need to be treated independently. This section presents insights on the projections on the overall new vehicle sales.

Projecting/forecasting future new vehicle sales is vital in determining the fleet composition in future years. MSs are recommended to consult with stakeholders in their country who may be able to provide best estimates of new vehicle sales or through analysis of historical trends in new vehicle sales and relationships with economic drivers or transport indicators for their country.

Key stakeholders in countries who may have considered future trends in new vehicle sales are likely to be transport ministries, government departments responsible for vehicle excise duty and taxation, car traders and vehicle trade associations (e.g. ACEA).

New vehicle sales might show a relationship with indicators such as GDP, population or number of households. Future predictions in changes in these indicators could then be used as a driver for changes in future new vehicle sales.

The growth of the transport activity for each transport mean is a key determinant for the evolution of the overall new vehicle sales. In the case of cars, the economic growth that is also reflected as an increase in the available disposable income of households will lead to an increase in the car ownership rates in the MS. This is particularly true for countries in which the current cars/capita indicator is below the EU average.

Projections in new market sales by fuel and technology

New vehicle sales and fleet turnover should be considered for each main vehicle type accounted for in the inventory: passenger cars, light-duty commercial vehicles, heavy goods vehicles (trucks), buses and mopeds and motorcycles. However, consideration should also be given to any predicted changes in fuel types and the rate of penetration of new fuels and technologies. For example:

- Will there be a change in new car purchasing behaviour with a switch in preference from diesel to gasoline cars? Recent trends have shown that the period of growth in diesel car sales experienced in some countries over the past 5-10 years has stopped in favour of sales in gasoline-powered cars.
- Will there be a growth in sales of hybrids, plug-in hybrids, battery electric vehicles, vehicles using alternative fuels such as LPG or compressed natural gas?

It is most likely that there will be a growth in these alternative vehicle technologies and fuels across the EU but at different rates in each MS. The potential replacement of conventional powertrains by ultra-low-emission vehicles ([21]) varies for different vehicle categories, as summarised in Table A1-3, showing what is available now and in the medium term. This table is meant as an indication at the present time (2019) of the technology-readiness level of the different powertrain types within each main vehicle category.

Table A1-3 Potential replacement of conventional powertrains by ultra-low-emission vehicles

Vehicle category	Hybrid electric vehicle	Plug-in hybrid vehicle	Battery electric vehicle	Hydrogen full cell	Methane
Petrol PC					
Diesel PC					
Petrol LCV					
Diesel LCV					
Rigid truck, 3.5-12 tonnes					
Rigid truck, > 12 tonnes					
Articulated truck					
Urban bus					
Coach					

Notes: LCV, low-carbon vehicle; PC, passenger car.

Key	Model availability
	Available now
	Few models available now, but increasing
	Very few models available now and decreasing

([21]) Low-emission vehicles are defined as those having tailpipe emissions of less than 50 g CO_2/km, which are principally plug-in hybrid vehicles, in addition to battery electric vehicles. See: https://ec.europa.eu/clima/policies/transport/vehicles/proposal_en

	Early days but may be important in the longer term

The projections of future numbers of these five types of powertrains are uncertain and are vehicle category dependent. For example, battery electric vehicles (BEVs) are currently replacing both petrol- and diesel-fuelled passenger cars, buses and, to a small degree, some light goods vehicles, but no commercially available electric > 12 tonne heavy goods vehicles or coaches are currently available. There is wide variation in the numbers of new vehicle registrations projected, which include systematic variations dependent on the origins of the projection. These can be broadly classified into:

- aspirational targets and ambitious aspirational targets by policymakers;
- market analysis by independent consultants or by industry.

The European Commission's recently adopted post-2020 CO_2 targets are that average emissions of new cars and vans should be 15 % lower in 2025 and 37.5 % or 31 % lower in 2030, relative to 2021, for cars and vans, respectively. For passenger cars, there are also 'benchmark' levels of zero- and low-emission vehicles of 15 % in 2025 and 35 % in 2030 ([22]). Data from ACEA ([23]) indicate that, in 2017, sales of BEVs were 0.7 % of the European car market, while plug-in hybrid electric vehicles (PHEVs) comprised 0.8 % of sales. Under the EU's proposal, sales of BEVs plus PHEVs would need to jump from the current 1.5 % of sales in 2017 to 35 % of sales in less than 12 years. Sales of ultra-low-emission vans have a benchmark target of 30 % by 2030.

As an example, the UK 'Road to Zero' vision describes the UK ambition of wanting to see at least 50 % (and as much as 70 %) of new car sales, and up to 40 % of new van sales, being ultra-low-emission vehicles by 2030 ([24]). (This is in the context of the United Kingdom's 2017 sales of such vehicles being around 1.8 %.)

The European Alternative Fuel Observatory report *The transition to a zero emission vehicles fleet for cars in the EU by 2050* (ACEA, 2017) undertook a literature survey of available market forecasts, which is reproduced in Figure A1-1. The report was published in November 2017 and takes into account a range of forecasts from 2011 and more recently.

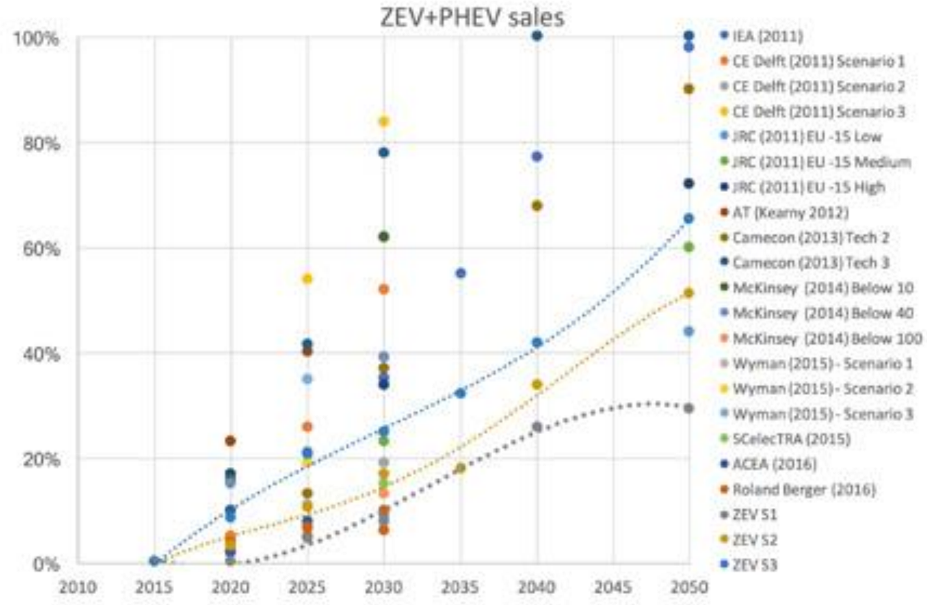
Notwithstanding the somewhat dated projections, three scenarios were developed for the uptake of zero-emission vehicles (principally BEVs). These provide realistic boundaries regarding levels of uptake of zero-emission vehicles, which range from 12 to 25 % by 2030.

([22]) See Council of the EU, 2019, 'CO_2 emission standards for cars and vans', 16 January (https://www.consilium.europa.eu/en/press/press-releases/2019/01/16/co2-emission-standards-for-cars-and-vans-council-confirms-agreement-on-stricter-limits/).

([23]) See ACEA, 2018, *Making the transition to zero-emission mobility*, European Automobile Manufacturers Association (https://www.acea.be/publications/article/study-making-the-transition-to-zero-emission-mobility).

([24]) See UK Department for Transport, 2018, *Road to zero, next steps towards cleaner road transport*, (https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/739460/road-to-zero.pdf).

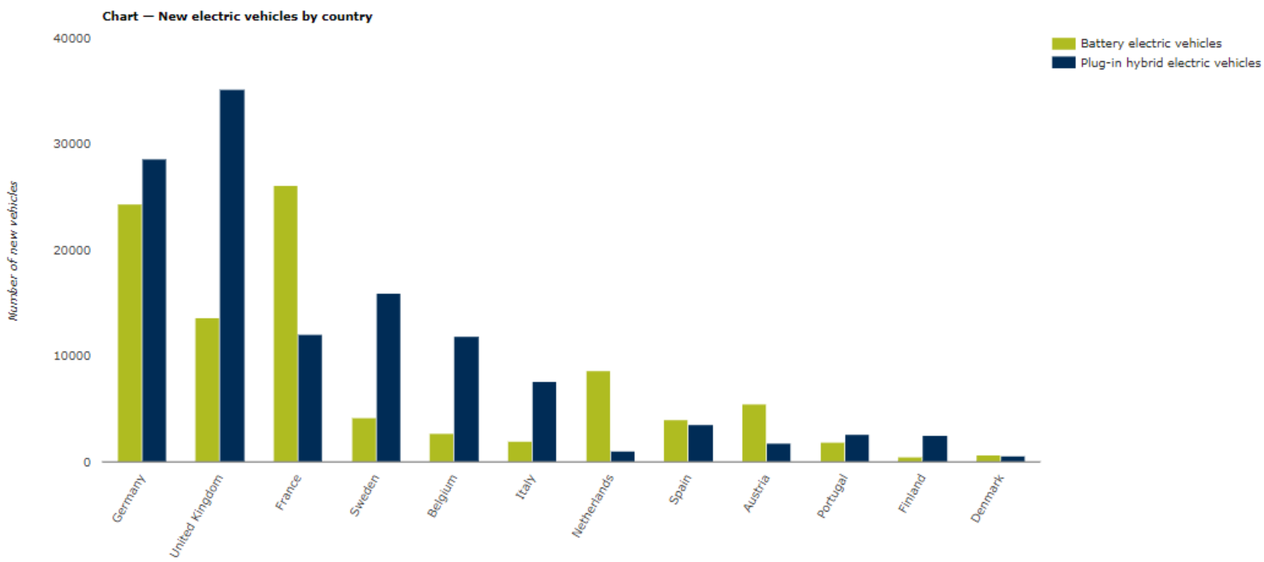
Figure A1-1 Forecasts for the combined zero-emission vehicle and PHEV market share



Note: ZEV, zero-emission vehicle.
Source (and for references in the figure): ACEA (2017)

However, sales within individual MSs vary widely and MSs should consider their own local situation. One reference point is the number of hybrid electric vehicles (HEVs), PHEVs and BEVs sold in recent years. A pictorial representation of this is given in Figure A1-2.

Figure A1-2 Market share of electrically chargeable cars



Source: (EEA indicator TERM034)

Factors to take into account when considering rates of BEV growth in different regions are MSs' per capita GDP, government incentives (affecting BEV affordability) and the maturity of electric vehicle recharging infrastructure, affecting usability.

These projections have been for new light-duty vehicle registrations, which would then be incorporated into the fleet turnover model, alongside registrations of vehicles with conventional powertrains to obtain the fleet composition. For heavy goods vehicles, the United Kingdom's *Road to zero* report (HM Government, 2018) indicates that it is premature to consider future market share for both 16 tonne rigid trucks and 44 tonne articulated trucks. The report states that 'electric and hydrogen trucks are not yet market ready but would offer the most significant Greenhouse Gases (GHG) and pollutant emission reductions'. Therefore, currently, it would be reasonable to project no electric or fuel cell vehicle registrations before 2025 (or even 2030) for trucks heavier than 12 tonnes gross vehicle weight and very modest (< 2 % sales) electric or hydrogen trucks in the range of 3.5-12 tonnes by 2025.

Notwithstanding, CO_2 emission reduction targets for trucks have also been adopted recently ([25]). The new rules will ensure that, between 2025 and 2029, new trucks will emit, on average, 15 % less CO_2 than 2019 emission levels. From 2030 onwards, they will be required to emit, on average, 30 % less CO_2. Therefore, projections of the powertrains used by heavy-duty vehicles should take these binding targets into account when projecting the powertrain mix for future years.

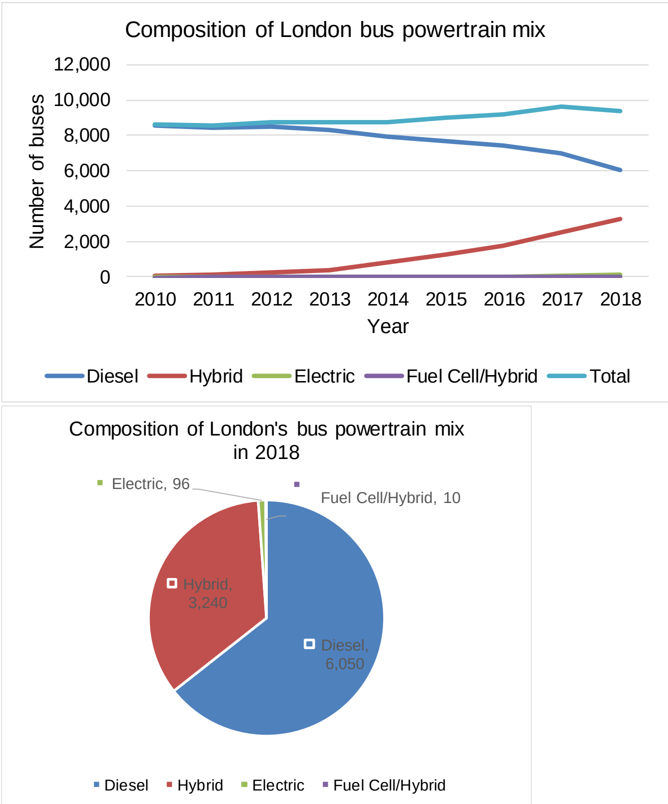
In contrast, for buses, the *Road to zero* report states that 'zero emission (and hybrid) buses are available now and offer significant GHG and pollutant emission reductions'. However, uptake rates are not only variable among MSs but also very variable for different cities within a single MS. For example, in the United Kingdom, some cities use only conventional diesel buses, whereas, for an environmentally-challenged city such as London, the uptake of hybrid and electric buses and the trialling of hydrogen buses may constitute a significant proportion of new sales.

For example, London's bus fleet powertrain profile has evolved in recent years, as shown in Figure A1-3 ([26]).

([25]) See Council of the EU, 2019, 'Heavy-duty vehicles: Council presidency agrees with Parliament on Europe's first-ever CO_2 emission reduction targets for trucks', 19 February (https://www.consilium.europa.eu/en/press/press-releases/2019/02/19/heavy-duty-vehicles-eu-presidency-agrees-with-parliament-on-europe-s-first-ever-co2-emission-reduction-targets/).

([26]) Data from the Transport for London website, available from: https://data.london.gov.uk/download/number-buses-type-bus-london/12ab947a-6d02-4792-93d1-dac9da2cc7d2/tfl-buses-type.xls

Figure A1-3 London's bus fleet powertrain profile



Consideration of future policies and measures

The above considerations are the minimum requirements for a baseline projection that considers the natural evolution of the vehicle fleet in response to current legislation and market forces across the EU. When parameters in the fleet turnover model are based on historical trends, such as average vehicle lifetime and usage patterns, it is important to consider how these might change in the future. It will be important to consider any national PaMs that may influence the development of the fleet in an MS. Such considerations could include, but are not limited to, whether or not scrappage schemes are to be introduced to remove older, higher emitting vehicles at an accelerated rate or whether low-emission zones are to be introduced, prohibiting access within a zone to vehicles older than a certain age or not compliant with a specified Euro emission standard. The fleet turnover model should be set up to be able to account for such interventions.

As well as removing older vehicles from the fleet or prohibiting access, scrappage schemes and low-emission zone schemes may lead to a higher volume of new vehicle sales, which would need to be factored in to the fleet turnover model.

Vehicle mileage by age

A fleet turnover model developed using trends in vehicle registration data and new vehicle sales will describe the composition of the fleet in terms of numbers of vehicles. However, it is vital to combine estimates on number of registrations by vehicle age with information on how annual mileage changes with age. In general, annual mileage tends to decrease with vehicle age, so on-road vehicle activities are biased towards newer vehicles.

Data on vehicle mileage with age may be available from national vehicle inspection programmes. There are also default figures given in existing COPERT software. The key point here is that it is the relative change in mileage with age, rather than absolute mileage, that is sufficient for combining with the fleet turnover model when determining the age structure of the fleet of vehicle activities on the road. This is because the absolute mileage is calibrated in models such as COPERT against fuel sales data. The relative change in mileage with age based on historical trends can be assumed to remain constant in future, although total mileage for future years may need to change (see the following).

Vehicle-kilometres

The MS should already be using annual mileage per vehicle type in models such as COPERT or the Handbook Emission Factors for Road Transport (HBEFA), which have been calibrated to fuel sales during the derivation of the emission inventory for historical years. It can be assumed in baseline projections that annual mileage per vehicle, and the distribution between road types (urban, rural, highway), remains unchanged in future years with total vehicle-kilometres changing according to changes in the number of vehicles in the fleet, as derived from the fleet turnover model.

