Analysis and development of methodologies for estimating potential industrial emissions reductions and compliance costs of BAT conclusions adopted under the Industrial Emissions Directive

Final Report for European Commission DG Environment
Analysis and development of methodologies for estimating potential industrial emissions reductions and compliance costs of BAT conclusions adopted under the Industrial Emissions Directive

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Executive summary

Background and problem definition

Directive 2010/75/EU on Industrial Emissions (IED) sets the overall framework for the permitting and control of emissions to all environmental media from the most polluting industrial activities. Under the IED framework, around 50,000 industrial installations operate subject to environmental permits, ranging from power plants to food and drink production. The IED aims to achieve a high level of protection of human health and the environment by avoiding or minimising pollution from industrial installations. It intends to accomplish this primarily through application of Best Available Techniques (BAT) which are legally defined through development and adoption of ‘BAT Conclusions’ (BATC) for each sector. BAT Associated Emission Levels (BAT-AELs) form part of BATC which are subsequently used by regulators as the legal reference point when setting the conditions of a permit. Following the publication of BATC (relating to the main activity of an installation concerned) in the official journal, Member States have a maximum of 4 years to update installations’ environmental permits in line with BAT-AELs and to ensure that the installations comply with those permit conditions.

A key difference between the IED and preceding legislation regarding industrial emissions is that, following permit updates, plant operators will be legally required to meet ELVs set no higher than the level of BAT-AELs (unless a derogation from the BAT-AELs is granted). Given this much stronger, formalised link between environmental permits and BATC, it is anticipated that the IED will lead to a significant reduction of emissions. To date there has been little quantification of how BATC may actually reduce industrial emissions to air and water. Further still, there is no adopted methodology across the EU for quantifying the impacts of each set of BATC on the relevant industry.

Objectives and approach of this study

To support further development of industrial emissions policy and to substantiate the BATC themselves there is a need for a better understanding of the role they play in reducing emissions and at what cost. The European Commission contracted Ricardo Energy & Environment to carry out a study to improve this understanding with the following key aims:

- Identify, compare and review the possible methodologies to assess the impacts of attainment of BAT-AELs. The methodologies need to estimate potential reductions in emissions and compliance costs, drawing on the best available data.
- Assess the robustness of methodologies – i.e. whether the estimates they produce are sufficiently accurate, and the feasibility of implementing them.
- To draw conclusions and recommendations regarding a preferred methodology for assessing the impacts of BAT-AELs. The methodology (or methodologies) was intended to have the capability and flexibility to assess BAT-AELs impacts across all IED sectors.

The approach to the study followed two sequential tasks. First, a targeted search of literature sources was undertaken to form the underlying basis for the study. This was complemented by engagement with a wide range of relevant stakeholders, including: relevant authorities in all EU-28 Member States, European trade associations representing individual industrial sectors, and NGOs. This was undertaken between December 2015 and February 2016 to gather studies and data sources which might not have been identified through literature search. Literature sources were then evaluated for relevance to inform a shortlist of studies. The shortlisted studies were then reviewed in more detail using a common assessment template to establish the methodologies and data sources used. The methods identified were categorised into specific elements of the analysis (emission reductions, costs and benefits). Finally, the applicability of the methods for assessing the impacts of BAT-AELs was tested through a review in the context of the iron and steel and production of polymers sectors (based on a selection of BAT-AELs, plants and Member States). These two sectors were chosen as illustrative examples for testing the methodologies as described below.

The second study task performed a more detailed feasibility analysis of the methodologies identified. First a set of criteria were defined against which the methodologies would be tested. These criteria were grouped against four headings: accuracy and uncertainty of assessment, resource
implications, practicality of implementation, and transparency and acceptability. Then application of the methodologies to the iron and steel and polymer production sectors was completed. Testing was undertaken for a sample of BAT-AELs to air and water applicable to these sectors. Data gathering and calculations were undertaken at facility level, for a selection of Member States. The results of this exercise, together with further stakeholder engagement regarding the availability of data, was used to support a multi-criteria analysis of each methodology against the set of criteria previously defined.

This analysis was used to inform draft conclusions and recommendations on the overall feasibility of methods and available data sources, which were presented to stakeholders at the workshop held in Brussels in September 2016. Feedback gathered from stakeholders during and following the workshop was used to finalise the findings of the study presented in this report.

Key findings: Categorisation of methodologies

Although numerous studies were identified as part of the review, there is a limited number of general methods that can be used in the context of assessing emission reductions, costs and benefits of BAT-AELs. More specifically no single study provided a ready approach that could be used as a reference method across all elements of the analysis. As noted above, following the review of the literature sources, the approaches identified were therefore first categorised against these different analytical elements. The methodologies were then further categorised based on the common methodological features. There exist multiple ways in which methodologies could be grouped. Groups were defined to allow for distinction to be drawn between the level of accuracy they offer and the resource intensity they require.

Baseline emissions, future emissions and emissions reductions

Studies which estimated emission reductions compared a scenario applying the environmental restraint (in this case BAT-AELs) relative to a counterfactual scenario. The counterfactual is a projection of baseline emissions (BE) for future years assuming no BAT-AELs are in place.

In the context of BAT-AELs, based on the studies reviewed, baseline emissions (see Table A) can be:

- **Modelled Baseline Emissions (BE1, BE2, BE5)** – several data parameters are combined to provide calculated baseline emissions at a required level such as process, facility or sector: BE1 uses an emission factor expressed in unit of mass per unit of activity, multiplied by corresponding activity value (e.g. mass or volumes produced, fuel consumption) whereas BE2 multiplies an output concentration (e.g. emissions levels in the flue gas or wastewater flow) by corresponding activity value (e.g. flue gas volumes). BE5 uses unabated emission factors and emission reduction efficiencies to obtain abated emission factors. These are then multiplied by the activity data. The outputs of this approach are the total emissions of pollutant in unit of mass per year.
- **Reported Baseline Emissions (BE3)** – emissions reported and available from existing data sources are used as the baseline for the assessment; or
Hybrid Baseline Emissions—several limitations could exist around reported data. To address these limitations, a baseline can be constructed on a basis of reported emissions (BE3) with any gaps filled using modelling approaches (BE1, BE2 or BE5).

Once the baseline is established, the methodologies in the sources reviewed either progressed directly to the assessment of emission reductions (ER) or included an intermediate step of defining a reference scenario. A future emissions scenario depicts emissions in a future year(s) without BAT-AELs in place (see Table B). If this step was taken, future emissions (FE) were either modelled (FE1: i.e. by applying a combination of parameters, such as anticipated plant closures, to the baseline to project how emissions will change in future years) or adopted from existing sources (FE2: e.g. use of national emission projections developed outside of the core study).

Having established the baseline and/or future emission scenarios, the next step consists of modelling the future scenario assuming BATC are in place (i.e. the ‘policy’ scenario). Calculation of the emission reduction could be done by either:

- Subtracting the policy scenario including BATC from the baseline or reference scenario. Typically this assumes BAT-AELs expressed as a unit of mass per unit of activity (ER1) or as an output concentration (ER2) are met, which are combined with activity data to calculate emissions under the policy scenario.
- Modelling the impact of specific abatement techniques: these are applied directly to either the baseline or future emission scenario by first estimating what reductions are required, then identifying specific techniques that could achieve these, and finally applying the associated abatement efficiencies (ER3).

Costs

The review identified and evaluated a number of studies which address the determination of compliance costs (CO) for industry. The methodologies have been summarised into three distinct groupings (also summarised in Table C):

- Marginal abatement costs (CO1): estimates of emission reductions are multiplied by a representative cost per tonne of pollutant abated to obtain an estimate of total cost.
- Direct costing of additional investment (CO2): Specific information on the costs associated with each individual mitigation measure identified is collected (e.g. capital costs, operating costs) and summed to derive an estimate of total cost. This approach is only applied where abatement measures are identified.
- Cost of lost productivity (CO3): focuses on the cost of reduced revenue associated with application of BAT. This applies in cases when the economic operation of an installation is affected by applying BAT. The costs captured under CO3 are typically distinct from and additional to those assessed under CO1 or CO2. As such CO3 was included as part of CO2 for the remainder of the assessment.
Benefits – emissions to air

The groupings of approaches differ both in terms of the detail of the approach and the situation in which they are applied. Typically, which approach is followed will depend on the situation and specifically the data, resource and modelling capability available.

The Impact Pathway Approach (ABE1 and ABE4) sets out a series of methodological steps from the identification of emissions source, to modelling of dispersion and exposure, assessing health and environmental impacts and finally to valuation. Damage cost functions methodology (ABE2) allow the user to directly combine an emissions or change in emissions, with a damage cost per tonne, to estimate the total value of benefits (i.e. damages avoided). The abatement cost approach (ABE3) is applied where abatement measures influence the achievement of legal limits restricting air pollutant concentrations. Rather than assessing the direct impacts of exposure to air pollutants, the abatement cost approach instead assesses the opportunity cost or cost saving of the measure considered in displacing an alternative that would have been required to achieve the limit values. The summary of approaches to estimating benefits from reductions in emissions to air is in Table D.

Benefits – emissions to water

There exist multiple methods (WBE2-7) for valuation of water quality which have been developed over the years and used in the context of the Water Framework Directive and/or the EU Nitrates Directive (e.g. revealed preference and stated-preference methods). However, these methods have not been directly applied to emission reductions to water from industrial facilities. In order to apply these methods, an understanding of how the change in emissions from industrial facilities impact on water quality is required, before proceeding to the valuation of the impacts. The summary of methods for valuing water impacts is in Table E.

The impact pathway approach (WBE1) presented above in the context of air emissions, can in theory be used to estimate the impact of emission reductions on water quality from compliance with BAT-AELs. This requires establishment of a link between decrease in emissions / concentrations in waste water discharge, concentrations of the emitted substance in the receiving water body and resultant impact on water quality. Although this works in theory, there are key stages missing in the underlying evidence base. In particular, the ones linking change in concentrations in water bodies to exposure, and change in concentrations to change in water quality for other ecosystem services.
Key findings: Data requirements

In order to identify the principal data requirements for the assessment of BAT-AELs, a screening of the BAT-AELs and AELs established under the IPPC regime (in case of BREF documents not reviewed yet after the entry into force of the IED) was undertaken. This was carried out for each BREF to ensure requirements and applicability for each sector are considered in the study conclusions and recommendations. This review identified that the most common metric to express BAT-AELs to air is concentration based (typically mg/Nm³). In a few instances, BAT-AELs are expressed per tonne of product or per mass or volume of raw materials used. BAT-AELs to water are established depending on whether a facility discharges into urban wastewater treatment plants or directly to a receiving body. They are commonly expressed in mg/l of wastewater, with a few instances of the use of production or raw materials metrics. Therefore, within a methodology there may still be variations in data requirements due to differences in the way in which the BAT-AELs themselves are expressed.

As part of the review of potential methods, the data sources needed to be able to apply them have also been considered; this is summarised in the following table relative to each of the methods.

<table>
<thead>
<tr>
<th>Type of data input (at BAT granularity)</th>
<th>Baseline emissions</th>
<th>Methodology</th>
<th>Future emissions</th>
<th>Emission reductions</th>
<th>Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>BE1</td>
<td>BE2</td>
<td>BE3</td>
<td>BE5</td>
<td>FE1</td>
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<tr>
<td>Plant characteristics</td>
<td></td>
<td></td>
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<tr>
<td>Activity (e.g. fuel consumption, raw / final product produced)</td>
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<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
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<td>Operating hours</td>
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<td>✔️</td>
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<tr>
<td>Gas and wastewater flows and parameters (incl. reference conditions)</td>
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<tr>
<td>Emissions</td>
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<tr>
<td>Reported emissions / external emission projections</td>
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<tr>
<td>Scaling factors for future emissions (e.g. growth)</td>
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<td>Abatement techniques</td>
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<tr>
<td>Abatement efficiency</td>
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<tr>
<td>Uptake of techniques (under baseline, future)</td>
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<td>Lifetime</td>
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<td>✔️</td>
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<tr>
<td>Costs</td>
<td></td>
<td></td>
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<tr>
<td>Marginal abatement costs (i.e. cost per tonne of pollutant abated)</td>
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<td>✔️</td>
<td>✔️</td>
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<tr>
<td>Individual cost components (CAPEX, OPEX, energy and fuel prices etc.)</td>
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<td>✔️</td>
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<tr>
<td>Discount rate</td>
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</tbody>
</table>

Several existing sources of data were identified, explored and used as part of the testing of the methodologies. These were: environmental permits, monitoring reports, BREFs, databases and models.
Analysis and development of methodologies for estimating potential industrial emissions reductions and compliance costs of BAT conclusions adopted under the Industrial Emissions Directive

(e.g. E-PRTR, Eurostat, GAINS), and other literature and online sources (e.g. sector journals, trade associations, company websites). Where gaps existed, modelling approaches and the feasibility of collecting primary data were considered.

Key findings: Feasibility to implement

Methodologies to assess baseline emissions

Development of the baseline emissions (BE) is the first and one of the most complex elements of the assessment of impacts of BAT-AELs. The accuracy of the baseline data and assumptions made at this early stage of the assessment will impact on the overall assessment results as it defines how close or far from meeting the BAT-AELs a given facility or sector as a whole, may be and sets the basis against which the subsequent analysis is based.

Overall, the feasibility of the methodologies is strongly dependent on the data sources used for the assessment, alongside the steps of the methodology itself. The methodologies to estimate baseline emissions rely on the same data sources and where the same source is assumed to be used across different methodologies, these methodologies would score similarly against the assessment criteria. That said, this has not prevented several conclusions being drawn from the assessment regarding the relative merits of the methodologies.

An ideal data source for the development of the baseline for the assessment of impacts of BAT-AEL is expressed in the same metric as the actual BAT-AEL, alongside mass emissions (benefits of BAT-AELs are assessed as annual emission loads). This enables direct comparison between the baseline and BATC scenarios in the latter stages of the analysis (calculation of emission reductions), with minimum need for transformations or complex modelling, and ease of estimation of impacts on emissions.

Approaches BE1 and BE2 are similar and only differ depending on whether emissions factors (mass of pollutants per unit of production) or emissions concentrations are applied. Ideally, the choice of approach would follow how BAT-AELs are expressed in the BATC. This enables direct comparison between the baseline and BATC scenarios, with minimum need for transformations or complex modelling, and ease of estimation of impacts on emissions.

The benefits of these methodologies is that they require a limited number of data inputs (though method BE2 is more data intensive compared to method BE1) and, subject to availability of appropriate data, do not involve complex calculations. That said, modelling baseline emissions requires technical expertise, and some sector-specific knowledge, and there are limitations.

In the absence of the data on production and emission factors at the level matching BAT-AELs, the modelling of baseline emissions can become less accurate and more complex. Testing with the polymer production sector demonstrated that some additional steps are required: e.g. installation level activity data had to be converted into product sub-categories to match emission factors available in the BREF. Furthermore, an assumption around performance of a site was needed to select appropriate emissions factors from a range of values provided in BREF. Both factors reduce the accuracy of the modelling and increase its complexity.

Testing of the method BE1 with the polymer production sector demonstrated that in case of emissions to air, it cannot be applied to fugitive emissions (leaks from gaskets, fittings and seals on pipes, pumps and other production devices). These emissions are not proportional to the production rates. This decreases the accuracy of the baseline emissions obtained in this way. In the polymer production sector fugitive emissions are a non-trivial source of overall plant emissions thus implications of this issue on the accuracy of the modelling results can be high.

Establishing the baseline using reported emissions (BE3) can be done with minimum additional assumptions although there are potential resource implications for accessing such data.

Given BE3 uses data directly reported by operators, this could be considered to provide the most accurate assessment of baseline emissions. In particular, given this is often based on sources regularly updated (e.g. annual monitoring reports). However, data may not be available for all parameters required. E-PRTR data offers a more easily-accessible source of reported emissions but was assessed to have limited applicability for establishing the baseline emissions for the assessment of BATC. This
is because E-PRTR data correspond to site rather than to emission source, channelled and fugitive emissions to air are reported combined, and reporting thresholds for pollutants apply. Splitting plant level emissions from E-PRTR to installation or emission source level have an arbitrary character and introduce a high degree of uncertainty unless additional information is used in the methodology.

Alternatively, the BE3 method can deliver results for establishing an emission baseline in every installation and unit subject to access to monitoring reports submitted to the authorities or monitoring data from the operators directly. That said, the details contained in the reports and the ease of accessing them vary depending on the Member State. Broadly, if a pollutant was covered by a previous BREF under the IPPC regime, it can be assumed that the monitoring data for such pollutant exists. If a BAT-AEL is however defined for a new pollutant, it might be that it has not been monitored widely across the potentially affected sites to date. Absence of monitoring data is expected to be more substantial for an assessment of impacts of newly established, horizontal BREFs applicable to sectors previously covered by separate, individual BREFs.

Where monitoring data are incomplete or cannot be accessed, modelling approaches such as BE1 and BE2 can be used to complete the dataset of baseline emissions. Methods BE1 and BE2 represent modelling approaches that could be used to estimate emissions using activity data and emission factors (expressed either as load or concentration). However, testing with the iron and steel and polymer production sectors demonstrated that the two methodologies cannot be used in place of one another uniformly in every sector.

The level of effort required in establishing baseline emissions varies depending on the method used…

Method BE3 can be the least resource intensive (where the information is readily available and accessible). This judgment does not consider the way the underlying data is collected; instead it is based on the complexity of the method, and the number of steps that are required to establish the baseline emissions for the pollutants being assessed. Methods BE1, BE2 and BE5 are modelling methods which rely on combining a number of data inputs together. While they require relatively simple calculations, the level of effort required in their execution increases with number of data inputs required (e.g. hence method BE1 is considered to require less effort, than BE2). Depending on the methodology adopted, method BE5 can combine the largest number of variables. The accuracy of the BE5 method is linked with uncertainties around the modelling of the abatement techniques already fitted in the sector (i.e. their uptake), and the accuracy of using unabated emission factors especially for process emissions.

…but the difference is primarily driven by the sources of data available and used for the assessment.

There is a finite number of data sources that provide the data at sufficient granularity level for the assessment of impacts of BAT-AELs. As demonstrated with testing of the methodologies with the iron and steel sector, permits can provide a good level of understanding and data required to determine baseline emissions. However, even just for a single facility, it is resource intensive to extract relevant content from the individual permit documents due to their size, national language, difference in content and lack of standardised formats to present the information (e.g. lack of standardised tables with emission limit values). Another option is to directly request the data from the operators of the industrial facilities or use existing monitoring reports. Yet these reports also suffer from the same limitations as permits noted above (i.e. due to size, national language, etc.), and can be the most burdensome approach both for the entity undertaking the assessment (in terms of identifying, contacting and managing exchange of data with the operators, compiling the information, quality assuring the data etc.) and the operators (who would be required to compile data sets that in some cases may not necessarily already be easily available to them). Even then, monitoring reports and permits may still not provide consistent information across the parameters required for the assessment, for example in terms of pollutants they would cover.

Methodologies to assess future emissions

Projecting future emissions from the baseline is inherently uncertain as it relies on assumptions about what is likely to happen in the future. These uncertainties may have an impact on acceptability of the assessment, especially if assumptions made about the future changes are made in a non-transparent
manner. Nevertheless, projecting the baseline into the future (e.g. into the year the policy starts) is a well-established step in ex-ante policy appraisal and provides an opportunity to consider in the assessment factors such as potential closures or downscaling of plants, impacts of other policies on the future emissions from the plants, IED transitional arrangements for LCPs, etc. From the resource point of view, projecting the baseline adds a step to the overall assessment, however deriving extrapolation factors for the projections can be a relatively simple step.

A decision on whether to project baseline emissions into the future should be made on the basis of availability of information regarding future changes in the sector which would have an implication for the assessment of impacts of the BATC, and confidence that such changes could occur. The factors to consider when making a judgement on whether to project emissions include confidence in likely plant closures, investments in the new abatement, change to existing processes, fuel and raw materials used etc. If there are no major changes predicted, and projecting to the future would solely be based on the changes in the overall economy (i.e. where activity data is extrapolated using forecasted changes in GDP), this step of the assessment may well be omitted. The likelihood of changes will be very sector specific and may vary plant by plant. If future emissions are projected, uncertainty around the results to the assumptions used should be quantified using sensitivity analysis.

Methodologies to assess emission reductions

Methods ER1/ER2 can underestimate the emission reductions achieved by BAT-AELs as they assume strict compliance with the limit values, i.e. they do not capture potential emission reductions beyond the limit value as a result of new abatement being installed. In reality, in an industrial process it will be difficult to reduce emission levels precisely to the BAT-AEL. Installation of new abatement techniques is likely to achieve emissions / concentrations lower than specified by BAT-AELs (i.e. it is likely to overshoot the limit value). In contrast method ER3 is likely to be more accurate in estimating real life emission reductions as it will capture potential overshoot.

Methods ER1/ER2 use BAT-AELs directly to develop future compliance scenarios. They are therefore relatively easy to apply and do not require particular technical or sector specific expertise. Method ER3 however requires determination of the action that will be undertaken by the operator in order to meet BAT-AELs. This is a more resource intensive process. Selection of the appropriate abatement technique requires: knowledge of what abatement is already in place, identification of additional feasible abatement options, and, where more than one option exists, the development of a decision rule to determine which abatement option is applied. ER3 feeds more directly into the cost assessment (using CO2) as specific techniques to be taken up will have been identified.

Methodologies to assess compliance costs

Selection of a suitable methodology to estimate costs can be influenced by the earlier steps in the assessment. In practice if the method ER3 is used to calculate emission reductions, the most resource intensive aspect of methodology CO2 i.e. selection of abatement technique, is already completed. Costing the abatement technique using capital (CAPEX) and operational (OPEX) expenditure is then relatively straightforward and can be supported by cost information from the literature or requested from equipment manufacturers. If instead methods ER1 and ER2 are used to calculate emission reductions, choosing the CO2 methodology would mean additional effort is required to identify abatement techniques.

Method CO1 which uses costs expressed per tonne of pollutant abated from literature (not derived from individual cost components in a specific assessment) can provide an indication of the likely costs of abatement. As such, it is more suitable for assessments at sector or national level, rather than facility level. It is attractive from the resource perspective as it involves simple calculation and minimum data collection efforts. However, it is likely to be less accepted by stakeholders as it is usually not tied to the specific techniques implied in BATC and/or does not take into account existing uptake of techniques across a sector. On the contrary method CO2 is more complex and resource intensive but provides greater accuracy of results and is linked to actual action that may be put in place in order to reach compliance with BAT-AELs.

Methodologies to quantify benefits

The main focus of the review of benefits quantification was on the scope for potential improvements, in terms of accuracy, to the existing damage cost functions used in the EU to assess value of benefits of
air emission reductions. The impact pathway approach offers a more accurate and detailed assessment of impacts, but requires significant resource, not least dispersion modelling capability. As such, the use of damage cost functions was considered in greater detail to explore whether improvements in the detail of these average damage costs could be made without losing the benefits of being simple and undemanding to apply.

It is recognised that neither damage cost functions nor Impact Pathway Approach methodologies reviewed are complete, as they do not capture the real value of a high level of environmental protection which is the aim of the IED and BATC. Nevertheless, despite this limitation and being prone to uncertainty, it is concluded that analysis based on estimated damage per tonne of pollutant emission can provide useful input to the assessment of impacts of BATC.

EEA (2014) provides estimates of damage per tonne emission of various air pollutants. The pollutants covered are NH₃, NOx, PM₂.₅, PM₁₀, SO₂, NMVOCs (via formation of ozone and secondary organic aerosols), some organic pollutants (1,3-butadiene, benzene, dioxins and furans, diesel exhaust, formaldehyde and PAH) and a number of metals (arsenic, cadmium, chromium, lead, mercury and nickel). These were applied by the European Environment Agency (EEA) to quantify damage from installations reporting to E-PRTR. Initial estimates were calculated as an average across all emissions within a country. However, the damage from any installation within a country will vary according to both its location and effective stack height (actual stack height plus plume buoyancy, linked to temperature, exit velocity and flue gas volume). Use of all-sector average estimates will lead to underestimation of impacts for some pollutants and overestimation for others. For some, particularly those with long environmental residence times (mercury being probably the best example), the site of release seems likely to play only a small role in determining the magnitude of damage. Recognising these issues, the EEA study applied some scaling factors to better estimate impacts linked specifically to industrial plant, though these adjustments were approximate. These adjustments were made to account for typical differences in the location and height at which emissions from industrial sources were released, which affect dispersion and exposure of people and ecosystems. These adjustments used information from the Eurodelta II study (Thunis et al., 2008) and compared modelling results from a range of European-scale dispersion models. For damage costs of HCl and HF some Member States have used a European Commission study on the Economic Valuation of Environmental Externalities from Landfill Disposal and Incineration of Waste (EC, 2000).

A number of different damage costs exist, and specific damage cost functions have been developed for Europe and in individual Member States (e.g. UK: [20]; Denmark: Andersen & Brandt, undated). Given the coverage of pollutants differs between sources, this raises issues such as: what course of action should be taken where a damage cost does not exist in the set applied but is available from another source, or what course of action should be taken where more than one damage cost is available (e.g. in Denmark where either national or European damage costs can be applied).

All air pollution is known to cause environmental damage either close to the source or as (precursor of) secondary air pollution with long range effects. Nevertheless as long as local impacts are considered, the variations in the effective stack height have been identified as relevant parameter affecting the derivation of damage cost functions. As such variations in stack height and plant location relative to centres of population can make a substantial difference to the results of benefit assessments for air emission reductions. To make the analysis more robust it is therefore considered appropriate to develop mechanisms for adjusting damage per tonne estimates in order to better account for variation between facilities. Both the UK and French studies summarised in the report highlight the possible level of variability that is present. Rather than undertaking this refinement for each IED sector separately, it would be appropriate to generate adjustment factors for different (effective) stack heights: it was noted that for the power sector there will be substantial variation between facilities, depending on what fuel they are using.

Three possible approaches for adjusting the existing damage cost functions were identified and considered with increasing complexity and resources alongside improvements in accuracy as you go down the list:

1. Use of existing adjustment factors, as applied in EEA (2014).
2. Use of a simple model to provide indicative adjustment factors for a range of stack heights and for defined regions within each country.
3. Use of sophisticated models to generate new pollutant transfer matrices that account for stack height and regions within each country.

A full analysis using the EMEP model will clearly be very time consuming, though simplifications could be made. Alternatively, the use of simpler models may be appropriate, given that the adjustment factors would be applied to damage per tonne estimates that are already rooted in the EMEP transfer matrices.

Assessment of benefits of emission reductions to water was not assessed further given the significant gaps in data and methodologies identified as part of the review of available methodologies. As such, it is proposed that quantitative assessment of water impacts is not included in a preferred methodology. Given limitations of the underlying evidence base and complexities in the approach, it is recommended that any impacts of emissions to water are assessed qualitatively.

**Recommendations**

The study has identified a range of methodologies and data sources which can support the assessment of BATC impacts at Member State or EU level. The selection of a suitable methodology to calculate emission reductions and costs is governed by the required or acceptable level of accuracy versus the level of effort required and available to undertake the assessment. Figure A presents an indicative summary of the assessment of identified methodologies against the accuracy and efforts required.

**Figure A Indicative accuracy and effort associated with assessment methodologies**

Some stakeholders consulted in the study expressed a preference for more accurate results with concerns raised regarding the use of less resource intensive and less accurate methods to inform policy decisions.

Testing methodologies for specific installations in two selected sectors in selected Member States (MS) has provided some insights into data sources and data availability. This testing with case studies have generated, based on the data gathered for specific installations, recommendations on methodologies suitable for those sectors. However, it must be noted that data availability for installations in those tested sectors may differ across other MS, and so this lowers the confidence in the conclusions.

Since the testing has been with only specific sectors, in order to generate a recommendation on suitable methodologies for assessing the costs and impacts of BAT conclusions for other sectors, we have relied
upon our own experience and knowledge of other sectors. In addition, other views, including from experts attending the workshop, were taken into account for formulating the recommendations below.

As the study did not focus on methodologies to assess potential cross media effects, no recommendations are made on how the cross media effects of the full implementation of BAT conclusions at sector level should be accounted for. However, this does not mean that the recommended methodology precludes the ability to assess cross media effects.

Instead the recommendations are formulated to inform sector level assessments of impacts on emission reductions and costs associated with compliance with BAT-AELs for air and water.

Based on the conclusions reached for the two sector case studies, which are presented in the case study annexes, our overall recommendations on methodologies to assess emission reductions and compliance costs of BAT-AELs at the sector level are as follows:

1. Accounting for the similarities and diversities among IED sectors, each sector will need to have a bespoke approach to the assessment of impacts, selecting the most appropriate approach from the options identified in this study. The choice of approach will be influenced by the metric(s) that BAT-AELs are expressed in, how the sector is split into subsectors or plant types, the number and spread of installations across MS, data availability, any overlap(s) with other BREFs and BATC, as well as time and resource implications of different approaches. Whilst a general framework can be prescribed to guide the assessment of impacts for one sector, there will be aspects associated with most sectors that require the selection of methodology to account for elements specific to the sector. Operators, industry associations and other sector experts are well placed to inform selection of the methodology for their respective sectors. The initial set up of the analysis will need to be adapted to the sector under consideration and format and disaggregation (in terms of the emissions sources they apply to) of the BATC. Once set up for a particular sector then there are likely to be a series of approaches for some impacts that may be common between sectors.

2. It is recommended that the first part of any assessment should be a scoping phase. The scoping phase should determine which aspects and impacts are important to take into account and which are feasible to take into account – a prioritisation exercise using a series of criteria such as identifying which of the BAT are likely to have the largest impacts. Industry stakeholders consulted in the course of this study stressed the importance of involving sector experts in that phase. This feasibility should consider for example data availability and where there are known data gaps or limitations that will otherwise dictate the choice of methodology. For example, it may need to be determined for LVOC installations what proportion of installations share common waste water treatment facilities with an adjacent refinery, and for these combined sites if this means that data on pollutant concentrations in water would only be available in aggregated form. The scoping phase should consider time and resource implications to undertake a worthwhile assessment. It should closely involve the stakeholders relevant to the sector to agree on BATC prioritisation, confirm data availability and data quality, as well as consider the potential to improve / gather other data from existing sources. Overall, the scoping phase balances which impacts to assess and what specifics of the sector to take into account against the data availability and resource implication constraints, and then selects which methodology is most appropriate. Results of a streamlined assessment as described in recommendation 4, could provide a basis for narrowing the scope of a full assessment to certain pollutants. While it will not allow for a comprehensive assessment of the sector it would allow an in-depth analysis of benefits and costs of those BAT-AELs considered the most critical for the industry.

3. Notwithstanding the above conclusion that each sector will need to have a bespoke assessment and includes its own scoping exercise, from the case studies completed, our own experience and feedback gathered from stakeholders, the framework for assessment of the costs and benefits of BATC across all sectors should include the following steps as best practice:

- **Estimate baseline emissions.** It is recommended this is based on reported emissions or concentrations where appropriate for the specific sector (method: BE3), in order to have data that are both accurate and which represent the real situation of installation performance with
sufficient granularity so that they can be compared to the BAT-AELs. Some consideration may need to be made for data sources that have reporting thresholds, especially if the data for certain plants are extrapolated to represent the wider sector. Data supporting the development of the baseline scenario should cover information on the existing facilities, processes and abatement techniques used in the sector.

- **Estimate future emissions**: it is recommended to make an assessment for the sector in question of whether relevant changes are expected for the sector over time, and only if this is the case to adjust the baseline emissions and so estimate future emissions. There is no specific recommendation of whether to adopt method FE1 or FE2 in this case, although preference may be given to projections that specifically consider changes in emissions. GAINS or PRIMES could be relevant here; however, stakeholders consulted in this study expressed mixed views on the appropriateness of using estimates from these models for their specific sectors.

- **Estimate emission reductions that would occur if BAT-AELs were applied**: it is recommended that if the assessment is carried out in parallel with the cost estimation, emission reductions calculations take into account the impacts of specific techniques (method: ER3). This method has the advantage of being a more specific depiction of changes that would occur at installations in the sector than a method that assumes that emissions reduce just to the level of BAT-AEL, which enables also a cost assessment. One stakeholder expressed the view that the greater accuracy of method ER3 is only relevant in the short-term (initial years following installation of the technique) and that if assessed over time, methods ER1, ER2 and ER3 would yield similar results due to degradation of equipment over time. However proper maintenance of abatement equipment should prevent or minimise the deterioration of its efficiency over time. Assumptions are ideally made at plant/process level, but could also be at a more aggregate level such as at Member State level. If no cost assessment is required, simpler methods (ER1 or ER2) are recommended alternatives.

- **Estimate the costs of meeting BAT-AELs**: it is recommended that this assessment is carried out in parallel with the emission reduction estimation by accounting for the costs of specific techniques needed to comply with BAT-AELs (method: CO2). This method enables a transparent assessment of costs, and is particularly suitable to those sectors with more straightforward or standardised plant designs for which it can be easier to characterise the available abatement techniques. However, there can remain obstacles to accurately estimating the costs of techniques to meet BAT-AELs. For example, to estimate the sizing or dimensioning of the technique(s) technical data which are not currently reported such as waste gas flow rates may be needed. If the data collected during the BREF review for the sector is incomplete or cannot be accessed, it would need to be newly gathered directly from the operators and/or competent authorities. Also, in those sectors where industrial plant designs can be very different (such as POL or LVOC) and where there is a business commercialising those designs (process licenses, catalyst, etc.) there is a risk in assessing emission reductions to meet BATC to focus only on secondary techniques and not on primary plant design or techniques which could have larger emission impacts. Wider cost impacts can also be considered in addition to those associated with air pollutant reduction techniques such as meeting monitoring requirements, or the quantification of impacts from changes in GHG emissions that can be quantified alongside changes in air pollutant emissions.

For some sectors it is much more challenging to simply model abatement options and impacts for each emission source as they depend on the process as a whole, taking into account raw materials used and so on. For the intensive livestock sector as an example, control options for housing and manure storage cannot be modelled independently as the nutrient content is linked to a number of factors through the process such as feedstock, manure storage. For these sectors CO2 could still be applied, with the caveat that higher uncertainties in the modelling would be expected, although it may be more effective to assess multiple BAT together as part of an integrated evaluation so that interactions between different stages are taken into account e.g. for intensive livestock assess the costs and benefits of BAT across the whole lifecycle from feed stock to manure storage and spreading.
• **Estimate benefits associated with the emission reductions if a case for action vis-à-vis as a comparison with costs is required**: whilst this study has not carried out a full comparison of benefits methodologies, from the recommended approach to estimating emission impacts, it is most straightforward to estimate benefits through the use of damage costs per tonne of pollutant abated (ABE2) for emissions to air.

However, given that damage cost functions do not monetise all impacts of pollution, the monetary cost benefit analysis may remain biased which has to be considered in any decision making. Several stakeholders consulted in the study expressed their concerns about that issue, noting that the aim of the BATC is to ensure a high level of environmental protection, and the human health impact primarily monetised in damage cost functions is only a fraction of the overall benefits. Therefore, when interpreting the cost benefit ratios, the following should be considered:

  o If the costs exceed the benefits, the limitation of benefits not being fully monetised increases uncertainty of any conclusions to be made, i.e. would the ratio of costs and benefits be the same if all benefits were monetised to the same extent as costs?
  o If the value of benefits exceeds the costs, there is a higher certainty that an intervention considered brings overall benefits.

Furthermore, to date, the transboundary impact of BAT have not been widely accounted for across Member States in national derived damage cost functions and BAT assessments. That considers both the impact of resulting emission reductions in a country on the neighbouring Member States, and the impact on a country from emission reductions in other Member States.

Whilst a number of methodologies have been identified for monetising the benefits associated with good water quality status, no particular methodology is recommended. No method feasible in sector level assessments has been identified to quantitatively assess the impact on water quality due to emission reductions from industrial installations. Valuation of impacts of emission reductions to water requires understanding of the quality status of affected water body and its use (e.g. for recreational purposes). It is therefore more feasible to undertake such valuation in facility-level assessments, where characteristics of the local water bodies are known.

• **Test sensitivity of the results against key assumptions**: irrespective of the combination of methodologies used, sensitivity of the results against the key assumptions made should be tested. This could consider, among others:

  o Baseline assumptions, such as variation in the level of emissions across the plants and abatement equipment already fitted
  o Assessing the difference in results between different levels of BAT-AELs to account for variation in the way BAT-AELs may be translated into permits
  o Investigating lower and higher cost estimates if the data gathered from different sources results in a wide range

Developing a range of sensitivity scenarios at the sector level to illustrate the likely scale of impacts under different assumptions and circumstances could be an efficient alternative to a more time consuming, full plant-by-plant assessment.

4. The best practices identified in recommendation 3 may need to be simplified to account for the available resources or time to undertake an assessment. In such cases, a simpler high level assessment, which could also form part of the scoping exercise (recommendation 2), could be carried out; recognising the need for an acceptable level of accuracy. It should be noted that this may differ depending on the sector and Member State, however some stakeholders expressed their concerns whether a more top-down approach would provide sufficiently reliable results. A high level methodology would be suitable for a streamlined assessments of impacts, for example when carrying out rapid high-level assessment across all BAT before prioritising (for the focussed approach) particular BAT considered to be at risk of costs exceeding benefits. This comprises the use of any of the baseline emissions methodologies, subject to best data availability, followed by the assessment of emission reductions using ER1 and ER2 methodologies. The high level
assessment ought to also include an indication of costs. However, a sufficient level of accuracy may not be possible using a streamlined method CO1, as it does not provide flexibility to reflect differences across the facilities and whether retrofitting the equipment is feasible.

5. Technical and economic expertise is needed for all methodologies, such as assessing the technical applicability of emission reduction techniques, and for assessing the marginal additional costs compared to a status quo. Any assumptions and calculations made should be well-documented and transparent to allow review by stakeholders. This should include economic parameters used in the assessment such as discount rate, method of annualisation of capital costs and key assumptions behind the damage cost functions (if used) such as the value of life lost.

6. Accounting for the reality that there may be difficulties in obtaining large amounts of data required for a particular sector to carry out the recommended methodology, some alternatives/variants have been identified. These include gathering smaller quantities of data for selected installations, and extrapolating the impacts of the BAT based on the assessment of impacts for these selected installations. The viability of this approach will vary by sector, according to the availability of data for the specific installations, diversity or similarity among installations within the sector (characterised principally in terms of emissions performance), and the ease with which the rest of the sector can be extrapolated. According to stakeholder feedback, for some sectors it may be more appropriate to attempt to collect data from all installations, to ensure the data collected is sufficiently representative of the characteristics of the sector. Some difficulties in data collection can be experienced given commercial sensitivity of information to be collected. In the past this has been successfully overcome by having an independent third party collating and analysing the data which otherwise would be considered confidential.

7. Data required for the assessments of potential industrial emissions reductions and compliance costs of BAT at sector level remain a key challenge. The consideration of developing future data sources to support the methodologies at sector level could take into account:

- That the Member States' reporting on implementation of the IED by September 2017 will include for all permitted installations: a web link to the active permit, information on application of the Article 15(4) derogation and on the preparation of the baseline report. In addition, Member States will be reporting data on the permit conditions, limit values and monitoring for the iron and steel and manufacture of glass sector.
- Whether the development of a pan-European system to systematise all permit information across Member States is feasible. Such a system could include information on ELVs applied, derogations granted, as well as process-level information such as information on the abatement equipment already installed on sites.
- The data sought via questionnaires as part of the existing ‘Sevilla’ process.

The level of effort required to develop future data sources may be minimised if the key data from permits is extracted during already-planned permit reviews (rather than retrospectively for all industrial sectors). The information for a given sector would then be available for the next time the BREF is reviewed. Making permit data more accessible could also facilitate the identification and definition of Key Environmental Issues (KEI) at the start of the BREF review process.
Executive Summary Annex: tables.

Note: The references for study citations (in square brackets: [ ]) are in a separate Excel file.

Table A Categorisation of methods for establishing baseline emissions

<table>
<thead>
<tr>
<th>ID</th>
<th>Method name</th>
<th>Description</th>
<th>Key inputs</th>
<th>Examples of studies using this approach</th>
</tr>
</thead>
</table>
| BE1 | Emission factor (EF)                            | Emission factor (kg/unit of activity) is multiplied by corresponding activity value.                                                                                                                                 | Activity levels  
Emission factors                                                                                       | [10], [11], [14]                              |
| BE2 | Concentration (emission limit value)            | Output concentration (in the flue gas or wastewater flow) is multiplied by corresponding activity value (and other inputs required to match concentration and activity values)  
Operating hours  
Current concentration in output  
Other parameters (gas flows, wastewater flows)  
Reference conditions (e.g. reference O₂ %)                                                                 |-----------------------------------------------------------------------------------------------------| [3], [6], [11]                                |
| BE3 | Reported emissions                              | Reported or monitored emission data are applied with no or minimum modifications.                                                                                                                                 | Reported emissions                                                                                   | [4], [5], [12], [13], [19], [21], [23], [28], [32]  
(plus examples gap-filling reported emissions with modelling: [C1], [4], [6], [25], [42], [43]) |                                                        |
| BE5 | Modelling using unabated emissions factors and abatement techniques | Reported or monitored emission data are used where available. Gaps in data are filled by either modelling approach BE1 or BE2. In addition, emission factors assuming no abatement in place are combined with activity data and the emission reduction efficiency of techniques assumed to be in place under the baseline scenario. | Unabated emission factors  
Activity levels  
Uptake of abatement techniques  
Emission reduction efficiency of applied abatement techniques                                              | [8]                                    |
Analysis and development of methodologies for estimating potential industrial emissions reductions and compliance costs of BAT conclusions adopted under the Industrial Emissions Directive

Table B Categorisation of methods for establishing future emissions (before implementation of BATC)

<table>
<thead>
<tr>
<th>ID</th>
<th>Method name</th>
<th>Description</th>
<th>Key inputs</th>
<th>Examples of studies using this approach</th>
</tr>
</thead>
<tbody>
<tr>
<td>FE1</td>
<td>Modelling with selected parameters</td>
<td>A selection of parameters is applied to the baseline emissions to reflect future changes.</td>
<td>Defined parameters e.g. scaling factors</td>
<td>[6], [12], [14], [42], [43], [53], [192], [C1]</td>
</tr>
<tr>
<td>FE2</td>
<td>Use of external emission projections</td>
<td>Emission projections developed externally from the assessment are applied</td>
<td>Projected emissions</td>
<td>[4]</td>
</tr>
</tbody>
</table>

Table C Categorisation of methods for calculation of emission reductions

<table>
<thead>
<tr>
<th>ID</th>
<th>Method name</th>
<th>Description</th>
<th>Key inputs</th>
<th>Examples of studies using this approach</th>
</tr>
</thead>
<tbody>
<tr>
<td>ER1*</td>
<td>BATC Emission factor (EF)</td>
<td>BATC Emission factor (kg/unit of activity) is multiplied by corresponding activity value in the year of BATC coming into force</td>
<td>Activity levels</td>
<td>[7], [10], [11], [14], [25]</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>BATC Emission factors</td>
<td></td>
</tr>
<tr>
<td>ER2*</td>
<td>BATC Concentration (BAT-AEL)</td>
<td>BAT-AELs (waste gas concentration) is multiplied by corresponding activity value in the year of BATC coming into force (and other inputs required to match concentration and activity values)</td>
<td>Operating hours</td>
<td>[4], [6], [11], [12], [21], [43] – Large combustion plant sector only, [C1]</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>BATC concentration in output</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Other parameters (gas flows, wastewater flows)</td>
<td></td>
</tr>
<tr>
<td>ER3**</td>
<td>Abatement techniques</td>
<td>Abatement efficiency (%) of techniques is applied to “future reference” or “baseline” scenario.</td>
<td>Reductions required to meet BAT-AELs</td>
<td>[3], [7], [8], [10], [19], [21], [23], [43] – other sectors, [53], [C1]</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Abatement efficiency of technique(s) (%)</td>
<td></td>
</tr>
</tbody>
</table>

*Emission reductions for method ER1 and ER2 are calculated by subtracting the policy from the reference or baseline scenario (ER1-FE1) or (ER1-BE1), or (ER2-FE1) or (ER2-BE2).

**Depending on the information available regarding the abatement technique, ER3 can be applied to all baseline (BE1, BE2, BE3, BE5) and future emissions excluding BAT (FE1-2) approaches. That said, this approach sits most consistently with BE5, where the abatement measures assumed in the baseline can be compared to those under the with-policy scenario to ensure consistency.
### Table D Categorisation of methods for cost calculation of required emission reductions

<table>
<thead>
<tr>
<th>ID</th>
<th>Method name</th>
<th>Description</th>
<th>Key inputs</th>
<th>Examples of studies using this approach</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO1</td>
<td>Using marginal abatement cost</td>
<td>Marginal abatement costs (expressed in the unit of cost per tonne of pollutant abated) are applied to the emission reductions associated with BAT-AELs. For selected primary or secondary measures, the costs of additional investment required to meet BAT-AELs is based on:  - Capital costs  - Operational costs Capital costs may be annualised using lifetime of a measure and discount rate to provide estimation of the total annual cost of measure. Otherwise costs can be presented as a total over the lifetime of the measure.</td>
<td>Marginal abatement cost (unit of cost per unit of pollutant abated) Emissions reductions of abatement technology</td>
<td>Studies that used marginal abatement costs: [7], [19], [23], [30], [53] Studies that derive marginal abatement costs: [8], [11], [18], [28], [45]</td>
</tr>
<tr>
<td>CO2</td>
<td>Costing of additional investment (using CAPEX and OPEX)</td>
<td>Costs are estimated based on the impact of the measures on the production or quality of the final product.</td>
<td>Capital cost (CAPEX / capital investment costs) Operational costs Lifetime of the measure Discount rate</td>
<td>[C1], [1], [2], [3], [7], [8], [9], [10], [11], [14], [19], [22], [24], [26], [28], [29], [32], [40], [41], [42], [43], [44], [46], [51], [52], [53], [54]</td>
</tr>
<tr>
<td>CO3</td>
<td>Loss in value added</td>
<td>Costs are estimated based on the impact of the measures on the production or quality of the final product.</td>
<td>Change in the quantity or type of product Change in quality of the product Price or change in price of product Added value per unit of product (i.e. profit per unit of product)</td>
<td>[C1], [24]</td>
</tr>
</tbody>
</table>
Table E Methods for assessment of benefits of emission reductions to air

<table>
<thead>
<tr>
<th>ID</th>
<th>Method name</th>
<th>Description</th>
<th>Key inputs</th>
<th>Examples of studies using this approach</th>
</tr>
</thead>
</table>
| ABE1 | Impact pathway approach (without monetisation)   | Primary effects are assessed quantitatively and expressed in terms of non-monetary impacts, for example number of health outcomes such as deaths or hospital admissions | Change in emissions  
    |                                                 |                                                                               | Change in concentrations (and population weighted concentrations)             | [22], [28], [36], [55]            |
|      |                                                 |                                                                               | Population  
    |                                                 |                                                                               | Baseline incidence rate  
    |                                                 |                                                                               | Exposure response function |                                     |
| ABE2 | Damage costs (EU, UK, DK)                        | Emissions are combined with damage costs (expressed in terms of monetary unit / tonne) to calculate total costs avoided | Change in emissions  
    |                                                 |                                                                               | Damage costs                  | [5], [7], [15], [20], [37], [38], [39], [41], [42], [51], [C1] |
| ABE3 | Abatement Costs (UK)                             | Emissions are combined with abatement costs (expressed in terms of monetary unit / tonne) to calculate total opportunity cost | Change in emissions  
    |                                                 |                                                                               | Abatement costs               | [20]                                 |
| ABE4 | Impact pathway approach (with monetisation) (EU, US, UK) | Primary effects are assessed quantitatively and expressed in terms of monetary terms | Change in emissions  
    |                                                 |                                                                               | Change in concentrations (and population weighted concentrations)             | [20], [21], [22], [24], [28], [30], [31], [33], [34], [37], [38], [39], [43], [52] |
    |                                                 |                                                                               | Population  
    |                                                 |                                                                               | Baseline incidence rate  
    |                                                 |                                                                               | Exposure response function  
    |                                                 |                                                                               | Unit impact values |                                     |
### Table F Methods to assess benefits of water quality improvements

<table>
<thead>
<tr>
<th>ID</th>
<th>Method name</th>
<th>Description</th>
<th>Key inputs</th>
<th>Reference studies for the methods</th>
</tr>
</thead>
<tbody>
<tr>
<td>WB1</td>
<td>Impact pathway approach</td>
<td>The method requires estimation of pollutant dispersion in the water bodies and identifying human and environmental exposure response functions to quantify the impact. This can then be monetised using methods B2-B6.</td>
<td>Dispersion in water bodies&lt;br&gt;Exposure-response function (human and environmental)</td>
<td>[34]&lt;br&gt;[172]</td>
</tr>
<tr>
<td>WB2</td>
<td>Market methods</td>
<td>Use changes in prices of goods and services traded in the market to value change in water quality</td>
<td>Market data on direct use values&lt;br&gt;Change in quality or quantity of the traded product</td>
<td>[192]</td>
</tr>
<tr>
<td>WB3</td>
<td>Cost-based valuation methods</td>
<td>Use the cost of maintaining environmental benefit as the valuation method</td>
<td>The costs of measures that would need to be taken to prevent environmental damages up to a certain point</td>
<td>[192]</td>
</tr>
<tr>
<td>WB4</td>
<td>Revealed preference methods</td>
<td>Uses specific modelling approaches. Based on the assumption that the environmental costs and benefits of a particular good can be revealed by comparing the values of (and consumer behaviour towards) different goods</td>
<td>Recreational demand models, hedonic pricing models and averting behaviour models</td>
<td>[192]</td>
</tr>
<tr>
<td>WB5</td>
<td>Stated preference methods</td>
<td>Uses willingness to pay studies to value the benefit of environmental improvements</td>
<td>Data drawn from surveys presenting a hypothetical scenario to the respondents in order to determine the Willingness to Pay</td>
<td>[192]</td>
</tr>
<tr>
<td>WB6</td>
<td>Value transfer</td>
<td>Unlike primary valuation studies (WB2-WB6) these use values from existing studies on the value of good water quality.</td>
<td>Information on environmental costs or benefits from existing studies</td>
<td>[192]</td>
</tr>
<tr>
<td>WB7</td>
<td>Clean-up / abatement costs</td>
<td>The approach assumes that clean-up costs are closely associated with the external costs of pollution.</td>
<td>Requires a measure of externalities of water pollution</td>
<td>[172]</td>
</tr>
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</table>
Abbreviations and Glossary

ABE*  Air quality benefits [methodology typology]
BAT  Best Available Technique
BATC  Best Available Technique Conclusions
BAT-AEL  Best Available Technique Associated Emission Level
BE*  Baseline emissions [methodology typology]
BOF  Basic oxygen furnace [steel making]
CAPEX  Capital expenditure
CO*  Cost [methodology typology]
CWW  Common Wastewater
ELV  Emission Limit Value
EF  Emission factor
ER*  Emission reduction [methodology typology]
FDM  Food Drink and Milk
FE*  Future emissions [methodology typology]
FMP  Ferrous Metal Processing
IED  Industrial Emission Directive
IPPC  Integrated Pollution Prevention and Control (IPPC) Directive
IRPP  Intensive rearing of poultry and pigs
LCP  Large combustion plants
LVOC  Large volume organic chemicals
MCA  Multi criteria analysis
MS  Member State(s)
OPEX  Operating expenditure
POL  Polymer production
STS  Surface Treatment using organic Solvents,
TXT  Textiles
WBE*  Water quality benefits [methodology typology]
WGC  Common Waste Gas Treatment in the Chemical Sector
WPC  Wood and wood-products Preservation with Chemicals
WT  Waste Treatment
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1 Introduction

1.1 This report

This is the final report for the study “Analysis and development of methodologies for estimating potential industrial emissions reductions and compliance costs of BAT conclusions adopted under the Industrial Emissions Directive”, specific contract number 070201/ENV/2015/715769/C4, which is service request 19 under framework contract ENV.C.3/FRA/2011/0030. The aims and objectives of the study are set out in section 1.3, and the scope of the study in section 1.4. The policy context for the study is presented in section 1.2. The rest of the structure of this report is explained in section 1.5.

1.2 Policy context

1.2.1 Industrial Emissions Directive and BAT Conclusions

Emissions from industrial installations are subject to EU wide legislation, in particular the Directive 2010/75/EU on Industrial Emissions (IED). The IED consolidated and streamlined several older directives. It sets the overall framework for the permitting and control of emissions to all environmental media from the most polluting industrial activities ranging from power plants to food and drink production (most industry sectors not covered by the IED are left to each EU Member State to decide how to control). Under the IED framework, around 50,000 industrial installations operate subject to environmental permits.

The IED aims to achieve a high level of protection of human health and the environment by avoiding or minimising pollution from industrial installations primarily through application of Best Available Techniques (BAT) which are legally defined through development and adoption of ‘BAT Conclusions’ (BATC) for each sector. BAT are defined through the development of a BAT Reference (BREF) document for a particular sector. BREFs are developed and reviewed through the information exchange process (the ‘Sevilla process’), on the basis of sound techno-economic information, and aim to set out BAT and emerging techniques in a transparent manner.

BAT Associated Emission Levels (BAT-AELs), derived on the basis of information collected in BREFs, form part of BATC. BATC are adopted through the Article 75 committee procedure and subsequently used by regulators as the legal reference point when setting the conditions of a installation’s permit, and to understand what may be technically possible and economically suitable for an installation, with the aim of improving their environmental performance.

It’s foreseen that BREFs are reviewed on a rolling 8-year cycle. Following the publication of BATC (relating to the main activity of an installation concerned) in the Official Journal, Members States have a maximum of 4 years to update installations’ environmental permits in line with the requirements set out in the document and to ensure that the installations comply with those permit conditions. An overview of the IED implementation process is presented in Figure 1.

---

Figure 1 Overview of the IED implementation

1.2.2 Derogation process under the IED

Article 15(4) of the IED affords limited possibility for permit ELVs to be set at a less strict level than the BAT-AELs listed in the BATC (the IED represents the minimum requirements in this case). Any such derogations need to be justified on the basis of assessment of disproportionality of the costs of meeting the BAT-AELs with benefits specifically which are due to the geographical location, local environmental conditions or technical characteristics of the installation. Furthermore, national authorities can only allow exceptions for emerging technologies for a maximum period of nine months. Given BAT-AELs are typically expressed as a range, it is not clear against which AEL derogations under Article 15(4) of the IED should be assessed (i.e. the higher / less strict limit, the lower / stricter limit, or something in between). The current most common approach at a Member State (MS) level is that the higher / less strict end of the range should be considered.

1.2.3 Impacts of BATC

Given this much stronger formalised link between environmental permits and BATC in the IED, compared to its predecessor the IPPC Directive, one would expect a significant reduction in emissions. However so far there has been little quantification of how BATC may reduce industrial emissions to air and water, not least because the first set of BATC were adopted in 2012 thus providing limited implementation time so far. The Economics and Cross-Media Effects BREF (ECM BREF) published in 2006 provided a methodology to quantify the impacts of BATC at installation level. It was intended to assist in the determination of best available techniques and is not easily transferable for assessing the overall impacts of the BATC. To support further development of industrial emissions policy and for justification of the BATC themselves there is a need for a better understanding of the role they play in reducing emissions and at what cost at the sector level. To date, there is no adopted methodology across the EU for quantifying the impacts of each set of BATC on the relevant industry.

In order to address this gap, the European Commission commissioned a study, published in 2015, to assess the potential emission reductions delivered by BAT Conclusions adopted under the IED (AMEC, 2015). The main aim of the AMEC (2015) study was to develop a methodology to estimate the potential emission reductions delivered by BAT Conclusions adopted under the IED. The methodology proposed was implemented in an Excel-based model and was tested with seven industrial sectors, using readily available data from the BREFs, E-PRTR and the GAINS model. The availability and quality of existing data for the IED activities was identified in the project as the main limitation. Key gaps were identified.
in data on industrial activity per sector and process, emissions split by sub-processes, uptake of BAT for different industrial activities and sub-processes within an activity and the extent of deviation from BAT and comprehensive data on baseline emissions to air and water from industrial installations.

1.2.4 Current status of BREF revisions

To date (November 2016), ten of the BATC (Commission implementing Decisions) have been published in the Official Journal. These sectors are iron and steel production (28/02/2012), manufacture of glass (28/02/2012), tanning of hides and skins (11/02/2013), production of cement lime and magnesium oxide (26/03/2013), production of chlor-alkali (9/12/2013), production of pulp, paper and board (26/09/2014), refining of mineral oil & gas (09/10/2014), wood based panels production (24/11/2015), waste water in the chemical sector (09/06/2016) and non-ferrous metals (30/06/16). The four year periods for Member States to ensure permit conditions have been updated to reflect the BATC and complied with for the iron & steel and manufacture of glass sectors expired in spring 2016.

At the time of writing this report, nine BREFs were at various stages of development:

- Intensive rearing of poultry and pigs (IRPP)
- Large combustion plants (LCP)
- Large volume organic chemicals (LVOC)
- Surface Treatment using organic Solvents (STS), including Wood and wood-products Preservation with Chemicals (WPC)
- Waste Treatment (WT)
- Food Drink and Milk (FDM)
- Waste Incineration (WI)
- Ferrous metals processing (FMP)

In addition, work on the new Common Waste Gas Treatment in the Chemical Sector (WGC) is starting.

1.3 Aims and objectives

The key aims of the study were to:

- Identify, compare and review the possible methodologies to assess the impacts of attainment of BAT-AELs. The methodologies need to estimate potential reductions in emissions and associated costs of techniques, drawing on the best available data.
- Assess the robustness of methodologies – i.e. whether the estimates they produce are sufficiently accurate, and the feasibility of implementing them.

The methodology (or methodologies) are required to have the capability and flexibility to assess BAT-AELs impacts across all IED sectors.

1.4 Scope of the study

The review focused on methodologies to undertake EU, national and sector level assessments of impacts on emission reductions and direct costs associated with meeting BAT-AELs. Furthermore, available methodologies for the monetisation of the impacts of emission reductions (i.e. benefits) were reviewed. The study investigated methodologies for ex-ante analysis of impacts (i.e. before adoption of the BATC).

The following were not covered within the scope of the study:

- Methodologies for ex-post analysis of impacts (i.e. actual impact following review of permit conditions in light of revised BATC).
- Methodologies for assessing cross-media impacts.
• Specific methodologies for cost benefit assessments for individual installations in the context of IED Article 15(4) derogations were not investigated².

• Impacts associated with implementation of other types of BATC such as other associated performance levels, monitoring requirements or qualitative objectives.

• Wider economic, social and environmental impacts (for example, on competitiveness, small and medium sized enterprises, employment, or ecosystem services).

While aspects of the recommendations of this work may overlap with the Sevilla process, the study was not intended to provide any recommendations on potential changes to the existing BREF review procedures.

1.5 Structure of this report

The results of the study are presented in the following sections:

• Section 2 describes the approach taken for the study.

• Section 3 presents an overview of the methodologies identified to assess impacts of BATC and section 4 summarises the data sources to support the assessments.

• Section 5 summarises key findings from the feasibility assessment of the methodologies, based on testing of the methods with two example sectors (iron and steel and polymer production). It also discusses possible improvements to the damage cost functions for air pollutants.

• Section 6 presents recommendations on the methodologies and data sources to assist with the assessment of BATC.

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² While some methodologies are similar whether conducted at installation level or sector level, site-specific cost-benefit assessments, for example for the purpose of derogation applications, could be more detailed than sector level assessments due to increased availability of better quality data for the individual site.
2 Approach taken in this study

2.1 Overview

The schematic overview of the approach taken for this study is presented in Figure 2.

Figure 2 Overview of project tasks

Task A Identification

- Identify all methodologies
  - Task A.1 Identify methodologies
  - Task A.2 Identify data sources
  - Task A.3 Analyse methodology combinations
  - Task A.4 High level review of applicability

Task B Feasibility analysis

- Selected methodologies
  - Baseline
  - BAU
  - Emission reductions
  - Costs
  - Task B.1 Define criteria for assessment
  - Task B.2 Multi-criteria assessment
  - Task B.3 Analyse combinations of methods
  - Task B.4 Detailed application to two sectors

Task C Draft Recommendations

- Single preferred methodology

Task D Workshop

- Task D.1 Preparation for event
- Task D.2 Delivery of event
- Task D.3 Event follow up

Task E Final reporting

- Incorporating stakeholders’ feedback gathered at and after the workshop

Task A commenced with a targeted search of literature sources which were then reviewed for relevance. This was complemented by engagement with a wide range of relevant stakeholders, including relevant authorities in all EU-28 Member States, as well as European trade associations representing individual industrial sectors, and NGOs in order to gather studies and data sources which might not have been identified through literature search. The shortlisted studies were then reviewed using a common assessment template in order to understand the methodologies and data sources that were used. The methods identified were categorised into specific elements of the analysis (emission reductions, costs and benefits) and data sources for these inputs were identified based on the literature sources reviewed. Finally, a preliminary review of the methods was performed in the context of the iron and steel and production of polymers sectors (air and water BAT-AELs) in order to test the applicability of the methods.
for the assessment of the impacts of BAT-AELs. The applicability of each methodology was tested at a high-level through identification and consideration of required data inputs, sources and likely gaps.

In Task B the feasibility of the methodologies identified under Task A was tested in more detail. First a set of criteria were defined against which the methodologies would be tested. Then an application of the methodologies to the iron and steel and polymer production sectors was undertaken: this involved data collection and performing calculations as defined by the methodologies identified. The results of this exercise, together with further stakeholder engagement regarding the availability of data, was used to support a multi-criteria analysis of each methodology against the set of criteria previously defined. This analysis was used to inform conclusions on the overall feasibility of methods and recommendations regarding a preferred methodology and data sources (Task C).