However, the MS should consider national and local circumstances that might change the total vehicle-kilometres travelled. These might be in response to transport policies and should be discussed with the relevant ministries responsible for transport and highways planning. The types of factors that could influence total vehicle-kilometres travelled (number of vehicles and/or distances travelled) include, but are not limited to:

- current road capacity (does the current road network have the capacity to accommodate additional vehicles?);
- road-building plans (e.g. are there plans to construct or expand highways linking major towns and cities or to introduce ring roads?);
- congestion charging schemes (being introduced to curtail further growth in traffic in congested areas);
- public transport schemes (encouraging less use of private passenger cars in favour of bus and rail — such a scheme may not affect the overall car population predicted as above, but may lead to lower usage (annual mileage));
- other forms of modal shift (e.g. moving road freight to rail or inland waterways, car sharing and changes in freight haulage logistics, such as moving freight around in fewer, but larger, trucks);
- fuel prices and taxation policies.

Each of these factors could be reflected in several different ways. The most useful way is if countries have projections expressed as the number of vehicle-kilometres. However, other metrics reflecting how these factors influence traffic levels or distances travelled could be used to scale the number of vehicle-kilometres travelled.

Fuel sales projections

The historical inventory developed by the MS should already be calibrated to national fuel sales. When considering road transport emission projections, the MS should check if any forecasts in fuel sales have been made, including separate forecasts for sales of petrol, diesel, LPG and biofuels. While not sufficient on its own, since one type of fuel will be used by a few different vehicle categories, forecasts in future fuel sales would provide a guide on expected changes in future vehicle activities and may be used to calibrate forecasts of future vehicle-kilometres derived by the bottom-up, vehicle-kilometres-based method described above.

Forecasts of future fuel sales may come from ministries involved in national energy forecasts or GHG projections, although it must be appreciated that these may be conducted at a macro-economic level, based on fuel prices, GDP, etc. However, the MS should find out if any detailed assessment has been made on fuel demand by the road transport sector and what assumptions were made underpinning these projections.

Other useful insights into future demand for fuels may come from the fuel industry, its associations within the MS, dealers and suppliers.

There will be cases where 'fuel used' (as related to vehicle activity within the country) does not coincide with 'fuel sold' and the MS will need to consider if an indicator for a change in fuel sales is a suitable indicator for a change in vehicle activities underpinning the emission projections, although emissions for the base year are calibrated to national fuel sales. This is especially the case in countries with a high share of transit traffic (i.e. road vehicles crossing the country and refuelling inside the territory of the country). The issue that arises is that the activity growth does not evolve in the same manner as the fuel quantities reported by Eurostat (e.g. transport activity statistics show a stagnation, while the energy balances for the transport sector show an increase).

Emission factors: current and conventional vehicle technologies

Emission factors for all current and near-future vehicle types, fuels and technologies (including conventional non-plug-in hybrid petrol cars and HEVs) are available in COPERT and the HBEFA and should be sufficient for all emission projections for the road transport sector, as they cover all vehicle types up to the latest Euro 6/VI standards, including the effect of the new EU RDE Regulations (Euro 6d). These factors are applicable to projections because no further legislative stages are currently in place. These factors are also available in this *guidebook*. Exhaust emission factors for NFR categories 1A3bi-iv should be assigned according to the fuel type, Euro standard based on the year of first registration and/or any other technology-related descriptor (e.g. whether the vehicles uses exhaust gas recirculation or SCR), as well as average vehicle speed (COPERT) or road type and traffic situation (HBEFA).

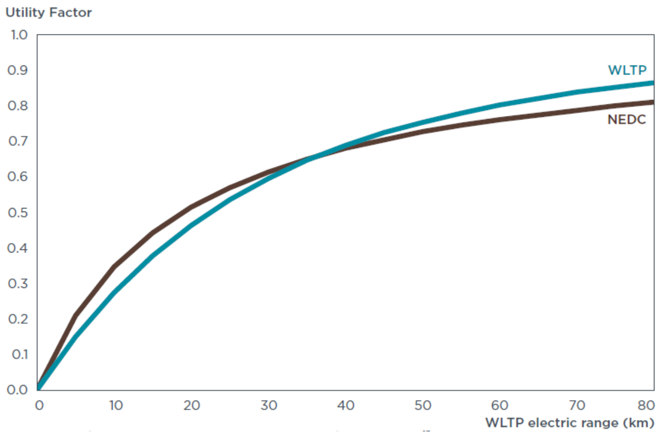
Emission projections for NMVOCs will need to include evaporative emissions from petrol vehicles (NFR category 1A3bv) and projections of particulate matter with a diameter of less than 2.5 micrometres ($PM_{2.5}$) and of less than 10 micrometres (PM_{10}) will need to cover non-exhaust emissions from tyre and brake wear (NFR category 1A3bvi) and road abrasion (NFR category 1A3bvii). For the baseline projections, these emission factors should be, for the time being, assumed to remain at levels representative of current vehicles in the fleet (i.e. that there are no current technological reasons for change).

Emission factors: alternative and non-conventional vehicle technologies

BEVs and hydrogen fuel cell vehicles have no exhaust/tailpipe emissions. However, they do generate non-exhaust particle emissions (NFR categories 1A3bvi and 1A3bvii) and so it is important to include these in the emission projection estimates.

PHEVs should be treated as comprising *X* % electric vehicles and (100 – *X*) % hybrid powertrain vehicles, where the factor '*X*' is known as the utility factor. It corresponds to the fraction of the vehicle's kilometres driven using electric power. It is a strong function of the vehicle's electric-only driving range. These are shown for the algorithms specified in the New European Driving Cycle (NEDC) and the Worldwide Harmonised Light Vehicle Test Procedure (WLTP) regulations in Figure A1-4; these relationships may be used as default values.

Figure A1-4 Fraction of a vehicle's kilometres driven using electric power



The utility factors shown in Figure A1-4 would enable an overall emission factor to be derived for a PHEV using the emission factors available for a conventional hybrid petrol car (e.g. where the utility factor is 0.1, the emission factors would be 0.9 × the factor for a HEV).

For real-world driving, Joint Research Centre (JRC) research (JRC, 2015) found that the utility factors in Figure A1-4 probably over-estimate the percentage of electrically powered vehicle-kilometres and that actual utility factors varied for PHEVs used in different European cities. Consequently, the utility factors shown in Figure A1-4 should be viewed as somewhat optimistic default values.

COPERT contains emission factors for hybrid passenger cars. A similar pro rata reduction relative to the non-hybrid internal combustion engine counterparts can be applied to low-carbon vehicles to obtain emission factors for hybrid vans. For buses, extensive research by Transport for London on its hybrid buses, which comprised 35 % of its fleet in 2018, indicates the scaling factors as given in Table A1-4.

For methane spark ignition (single fuel) buses and trucks, a number of studies have indicated that, for example, for Euro IV vehicles, methane vehicles have markedly lower PM and NO_X emissions than their diesel counterparts. However, recent studies comparing their emissions with Euro VI diesel vehicles equipped with SCR plus a diesel particulate filter indicate that the difference is generally reducing ([27]).

Scaling factors for methane spark ignition buses and trucks, relative to their diesel counterparts, are included in Table A1-4.

Table A1-4 Scaling factors for buses and trucks, relative to their diesel counterparts

	Hybrid vehicles		Natural gas-fuelled vehicles	
Heavy-duty vehicle emissions standard	**NO_x**	**PM**	**NO_x**	**PM**
Euro 4	0.8	1.0	0.5	0.1
Euro 5	0.8	1.0	0.7	0.4
Euro 6	1.0	1.0	1.0	1.0

([27]) From Transport for London studies on methane-fuelled buses, June 2017, available from: http://content.tfl.gov.uk/sshrp-20170626-item10-low-emission-bus-cng.pdf

For these heavy-duty vehicles in the future, it could also be assumed that their emission factors are the same as the low emissions from conventional diesel vehicles fitted with advanced exhaust after-treatment systems.

However, while these are useful generalisations, there is increasing evidence (see, for example, JRC (2015)), that, at the lowest speed applicable to urban buses in a congested city, NO_x emissions are reduced relative to diesel counterparts for the methane-fuelled vehicles because the SCR abatement is less effective, whereas, for higher load operations, the diesel vehicles have NO_x emissions that are comparable to, or even lower than, the methane-fuelled equivalent. Inventory compilers should keep abreast of the most recent evidence on the relative emissions of natural gas-fuelled vehicles if their inventory contains significant quantities of these alternative-fuelled vehicles.

Environmental factors

There are several environmental factors that can have an impact on emissions. These include:

- ambient temperature for cold start and evaporative emission calculations;
- road gradient: this is a parameter already required in models such as COPERT for calculating the historical emission inventory; unless an MS already has information on distances travelled on roads with significant gradients (e.g. in a country with many significant highways over mountain ranges), a value of zero gradient will most likely be assumed in its historical inventory and should be retained at this level for projections;
- vehicle load;
- Reid vapour pressure of petrol (for evaporative emission calculation).

The tier 3 method in the Guidebook, as embedded in COPERT, includes default parameters for variables such as road gradient and vehicle load. These are not expected to change substantially with time, and calculations can therefore be undertaken without changing the existing parameters. However, as ambient temperatures vary each year, it is recommended that the type of temperature data used for estimating these emissions in the historical inventory, averaged over the past 10 years, be used in deriving an appropriate emission factor for future years. Consideration can also be given to how future temperatures are expected to differ from current years.

A1.5.3 NFR 1A3c: railways

Rail activity projections can be derived from national projections on specific freight and passenger numbers, if available. Often, projections of passenger/freight-tonne mileage data are available and can be used to scale historical activity data accordingly. When these data are not available, more general population or GDP projections can be used or emissions assumed to be the same as the latest historical year (when rail is not a key category).

Emission factors need to account for any change in the split in train-kilometres between electric and diesel lines, new diesel technology in the rail fleet and/or changes to fuel quality (e.g. the sulphur content). It is worth noting that the use of high-speed locomotives may actually be less fuel efficient than ‘traditional’ locomotives, partly because they are, in general, required to meet more stringent safety requirements.

A1.5.4 NFR 1A3d: navigation (shipping)

When shipping is a key category, it is recommended that, as a minimum, a tier 2 approach be used for both the historical inventory and projections. The advantage of a tier 2 inventory approach to estimate emissions from national navigation for current and historical years is that it provides a firmer basis for projecting future emissions by consideration of activity drivers relevant to different types of vessels (e.g. cargo versus passenger) and for accounting for PaMs that affect specific segments of this sector.

There are three main aspects for forecasting future emissions from ships:

1. projecting future vessel activities (e.g. port callings, number of vessels);
2. improvements in vessel fuel efficiencies;
3. changes in future emission factors.

The main challenge in projecting future emissions from this sector is estimating future shipping activities and fuel consumption.

Projections in future vessel activities

Projecting future vessel activities would be based on a consideration of growth in port callings or number of active vessels. This is likely to be one of the main areas of uncertainty and can be based only on best judgement through engagement with various stakeholders familiar with this sector.

There are no hard and fast rules on what sort of metric could be used as an indicator for future activities by the national navigation sector, but the following are a few suggestions and questions that an inventory team could consider and perhaps approach with the relevant agencies or industries:

- Are there any port expansion plans? Discuss with relevant port authorities how they see demand for port callings growing in future and what vessel types they might expect to harbour.
- Check with coastguard and customs agencies how they see shipping activities and port entries changing in future. Have they had to consider this in their own development plans?
- Have there been any considerations of future cargo handling or passenger movement activities (again, by port and city authorities, businesses involved in freight movements, passenger ferry operators)?
- Has there been any consideration of future demand for fuel by marine fuel suppliers? Such businesses may have had to consider this as part of their wider business plans.
- Check with tourism agencies, harbours and businesses if there has been any consideration of demand for future tourism affecting cruise ship callings, hiring or sale of small recreational craft for day trips, fishing, other pleasure craft, etc.
- Are there any other economic indicators for future growth in activities such as GDP, tourism or population growth? It might be useful to look at past trends and establish if there have been correlations between such indicators and port callings or fuel consumption in the past, to get a feel for how reliable they might be as a measure for future growth.

When considering any of these indicators, some thought should be given, if possible, as to how they might affect different types of vessels (e.g. cargo, container, tankers, passenger, fishing, service vessels such as tugs, recreational craft). It is also worthwhile considering maritime activity assumptions and emission projection approaches developed by, or for, other countries and regions.

It should be noted that previous maritime transport emission projections used in the International Maritime Organization (IMO)'s first and second global GHG studies have been based on forecasts of GDP. In its third assessment, the IMO (2015) identified that basing future shipping activity projections on forecast GDP change is a basic method and that a more advanced method separates different cargo types. The following are a few examples of recent studies:

- A study by IIASA (2018) explored the potential for cost-effective air pollutant emission reductions from international shipping through the designation of further emission control areas in European seas with a focus on the Mediterranean Sea.
- The United Kingdom recently developed a detailed tier 3 inventory approach and considered a number of different sources of information on projected growth in shipping activities around

the United Kingdom, including looking at past trends and port-level activity projections for some of the United Kingdom's major ports (Ricardo, 2017).

- A study by VITO (2013) involved an evaluation of emissions from shipping, including an assessment for the establishment of possible new emission control areas (ECAs) in European seas. It looked at scenarios on the effects of imposing ECA legislation in seas surrounding southern Europe (the Mediterranean and Black Seas).

Improvements in vessel fuel efficiencies

Combined with changes in future vessel activities, projections in emissions need to consider changes in fuel consumption accounting for improvements in vessel fuel efficiencies.

It is expected that shipping transport efficiency will increase over time in response to financial and regulatory drivers. Financial drivers include the trends seen over time in the increasingly large container vessels being used, which leads to lower emissions per unit of goods transported. Regulatory drivers include the Energy Efficiency Design Index, which should lead to newer vessels being more fuel efficient. However, the a long lifetime of ships means that these improvements will take a relatively long time to penetrate the fleet. Most studies, including the most recent study by the IMO, have suggested a fuel efficiency improvement in the global fleet of around 1 % per year.

Changes in emission factors

Table 3-4 of the 2019 *EMEP/EEA air pollutant emission inventory guidebook* provides tier 2 default emission factors for NO_x and PM by fuel type and engine type. It is assumed that an MS would already have taken into account in its historical inventory whether the relevant sea territory is currently a sulphur ECA (SECA) or not (e.g. the North Sea and Baltic Sea are already designated as SECAs, but the Mediterranean Sea is not). Future projections need to consider the establishment of a new ECA already in legislation (e.g. the NO_x ECA from 2021 applicable to the Baltic and North Seas) or the possibility of an ECA being implemented in a future scenario even if not in legislation at present.

Values for NO_x are given for the global shipping fleet in 2000, 2005 and 2010 in units of kg/tonne fuel. These show a small reduction in emission factors of NO_x between 2000 and 2010, reflecting the continued turnover in the fleet with gradual penetration of ships with new engines compliant with the IMO MARPOL Annex VI NO_x Technical Code. This legislation provides NO_x emission standards for ship engines, depending on the year of installation on a ship.

Emission projections for NO_x should assume this improvement continues with the penetration of engines meeting the more stringent NO_x emission tiers. The IMO (2015) study indicates a continued reduction in NO_x emission factors of 0.5 % per year for ships running on heavy fuel oil (HFO) and marine diesel oil (MDO)/marine gas oil (MGO). Note that the implementation of a SECA, if considered for a future scenario in, for example, the Mediterranean Sea, which is not already designated a SECA, would require the switching from HFO to MDO/MGO, which would lead to a further small reduction in NO_x emissions. From 2021, a further reduction in emissions should be taken into account if the ships are operating in a NO_x ECA. The IMO agreed in October 2016 that the North Sea and Baltic Sea will be a NO_x ECA from 2021, with tier 3 NO_x emission requirements placed on engines in ships constructed from 2021, requiring an 80 % reduction relative to tier 1 NO_x emission levels, namely the limits required for engines installed on ships between 2000 and 2011. Adopting a simple fleet turnover model, the study on UK shipping emissions by Ricardo (2017) estimated that this would equate to approximately a 4 % per year reduction in NO_x emission factors from the fleet operating in a NO_x ECA from 2021.

Emission factors for PM should remain constant at the values given in Table 3-4 of the Guidebook's '*1A3dc Navigation (shipping)*' chapter for each fuel type. However, note, again, that the lower PM factors for MDO/MGO than for HFO would mean that any future fuel-switching scenario to meet SECA requirements would lead to a reduction in PM emissions.

Emissions of SO_2 relate directly to the sulphur content of the fuel. Even outside a SECA, the sulphur content of marine fuels is still limited to a maximum of 3.5 % by current MARPOL legislation and will be reduced to 0.5 % by 2020. Thus, emission projections for national navigation will need to take account of this reduction in SO_2 emission factors from 2020 and/or any SECA impact. Note that there is also a requirement by EU legislation for all passenger vessels operating between EU ports to use fuel with a sulphur content no higher than 1.5 %, even in non-SECA areas, and for ships at berth in EU ports to use fuel with a sulphur content no higher than 0.1 %.

For recreational craft, the Guidebook provides separate tier 2 and tier 3 emission factors for 'conventional' vessels and those compliant with Directive 2003/44/EC (EU, 2003) emission limits referring to vessels entering service from 2006/2007. It will be necessary for the MS to estimate the proportion of conventional and Directive 2003/44/EC-compliant vessels in the fleet in future years. It may be difficult to find the necessary information to make such an estimate. Vessel and engine maintenance yards, equipment suppliers and insurance and rental companies may be able to provide estimates on average vessel lifetimes and projected sales figures. Projections in tourism and leisure activities could be used as proxies for future trends in new vessel/engine sales.

A1.5.5 NFR 1A3e: pipeline transport

There is no guidance for this source category.

A1.6 NFR 1A4: small combustion — stationary

A1.6.1 NFR 1A4bi: residential small-scale

Introduction

This section considers combustion technologies for single households or apartments, typically in the range of 5-70 kW output. Larger appliances including combined heat and power systems may be applied for centralised heating systems. Note that appliances ≥ 1 MW thermal input are regulated under the Medium Combustion Plant Directive (EU, 2015) which applied to new plants from 20 December 2018 and, in general, will be implemented in the period 2024-2029 for existing plants.

Compared with industrial combustion, generating projections for residential combustion should be simpler, given that domestic combustion appliances are generally not individually regulated and that there is no need to consider changes to the technology in use at individual sources other than through replacement of appliances. Table A1-5 provides some of the key policies and regulations that may have an impact on air pollutant emissions arising from the small stationary combustion sector. Please note, however, that this list is not exhaustive and items may be superseded following publication of the chapter.

Table A1-5 Summary of important EU legislation relevant to residential heating combustion products

Description	Legislation	Coverage
	Cross-cutting	
EU Energy Efficiency Directive	Directive 2012/27/EU amending Directive 2009/125/EC	
Boiler Efficiency Directive	Council Directive 92/42/EEC	Gas/liquid fuel boilers
Construction Products Regulation	Regulation (EU) No 305/2011	Applies to solid fuel room heaters

Directive on ecodesign requirements for energy-related products	Directive 2009/125/EC	Framework (requirements set through separate regulations)
Medium Combustion Plant Directive	Directive (EU) 2015/2193	Boilers, engines and gas turbines ≥ 1 MW thermal input (not single household but may be used for centralised communal/district heating)
Directive on the promotion of the use of energy from renewable sources	Directive (EU) 2018/2001	Emission factors, GHG emissions saving criteria for biofuels, bioliquids and biomass fuels
Product controls		
Commission Regulation with regard to ecodesign requirements for space heaters and combination heaters	Commission Regulation (EU) No 813/2013	NO_X emissions from gas, liquid fuel water heaters and boilers (and small cogeneration units); applied from 26 September 2018
Commission Regulation with regard to ecodesign requirements for solid fuel boilers	Commission Regulation (EU) 2015/1189	PM, NO_X, OGC (VOC) and CO emissions from solid fuel boilers; applies from 1 January 2020
Commission Regulation with regard to ecodesign requirements for local space heaters	Commission Regulation (EU) 2015/1188	NO_X emissions from gas, liquid room heaters (local space heaters); applied from 1 January 2018
Commission Regulation with regard to ecodesign requirements for solid fuel local space heaters	Commission Regulation (EU) 2015/1185	PM, NO_X, OGC (VOC) and CO emissions from solid fuel room heaters (local space heaters); applies from 1 January 2022

Note: OGC, organic gaseous carbon; VOC, volatile organic compound.

Some of the difficulties we see for NFR categories 1A2 ([28]), 1A4a ([29]) and 1A4c ([30]) are also a problem for residential combustion, and there are additional problems:

- A very large number of individual combustion appliances and a wide range of combustion technologies are in use, so it can be very difficult to determine what the appliance population looks like in a given country (e.g. whether solid fuels are burnt in open fires, stoves or small boilers, etc., or, if it is a mixture, what the proportions are).
- The use of the appliances has generally not been subject to regulation (other than perhaps controls over fuel quality) and so it is difficult to be certain about the operation of devices. In some cases, such as with solid fuel open fires and stoves, the way that the device is operated will have a significant impact on emissions.
- Fuel quality controls may be in place but, for some types of devices, there is the potential to use non-standard or non-prescribed fuels (e.g. the use of bituminous coal in regions where smokeless fuels should be used or the use of unseasoned wood or wood obtained from the 'grey' market, that is, not from normal fuel suppliers). This can lead to difficulties in terms of both establishing the historical activity and, particularly in the case of biomass fuels obtained from the grey market, projecting activity data, since the consumption of these fuels is likely to be difficult to estimate.
- Other than controls on fuel quality, the main instrument of change in emissions from the residential sector is the replacement of older appliances with newer, less-polluting equipment (e.g. room heaters and boilers subject to ecodesign regulations). It may be very difficult to

([28]) NFR category 1A2: manufacturing industries and construction.
([29]) NFR category 1A4a: commercial and institutional combustion (stationary and mobile).
([30]) NFR category 1A4c: combustion within agriculture, forestry, fishing (stationary and off-road vehicles and other machinery).

quantify this, unless good data are available on the sales of new appliances. However, even in this case, the understanding of the appliance population would be incomplete, since the sales data would not identify what appliances are being replaced (e.g. a new gas-fired boiler might replace an old gas-fired boiler, an old oil-fired boiler or even space heating using open fires or solid fuel stoves). Similarly, should old appliances be lost from the population without being replaced, this will also not be apparent from sales data. Therefore, it is recommended that countries carry out periodic surveys to both establish the characteristics of the residential sector in a base year and identify trends in the sector, such as changes from one type of fuel to another or changes in the types of appliances being used.

The 2023 EMEP/EEA Guidebook provides a range of tier 2 emission factors for wood-burning appliances, which, because they cover both basic appliances such as open fires and modern/advanced appliances, can provide the basis for simple projections that reflect the main changes in the appliance population, if not the fine detail. The 2023 EMEP/EEA Guidebook emission factors for gas, oil and coal fuels generally do not cover the same range of technologies as the emission factors for wood burning, but there are opportunities to develop technology improvements or regulatory emission limits into projections.

Note that other factors such as the impacts of different types of biomass fuel (seasoned or unseasoned wood, for example) and misuse are not available within the 2023 EMEP/EEA Guidebook and are difficult to address. However, higher tier approaches in the historical inventory allow more scope for reducing uncertainty in projections.

In the absence of country-specific research to establish appliance population and trends in appliance use, it is possible to adopt assumptions on technology or activity mix and a basic stock model assuming a constant turnover in appliances and an average lifetime. Countries should assess if such data are representative of residential combustion for their country and, if not, should plan to address data needed to develop more robust projections. Country-specific research on activity, emission factors and use will allow a country to improve uncertainty in the historical inventory and provide more robust projections.

Potential data sources for technology and activity mix

To develop projections for residential combustion, ideally, the historical inventory should be at a higher tier than tier 1 (at least for the most significant pollutants) ([31]). A survey of the residential appliance population is helpful to understand the types of appliances and fuels used and potentially trends in appliance use. Note that national energy models for the residential sector may incorporate such information or assumptions on residential heating equipment.

In the absence of national information, it is possible to adopt a first iteration of a technology mix from the assumptions and estimates within the ecodesign preparatory studies or GAINS model ([32]). Table A1-6 provides a summary of solid fuel heating appliances from an ecodesign preparatory study (for solid fuel boilers and local space heaters (LSHs)). Fuel data from the ecodesign study are notionally for 2007 but may allow development of a baseline technology split.

Table A1-6 Annual energy consumption (petajoules) by appliance type

Appliance type	Country group ([a])						EU total
	1	2	3	4	5	6	

([31]) Examples here would be NO_x for gas combustion and NO_x/SO_2 for oil.
([32]) Available from: http://gains.iiasa.ac.at/models/

Open fireplace	6.85	5.86	121.14	23.53	46.11	40.07	243.56
Closed fireplace	7.91	6.78	139.99	27.20	53.29	46.30	281.47
Stove	30.97	3.86	79.66	125.31	245.53	73.09	558.42
Cooker	3.75	0.58	11.89	5.06	9.92	24.47	55.66
Pellet stove	0.24		4.13	0.71		23.67	28.76
Slow heat release	20.35			74.46			94.81
Domestic boilers	62.33	33.79	33.10	73.46	245.24	32.57	480.49
Non-domestic boilers	26.23	14.22	13.93	30.92	103.21	13.71	202.22

Notes:

Energy consumption represents wood and mineral solid fuels.

([a]) The numbered columns represent country groups: (1) Denmark, Estonia, Finland, Latvia, Lithuania and Sweden; (2) Ireland and the United Kingdom; (3) Belgium, France, Luxembourg and the Netherlands; (4) Austria, Germany and Slovenia; (5) Bulgaria, Czechia, Hungary, Poland, Romania and Slovakia; and (6) Cyprus, Greece, Italy, Malta, Portugal and Spain.

Source: BioIS, 2009, Table 3-23.

The GAINS model provides technology-based activity data for coal and biomass appliances, including future assumptions at the MS level. Selected activity splits for coal and wood fuels for 2010, 2020 and 2030 are provided in Tables A1-7 to A1-10. These are from the GAINS scenario entitled 'TSAP Consultation 2014 CLE' and are available for MSs and other countries. Other scenarios are available from GAINS, including more recent activity scenarios.

Published scenarios can be reviewed by MSs to determine if they can be applied to residential combustion directly or used with national energy projections to develop more disaggregated emission projections and hence potentially allow regulatory changes to be assessed.

However, it should be noted that both the ecodesign and the GAINS technology descriptions may not align with the technologies described in the EMEP/EEA Guidebook or to specific countries.

Table A1-7 Summary of GAINS residential technology share for coal (2010)

2010	Brown coal (%)		Derived coal (%)		Hard coal (%)		
MS	Boiler (manual)	Stove	Boiler (manual)	Stove	Boiler (auto)	Boiler (manual)	Stove
Austria	66.67	33.33	66.67	33.33	0.00	66.67	33.33
Belgium	60.00	40.00	11.11	88.89	0.00	0.00	100.00
Bulgaria	5.88	94.12	50.00	50.00	0.00	40.00	60.00
Croatia	60.00	40.00	11.11	88.89	0.00	28.57	71.43
Cyprus	60.00	40.00	100.00	0.00	0.00	50.00	50.00
Czechia	88.24	11.76	11.11	88.89	1.90	98.10	0.00
Denmark	0.00	0.00	11.11	88.89	0.00	28.57	71.43
Estonia	50.00	50.00	11.00	89.00	0.00	100.00	0.00
Finland	11.00	89.00	11.11	88.89	100.00	0.00	0.00
France ([a])	100.00	0.00	100.00	0.00	0.00	100.00	0.00
Germany	0.00	0.00	100.00	0.00	0.00	50.00	50.00
Greece	60.00	40.00	11.11	88.89	0.00	28.57	71.43
Hungary	28.57	71.43	11.11	88.89	0.00	66.67	33.33
Ireland	100.00	0.00	11.11	88.89	0.00	50.00	50.00
Italy	60.00	40.00	11.11	88.89	0.00	60.00	40.00
Latvia	100.00	0.00	11.11	88.89	0.00	50.00	50.00
Lithuania	100.00	0.00	11.11	88.89	0.00	58.33	41.67
Luxembourg	0.00	0.00	11.11	88.89	0.00	28.57	71.43
Malta	0.00	0.00	100.00	0.00	0.00	50.00	50.00
Netherlands	0.00	0.00	0.00	0.00	100.00	0.00	0.00

Poland ([b])	50.00	50.00	15.00	85.00	0.00	50.00	50.00
Portugal	0.00	0.00	11.11	88.89	0.00	28.57	71.43
Romania	5.88	94.12	50.00	50.00	0.00	40.00	60.00
Slovakia	50.00	50.00	11.11	88.89	0.00	17.65	82.35
Slovenia	66.67	33.33	66.67	33.33	0.00	66.67	33.33
Spain	60.00	40.00	11.11	88.89	0.00	28.57	71.43
Sweden	0.00	0.00	11.11	88.89	0.00	28.57	71.43
United Kingdom ([a])	0.00	0.00	66.40	33.60	22.10	44.30	33.60

Notes: This table is derived from the country summaries in the GAINS scenario entitled 'TSAP Consultation 2014 CLE', providing shares of coal and biomass in the domestic sector for policy measures in place in 2014. Note that changes arising from consultation are not included.
The GAINS model does not include a fireplace technology for coal fuels in this scenario.
The GAINS model splits brown coal into two types and hard coal into three types.
([a]) GAINS applies different technology shares for the two brown coals and the three hard coals in this MS; please refer to the GAINS model for further details.
([b]) GAINS applies different technology shares for the three hard coals in this MS; please refer to the GAINS model for further details.

Table A1-8 Summary of GAINS residential technology share for coal (2020)

2020	Brown coal (%)		Derived coal (%)		Hard coal (%)		
MS	Boiler (manual)	Stove	Boiler (manual)	Stove	Boiler (auto)	Boiler (manual)	Stove
Austria	66.67	33.33	66.67	33.33	0.00	66.67	33.33
Belgium ([b])	60.00	40.00	11.11	88.89	0.00	0.00	100.00
Bulgaria	12.50	87.50	50.00	50.00	20.00	60.00	20.00
Croatia	60.00	40.00	11.11	88.89	0.00	27.27	72.73
Cyprus	60.00	40.00	100.00	0.00	0.00	50.00	50.00
Czechia	100.00	0.00	11.11	88.89	47.60	52.40	0.00
Denmark	0.00	0.00	11.11	88.89	0.00	27.27	72.73
Estonia	50.00	50.00	11.00	89.00	0.00	100.00	0.00
Finland	11.00	89.00	11.11	88.89	100.00	0.00	0.00
France ([a])	100.00	0.00	100.00	0.00	0.00	100.00	0.00
Germany	0.00	0.00	100.00	0.00	0.00	50.00	50.00
Greece	60.00	40.00	11.11	88.89	0.00	27.27	72.73
Hungary	0.00	100.00	11.11	88.89	0.00	83.33	16.67
Ireland	100.00	0.00	11.11	88.89	0.00	50.00	50.00
Italy	60.00	40.00	11.11	88.89	0.00	80.00	20.00
Latvia	100.00	0.00	11.11	88.89	0.00	50.00	50.00
Lithuania	100.00	0.00	11.11	88.89	0.00	58.82	41.18
Luxembourg	0.00	0.00	11.11	88.89	0.00	27.27	72.73
Malta	0.00	0.00	100.00	0.00	0.00	50.00	50.00
Netherlands	0.00	0.00	0.00	0.00	100.00	0.00	0.00
Poland ([b])	50.00	50.00	15.00	85.00	0.00	60.00	40.00
Portugal	0.00	0.00	11.11	88.89	0.00	27.27	72.73
Romania	12.50	87.50	50.00	50.00	20.00	60.00	20.00
Slovakia	50.00	50.00	11.11	88.89	0.00	15.38	84.62
Slovenia	66.67	33.33	66.67	33.33	0.00	66.67	33.33
Spain	60.00	40.00	11.11	88.89	0.00	27.27	72.73
Sweden	0.00	0.00	11.11	88.89	0.00	27.27	72.73
United Kingdom ([a])	0.00	0.00	66.40	33.60	22.10	44.30	33.60

Notes: This table is derived from the country summaries in the GAINS scenario entitled 'TSAP Consultation 2014 CLE', providing shares of coal and biomass in the domestic sector for policy measures in place in 2014. Note that changes arising from consultation are not included.
The GAINS model does not include a fireplace technology for coal fuels in this scenario.
The GAINS model splits brown coal into two types and hard coal into three types.
([a]) GAINS applies different technology shares for the two brown coals and the three hard coals in this MS; please refer to the GAINS model for further details.

([b]) GAINS applies different technology shares for the three hard coals in this MS; please refer to the GAINS model for further details.