Draft recommendations of the study were presented at the stakeholder workshop (Task D) held in Brussels on 15 September 2016. A background paper was provided to all attendees ahead of the workshop to facilitate feedback gathering on the day. In addition, stakeholders were given a period of 3 weeks following the workshop to submit any additional information.

All comments received were reviewed by the project team and used to update the report and produce a final set of conclusions and recommendations (Task E).

### 2.2 Identification of the methodologies and data sources

#### 2.2.1 Literature review

**Identification of literature sources**

A literature search was undertaken in order to identify studies which either assessed the impacts of BATC, or assessed at least one of the elements covered by the scope of this study, i.e. emission reductions, costs and/or benefits of achieving emission reductions. The search for scientific literature was undertaken in Science Direct\(^3\), complemented with Google Scholar\(^4\). In addition, ‘grey’ literature was identified through internet searches. The key words used for the literature search are presented in Table 1.

<table>
<thead>
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<th>Key words</th>
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<td>best available techn*; industrial emission*; cost; emission*; reduction*; water quality; air; impact*; method; model; life cycle assessment</td>
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The search for scientific literature was undertaken in Science Direct using the expert search field. In order to capture literature published in languages other than English, the searches in both Science Direct and Google were also undertaken in other European languages, specifically: Spanish, Italian, Portuguese, German, French and Polish. The key words were translated into these languages, taking into consideration that a single term can often be translated in more than one way into another language. The languages selected for the search were dictated by the language capabilities of the core project team. The findings of these searches have shown that relevant scientific literature was published predominantly in English in the scientific literature, and searches in other European languages did not yield a substantial number of additional references.

The internet search for grey literature was undertaken using Google Scholar. Different permutations and combinations of the key words were used. Given the large amount of results obtained via internet searches, the first one hundred results were reviewed by the project team each time. The internet search in other EU languages proved more successful compared to the search in scientific literature, resulting in multiple studies being logged to the literature register. A copy of the literature register containing the sources reviewed as part of this study is provided in Appendix A to this report.

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\(^3\) [http://www.sciencedirect.com/](http://www.sciencedirect.com/)

\(^4\) [https://scholar.google.co.uk/](https://scholar.google.co.uk/)
Review for relevance

All search results were reviewed for relevance to the study objectives. The relevance was assessed by reviewing the title, key words and abstract and/or executive summary.

It should be noted that there is a vast amount of literature that is available on monitoring, modelling, projecting and managing air and water emissions. However primary selection criterion used in this study to identify core literature was whether the source contained a relevant methodology (or methodologies) to assess the impacts of BATC (on emission reduction, costs and/or benefits).

Application of this criterion narrowed down the number of studies selected for more detailed review according to the assessment template to 56 from a total of 193.6

The following types of studies were excluded from the assessment:

- Studies which did not clearly describe the methods applied thus not providing a clear understanding of the key steps taken;
- Generic Impact Assessment Guidelines developed by national governments – these documents, while providing specific country assumptions, do not generally provide insights on the methodologies for assessment of emission reductions. They are generally more applicable to the assessment of costs and benefits, but focus on the generic principles such as the use of net present value, or specific parameters such as discount rate etc. While these guidelines may differ amongst the Member States and may therefore influence the results of the analysis undertaken in different countries, these were not considered a key focus for this study as they do not provide anything novel in terms of evaluating the impacts of the BATC.
- Studies which provided supporting evidence, but did not cover any method – these studies are included in the list of potential data sources but have not been evaluated according to the assessment template.
- Guidelines on compiling emission inventories – while potentially providing a useful data for some inputs in the methods identified (i.e. development of an emissions baseline), the methodologies in the EMEP/EEA air pollutant emission inventory guidebook [191] have not been assessed according to the assessment template. The guidebook is used by the Member States for the purpose of reporting under the NECD and CLRTAP. Its content is referenced in the section on data sources.
- Air quality or hydrological modelling methods and any associated guidelines.
- In the context of assessing wider environmental impacts of emissions, ecosystem impact valuation framework could also be relevant, however given this remains a relatively early stage of development these were not considered in the study.

Furthermore, in cases where several updates of a report were published across a number of years, only the latest study was selected for review. This allowed capturing the state of the art methods, and (to the extent possible) to exclude derivative studies from the review. This was particularly important in the case of sources covering the health and environmental impacts of emission reductions to air. Given significant research effort undertaken in this space over the last decade, especially in the context of the review of the Thematic Strategy on Air Pollution (TSAP), it was important to identify the key reference studies that reflected the latest thinking and evidence in that area.

Results of the review of literature sources and methods identified are presented in Section 3 of this report.
2.2.2 Consultation

Stakeholder involvement in the study was considered critical in order to make the process of the development of the methodology transparent as well as to ensure comprehensive coverage of methodologies and data sources used to date to undertake assessments of BATC.

In Task A, the key purpose of the consultation with stakeholders was to gather studies and data sources which might not have been identified through the literature search but which could provide useful insights. These studies might not have been identified because these were not available in public domain, were published in a language in which the searches were not conducted or did not contain the key words used for the search. Undertaking the consultation in task A also ensured that stakeholders became aware of the study, its scope, and of the workshop that took place in the later stages of the project.

The consultees list included relevant authorities in all EU-28 Member States, as well as European trade associations representing individual industrial sectors and NGOs. The list of the relevant contacts at the Member State authorities and trade associations was provided by the European Commission. This was complemented by additional contacts at research organisations and consultancies where relevant. The initial email to consultees requesting inputs to the study was sent on 9 December 2015, with a subsequent reminder on 18 December 2015. The next communication to stakeholders was issued on 15 January 2016 informing about the extension of the deadline to submit evidence until 31 January 2016 and of the focus of the sectoral review of methods (task A4) on the iron and steel and production of polymers sectors.

To inform task A, the stakeholders were asked to provide:

- Existing EU, national, regional and local level methodologies and models documented in study reports which quantify one or more of:
  - the reductions in emissions to air and water from industrial facilities
  - associated costs of measures required to achieve these emission reductions
  - benefits associated with emission reductions and measures.
- Existing EU, national, regional and local level data sources that could be used to support such methodologies on:
  - current and projected industrial activity levels (across all IED sectors)
  - current and projected emissions and emission levels to air and water from industrial activities
  - costs of implementation of techniques to abate emissions to water and air
  - quantification and monetisation of benefits.

Authorities from nine Member States and nine trade associations submitted evidence for the review. Several responses acknowledging the receipt of the request were received, yet provided no information. At this stage communication was limited to information exchange via email, with the exception of the Danish authorities with whom a conference call was arranged as the relevant studies could not be shared due to the confidential information they contained.

Evidence submitted was reviewed for relevance and the identified information sources were included in the list for the assessment. All outgoing and incoming communication from stakeholders was registered in a consultation log. A summary of the evidence submitted by respondents is presented in Appendix B.

In Task B, a sample of Member States were consulted in order to explore availability of, and to provide, data for the testing of the methodologies identified in task A with the iron and steel and polymer production sectors. Evidence collected through this additional consultation has been incorporated into the feasibility analysis (see section 5).

Additional information sources were also provided by stakeholders during and following the stakeholder workshop (task D).
2.3 Feasibility analysis of selected methodologies

2.3.1 Testing of methods with sectors

Task B aimed to test the feasibility and applicability of the methodologies identified in task A for estimating emission reductions and costs of implementing the BAT conclusions. The task had to confirm that methodologies will stand up to the scrutiny required in terms of accuracy, but also that they can feasibly be carried out.

In order to achieve this, the methodologies were applied to assess impacts of BATC at facility level, in the two example sectors selected for testing (polymer production and iron and steel) in a sample of Member States. Detail on the rationale underpinning the sector selection is provided below. This more detailed assessment for two sectors provides valuable context for undertaking feasibility assessment using the Multi-Criteria Analysis. For each of the two sectors, the feasibility of applying the methodologies, what data are available and/or needed and resources to do this have been assessed.

The outputs of testing the methods were:

- Completed multi-criteria analysis (MCA) tables, covering applicability and feasibility of methods;
- Qualitative descriptions of how well the methods worked and reflections on their application.

To test out the methods and provide concrete examples of applying them, additional data had to be gathered. Given that the study was aiming to provide examples of applying the methodologies, it was not proposed to gather comprehensive data for all the facilities within the example sector. Instead, it was decided that the project would focus on (1) gathering fully detailed data required by the methodologies for selected facilities in selected MS, and (2) discussing with MS authorities (and, where relevant, other appropriate organisations such as trade associations) whether the detailed data sought are available, or if aggregate MS level data are also available.

Introduction to the iron & steel production sector and rationale for its selection

In Europe, steel is mainly produced in two production routes, depending on the raw material:

- Using iron ore in Integrated Steel Plants (primary steel): The key steps in the production process are: coke production, sinter and/or pellets production, reduction of iron-ore in the blast furnace, lowering the carbon content in the basic oxygen furnace, continued casting and other processing depending on the type of final products. Steel produced in this way is commonly also called oxygen steel or Basic Oxygen Furnace (BOF) steel. In the EU, 86 blast furnaces were in operation in 2006 according to the I&S BREF.
- Using scrap as the basic raw material: This production process comprises scrap preheating, melting in electric arc furnace, and continuous casting and other processing. The process is less energy intensive and has a lower impact on the environment compared to BOF steel production. Steel produced in this manner is commonly called Electric Arc Furnace (EAF) steel. In 2006, the then EU27 had 231 EAF installations.

The I&S BREF confirms that the key air emission sources in integrated steel plants are sinter plants (dust, heavy metals, SO₂, HCl, HF, PAH and persistent organic pollutants such as PCB and PCDD/F)), coke oven plants (dust, SO₂, volatile organic compounds), blast furnaces (dust, SO₂, H₂S) and basic oxygen furnaces (dust). Key environmental concerns for water and waste are blast furnaces (waste water, sludge) and basic oxygen furnaces (waste). For EAF installations, the key environmental issues are energy consumption, wastes and by-products, and air emissions (iron oxide dust, heavy metals, PCB and PCDD/F).

For evaluation of the applicability of methodologies for quantifying emissions reductions and costs, the focus of this review was on basic-oxygen furnace (BOF) steel production given the greater complexity and higher environmental impact of this production process compared to other processes in the iron and steel sector. BOF steel production in Europe is characterised by a limited number of plants and hence is a good candidate for application of assessment methodologies on a plant by plant basis. Although there are differences in the product range (flat steel, long steel, quality differences), the processes and the way of operating are very similar.
Introduction to the polymer production sector and rationale for its selection

Polymer production takes place in industrial installations that are similar to those in the large volume organic chemical (LVOC) sector. The feedstocks for polymer production are monomers produced in these LVOC sites. These are often produced at the same site and by the same company. More than 100 companies, across around 350 sites (according to E-PRTR) produce polymers in the EU. Within the polymers sector, the polyolefin, PVC and polystyrene production contribute the majority of emission loads and production volumes.

These three subsectors, together with unsaturated polyesters, were selected as the four polymer production subsectors taken forward for testing. Inclusion of the unsaturated polyesters was aimed at assessing whether the approach based on data collection of emissions, emissions factors, abatement efficiency is feasible for sectors with smaller production capacities (i.e. more niche sectors).

The key environmental issues of the polymer sector are emissions to air of volatile organic compounds, in some cases waste waters with potentially high loads of organic compounds, relatively large quantities of spent solvents and non-recyclable waste as well as high energy demand. The fugitive and diffuse emissions to air of VOCs are also relevant but the absence of proper monitoring has hindered the derivation of AELs on this matter. The emission from storage is also significant but not covered by the POL BREF.

In contrast to the iron and steel sector, the polymer production sector is characterised by a large number of installations, across a wide variety of subsectors. As such it is representative of European industrial clusters with a complex segmentation (similarly to the food and drink sector, large volume organic chemicals). It was expected that testing several methodologies with the BAT-AELs in the polymer and CWW BREF would allow development of recommendations on the possible approaches flexible enough to cope with complex scenarios, such as when emissions from an installation could be categorised under two different BREFs (e.g. LVOC and POL).

2.3.2 MCA Framework and assessment

The aim of Task B was to test the feasibility and applicability of applying the methodologies identified in task A. To consistently assess the prospects of the methodologies, each was assessed against a set of common criteria in a multi-criteria analysis. These are set out in Table 2 together with the scoring guidance for Red-Amber-Green (RAG) rating used in the MCA.

Each methodology was assessed against each criterion and awarded a simple RAG rating. The rating was supported by a description of how each methodology scores against each criterion, highlighting pros and cons. Each methodology is assessed at the data input level, given the feasibility of each methodology is inherently dependent on the availability and accessibility of supporting data. Summing up the ratings against the groupings of criteria provides an overall picture of the appropriateness and feasibility of applying the methodologies.

The ratings awarded are predominantly based on supporting evidence from the detailed sector assessment and wider stakeholder consultation regarding availability and access to data sources. It is recognised that the examples, and the results of feasibility testing of the methods with the two selected industries, may not be representative of all industrial sectors covered under the IED.

Consistency across scoring of individual methodologies was ensured through close communication across the team over the period in which assessments were completed and a full technical review of all methodology assessments by a single moderator.

2.4 Stakeholder workshop

The results of the feasibility assessment of the methodologies and draft recommendations were presented and validated with stakeholders during the workshop in Brussels, Belgium on 15 September 2016. The findings of the study were then updated for this report, based on the comments received from stakeholders during and following the workshop.
### Table 2 Multi-criteria analysis scoring criteria

<table>
<thead>
<tr>
<th>#</th>
<th>Criteria</th>
<th>Indicative scoring criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Group 1 – Accuracy and uncertainty assessment</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.1</td>
<td>Are the data modelled or measured?</td>
<td>The scoring was undertaken based on the data sources identified for the polymers and/or iron and steel sector during method testing. R: The data used are modelled using a limited methodology (e.g. there are significant caveats to the approach such as limited underlying data, stretching assumptions, accuracy has not been tested or verified with stakeholders) or unknown. A: The data are based on primary data (but only on a limited example/sample that is extrapolated) or modelled using a robust methodology (e.g. data inputs were verified / tested with stakeholders). G: The data are close to true values and based on comprehensive collection of primary data.</td>
</tr>
<tr>
<td>1.2</td>
<td>Periodicity of data</td>
<td>The scoring was undertaken based on the data sources identified for the polymers and/or iron and steel sector during method testing in the sample of Member States. R: Data sources are not periodically updated; key data sources are relatively old. A: Data are collected and published every few years; relatively recent data are available. G: Collected and published annually.</td>
</tr>
<tr>
<td>1.3</td>
<td>Granularity of available data (BAT-AELs)</td>
<td>The scoring was undertaken based on the data sources identified for the polymers and/or iron and steel sector during method testing. R: Data are available at country level or higher, not matching granularity of BAT-AELs. Cost data are only available in highly aggregated format (e.g. sector level or higher) and not split by abatement measures. A: Input data available at the facility or sector level, without the disaggregation into BAT-AELs granularity. Cost data available for generic abatement measures but are not sufficiently disaggregated (e.g. not sector or process specific). G: Input data available at the sub-process, product or sub-sector level, matching BAT-AELs granularity. Cost data matches specific equipment at the sub-process or process level.</td>
</tr>
<tr>
<td>1.4</td>
<td>Applicability to IED sectors</td>
<td>Conclusions on the applicability were drawn based on the similarity of sectors and metrics used to express BAT-AELs across the IED sectors, with the BAT-AELs for the polymer production and iron and steel sectors. R: Can only be readily applied (i.e. without involving multiple transformations) to a limited number of IED sectors. A: Can be readily applied to most, but not all IED sectors. G: Can be universally applied to all IED sectors.</td>
</tr>
<tr>
<td>1.5</td>
<td>Completeness of data (coverage across Member States)</td>
<td>The scoring was undertaken based on the data sources identified for the polymers and/or iron and steel sector during method testing in the sample of Member States. Based on the findings, conclusions will be drawn on whether data are likely to be available universally across all / most EU Member States. R: Data primarily sourced from outside the EU. A: Data available for one representative / select EU Member States. G: Data available separately for all/most Member States.</td>
</tr>
<tr>
<td>1.6</td>
<td>Availability of information across air and water pollutants</td>
<td>The scoring was undertaken based on the assessment of BAT-AELs identified for the polymers and/or iron and steel sector during method testing in the sample of Member States. R: Method can be executed for a minority of the applicable BAT-AELs (i.e. less than half of pollutants identified in the BREF can be analysed quantitatively based on the data and information available). A: Method can be executed for a majority of the applicable BAT-AELs. G: Method can be executed for most of the applicable BAT-AELs.</td>
</tr>
</tbody>
</table>
### Indicative scoring criteria

<table>
<thead>
<tr>
<th>#</th>
<th>Criteria</th>
<th>Scoring was undertaken based on the internal assessment of the effort that was required to process the data by project team.</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1</td>
<td>Effort / human resource required to extract, process, clean and/or sort existing available data.</td>
<td>Scoring was undertaken based on the internal assessment of the effort that was required to process the data by project team.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>R: High cost (i.e. in terms of person-days or high-cost expertise) required to use data.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>A: Some cost required to use data.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>G: Minimal cost required to use data.</td>
</tr>
<tr>
<td>2.2</td>
<td>Effort / resource to operate methodology (in connection to complexity of the approach / time and resource required to understand and run the methodology / time and resource required QAQC)</td>
<td>Scoring was undertaken based on the internal assessment of the effort that was required to process the data by project team.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>R: High cost to operate methodology (i.e. in terms of person-days or cost of expertise required); modelling is complex, requires highly technical, sector-specific and economic expertise and knowledge, or is resource intensive.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>A: Moderate cost to operating methodology: moderate level of complexity in calculations involving several parameters, method requires some technical, sector specific or economic expertise (which is relatively common across institutions), requires moderate level of resource.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>G: Minimal cost to operating methodology: Simple calculations are required using few parameters, method can be executed without deployment of technical, sectoral or economic experts, requires low level of resource to understand and/or run the model.</td>
</tr>
<tr>
<td>2.3</td>
<td>Effort to gather new / primary data to ensure BAT-AEL level of granularity (per stakeholder group)</td>
<td>Scoring was supported by responses collated through consultation with MS authorities and industry for the example sectors.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>R: High cost to collecting new data: large amount of primary data required to be collected (not covered by existing reporting arrangements); Required to be collected from a large number of stakeholders; required to be collected from several new / individual private sector stakeholders (with likely lower response rate); data required is commercially sensitive.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>A: Moderate cost to collecting new data: some primary data required to be collected (Some not covered by existing reporting arrangements); Involves collection from private sector industry representatives (e.g. trade associations) / limited number of new relationships /contacts or few individual private sector companies; data not commercially sensitive.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>G: Minimal cost to collecting new data: Limited amount of primary data required (Data required likely to be captured under existing reporting arrangements); Can be gathered from well-known / easily-identifiable, stakeholders through established networks / groups associated with IED; data not commercially sensitive.</td>
</tr>
<tr>
<td>2.4</td>
<td>What effort is required to keep the data used (existing and collected) up to date?</td>
<td>Scoring was based on the data identified for the polymers and iron and steel sectors.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>R: High level of effort required to keep data up-to-date: data expires quickly / Regular (annual or more frequent) data collection is required to keep the data up to date. Or update of data is a resource-intensive process or takes a long-time, engaging a wide number of stakeholders, or use of a novel process each time.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>A: Moderate effort required to keep data up-to-date: data can change over time but within moderate margins (e.g. some data points can move significantly but others less so, or all data points show moderate variability); updating data requires moderate resource or takes a reasonable amount of time.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>G: Low effort required to keep data up-to-date: data changes over time but within very limited margins (and no data points subject to large variance). Updating data requires limited amount of effort and can apply existing processes.</td>
</tr>
<tr>
<td>2.5</td>
<td>Financial cost of data (e.g. data licensing)</td>
<td>Scoring was based on the data identified for the polymers and iron and steel sectors.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>R: Significant financial cost required to access data.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>A: Small financial cost required to access data.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>G: Data are publically available requiring no additional financial cost.</td>
</tr>
<tr>
<td>#</td>
<td>Criteria</td>
<td>Indicative scoring criteria</td>
</tr>
<tr>
<td>---</td>
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</tr>
<tr>
<td><strong>Group 3 – Practicality of implementing</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
| 3.1 | Compatibility with other methods across other elements of the analysis (emission reduction, costs, benefits) | Scoring will be based on the application of individual methodologies to the polymers and iron and steel sectors, and observations made on whether and how different aspects of the methodologies best fit together.  
R: The method is not easily compatible with any other methods identified for other elements of the analysis.  
A: The method is easily compatible only with a single methodology identified for other elements of the analysis.  
G: The method is easily compatible with more than one element of the analysis. |
| 3.2 | Availability of methodologies (i.e. existence of commercial limitations around application of methodology) | R: Methodology is privately owned and unavailable for separate licencing (or needs to be purchased on subscription basis).  
A: Methodology is privately owned but can be purchased through one off purchase.  
G: Method is based on publically available intellectual property (IP). |
| 3.3 | IT requirements | R: Method requires specific IT packages not widely used.  
A: Method uses IT platforms which are generally used by at least a limited number of staff across most institutions.  
G: Method uses common IT platforms typically used by most staff across most institutions. |
| **Group 4 – Transparency and acceptability** | | |
| 4.1 | Transparency of the methodology (i.e. availability of information documenting underlying approach) | Assessment was based on the experience of applying the method to the polymer production and iron and steel sectors. In addition, the scoring was supported by the outcomes of the literature review in task A.  
R: Only limited information is available publically on any aspect of the methodology, assumptions or data sources making it difficult to judge robustness. Large number of methodological assumptions was needed to execute the method.  
A: Some aspects of methodology, assumptions and data sources are well-documented, but not all. Or some (but incomplete) information is publically available on all aspects. Some assessment of robustness / appropriateness can be made but with reservations. Some methodological assumptions were needed.  
G: All aspects of the methodology, assumptions and data sources are well-documented in publically available reports. A confident assessment of robustness / appropriateness can be made. Small number or none of methodological assumptions was needed to execute the method. |
| 4.2 | Acceptability of the methodology to stakeholders | Scoring was based on the responses from the consultation in task A and additional consultation in task B.  
R: MS / trade associations are aware / show understanding of approach and are critical of / note criticisms associated with it.  
A: MS / trade association are aware of / show understanding of the approach / have considered its use but have never applied it in practice but are neutral in terms of whether it is a good or bad approach Stakeholders show no awareness of approach.  
G: The MS / trade association have used this method before. MS / trade associations show awareness / understanding of approach and are on balance positive regarding its application. Stakeholders note the method is considered widely accepted. |
3 Identification of methodologies

This section sets out the outputs of the identification of methodologies to assess the impacts of BAT-AELs. First a horizontal summary of the literature sources assessed is presented. This provides an overall split of sources across: countries, IED activities and the focus of the analysis contained (i.e. assessment of one or more of emissions reductions, costs or benefits). In order to synthesise the comparison of studies, the analytical methodologies are then grouped according to commonalities in their approaches to: determining baseline emissions, modelling future emissions, calculating emissions reductions, assessing costs and benefits of air and water pollutant emission reductions. Key inputs for each common approach are identified. Data sources used across the studies to provide these key inputs are reviewed and common sources of information are identified.

Note on citations: in contrast to the rest of this report, this chapter references the very large number of literature sources identified using a [number] citation for brevity due to the large number of references. Elsewhere in the report citations are presented in the more conventional (author, date) format.

3.1 Horizontal summary of the literature sources identified

55 literature sources were analysed according to the assessment template. In addition, one assessment has been completed based on the information gathered through the direct consultation with the authors of one relevant assessment (in Denmark) 7.

3.1.1 Context for the studies assessed

The process of selecting relevant studies for the assessment is described in section 2.2.1 of this report. In the selection process it was important to ensure that the studies together covered all elements of the assessment i.e. emission reductions, costs and benefits, even if these were undertaken in a context other than assessment of impacts of BATC.

Only 16 of the analysed studies focused on impacts of BATC or similar (i.e. emission limit values established under the IPPC regime, or other emission limit values established in a different context or geography). Two sources supported assessment of costs and benefits in the context of applying for derogations from the BATC. Other studies were developed in the context of the IED and/or IPPC Directive more generally, the National Emission Ceiling Directive, the Water Framework Directive or outside of the European legislative context. A number of studies identified also focused on the processes of determining what the BAT or BAT-AEL could be for a given sector or process, as well as the methodologies for selection of the abatement techniques required to comply with the BAT. Specific studies were also identified on the application of the Life Cycle Assessment in the context of the BAT.

While applicability of some of these studies may not appear relevant at the outset, taking such a wide-ranging approach to the literature review (i.e. not simply considering studies that have narrowly assessed the impacts of BATC) has ensured that the evidence gathered provides a more comprehensive coverage of the various permutations, assumptions and data sources for impact assessment methods. Furthermore, it allowed the completion of some gaps in the methodologies identified. For example, very few examples of assessments of benefits of emission reductions to water have been identified in the studies focused on ELVs / BAT-AELs. The only way to fill this gap was to consider a broader spectrum of studies such as those developed in the context of the Water Framework Directive.

3.1.2 Scope and content of the studies assessed

Geographical focus

23 sources presented analysis at the EU-level or covered methods applicable to the EU level. 35 studies focused on specific EU countries 8. Studies reviewed presented assessments for the following EU

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7 The impact assessments of the BATC undertaken in Denmark have not been provided for the analysis because the reports contained confidential industrial information. A conference call between the Danish authorities and a member of the project team was held to gather required information on the method applied.

8 A single study could have covered more than one country.
Member States: Austria, Belgium, Bulgaria, Czech Republic, Germany, Denmark, Spain, Finland, France, Netherlands, Romania and United Kingdom. In addition, examples of relevant studies from the USA were assessed.

Coverage of the IED activities

22 studies presented approaches that were either specifically designed and developed for application to industrial activity covered by the IED as part of the study undertaken, or were developed for more general use but are applicable to these industrial activities. It should be noted that eight of these studies covered solely the methods for assessment of health benefits associated with emission reductions to air, which are not sector specific. Excluding the studies that were judged as applicable to any industrial sector, the most common IED activities covered by the studies were (noting that many studies covered more than one industrial sector):

- 1.1 Combustion of fuels in installations with a total rated thermal input of 50 MW or more – 15 studies
- 6.1 Pulp, paper and wood based panels – 12 studies
- 1.2 Refining of mineral oil and gas – 10 studies
- 1.3 Production of coke, 2.2 Production of pig iron or steel, 2.5 Processing of non-ferrous metals – 9 studies each

Some studies were developed in a different context to the IED or BATC. Nevertheless, based on these overview figures it can be concluded that methodologies for large combustion plant sector are more comprehensively covered by the evidence gathered in this study, compared to other sectors (albeit not significantly more than pulp, paper and wood based panels sector), which is not surprising considering the attention given to the sector during the development and implementation of the LCP, IPPC and IE Directives (reflective of the significance of the sector's emissions to air).

Emission reductions

Assessment of emission reductions to either air or water was undertaken in 44 of the studies assessed. Over two thirds of the studies covered air emissions reductions only. Studies focused on emissions to water only were in minority, with a quarter of the studies covering the emission reductions to both air and water.

Out of 44 studies covering emission reductions, 25 studies assessed these at the process or emission source level (i.e. at the point of release: this can be channelled or fugitive emissions) and 19 at the site level (i.e. a single site can have a number of installations, which in turn can have one or more emission sources). Only seven examples were identified where emission reductions were assessed at a sector level, without going down to the facility or process level assessments.

Costs and benefits

Out of 44 studies that covered assessment of emission reductions, 35 studies also assessed costs and 19 both costs and benefits. To supplement it, eight studies focusing solely on the methodologies for assessment of benefits associated with the air emission reductions were assessed. Only one study applied a methodology to assess benefits of emission reductions to water.

3.1.3  Key observations from the assessment of literature sources

It was hypothesised that methods for assessment of emission reductions, costs and benefits can be broadly divided into top down and bottom up approaches. For this study, ‘top-down’ approaches were defined as those which start from a sector or country-wide aggregation, relative to ‘bottom-up’ approaches which use data and undertake analysis at the facility or process level first, before potentially aggregating to a broader category such as sectoral or country level.

Upon review of the identified literature sources, the study by Amec Foster Wheeler, “Service contract for assessing the potential emission reductions delivered by BATC adopted under the directive on industrial emissions” [6] was the only study identified that investigated the impact of BATC without going down to a facility level (the study did consider impacts at process level but only at a national sector aggregation).
Based on the evidence reviewed it is therefore apparent that the majority of existing studies assess the impacts at least at individual facility level, and in some cases then proceeding to sectoral estimates by summing up the impacts for individual facilities (or defining model facilities to assess the impacts for a sector as a whole). These assessments used official data sources, but often were supported by dedicated data collection at facility level.

All methodologies identified in the studies could in theory be implemented as bottom-up methodologies (determining impact at process or facility level and then aggregating to sectoral, country or EU-level), if sufficiently detailed data are available. In the following sections of the report, the division between top down and bottom up methodologies is therefore no longer made. Instead, all methodologies are considered for implementation at process, facility and sector level simultaneously, and feasibility of execution of these methodologies against the available data sources and other criteria is assessed in Section 5.

The principle of proportionality has also been commonly applied across the studies for all impacts: emission reduction, costs and benefits. Under a ‘proportionate’ approach, only the most significant impacts are included in the scope of the assessment (i.e. those which could be large enough to influence the outputs of the analysis, typically the balance between costs and benefits). Following this principle recognises that there will only be a finite level of resource available to carry out appraisal; thus that the analysis should focus more on the important impacts and improving the detail and robustness of the assessment of these effects, and commit less resource to those which are unlikely to influence the overall conclusions drawn from the appraisal.

3.1.4 Review of existing BAT-AELs and emission limits in the BREFs

In addition to the assessment of studies as described above, existing BREFs (published under the IED, or the IPPC in case of BREF documents not reviewed after the entry into force of the IED) have been reviewed in order to identify commonalities and differences with respect to the metrics used for setting BAT-AELs for emissions to air and water. The aim of carrying out this comparison was to provide background to how and why certain methodologies may not be applicable to certain BREFs if, for example, the metrics used to specify the BAT-AELs are incompatible with the methodology in question.

28 BREF documents (as presented in Appendix D) were reviewed. The structure of the BREF / BAT Conclusions documents can be divided into three broad categories:

- Generic – those that set BAT-AELs for the whole sector.
- By sub-sector or product – those that set specific BAT-AELs per sub-sector or type of product produced at the facility.
- By process – those that set specific BAT-AELs per process or emission source.

The majority of the sectors have BAT-AELs established for both air and water. The exception from this is the common waste water treatment in the chemical sector BREF which only contains BAT-AELs to water, and the intensive rearing of poultry and pigs, production of cement, lime and magnesium oxide and smitheries and foundries BREFs which only contain BAT-AELs to air.

The review has identified that the most common metric to express BAT-AELs to air is concentration based (typically mg/Nm³). In a few instances (including the polymer sector), the BAT-AEL is expressed per tonne of product (e.g. in the manufacturing of glass BREF AELs are expressed per tonne of melted glass) or, per mass or volume of raw materials used (as is the case with the smitheries and foundries). BAT-AELs for emissions to water are commonly expressed in mg/l of wastewater, with a few instances of the use of production or raw materials metrics (e.g. for the production of pulp, paper and board and specialty inorganic chemicals).

3.2 Categorisation of the methods based on reviewed literature sources

Despite numerous studies being identified, there is a finite number of general methods that can be used in the context of assessing emission reductions, costs and benefits of BAT-AELs. More specifically no
single study provided a ready approach that could be considered a “reference method” for each element of the analysis (i.e. emission reductions, costs, and benefits). Following the review of the literature sources, the approaches identified were therefore first grouped against these different analytical elements and further categorised based on the common methodological features.

There exist multiple ways in which methodologies could be grouped. There is also lack of consistent terminology used across the studies reviewed. For the purpose of this study, methodology groups were defined to allow for distinction to be drawn between the level of accuracy offered by the methods and the resource intensity they require. It is worth noting that methodologies identified within a single group are often interlinked with each other e.g. one method can be used to derive inputs to the other method. Such interlinkages have been highlighted where relevant. Definition of the method groups and other commonly used terms is presented in Table 3.

<table>
<thead>
<tr>
<th>Method grouping</th>
<th>Abbreviation</th>
<th>Definition</th>
<th>Other commonly used terms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>BE</td>
<td>Methods to define a single year of historical emissions.</td>
<td>Base year</td>
</tr>
<tr>
<td>Future emissions</td>
<td>FE</td>
<td>Methods to define projected emissions for future years, assuming BATC not in place.</td>
<td>Reference scenario</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Business as usual scenario</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Counterfactual</td>
</tr>
<tr>
<td>Emission reductions</td>
<td>ER</td>
<td>Methods to quantify the difference between future emissions with and without BATC.</td>
<td>Beyond business as usual</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Policy scenario</td>
</tr>
<tr>
<td>Costs</td>
<td>CO</td>
<td>Methods to calculate direct compliance costs for the operators associated with attainment of BATC.</td>
<td>Cost of abatement</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Costs of emission reductions</td>
</tr>
<tr>
<td>Benefits</td>
<td>ABE (air)</td>
<td>Methods to monetise the value of emissions reductions achieved through compliance with BATC.</td>
<td>Damages avoided</td>
</tr>
<tr>
<td></td>
<td>WBE (water)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

This section presents the methods identified for calculating emission reductions, costs and benefits and captures different permutations of the methods as applied in the studies reviewed. For each group, unique approaches identified in the analysed studies are presented. An overview of the method categorisation is presented in Figure 3.
Figure 3 Overview of the method categories identified for each element of the analysis

**EMISSION REDUCTIONS**

- **BASELINE EMISSIONS**
- **FUTURE EMISSIONS (excl. BATC)**
- **FUTURE EMISSIONS (incl. BATC)**
  - Methods to select abatement techniques
  - Abatement techniques
  - Subtracting future emissions (incl. BATC) from future emissions (excl. BATC) or from the baseline emissions
  - Estimate of total emission reductions per BAT-AELs

**COSTS**

- Detailed cost assessment (CAPEX, OPEX)
- Loss in value added
- Using marginal abatement cost (cost per unit of pollutant abated)

**BENEFITS**

- **AIR**
  - Impacts per tonne
  - Impact pathway approach (with/without monetisation)
  - Damage costs
  - Abatement costs
- **WATER**
  - Methods to estimate impacts on water quality
  - Impact pathway approach
  - Various valuation techniques

**Estimate of costs of emission reductions**

**Estimate of benefits of emission reductions**
3.3 Methods to assess impact on emissions reductions

3.3.1 Overview

Calculation of emission reductions is the first element of the analysis and is necessary for the estimation of costs (although in certain circumstances the cost analysis can influence estimation of emissions reductions, e.g. influencing selection of abatement techniques) and benefits of compliance with BAT-AELs. Studies which included estimations of emission reductions assessed this impact compared to a counterfactual scenario. The counterfactual is a projection of emissions for future years assuming (new) BAT-AELs are not in place. Based on the studies reviewed, the baseline could be:

- Modelled – several data parameters are combined to provide calculated baseline emissions at a required level such as process, facility or sector;
- Reported – emissions reported and available from existing data sources are used as the baseline for the assessment; or
- Hybrid – baseline is constructed on a basis of reported emissions; gaps filled using modelling.

Once the baseline is established, the methodologies in the sources reviewed either:

- Progressed directly to the assessment of emission reductions. Impacts were assessed by directly comparing to baseline in studies [1], [2], [3], [4], [5] (studies listed in Appendix A).
- Or included an intermediate step of defining future emissions. This depicts emissions in a future year(s) without BAT-AELs in place. If this step was taken, future emissions were either modelled (i.e. combination of parameters was applied to the baseline in order to project how the baseline will change in future years) – see studies [11], [6], [54] – or the emission projections were adopted from existing sources (e.g. use of national emission projections developed outside of the core study as in [7]).

Having established the baseline and/or future emission scenarios, the next step consists of modelling the future scenario assuming BATC are in place (i.e. the ‘policy’ scenario). Calculation of the emission reduction could then be done by either:

- Subtracting the policy scenario including BATC from the counterfactual: i.e. simply assuming BAT-AELs are met.
- Or modelling the impact of abatement techniques applied directly to either the baseline or reference scenario i.e. estimating what reductions are required (by comparing emission levels in the counterfactual with the BAT-AELs) and the techniques that could achieve these followed by applying the specific associated abatement efficiencies.

A schematic diagram of the steps described above and the high level grouping of the methods applied based on the sources reviewed is presented in Figure 4 and then discussed in subsequent sections.

![Figure 4 Overview of the methodologies used to assess emission reductions](image-url)
3.3.2 Determining baseline emissions (methods BE1, BE2, BE3, BE5)

The following methods for modelling of the baseline emissions have been identified across the studies which assessed emission reductions⁹.

**BE1: Modelling using emission factor and activity data.**

This approach uses an emission factor expressed in unit of mass per unit of activity, multiplied by corresponding activity value. This approach has been used in [10] and [14]. This approach is also a tier 1 or 2 default approach in the EMEP/EEA emission inventory guidelines [191] for estimation of emissions of pollutant from industrial sectors. The outputs of this approach are the total emissions of pollutant in unit of mass per year. An illustrative example of applying method BE1 derived from the polymer production case study is presented in Box 1.

**Box 1 Application of BE1**

Under BE1, baseline emissions are calculated by applying the following equation:

\[
\text{Baseline emissions} = \text{Emissions factor}_{\text{baseline}} \times \text{Activity value}
\]

The following example presents sample application of the method to the polymer production sector, using emission factors from the POL BREF (expressed in terms of grams of pollutant emitted per tonne of product) and activity values (i.e. installations’ production capacities) from environmental permits for individual installations (expressed in kilo tonnes of product per annumⁱ⁰). These calculations were undertaken at installation level. POL BREF provides a range of possible emissions factors depending on whether a plant is the best, worst or average performer. In the absence of sufficient contextual information (e.g. on what abatement equipment is already fitted at each installation), an assumption has been made to use the average values. Furthermore, actual activity values (i.e. output of the installation) can vary from capacity depending on actual plant utilisation. In this case, polymer production units generally operate below their nameplate capacity but for the purpose of modelling full utilisation of the capacity was assumed.

The data inputs and results of these calculations for the polyolefins sub-sector for the three MS case studies are presented in the following table:

<table>
<thead>
<tr>
<th>Plant</th>
<th>Pollutant</th>
<th>Product rate (kt/year)</th>
<th>Emission factor (g/t)</th>
<th>Calculated emissions baseline (t/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plant A</td>
<td>PM</td>
<td>323</td>
<td>46</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>VOC</td>
<td>323</td>
<td>2,475</td>
<td>799</td>
</tr>
<tr>
<td></td>
<td>COD</td>
<td>323</td>
<td>67</td>
<td>22</td>
</tr>
<tr>
<td>Plant B</td>
<td>PM</td>
<td>408</td>
<td>46</td>
<td>19</td>
</tr>
<tr>
<td></td>
<td>VOC</td>
<td>408</td>
<td>2,475</td>
<td>1,010</td>
</tr>
<tr>
<td></td>
<td>COD</td>
<td>408</td>
<td>67</td>
<td>27</td>
</tr>
<tr>
<td>Plant C</td>
<td>PM</td>
<td>340</td>
<td>46</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td>VOC</td>
<td>340</td>
<td>2,475</td>
<td>842</td>
</tr>
<tr>
<td></td>
<td>COD</td>
<td>340</td>
<td>67</td>
<td>23</td>
</tr>
</tbody>
</table>

There are many potential variations of plant configuration, technology used and the unit engineering design across the sector. The level of contextual information available on the installations assessed was insufficient to select more accurate emission factors for each site.

---

⁹ In the initial literature review a method BE4 had been identified. After further reflection, this method BE4 has been removed on the basis that many methods require gap-filling / combination with other methods and hence there isn’t a need to label a specific combination as BE4. The methodologies have not been renumbered.

¹⁰ The case study incorporated a review of permits for the selected POL installations.
BE2: Modelling using concentrations (emission levels) and activity data

This approach uses an output concentration (e.g. emissions levels in the flue gas or wastewater flow) multiplied by corresponding activity value (e.g. flue gas volumes). This approach has been used in studies [3], [6] and [4]. The outputs of this approach are the total emissions of pollutant in unit of mass per year. An illustrative example of applying method BE2 for the iron and steel case study is presented in Box 2.

**Box 2 Application of BE2**

BE2 has been illustrated through application to the Iron and Steel sector. The approach was applied to calculate emissions from a single facility.

Three parameters were combined to calculate emissions as follows:

\[
\text{Baseline emissions} = \text{Operating hours} \times \text{Flue gas volume} \times \text{Flue gas concentration}\_\text{Baseline}
\]

Flue gas volumes were sourced from the environmental permit. Data on operating hours and flue gas concentrations were taken from the annual emission report for the site. Emissions were calculated separately for three pollutants (NOx, SO\textsubscript{2} and PM) across 4 different processes: coke production, sinter production, blast furnace and steel production. A sample of the data inputs and calculations for sinter production in 2011 are included in the following table.

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>Annual operating hours</th>
<th>Flue gas volume (Nm\textsuperscript{3}/hour)</th>
<th>Flue gas conc. (mg/Nm\textsuperscript{3})</th>
<th>Calculated emissions (t)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NOx</td>
<td>6718</td>
<td>600,000</td>
<td>144</td>
<td>580</td>
</tr>
<tr>
<td>SO\textsubscript{2}</td>
<td>6718</td>
<td>600,000</td>
<td>65</td>
<td>262</td>
</tr>
<tr>
<td>PM (primary)</td>
<td>6718</td>
<td>600,000</td>
<td>67</td>
<td>271</td>
</tr>
<tr>
<td>PM (casting house)</td>
<td>6718</td>
<td>600,000</td>
<td>N/A</td>
<td>N/A</td>
</tr>
</tbody>
</table>

Both methods BE1 and BE2 can be applied at installation, sector or country level. However, BE2 requires more contextual information, specifically the flue gas and wastewater volumes, as well as concentration data. These can usually be obtained only from data sources available for individual installations. As such, some stakeholders expressed concerns that method BE2 may require too much effort if applied to a whole sector.

Modelling of baseline emissions using either BE1 or BE2 could take into consideration application of BAT or other abatement techniques across the sector. This can be reflected in using technology specific emission factors or concentration values, in place of average emission factors for the sector. While this adds complexity to the assessment and requires an understanding of the abatement techniques already installed on sites, it could improve the accuracy of the modelling results.

In the absence of facility specific emission factors or emission concentrations, ELVs included in the permit can be a useful proxy to use for the assessment. For example, in study [3] ELVs in the LCP Directive were used for establishing baseline emissions. These limits represent the maximum that installations can emit without breaching environmental quality standards under the baseline scenario. In reality, most installations would emit below the permit ELV. Thus the use of permit ELVs could overestimate baseline emissions (and hence also overestimate the costs and benefits of applying new BAT-AELs as it would be assumed that greater reductions in emissions are needed to meet BAT-AELs).

Finally, methods BE1 and BE2 are not mutually exclusive. As shown in study [11], concentration levels could be one of the parameters used to derive the emission factor.

**BE3: Baseline emissions compiled using monitored emissions data.**

This method uses current monitored emissions data with only limited or no modifications to establish the baseline. Required data can be sourced from the operators reporting on monitoring to the competitive authorities. The outputs of this approach are either the total emissions of pollutant in unit of mass per year, or baseline concentrations values in emission streams, depending on the source of data. An illustrative example of applying method BE3 is presented in Box 3.
Box 3 Application of BE3

BE3 forms a baseline using reported emissions. This approach was tested for both the Polymers and Iron and Steel sector.

For Iron and Steel, again the approach was tested for an example plant. Emissions for the plant were taken from reported emission data provided by the site operator to the Member State Ministry. Reported emissions for sinter production in 2011 are presented in the following table, relative to the outputs of BE1 and BE2 calculations for the same plant.

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>BE1 calculated emissions (tonnes)</th>
<th>BE2 calculated emissions (tonnes)</th>
<th>BE3 reported emissions (tonnes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NOx</td>
<td>506</td>
<td>580</td>
<td>545</td>
</tr>
<tr>
<td>SO2</td>
<td>453</td>
<td>262</td>
<td>127</td>
</tr>
<tr>
<td>PM (primary)</td>
<td>228</td>
<td>271</td>
<td>385</td>
</tr>
<tr>
<td>PM (casting house)</td>
<td>N/A</td>
<td>N/A</td>
<td>42</td>
</tr>
</tbody>
</table>

As can be seen from the table, there is some variation in the figures between the approaches. The calculations for the sinter plant are somewhat complicated due to the fact that the two sinter plants have been operated partially with a waste gas recirculation system. This has an influence on the waste gas volumes which have not been reported individually. This uncertainty in waste gas volumes drives the differences between the results.

Data was gathered for the Polymers sector from two sources: PRTR and annual emission reports. A sample of the results for the Polyolefins sub-sector is presented in the following table. Results were only available for VOC emissions in two tested plants. However, data was limited, with no information available on PM emissions or COD.

<table>
<thead>
<tr>
<th>Plant</th>
<th>Pollutant</th>
<th>Reported Emissions: PRTR (tonnes)</th>
<th>Reported emissions: annual reports (tonnes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plant A</td>
<td>VOC</td>
<td>1,120</td>
<td>1,063</td>
</tr>
<tr>
<td>Plant B</td>
<td>VOC</td>
<td>270</td>
<td>292</td>
</tr>
<tr>
<td>Plant B</td>
<td>COD</td>
<td>No data</td>
<td>29.2</td>
</tr>
</tbody>
</table>

In several studies, such as [5], [19], [21], [32], the baseline emissions for the assessment have been derived from reported data (method BE3). It should be noted however that some of these studies used data reported at site (and sometimes process) level which was specifically collected for the purpose of the study (for example [19]). Therefore, the detail of the emissions data often matched the granularity of BATC. That said, use of emissions reported at the site level (e.g. from E-PRTR as in [5]) requires assumptions to be made to fit the baseline emissions with BAT-AELs for specific processes within sites. In addition, in [21] the emissions reported in the E-PRTR appeared wrong and thus were first refined by the study authors to correct the errors before proceeding with the analysis.

The key considerations when applying reported emissions as a baseline are:

- If reported emissions are not at BAT granularity level, additional assumptions and data inputs are required to break-down reported emissions to granularity of BAT-AELs. This introduced uncertainty into the overall assessment.
The reported emissions may not be complete for all facilities, years or emission sources. This can also be affected by reporting thresholds in case of obligations such as under the E-PRTR.

The emissions available in the emission inventories and databases may not be available for all pollutants for which BAT-AELs were defined.

The reported emissions are unlikely to provide detail regarding factors which affect emissions, e.g. level of existing compliance with BATC, or application of abatement techniques.

There may be limited available data on the emissions of substances newly introduced to the scope of the BATC (for which no previous BAT-AELs were established).

Similarly, the availability and quality of data will differ for substances monitored continuously and those monitored periodically. Estimations of baseline emissions for the latter may be more difficult and less accurate.

To address some of those limitations, hybrid approaches have been used in a number of studies. These approaches combine reported emissions (method BE3) with modelling approaches (methods BE1 and BE2) to form a baseline. These are often unique for a specific study or model. For example, for the purpose of the assessment of the impacts of BATC on the large combustion plant sector in Denmark, the baseline emissions at facility level have been taken from the national emission database (this is used for the purpose of reporting to the E-PRTR but includes more detailed information than is reported to the E-PRTR). For plants for which information was missing, the baseline emissions were modelled using the activity data and the IED ELVs (corresponding to method BE2).

**BE5: Modelling using unabated emission factors, emission reduction efficiencies of abatement equipment already installed in the sector for a given process and activity data.**

In this method, unabated emission factors and emission reduction efficiencies are combined to obtain abated emission factors which are then multiplied by the activity data. The outputs of this approach are the total emissions of pollutant in unit of mass per year. An illustrative example of applying method BE5 is presented in Box 4.

**Box 4 Application of BE5**

Calculation of emissions in the GAINS model is undertaken separately for each country and pollutant type. The calculation combines: sector activity (i.e. quantity of production), an emissions factor for unabated production, efficiency of the control strategy in place and a proportion of production to which the control strategy already applies (i.e. the ‘capacities controlled’).

The table below presents a sample of the results of the calculations of the total PM emissions from the basic oxygen furnaces and coke ovens for a sample country, using methodology and data from GAINS. In this case, none of the sinter production in the sector is assumed to be unabated. Examples using GAINS were derived for PM, NOx and SO\(_2\), for all sub-processes distinguished for the iron and steel industry in GAINS (i.e. coke ovens, sintering, blast furnace and oxygen furnace). Further detail on the approach taken is included in Section 5.2.5.

<table>
<thead>
<tr>
<th>Sector</th>
<th>Technology</th>
<th>Sectoral activity [Mt]</th>
<th>Unabated emission factor [kt/Unit]</th>
<th>Removal efficiency [%]</th>
<th>Abated emission factor [kt/Unit]</th>
<th>Capacities controlled [%]</th>
<th>Emissions [kt]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sinter</td>
<td>Electrostatic Precipitator 1 field</td>
<td>7.5</td>
<td>8.6</td>
<td>97</td>
<td>0.3</td>
<td>61</td>
<td>1.3</td>
</tr>
<tr>
<td>Sinter</td>
<td>Electrostatic Precipitator 2 field</td>
<td>7.5</td>
<td>8.6</td>
<td>100</td>
<td>0.0</td>
<td>39</td>
<td>0.0</td>
</tr>
</tbody>
</table>

Some stakeholders commented that method BE5 may in certain circumstances give inaccurate results – it assumes that unabated emissions and abatement efficiency per technique are consistent over all
installations considered by a particular study, but this is not always the case as different site specific factors can affect the unabated emissions.

Additional considerations

Based on the review of the approaches to establish a baseline, the following observations have been made:

- There are strong interlinkages between the methods identified for estimation of baseline emissions. This is because emission factors (BE1) and emission concentration (BE2), or operating hours (BE2) and activity data (BE1 and BE2) are closely linked and can usually be easily converted from one to the other. Similarly reported emissions (BE3) could be used to derive emission factors using activity data. Some stakeholders expressed the view that in order to use method BE1 reliably, real emissions data (BE3) is required at least for a representative selection of installations. For example, it may be possible to extrapolate from reported emissions (BE3) for a few installations, to overall emissions for the sector as long as emission factors derived based on the reported data are reasonably representative of the sector. Consistency with any aggregated emissions data (BE3 results) needs to be ensured.

- In the case where a sector has a large number of individual installations, a smaller number of reference plants could be used to model the sector. In [15] a dedicated model was built to assess the impacts of BAT in more than 800 installations, across 33 sub-sectors. In order to reduce the size of the dataset and the model developed in the project, 52 “reference” installations were defined based on the sub-sector and common characteristics of the installations. The ability to adopt this approach depends on the similarity between the characteristics of installations in a given sector.

- Irrespective of the method used, the baseline emissions should to the extent possible reflect the existing situation and techniques installed in existing plants. These affect how feasible it is to retrofit the plant, what techniques could be selected and eventually what the associated costs would be. The emission values available from databases or inventories may not always be sufficient to undertake the assessment. Where the installations within a sector differ widely between one another, application of “typical” or “average” emission factors may not be representative. In one study delivered in Finland [25], the baseline was established based on the emissions available from the permitting system (i.e. national inventory of emissions). However, the information was then complemented by an e-mail survey to operators to determine the techniques already installed at the facilities.

- Several models or guideline documents assessed [33, 34, 40, 41, 46] require the users to input the baseline. In these studies, the user input would generally represent a “do nothing” scenario. Because the baseline is defined by the user, the approaches presented in these studies have been assigned to any specific method category. For example, the guidelines for the economic analysis in the context of the IED derogation application in the Czech Republic [46] states that the baseline used for the assessment could either be the “current status” or the “future status” of the plant accounting for changes between the current year and entry into force of the BATC.

Summary of methods for determining baseline emissions

Table 4 presents a summary of methods for the identification of the baseline for the assessment, together with examples of studies in which a given method was applied. In some instances (study [11] and [4]), more than one was used in which case these are reported against more than one category.
### Table 4 Categorisation of methods for establishing baseline emissions

<table>
<thead>
<tr>
<th>ID</th>
<th>Method name</th>
<th>Description</th>
<th>Key inputs</th>
<th>Examples of studies using this approach</th>
</tr>
</thead>
<tbody>
<tr>
<td>BE1</td>
<td>Emission factor (EF)</td>
<td>Emission factor (kg/unit of activity) is multiplied by corresponding activity value</td>
<td>Activity levels, Emission factors</td>
<td>[10], [11], [14]</td>
</tr>
<tr>
<td>BE2</td>
<td>Concentration (ELV)</td>
<td>Output concentration (in the flue gas or wastewater flow) is multiplied by corresponding activity value (and other inputs required to match concentration and activity values)</td>
<td>Operating hours, Current concentration in output, Other parameters (gas flows, wastewater flows), Reference conditions (e.g., reference O\textsubscript{2} %)</td>
<td>[3], [6], [11]</td>
</tr>
<tr>
<td>BE3</td>
<td>Reported emissions</td>
<td>Reported or monitored emission data are applied with no or minimum modifications.</td>
<td>Reported emissions</td>
<td>[5], [4], [12], [13], [19], [21], [23], [28], [32], (plus examples gap-filling reported emissions with modelling: [C1], [4], [6], [25], [42], [43])</td>
</tr>
<tr>
<td>BE5</td>
<td>Modelling using unabated emissions factors and abatement techniques</td>
<td>Reported or monitored emission data are used where available. Gaps in data are filled by either modelling approach BE1 or BE2. In addition, emission factors assuming no abatement in place are combined with activity data and the emission reduction efficiency of techniques assumed to be in place under the baseline scenario.</td>
<td>Unabated emission factors, Activity levels, Uptake of abatement techniques, Emission reduction efficiency of applied abatement techniques</td>
<td>[8]</td>
</tr>
</tbody>
</table>
3.3.3 Determining future emissions (FE1, FE2)

Several studies [6, 7, 8] used estimates of future emissions for the purpose of calculating the impact on emission reductions. As explained earlier this considered future emissions from the plant or sector, assuming BAT are not in place.

**FE1: Modelling future emissions**

Future emissions can be modelled taking into consideration the drivers for change in:

- **Activity values**: these include anticipated plant closures and new plants openings, changes in production processes (including fuel changes) and production outputs.
- **Emission factors**: these include change in BAT compliance above the baseline, adjustments for planned replacement of abatement techniques and impacts of other legislation (e.g. affecting the use of specific fuel or energy efficiency).

Box 5 highlights the application of method FE1 for the polymer sector.

<table>
<thead>
<tr>
<th>Box 5 Application of FE1 (POL sector)</th>
</tr>
</thead>
<tbody>
<tr>
<td>The formula for estimating future emissions is as follows:</td>
</tr>
</tbody>
</table>

\[
\text{Future emissions}_{t+y} = \text{Baseline emissions}_t \times \text{Activity change driver}_y \times \text{emission factor change driver}_y
\]

Where:
- \( t \) = baseline year
- \( y \) = number of years elapsed between the baseline and the year for which future emissions are being estimated.

A review of published sector and sub-sector market volume forecasts, which were based on consideration of the relative influence of (and future change in) different drivers of production, produced a range of predicted activity growth rates from which an assumption was chosen (1% growth per annum). No other future changes that could be confidently quantified and that would otherwise affect emissions were identified.

The US EPA Cost model [53] uses reported emissions to create the baseline scenario. Based on that it applies a number of parameters (including forecasts of growth, impacts of rules and regulations that are final but that will be implemented over time, planned plant closures, etc.) to determine the emissions scenario for future years. In the UK Environment Agency’s IED derogation tool [41], the counterfactual is input by the user of the model; it is therefore impossible to pre-determine whether the user will take an approach of projecting future emissions or use the baseline scenario. Nevertheless, the tool was designed on the assumption that the user will input future (i.e. projected), rather than historic emissions.

In practice, modelling of future emissions using selected parameters (method FE1) is often supported by existing data sources which provide information on future drivers for changes in activity and emission factors. At the EU level, such drivers are already modelled in the PRIMES model, which covers the European energy system and markets on a country-by-country basis and across Europe. Assumptions in PRIMES are then reflected in other EU-wide models such as GAINS. While these two models provide useful data to support future emissions modelling and ensure consistency with modelling in other policy areas, some stakeholders expressed their concerns that they are not sufficiently accurate for their industrial sectors, and their use adds uncertainty to the assessment without providing clear advantages.

**FE2: Use of emission projections developed elsewhere**

Method FE2 is an alternative approach in which emission projections developed elsewhere are used – for example in case of emission to air, these could be Member State projections reported under
Analysis and development of methodologies for estimating potential industrial emissions reductions and compliance costs of BAT conclusions adopted under the Industrial Emissions Directive

CLRTAP\textsuperscript{11}. This approach is used in [7] but carries additional uncertainties. This includes the possibility of a lack of information on the exact assumptions behind the projections, including if and how the impact of BATC have already been taken into account.

Additional considerations

Based on the review of the approaches for determining future emissions, the following observations could be made:

- There are different arguments for and against projecting future emissions before estimating impacts on emission reductions. While development of a future emission scenario may introduce uncertainties into the analysis (e.g. because of doubts around supporting parameters used such as growth), it does provide an opportunity to consider factors such as potential closures or downscaling of plants, and impacts of other policies on future emissions from the plants.
- Comparing the emission reductions versus the baseline on the other hand assumes that BATC are applied to the current situation, and that no other changes will affect the sector ahead of the implementation of BATC. While this could provide greater certainty in terms of emission levels (especially when the monitored emissions are used), it is likely to omit potential changes which affect the sector in the future ahead of the BAT-AELs being translated into permit conditions.
- Some stakeholders expressed their views that only changes with a high degree of certainty, such as the planned closure of a particular installation, should be taken into consideration when projecting future emissions. In case of some sectors, obtaining information on the future activity levels may be subject to competition laws.

Summary of methods for determining future emissions

A summary of the methods is presented in Table 5.

Table 5 Categorisation of methods for establishing future emissions (before implementation of BATC)

<table>
<thead>
<tr>
<th>ID</th>
<th>Method name</th>
<th>Description</th>
<th>Key inputs</th>
<th>Examples of studies using this approach</th>
</tr>
</thead>
<tbody>
<tr>
<td>FE1</td>
<td>Modelling with selected parameters</td>
<td>A selection of parameters is applied to the baseline emissions to reflect future changes.</td>
<td>Defined parameters e.g. scaling factors</td>
<td>[6], [12], [14], [42], [43], [53], [192], [C1]</td>
</tr>
<tr>
<td>FE2</td>
<td>Use of external emission projections</td>
<td>Emission projections developed externally from the assessment are applied</td>
<td>Projected emissions</td>
<td>[4]</td>
</tr>
</tbody>
</table>

3.3.4 Calculating emission reductions (ER1, ER2, ER3)

ER1 and ER2: Modelling future emission levels using BAT-AELs

The calculation of emission reductions associated with implementing AELs can be undertaken by modelling the level of emissions assuming BAT-AELs in place. This forms a ‘policy’ scenario. To model the policy scenario, the same modelling techniques can be used as for modelling the baseline or future emissions scenarios (i.e. the same techniques to reflect the impact of BAT can be used whether applied to a single historical year – the baseline – or a future projection of emissions excluding BAT – the future emissions scenario). In methods ER1 and ER2 the policy scenario is modelled by using either an

updated emission factor (ER1) or emission concentration level (ER2) which is adjusted to take into account the impact of BAT. In many cases, these factors or concentrations are presented in the BREFs through the BAT-AELs. These can then be directly combined with activity data to calculate emissions under the policy scenario. Emission under the policy scenario are then subtracted from the baseline or the future emissions scenario to estimate the change in emissions as a consequence of implementing BAT. Box 6 provides an example application of method ER1, and Box 7 provides an example application of method ER2.

**Box 6 Application of method ER1**
To calculate emissions under the policy scenario in the Polymers case study, emissions factors which reflect the anticipated impact of BAT were taken from the BREF. Policy scenario emissions have been calculated as follows:

\[
\text{Policy emissions} = \text{Emissions factor}_{\text{Policy}} \times \text{Activity value}
\]

Emissions reductions are then calculated using:

\[
\text{Emissions reductions} = \text{Baseline emissions} - \text{Policy emissions}
\]

Calculations are presented below using the example of a plant in the polyolefins sector and emissions to air:

<table>
<thead>
<tr>
<th>Plant</th>
<th>Method step</th>
<th>PM</th>
<th>VOC</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Baseline emissions (t/year)</td>
<td>15</td>
<td>799</td>
</tr>
<tr>
<td></td>
<td>Baseline activity (kt/year)</td>
<td>323</td>
<td>323</td>
</tr>
<tr>
<td></td>
<td>BAT-AELs (g/t)</td>
<td>26</td>
<td>1,248</td>
</tr>
<tr>
<td></td>
<td>Policy emissions (t/year)</td>
<td>8.5</td>
<td>403</td>
</tr>
<tr>
<td></td>
<td>Emission reductions (t/year)</td>
<td>6.5</td>
<td>396</td>
</tr>
</tbody>
</table>

**Box 7 Application of ER2**
The ER2 approach was tested through application to the Iron and Steel sector case study. Policy emissions are calculated as follows:

\[
\text{Policy emissions} = \text{Operating hours} \times \text{Flue gas volume} \times \text{Flue gas concentration}_{\text{Policy}}
\]

The flue gas concentrations were taken from the BAT-AELs in the BREF. Given these AELs are expressed as concentrations, the methodology requires no conversion from emissions factors.