Table A1-9 Summary of GAINS residential technology share for firewood (2030)

2030	Brown coal (%)		Derived coal (%)		Hard coal (%)		
MS	Boiler (manual)	Stove	Boiler (manual)	Stove	Boiler (auto)	Boiler (manual)	Stove
Austria	66.67	33.33	66.67	33.33	0.00	66.67	33.33
Belgium	60.00	40.00	11.11	88.89	0.00	0.00	100.00
Bulgaria	18.75	81.25	75.00	25.00	20.00	60.00	20.00
Croatia	60.00	40.00	11.11	88.89	0.00	0.00	100.00
Cyprus	60.00	40.00	100.00	0.00	0.00	50.00	50.00
Czechia	100.00	0.00	11.11	88.89	90.00	10.00	0.00
Denmark	0.00	0.00	11.11	88.89	0.00	0.00	100.00
Estonia	50.00	50.00	11.00	89.00	0.00	100.00	0.00
Finland	11.00	89.00	11.11	88.89	100.00	0.00	0.00
France ([a])	100.00	0.00	100.00	0.00	0.00	100.00	0.00
Germany	0.00	0.00	100.00	0.00	0.00	50.00	50.00
Greece	60.00	40.00	11.11	88.89	0.00	0.00	100.00
Hungary	0.00	0.00	11.11	88.89	100.00	0.00	0.00
Ireland	100.00	0.00	11.11	88.89	0.00	0.00	100.00
Italy	60.00	40.00	11.11	88.89	0.00	95.00	5.00
Latvia	100.00	0.00	11.11	88.89	0.00	50.00	50.00
Lithuania	100.00	0.00	11.11	88.89	0.00	55.56	44.44
Luxembourg	0.00	0.00	11.11	88.89	0.00	0.00	100.00
Malta	0.00	0.00	100.00	0.00	0.00	50.00	50.00
Netherlands	0.00	0.00	0.00	0.00	100.00	0.00	0.00
Poland ([b])	50.00	50.00	15.00	85.00	0.00	60.00	40.00
Portugal	0.00	0.00	11.11	88.89	0.00	0.00	100.00
Romania	18.75	81.25	75.00	25.00	20.00	60.00	20.00
Slovakia	50.00	50.00	11.11	88.89	0.00	15.38	84.62
Slovenia	66.67	33.33	66.67	33.33	0.00	66.67	33.33
Spain	60.00	40.00	11.11	88.89	0.00	0.00	100.00
Sweden	0.00	0.00	11.11	88.89	0.00	0.00	100.00
United Kingdom ([a])	0.00	0.00	66.40	33.60	22.10	44.30	33.60

Notes: This table is derived from the country summaries in the GAINS scenario entitled 'TSAP Consultation 2014 CLE', providing shares of coal and biomass in the domestic sector for policy measures in place in 2014. Note that changes arising from consultation are not included.

The GAINS model does not include a fireplace technology for coal fuels in this scenario.

The GAINS model splits brown coal into two types and hard coal into three types.

([a]) GAINS applies different technology shares for the two brown coals and the three hard coals in this MS; please refer to the GAINS model for further details.

([b]) GAINS applies different technology shares for the three hard coals in this MS; please refer to the GAINS model for further details.

Table A1-10 Summary of GAINS residential technology share for firewood (2010, 2020 and 2030)

MS	2010				2020				2030			
	Fireplace firewood (%)	Stove (%)	Boiler (manual) (%)	Boiler (auto) (%)	Fireplace firewood (%)	Stove (%)	Boiler (manual) (%)	Boiler (auto) (%)	Fireplace firewood (%)	Stove (%)	Boiler (manual) (%)	Boiler (auto) (%)
Austria	1.23	27.17	60.1	11.5	1.27	22.78	57.85	18.1	1.3	18.18	56.02	24.5
Belgium	7.69	84.6	3.85	3.85	7.69	84.6	3.85	3.85	7.69	84.6	3.85	3.85
Bulgaria	0	94.32	4.55	1.14	2.35	88.24	7.06	2.35	2.35	82.35	11.76	3.53
Croatia	6.06	66.67	27.27	0	6.25	65.63	21.88	6.25	6.67	66.67	13.33	13.33
Cyprus	8.33	25	8.33	58.33	8.33	25	8.33	58.33	8.33	25	8.33	58.33
Czechia	2.5	55.83	33.33	8.33	3.33	46.67	25	25	3.33	46.67	25	25
Denmark	1	48	24	27	1	44	27	28	1	42	27	30
Estonia	6	69	24.5	0.5	5	69	24	2	4	69	22	5
Finland	6	68	22	4	5	64	23	8	5	61	25	9
France ([a])	6.6	82.3	11.1	0	3.1	78.5	18.4	0	0.6	73.8	25.6	0
Germany	8.33	25	8.33	58.33	8.33	25	8.33	58.33	8.33	25	8.33	58.33
Greece	6.25	62.5	18.75	12.5	6.67	53.33	20	20	6.67	53.33	20	20
Hungary	2.17	48.91	43.48	5.43	4	56	20	20	4	56	20	20
Ireland	17.53	77.32	4.12	1.03	10.75	76.34	2.15	10.75	10.75	67.74	0	21.51
Italy	63	37	0	0	63	37	0	0	63	37	0	0
Latvia	8.33	75	13.33	3.33	5.77	76.92	5.77	11.54	10	70	0	20
Lithuania	7	50	40	3	5	54	35	6	4	61	25	10
Luxembourg	6.25	62.5	18.75	12.5	6.67	53.33	20	20	6.67	53.33	20	20
Malta	8.33	25	8.33	58.33	8.33	25	8.33	58.33	8.33	25	8.33	58.33
Netherlands	80	20	0	0	80	20	0	0	80	20	0	0
Poland ([b])	5	86	8	1	5	86	6	3	5	86	4	5
Portugal	20.69	51.72	13.79	13.79	17.84	30.86	25.65	25.65	15	10	37.5	37.5
Romania	0	94.32	4.55	1.14	2.35	88.24	7.06	2.35	2.35	82.35	11.76	3.53
Slovakia	4	84	11.5	0.5	4	84	10.5	1.5	4	84	9.5	2.5
Slovenia	0	7.37	84.21	8.42	0	5.38	78.49	16.13	0	3.33	63.33	33.33
Spain	6.25	62.5	18.75	12.5	6.67	53.33	20	20	6.67	53.33	20	20
Sweden	6	14	59	21	5	14	58	23	4	14	57	25
United Kingdom ([a])	11.5	22.1	16.6	49.8	11.5	22.1	16.6	49.8	11.5	22.1	16.6	49.8

Notes: This table is derived from the country summaries in the GAINS scenario entitled 'TSAP Consultation 2014 CLE', providing shares of coal and biomass in the domestic sector for policy measures in place in 2014. Note that changes arising from consultation are not included.

([a]) GAINS applies different technology shares for the two brown coals and the three hard coals in this MS; please refer to the GAINS model for further details.

([b]) GAINS applies different technology shares for the three hard coals in this MS; please refer to the GAINS model for further details.

Stock model approach

If an activity split is known (or derived from ecodesign or GAINS) for a baseline year, a basic stock model assuming a constant turnover in appliances from an average lifetime can be developed. This could be used to model the replacement of, for example, older technologies or the impact of regulatory controls on emissions.

Table A1-11 provides average product lifetimes developed during ecodesign preparatory studies for assessing product life cycle impacts and the impact of regulation. These lifetimes may not reflect the use of the oldest appliances and their contribution to emissions. However, information on the range of appliance ages can be established from user surveys and the simple model adapted as needed.

Table A1-11 Ecodesign product lifetimes

Heating appliance	Fuel	Product life (years)	Source	Comment
Boiler/water heater	Gas, oil	15	VHK, 2007	Derived from industry consultation
	Wood	17.5 – 20	BioIS, 2007	Derived from industry consultation
	Coal	20		
Fireplace (open)	Wood, coal	35		
Insert, closed fireplace	Wood, coal	20		
Stove	Wood, coal	27.5		
Slow heat release stove	Wood	27.5		
Pellet stove	Wood (pellet)	12.5		
Cooker	Wood, coal	20		
Fireplace	Gas	20	BioIS, 2012	Derived from industry consultation

Basic stock model calculations

For a baseline year:

Total emissions = sum of (activity for an appliance type × emission factor for the appliance type)

To estimate the impact of a change in stock such as the replacement of an open fireplace or a conventional stove, one needs to calculate and add emissions from the existing (old) and replacement (new) technologies:

Existing appliances/baseline:

$$\text{Emission\_old} = \text{projected activity} \times (1 - (n / L) \times \text{emission factor\_old}$$

Replacement appliances:

$$\text{Emission\_new} = \text{projected activity} \times n / L \times \text{emission factor\_new}$$

where:

n = future years from baseline

L = appliance lifetime.

Note that, where $n > L$, the proportion of 'old' technology must be set to zero or there will be a negative emission.

Emission factors for 'new' technology may be based on lower emission technology tier 2 factors in the 2019 EMEP/EEA Guidebook or derived from regulatory emission limits.

Significant growth or decline in fuel use makes a simple model uncertain. In addition, activity is assigned to the proportion of appliances rather than accounting for the specific fuel use of appliances. This is a simplification because, for example, modern stoves are more fuel efficient than older stoves, which are more fuel efficient than open fireplaces.

In the case of activity growth, for example because of incentivisation of automatic appliances, it may be reasonable to assume that activity increase is used in lower emission technology.

Notwithstanding the uncertainties, a stock model allows countries to forecast the potential mix of technology at some point in the future and this can be used to develop emission projections.

This approach has other uncertainties, including that the appliance age profile is unlikely to be uniform and there may be a small proportion of longer life appliances that have a disproportionate impact on emissions. This may be mitigated by establishing the age profile of appliances in a national survey.

Emission factors

Guidebook default emission factors: wood and solid mineral fuel appliances tend to have the most significant emissions and the Guidebook has a range of tier 2 emission factors for different heating technologies (in particular for stoves and boilers) for these fuels. In the absence of country-specific research to establish emission factors, the Guidebook factors represent a good starting point for assessing pollutant emissions with the activity mix provided in Figure A1-5 or in Tables A1-6 and A1-9 of the Guidebook chapter on small combustion.

A stock model can then allow development of emission projections from a baseline appliance population and projected residential activity or GAINS changes in appliance use (Tables A1-7 to A1-10) by applying tier 2 emission factors for lower emission technologies to the proportion of activity assigned to 'new' appliances.

Regulatory emission limits: for oil- and gas-fuelled residential heating, the Guidebook tier 2 factors do not cover a wide range of technologies and do not provide the same opportunity for estimating emissions based on cleaner technologies. However, it is not unreasonable to apply emission factors for NO_x based on the NO_x emission limit values for boilers/water heaters and room heaters or LSHs in Ecodesign Regulations 813/2013 and 2015/1188, respectively.

There are Ecodesign Regulations and associated emission limit values for pollutants from solid fuel boilers (2015/1189) and LSHs (2015/1185). However, for solid fuel LSHs, it should be noted that there are different PM emission limit values applicable to LSHs based on different measurement approaches and test cycles applied in Europe.

It should also be noted that, for all ecodesign emission limits, compliance is assessed by measurement during type approval, which can be very different from real-world operation.

A1.7 NFR 1A4 and 1A5: small combustion — mobile (non-road mobile machinery)

When non-road mobile machinery (NRMM) sources are a key category, it is recommended that, as a minimum, a tier 2 approach is used for both the historical inventory and projections. The advantage of a tier 2 or 3 inventory approach is that it takes account of the different stages of emission limits (under the NRMM Directives) set for the relevant NRMM categories and other measures such as control of the fuel quality over time.

There are two main aspects for forecasting future emissions from NRMM:

1. projecting future NRMM activities (e.g. future population and usage of different NRMMs, fuel consumption by different NRMM);
2. penetration of new machinery meeting different stages of emission limits over time, which in turn determines changes in future emission factors.

The main challenge in projecting future emissions from this sector is estimating future NRMM activities, mainly because of the diverse nature of this sector and the limited availability of data (which is also a challenge for the historical inventory).

A1.7.1 Projecting fuel consumption by NRMM

When fuel consumption forecasts by NRMM are not available for a country, it is possible to project fuel consumption in different NRMM categories by using surrogate data. The *EMEP/EEA air pollutant emission inventory guidebook's* chapter *'1.A.4 Non road mobile machinery'* describes this approach for historical inventory compilation purposes, but such an approach can also be applied for projection purposes. For NRMM used in manufacturing industries and construction (NFR category 1A2gvii) and in agriculture and forestry (NFR category 1A4cii), the Guidebook suggests that a strong relationship has been found between the liquid fuel used in the NRMM and the gross value added (GVA) for these categories. Therefore, projected GVA for manufacturing and construction and projected GVA for agriculture, forestry and fishing can be considered as surrogate data for projecting fuel consumption for these NRMM categories. However, such a relationship may vary between countries and so it might be useful to look at past trends and establish if there have been correlations between such indicators and fuel consumption in the past to get a feel for how reliable they might be as a measure for future growth.

The 2019 Guidebook suggests that it was not possible to determine a strong and consistent relationship between the fuel used for NRMM in the residential sector (NFR category 1A4bii) with commonly available data sets. However, as a first approximation, the Guidebook suggests that it can be assumed that 1-2 % of the total liquid fuel used in the domestic sector is used for NRMM. If an MS is using this approximation in its historical inventory, then similar approximation may be applied to the total projected fuel used in the domestic sector (in the absence of any other information).

The inventory compilers may also wish to explore other potential surrogate (or macro-economic) data available in their countries and analyse the past trends and establish if any correlations exist between such indicators and fuel consumption, and thus the suitability of these data to project fuel use for NRMM in the future. Table A1-12 provides some suggestions of proxy data for the main NRMM categories.

Table A1-12 Potential proxy data to forecast activity projections for the main NRMM categories

NFR sector	Potential proxy data
1A2gvii: mobile combustion in manufacturing industries and construction	• Industry and construction output • GVA for manufacturing and construction (million euros current value)
1A4bii: residential — household and gardening (mobile)	• Number of households
1A4cii: agriculture/forestry/fishing — off-road vehicles and other machinery	• Agriculture output or land cover (see also Annex 3 of this chapter for sources of agricultural projection data for Europe) • GVA for agriculture forestry and fishing (million euros current value)
Airport support vehicles	• Aviation passenger forecasts

A1.7.2 Projecting emission factors for NRMM

The tables of emission factors in the Guidebook for the historical inventory are applicable to projections, although some consideration needs to be given as to what tiered approach should be used.

Tier 1 approach

The aggregated emission factors provided in Table 3-1 of the Guidebook are constant values in time. This implies that they do not account for the penetration of newer legislated stages introduced in recent and future years that will lead to a reduction in emissions per unit of fuel used. These factors are drawn from the TREMOD NRMM model, which calculates emissions following a detailed tier 3 approach, and are then aggregated by information from the Danish NRMM fleet and usage. The aggregation is according to the results from the 2006 historical year.

Logically, and to retain consistency with a tier 1 approach used for the historical inventory, the same factors would be used with activity data projected forward from the latest inventory year using proxy data for future years as suggested in Table A1-12. However, while a tier 1 approach may be acceptable to a country's inventory for a historical year on the grounds that the source is not a key category, a tier 2 or a tier 3 approach should be used, if possible, for projection years to account for the anticipated reduction in emission factors occurring with the penetration of later legislative stages (stage V) in the NRMM fleet. Without accounting for these reductions, while NRMM sources may not be a key category in historical years, they could become so in future years when emissions from other sources are predicted to decline.

Tier 2 approach

The tier 2 approach for historical years uses grams/tonne fuel emission factors for different legislative stages up to stage V for each main machinery/engine class. These factors are applicable to projections because no further legislative stages are currently in place. Using this approach for a historical inventory implies that some knowledge of the distribution in fuel consumption between legislative classes is available to the country. It means that the turnover in the NRMM fleet and the effect this has on implied emission factors is already taken into account.

As emission factors for legislative classes up to the current stage V are included in the Guidebook (Table 3-2), the challenge becomes predicting the turnover in the NRMM fleet and fuel consumption by each of these stages in future years. Beyond 2020, all new machinery must be compliant with stage V limits (Tables 2-3 and 2-4 in the Guidebook). Predicting the turnover in the fleet in projection years requires making assumptions about new machinery sales and equipment lifetimes. An MS may be able to obtain this information from equipment suppliers, manufacturers or trade associations. If this is not possible, then an MS may use as a default the fleet composition splits by legislative class for each general category of machinery provided up to 2040 in Tables A1-13 to A1-17.

These default splits are derived from the equipment age splits given in Table 3-3 of the 2023 EMEP/EEA Guidebook in conjunction with the implementation dates of the various legislative stages given in Tables 2-3 and 2-4. This assumes that the age splits in Table 3-3 according to Danish information remain constant in all future years. It therefore does not account for any significant changes in sales of new machinery and lifetime/scrappage behaviour of old machines from the fleet in the future. If an MS anticipates that such changes will occur, then it should use a fleet turnover model to develop alternative, country-specific activity splits using assumed equipment sales and lifetimes as suggested above.