Emissions reductions were calculated for SO\(_2\) and PM emissions for a single plant (I&S Plant B). Emissions reductions for both were expected for sinter production given current emissions are above the upper BAT-AELs.

Assuming the same activity (operating hours and flue gas volume) as the baseline, emissions reductions were calculated of 1,398 tonnes of SO\(_2\) and 287 tonnes of PM.

Methods ER1 and ER2 can underestimate the emission reductions from an installation that has installed BAT. This is because real emission levels will generally be lower than the relevant BAT-AELs, as the installed equipment will need to ensure compliance with the BAT-AEL under a range of variations from normal operating conditions.

It is also important to note that most of the BAT-AELs which are expressed in concentrations are related to short periods of time (half-hourly, hourly and daily averages). Estimation of the yearly load using these average values may be therefore lead to inaccuracies.
ER3: Modelling future emission levels using abatement techniques

An alternative (or additional) method to calculate emission reductions is to consider the applicability of specific abatement techniques (ER3). In this case, rather than applying an adjustment directly to the (or adopting a new) emissions factor or emissions concentrations in order to reflect the impact of BAT, specific abatement techniques are selected to be applied. Emissions reductions are then calculated based on the efficiency improvements directly associated with the specific measure and the variance of this depending on the specific circumstances of the site. Where existing abatement techniques are in place, emissions reductions are calculated as the additional impact relative to the existing technique, whether this is replaced or improved. Considering specific abatement techniques is therefore inherently a more detailed approach. An example of this method is shown in Box 8.

BATC do not link specific techniques with BAT-AELs values but more generally indicate what techniques are considered as BAT (often one or combination of techniques is suggested). In order to apply method ER3, a methodology for selection of the abatement techniques needs to be determined first. This could be based on one or more of the following criteria:

- The reduction required to meet BAT-AELs, and the abatement efficiencies of techniques
- Suitability of technique for specific site and with respect to techniques already installed
- Value of upfront capital investment (e.g. affordability of the technique)
- Cost-effectiveness (i.e. lowest cost per tonne of pollutant abated)
- Optimisation approach which finds the least cost approach to a set of targets across multiple pollutants
- Life cycle assessment approach.

The selection of the abatement technique may also be further influenced by the national, regional, local priorities, and/or size, structure and economic importance of the industry.
Box 8 Application of ER3

The ER3 approach was tested through application to the Iron and Steel sector, and specifically to a sinter plant example.

Information on the abatement efficiency of abatement measures in the Iron and Steel sector is considered to be widely available. In this case, information on potential measures was taken from the BREF. Two measures were considered: install Regenerative Activated Carbon (RAC) or Selective Catalytic Reduction (SCR) to the process. Both are considered as BAT however the RAC process is more expensive but has the potential for reducing both SO$_2$ and NOx emissions simultaneously. In contrast, SCR only has an impact on NOx emissions.

Another key challenge for the approach is how to determine which abatement technology is assumed to be taken up/required. In this case, an abatement technology was selected first based on compliance criteria (i.e. is the measure applicable to the specific plant taking into account flue gas volumes, temperatures composition etc.) and other limiting factors (e.g. available space). If different options were still available to meet AELs, the least-cost option from the operator’s perspective was chosen. This draws a clear link between this approach to calculating emission reductions and the approaches to assessing costs below.

Once an abatement measure is selected, the emissions reductions are calculated directly as follows:

\[ \text{Emissions reductions} = \text{Abatement efficiency} \times \text{Baseline emissions} \]

As noted above, information on the abatement efficiency of the two measures was taken from the BREF. Information on unabated emissions was extracted from annual emission reports.

An illustration of the calculation of emission reductions is included in the table below.

<table>
<thead>
<tr>
<th></th>
<th>RAC process</th>
<th>SCR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abatement efficiency NOx</td>
<td>80%</td>
<td>80%</td>
</tr>
<tr>
<td>Abatement efficiency SO$_2$</td>
<td>90%</td>
<td>0%</td>
</tr>
<tr>
<td>Unabated emissions NOx (tonnes/y)</td>
<td>545</td>
<td>545</td>
</tr>
<tr>
<td>Unabated emissions SO$_2$ (tonnes/y)</td>
<td>116</td>
<td>116</td>
</tr>
<tr>
<td>Emissions reduction NOx (tonnes/y)</td>
<td>436</td>
<td>436</td>
</tr>
<tr>
<td>Emissions reduction SO$_2$ (tonnes/y)</td>
<td>104</td>
<td>0</td>
</tr>
</tbody>
</table>

Additional considerations

Based on the review of approaches to calculating emission reductions, the following observations have been made:

- An important consideration when modelling a policy scenario is what level of BAT-AEL to select, given these are commonly expressed as ranges. Ahead of the adoption of BATC and review of permits it is impossible to predict how the BAT-AELs will be translated into permit conditions – e.g. whether the lower end, higher end or a value in-between the range would be used by competent authorities. This will depend on national policy, and site specific conditions. In case of all methods (ER1, ER2 and ER3), selection of the BAT-AEL value for the assessment will have direct impact on the resulting emission reductions calculated. Specifically in method ER3, a different technique may be required to meet lower and higher end of the BAT-AEL range. The ambition level at which the BAT AEL range is implemented has therefore a crucial role for assessment of benefits of emissions reductions and subsequently costs of their attainment.
The methodologies for calculating emission reductions are not mutually exclusive:

- In order to meet certain BAT-AELs a combination of primary measures (changes to processes, fuel inputs) and secondary measures (installation of end of pipe abatement techniques) might be required. To assess emission reductions associated with a combination of primary and secondary measures it may be appropriate to assess emissions reductions achieved by primary measures using methodologies ER1 or ER2. This is based on the assumption that primary measures could result in a change of the activity levels compared to the baseline. Modelling of secondary measures may be more straightforward using end of pipe emission abatement techniques (method ER3).

- Where baseline emissions have been quantified using measured data (BE3), a variation on combination of methods ER1, ER2 and ER3 could be applied. In this approach, following selection of BAT to be applied (ER3), a ratio between current average concentrations and the expected average concentrations after implementation of BAT is calculated. This is then applied to the baseline emissions. The policy scenario emissions (which could consider specific BAT installed) would then be calculated as:

\[
\text{Policy emissions} = \frac{\text{Baseline emissions} \times \text{Concentrations under policy scenario}}{\text{Concentrations under the baseline scenario}}
\]

This approach is expected to have the same level of accuracy as methods ER1 and ER2, but could be simpler to apply.

- When applying the methodologies for calculating emissions reductions to the sector level assessments, it would usually be assumed that unabated emissions and abatement efficiency per technique are consistent over all installations considered. In reality this will not always be the case. For example, unabated emissions from sinter plants on integrated steelworks can be influenced by the types of iron ore processed, which can vary from one installation to another. In other sectors, different raw materials selections may lead to different emissions.

- Very few of the studies assessed estimated emission reductions to water. Some examples of the specific approaches taken include:

  - The costs of meeting the BAT-AELs to water in the refineries sector were assessed in [2]. While the approach to estimating the costs was not described in detail, the study estimated the number of refineries in the EU that will require additional investment in on-site waste water treatment. However, the details of the technology selection process were not described and it is unclear based on the study which BAT-AELs were considered. Nevertheless, the general approach followed the ER3 methodology as upgrade of the existing water treatment facilities was assumed.

  - Study [25] for the pulp and paper sector used reported emission levels to water across the sector, and divided them by product output in order to compare them to the BAT-AELs which for the pulp and paper sector were defined per tonne of product. The general approach applied followed the ER1 / ER2 methodologies in that emissions under the BATC scenario (in this case expressed per unit of product) were compared to emissions reported under the baseline.

Summary of methods for calculating emission reductions

Table 6 presents a summary of the methods for the final step of estimating emission reductions, including examples of studies where a given approach was used. Because more than one approach could have been used in a single study, the same reference can be included for more than one method category.
Table 6 Categorisation of methods for calculation of emission reductions

<table>
<thead>
<tr>
<th>ID</th>
<th>Method name</th>
<th>Description</th>
<th>Key inputs</th>
<th>Examples of studies using this approach</th>
</tr>
</thead>
<tbody>
<tr>
<td>ER1*</td>
<td>BATC Emission factor (EF)</td>
<td>BATC Emission factor (kg/unit of activity) is multiplied by corresponding activity value in the year of BATC coming into force</td>
<td>Activity levels, BATC Emission factors</td>
<td>[7], [10], [11], [14], [25]</td>
</tr>
<tr>
<td>ER2*</td>
<td>BATC Concentration (BAT-AEL)</td>
<td>BAT-AELs (waste gas concentration) is multiplied by corresponding activity value in the year of BATC coming into force (and other inputs required to match concentration and activity values)</td>
<td>Operating hours, BATC concentration in output, Other parameters (gas flows, wastewater flows)</td>
<td>[4], [6], [11], [12], [21], [43] – LCP sector only, [C1]</td>
</tr>
<tr>
<td>ER3**</td>
<td>Abatement techniques</td>
<td>Abatement efficiency (%) of techniques is applied to “future emissions” or “baseline” scenario.</td>
<td>Reductions required to meet BAT-AELs, Abatement efficiency of technique(s) (%)</td>
<td>[3], [7], [8], [10], [19], [21], [23], [43] – other sectors, [53], [C1]</td>
</tr>
</tbody>
</table>

*Emission reductions for method ER1 and ER2 are calculated by subtracting the policy from the future emissions or baseline scenario (ER1-FE1) or (ER1-BE1), or (ER2-FE1) or (ER2-BE2).

**Depending on the information available regarding the abatement technique, ER3 can be applied to all baseline (BE1, BE2, BE3, BE5) and future emissions excluding BAT (FE1-2) approaches. That said, this approach sits most consistently with BE5, where the abatement measures assumed in the baseline can be compared to those under the with-policy scenario to ensure consistency.
3.4 Methods to assess the costs of achieving emission reductions

3.4.1 Overview

The review identified and evaluated a number of studies which address the costs of emissions abatement from industry. The methodologies have been summarised into three distinct groupings, as presented in Figure 5 below. These are:

- use of marginal abatement costs (method CO1)
- direct costing of additional investment (method CO2), and
- costing of the impact of BATC on the basis of loss in productivity (method CO3)

The approaches vary both in terms of the detail of the assessment and what impacts are included.

For example, the costs captured by approaches CO1 or CO2 are likely to be similar in nature (e.g. CAPEX, OPEX), although the coverage of exactly what cost components are included vary both between the methodologies and between studies following the same approach. Given the potential overlap in coverage, approaches CO1 and CO2 are considered mutually exclusive. However, some studies applied these together for the same sector. In [7], in cases where insufficient data was available to apply method CO2, method CO1 was used to estimate costs to emissions abatement. It should also be noted that method CO2 is used as the basis of deriving marginal abatement costs for approach CO1, as demonstrated in [11] and [28].

The costs captured under approach CO3 (which assesses impacts on productivity) are typically distinct from and additional to those assessed under CO1 or CO2. As such, CO3 can usually be implemented alongside the other approaches, typically as one of the cost components of CO2. For example, [40] advises that assessment of operating costs should include any changes in production capacity.

Whether meeting BATC affects emissions to air or water, the methodological options for assessing costs are similar: there is less difference relative to the assessment of benefits discussed in the following section.

Across all three approaches, there are a number of factors which need to be considered when assessing the costs of abatement technologies:

- **The approach used will be strongly linked to the methodology taken to assess emissions impacts**: For example, where emissions reductions are assessed at a high level and specific abatement options are not identified, then this exercise would need to be undertaken as part of the costings if CO2 was applied. However, combining these two approaches could create inconsistencies in outputs as the benefits would potentially be underestimated (as they would
be based on achieving the BAT-AELs precisely rather than over-achieving through application of specific abatement techniques). In this case it may be more appropriate to apply generic marginal abatement costs (CO1) for consistency. Hence the granularity of the emissions assessment will influence what cost assessment approach are appropriate and feasible.

- **It is important to define the perspective of the analysis:** Costs can be assessed from a range of different viewpoints: e.g. cost to private firms, consumers, government or on society as a whole. Depending on the viewpoint of the analysis, particular costs may be included or excluded (e.g. taxes, subsidies and other transfers would not be included under a ‘societal’ analysis). Given the assessment of BATC typically entails comparing the relative size of private costs to societal benefits, cost-benefit analysis most often adopts a societal perspective. This is consistent with the Guide to Cost-benefit Analysis of Investment Projects (EC, 2015). This will also have an influence on other parameters for the analysis, such as the discount rate used.

- **Typically, assessment follows a principle of proportionality:** Following this principle, costs are only assessed where they are considered likely to be significant such as to have a bearing on the overall conclusions of the analysis. Hence some cost components may be omitted where they are considered negligible.

- **Inclusion of indirect costs:** There are three types of costs which can be assessed: direct (i.e. financial or administrative costs), indirect (wider costs to the installation) or induced costs (secondary knock-on effects) [192]. Generally, many of the studies that assess costs focus on the direct costs of meeting BAT, i.e. the capital costs and operating costs of the measure. Some studies also estimate indirect or induced impacts of emission mitigation technologies, such as [52] which also assesses macro-economic costs and employment impacts of new regulation. Impacts on the security of energy supplies is a further example of indirect costs, most applicable to LCPs. These impacts can be assessed by valuing directly the change in energy served using either estimates of Willingness-to-Pay for increased reliability and security of energy supply or a social-cost of non-served energy (EC, 2015). Where a reduction in energy security is considered, an alternative approach to valuation is to apply the cost of an alternative, new source of supply to mitigate any potential shortfall in energy served (i.e. applying a ‘cost-based’ valuation method). Typically, indirect and induced costs tend to be less significant, require more resource to assess, are more difficult to quantify and monetise, and have a greater level of uncertainty: hence the focus of this study is on methodologies to assess direct costs. Whichever costs are included in the assessment, where more than one option is assessed it is important that in the analysis consistent cost categories are assessed across scenarios as emphasised by [46].

- **Information required for cost assessment is often commercially sensitive:** Costs of applying abatement technologies will be facility-specific and among other, will depend on volume of flue gas or wastewater that requires treatment. As such, where costs are assessed (particularly at a high-level of granularity), it may be difficult to acquire reliable data given commercial sensitivities and/or data needs to be handled appropriately (that said, abatement techniques tend to be fairly standard and as such costs can be similar: variation often relates to space or access for installing equipment). Furthermore, where data can be gained it may then be difficult to verify the robustness given lack of comparable data, in particular where incentives exist which may influence the providers of information (e.g. in application for derogation where information is provided by the applicant). For that reason, in modelling of impacts of BATC by Danish Ministry of Environment [C1], data on cost of abatement equipment collected from suppliers of abatement techniques was favoured given their experience of installing equipment in different types of installations. Existing data sources on the costs of abatement equipment are discussed in section 4.2.

- **What output is required:** Cost information can be presented in a range of different ways. Depending on the outputs of the analysis, this may have an influence on the approach selected. For example, where a lifetime net present value is required, a more detailed approach under CO2 may be more attractive over CO1 to ensure the required outputs are delivered.

- **Expressing costs as relative rather than absolute values:** Presenting costs as absolute values does not provide an understanding on whether the costs are acceptable or proportionate. Setting the costs in the context of the benefits (i.e. damages avoided) or
expressing costs per unit produced and comparing these to the unit production costs, can be used to provide indication of the scale of the costs.

Furthermore, in cases where BAT-AELs are expressed as a range, the upper BAT-AELs (less strict) would represent the minimum cost to the industry of achieving BAT-AELs. The choice of which BAT-AEL from a range is used for estimating costs must be consistent with the choice used to estimate emission reductions.

3.4.2 CO1: Marginal abatement costs method

Under this approach, estimates of emission reductions are multiplied by a representative cost per tonne of pollutant abated to obtain an estimate of total cost. This method assumes use of ready marginal abatement cost data (rather than initial derivation of the marginal abatement costs). This approach is generally high-level and less detailed compared to method CO2 (see section 3.4.3). A number of studies apply this approach (studies listed in Table 7), however overall fewer examples were identified across the studies reviewed compared to method CO2. Studies identified which applied this approach typically use cost per tonne estimates from secondary sources (such as the GAINS model and BREFs), rather than primary data collection. Box 9 illustrates the application of method CO1.

**Box 9 Application of CO1**

A useful illustration of CO1 can be provided using data available from the GAINS model (as discussed in further detail in Section 5.2.5). GAINS provides (output) cost information for a given control strategy expressed either as cost per tonne of pollutant abated, or as cost per unit of activity abated. This data can then be multiplied by the calculated emission reduction, to obtain the estimate of the total abatement cost.

\[
\text{Total abatement cost} = \text{Emissions reduction} \times \text{Cost per tonne of pollutant abated}
\]

The table below presents example cost information provided in GAINS (which would vary by MS) for some control strategies for sinter as an illustration. Note GAINS calculates output cost per unit of activity abated based on detailed capital and operating input cost data.

<table>
<thead>
<tr>
<th>Sector</th>
<th>Abatement description</th>
<th>Cost (million EUR per million tonnes of sinter)</th>
<th>Cost (EUR per tonne of PM$_{2.5}$ abated)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PR_SINT</td>
<td>Cyclone</td>
<td>0.2</td>
<td>1,456</td>
</tr>
<tr>
<td>PR_SINT</td>
<td>ESP 1 field</td>
<td>0.3</td>
<td>641</td>
</tr>
<tr>
<td>PR_SINT</td>
<td>ESP 2 field</td>
<td>0.4</td>
<td>746</td>
</tr>
<tr>
<td>PR_SINT</td>
<td>High efficiency deduster</td>
<td>0.5</td>
<td>834</td>
</tr>
</tbody>
</table>

Where the calculation of emission reductions does not identify a specific abatement technique (method ER1 or ER2 is used) and the share of total activity that needs to be abated is also unknown, an average cost per unit of activity or per tonne of pollutant abated could be used in the following equation:

\[
\text{Total abatement cost} = \text{Emissions reduction} \times \text{Average cost per tonne of pollutant abated}
\]

\[
\text{Total abatement cost} = \text{Activity} \times \text{Average cost per unit of activity}
\]

This calculation could provide a high level assessment of likely costs of compliance with BATC in cases where there is high uncertainty around the techniques that will be taken up.

An example of the calculation is provided in Section 5.2.5, which discusses the use of the GAINS model as a data source.

One of the advantages of this method comes from its simplicity: as the approach is relatively high-level, it can be applied in situations where mitigation measures are not identified, either due to lack of granularity in modelling, limited data or uncertainty around mitigation measures deployed. Costs of abatement techniques will be inherently installation specific: in order to simplify the assessment marginal abatement costs represent an average application of a technique. Depending on the
methodology used to develop the costs, this could be an average across a group of installations, a sub-sector, a sector or wider.

There are a number of factors to consider when applying this approach, in particular around the application of cost per tonne estimates from secondary sources:

1. Is it clear what the cost per tonne figure is and what it represents (e.g. unit or sector specific)? For example, both the numerator and denominator could be expressed in terms of annualised or lifetime figures.

2. Is the methodology with which the cost per estimates have been estimated clearly documented? For example, different studies could use different discount rates (or even not apply discounting) or price bases.

3. Is it clear what costs are included? For example, are capital costs, fixed and variable operating costs included? Are impacts on other pollutants included? How have financing costs been treated? In addition, is it clear what costs are not included?

4. Are the sources of data used to estimate the cost per tonne figures clearly documented? Are they appropriate to the situation to which they are being applied? For example, where cost per tonne estimates are taken from a particular installation, it may apply country-specific energy prices or facility specific-costs?

5. Are costs:
   a. Technology specific (i.e. cost of achieving a unit of emissions reductions using specific type of equipment)
   b. Average for the sector (i.e. average cost of achieving a unit of emissions reductions in a given sector, based on the modelling of different abatement techniques applicable to the sector)?

6. Based on the above, are cost estimates consistent with any over-arching appraisal guidance which needs to be adhered to?

Marginal abatement costs calculated in different ways can equally be useful in the calculation (e.g. if these are annualised or estimated on a lifetime basis). Most importantly, knowledge of these different factors is important to ensure the marginal abatement costs available are applied correctly in the calculation of costs (and to know whether they need to be adjusted), and to ensure the results are presented and interpreted appropriately. The accuracy of the method CO1 would depend on how representative the marginal costs are of the installations within a sector. In cases where these differ widely (e.g. due to the age of the plants), application of “typical” costs per tonne of pollutant abated may not be appropriate. In the course of the study some industry stakeholders raised concerns over the use of the CO1 methodology since it fails to account for differences between installations.

3.4.3 CO2: Detailed cost assessment

This method is only applied where abatement measures are identified, for example as part of the emissions assessment (if method ER3 is used), or as an additional step if methods ER1 or ER2 are used. In this method specific information on the costs associated with each mitigation measure is collected (e.g. capital costs, operating costs). The ECM BREF recommends that all costs should be calculated and presented as annual costs\(^\text{12}\). Two approaches for such calculations are recommended in the ECM BREF. The methods are presented in Box 10 and applied as examples in Box 11. As demonstrated in the examples, in the case where capital costs are incurred in year 0 only and operating costs are fixed each year, the two approaches are the same and yield the same result.

\(^{12}\) Also referred to as ‘equivalent uniform annual cost’, ‘equivalent uniform annual net disbursements’, ‘annual worth-cost’, or ‘annualised cost’.
Box 10 Two methods of calculating annual costs

**Approach 1**

In this approach total annual costs are calculated by multiplying present value of the total cost stream by the capital recovery factor.

\[ \text{Total annual costs} = \text{present value of the total cost stream} \times \text{capital recovery factor} \]

The present value of the total cost stream is investment expenditure plus net operating and maintenance costs. Net costs mean the difference between additional gross costs associated with implementing a technique and the benefits, revenues, and avoided costs that will result. In case of profitable techniques, costs will be negative.

\[
\text{Present value of the total cost stream} = \sum_{t=0}^{n} \frac{(C_t + OC_t)}{(1 + r)^t}
\]

where:
- \(t=0\) the base year for the assessment
- \(C_t = \text{total investment expenditure on the proposal in period } t\) (typically one year)
- \(OC_t = \text{total net operating and maintenance cost on the proposal in period } t\)
- \(r = \text{the discount (interest) rate per period}\)

The capital recovery factor is calculated using the discount rate \(r\) and the economic lifetime of the equipment in years \(n\), according to the following equation:

\[
\text{Capital recovery factor} = \frac{r (1 + r)^n}{(1 + r)^n - 1}
\]

Total annual cost = the present value of the total cost stream (investment expenditure plus net operating and maintenance costs) \(\times\) capital recovery factor

**Approach 2**

In this approach capital costs are first annualised. Total net annual operating and maintenance costs are then added to obtain the total annual cost.

\[
\text{Total annual costs} = (\text{capital costs } \times \text{capital recovery factor}) + \text{total net annual operating and maintenance costs}
\]

The capital recovery factor is calculated in the same way as in approach 1.
Box 11 Examples for calculating annual costs

**Approach 1**

Assuming the following parameters:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Discount rate per period (r)</td>
<td>12%</td>
</tr>
<tr>
<td>Economic lifetime of experience (n)</td>
<td>15 years</td>
</tr>
<tr>
<td>Total investment (CAPEX, C&lt;sub&gt;t&lt;/sub&gt;)</td>
<td>EUR 73,000,000</td>
</tr>
<tr>
<td>Annual net operating and maintenance costs (OPEX, O&lt;sub&gt;t&lt;/sub&gt;)</td>
<td>EUR 780,000 per year</td>
</tr>
</tbody>
</table>

Present value of the total cost stream:

<table>
<thead>
<tr>
<th>Year</th>
<th>CAPEX (mEUR)</th>
<th>OPEX (mEUR)</th>
<th>Total cost (CAPEX and OPEX discounted) (mEUR)</th>
<th>Present value of the total cost stream (mEUR)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>73</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td></td>
<td>0.78</td>
<td>73 * 0.78 / (1 + 0.12)&lt;sup&gt;15&lt;/sup&gt; = 70.32</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>0.62</td>
<td>73 * 0.78 / (1 + 0.12)&lt;sup&gt;15&lt;/sup&gt; = 70.32</td>
<td>78.31</td>
</tr>
<tr>
<td>3</td>
<td></td>
<td>0.56</td>
<td>73 * 0.78 / (1 + 0.12)&lt;sup&gt;15&lt;/sup&gt; = 70.32</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td>0.50</td>
<td>73 * 0.78 / (1 + 0.12)&lt;sup&gt;15&lt;/sup&gt; = 70.32</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
<td>0.44</td>
<td>73 * 0.78 / (1 + 0.12)&lt;sup&gt;15&lt;/sup&gt; = 70.32</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td></td>
<td>0.40</td>
<td>73 * 0.78 / (1 + 0.12)&lt;sup&gt;15&lt;/sup&gt; = 70.32</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td></td>
<td>0.35</td>
<td>73 * 0.78 / (1 + 0.12)&lt;sup&gt;15&lt;/sup&gt; = 70.32</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td></td>
<td>0.32</td>
<td>73 * 0.78 / (1 + 0.12)&lt;sup&gt;15&lt;/sup&gt; = 70.32</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td></td>
<td>0.28</td>
<td>73 * 0.78 / (1 + 0.12)&lt;sup&gt;15&lt;/sup&gt; = 70.32</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td></td>
<td>0.25</td>
<td>73 * 0.78 / (1 + 0.12)&lt;sup&gt;15&lt;/sup&gt; = 70.32</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td></td>
<td>0.22</td>
<td>73 * 0.78 / (1 + 0.12)&lt;sup&gt;15&lt;/sup&gt; = 70.32</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td></td>
<td>0.20</td>
<td>73 * 0.78 / (1 + 0.12)&lt;sup&gt;15&lt;/sup&gt; = 70.32</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td></td>
<td>0.18</td>
<td>73 * 0.78 / (1 + 0.12)&lt;sup&gt;15&lt;/sup&gt; = 70.32</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td></td>
<td>0.16</td>
<td>73 * 0.78 / (1 + 0.12)&lt;sup&gt;15&lt;/sup&gt; = 70.32</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td></td>
<td>0.14</td>
<td>73 * 0.78 / (1 + 0.12)&lt;sup&gt;15&lt;/sup&gt; = 70.32</td>
<td></td>
</tr>
</tbody>
</table>
The majority of studies reviewed which assess costs are observed to apply method CO2. Relative to CO1, this method is typically more resource intensive given its higher level of detail and can involve gathering information from either primary (e.g. [41] or [13]) or secondary sources (e.g. costs quoted in BREF used in [19]).

Given the higher level of detail required, there are more considerations to take into account when applying this method:

1. To the extent possible, only costs which are additional to the baseline or future emission scenarios should be included. As such, whether the investment is additional to, replaces (in part or fully) existing or future planned abatement technology, this needs to be defined and accounted for. Given that the same measure at two similar installations may be very different, understanding the installation specific retrofit components of the costs is critical for successful application of method CO2 in the view of some industry stakeholders. Furthermore, to recognise the variability of costs across installations, a range of cost values could be used for sector-level assessments to account for sensitivity of final results to changes in cost assumptions. Where existing abatement techniques are replaced, the residual value or any stranded costs should be included in the assessment. The type and age of the existing abatement technology may influence the comparison between costs and benefits, in particular where discounting is applied. It is recognised that data on the costs of the abatement already fitted across installation are challenging to gather, partly because of the potential commercial sensitivity of this information.

2. The discount rate applied, assumed lifetime of the techniques, any inflation parameters and price base year should be clearly defined in the assessment and consistent with the assumptions used for the assessment of benefits. These parameters are necessary for execution of the CO2 method and can influence the results of a cost-benefit analysis. Furthermore, the level of discount rate or inflation parameters to be used in the assessment is likely to differ across EU Member States as it could be pre-defined in national impact assessment guidelines.

3. The coverage of capital costs: There are a list of possible upfront costs which could be applicable, including: project definition, design and planning; purchase of land; general site preparation; buildings and civil works; engineering, construction and field expenses; contractor selection costs; contractor fees; performance testing; start-up costs; cost of working capital; and decommissioning costs. Ideally, when determining capital costs of the abatement technique the capacity of the installation (e.g. emission flow volumes, electrical capacity of the installation) should be considered. For example, [1] directs the user to include different elements of capex including project development expenditure, installation, administration, start up, and financing costs but not all studies cover all or the same categories of cost. This depends on what is relevant and feasible in each case. In some cases, there may be no capital costs applicable: for example, [9] assesses only changes in operating costs under alternative management scenarios of a manufacturing unit. Depending on the study, capital costs may or may not include financing costs (also referred to cost of capital). Consideration of the financing costs could consider the payback period for any capital, and a weighted average cost of capital (WACC)\(^\text{13}\).

4. The coverage of operating costs: as with capital costs, there are numerous types of operating costs which may be applicable. Operating costs can be split into fixed (i.e. elements independent from the output of the plant such as insurance premiums, license fees, emergency provisions, administration and other general overheads) and variable (i.e. elements dependent on the output of the plant, such as labour costs: operating, supervisory, maintenance staff, training) costs. The impact of operating costs should not be underestimated as views from some

\(^{13}\) Weighted average cost of capital is the cost that an operator pays to borrow money to fund the investment. It is composed of interest on loans and dividends on equity.
stakeholders collected in the course of the study suggested that operating costs may often be more important (i.e. have higher impact) than capital costs. For example, [3] includes both fixed (insurance and maintenance not related to operating hours) and variable costs (spare parts / energy) in its assessment. All types of operating costs should be considered: their inclusion will depend on the availability of data and information to assess the impacts, and their likely significance (assuming the principle of proportionality is followed). It is also important to note that operating costs are sometimes presented net of cost savings, for example as in [40].

5. Depending on the perspective of the analysis, it may be appropriate to include additional cost elements such as taxes, subsidies and revenues as discussed in [24].

6. Finally (and in connection to method CO3), some sources include subsequent costs and benefits of the measure resulting from changes in effectiveness of production or of quality of the product within this calculation [24]. Changes in production represent a real cost or benefit to society and hence should be included in the assessment, although these should be detailed separately to the direct costs as noted in [24]

Considering costs of achieving water emissions reductions, Annex D1 to the WATECO guidelines describes methodological tools for undertaking the economic analysis in the context of the Water Framework Directive (WFD). The WFD defines the costs of measures as ‘economic costs’ – these are the costs to society as a whole, rather than costs to a specific economic operator. The specific components of the economic costs are:

- Financial costs – these are capital, operational and maintenance costs, administrative costs as well as other direct costs; these need to focus on the net cost including any savings or financial benefits, also known as ‘negative costs’.
- Resource costs – these are scarcity costs.
- Environmental costs – water and non-water related environmental costs\(^{14}\).

In terms of application of the costing principles outlined in the guidelines to the impact of BAT-AELs (the ECM BREF, reference [24]), the estimation of financial costs aligns with method CO2. The guidelines specify that capital costs should be spread over a number of years using the Annual Equivalent Cost method; and that depreciation, cost of capital and administrative costs should be included in the assessment. Notably the guidelines also state that other direct costs, such as the cost of productivity losses due to restrictive measures should also be captured in the assessment.

Method CO2 is applied as an illustration in Box 12 for the iron and steel sector case study.

\(^{14}\) Represents the costs of damage that water uses impose on the environment and ecosystems and those who use the environment. Where a policy reduces water use or its potential associated damages, this would represent a negative cost or a benefit.
Box 12 Application of CO2

The illustration of emissions reduction calculations following the ER3 approach under the Iron and Steel sector case study was continued to calculate costs following CO2. Costs were calculated for the two abatement options (RAC and SCR) considered for a sinter plant.

Information on CAPEX and OPEX associated with each measure was taken from the BREF. In its simplest form, the calculation then involves summing the costs for each measure type. However, some adjustments to these costs may be required to ensure they are consistent. In this case, capex costs were adjusted to reflect: the site specific capacity, the premium for higher efficiency DeNOx configuration and to inflate the costs to a consistent price base. Further, an interest rate of 12% and an economic lifetime of 15 years was used to annualise the costs to reflect the nature of the investment from a private perspective.

In this case, the total cost was calculated and expressed as a percentage of production cost for reference: The installation of RAC process would increase the production cost by almost 5% whereas the impact of an SCR is 3%. Further a unit of NOx reduction is evaluated at €17 per kg for an SCR. For RAC the cost is estimated to be € 32 per kg but this does not include for the additional SO2 benefit. An illustration of the data inputs and the calculation are presented in the following table.

<table>
<thead>
<tr>
<th>Calculation step / result</th>
<th>Units</th>
<th>Abatement measure: RAC process</th>
<th>Abatement measure: SCR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sinter production</td>
<td>Tonnes</td>
<td>758,800</td>
<td>758,800</td>
</tr>
<tr>
<td>CAPEX reference installation</td>
<td>€m</td>
<td>73</td>
<td>27</td>
</tr>
<tr>
<td>Year reference installation in BREF</td>
<td>Year</td>
<td>1991</td>
<td>1997</td>
</tr>
<tr>
<td>Capacity factor (volume)</td>
<td>(Unit-less factor)</td>
<td>0.53</td>
<td>1</td>
</tr>
<tr>
<td>Inflation factor (2% per annum)</td>
<td>(Unit-less factor)</td>
<td>1.6</td>
<td>1.5</td>
</tr>
<tr>
<td>Premium for higher efficiency DeNOx configuration</td>
<td>(Unit-less factor)</td>
<td>1.36</td>
<td>1</td>
</tr>
<tr>
<td><strong>Total estimated CAPEX</strong></td>
<td>€2016m</td>
<td>86</td>
<td>39</td>
</tr>
<tr>
<td>Discount rate</td>
<td>%</td>
<td>12%</td>
<td>12%</td>
</tr>
<tr>
<td>Depreciation period</td>
<td>Years</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td><strong>Yearly capital cost</strong></td>
<td>€m</td>
<td>12.6</td>
<td>5.8</td>
</tr>
<tr>
<td><strong>Capital cost/tonne sinter</strong></td>
<td>€/ tonne sinter</td>
<td>16.6</td>
<td>7.6</td>
</tr>
<tr>
<td>OPEX reference installation</td>
<td>€/ tonne sinter</td>
<td>0.75</td>
<td>2</td>
</tr>
<tr>
<td>Premium for higher efficiency DeNOx configuration</td>
<td>(Unit-less factor)</td>
<td>1.66</td>
<td>1</td>
</tr>
<tr>
<td>Maintenance</td>
<td>€/ tonne sinter</td>
<td>0.28</td>
<td>0</td>
</tr>
<tr>
<td><strong>Total unit cost/tonne sinter</strong></td>
<td>€/ tonne sinter</td>
<td>18</td>
<td>9.6</td>
</tr>
<tr>
<td><strong>Impact on steel production cost</strong></td>
<td>%</td>
<td>5%</td>
<td>3%</td>
</tr>
</tbody>
</table>

Note that the 12% discount rate illustrated may reflect the costs borne by industry when financing investments. However, 4% is the typical discount rate recommended for use by Commission evaluation guidance.

---

15 For RAC, a single stage process for NOx abatement will reduce emissions by around 40%. In order to achieve higher abatement efficiency, a two stage process should be deployed. The premium for higher efficiency DeNOx configuration reflects that cost of a two stage process is expected to be around 36% higher compared to the reference installation in the underlying data source.
3.4.4 CO3: Cost of lost value added

The third approach identified focuses on the cost of reduced revenue associated with application of BAT. This applies in cases when the economic operation of an installation is affected by applying BAT: either the quantity, quality or type of products produced may change, which in turn may have an influence on revenue of the operator. Evidence of this approach has been identified in study [C1] on the impacts of BATC for the intensive rearing of poultry and pigs sector. In the study the implementation of BATC was identified to require major infrastructure changes (i.e. closure / reconstruction of existing buildings) and/or decrease in productivity due to changes in the composition of animal feed. Assessing impacts on productivity was also proposed as one of the cost components in the ECM BREF [24]. Typically, however, impacts on economic operation of installations are difficult to verify, in particular in the medium to long term, given the large number of factors influencing operations.

3.4.5 Additional considerations

Based on the review of the approaches to calculating costs of emission reductions, the following observations could be made:

- Similarly to the methods for establishing baseline emissions, the identified methodologies to assess the costs of emission reductions are also interlinked. Specifically method CO2 is used to derive cost per tonne of pollutant abated (used in method CO1) and method CO3 could be one of the cost components for execution of method CO2.

- Consideration of the loss in value added could be included as part of the CO2 methodology (for example as suggested in European Commission (2003)). For example, this could account for the value lost during the plant shutdown for the purpose of retrofitting the abatement equipment. However, in some studies [41] this cost element has been purposely excluded on the assumption that implementing BAT would not change the output / operation of the plant – i.e. quantity or quality of output.

3.4.6 Summary of methods for calculating costs

Table 7 presents a summary of the methods for calculating costs of achieving emission reductions, including examples of studies where a given approach was used. Because more than one approach could have been used in a single study, the same reference can be included for more than one method category.
### Table 7 Categorisation of methods for cost calculation of required emission reductions

<table>
<thead>
<tr>
<th>ID</th>
<th>Method name</th>
<th>Description</th>
<th>Key inputs</th>
<th>Examples of studies using this approach</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO1</td>
<td>Using marginal abatement cost</td>
<td>Marginal abatement costs (expressed in the unit of cost per tonne of pollutant abated) are applied to the emission reductions associated with BAT-AELs.</td>
<td>Marginal abatement cost (unit of cost per unit of pollutant abated)</td>
<td>Studies that used marginal abatement costs: [7], [19], [23], [30], [53]</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Emissions reductions of abatement technology</td>
<td>Studies that derive marginal abatement costs: [8], [11], [18], [28], [45]</td>
</tr>
<tr>
<td>CO2</td>
<td>Costing of additional investment (using CAPEX and OPEX)</td>
<td>For selected primary or secondary measures, the costs of additional investment required to meet BAT-AELs is based on: Capital costs and Operational costs. Capital costs may be annualised using lifetime of a measure and discount rate to provide estimation of the total annual cost of measure. Otherwise costs can be presented as a total over the lifetime of the measure.</td>
<td>Capital cost (CAPEX / capital investment costs)</td>
<td>[C1], [1], [2], [3], [7], [8], [9], [10], [11], [14], [19], [22], [24], [26], [28], [29], [32], [40], [41], [42], [43], [44], [46], [51], [52], [53], [54]</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Operational costs</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Lifetime of the measure</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Discount rate</td>
<td></td>
</tr>
<tr>
<td>CO3</td>
<td>Loss in value added</td>
<td>Costs are estimated based on the impact of the measures on the production or quality of the final product.</td>
<td>Change in the quantity or type of product</td>
<td>[C1], [24]</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Change in quality of the product</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Price or change in price of product</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Added value per unit of product (i.e. profit per unit of product)</td>
<td></td>
</tr>
</tbody>
</table>
3.5 Examples from literature of combination of methodologies used to assess emission reductions and costs of BATC

This section summarises approaches used in two studies that have assessed the impacts of BATC. Both adopt approaches to set a baseline, assess emissions reductions and the costs associated with the BAT-AELs. A key difference between the two is the overall approach to the assessment at sector level: the first study by CONCAWE takes a detailed plant-by-plant approach to assess impacts for the refinery sector across Europe, whereas the second study – by Pöyry – assesses the impacts for a representative plant. The examples illustrate potential combination of methodologies for calculation of emission reductions, costs and benefits that have been used.

CONCAWE (2014): The estimated forward cost of EU legislation for the EU refining industry (application of methods BE3 and BE2 for baseline, ER3 and CO2 to the plant-by-plant assessment)

This study investigated the potential cost burden of a number of EU legislative and implementing acts that are applicable to the refining sector, including the IED.

The study first developed a baseline of air pollutant emissions for the refinery sector in the EU on a plant-by-plant basis. CONCAWE used detailed data from its four-yearly ‘Refinery Sulphur Survey’ regarding the actual physical and operational situation across European refineries. This activity was combined with assumed ranges of ‘current’ NOx and dust concentrations given actual concentration data was not available from the sulphur survey (method BE2 for NOx and dust). Baseline emissions were not projected forward to develop a future emission scenario (FE1 method not used).

Emission reductions were assessed through a detailed, bottom-up assessment approach: for each individual refinery unit level. Abatement techniques were considered for the fluid catalytic cracking unit (FCCU), the sulphur recovery unit (SRU) and the combustion stack. Their applicability was assessed and techniques allocated based on the detailed installation data provided by the refinery sulphur survey (including consideration of technologies currently in place). Achievement of AELs was then determined by comparing the achieved level of emissions and performance in each specific unit against the upper and lower BAT-AELs proposed for the fluid catalytic cracking unit (method ER3). The total sector-wide cost of additional abatement measures required to comply with proposed AELs was the sum of the costs of the techniques required to achieve AELs at each individual refinery unit (method CO2).

Given that the sulphur survey did not cover every single refinery in the EU, the results obtained for the participating facilities were extrapolated to the EU-level using a ratio between the total crude processed in the EU in 2010, and the crude processed in the participating refineries.

Pöyry (2013): Cost analysis of reducing flue gas emissions to achieve the BAT emission levels in peak load boilers using liquid fuels and natural gas (application of methods BE2, ER3 and CO2 to a hypothetical plant)

This study investigated the impacts of BAT-AELs proposed for existing boiler plants in the draft LCP BREF during its development. The scope covered 55MW boilers currently using heavy oil or natural gas, and considered the cost-efficiency of reducing flue gas emissions in peak load boilers. Rather than assessing the impacts of BATC at a particular plant or for all installations in a given MS, the study instead considered the impacts for a single, hypothetical plant.

To set a baseline, current emission limit values based on the LCP Directive (2001/80/EC) for existing boilers were used (method ER2). The required emissions reductions were assessed by comparing these current limits with the AELs proposed in the draft BREF. Different abatement techniques were assumed to be applied to the hypothetical plant and the impact on emission concentrations was assessed (method ER3). Resulting concentrations were compared to the proposed AELs to assess compliance.

The study undertook a detailed assessment of costs associated with the different abatement techniques. This captured the investment cost (including financing costs, cost of the equipment, tie-ins and project management and site supervision costs) and operational costs (e.g. energy and maintenance costs) (method CO2). Different costs were calculated for different boiler types (peak, mid-merit or base load) with different annual operation times. The study was undertaken based on the
3.6 Methods to assess benefits of emission reductions

The primary benefits of meeting BAT-AELs will be reductions in emissions of pollutants to air and water. From the literature review, a range of methods have been identified to monetise the subsequent affects. These methods have been summarised into 5 groups for air and 6 groups for water.

The methods described in section 3.6.1 and section 3.6.3 monetise: for air, the benefits of emission reductions by valuing impacts on human health, and for water, the value of good quality water respectively. Some stakeholders stated that these methodologies are incomplete, as neither monetises the real (full) value of a high level of environmental protection. Nevertheless, understanding the costs of compliance with BAT-AELs should be set in the context of the benefits the policy achieves. A method to monetise benefits of emission reductions, even if incomplete, allows comparing cost to operators with benefits to the environment.

Two factors should be considered when estimating impacts for either air or water. **First, the inclusion of secondary benefits.** Alongside influencing emissions to air and water, applying BAT could also have a number of wider effects, such as reducing GHG emissions or fuel consumption. These are often assessed in addition to impacts on air or water emissions, for example as in the UK’s MPMD [7]. As discussed in section 1.3, the study has not considered the methodologies to account for cross-media effects. The wider economic benefits of the BATC could include, among others, market share and jobs for technology providers, incentive for technology development, and opportunity for export of green technologies.

Feedback from some stakeholders suggested that the benefits of BATC at the sectoral level should only cover quantification of emission reductions (i.e. without an attempt to monetise wider benefits). On the contrary, others were of the opinion that monetisation of benefits seems to be the only approach to enable a meaningful comparison with costs of compliance.

**The second is what impacts are not captured.** Using existing appraisal methodologies will inherently omit some impacts associated with air and water pollution from the analysis. Appraisal approaches are a work-in-progress. Where there is sufficient confidence in the underlying evidence base and data are available, assessment methodologies have been developed to allow quantitative assessment of impacts (e.g. the mortality effects of chronic exposure to particulates in the air). In some cases, although certain impacts are known to be associated with pollutants, the evidence base supporting assessment is considered not yet strong enough to allow quantitative assessment. This includes a range of human and environmental health effects of air pollution (e.g. many of the effects of air pollutants on ecosystem services) and the impacts of the emission of many pollutants to water. When drawing together the analysis performed, it is important to recognise which impacts have and have not been captured in the analysis to be transparent about the comprehensiveness of the assessment.

### 3.6.1 Methods for monetising the impacts of emission reductions to air

**Overview**

The groupings of approaches differ both in terms of the detail of the approach and the situation in which they are applied. Typically which approach is followed will depend on the situation and specifically the data, resource and modelling capability available. The outputs from the preceding emissions assessment are a key input in assessing the benefits associated with a change in emissions to both air and water.

A key consideration when estimating impacts to air is the availability of data, models and modelling expertise: The Impact Pathway Approach (ABE1 and ABE4) is relatively resource intensive relative to the damage (ABE2) or abatement cost (ABE3) approaches. As such, resource and access to relevant models may influence choice of approach.
Figure 6 Methods for assessment of benefits of air emission reductions

ABE1 and ABE4: Impact pathway approach without and with monetisation

The impact pathway approach (see Figure 7) sets out a series of methodological steps from the identification of source and quantity of emissions, modelling of dispersion and exposure, assessing health and environmental impacts using exposure-response functions and finally to valuation. Application of the impact pathway approach requires access to dispersion and exposure modelling tools and resources and is relatively data intensive. In the literature reviewed, applying the impact pathway approach to monetise health impacts of air pollution was the most common approach across studies assessing benefits.

Studies following the impact pathway approach have assessed the impacts of air pollution in the UK, EC and the US. Across the studies, the impact pathways included and the concentration-response functions (CRFs) applied vary due to differing opinions in the interpretation of the robustness of the relationships between air pollutant concentrations and health impacts found in the underlying epidemiological literature.

16 Exposure modelling tools typically overlay air pollution effects with a range of other information (including population, land-use, air pollution exposure to health epidemiological studies) to estimate exposure and health impacts. Examples of these tools include BenMAP (US EPA), GAINS and the tools and manuals produced by the European Study of Cohorts for Air Pollution Effects (ESCAPE) project.
Figure 7 Impact Pathway Approach, tracing the consequences of pollutant release from emission to impact and economic value (source: EMRC, 2014)

**ABE2: Damage costs per tonne of pollutant abated**

The damage cost functions methodology is considerably less resource intensive compared to ABE1 and ABE4. It allows the user to directly combine a change in emissions (calculated using any of the ER methods), with a damage cost per tonne, to estimate the total value of benefits (i.e. damages avoided). A number of different damage costs exist, and specific damage cost functions have been developed for Europe and in individual Member States (e.g. UK: [20]; Denmark: Andersen & Brandt, undated)). For the costs of hydrogen chloride (HCl) and hydrogen fluoride (HF), many studies have drawn upon a study on the valuation of environmental externalities from landfill (EC, 2000).

The impacts of air pollutant emissions are inherently country and case specific: to develop damage costs, assumptions are made regarding emissions, dispersion and exposure across a chosen coverage of sectors and countries to construct an average impact estimation. Given in particular that sources of emissions, dispersion and exposure can vary widely between geographical areas, the appropriateness of the underlying estimation methodology must be considered carefully before applying damage costs to a geographical area or sector for which they were not originally specified. Where the scope of the application is different to the original estimation, the average values used to estimate the damage costs may not be representative of the case in question. Modelling of damage cost functions by different countries and organisations means that underlying assumptions to derive these damage costs also differ. For example, the life years lost is valued differently across EU Member States and in the USA.

Transboundary impacts of emissions to air are also not uniformly reflected in the damage cost functions. For example, in the development of damage cost functions, the UK restricted their modelling to the effects of national emissions on the national population, thus not accounting for the value of potential benefits of emission reductions in other countries. In Denmark, marginal external costs from Danish sectors17 are available for impacts in Denmark, and outside of Denmark. In case of European wide policy like BATC, the reduction in air emissions of transboundary pollutants in one Member State are likely to have a positive impact on air quality (and thus lead to reduction in adverse health impacts) in another country. Hence a methodology to monetise the benefits of emission reductions achieved in a

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17 Defined by SNAP category
A comprehensive application of damage cost functions in the context of assessments of BAT-AELs can be challenging as not all pollutants for which BAT-AELs have been defined have damage cost functions available. In some instances, it may be possible to apply adjustment factors to match the pollutant for which BAT-AEL are proposed, with that for which damage cost functions have been developed. For example, BAT-AELs are commonly specified for total dust, whereas corresponding damage costs are normally defined for PM$_{2.5}$ or PM$_{10}$.

Furthermore, given the coverage of pollutants differs between sources, this raises issues such as: what course of action should be taken where a damage cost does not exist in the set applied but is available from another source, or what course of action should be taken where more than one damage cost is available (e.g. in Denmark where either national or European damage costs can be applied).

Development of a consistent, peer reviewed set of damage costs is considered a priority by some stakeholders, though a need to reflect differences in likely impacts between the height at which emissions are released, sectors and Member States have been recognised. Options to increase the accuracy of assessment of benefits of emission reductions to air using damage cost functions by distinguishing between low and high stack emissions is discussed further in section 3.6.2.

**Abatement costs (ABE3)**

The abatement cost approach was only identified in the UK [20]. This approach has been developed by UK Defra to support assessment of the benefits of mitigation measures where applying these measures influences the achievement of legal limits restricting air pollutant concentrations in ambient air, specifically in cases of decisions which are expected to:

- Cause an exceedance of a legally binding obligation;
- Increase or reduce emissions in an area where a legally binding obligation is already being breached.

Rather than assessing the direct impacts of exposure to air pollutants (which is undertaken in methods ABE1, ABE4 and ABE2), the unit abatement costs provide an indicative marginal cost per tonne of emission based on the average marginal abatement technology. According to guidelines produced by Defra (2013) ‘unit costs help indicate the scale of air quality impacts from key pollutants and thus can inform decisions about what level of analysis will be proportionate’. The guidance further provides recommendations on the application of the detailed assessment where the assessment using unit abatement costs indicate impacts in excess of £50 million (EUR 56 million$^{18}$).

**Summary of methods for monetising benefits of emission reductions to air**

Table 8 presents the summary of the methods identified for the assessment of benefits of emission reductions to air. Some studies, such as [20] provides background information on more than one method and is therefore included in multiple rows.

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$^{18}$ Assuming exchange rate of 1 GBP = 1.12 EUR as of 22 October 2016
### Table 8 Methods for assessment of benefits of emission reductions to air

<table>
<thead>
<tr>
<th>ID</th>
<th>Method name</th>
<th>Description</th>
<th>Key inputs</th>
<th>Examples of studies using this approach</th>
</tr>
</thead>
</table>
| ABE1 | Impact pathway approach (without monetisation)  | Primary effects are assessed quantitatively and expressed in terms of non-monetary impacts, for example number of health outcomes such as deaths or hospital admissions | Change in emissions  
Change in concentrations (and population weighted concentrations)  
Population  
Baseline incidence rate  
Exposure response function | [22], [28], [36], [55] |
| ABE2 | Damage costs (EU, UK, DK)                       | Emissions are combined with damage costs (expressed in terms of monetary unit / tonne) to calculate total costs avoided | Change in emissions  
Damage costs | [5], [7], [15], [20], [37], [38], [39], [41], [42], [51], [C1] |
| ABE3 | Abatement Costs (UK)                            | Emissions are combined with abatement costs (expressed in terms of monetary unit / tonne) to calculate total opportunity cost | Change in emissions  
Abatement costs | [20] |
| ABE4 | Impact pathway approach (with monetisation)     | Primary effects are assessed quantitatively and expressed in terms of monetary terms                | Change in emissions  
Change in concentrations (and population weighted concentrations)  
Population  
Baseline incidence rate  
Exposure response function  
Unit impact values | [20], [21], [22], [24], [28], [30], [31], [33], [34], [37], [38], [39], [43], [52] |
3.6.2 Feasibility of making improvements to the existing methodologies for estimating benefits of emission reductions from industrial installations

This section focuses specifically on the scope for potential improvements, in terms of accuracy, to the existing damage cost functions used in the EU to assess value of benefits of air emission reductions.

Assessment of benefits of emission reductions to water is not covered in this section given significant gaps in the context of emissions from industrial installations specifically, as presented in section 3.2. Given limitations of the underlying evidence base and complexities in the approach, it is recommended that any impacts of emissions to water are assessed qualitatively.

Latest EU damage cost functions for air pollutants

EEA (2014) provides estimate of damage per tonne emission of various air pollutants. The pollutants covered are NH₃, NOₓ, PM₂.₅, PM₁₀, SO₂, NMVOCs (via formation of ozone and secondary organic aerosols), some organic pollutants (1,3-butadiene, benzene, dioxins and furans, diesel exhaust, formaldehyde and PAH) and a number of metals (arsenic, cadmium, chromium, lead, mercury and nickel). These were applied by the EEA to quantify damage from installations reporting to the E-PRTR (European – Pollutant Release and Transfer Register). Initial estimates were calculated as an average across all emissions within a country. However, the damage from any installation within a country will vary according to both its location and effective stack height (actual stack height plus plume buoyancy, linked to temperature, exit velocity and flue gas volume). Use of all-sector average estimates will lead to underestimation of impacts for some pollutants and overestimation for others. For some, particularly those with long environmental residence times (mercury being probably the best example), the site of release seems likely to play only a small role in determining the magnitude of damage. Recognising these issues, the EEA (2014) study applied some scaling factors to better estimate impacts linked specifically to industrial plant, though these adjustments were approximate. These adjustments were made to account for typical differences in the location and height at which emissions from industrial sources were released, which affect dispersion and exposure of people and ecosystems. These adjustments used information from the Eurodelta II study (Thunis et al., 2008) and compared modelling results from a range of European-scale dispersion models. Stakeholders consulted in the course of the study supported, where possible, use of sector-specific and local estimates of damage costs. This section considers whether it is appropriate to develop a more structured and detailed approach to dealing with these issues.

IEA (2016) recognises this problem, noting that:

- The impact of a pollution source depends strongly on the relation between the site and stack height of the source and the distribution of the affected population;
- Such variation with site and stack height is especially strong for primary pollutants (e.g. PM₂.₅);
- The impact per kg of PM₂.₅ emitted by cars in a metropolis like Paris is two orders of magnitude higher than for the same kg of PM₂.₅ emitted from a tall stack in a rural zone;

Variation with site and stack height is weaker for ozone and much weaker for sulphate and nitrate aerosols because these pollutants are formed only gradually over tens (for ozone) to hundreds (for nitrates and sulphates) of kilometres from the source. Available data

Some insight on the variability of results according to these factors can be gained from analysis by Defra in the UK (2015)) and reports from the ExternE Project series (ExternE, 1997, featuring analysis of a number of facilities within France, varying with respect to location and stack height, with location of plant shown in Figure 8)¹⁹. The Defra analysis, covering emissions of NOₓ, SO₂ and PM₂.₅, shows that emissions from industry in the UK cause a lower level of damage within the UK (noting that this restriction is a distinct limitation of the Defra analysis) than the average for all emissions on which the national estimates of damage per tonne are based. Results indicate that agricultural sources have

¹⁹ The Defra analysis is restricted to impacts of emissions from UK facilities on UK citizens, though the extreme differences between facilities highlight the issues faced from variation in the height of emission and location of sources relative to centres of population. The ExternE results, though almost 20 years old, remain valid given the models used for the analysis.
damage that is 70% lower than average, waste processing 35% lower and industry 21% lower.\textsuperscript{20} There is no difference in the ratios between sources for the different pollutants, implying that the recent analysis for NO\textsubscript{2} simply applies the same ratios as observed in the analysis for PM\textsubscript{2.5}. Given the reactivity of NO\textsubscript{2} (relative to the non-reactivity of primary particles), a difference in the ratios would be observed if analysis were performed using the full impact pathway approach.

Table 9 Ratio of damage by sector relative to average damage across all sectors for a primary air pollutant (adapted from Defra, 2015)

<table>
<thead>
<tr>
<th>Sector</th>
<th>Ratio of sector damage per tonne to national average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agriculture</td>
<td>0.30</td>
</tr>
<tr>
<td>Waste</td>
<td>0.65</td>
</tr>
<tr>
<td>Energy supply industry (ESI)</td>
<td>0.08</td>
</tr>
<tr>
<td>Industry</td>
<td>0.79</td>
</tr>
<tr>
<td>Domestic</td>
<td>0.88</td>
</tr>
<tr>
<td>Transport</td>
<td>1.51</td>
</tr>
</tbody>
</table>

\textsuperscript{20} The very low result for the ESI in particular is partly an artefact of the exclusion of non-UK damage from the Defra analysis.

The differentiation of sources in the Defra work by sector raises some important issues, in particular the factor 10 difference between damage costs from the ESI and industry. It is understood that the pollutant modelling for the ESI is based on analysis for large coal fired power plant, with high stacks (>200m).

The results for France cover analysis of waste incinerators only, though demonstrate sensitivity to both the location within France and the stack height. Unlike the Defra analysis, they address impacts outside the emitting country, across the whole of Europe. For effects of sulphates and nitrates derived from emissions of SO\textsubscript{2} and NO\textsubscript{x} respectively, damage per tonne varies by roughly a factor 2 across the four sites. For primary pollutants (SO\textsubscript{2} and PM\textsubscript{10}) results vary by roughly a factor 8 for the same stack height. Increasing the stack height from the reference case (100m) to 250m leads to a 40% reduction in damage per tonne for primary pollutants for the Paris site and roughly 25% for the other sites. Reducing stack height to 1 m (used purely for sensitivity analysis to show the absolute range possible) would double damage per tonne. The authors conclude that there is little stack height dependence for the secondary pollutants (sulphates and nitrates) given that these pollutants take time to form in the atmosphere, allowing a significant level of mixing within the boundary layer.

\textbf{Figure 8 Location of the emission sources from Figure 9 within France.}

\textsuperscript{20} The Defra results show the same ratio between sources relative to the average for both NO\textsubscript{x} and PM\textsubscript{2.5}. However, this is a result of extrapolation of the PM results, rather than a full analysis of each pollutant.
Adjustment of damage factors to account for variability between sectors was applied in the analysis carried out by EEA (2014). Adjustments were based on results of the Eurodelta II study which brought together modellers from 5 institutes to make a comparative study across a common domain that covered most EU Member States and some non-Member States. Analysis addressed emissions from 11 sectors in 4 countries (France, Germany, Spain, UK)\textsuperscript{21} and was carried out for primary PM\textsubscript{2.5}, secondary PM\textsubscript{2.5} (nitrates, sulphates) and ozone, generating relationships between average and sector-specific exposure factors. Results are shown in Table 10, Table 11 and Table 12 and summarised in Table 13. It is noted that:

- Variability is greater for the primary pollutant (PM\textsubscript{2.5}) than it is for the secondary pollutants, roughly a factor of 2 between industrial and ‘average’ sources, reflecting the patterns seen above in Table 9, with industrial and public power sources having lower than average damage per tonne because they release to the atmosphere from tall stacks, often remote from centres of population.
- Results for SO\textsubscript{2} are close to average for both sources considered, because for the countries included in the analysis emissions from other sources are low (i.e. the sectors for which effects were quantified dominate the analysis to a large degree). The same may not be true for (e.g.) Poland, where there remains much low-level release of SO\textsubscript{2} from domestic coal burning.
- For NO\textsubscript{x}, results show a reduction in damage per tonne for public power and industrial sources and an increase for process industry and transport.

\textsuperscript{21} Other sectors considered include agriculture and domestic, but these are not relevant to the present study. Not all sectors were considered for all pollutants, reflecting the strength of different emission sources. For example, SO\textsubscript{2} was not considered for transport in most countries, because associated emissions are now very low reflecting current emission controls.
Table 10 Exposure of sectoral SO\(_2\) reductions for secondary PM\(_{2.5}\) impacts on Europe relative to the average for all sectors

<table>
<thead>
<tr>
<th>Sector exposure / average all sectors exposure</th>
<th>Public power</th>
<th>Industrial</th>
<th>Other transport</th>
</tr>
</thead>
<tbody>
<tr>
<td>FR</td>
<td>0.74</td>
<td>1.06</td>
<td></td>
</tr>
<tr>
<td>DE</td>
<td>0.86</td>
<td>1.03</td>
<td></td>
</tr>
<tr>
<td>ES</td>
<td>1.01</td>
<td>1.03</td>
<td>1.06</td>
</tr>
<tr>
<td>UK</td>
<td>0.86</td>
<td>0.96</td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td>0.87</td>
<td>1.02</td>
<td>1.06</td>
</tr>
<tr>
<td>Range</td>
<td>±0.14</td>
<td>±0.06</td>
<td></td>
</tr>
</tbody>
</table>

Table 11 Exposure of sectoral NO\(_x\) reductions for secondary PM\(_{2.5}\) impacts on Europe relative to the average for all sectors

<table>
<thead>
<tr>
<th>Sector exposure / average all sectors exposure</th>
<th>Public power</th>
<th>Industrial</th>
<th>Road transport</th>
</tr>
</thead>
<tbody>
<tr>
<td>FR</td>
<td>0.91</td>
<td>0.87</td>
<td>1.05</td>
</tr>
<tr>
<td>DE</td>
<td>0.80</td>
<td>0.84</td>
<td>1.06</td>
</tr>
<tr>
<td>ES</td>
<td>0.65</td>
<td>0.93</td>
<td>1.15</td>
</tr>
<tr>
<td>UK</td>
<td>0.74</td>
<td>0.79</td>
<td>1.21</td>
</tr>
<tr>
<td>Average</td>
<td>0.78</td>
<td>0.86</td>
<td>1.12</td>
</tr>
<tr>
<td>Range</td>
<td>±0.13</td>
<td>±0.07</td>
<td>±0.09</td>
</tr>
</tbody>
</table>

Table 12 Relative efficiency of sectoral primary PM reductions for PM\(_{2.5}\) impacts on Europe.