Table A1-13 Default split in fuel consumption/activities (%) by NRMM Directive legislative stages for agricultural machinery (NFR category 1A4cii)

	2015	2016	2017	2018	2019	2020	2025	2030	2035	2040
Pre-1981	0	0	0	0	0	0	0	0	0	0
1981-1990	6	4	3	2	1	0	0	0	0	0
Pre-stage I	18	17	16	15	15	14	6	1	0	0
Stage I	6	5	4	4	4	4	3	2	0	0
Stage II	14	12	11	9	8	7	6	4	1	0
Stage IIIA	28	26	24	22	20	18	10	8	6	1
Stage IIIB	20	19	17	16	15	14	9	5	4	3
Stage IV	10	17	24	31	37	35	25	14	9	7
Stage V	0	0	0	0	0	8	42	66	80	89

Table A1-14 Default split in fuel consumption/activities by NRMM Directive legislative stages for forestry machinery (NFR category 1A4cii)

	2015	2016	2017	2018	2019	2020	2025	2030	2035	2040
Pre-1981	0	0	0	0	0	0	0	0	0	0
1981-1990	0	0	0	0	0	0	0	0	0	0
Pre-stage I	1	0	0	0	0	0	0	0	0	0
Stage I	5	4	2	0	0	0	0	0	0	0
Stage II	8	8	8	8	6	4	0	0	0	0
Stage IIIA	44	34	24	16	11	9	3	0	0	0
Stage IIIB	27	27	27	25	20	13	5	0	0	0
Stage IV	15	27	39	51	57	56	16	7	0	0
Stage V	0	0	0	0	6	18	76	93	100	100

Table A1-15 Default split in fuel consumption/activities by NRMM Directive legislative stages for industrial and construction machinery (NFR category 1A2gvii)

	2015	2016	2017	2018	2019	2020	2025	2030	2035	2040
Pre-1981	0	0	0	0	0	0	0	0	0	0
1981-1990	0	0	0	0	0	0	0	0	0	0
Pre-stage I	1	1	0	0	0	0	0	0	0	0
Stage I	8	6	5	4	3	2	0	0	0	0
Stage II	29	22	15	10	7	6	1	0	0	0
Stage IIIA	26	26	26	24	20	13	3	0	0	0
Stage IIIB	22	22	22	22	22	22	4	2	0	0
Stage IV	13	22	31	40	40	40	29	6	1	0
Stage V	0	0	0	0	9	18	62	92	99	100

Table A1-16 Default split in fuel consumption/activities by NRMM Directive legislative stages for two-stroke machinery (NFR categories 1A2gvii, 1A4bii and 1A4cii)

	2015	2016	2017	2018	2019	2020	2025	2030	2035	2040
Pre-1981	0	0	0	0	0	0	0	0	0	0
1981-1990	0	0	0	0	0	0	0	0	0	0
Pre-stage I	0	0	0	0	0	0	0	0	0	0
Stage I	1	0	0	0	0	0	0	0	0	0
Stage II	99	100	100	100	71	42	4	0	0	0
Stage IIIA	0	0	0	0	0	0	0	0	0	0
Stage IIIB	0	0	0	0	0	0	0	0	0	0
Stage IV	0	0	0	0	0	0	0	0	0	0
Stage V	0	0	0	0	29	58	96	100	100	100

Table A1-17 Default split in fuel consumption/activities by NRMM Directive legislative stages for four-stroke machinery (NFR categories 1A2gvii, 1A4bii and 1A4cii)

	2015	2016	2017	2018	2019	2020	2025	2030	2035	2040
Pre-1981	0	0	0	0	0	0	0	0	0	0
1981-1990	0	0	0	0	0	0	0	0	0	0
Pre-stage I	1	0	0	0	0	0	0	0	0	0
Stage I	8	5	3	2	1	0	0	0	0	0
Stage II	91	95	97	98	85	71	13	0	0	0
Stage IIIA	0	0	0	0	0	0	0	0	0	0
Stage IIIB	0	0	0	0	0	0	0	0	0	0
Stage IV	0	0	0	0	0	0	0	0	0	0
Stage V	0	0	0	0	15	29	87	100	100	100

Tier 3 approach

If an MS already uses a detailed tier 3 approach for its historical inventory, then this should be used for the projections. The use of a tier 3 approach implies knowledge of the population, usage and turnover in the fleet. The data requirements and methodology for predicting the future fleet composition are largely the same as described above for a tier 2 approach (i.e. using default splits in legislative stages or country-specific splits from projected new machinery sales and assumed lifetimes).

In this case, the turnover of the fleet of individual types of machinery and engines should be predicted. The same growth rate assumptions in new machinery sales could be applied to all types of machines of a common type (e.g. all types of agricultural machinery, all types of residential/garden machinery). Overall, activities defined as the product of population × hours of use can be scaled using the general proxy drivers described earlier, as these would be proportional to changes in fuel consumption.

The additional requirement for a tier 3 approach is to account for emission deterioration with age of machinery and not just its legislative class. The Guidebook provides a set of tier 3 emission factors in grams/kilowatt hours for each legislative stage up to stage V for diesel and petrol two-stroke and four-stroke engines in different engine power bands (Tables 3-6 to 3-8) and deterioration adjustment factors (Tables 3-11 to 3-13). For the historical inventory, these are to be used with the detailed tables of age distribution information available in Tables 3-5 to 3-9 of the Excel annex accompanying the Guidebook chapter '*1.A.4 Non road mobile machinery*'. To a first approximation, these tables providing age splits for years up to 2020 can quite simply be extended to future years following the same logic by shifting the legislative stage split for an *n*-year-old machine in year *y* to an (*n* + 1)-year-old machine in year (*y* + 1). By way of example, the matrix of age/emission legislative stage split combinations for agricultural machinery Table 3-5, given in the Guidebook for years up to 2020 is in the Excel annex extended to 2040. The same pattern can be used for the other NRMM categories. However, a detailed fleet turnover model, as described above, would allow a more precise, country-specific account of the age and legislative class distribution to be used in the projections for a tier 3 approach.

The MS should also consider the possibility of an NRMM retrofit programme, which would mean modifications to the legislative class split according to the proportions of a legislative class being upgraded to a later legislative class with a lower emission factor. The MS would need to estimate or seek advice from relevant stakeholders (e.g. suppliers of retrofit devices, regulatory bodies or equipment hire companies) on the numbers or proportions of machinery that have been retrofitted.

Annex 2 NFR 2: industrial processes and product use

A2.1 NFR 2D-2L: other solvent and product use

A number of specific international PaMs will have an effect on air emissions in the future. Table A2-1 provides some of the key policies and regulations that may have an impact on air pollutant emissions arising from the solvent sector. Please note, however, that this list is not exhaustive and items may be superseded following publication of the chapter.

Table A2-1 Summary of EU legislation relevant to the solvent sector

Description	Legislation	Parameters/variables
Cross-cutting		
Emissions Trading Scheme amending the EU Emissions Trading Scheme to improve and extend the GHG emission allowance trading scheme of the Community	Directive (EU) 2018/410, amending Directive 2009/29/EC and Directive 2003/87/EC to enhance cost-effective emission reductions and low-carbon investments, and Decision (EU) 2015/1814	Carbon price, carbon content of process input, electricity consumption, emission factors, energy efficiency, final energy consumption by sector by fuel type, share of different forms of energy
Directive on the reduction of national emissions of certain atmospheric pollutants	Directive 2001/81/EC and Directive (EU) 2016/2284	Emission reduction commitments for air pollutants
Industrial Emissions Directive	Directive 2010/75/EC	Emission reduction commitments for air pollutants, emission factors, energy production, final energy consumption by sector by fuel type, fuel efficiency, share of different technologies
Medium Combustion Plant Directive	Directive (EU) 2015/2193	Boilers, engines and gas turbines ≥ 1 MW thermal input (not single household but may be used for centralised communal/district heating)
Effort Sharing Decision and Effort Sharing Regulation	Decision No 406/2009/EC and Regulation (EU) 2018/842	Share of different forms of energy
Industrial process		
Directive on the limitation of emissions of volatile organic compounds due to the use of organic solvents in decorative paints	Directive 2004/42/EC amending Directive 1999/13/EC (the Paints Directive)	Sets out two sets of limit values for the maximum contents of VOCs (in grams/litre of the product ready for use)

and varnishes and vehicle refinishing products		
Directive on the approximation of the laws of the MS on extraction solvents used in the production of foodstuffs and food ingredients	Directive 2009/32/EC	Conditions of use and maximum residue limits in the extracted foodstuff or food ingredient

It is known that countries across Europe adopt a wide range of methods to estimate historical NMVOC emissions from NFR category 2D3 (solvent use). They do this because of differences in the level of data available. For example, in the case of activity data, some countries may have very detailed consumption data for individual types of solvent-containing product, whereas other countries may have no significant data at all.

These differences in approach for the historical estimates have a bearing on how emission projections can be developed, and indeed can, to some extent, dictate how projections must be done and how difficult it is to do projections at all. For example, if historical emissions are derived only from estimates of the solvent supplied to a given sector, then it is not necessarily very easy to determine what level of control exists in that sector: taking the case of degreasing, just knowing the quantity of cleaning solvent consumed in a country would not tell you how that solvent was being used or what level of control was in place. In this case, it would be difficult to determine what impact there would be on emissions from future controls because the historical context is not fully understood. As a result, it is unrealistic to recommend a single approach to all countries; instead, they must develop projections that fit with the approach used for historical estimates and that reflect, as best as possible, the factors that will influence emissions into the future. In the longer term, countries should aim to improve both historical and projected emission estimates so that these reflect the realities within that country — the types of abatement in use, or the formulations used for products, and the regulations in place or imposed in the future. For solvent use, the development of historical and projected emission estimates should ideally be considered as a single task.

A2.1.1 Activity data projections

Organic solvents are used in numerous industrial sectors, as well as being used in many different types of products used by consumers. For some industrial sectors (such as industrial coating processes), that solvent will be used in perhaps hundreds of different products. Because of this diversity in the use of solvents, it is unlikely that national projections exist that are specific to each type of emission source. For most countries, therefore, it is anticipated that there are two options for projecting activity for solvent use:

1. Use more general economic-based growth factors to project activity data for industrial solvent use and population growth to project activity data for domestic solvent use.
2. Consult with trade associations and/or individual businesses that are representative of solvent suppliers and/or solvent users and develop sector-specific or product-specific growth factors with input from industry.

In the first case, it is likely that economic projections will be either for the economy as a whole (e.g. GDP) or, at best, for broad sectors of industry (e.g. production of chemicals). These types of broad projections are unlikely to always prove accurate for industrial solvent use. In many cases, the processes that use large quantities of solvent are just one part of a larger sector and so the economic growth of that sector as a whole may be very different from that of the sub-sector using solvent. For example, in the United Kingdom, growth factors are available for the paper, printing and publishing sector, but this covers a much wider group of businesses than, say, publication gravure printing, where there are a handful of sites using hundreds or thousands of tonnes of solvent each. One of those print works could be scheduled to be closed or to be greatly enlarged and this would probably not show up in the broad growth factor. Thus, countries should always consider if the use of national economic-based growth factors is particularly appropriate for each solvent use source. In cases such as the use of cleaning solvents, these growth factors might be appropriate, because of the widespread nature of that activity, but, for more specialised processes such as publication gravure printing, seed oil extraction or coil coating, it would probably be better to derive assumptions specific for that process, in consultation with industry. It is recommended that the use of broad national economic growth factors should be considered as essentially a tier 1 approach for NFR category 2D3.

In the case of domestic solvent use, population growth is probably as good a means to project activity data as any, because of the huge range of products being used and the fact that many products will be in widespread use across the population. Because of the large range of solvent-containing products and the large number of product suppliers, it is likely to be difficult to obtain more specific growth factors from industry. The main exception to this would probably be decorative paints, for which products can be divided into a relatively small number of types and there might be only a small number of major suppliers. In this case, it may be realistic to obtain growth estimates from industry. Another advantage of seeking industry help here would be that they might be able to provide different growth factors for water-borne and solvent-borne paints. This is important, since decorative paints are subject to Directive 2004/42/EC that will reduce the VOC content of paints over time. In comparison, one might expect the solvent content of many other consumer products to remain constant over time.

A2.1.2 Emission factors

As discussed previously, countries adopt a range of approaches to estimate NMVOCs from NFR category 2D3 and this has a bearing on how easy it is to then make projections. Ideally, information collected for the historical inventory will allow the historical context to be understood (i.e. what level of control is already in place in the base year and perhaps also the structure of the industry) and thus the likely impact of regulation. If historical estimates are based only on simple industry estimates of solvent consumption or site emissions data from the European Pollutant Release and Transfer Register, for example, then this historical context might be lacking, in which case it will be very difficult to derive robust projections. For this reason, therefore, development of the historical inventory may be a pre-requisite for good emission projections.

Key to projections is the need to understand what level of control of emissions is occurring in the base year and, therefore, what further control may occur in the future. Most of the solvent in products is designed to be evaporated (i.e. emitted during use of the product). For example, the solvent in aerosols is released when the product is discharged from the aerosol can and solvents in heatset offset inks need to be driven off from the printed substrate. So, in the worst case, all or almost all of the solvent content in products can be emitted. Control of NMVOC emissions in most cases can be achieved either through capturing/destroying the emission or by reducing or eliminating the potential for emission in the first place by reformulating the product (e.g. to use water as a solvent instead). For some uses of solvent, such as cleaning/degreasing, it is possible to minimise the emissions themselves by better control and containment of processes. Unfortunately for the inventory compiler, a wide range of strategies will often be employed within a sector, so it is difficult to develop robust projections (or historical emission estimates) without first understanding, in some detail, what techniques are already in use in a sector and what will be done in future. Regulators and trade bodies may be able to provide a good overview of practices within sectors and so consultation with one or both is recommended. For industrial solvent use, it is vital to remember that solvent-using products may be used by both large, regulated, processes and smaller operations that are not subject to the same regulations. For some types of processes, such as coil coating, it is highly likely that all sites will be large and regulated, whereas, for other processes, such as vehicle refinishing, there may be very significant quantities of products used by small businesses. Understanding how much of a sector is unregulated is therefore essential and trade bodies may be able to help in this area.

Regulations such as the IED recognise that a range of strategies are appropriate for solvent-using processes and therefore not only provide differing requirements for different sectors but also allow flexibility in the strategies employed by operators (e.g. in the fugitive emission limit values, where operators can select whatever strategies they wish to meet the limits). Annex VII of the IED may be useful for compilers, since the emission limit values and fugitive emission limit values could be used to model the impact of the directive on NMVOC emissions from most types of industrial solvent use. Similarly, Directive 2004/42/ECgives detailed VOC content limit values (in Annex II) for different types of decorative coatings that could be used to model reductions in NMVOC emissions. In both cases, however, it would be necessary to have a detailed historical inventory that provided detail by sector and also established the baseline level of control.

The 2019 EMEP/EEA Guidebook provides some help on the impact of controls. For example, the chapter on NFR category '*2D3d Coating applications*' provides some guide values for generic classes of coating (Table 2-1), summarises VOC content limit values for decorative paint (Table 2-2) and gives detailed abatement efficiency factors for both decorative coatings and various types of industry coating (Tables 3-17 to 3-26). Other Guidebook chapters have similar information. However, it should be stressed that using these Guidebook resources does require the inventory compiler to have a good understanding of the sector baseline and the regulatory background. For example, the abatement efficiency factors for industrial coatings are highly specific (e.g. for truck cabin coating) and several highly detailed abatement options are listed for this source. A highly detailed inventory is therefore needed and compilers also need a good understanding of the baseline level of control, the likely extent of regulation and the requirements that are likely to be placed on operators by regulators.

Tier 1 methods in the Guidebook do not allow any modelling of abatement options, so robust projections are not possible in cases in which a tier 1 method is used for the historical inventory. In these cases, all that is possible is a tier 1 projection (i.e. continued use of the tier 1 emission factor(s) for future years), coupled with suitable activity projections.

Annex 3 NFR 3: agriculture

A3.1 NFR 3: agriculture

A3.1.1 Introduction

Estimating emission projections from agricultural activities is challenging for a wide variety of reasons. Emission factors are influenced by a wide range of different parameters and understanding how these parameters change with time is difficult to determine. Trends in national agricultural production levels are linked to local and global commodity prices, policy goals and climatic factors. Trends and changes in farming practices must also be considered and these are often strongly driven by national and international policies. Projections of farming practices are also complicated by the heterogeneity of farm businesses in terms of their size and degree of specialisation, which influences the cost-effectiveness of different practices. While historical trends can be extrapolated to predict the future, there are examples for which this would give misleading and even unrealistic results.

A3.1.2 Sources of air pollutants

The emissions sources included in the agriculture sector are described in Table A3-1. For ammonia (NH_3), the largest sources are typically manure management (from housing, storage and handling), animal manure and inorganic nitrogen (N)-fertilisers applied to soils, and urine and dung deposited by grazing animals. N-fertilisers applied to soils is the main agricultural source of NO_x and manure management is the largest agricultural source of NMVOCs. Agriculture can also be a significant source of primary $PM_{2.5}$ in some countries, because of farm-level operations such as soil tillage and crop harvesting, manure management and field burning of agricultural residues.

Table A3-1 Air pollutant emissions included under the agriculture sector

Source	NFR code	Pollutants	Categories
Livestock	3B	NH_3, NMVOC, NO_X, PM	Dairy cattle, non-dairy cattle, sheep, swine, buffalo, goats, horses, mules and asses, laying hens, broilers, turkeys other poultry, other animals
Agricultural soils	3Da	NH_3, NO_X	Inorganic N-fertilisers (also includes urea application), animal manure applied to soils, sewage sludge applied to soils, other organic fertilisers applied to soils (including compost), urine and dung deposited by grazing animals
	3Dc	PM	Farm-level agricultural operations including storage, handling and transport of agricultural products
	3De	NMVOC	Cultivated crops
	3F	NH_3, NMVOC, NO_X, PM	Field burning of agricultural residues
	3I	NH_3	Agriculture other: use of straw
	3Da4, 3Db, 3Dd, 3Df	No guidance in EMEP/EEA Guidebook	Crop residues applied to soils; indirect emissions from managed soils; off-farm

			storage, handling and transport of bulk agricultural products; use of pesticides

A3.1.3 Grade 1, grade 2 and grade 3 approaches

The extent to which detailed data are available for the agriculture sector varies greatly across different countries. As a result, the use of a graded approach is particularly important in supporting the calculation of emission projections for agriculture. This grading system is not to be confused with the different tiers, as referred to in the EMEP/EEA Guidebook.

The most basic kind of projection (grade 0) involves extrapolating emissions linearly from historical trends, or the latest inventory year's value is simply rolled forward (i.e. no change is assumed). This kind of projection is unlikely to be realistic and does not supply useful information on the effect of PaMs on emissions. Grade 1 to 3 approaches are improvements on this approach.

A grade 1 approach tends to use easily available proxies or aggregated activity data, alongside default emission factors to simulate future development of emissions ([33]); grade 2 uses the most relevant existing parameters — more disaggregated than the grade 1 level — or projection results (from relevant studies or models executed at EU level); and grade 3 uses complex country-specific parameters or models, in most cases developed within the MS.

Table A3-2 provides a summary of the data requirements for different grades of projection, for each source category.

Table A3-2 Overview of parameters per grade for agriculture projections

Grade 1	Grade 2	Grade 3
Manure management		
Projected livestock numbers Projected N excretion	Projected livestock numbers Projected N excretion (country specific) Projected use of different manure management systems	Projected livestock numbers Full N-flow assessment
Agricultural soils		
Projected livestock numbers Projected synthetic fertiliser use Projected arable areas	Projected livestock numbers Projected yield data ([a]) Projected synthetic fertiliser use Projected use of different application techniques ([b]) Projected arable areas	Projected livestock numbers Projected yield data ([a]) Projected arable areas Projected yield data (tonnes/ha) Projected field conditions during application ([c]) Projected use of different application techniques ([b])
Field burning of agricultural residues		
Current area of field burning	Projected area of field burning	Projected area of field burning by crop type Projected crop yields

Notes: ([a]) Litres milk/head, kilograms meat/head, etc.
([b]) Broadcast, trailing hose, trailing shoe, injection, etc.
([c]) Soil type, meteorological conditions, etc.

Source: DG CLIMA, 2012.

As stated in the EMEP/EEA Guidebook, emission estimates for agriculture sources that are key categories should be developed using a tier 2 approach for the historical emission estimates and should therefore aim to use tier 2 for projections. Emission projections are usually derived from the latest historical inventory and the same emission methodology tier will be used for the projections. However, in the agriculture sector, since assessing some of the future policies and measures requires a rather detailed approach, it is possible that projected emissions are calculated using a higher tier method than historical emission estimates (although typically this would then be used with the historical input data sets). Currently, MSs generally fall into one of two categories: countries with highly sophisticated country-specific systems that have been developed across many years and countries with very simple approaches that often do not take into account the impact of existing and future PaMs. As a result, there are some national projections that should be regarded as not being up to the standard of grade 1 projections. While there are

([33]) A proxy is a measurable unit that can be used to construct a non-direct measurable unit. For example, at the most basic level, forecasts of population or GDP can be used as proxies.

'off-the-shelf' models or tools that have the capability of making emission projections (such as CAPRI), it is also possible to develop national systems.

A wide range of agriculture models are available, with a focus on projecting production, consumption, demand, price, etc., of agricultural products, but without the air pollution element. While these would provide key input activity data to emission projections, an emissions inventory team is not expected to oversee and run these kinds of models. It is more likely that the use of these models by agriculture ministries and government departments would allow reliable activity data projections to be provided to the emissions inventory team.

A3.1.4 General guidance

It is necessary for the future activity data and future emission factors to show an explainable development from the historical values; this will then allow integration and comparison of trends and estimates of mitigation impacts of different policies. Therefore, it is first important to understand historical trends and key drivers.

While sudden changes in farming practices are possible (e.g. through the introduction of specific legislation) they are generally not common. It is also essential to consider the consistency with the GHG projection estimates under the Greenhouse gas Monitoring Mechanism Regulation (Regulation (EU) No 525/2013) (EU, 2013)([34]). Primary activity data, parameters and assumptions affect both GHG and air pollutant estimates (livestock population, use of manure management systems, fertilisers applied to soils, etc.), so these should be used for both.

Consideration also needs to be given to potential impacts on other source sectors. For example, the growth or reduction of the livestock sector in agriculture can give rise to changes in the levels of farming crops, and animal wastes or crop residues can be diverted towards the waste or energy sectors.

A3.1.5 Relevant policies and measures

A number of specific international PaMs will have an effect on agriculture emissions in the future. Table A3-3 provides some of the key policies and regulations that may have an impact on air pollutant emissions arising from the agriculture sector. Please note, however, that this list is not exhaustive and items may be superseded following publication of the chapter.

Table A3-3 Summary of important EU and international policies that may have an impact on the agriculture sector

Description	Legislation	Parameters/variables
Cross-cutting		
Renewable Energy Directive (RED)	Directive 2009/28/EC	Final energy consumption by sector by fuel type, fuel specification
Industrial Emissions Directive (IED	Directive 2010/75/EU replacing Directive 2008/1/EC	Intensive rearing of poultry and pigs
Directive on integrated pollution prevention and control (recast)	Directive 2010/75/EU	Intensive rearing of poultry and pigs
Directive on the reduction of national emissions of certain atmospheric pollutants	Directive 2001/81/EC and Directive (EU) 2016/2284	Mandatory measures: control ammonia emissions, emission reduction measures to control emissions of $PM_{2.5}$ (fine particulate matter) and black carbon, preventing impacts on small farms
Ambient Air Quality Directives	Directives 2008/50/EC and Directive 2004/107/EC	New air quality objectives for $PM_{2.5}$ (fine particulate matter) including the limit value
Water Framework Directive	Directive 2000/60/EC	N input to managed soils from organic fertiliser
Effort Sharing Decision and Effort Sharing Regulation	Decision No 406/2009/EC and Regulation (EU) 2018/842	Electricity consumption, final energy consumption by sector by fuel type, share of different forms of energy
Agriculture		
Common agricultural policy and reform ([a])	Regulation (EU) No 1305/2013, Regulation (EU) No 1306/2013, Regulation (EU)	

([34]) Note that Regulation (EU) No 525/2013 will be repealed, with effect from 1 January 2021, by Regulation (EU) 2018/1999 of the European Parliament and of the Council of 11 December 2018 on the Governance of the Energy Union and Climate Action.

	No 1307/2013 and Regulation (EU) No 1308/2013	
Nitrate Directive	Council Directive 91/676/EEC	N input to managed soils from organic fertiliser, N input to managed soils from different types of synthetic fertiliser
Sewage Sludge Directive	Council Directive 86/278/EEC	N input to managed soils from organic fertiliser
Regulation relating to fertilisers	Regulation (EC) No 2003/2003	N input to managed soils from organic fertiliser, N input to managed soils from different types of synthetic fertiliser

Notes: ([a]) For further information on the common agricultural policy and legislative proposals, see 'Future of the common agricultural policy' (https://ec.europa.eu/info/food-farming-fisheries/key-policies/common-agricultural-policy/future-cap).

Source: Updated from *DRAFT GHG projection guidelines: part B — sectoral guidance* ([35]).

MSs may have evaluated the impact of these policies in preparation for regulation negotiations, such as negotiations to approve regulations of the common agricultural policy (CAP), within the EU. MS evaluation of the impact of these policies and measures would have resulted in parameters and variables associated with determining emission projections at higher grade levels being available. However, the impact of these PaMs is difficult to quantify. For some of the PaMs in Table A3-3, parameters and variables have not been identified, because, while recognising that they may bring about broad changes to farming practices, it is not possible to determine the relevant physical parameters and variables that may be influenced. In addition to the key EU-level PaMs listed in Table A3-3, there may also be additional national-level legislation and targets relevant to agricultural emission projections.

When calculating the future impact of PaMs, it should also be acknowledged that it very much depends on the way PaMs are introduced or the level to which they are enforced at the national level; furthermore, significant changes can take a number of years to materialise, which should be considered when assessing when changes are likely to occur in the projected time series.

As indicated in the section above, in addition to PaMs, there are other external factors that have the potential to influence emissions. These include market changes (changes in the demand for biofuels, changes in the demand for different food types, caused by the buying patterns of consumers or to changes in food prices, or significant changes to the importation of food from outside the EU area), the introduction of new crop strains or increased use of particular animal breeds, and climate condition changes, which can result in changes to farming practices and changes to the crops that are farmed.

Clearly, trying to capture the impact of PaMs and other factors is a complex process; therefore, the use of higher grades (2 or 3) that involve several parameters influencing activity data and emission factors is preferable for many of the sources in the agriculture sector and obviously for those that are key sources.

A3.2 NFR 3B: manure management

As for inventory compilation, accurate projections of emissions from manure management systems require projections on manure production by livestock type, allocation to different storage systems and, to the extent possible, abatement measures employed affecting emission factors. Depending on the availability of projected activity data and emission factors, different grades of emission projections are possible.

([35]) Available from: https://ec.europa.eu/clima/sites/clima/files/strategies/progress/monitoring/docs/ghg_projection_guidelines_b_en.pdf

A3.2.1 Activity data projections

Livestock numbers

Livestock numbers are the basic activity data for estimating emissions and projections: they are the activity data for NH_3, NO_x, NMVOC and PM of manure management and will therefore have an impact on NH_3 and NO_x emissions from agricultural soils and levels of urine and dung deposited by grazing animals.

Official data sets of projected national livestock numbers are available in most countries and these should be used (although it is important to understand the details of the scenario that has been used to generate the projected livestock data set). If projected livestock numbers need to be generated, then approaches with different levels of sophistication can be used —in terms of both the factors that are considered and the detail to which different livestock classes and sub-classes are quantified. It is recommended that efforts are focused on cattle numbers (split by dairy and non-dairy), as these are normally key categories for NH_3 and would also represent a significant share of NO_x emissions from manure applied to soils. Livestock sub-categories can be simple. For example, cattle may be split into only dairy and non-dairy cattle, and it may be necessary to assume that the proportions of the total remain constant with time if data are available only on the total number of cattle.

At the simplest level, historical trends in livestock numbers can be extrapolated into the future, without regard for the underlying drivers (i.e. applying a purely mathematical extrapolation of the historical trend). Assuming a constant value is not recommended; this approach would be used only for non-key animal categories with an almost flat trend in the historical data. While using this approach, it is important to carefully select the period that the extrapolation would be based on, as it will hugely influence the projections. Improvements can be made by considering the key policy and exogenous drivers underlying trends in the historical animal numbers and using expert judgement or model output to extrapolate accordingly to obtain a WM scenario. For example, consumption of animal products originating from the country, such as meat, milk and eggs, could be related to human population, for which projections are available, and in turn consumption could be related to production and livestock numbers. Several assumptions would be needed regarding the evolution of the links between consumption, production and population, and consumption and production are probably affected by other variables, such as price and consumer habits. Nonetheless, this approach may have advantages over pure extrapolation from historical livestock numbers, such as better understanding of past trends and transparent justification of assumptions underlying the projection of livestock numbers.

However, farming practices in the agriculture sector are influenced by extensive PaMs and taking into account the impact of these on activity data statistics such as livestock numbers can be complex. Specific regional policies or initiatives may have a significant impact on emissions, for example the CAP. These impacts will need to be determined through the involvement of national CAP contact points. It is also important to consider national constraints on livestock numbers because of space requirements, for example, which would prevent consistent linear changes. Trends in livestock population and management practices are variable from country to country, which means that it is not always appropriate to use information/data from other countries.

Nitrogen excretion

Nitrogen excretion by animals is another key parameter and is the activity data required when applying a tier 2 approach for NH_3 and NO_x. Note that when a tier 2 or 3 approach is used, there is a dependency between emissions of NH_3 and NO_x from manure management and emissions from agricultural soils following manure application and from urine and dung deposited by grazing animals. This dependency needs to be explicitly taken into account.

In the N-flow approach, it is important to be able to quantify the N being excreted by the livestock and all of the subsequent N losses through the management process. If the historical emissions inventory uses a tier 2 methodology, it should be possible to use these country-specific data to estimate future country-specific N excretion rates for different livestock types (if this is not already available).

Calculating the future N excretion requires data on the properties and amount of animal feed, animal weights and production levels per animal (e.g. milk yield, weight gain, egg production). Changes to diet can be related to PaMs but are not necessarily so. For example, changes may make it economically more or less favourable to provide animals with feed, rather than grazing on pasture.

If projections are not available for diet, but are for production levels, a simpler approach taken by some countries is to analyse the statistical relationship (e.g. fit a linear regression model) between production level and N excretion in the historical inventory, then project that relationship into the future. In the past, there has tended to be a strong correlation between milk yields and N excretion of dairy cows, for example. While the future relationship may differ from the historical one to an extent, this approach to estimating N excretion is nonetheless likely to be more accurate than simple mathematical extrapolation of N excretion rates or an assumption of no change.

However, even projections of productivity per animal may not always be available and linear extrapolation from historical trends may not be appropriate. Milk yield per animal has increased with time, but future increases are expected to be smaller, as milk yields in most European countries are already considered to be high. Future milk yields will be influenced by trends towards more sustainable and closed-loop-oriented production. Feeding of high amounts of concentrated feed to dairy cows is being investigated in some countries. In addition, dairy cattle in some countries are fed a mainly grass-based diet and therefore there will be limited increase in the milk yield. As a result, milk yield increases are expected to vary across European countries but will probably not continue to increase at the rate seen in recent years. Countries with lower milk yield can investigate the evolution of milk yields in the highest producers in Europe as a starting point to analyse future trends.

Different manure management practices

The use of different manure management practices strongly influences emissions of N compounds from manure storage. Emission factors vary considerably between different manure management systems (i.e. slurry versus solid), but also because of specific characteristics (slurry systems with or without natural crust) and abatement practices used. Different manure management systems also affect the emissions from manure applied to soils and from urine and dung from grazing animals (considering grazing systems as a manure management system).

Obtaining a full understanding of the manure management practices being used, and predicting how these will change with time, requires a large farm survey across several years. Some countries may have information on changes in historical manure management practices from country-specific surveys (or expert judgement) and should start from the understanding of the current situation. Countries using the same manure management distribution over several years of the historical time series may require a bigger effort. It is recommended that countries collect information on historical distribution of manure management systems, which would help determine future trends.

If it is not possible to obtain country-specific data, then it may be possible to use data on manure management systems from neighbouring countries. While this is not genuinely country specific, it is likely to be a better approach than using default values from the EMEP/EEA Guidebook, which would remain constant for the whole time series.

At this point, it is important to consider interdependencies with other sectors. For example, some manures (mainly slurries) will be used as feedstocks for anaerobic digestion in biogas facilities (emissions that are calculated and reported under the waste sector). This is a treatment that is being incentivised by national policies and for which implementation may be expected to expand in the future.

There is also a general trend towards more intensive farming practices. In such cases, the time that livestock spend in housing tends to increase and the time spent on pasture tends to decrease. This means that deposits directly to the soil from grazing livestock would decrease and this would be replaced by an increase in the amount of N being handled by different manure management systems. Increased intensity may also increase the total N excretion per head of livestock.

A3.2.2 Emission factors

When emissions are not key sources and there are no national data on future changes in practices, emission factors from the most recent year of the historical national inventory can be applied to projected activity data to estimate emissions. This approach assumes that there are no changes in the emission factors over time.

For key categories and when data on future changes in practices are available, emission projections will need to incorporate assumptions about changing practices in livestock farming and the impacts of these on future emission factors (e.g. not only projected numbers of cows, but also projected yields of milk). Methods described in the higher tiers (2 and 3) in the respective main agriculture chapters of the Guidebook (i.e. '*3.B Manure management*' and '*3.D Crop production and agricultural soil*') should be used to help apply the relevant variables to account for future policies and measures that will change practices (e.g. manure management and fertiliser use).