<table>
<thead>
<tr>
<th>Sector exposure / average all sectors exposure</th>
<th>1 Public power</th>
<th>2 Industrial / commercial</th>
<th>3 Industrial</th>
<th>4 Production processes</th>
<th>7 Road transport</th>
</tr>
</thead>
<tbody>
<tr>
<td>FR</td>
<td>0.64</td>
<td>1.03</td>
<td>0.63</td>
<td>1.08</td>
<td>1.26</td>
</tr>
<tr>
<td>DE</td>
<td>0.51</td>
<td>1.07</td>
<td>0.55</td>
<td>1.38</td>
<td>1.05</td>
</tr>
<tr>
<td>ES</td>
<td>0.39</td>
<td>1.78</td>
<td>0.52</td>
<td>0.84</td>
<td>1.09</td>
</tr>
<tr>
<td>UK</td>
<td>0.47</td>
<td>1.04</td>
<td>0.58</td>
<td>1.31</td>
<td>1.51</td>
</tr>
<tr>
<td>Average</td>
<td>0.50</td>
<td>1.23</td>
<td>0.57</td>
<td>1.15</td>
<td>1.23</td>
</tr>
<tr>
<td>Range</td>
<td>±0.14</td>
<td>-0.20 – +0.55</td>
<td>±0.06</td>
<td>-0.31 – +0.23</td>
<td>-0.18 – +0.28</td>
</tr>
</tbody>
</table>

Table 13 Summary of ratios shown in Table 10, Table 11 and Table 12 for differences between average and sectoral damage factors.

<table>
<thead>
<tr>
<th>Sector exposure / average all sectors exposure</th>
<th>1 Public power</th>
<th>2 Industrial / commercial</th>
<th>3 Industrial</th>
<th>4 Production processes</th>
<th>7 Road transport</th>
</tr>
</thead>
<tbody>
<tr>
<td>SO(_2)</td>
<td>↓</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NO(_x)</td>
<td>↓↓ (↓)</td>
<td></td>
<td></td>
<td>↑</td>
<td>(↑↑↑)</td>
</tr>
<tr>
<td>PM(_{2.5})</td>
<td>↓↓</td>
<td>↑(↑↑)</td>
<td>↓↓</td>
<td>↑↑ (↓)</td>
<td>↑↑(↑)</td>
</tr>
</tbody>
</table>

Arrows in brackets highlight individual cases where the ratios were different due to average. Key:

- >1.20
- 1.05 to 1.20
- 0.80 to 0.95
- < 0.80
- Close to average (0.95 – 1.05)
A number of limitations of the Eurodelta analysis were identified including:

- Unlike the Defra work, Eurodelta pre-dated the availability of response functions for NO\(_2\) (rather than functions for PM\(_{2.5}\) applied to nitrate aerosols formed in the atmosphere after release of NOx). Inclusion of NO\(_2\) functions would both increase NOx damage estimates and strengthen the sector specificity of NOx emissions.

- Analysis considered emissions from only four countries. The representativeness of these countries is questionable.

- One of the objectives of Eurodelta was to compare the results of different European-scale models. With this in mind it was necessary to define a common modelling domain between the 5 models used. The effect of this is to limit the overall area of the domain. A number of EU member states fall wholly or partially outside the modelled domain – Bulgaria, Cyprus, Estonia, Finland, Ireland, Malta (possibly), northern Scotland and much of Latvia, Lithuania, Romania and Sweden. Countries further east (e.g. Ukraine, Moldova and Russia are also excluded. The results will therefore under-predict exposure to ozone and PM\(_{2.5}\).

- No account is taken of enhanced urban exposures, though for the emission sources relevant to BAT-AELs assessment this is unlikely to be of great importance.

- The limitation of most importance may well relate to the treatment of stack height and the effective height of release. It is unclear how representative the assumptions made in Eurodelta II were of emission sources in the various sectors in the countries considered. Hence, whilst the assumptions made may be useful for demonstrating that there is an issue that should be addressed in analysis performed in support of policy making, it is unclear how relevant the results of that modelling are to plant across the EU, taking into account different attitudes to stack height calculation and (e.g.) different emissions linked to the use of different fuels (noting, for example, that the stack height for a coal fired power plant is typically much greater than for a similar sized gas fired plant).

Overall, it is concluded that the use of existing national average estimates of damage per tonne of emission introduces some systematic bias to the analysis. For some pollutants (e.g. primary PM) this is more important than for others (e.g. SO\(_2\)). In general, the bias for industrial sources (including public power plants) is to overestimate the quantified effects, though there are situations where underestimation may occur (e.g. releases in or close to major conurbations).

**Possible approaches for deriving adjustment factors**

Three approaches are considered:

1. **Use of existing adjustment factors, as applied in EEA (2014).**

   The first option has been used by EEA (2014) to generate adjustment factors to apply to facilities reporting to the E-PRTR, in a plant by plant assessment. The purpose of this analysis was to identify the most damaging facilities in Europe. The provision of a more disaggregated set of damage factors that accounted for stack height and location within a country could help increase confidence that results were a reasonable approximation of reality: as noted above, there can easily be a factor of 2 or more difference in damage cost estimates according to assumptions made on these factors, and this may be sufficient to change the overall balance between the costs and environmental benefits of BAT-AELs.

2. **Use of a simple model to provide indicative adjustment factors for a range of stack heights and for defined regions within each country**

   This option could use simple models, such as the Riskpoll model described by Rabl et al (2014) to generate a set of adjustment factors, taking account of differences in exposure linked to stack height and national region. Such a tool could also generate further factors to account for proximity of plant to large centres of population, which may be desirable for plant with short stacks that may be found within cities. Whilst not utilising the most sophisticated tools available, resulting damage costs would be referenced against damage per tonne estimates derived using the EMEP transfer matrices, significantly reducing the potential for deviation from the accepted EU wide position. This simple modelling option also benefits from a significant level of flexibility that the other two options lack.

3. **Use of sophisticated models to generate new pollutant transfer matrices that account for stack height and regions within each country**
The third option would require a set of transfer matrices to be developed for a set of stack heights and for each region of each country, using a sophisticated and widely recognised model such as EMEP (the dispersion model that underpins policy analysis for both the European Commission and the Convention on Long Range Transboundary Air Pollution under UN/ECE), or broadly similar models (for a list see the Eurodelta III report). This has the advantage of using more established tools, but may require a substantial amount of effort. Discussion with the EMEP team reached the following conclusions:

- A large number of model runs would be needed to cover several stack heights, different pollutants and different regions.
- In principle it would be possible to cover even 300 regions however it would require a significant amount of work and time. 300 modelling runs would take roughly a month (with planning/set-up before that), but it would take further several months for 5 pollutants and different stack heights. Furthermore, if it was necessary to run the model for 5 different years of meteorology, it would become a very long task.
- Several shortcuts could reasonably be applied to limit the number of runs needed.
- Underlying databases used by EMEP may need to be checked for accuracy.

It is understood that WWF have commissioned some runs of the EMEP model for consideration of power stations in different locations in support of a report just published (WWF et al, 2016). Due to the very recent release of this report it will be reviewed later.

3.6.3 Methods for monetising the impacts of emissions reductions to water

Overview

The overview of the methodologies identified for estimation of the benefits of emission reductions to water is presented in Figure 10. There exist multiple methods (WBE2-7) for valuation of water quality which have been developed over the years and used in the context of the Water Framework Directive and/or the EU Nitrates Directive. However, these methods have not been directly applied to emission reductions to water from industrial facilities. In order to apply these methods, an understanding of how the change in emissions from industrial facilities impact on water quality is required, before proceeding to the valuation of the impacts.

High-level approaches applicable at the sector level (equivalent to damage costs for air emissions) do not currently exist for water emissions at an EU level. However, some examples are available where such attempts have been made. In Denmark, damage costs associated with health impacts have been developed with regards to presence of nitrates in drinking water. The impact is expressed as monetary value per mg of NO\textsubscript{3} per litre of drinking water per capita. Similarly, damage to coastal waters due to eutrophication has been valued in Denmark using the hedonic price model (i.e. expressed as an impact on house prices)\textsuperscript{22}.

\[ \text{[172] provides multiple reasons for little progress in quantification of externalities of water pollution:} \]

Most importantly, the effects of pollutants emitted to water are likely to be more site-dependent than those of emissions to air and the pathway from emission to the exposure of receptors is more challenging for water pollutants, particularly in relation to human health impact assessment. The report further explains that effects of pollutants emitted to water are very much dependent on the body of water that they are emitted to. Aspects such as use of the water (whether as drinking water, agriculture, tourism etc.), flow rates, types of water body, existing concentrations, potential for synergistic effects among pollutants and other stress on the environment not related to pollution (such as over fishing) would need to be determined.

Some stakeholders shared the view that the environmental costs of water emissions are strongly dependent on the local features, the way a given water body is used, and how this use is affected by pollution from point sources. There was also some scepticism expressed about the feasibility of deriving a generic damage cost for a specific substance released to any water body (as has been done in the case of air emissions). Despite these difficulties, some stakeholders expressed their view that benefits

\[ \text{[22 See the catalogue of environmental economic indicators published at the website of the Danish Ministry of Environment}\]

http://mfvm.dk/miljoe/miljoeekonomiske-noegletal/
of reducing emissions to water should be assessed within the same framework as benefits of reducing emissions to air and costs of compliance.

**Figure 10 Methods for assessment of benefits of water emission reductions**

Methods to estimate impacts on water quality

A critical element for the application of the impact pathway approach (WBE1) or any of the valuation techniques (WBE2-7) is the estimation of the impact of emission reductions on water quality, from compliance with BAT-AELs. This estimation needs to provide a net change in water quality, as a result of lower emissions to water from industrial facilities. This requires establishment of a link between decrease in emissions / concentrations in waste water discharge, concentrations of the emitted substance in the receiving water body and resultant impact on water quality. This view has been supported by some stakeholders which pointed out that for example estimating the loss of recreational value for a water body requires a good understanding of the quality status of the affected water body as well as information on its recreational use of the water body (e.g. whether it is used for recreational fishing activity).

In the UK the link between emissions in wastewater and concentrations in the receiving body was established in the guidelines for permit applications by the Environment Agency (Environment Agency, 2011). The guidelines require the operators applying for a permit to calculate the “process contribution” (PC) expressed in concentration units. PC is defined as the concentration of each effluent constituent in a surface water after dilution. This is calculated by multiplying the release concentration of the pollutant in the effluent (μg/l) by the effluent flow rate (m³/s) and dividing by the sum of the effluent flow rate (m³/s) and river flow rate (m³/s). Data sources on the river flow rates are provided in the guidelines.

A similar method for calculation of the process contribution to estuaries and coastal waters are provided in the guidelines. The obtained values are then compared to the environmental quality standards to determine whether the contribution is significant. If the release is considered significant, Predicted Environmental Concentration (PEC) in the water bodies needs to be calculated and more detailed modelling of discharges might need to be undertaken. However, such an approach requires both information on the water flows and effluent flows, and overall would not provide information sufficient for applying valuation methodologies.

In Silvo et al (2000), different methods available for estimating environmental costs caused by water emissions from point sources were investigated. The report concluded that contingent valuation method (WBE5) is the most suitable for this purpose, particularly in cases where the loss of recreational value of the water body is affected. For impact on fisheries, the market based method (WBE2) using the market of price of fish was suggested. The study estimated value of damages caused by the emissions from case study of the pulp and paper mill in Finland. The most significant emissions from the plant were total phosphorus and COD. Using contingent valuation method (WBE5) the damages caused by water emissions from the plant to the recreational value of affected water body and fisheries were estimated.

In Finland, a sector level assessment of impacts of IPPC Directive for the pulp and paper sector has been undertaken (Silvo, 2009). This proposed a method for assessment against the local impact indicators including impacts on water quality. The method is based on summary of the impacts caused by installation on the water quality by compiling data on the good ecological status according to the WFD in the local environment of the installation, and the impact on the water quality by the installation. The impacts are then assessed qualitatively, at the quality element level (i.e. indicator by which quality of water bodies is assessed, such as aquatic flora), not against the specific BAT-AELs. For each quality
element, it is assessed if the local water body is or is not in compliance, or whether the quality element is not relevant. The impact of the facility on the local quality of water bodies is then evaluated on the basis of whether the impacts is or is not acceptable, or if there is no significant impact. By aggregating this information at the sector level, conclusions could be drawn on what water quality parameters are most affected by the installations, and in cases where this impact is significant, to what extent introducing new BAT-AELs could reduce this impact. The method proposed in the study used a bottom-up approach by collecting information from 29 pulp and paper installations in the country, thus allowing consideration of environmental impacts in the proximity of the installation.

The Economics and Cross-media BREF provides a methodology to assess the impact of emissions on aquatic toxicity, which is defined as the quantity of water (m$^3$) required to achieve the predicted no effect concentration in water. The method requires mass of pollutant released and the ‘predicted no effect concentration’ of that pollutant. The ECM BREF however clearly states that this methodology is not applicable to discharges at facility level, and that it is associated with substantial uncertainty. There is also no monetisation step applied to the assessment of aquatic toxicity impacts.

WBE1: Impact pathway approach

The impact pathway approach (WBE1) presented above in the context of air emissions, can also be used in the context of estimating impacts of emissions to water (Hansen et al., 2009). Starting from emissions of pollutants in wastewater, the first step in the approach is to calculate the dispersion of pollutants in the water bodies (i.e. streams and rivers, lakes, surface waters, groundwater and drinking water). The next step is assigning a dose-response function, for example in the context of human health, ecological or other impact. Once the response is quantified, the impact can be monetised using several available approaches (discussed below) and the values can then be aggregated across pollutants and impacts. Although this works in theory, there are key stages missing in the underlying evidence base. In particular, the ones linking change in concentrations in water bodies to exposure, and change in concentrations to change in water quality for other ecosystem services.

[172] states that the impact pathway approach could be applied to some water pollutants, specifically organic pollutants and some heavy metals, though the following would be required:

- analysis of the dispersion of the pollutant in the aquatic environment; and
- establishing human exposure via for example drinking water or and pollutant levels in shellfish, fish or agricultural outputs that have been produced using the polluted water.

Similarly to application of the impact pathway approach to emissions to air, some stakeholders consulted in the study were of an opinion that application of the impact pathway approach to emissions to water would be very resource intensive.

WBE2 - WBE7: Valuation methods

Significant research into valuation of benefits of improved water quality has been undertaken in the context of the Water Framework Directive, specifically the benefits of achieving good ecological status (GES) in water bodies (methods WBE3-7). While reducing emissions to water from industrial facilities is only a part of the solutions to achieve GES, the methods developed for the economic analysis under the Water Framework Directive could theoretically be applicable for the study.

According to the [192] the measures implemented in the context of the WFD, can bring two types of benefits:

- Use value – these are linked to the way water resources are used, and can be expressed as change in traded products or services associated with the use of water (e.g. fishing yields).
- Non-use value – these are not associated with any specific use, but are based on the value individual assign to ecological resources.

In order to assess these benefits in monetary terms (so that they can be compared to the costs), valuation methods are applied. There exist several direct valuation techniques to assess the above benefits:

- **Market methods (WBE2)** – these are applied to assess “use values” and use prices for goods and services trade in the market. For example, if improved water quality results in higher fishing
yields or higher quality of fish, the benefits could be valued using an increase in revenue or price of fish. Relative to the other valuation methodologies, given the values have been observed in a market, the uncertainty around the valuation element of this approach could be considered lower.

- **Cost-based valuation methods (WBE3)** – these are based on the assumption that the cost of maintaining environmental benefit is a reasonable estimate of its value. A valuation is derived based on an estimation of the costs of preventative and/or mitigation measures which could be put in place to maintain the environmental benefit. However, mitigation measures may not be achievable in all cases and as such any mitigation costs may underestimate the true environmental cost. Further, this is more logically applied to interventions which increase the risk of environmental harm, rather than (as in the case of BATC) those which consider options to deliver environmental benefits.

- **Revealed preference methods (WBE4)** – these involve use of specific models and are based on the comparison of the characteristics and values of different goods (including using market values) to isolate the value of the relevant environmental values. This method is based on the underlying assumption that the value of goods in a market reflects a set of environmental costs and benefits and it is possible to isolate the value of the relevant environmental values. Any difference in value between two goods is allocated to the differences between them: for example, the change in property price corresponding to an environmental degradation, for example the pollution of a river or lake, is the cost of this degradation.

- **Stated preference methods (WBE5)** – based on the measure of willingness to pay through asking the consumers hypothetical questions (also referred to as contingent valuation).

An alternative to the direct valuation is the use of **value transfer (WB6)**. In this method, information on environmental costs or benefits from existing studies is used for the purpose of valuing the benefits. One study [172] suggests an additional method based on a consideration of **clean-up/abatement costs (WB7)** which assumes that abatement costs are closely associated with external costs. However, to apply that methodology, the externalities related to water emissions would first need to be measured and this is not currently available.

The above mentioned valuation methods rely on the significant shift (a step change) in the quality of the receiving environment [172]. Therefore, in the context of assessing the impact of attainment of BAT-AELs, unless installation of improved water treatment facilities results in a significant shift in the quality of the water body, the assessment would show no benefits [172]. As such, any method may only applicable to relatively large polluters of relatively small water bodies. Some stakeholders consulted in the study expressed an opinion that methods WBE4 and WBE5 may be the most practical for this purpose.

Box 13 summarises the application of assessment of benefits from water emission reductions.
Box 13 Assessment of benefits from water emission reductions in the studies reviewed

The only example identified in the studies reviewed which monetised the impact of BAT conclusions on water quality is the tool developed for the purpose of cost-benefit analysis in the context of derogation from the BAT-AELs [41] in the UK. The method deployed in the tool was based on the UK Water Appraisal Guidance [29]. Despite the fact that impacts on water quality can be assessed using the tool, an effect will only be valued where the impacts of BATC on water quality are significant given the coarse granularity of the water quality categories between which quality can change. Furthermore, given the uncertainties in valuation of the benefits on water quality, the assessment is only done as part of sensitivity analysis, thus it is not core to the main cost and benefits analysis. The assessment requires the user to input the following parameters:

- Length or area of water body affected (separately for rivers and coasts, lakes and transitional waters).
- Select appropriate category of water quality (e.g. poor, moderate, good, etc.) under BAU and BAT scenarios against pre-determined quality guidelines.

The tool then applies a specific willingness to pay values developed for the UK for each quality category to monetise the benefits.

The UK Water Appraisal Guidance [29] provides step by step guide to assessing benefits of improving water quality (i.e. this is not linked directly to emissions from industrial facilities). Given the complexity of assessment, guidance follows a triage approach, first assessing impacts qualitatively, then quantitatively, then proceeding to valuation. In the initial stage, the user assesses the impact of measures on a pre-defined list of ecosystem services, identifying type, size and receptor. The user then assesses these impacts using quantitative indicators where possible. Such impacts can then be monetised but the user of the tool must assess environmental effects of measures and map these against a pre-defined list of water quality indicators, provide the area of impact and select key parameters to monetise impacts. The approach, while potentially applicable to reduction in water emissions resulting from compliance with BATC, does not appear to be easily replicable beyond a local, facility level.

Summary of methods for monetising benefits of water quality improvements

Table 14 presents the summary of the methods identified for monetising benefits of water quality improvements.
Table 14 Methods to assess benefits of water quality improvements

<table>
<thead>
<tr>
<th>ID</th>
<th>Method name</th>
<th>Description</th>
<th>Key inputs</th>
<th>Reference studies for the methods</th>
</tr>
</thead>
</table>
| WB1 | Impact pathway approach           | The method requires estimation of pollutant dispersion in the water bodies and identifying human and environmental exposure response functions to quantify the impact. This can then be monetised using methods B2-B6. | Dispersion in water bodies  
Exposure-response function (human and environmental) | [34] [172] |
| WB2 | Market methods                    | Use changes in prices of goods and services traded in the market to value change in water quality | Market data on direct use values  
Change in quality or quantity of the traded product | [192] |
| WB3 | Cost-based valuation methods      | Use the cost of maintaining environmental benefit as the valuation method    | The costs of measures that would need to be taken to prevent environmental damages up to a certain point | [192] |
| WB4 | Revealed preference methods       | Uses specific modelling approaches. Based on the assumption that the environmental costs and benefits of a particular good can be revealed by comparing the values of (and consumer behaviour towards) different goods | Recreational demand models, hedonic pricing models and averting behaviour models | [192] |
| WB5 | Stated preference methods         | Uses willingness to pay studies to value the benefit of environmental improvements | Data drawn from surveys presenting a hypothetical scenario to the respondents in order to determine the Willingness to Pay | [192] |
| WB6 | Value transfer                    | Unlike primary valuation studies (WB2-WB6) these use values from existing studies on the value of good water quality. | Information on environmental costs or benefits from existing studies | [192] |
| WB7 | Clean-up / abatement costs        | The approach assumes that clean-up costs are closely associated with the external costs of pollution. | Requires a measure of externalities of water pollution | [172] |
4 Data requirements and data sources

This section presents the data inputs required for methods to calculate emission reductions and costs and discusses them in the context of the metrics used for definition of BAT-AELs as well as data sources identified through assessment of literature sources and consultation with Member States and trade associations. Specific examples of data sources identified, their benefits and limitations are discussed using examples of the polymer production and iron and steel sectors.

4.1 Data inputs for calculation of emission reductions

The key data inputs required to execute the methods for baseline and future emissions, as well as emission reductions and costs (as presented in section 3) are summarised in Table 15. Data inputs are grouped as follows: plant characteristics, emissions, abatement techniques, costs. The table can be read vertically to identify data inputs required for each method, but also horizontally to identify similarities between the types of inputs required across different elements of the assessment.

Table 15 Data inputs to methodologies for calculating emission reductions and costs

<table>
<thead>
<tr>
<th>Type of data input (at BAT granularity)</th>
<th>Baseline emissions</th>
<th>Methodology</th>
<th>Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>BE1</td>
<td>BE2</td>
<td>BE3</td>
</tr>
<tr>
<td>Plant characteristics</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Activity (e.g. fuel consumption, raw / final product produced)</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Operating hours</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gas and wastewater flows and parameters (incl. reference conditions)</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Emissions</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Emission factors</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Emission concentration</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Reported emissions / external emission projections</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Scaling factors for future emissions (e.g. growth)</td>
<td></td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Abatement techniques</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Abatement efficiency</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Uptake of techniques (under baseline, future)</td>
<td></td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Lifetime</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Costs</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Marginal abatement costs (i.e. cost per tonne of pollutant abated)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Individual cost components (CAPEX, OPEX, energy and fuel prices etc.)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Discount rate</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Clearly there are some overlaps in the type of inputs required for different elements of the assessment. For example, emission factors are used in method BE1 (these are baseline abated emission factors), BE5 (these are baseline unabated emission factors), method FE1 (these are future emission factors assuming BAT is not in place) and ER1 (these are future emission factors assuming BAT is in place). Similarly activity data are required to execute methods BE1, BE2, and BE5 (all require baseline activity data), FE1 (future activity, also can be calculated by combining baseline activity with the scaling factor), and ER1 and ER2 (activity under the BATC scenario).

The data sources providing the above data inputs and used in testing with the iron and steel and polymer production sector are discussed in the sections below. For each data source the data input that can generally be obtained from that source (as concluded from the testing with two sectors) is indicated with a “✓” in the table upfront in each section. It is recognised that not all data inputs are uniformly available in these data sources across all Member States and sectors. While single plant data provide the most accurate inputs, a mix of sector and plant level data will usually provide a good picture for a given industrial sector and/or country.

Furthermore, some stakeholders consulted for the study recommended that industry experts are involved in the assessment of the suitability of potential data sources for a given sector. In addition, the data extracted for use from any given source should be checked for correctness before it could be confidently used. Expert solicitation could support that initial data verification. Stakeholders also indicated that it is necessary to ensure transparency of the data used, especially concerning costs and emission reductions potential of given installation or sector.

4.2 Key data sources and availability of data inputs

4.2.1 Environmental permits

<table>
<thead>
<tr>
<th>Data type (at BAT granularity) from Table 15</th>
<th>Coverage of this source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Activity (e.g. fuel consumption, raw / final product produced)</td>
<td>✓ (nominal capacity)</td>
</tr>
<tr>
<td>Operating hours</td>
<td>✓ (maximum permitted)</td>
</tr>
<tr>
<td>Gas and wastewater flows and parameters (incl. reference conditions)</td>
<td>✓ (maximum permitted)</td>
</tr>
<tr>
<td>Emission factors</td>
<td>✓ (permitted emission limit values)</td>
</tr>
<tr>
<td>Emission concentration</td>
<td>✓ (permitted emission limit values)</td>
</tr>
<tr>
<td>Abatement techniques efficiency</td>
<td>✓ (permitted)</td>
</tr>
<tr>
<td>Uptake of abatement techniques (under the baseline and in the future)</td>
<td>✓ (abatement equipment installed)</td>
</tr>
</tbody>
</table>

All installations covered by the IED across the MS have permits. However, it is not expected that permits in all Member States are easily accessible online. Under the 2017 IED reporting, Member States are invited to provide details of all permits and web links where these can be accessed. Even then, given its voluntary nature, permits may not be universally accessible across all Member States.

Environmental permits were a key source of information for testing of the methodologies for the Polymer and Iron and Steel sectors. However as indicated in the table above, permits contain data on the nominal / maximum values for the data inputs, and not the actual values reflecting real plant operations. Accuracy of results obtained using permit data may therefore be lower compared to assessments using actual data. The permits themselves were sourced from the websites of competent authorities in the Member States, or directly from the authorities. Environmental permits viewed for the sector testing contained a range of information useful for assessing the costs and benefits of applying BAT:

- An environmental permit viewed for the steel case study provided multiple inputs into the assessment: maximum production capacities (or ‘nameplate’ capacity), characteristics of the coke and sinter plant and of the blast furnace, permitted operating hours and emissions levels (in unit of mass per hour).
- For one steel plant in the case study, the environmental permit specified – for each emission source – the flue gas volume rate (Nm³/hr), flue gas exhaust velocity (m/s), flue gas exhaust...
temperature (°K), operating hours per year, the technique used to abate pollution and the abatement efficiency (%) of that technique.

- An environmental permit viewed for the polymers case study specified production capacity rates in tonnes per year for each product type, and the storage type and capacities for those products.

- An environmental permit viewed for the polymers case study specified maximum water consumption rates in both m³/hour and m³/year, as well as indicating the proportion used for each purpose. The same permit placed waste water management restrictions also in terms of different averaging periods (yearly, daily, hourly).

- An environmental permit for a polymer installation in another Member State also included production capacity data.

However, there may be difficulties in finding and extracting the necessary data from permits. In the case studies, gathering the relevant data from environmental permits encountered the following limitations:

- In a Polymer example there were 24 documents in an online register published within 4 years relating to the permit for a single installation. It can be complicated (in particular for someone not familiar with permits) and time consuming to identify the most relevant documents.

- It was also identified that there is no standardised permit format across Member States, and furthermore, the permit format can vary from one region within a country to another.

- Content will be in the local language, and this may not be the national language. Although language is not anticipated to be a barrier for the Commission to overcome, it again could add to the resource required to extract the relevant data.

- One may need additional information to extract the correct information. For example, one Member State’s industrial permit system included geo-referencing. As such, in the Polymer example, one needed to know where an installation was located in order to identify the permit documents.

These factors increase the time and resources required to access the necessary information from permits. Once accessed, there may be limitations with the information presented in the environmental permits, specifically:

- Regarding BAT granularity, permits typically follow a consistent structure of pollutant types (water, air, etc.) but the key pollutants monitored do not always match with BAT-AELs. This may be the case if some pollutants specified with BAT-AELs in the BREF are not relevant to the emission sources covered by the permit.

- Permits often present ‘maximum’ levels for a given parameter. For example, in the case of emission data, using permit data for evaluation would implicitly assume an installation is emitting at the level of the Emission Limit Values (unless an assumption is applied regarding how far below a limit a plant may operate). Furthermore, using nameplate capacities from environmental permits can overstate activity data as real life production is often less than nominal production capacity.

- In some cases of the polymer production sector, the sub-sectors apply different process technology leading to variation in specific emission loads. The information to determine the type of process technology of the plant is not always available in the environmental permit. This information is also not available elsewhere in a systematic manner and so would require a dedicated data collection.

- There is uncertainty regarding how up-to-date permits and the information they contain are. Usually, permits are updated in light of new BATC being published, changes in other relevant legislation and technical modifications in the plant. For sectors with IED BATC already published, it can be assumed that permits will be updated within 4 years of the BATC adoption. The Polymer example highlighted that some time is required to review permits and check no revamp to plant has taken place. However, this is unlikely to be a significant issue given major modifications have to be granted a permit variation.

- Finally, some country’s permit formats may generate a greater level of information, and some less, reflecting the variation in permit format and content across the EU.
4.2.2 Monitoring and inspection reports

<table>
<thead>
<tr>
<th>Data type (at BAT granularity) from Table 15</th>
<th>Coverage of this source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Activity (e.g. fuel consumption, raw / final product produced)</td>
<td>Possibly</td>
</tr>
<tr>
<td>Operating hours</td>
<td>✓</td>
</tr>
<tr>
<td>Gas and wastewater flows and parameters (incl. reference conditions)</td>
<td>✓</td>
</tr>
<tr>
<td>Emission factors</td>
<td>Possibly</td>
</tr>
<tr>
<td>Emission concentration</td>
<td>✓ (Baseline)</td>
</tr>
<tr>
<td>Reported emissions / external emission projections</td>
<td>✓</td>
</tr>
</tbody>
</table>

**Monitoring reports** refer to reports prepared by operators (or third parties on the behalf of the operators) which contain information on emission monitoring at the facility. The reports may contain information on monitoring methods, monitoring frequency, actual value of emission loads and emission concentrations. Some monitoring reports reviewed in the polymer and iron and steel case studies also contained comparison of monitored concentrations with emission limit values set in the permits. Monitoring reports are a rich source of information for assessing the impacts of BAT.

- Those accessed for a Polymer sector water effluent example included, for each pollutant, the measured mean concentration (mg/l) and estimated conversion to emission load (kg/year), alongside wider information on the monitoring device and context.
- One report viewed for the iron and steel case study included other useful data, such as operating hours and production. Specifically production values in kt/year were available for 2010 and 2015 for each product (coke, sinter, pig iron and steel) and for each part of the installation.