Air pollutant emission factors from manure management and animal housing will be affected by the following key abatement measures.

Ammonia

- Reducing surplus N in animal feed through matching intake to requirements.
- Livestock housing measures, such as adsorption or rapid removal of urine, reduced temperature/air movement and NH_3 scrubbing.
- Increased grazing time, where urine is absorbed rapidly into the soil.
- Decreasing volatilisation from manure, such as by covering solid and liquid manure stores or lowering pH.

Average reductions in NH_3 emission factors for these abatement measures are provided in the *Guidance document on preventing and abating ammonia emissions from agricultural sources* prepared by UNECE in 2014 ([36]).

Particulate matter (from 2019 EMEP/EEA Guidebook, Chapter 3B)

- Preventive measures, such as wet feeding, adding fat to feed and oil/water sprinkling.
- PM filters, precipitators, scrubbers and other purification systems for waste air from housing.

Non-methane volatile organic compounds

- Techniques effective in abating NH_3 emissions from livestock manure are effective in reducing NMVOC emissions.
- NMVOC emissions from silage can be reduced by covering silage stores and minimising the surface area exposed by other means.

If possible, projections of the uptake of these measures over time under WM and WAM scenarios should be incorporated into projected emission factors by either varying these over time or using projected activity data stratified by the presence/absence of abatement measures, each with separate emission factors.

Note that, when using the N-flow approach, animals should ideally be modelled separately for each combination of management practices and abatement measures employed at the various stages in the manure management and application process (the 'system'). This is because emissions abatement measures employed at one stage affect the N remaining for subsequent stages, which affects the emission reduction potential of downstream abatement measures. Applying emission factors averaged across all systems at each stage ignores this interdependence. One suitable approach is to use the N-flow methodology to first calculate an implied emission factor per animal for each system (which may remain static over time), then apply these implied emission factors by system to projections of animal numbers managed under each system.

When considering abatement techniques in projections, it should also be acknowledged that some of the abatement techniques may be more cost-effective on large farms than on small farms, because of economies of scale, and therefore information on the national farming system structure can be a key parameter too.

([36]) https://www.unece.org/fileadmin/DAM/env/documents/2012/EB/ECE_EB.AIR_120_ENG.pdf

Projected emission factors for animal housing and manure management will also be affected by future changes in temperature, precipitation and humidity, as this affects variables such as dampness inside animal houses, crust formation on slurry and decomposition rates.

A3.3 NFR 3D: agricultural soils

The use of synthetic fertilisers, manure applied to soils, and urine and dung deposited by grazing animals are the biggest sources of NH_3 and NO_x emissions. For estimating these emissions, the amount of N that is added to soils is multiplied by emission factors.

A3.3.1 Activity data projections

Projections of the amount of manure applied to soils and N deposited by grazing animals depend on animal numbers, N excreted and manure management systems, as explained in section A3.1. In a simple approach based on animal numbers only, the quantity of N applied and deposited by grazing animals would be directly proportional to the number of animals. In more sophisticated approaches, using N excretion and N-flow, the projected quantity of N available for emission from soils will depend on changes in N excretion, losses from manure storage and manure management practices.

For projections of N emissions from synthetic (mineral) fertilisers applied, projections of the total quantity of different kinds of compounds applied are often readily available at the national level. There are increasingly stringent controls on the amount of synthetic fertiliser (and other sources of N) that are being applied to cropland, which are aiming to reduce groundwater pollution and implement climate change mitigation policies for efficient fertilisation. Therefore, it would be reasonable to expect that, because of these policies, the amount of excess N being applied to soils would be reduced over time. In the absence of projections of total N application, projections of cropland and grassland areas or production quantities, in tandem with typical application rates, could be used to make projections of N application. Different technologies may also have an effect on the amount of N applied. In Ireland, the WAM scenario for emissions from synthetic fertiliser applications include the potential savings from application of nitrification and urease inhibitors/stabilisers, which would reduce the quantity of N-fertiliser required (through reduced losses from volatilisation and leaching) and reduce the emission factor for NH_3 and/or NO_x.

Agricultural soils are also a source of NMVOC and PM emissions. For both sources, the estimations are based on the area cultivated (hectares) and, in the case of PM, tier 2 estimates incorporate information on management practices. Projected areas of crop can often be obtained from agricultural projections or from projected tonnes of production (noting that the yield may change with time). If the harvested area for future years is not available, it may be estimated by extending current and historical trends to future years, ensuring that constraints on the total area of suitable agricultural land available are respected. It is good practice to ensure consistency with the information on croplands reported within land use and forestry under the UNFCCC.

A3.3.2 Emission factors

Air pollutant emission factors from agricultural soils will be affected by some key abatement measures related to NH_3:

- reducing surplus N applied in mineral fertilisers, crop residues, urea, manure/slurry and sewage sludge by adjusting quantity and timing to maximise N use efficiency;
- decreasing the surface area and/or time over which emissions take place through band spreading, trailing shoe application, injection of slurry and direct incorporation of solid manure;
- reducing NH_3 formation by applying urease inhibitors with fertiliser or lowering soil pH.

Average reductions in NH_3 emission factors for these abatement measures are provided in UNECE (2014).

If possible, projections of the uptake of these measures over time under WM and WAM scenarios should be incorporated into projected emission factors by varying these over time, or by use of projected activity data stratified by the presence/absence of abatement measures, each with separate emission factors.

Projected emission factors from agricultural soils will also be affected by future changes in temperature, precipitation and humidity. For example, less moisture in the soil or crop surface leads to higher PM emissions from harvesting and tillage, and higher temperatures generally increase NH_3 volatilisation from applied fertiliser (2023 EMEP/EEA Guidebook, Chapter 3D).

A3.4 Good practice for including abatement techniques

Implementation of abatement techniques will be highly important to controlling emissions from the agriculture sector, in a scenario of growing population and growing demand for agricultural products, and in particular animal products. Understanding the reduction potential and implementation rates within a country is essential in order to incorporate them into projection estimates.

This section includes relevant questions to consider and caveats to be considered, relating to abatement measure in general but in particular referring to those detailed in the *Guidance document on preventing and abating ammonia emissions from agricultural sources*, prepared by UNECE in 2014. This document contains a comprehensive description of the abatement techniques and as such is an important resource for MSs.

A3.4.1 Strength of evidence and practicality of implementation

In the UNECE (2014) guidance, strategies and techniques for the abatement of NH_3 emissions and N losses are grouped into three categories:

1. well-researched techniques and strategies that are considered to be practical or potentially practical, for which there are quantitative data on the abatement efficiency, at least on the experimental scale;
2. promising techniques and strategies, but for which research is at present inadequate or for which it will always be difficult to generally quantify the abatement efficiency — this does not mean that they cannot be used as part of an NH_3 abatement strategy, depending on local circumstances;
3. techniques and strategies that have not yet been shown to be effective or are likely to be excluded on practical grounds.

Therefore, when projecting the uptake of the different abatement techniques one should consider the following: based on the available research, is this technique considered as already verified for use in abatement strategies (category 1) or is further verification needed to demonstrate NH_3 emission reductions (category 2 and category 3)?

A3.4.2 Applicability of the reference situation to the national context

The UNECE (2014b) document presents, wherever possible, the reduction potential for category 1 and category 2 techniques, in comparison with a reference situation ([37]) or unabated situation. For the reduction potential values to be meaningful, the reference situation needs to represent the national circumstances. At this point, it is clear that a good understanding of management practices in the historical period is required. Therefore, one should consider the following: in view of the reference situation described in UNECE (2014b), how well does it represent the specific national circumstances? Are the emissions of the historical period sufficiently representative of the management practices in the country?

A3.4.3 Combinations of abatement measures employed

As already mentioned in the section 'Emission factors' in Chapter 3B, 'Manure management', it is important to consider that combinations of measures are not simply additive in terms of their combined emission reduction (UNECE, 2014). Therefore, for a more accurate estimate of the potential of the abatement techniques to be implemented, countries would need to collect data and understand the diverse combinations of abatement techniques. While it might be virtually impossible to get this information for all farms in the country in the historical period, one should consider the following: what two or three combinations of abatement techniques are most used in the farms? By animal type or category? Does it depend on the size of the farm?

([37]) 'The reference situation, against which percentage emission reduction is calculated is defined at the beginning of each chapter. In most cases the reference is the practice or design that is the most commonly practised technique presently found on commercial farms in the ECE region and is used to construct baseline inventories' (UNECE, 2014).

A3.4.4 Likely future uptake of abatement techniques

The future uptake of the abatement techniques will depend on many factors. Therefore, when projecting their future implementation, the following will need to be considered:

- **Applicability:** UNECE (2014) includes information on the applicability, or otherwise, of the different techniques, which can help to assess the potential uptake of the technique in the national circumstances. Clearly, to make best use of this information, a good understanding of the farming systems in comparison with what is required for historical emissions is needed. For example, a reduction in NH_3 emissions from slurry stores is possible by allowing formation of a natural crust, through reducing mixing and manure input below the surface; however, this technique is only suitable for slurries with a higher content of fibrous material. Therefore, knowledge of the proportion of slurries with/without higher content of fibrous material may be needed to establish a limit to the implementation of this technique in the country. One should consider the following: what types of farms/management practices are the possible/most likely potential target(s) of a particular abatement technique? What proportion of the agriculture sector (e.g. fraction of livestock herd, N application) does this type of farm/management practice represent in the country?
- **Cost:** UNECE (2014) also includes information on costs, with costs influencing the techniques that are likely to be implemented. In this regard, the impact of any relevant economic incentives also need to be taken into account. It should be noted that the cost varies from country to country and from farm to farm. One should consider the following: is the cost of the abatement technique a barrier for its implementation? For which type of farms/management systems would this be a barrier, and what proportion of the agriculture sector do they represent? Will the policies adopted or planned, depending on the scenario, help to overcome this barrier? What are the abatement techniques most likely to be implemented based on the cost?
- **Past and current use:** it is useful to understand the current use (or not) of particular abatement techniques, and especially any drivers or barriers that have promoted or prevented their implementation. One should consider the following: to what extent is each abatement technique already implemented? How has the prevalence changed over time? Are there any particular drivers/barriers affecting implementation? How are these drivers/barriers expected to evolve in the future?

A3.5 NFR 3F: field burning of agricultural residues

A3.5.1 Introduction

Field burning of agricultural residues is a source of NMVOC, NO_x, SO_x and PM emissions. This practice has been gradually restricted by national environmental legislation and the conditionality of CAP payments. However, there are exceptional cases in which field burning is allowed, after authorisation, for phytosanitary purposes, such as disease or pest control, and it is acknowledged that illegal burning also occurs in certain regions.

A3.5.2 Activity data projections

The primary activity data required for projections are harvested areas of crops or quantities of crop residue. The activity data for estimating NMVOC and PM emissions from agricultural soils could therefore be used (see section A3.2).

A3.5.3 Emission factors

Emission factors can be kept constant for the projected time series, as parameters influencing the emissions of NMVOC and PM are not expected to vary significantly in the future.

A3.6 International sources of activity forecast

As mentioned above, in many countries, government forecasts are available for the key activity data necessary for agricultural emission projections, such as livestock numbers. If national projections of activity data are unavailable, there are a number of international sources of information on agricultural projections. A selection of these are listed below.

A3.6.1 Food and Agriculture Organization of the United Nations projections

In December 2018, FAO released the report *The future of food and agriculture — alternative pathways to 2050* ([38]). The report outlines three broad alternative scenarios of how the agricultural sector could evolve towards 2050, labelled 'business as usual', 'towards sustainability' and 'stratified society', based on differing economic assumptions around strategies and policies adopted to meet the challenges facing global agriculture. For each scenario, quantitative projections are made using the FAO Global Agriculture Perspectives System ([39]) and ENVISAGE ([40]) models, calibrated based on Faostat and other relevant data and models. Country-specific projections of a range of relevant parameters at 5-year intervals to 2050 are available to view and download in the accompanying database ([41]), including:

- livestock herd sizes;
- meat and milk production per animal;
- harvested crop areas;
- crop yields per hectare.

Projections of mineral fertiliser (nitrogen, phosphorus, potassium (NPK) consumption are also provided, but these are not disaggregated by nutrient so are probably less useful for projecting emissions than the projections produced by Fertilizers Europe (see sub-section A3.6.3).

A3.6.2 The CAPRI model

The CAPRI model has been developed from European Commission research funds across the last two decades. It is tailored to reflect the agriculture sector under the EU CAP and is therefore directly relevant for MSs. The model produces projections of key activity data such as crop and livestock production and can be used for assessing policy impact (*ex ante*) and is therefore well suited to estimating WM and WAM scenarios; however, typical model outputs provide results for only an 8-year time horizon.

The model is freely available and is developed with an 'open source' approach, but the use of CAPRI requires considerable investment in expertise and time, or collaboration with advanced users. Some MSs (e.g. Hungary) do make use of CAPRI directly to supply tailored activity data projections.

A3.6.3 Published agricultural scenarios for Europe

A useful resource when developing activity data projections may be published scenarios of the development of the Europe-wide agricultural sector, of which several recent examples are available. These may even contain country-specific results for relevant indicators, which can then be directly or indirectly used to infer the necessary activity data for use in emission projections. Some key examples are listed below:

- **Scenar 2030 ([42]):** produced by the European Commission (JRC), this report describes alternative scenarios for the evolution of relevant activity data to 2030. It was produced by combining the outputs of several models (CAPRI, the individual farm model for the CAP and MAGNET). The 'reference' scenario models the situation of 'no change' in the CAP and three other alternative scenarios are also presented. Country-specific outcomes are detailed for land areas, crop production, N surplus and dairy/livestock production.
  Accompanying the report, a 'dashboard' ([43]) also allows the download of numerical results by MS, comparing the scenarios.
- **EU Agricultural Outlook 2018-2030 ([44]):** produced by the European Commission (JRC), the outlook is based on coherent macroeconomic assumptions combined with the Organisation for Economic Co-operation and Development (OECD) and FAO agricultural outlook, and development in the agriculture sector subject to the CAP reform from 2013 (modelled using CAPRI). However, no country-specific results are presented.

([38]) http://www.fao.org/3/I8429EN/i8429en.pdf
([39]) Further information on this system can be found at: http://www.fao.org/global-perspectives-studies/resources/detail/en/c/1161773/
([40]) The Environmental Impact and Sustainability Applied General Equilibrium model.
([41]) http://www.fao.org/global-perspectives-studies/food-agriculture-projections-to-2050
([42]) https://ec.europa.eu/jrc/en/publication/eur-scientific-and-technical-research-reports/scenar-2030-pathways-european-agriculture-and-food-sector-beyond-2020
([43]) https://datam.jrc.ec.europa.eu/datam/mashup/SCENAR2030_DASHBOARDS/index.html
([44]) https://ec.europa.eu/agriculture/markets-and-prices/medium-term-outlook_en

- **Fertilizers Europe ([45]):** forecasts of mineral fertiliser use are presented by country, by crop and by element, updated annually with a 10-year horizon, based on FAO-OECD, United States Department of Agriculture, Food and Agricultural Policy Research Institute and European Commission quantitative information, as well as qualitative judgement of Fertilizers Europe experts.

While these may help in taking exogenous economic factors and expected effects of the CAP into account, it may be difficult to reliably link results presented in published scenarios to WM or WAM projections incorporating specific national PaMs. Specific questions to consider may include:

- If more than one scenario is presented, which one should be used?
- How well does the wider socio-economic trajectory (e.g. population growth, GDP) of the chosen scenario align with official national projections of these indicators for the MS?
- Are there any planned national policies not taken into account, which may render the projections inaccurate? Most of the quantifiable agriculture-related PaMs taken into account in WM and WAM scenarios tend to be abatement measures, which reduce emission factors rather than affect activity indicators, but it is possible that some measures (such as nitrate pollution legislation) may act to increase or decrease activity.
- If the projection baseline is prior to the latest historical year, how well do the projections of the key indicators match observed data for the MS?

Published documentation may not be sufficiently detailed to understand which PaMs are included in each scenario, so additional methodological detail may need to be requested. It is also worth noting that those published scenarios listed above are based on the continuation of the CAP following the 2013 reform, but do not include the post-2020 CAP reform proposals. If required, more recent published scenarios should be sought that include post-2020 CAP reform proposals, either as WAM scenarios or WM scenarios once new legislation is passed.

When country-specific projections are not available from these published scenarios, it will be necessary to use expert judgement to assess what the European or global-level patterns may mean for the country in question.

Annex 4 NFR 5: waste sector

A4.1 NFR 5: waste

A4.1.1 Introduction

Typically, emissions from the waste sector are estimated by understanding the utilisation of treatment systems for both solid and liquid waste. The quantity of waste handled by each treatment system is combined with parameters and emission factors to determine emissions. When considering waste sector projections, it is important to understand:

- how national waste generation (quantities and types) will change in future years;
- how the utilisation (percentage share) of treatment, disposal and recycling systems will evolve;
- whether or not waste parameters and emission factors will change (e.g. because of technological advances or through the planned uptake/retrofitting of abatement systems).

It is possible that PaMs will have an impact on any, or all, of the above aspects. It is therefore important to understand potential co-dependencies and relationships between treatment pathways. Considering the current and future mass flow of waste may assist projections compilers in this regard.

Emissions from the waste sector tend to be of greater significance for GHGs than for air pollutants. The waste sector may be a minor to moderate source for several pollutants depending on national waste management practices.

([45]) https://www.fertilizerseurope.com/media/news/single/article/forecast-2017-2027

Waste incineration can be an important source for some pollutants including heavy metals and persistent organic pollutants. Activity data should be aligned with the data used for the GHG inventory, where possible.

Emissions from landfill, anaerobic digestion, composting, waste incineration and waste water are covered in these guidelines. Care should be taken to ensure that emissions resulting from the generation of electricity from waste are accounted for in the energy sector and not double counted.

A4.1.2 Activity data projections

Ideally, national survey data on historical waste creation and handling activities will be available to form the basis of waste sector projections. These data may be supplemented with facility-level data where this is reported. For some categories, it may be necessary to make assumptions and estimates to account for potentially missing waste quantities in national statistics. This may include sources such as open burning of agricultural waste and small-scale home composting. If there are national data available on populations with and without formal waste collection services, this may be of use as a proxy for identifying these potentially missing waste streams.

By default, population projections can be used as an indicator for the projection of municipal waste streams. For industrial waste streams, economic indicators (e.g. production, GDP or GVA forecasts) can be used. Ideally, potential indicators will be compared with historical emissions data to determine the data set that shows greatest alignment of trends.

In both developing and developed economies, there is evidence of decoupling between waste generation rates and both population growth and GDP. This could be a result of evolving waste management practices and may be heavily linked to PaMs adopted through the development of a national waste prevention programme, as is required under the EU Waste Framework Directive (2008/98/EC) (EU, 2008). This directive has put in place a waste management hierarchy that promotes treatment pathways designed to reduce the disposed portion of waste. In turn, this should act as a vessel to decouple waste generation from economic growth.

Given the potential for decoupling, MSs should consider if available proxy indicators are appropriate for determining the projected waste generation rates. This may be identified through observation of a gradual or a more sudden drop in correlation between these historical data sets across a time series. As such, projecting national waste generation or waste generation per capita using proxy data sets can be a major cause of uncertainty in waste sector projections.

Typically, PaMs may be in place that are designed to reduce the quantities of materials disposed of as waste. These may focus on specific waste streams (e.g. biodegradable waste from commercial premises) or may be more broadly targeted (e.g. obligations placed on relevant authorities to reduce the quantities of waste generated). Policies may comprise voluntary measures, mandatory measures or a mix of measures. Projections compilers should aim to take such PaMs into consideration when forecasting future waste arisings. The method for calculating this impact is likely to be determined by the PaM time-frame. For example, a policy to reduce waste arising from a waste stream may lead to a stable/increasing/diminishing percentage reduction in the future time series from the point of implementation. Alternatively, PaMs may be in place that prohibit waste stream utilisation from a specific date, in which case projections will see an immediate decline in utilisation and emissions from the point of implementation.

As well as forecasting the future generation of municipal and industrial waste streams, it is necessary to identify the future mix and interaction of treatment pathways and systems that are to be utilised at the national level. This may be determined from international/national legislation that affects the phasing out or encouragement of specific treatment options. Table A4-1 provides some of the key policies and regulations that may have an impact on air pollutant emissions arising from the waste sector. Please note, however, that this list is not exhaustive and items may be superseded following publication of the chapter.

Table A4-1 Summary of important EU legislation relevant to the waste sector

Description	Legislation	Parameters/variables
Cross-cutting		
Regulation establishing a European energy programme for economic recovery	Regulation (EC) No 663/2009	Methane recovery, sludge removal, waste incinerated, waste open burned
Renewable Energy Directive (RED)	Directive 2009/28/EC	Energy efficiency, methane recovery, share of renewables in electricity generation, sludge removal, waste water sludge removal for energy generation, waste incinerated, waste open burned
Directive on integrated pollution prevention and control (recast)	Directive 2010/75/EU	Solid Waste Disposal (SWD) waste composition, SWD total waste (kg) by type of site, methane recovery, SWD types, sludge removal, waste water, percentage of population utilisation of waste water treatment, share of total waste water going to different pathways, waste incinerated, waste open burned
Industrial Emissions Directive	Directive 2010/75/EU	Emission factors, energy production, final energy consumption by sector by fuel type, fuel efficiency, share of different technologies
Directive on the Kyoto Protocol project mechanisms	Directive 2004/101/EC	Emission factors
Emissions Trading Scheme Directive	Directive 2003/87/EC amending Directive 2009/29/EC	Electricity consumption, emission factors, final energy consumption by sector by fuel type, share of different forms of energy, CO_2 price
Directive on the reduction of national emissions of certain pollutants	Directive 2001/81/EC and Directive (EU) 2016/2284	Emission reduction commitments for air pollutants
Directive on the promotion of electricity from renewables	Directive 2001/77/EC	Methane recovery, share of renewables in electricity generation, share of renewables in energy production, sludge removal, waste incinerated, waste open burned
Effort Sharing Decision and Effort Sharing Regulation	Decision No 406/2009/EC and Regulation (EU) 2018/842	Share of different forms of energy
Ambient Air Quality Directives	Directive 2008/50/EC and Directive 2004/107/EC	New air quality objectives for $PM_{2.5}$ (fine particulate matter) including the limit value
Waste		
Waste Management Framework Directive	Directive 2008/98/EC	SWD waste composition, SWD total waste by type of site, methane recovery, SWD types, sludge removal, waste water generated, percentage of population utilisation of waste water treatment, share of total waste water going to different pathways, waste incinerated, waste open burned
EU Monitoring Framework for the Circular Economy ([46])	Launched in January 2018	Part of the EU action plan, adopting a new set of measures including, for example, a Europe-wide EU strategy for plastics in the circular economy, as well as a monitoring framework on progress towards a circular economy at EU and national level
Directive on waste	Directive 2008/98/EC	Percentage of population utilisation of waste water treatment, methane recovery, share of waste water going to different pathways, sludge recovery, sludge removal, SWD total waste by type of site, SWD types, SWD waste composition, waste incinerated, waste open burned, waste water generated
Packaging and packaging waste directives	Directive 2005/20/EC, Directive 2004/12/EC and Directive 94/62/EC	SWD waste composition
Waste electrical and electronic equipment directives	Directive 2011/65/EU and Directive 2012/19/EU	Disposal of domestic refrigerators
Water Framework Directive	Directive 2000/60/EC	
Landfill Directive and revised version as agreed in co-decision in May 2018	Council Directive 1999/31/EC	Disposal of domestic refrigerators, methane recovery, sludge removal, SWD waste composition, SWD total waste by type of site, SWD types
Directive on urban waste water treatment	Commission Directive 98/15/EC amending Council Directive 91/271/EEC	Percentage of population utilisation of waste water treatment, N removed with sludge, share of total waste water going to different pathways, waste water generated

([46]) For more information, see: https://ec.europa.eu/eurostat/web/circular-economy

Waste Incineration Directive	Directive 2000/76/EC	Waste incinerated

Note: SWD, solid waste disposal.

National PaMs may also promote future waste treatment systems and technologies that will alter the utilisation of treatment systems. An analysis should be undertaken into the potential co-dependencies and relationships between treatment pathways. For example, development of anaerobic digestion facilities to handle municipal waste may divert waste from a single existing system (e.g. landfill) or multiple systems. In the latter case, further understanding of the waste diversion and resultant mass flow of waste will be required.

It is important to check if the total waste generation exceeds limits relative to the planned future waste handling capacity of any utilised treatment options. For example, it is possible to develop a scenario in which total waste generation exceeds the capacity of currently available infrastructure, but there is a commitment to provide suitable infrastructure ahead of this point (which may not yet be fully understood). In such cases, it is appropriate to highlight these potential issues, but to proceed with developing projections on the basis of forecast waste generation and treatment.

A4.1.3 Emission factors

Tier 1 emission factors from the Guidebook are often utilised by MSs for calculating emissions from the waste sector, when key category identification is generally unlikely for air pollutants. There is little information available in the Guidebook at tier 2 level (presenting technology-specific information). As such, projections compilers should generally maintain emission factors for treatment systems to future years unless national understanding of technology implications on air pollutant emissions is available. If waste incineration technologies are utilised, it may be necessary for compilers to understand the existing and planned uptake or retrofit of abatement technologies. Please refer to tables in the Guidebook for data on abatement efficiencies (for table references, see section A4.4).

In specific cases and, in particular, when key categories are identified, it may be necessary to obtain technology-specific, or plant-/facility-level, data.

A4.2 NFR 5A: solid waste disposal on land

Solid waste disposal on land (NFR category 5A) is only a minor source of air pollutant emissions; GHGs (methane, CO_2 and N_2O) are typically more significant. Small quantities of NMVOCs, NO_x, NH_3, CO and PM (PM_{10} and $PM_{2.5}$) may be emitted.

Typically, activity data projection will require:

- total waste to landfill (kg) or total waste arising (kg) and, where this is unavailable, the percentage of solid waste going to landfill;
- future population growth and per capita waste generation (check consistency with GHG inventory);
- information on the composition of waste streams.

Policies for waste minimisation, recycling/reuse and diversion from solid waste disposal will have an impact on the quantity and nature of waste landfilled, and hence will affect emissions from landfills.

Tier 1 emission factors for NMVOCs, total suspended particles, PM_{10} and $PM_{2.5}$ are provided in the Guidebook. It is appropriate to report other potential pollutants as not estimated for this source. Emission factors should be maintained for future years unless country-specific data on landfill management and its impacts on air pollutants are available.

Emissions may also be generated from the collection and combustion of landfill gas. If this is combusted for energy generation, resulting emissions and projections should be reported in the energy sector. However, it may be appropriate for the waste sector expert to contribute to the projections calculations when there is a need to understand current or planned cross-sectoral waste and regulatory/energy policy to determine projected activity levels.

A4.3 NFR 5B: biological treatment of solid waste — composting and anaerobic digestion at biogas facilities

Composting (NFR category 5B1) and anaerobic digestion (NFR category 5B2) may produce small amounts of NH_3. Emissions relate to NH_3 that derive from the breakdown of N in the waste stream, largely as it decays under storage conditions (pre-process). In-process emissions may occur through the release of pressure valves under high pressure, but the NH_3 content of the released gas at this stage is considered negligible. The impact of emissions of GHGs is of greater importance, because of the high methane content in the produced biogas. Anaerobic digestion may also produce small quantities of nitric oxide and dust, which are not considered in this guidance.

Typically, activity data projection will require:

- biologically treated total waste (kg) by type of treatment;
- future population growth.

For many MSs, this category will be a growing source of emissions because of its increasing popularity as a waste treatment option. If possible, it may be beneficial to gather understanding of the historical trend in biologically treated waste to assist with projecting future growth of biological treatment options. This will often give a more likely projected trend than using available proxy data such as population growth.

PaMs may be in place that will promote the use of small- (home) or industrial-scale composting and industrial-scale biogas facilities. There is the potential for diversion of waste streams away from other solid waste management practices. This should be taken into account in developing projections, to avoid any risk of double counting of emissions.

In the absence of better data, projections of biologically treated waste generation can be aligned with specific industry forecasts or expected population growth if the former are unavailable.

Tier 1 emission factors for CO (windrow composting only) and NH_3 are provided in the Guidebook. Emission factors should be maintained for future years unless country-specific data on biological treatment systems and their impacts on air pollutants are available.

For waste category 5B, the Guidebook does not yet provide any higher tier methodologies that take into consideration any variety in waste storage practices of composting and anaerobic digestion facilities. There may be significant differences in NH_3 emissions depending on the on-site waste storage stages and practices. Inventory compilers are encouraged to engage with stakeholders, data providers and facilities to better understand these aspects and to help develop a more accurate understanding of potential emissions and future projections. In particular, waste sector compilers should engage with their counterparts and data providers under the agriculture sector. It is likely that these experts will be best placed to advise on the N content of the waste. Aspects that are particularly likely to have an impact on emissions of NH_3 include (Holly et al., 2017):

- solid-liquid separation;
- the use of manure/waste storage covers;
- other beneficial management practices.

Attempting to improve projections for this category will often be a priority when the activity is projected to increase as a result of PaM interventions.

A4.4 NFR 5C: waste incineration

Waste incineration (NFR category 5C) may include the incineration of waste types at specific facilities, including:

- municipal waste (5C1a);
- industrial waste (5C1bi);
- hazardous waste (5C1bii);
- clinical waste (5C1biii);
- sewage sludge (5C1biv);
- cremation (5C1bv).

It may also include the open burning of waste (NFR category 5C2).

The emissions of compounds such as NMVOCs, SO_2, hydrogen chloride and PM from waste incineration are unlikely to contribute significantly to total emissions. In addition, emissions of all air pollutants are likely to be minor when European or equivalent national emissions limits on incinerators apply. However, outside such regulations, waste incinerators have been a major source of emissions of polychlorinated dibenzo-dioxins and polychlorinated dibenzo-furans, other persistent organic pollutants and some heavy metals such as cadmium and mercury. Incomplete combustion associated with open burning of agricultural or household wastes and associated plastics and other materials (e.g. materials with high moisture content and materials containing metals such as treated wood) may give rise to toxic air pollutants.

Care must be taken to prevent double counting of emissions reported here and in the relevant combustion source category in 1A (where energy is recovered). Potential double counting of emissions associated with field burning (accounted for in agriculture category 4F) should also be avoided.

Typically, activity data projection will require:

- total waste incinerated and open burned (kg);
- future population growth;
- economic indicators (e.g. production, GDP or GVA forecasts);
- waste composition into the above waste types (and reporting categories).

Population growth should be applied for projecting waste generation within the municipal waste stream and cremation. Economic indicators should be applied for projecting the industrial waste streams.

Compilers should consider the potential diversion of waste from other treatment systems. This may be particularly true when there are PaMs and incentives to divert biodegradable wastes from solid waste disposal on land to incinerators and other energy generation systems. Societal trends in the adoption of cremation may be relevant when considering activity data for this sector.

Tier 1 emission factors are available for many pollutants for waste incineration activities. When there is a key category identified, obtaining country-specific data or facility-level reported data should be prioritised. It is important to consider the impact of technological advances on emission factors. Compilers should refer to the Guidebook for default information on abatement efficiencies associated with various legislative and technological responses:

- Table 3-3 of the municipal waste incineration ('*5.C.1.a Municipal waste incineration'* chapter);
- Tables 3-3 and 3-4 of the industrial waste incineration ('*5.C.1.b Industrial waste incineration including hazardous waste and sewage sludge*' chapter);
- Tables 3-3, 3-4 and 3-5 of the clinical waste incineration ('*5.C.1.b.iii Clinical waste incineration*' chapter).

As highlighted above, these sources and abatement efficiencies are relevant only for installations for which energy is not recovered.

If there is no key category, emission factors can be maintained for future years unless country-specific data on incineration practices and its impacts on air pollutants are readily available.

A4.5 NFR 5D: waste water handling

In most cases, emissions from domestic (NFR category 5D1) and industrial (NFR category 5D2) waste water handling will be an insignificant source of air pollutants. However, NMVOC and NH_3 emissions from waste water treatment plants and latrines may occur. Waste water handling is a higher priority for emissions of GHGs, because of the potential anaerobic production of methane from organic content in the waste water, and the degradation of N components to form N_2O.

Typically, activity data projection will require:

- total waste water handled (m^3) by treatment plant and latrines;
- future population growth;
- economic indicators (e.g. production, GDP or GVA forecasts).

For liquid waste, there is less potential for divergence between waste streams in comparison with solid waste streams. However, this may be a consideration if PaMs will lead to increasing populations connected to advanced treatment plants over alternatives (e.g. latrines, septic systems).

The current Guidebook approach does not distinguish between the tier 1 emission factor and tier 2 (industrial waste water specific) emission factor for NMVOCs. In addition, there is a single tier 2 emission factor for NH_3 from latrines. As such, deriving the total quantity of waste water handled has often been sufficient for use in the historical inventory. However, for waste water projections, it is advisable to split the activity data between domestic and industrial generation, where possible. This allows the domestic portion to be projected in line with population growth data and the industrial portion to be projected in line with more appropriate economic indicators.

If PaMs lead to a change in treatment methods, ideally country-specific information will be sought to consider the implications on emission factors. In most cases, if there is no key category, emission factors can be maintained for future years unless such country-specific data on waste water treatment and its impacts on air pollutants are readily available.