As with permits, using monitoring reports as a source of information to inform the assessment of the impacts of BAT is not without limitation. Monitoring reports may be confidential and must be requested from Competent Authorities. In some cases, Competent Authorities may be reluctant to provide reports and/or it may take substantial time and resource to request and gain access to them (that said it is anticipated that these reports would be easier for the Commission to access relative to a private consultancy as in the case of this study). In the Polymers case study example, monitoring reports were requested for each of the three Member States but received only for two out of three Member States within the study period. For the Iron and Steel example, monitoring reports for one installation were received in full, however only sections of reports were gained for another installation.

Furthermore, monitoring reports are likely to include information only related to current environmental restrictions. For example, in the Polymer case study, the updated CWW BREF currently in development could place an obligation on TSS emissions from plants. This was not the case in the past since the POL BREF did not set a BAT-AEL on this parameter. As such, information on TSS emissions is not included in the monitoring reports accessed during the study.

Similar to the environmental permits, monitoring reports are typically issued in local languages and can include a range of documents. For polymer producers in one Member State in the case study, monitoring reports typically consisted of 4 to 10 different document types which required review. Furthermore, each competent authority has its own set of rules and formats for the operator to provide the emissions information requested in the permits; as such frequencies, formats and contents of the reports vary from one region to another. All these factors increase the time and resource required to extract the necessary information.

**Inspection reports** are prepared by competent authorities following on-site visits at a facility. These reports are publically available as required by Article 23 of the IED. No inspection reports were evaluated for the plants analysed in the polymer and iron and steel case studies.
4.2.3 BREFs and data collected during the BREF review process

<table>
<thead>
<tr>
<th>Data type (at BAT granularity) from Table 15</th>
<th>Coverage of this source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Activity (e.g. fuel consumption, raw / final product produced)</td>
<td>Sometimes</td>
</tr>
<tr>
<td>Operating hours</td>
<td>✔</td>
</tr>
<tr>
<td>Gas and wastewater flows and parameters (incl. reference conditions)</td>
<td>Sometimes</td>
</tr>
<tr>
<td>Emission factors</td>
<td>✔ (Baseline, commonly ranges for the sector across Europe)</td>
</tr>
<tr>
<td>Emission concentration</td>
<td>✔ (Baseline, commonly ranges for the sector across Europe)</td>
</tr>
<tr>
<td>Abatement techniques efficiency</td>
<td>✔</td>
</tr>
<tr>
<td>Uptake of abatement techniques (under the baseline and in the future)</td>
<td>✔</td>
</tr>
<tr>
<td>Lifetime</td>
<td>✔</td>
</tr>
<tr>
<td>Marginal abatement costs (i.e. cost per tonne of pollutant abated)</td>
<td>Sometimes</td>
</tr>
<tr>
<td>Data on individual cost components (CAPEX, OPEX, energy and fuel prices etc.)</td>
<td>✔</td>
</tr>
</tbody>
</table>

BREFs contain useful information regarding the environmental performance of the sub-sector, such as emission factors or concentrations. This is highlighted by the Polymer example: The POL BREF section ‘Current emissions and consumptions’ contains a table with emission factors expressed in specific emission loads terms. This table shows both an average, worst (maximum) and best performers (‘average for top 50%’) emission load value for the key, most relevant pollutants in each area. This is shown in Figure 11. Furthermore, BREFs should generally allow determining performance of abatement techniques, including the range of resulting emissions concentrations in the waste gas or waste water flows.

For the Polymer sector specifically, plant configuration, technology used and the engineering design of the unit have many variations and differences. In this case, the BREF has tried to generate technology categories that refer to the portfolio of polymer products being manufactured at each site and provide emission factors for each one of these subsectors.

In the BREFs reviewed under the IED, it is possible to find more data on the emission performance of each candidate BAT (both in the baseline and in the technique description sections) compared to BREFs published under the IPPCD. This allows more precise estimations of baseline emissions, when information on the abatement techniques already installed at a given installation is in place.

Useful information regarding emissions performance was also found in the Iron and Steel BREF. For example, the BREF indicates pollutant concentrations and emission factors for the blast furnace slag granulation installation as illustrated in Figure 12.

This information can be used to depict either current emissions performance (in the baseline scenario) or expected performance under BAT (in the emissions reduction scenario). For example, BAT-AELs applicable to one plant analysed in the Polymer case study are presented in Figure 13.

BREFs also often contain useful information regarding flue gas volumes per tonne of production (as in the case of Iron and Steel, useful for calculating baseline emissions) and the efficiency and cost of specific abatement techniques (which can inform the assessment of emissions reductions and costs).
Figure 11
POL BREF extract containing emission factors (/t product) for general purpose polystyrene

<table>
<thead>
<tr>
<th>Unit</th>
<th>Average top 50%</th>
<th>European average</th>
<th>Maximum value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Air Emissions</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dust</td>
<td>g</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>VOC, total</td>
<td>g</td>
<td>55</td>
<td>120</td>
</tr>
<tr>
<td><strong>Water emissions</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>COD¹</td>
<td>g</td>
<td>30</td>
<td>40</td>
</tr>
<tr>
<td>NOx</td>
<td>g</td>
<td>20</td>
<td>40</td>
</tr>
<tr>
<td>Suspended solids¹</td>
<td>g</td>
<td>30</td>
<td>50</td>
</tr>
<tr>
<td>Hydrocarbons total¹</td>
<td>g</td>
<td>1.5</td>
<td>4</td>
</tr>
<tr>
<td>Waste water²</td>
<td>t</td>
<td>0.8</td>
<td>1.1</td>
</tr>
<tr>
<td>Cooling tower purge water</td>
<td>t</td>
<td>0.5</td>
<td>0.6</td>
</tr>
<tr>
<td><strong>Solid waste</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hazardous</td>
<td>kg</td>
<td>0.5</td>
<td>0.6</td>
</tr>
<tr>
<td>Nonhazardous</td>
<td>kg</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td><strong>Inputs</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total energy</td>
<td>MJ</td>
<td>1.08</td>
<td>1.80</td>
</tr>
<tr>
<td>Styrene</td>
<td>t</td>
<td>0.985</td>
<td>1.020</td>
</tr>
<tr>
<td>Ethyl benzene</td>
<td>t</td>
<td>0.102</td>
<td>0.06</td>
</tr>
<tr>
<td>Mineral oil</td>
<td>t</td>
<td>0.02</td>
<td>0.06</td>
</tr>
<tr>
<td>Cooling water (closed circuit)</td>
<td>t</td>
<td>50</td>
<td>100</td>
</tr>
<tr>
<td>Process water</td>
<td>t</td>
<td>0.596</td>
<td>0.600</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>t</td>
<td>0.022</td>
<td>0.050</td>
</tr>
<tr>
<td>Diluent</td>
<td>t</td>
<td>0.001</td>
<td>0.001</td>
</tr>
<tr>
<td>Additives</td>
<td>t</td>
<td>0.005</td>
<td>0.010</td>
</tr>
</tbody>
</table>

1) The emission values in the water are measured after treatment. The waste water treatment facility can be inside the plant or at a centralised location. These values are not necessarily correlated as they all represent average emission values. Each plant emits according to local permits and site-specific treatment plant specifications. Water treatment may be required according to local regulations.

2) Not including cooling tower purge water.

Figure 12
Pollutant concentrations, emission factors for blast furnace slag granulation (BREF I&S, p313)
BREFs are developed through an intensive engagement and data gathering exercise and as such are based on a wide range of actual data. Data in BREFs are presented for individual or small groups of plants and/or selected Member States (rather than for all installations in a given sector in Europe). Furthermore, they are publically available and cover all IED sectors. However, using data from the BREFs may have limitations:

- Although under the IED the BREFs are updated following a regular schedule, the time needed for the reviews could result in the information being relatively out-dated. For example, the POL BREF was published in 2007 as such the information on which it was based could now be more than a decade old. Often information in the actual BREFs is at least 3-4 years old at publication due to the length of the review exercise.

- In addition, BREFs do not contain environmental performance data for all sites individually (even though it often presents data for certain example plants). As such, when applying the AELs from the BREF, one must select whether a given site represents worst, average or best environmental performance.

- Some specific emission to air load sources, such as the POL BREF, may include diffuse and/or fugitive emissions which do not scale with activity in the way that channelled emissions do.

A collection of the available data from the POL BREF regarding pollutants across different subsectors is included in Table 16.

### Table 16 Available baseline data from the POL BREF

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>Unit</th>
<th>GPPS*</th>
<th>HIPS*</th>
<th>EPS*</th>
<th>S-PVC*</th>
<th>E-PVC*</th>
<th>USPOLYESTER*</th>
</tr>
</thead>
<tbody>
<tr>
<td>dust</td>
<td>g/tonne</td>
<td>4</td>
<td>4</td>
<td>30</td>
<td>40</td>
<td>200</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>30</td>
</tr>
<tr>
<td>VOC</td>
<td>g/tonne</td>
<td>120</td>
<td>120</td>
<td>700</td>
<td>43</td>
<td>813</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>100</td>
</tr>
<tr>
<td>VCM</td>
<td>g/tonne</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CO</td>
<td>g/tonne</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NOx</td>
<td>g/tonne</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SO2</td>
<td>g/tonne</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>COD</td>
<td>g/tonne</td>
<td>40</td>
<td>40</td>
<td></td>
<td>480</td>
<td></td>
<td>340</td>
</tr>
<tr>
<td>TSS</td>
<td>g/tonne</td>
<td>10</td>
<td>10</td>
<td></td>
<td>0.3</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*GPPS General Purpose Polystyrene  HIPS High impact polystyrene  EPS Expandable polystyrene  S-PVC Suspension Polyvinyl chloride  USPOLYESTER Unsaturated polyester

Several stakeholders consulted in the course of the study expressed the view that the data provided by the operators in the questionnaires prepared for the BREF review provide useful information for the purpose of the assessment, specifically in order to determine baseline emissions and techniques already installed across the sites. It has also been highlighted that participants of the Technical Working...
Groups are usually in a good position to validate assumptions for the assessment and consider which techniques are likely to be applied across the installations affected by any new requirements.

The data gathered in the questionnaires could also be useful for other tasks supporting the assessment (e.g. unit conversion). The questionnaire design is decided by the Technical Working Groups for a given BREF review, and is not standardised across IED sectors. In some TWGs data required for unit conversion (such as production rates) may be considered confidential or commercially sensitive and this may limit the number of responses received to the questionnaire from industry representatives.

Restricted access and confidentiality of the data may be one of the issues hindering use of this information, though this depends on what party is undertaking the assessment. Furthermore, while the questionnaires contain emission and techniques data, data on the costs of the application of techniques will be limited. The data collected may also cover well the best performing plants in the sector in the EU (those already applying BAT and likely to be already compliant with the BAT-AELs proposed) but not provide similarly comprehensive data for the worst performing plants, which will need to make changes in order to achieve compliance (i.e. plants for which the impacts of proposed BAT-AEL may be the highest). It is recognised that this will differ on a case by case basis and that in general it is difficult to have conclusive evidence of how well the sample of installations in the BREF review statistically represent the sector as a whole.

4.2.4 Data collected in Member States reports on the implementation of the IED

Member State reporting on the implementation of the IED can also provide valuable inputs to the assessments in view of some stakeholders. Among information on the permitted facilities under the IED, Member States will report on the implementation of the BATC in two sectors (in 2017 reporting) and application of Article 15(4) derogations. This data could be useful for assessments undertaken in the context of future BREF revisions.

4.2.5 Databases and models

E-PRTR

<table>
<thead>
<tr>
<th>Data type (at BAT granularity) from Table 15</th>
<th>Coverage of this source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reported emissions / external emission projections</td>
<td>✓</td>
</tr>
</tbody>
</table>

The European Pollutant Release and Transfer Register (E-PRTR) is a database of environmental data from industrial facilities in EU MS. It is the only EU-wide comprehensive source of emissions data for E-PRTR facilities (which are however largely identical to IED installations), excluding emissions not exceeding reporting thresholds. It is publically available and data regarding emissions from facilities are relatively easy to find.

The E-PRTR contains data reported annually by more than 30,000 industrial facilities covering 65 economic activities across Europe.

A sample of data extracted from the Member State’s national PRTR database (which feeds in to the E-PRTR) for one polymer production installation showed that for most pollutants, no data were reported for the installation – only non-methane VOCs were reported. This is because reporting is only required where emissions exceed reporting thresholds. The database may not include information for a large number of plants where their emissions fall below the thresholds for reporting.

In addition, data series from individual facilities might be interrupted if their emissions drop below the thresholds (e.g. due to changes in production volumes). This makes it more challenging to identify emission trends and draw other conclusions from the data.

PRTR emission data are reported and presented at facility level: for a substantial part of the data sets these facilities match the IED installation and consequently the granularity corresponds in some cases with the BREF BAT granularity. This is especially true for the polymer case study but for some other sectors the BAT-AELs are derived at a greater level of detail than the facility level (e.g. process, sub-process). For example in the case of coke production there are separate BAT-AELs for coal grinding, coke charging, coke pushing etc., while the E-PRTR emissions are reported on the accumulated facility
level. This can create an additional issue where multiple industrial activities are located on one site. For example, in the Polymer case, polymer manufacturing plants are often located next to their feedstock (large volume organic chemicals plants, LVOC), which in turn also typically operate close to a refinery. The E-PRTR reporting format may combine all these site activities in a single value, though Member States often register these installations individually.

A further limitation is that although estimated total industrial diffuse emissions are mapped on E-PRTR, no diffuse or fugitive emissions specific for a facility are available separately from channelled emissions. Stakeholders consulted in the course of the study generally supported the above limitations in the use of E-PRTR data for the purpose of the assessments. Some views gathered suggested that over time, E-PRTR could be used to demonstrate the impact of BATC on emissions reductions achieved. It was suggested that such assessments should consider changes in activity data e.g. from potential plant closures.

Eurostat

<table>
<thead>
<tr>
<th>Data type (at BAT granularity) from Table 15</th>
<th>Coverage of this source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Activity (e.g. fuel consumption, raw / final product produced)</td>
<td>Varies by sector</td>
</tr>
</tbody>
</table>

The Commission (Eurostat) holds a database containing a range of information that could be used in the assessment of impacts of BAT-AELs. For the purpose of the case studies, Eurostat was reviewed for availability of the activity data, specifically production volume data split by type of good. PRODCOM\(^23\) provides statistics on the production of manufactured goods in mining, quarrying and manufacturing. The data is presented using product codes specified on the PRODCOM list which at the time of the review this included around 3,900 different manufactured products. Although it takes some time to identify appropriate PRODCOM codes, production data per MS and year can be extracted to provide activity data.

Eurostat also contains useful information which can inform the cost assessment. Exchange rates ('[ert_bil_eur_a]')\(^24\) can be used to convert cost data expressed in a different currencies into a consistent currency for the analysis (likely to be Euro’s in this case). Further GDP Deflators (‘teina110’\(^25\)) can be used to convert monetary data into a consistent price base to ensure comparability between costs and benefits.

In the Polymer case study, production data were used to develop a trend with which sector activity could be projected into future. This was based on the historical rate of change of output. However, in some cases, the underlying data are either confidential or estimated. As such, this creates uncertainty around the accuracy of the Eurostat data.

GAINS model

<table>
<thead>
<tr>
<th>Data type (at BAT granularity) from Table 15</th>
<th>Coverage of this source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Activity (e.g. fuel consumption, raw / final product produced)</td>
<td>✓</td>
</tr>
<tr>
<td>Gas and wastewater flows and parameters (incl. reference conditions)</td>
<td>✓</td>
</tr>
<tr>
<td>Emission factors</td>
<td>✓</td>
</tr>
<tr>
<td>Abatement techniques efficiency</td>
<td>✓</td>
</tr>
<tr>
<td>Uptake of abatement techniques (under the baseline and in the future).</td>
<td>✓</td>
</tr>
<tr>
<td>Lifetime</td>
<td>✓</td>
</tr>
<tr>
<td>Marginal abatement costs (i.e. cost per tonne of pollutant abated)</td>
<td>✓</td>
</tr>
</tbody>
</table>

\(^23\)http://ec.europa.eu/eurostat/web/prodcom
\(^24\)http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=ert_bil_eur_a&lang=en
\(^25\)http://ec.europa.eu/eurostat/tgm/table.do?tab=table&init=1&language=en&pcode=teina110&plugin=1
For the purpose of the review of available data sources, emission and control option data from GAINS has been downloaded for the years 2010 and 2015\textsuperscript{26} although the model also provides data for a number of scenarios up to 2030 (at 5 yearly intervals). The data contained the following parameters:

- **Sector** – the iron and steel sector is disaggregated into the following processes: Basic oxygen furnace; Coke oven; Pig iron, blast furnace; and agglomeration plant – sinter. For sinter and pig iron GAINS includes separate sectors for fugitive emissions.
- **Activity** - commonly referring to fuel use; in the case of the processes in the iron and steel sector the activity data represent production values, and is not linked to fuel used.
- **Technology** - abatement technology applied to each sector.
- **Capacities controlled** – uptake of a given technology expressed as a percentage of the activity.
- **Removal efficiency** – abatement efficiency of a given technology.
- **Unabated emission factor** – assumed emission factor for unit of activity before abatement is applied.
- **Abatement costs** – for a given scenario, GAINS generates costs of abatement for each technology, expressed in Euros per unit of activity and per tonne of pollutant abated. These costs are the output of a calculation of total abatement cost per year for each sector using CAPEX and OPEX input data.

The table below presents an extract of the data for basic oxygen furnace and coke ovens in the iron and steel sector for Italy for 2010.

**Table 17 Extract of sample data from the GAINS model for the iron and steel sector**

<table>
<thead>
<tr>
<th>Sector</th>
<th>Technology</th>
<th>Technology description</th>
<th>Activity (Mt)</th>
<th>Capacities controlled (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PR_BAOX</td>
<td>PR_ESP2</td>
<td>Electrostatic Precipitator 2 fields</td>
<td>8.6</td>
<td>3</td>
</tr>
<tr>
<td>PR_BAOX</td>
<td>PR_HED</td>
<td>High efficiency deduster</td>
<td>8.6</td>
<td>97</td>
</tr>
<tr>
<td>PR_COKE</td>
<td>PR_ESP1</td>
<td>Electrostatic Precipitator 1 field</td>
<td>4.0</td>
<td>15</td>
</tr>
<tr>
<td>PR_COKE</td>
<td>PR_ESP2</td>
<td>Electrostatic Precipitator 2 fields</td>
<td>4.0</td>
<td>85</td>
</tr>
<tr>
<td>PR_COKE</td>
<td>SO2PR1</td>
<td>Stage 1 - Process SO\textsubscript{2} control</td>
<td>4.0</td>
<td>30</td>
</tr>
<tr>
<td>PR_COKE</td>
<td>SO2PR2</td>
<td>Stage 2 - Process SO\textsubscript{2} control</td>
<td>4.0</td>
<td>70</td>
</tr>
</tbody>
</table>

**Other models**

<table>
<thead>
<tr>
<th>Data type (at BAT granularity) from Table 15</th>
<th>Coverage of this source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Activity (e.g. fuel consumption, raw / final product produced)</td>
<td>Varies by model</td>
</tr>
</tbody>
</table>

PRIMES model\textsuperscript{27} - European Union energy markets model, can provide data on the future demand and supply of energy in the EU. PRIMES data on energy production and consumption are used as inputs into the GAINS model. The JRC is currently developing the POTEnCIA model\textsuperscript{28}, which is also for the EU energy system. Livestock numbers and fertilizer application activity data can be sourced from the CAPRI agricultural sector model\textsuperscript{29} (also used in GAINS).

\textsuperscript{26} Scenario: WPE_2014_CLE (ID: WPE_2014_CLE)
\textsuperscript{27} http://ec.europa.eu/environment/archives/air/models/primes.htm
\textsuperscript{28} https://ec.europa.eu/jrc/en/potencia
\textsuperscript{29} http://ec.europa.eu/environment/archives/air/models/capri.htm
4.2.6 Other literature and online sources

<table>
<thead>
<tr>
<th>Data type (at BAT granularity) from Table 15</th>
<th>Coverage of this source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Activity (e.g. fuel consumption, raw / final product produced)</td>
<td>✓</td>
</tr>
<tr>
<td>Emission factors</td>
<td>✓</td>
</tr>
<tr>
<td>Abatement techniques efficiency</td>
<td>✓</td>
</tr>
<tr>
<td>Uptake of abatement techniques (under the baseline and in the future)</td>
<td>✓</td>
</tr>
<tr>
<td>Discount rate</td>
<td>✓</td>
</tr>
</tbody>
</table>

**Activity data**

Several alternative sources of activity data were identified in the case studies.

For example, the Polymer example considered the use of data published by journals in order to update production rate values or to derive an approximate value. ICIS webpages ‘European chemical profile: polystyrene’ was one example identified which listed polystyrene plant capacity in tonnes per year for specific named company/location installations.

Similarly, the iron and steel case study highlighted that such data may also be available from plant websites and/or published by trade associations. For example, the German Steel Association (VdEh Stahl) maintains a database of iron and steel plants in Germany, ‘PLANTFACTS’. It contains information on the maximum technical production capacity of the company/location installations but not actual production data. Also, aggregated country level steel production data for EU-28 are available from the websites of World Steel Association and Eurofer. These statistics do not distinguish between the volume of steel produced in integrated steel plants versus electric arc furnaces.

Journals typically gather information from a wide range of sources to underpin the data presented, including: press releases from operators, communications from engineering firms on awarded contracts or even annual environmental reports from corporations.

Journals or data produced by trade associations may also include forecasts of future production. Such data was reviewed in the Polymer case study as a potential basis on which activity could be projected into the future. Relative to using historical data (e.g. from Eurostat), these are based on a view of how the different drivers of production could change going forward (although as such are based on a range of other assumptions). An example was identified of a polypropylene production forecast, although it was not directly applicable, as it was for North America.

However, there are several limitations to using data from journals, websites and trade associations:

- Relative to environmental permits or monitoring reports, accessing this information may incur a financial cost as this information is often sold by journals and others.
- These sources typically release site or installation level data, and rarely include information at source level or at BAT granularity.
- These data may not be available across all industrial sectors or for all sites within a given sector and MS. Where data are available at MS level, this is only suitable for identifying plant level production where MS have only one installation.
- Data may not be available for all products: for example in the Iron and Steel case study, data for steel production was often available but not for pig iron, coke or sinter.
- Even where this information is available, the frequency of updated releases may not be regular.

In addition there are further sectoral reports covering activity (and other) information, e.g.

- produced to underpin policy development in other areas, e.g. sector benchmarking reports for the EU ETS;

31 [http://www.eurofer.org](http://www.eurofer.org)
• national level BAT assessments; or
• NGO reports.

Emissions factors / concentrations

Alternative sources may also be available to inform emissions factors or concentrations. For example, the Polymer case study considered emissions factors from the US EPA which are published for most industrial sectors. An example of these data is included in Figure 14. However, in exploring these data the case study noted that: some of these reports are very old and outdated; the data are not comparable to the BREF as it is reported per emission source or production unit rather than per plant; and its applicability to EU installations is questionable.

Figure 14 Extract from the USEPA Polystyrene emission factors (1995)

In some cases, emission concentrations of flue gases are published online. However, the availability of such data is limited and was only identified in the Iron and Steel case study for one plant.

Abatement techniques and their costs

During the course of the stakeholder engagement, it was suggested that studies assessing the potential to reduce GHGs from the iron and steel sector may provide relevant data / information regarding abatement techniques for wider pollutants. This information is likely to consider both the technical and economic feasibility of abatement measures.

Useful databases and reports which contain information on the cost of abatement techniques include:

• Reports published based on research by the Task Force on Techno-Economic Issues (TFTEI) into abatement technologies for stationary and mobile sources of air pollutants
• Research and reports disseminated by the Technology Transfer Network under the Clean Air Technology Centre
• National Member States resources, such as the Multi-Pollutant Measures Database in the UK and the studies on state for the art in different industrial sectors developed by the Austrian Environment Agency (e.g. [45]).
• Sector organisation’s technical reports, such as Clean Coal Centre.

33 E.g.: https://www3.epa.gov/ttn/crtic1/products.html
34 http://www.iea-coal.org.uk/site2010/home
Analysis and development of methodologies for estimating potential industrial emissions reductions and compliance costs of BAT conclusions adopted under the Industrial Emissions Directive

Guidelines developed in the context of the Minamata Convention on Mercury (e.g. for coal-fired power plants and industrial boilers, smelting and roasting processes referred to in the Convention as non-ferrous metals, waste incineration facilities, cement clinker production facilities)35

Some stakeholders further suggested that national systems for management of environmental funding could provide valuable information on the real cost of abatement techniques. Furthermore, some stakeholders stated that you need to be cautious when using cost data from the literature, specifically with regard to the common focus on capital, rather than operating costs and lack of transparency on the cost components of the data.

4.2.7 Gap filling

Level of effort required by industry to collect additional data via trade associations

Where published data is unavailable or incomplete, the collection of additional primary data (with data from plant manufacturers, technology providers and operators who have recently installed required equipment in comparable installations being suggested by some stakeholders) is one option to fill the gaps. However, doing so takes time and resources. Several stakeholders from the iron and steel and polymer production sectors were engaged as part of the study to canvass thoughts on the feasibility of collecting additional data through the trade associations. Trade associations are considered specifically as they are considered to be in a good position to collect additional data given their existing contacts with companies and operators, and many have hands-on experience of data collection (either because they collect their own data or have been involved in data gathering exercises in the past). Existing data collection initiatives for the iron and steel sector are described in Box 14; data sources developed in the context of life cycle assessment are shown in Box 15.

Box 14 Existing data collection involving trade associations: Iron and Steel sector

The last initiative to gather environmental data for the Iron and Steel sector was the BREF review between 2007-2012. Under the review, evidence was gathered directly from individual operators. Since the BREF review, no further or updated information on the environmental performance or implementation status of the BATC has been collected. However, by 30 September 2017, Member State authorities will submit to the European Commission their reports on the implementation of the IED in the period 2013 - 2016. These reports will include focused information on the iron and steel installations for which permit reconsideration / review was triggered following publication of BAT Conclusions. This will also cover reporting on the installations that were granted a derogation.

In the BREF review process, Shadow Working Groups are established through which stakeholders are engaged and evidence is collected. Data collection in the BREF process is principally done by a questionnaire provided by the EIPPCB. In the working groups, brief general updates are provided orally by the members on the status of IED implementation and changes to permits. These updates are high level and quite brief. The information collected as part of the BREF review is held by the EIPPCB.

Trade associations often have a direct role in the process. Vdeh (Association of German Steel Manufacturers) noted that they are involved in the development of the data gathering questionnaires and that the process is supported by additional data gathering by associations themselves. Furthermore, Eurofer noted they contact operators to help form the membership of the working groups.

More widely, Eurofer collect their own data and information regarding the Iron and Steel industry. These data, regarding production and other statistics, are collected by a market analysis department and used in Eurofer publications.

Box 15 Existing data collection involving trade associations: Life-cycle assessment

The following data sources developed in the context of Life Cycle Assessment (LCA) can provide additional information on some of the manufacturing processes covered by the IED.

The European Platform on Life Cycle Assessment (EPLCA)\(^ {36}\)

The European Platform on Life Cycle Assessment (EPLCA) is the EU’s knowledge base responding to business and policy needs for environmental assessments of supply chains and end-of-life waste management, otherwise known as life cycle assessments. It comprises the Life Cycle Data Network, the European Life Cycle Database, the International reference Life Cycle Data System, Life Cycle Impact Assessment and the Resource Directory.

Related to the EPLCA, JRC is also developing life cycle based indicators describing the environmental impacts due to European consumption at the EU and Member State level.

Life Cycle Data Network (LCDN)\(^ {37}\)

With the Life Cycle Data Network (LCDN) the JRC provides the IT infrastructure for data providers worldwide to share their data on resource consumption and emissions for product supply chains, their use, and end-of-life waste management options via a common network if certain quality criteria are met. Data providers are free to set their own access requirements, e.g. a fee may be charged for data.

European Life Cycle Database (ELCD)\(^ {38}\)

The European Life Cycle Database (ELCD) provides resource and emissions inventory data that are key for many European life cycle assessments. It has a focus on European average data and often data is provided by European industry associations. The ELCD will be transferred more and more into the LCDN. The data in the ELCD is free for the user.

International reference Life Cycle Data System (ILCD) Handbook\(^ {39}\)


Life Cycle Impact Assessment (LCIA)\(^ {40}\)

Specific guidance and recommended data are provided for the impact assessment phase in life cycle assessments, covering a wide range of environmental impacts from water, energy and resource consumption, over climate change, to acidification, nutrients in the environment and toxicity related issues.

LCA Resources Directory (RD)\(^ {41}\)

The Resource Directory is a repository of life cycle based studies, reports and documents, including information on data and software developers/suppliers as well as life cycle service providers.

Level of effort

A key consideration of whether to undertake additional data collection is the level of effort required. This in turn will depend on a number of variables, including the: importance of the data to the quantification of impacts, scope of the BREF and data required, size of the industry and number of operatives, the availability of existing data and/or data collection processes, and the complexity of the information being collected.

\(^{36}\) http://eplca.jrc.ec.europa.eu/
\(^{37}\) http://eplca.jrc.ec.europa.eu/LCDN/
\(^{39}\) http://eplca.jrc.ec.europa.eu/?page_id=86
\(^{40}\) http://eplca.jrc.ec.europa.eu/?page_id=1159
Although not directly concerned with gathering data to facilitate the assessment of BATC, an illustration of the level of effort required to undertake a detailed data collection exercise across an industrial sector (and related to emissions reduction technologies) can be gained from the BREF process. A view from one stakeholder was that the complexity and level of effort required for data gathering increases with the number of production steps involved in the manufacturing process and number of installations. In some cases, information needs to be gathered from more than one person per company (e.g. separate environmental experts on waste water, air quality control and waste management). Additional time is needed for checking, evaluating and compiling the data.

**Time required**

Alongside level of effort, collecting additional data may need to be spread over a long period of time. This is because information may not be readily available to operators in a suitable format. As such, time is required for operators to understand the requirement, collect, clean and provide data, and for this to be checked and verified. Furthermore, resource for operators to support such activities may be limited and prioritised according to Members’ views.

For example, in the case of the Iron and Steel BREF, data gathering was spread over 2 to 3 months. In this case, timelines for data collection are guided by the BREF Guidance (in the context of IED Article 75, 2012). Interestingly, one stakeholder suggested that shorter deadlines for data collection (e.g. one month) may be productive to reduce the risk that operators unnecessarily delay providing data.

If the formal information exchange process supporting the BREF development were to be used to help feed into the evaluation of impacts of any BATC (i.e. to avoid implying the need for a separate dedicated data collection) it may need to broaden in coverage to a wider set of plants that are not industry leading nor potentially with BAT deployed.

**Engagement of stakeholders**

Where data are gathered outside of legal obligations, it is done so on a voluntary basis. As such the willingness of operators or competent authorities to engage in the data gathering is a key factor in collating a comprehensive and robust dataset. Technology suppliers have also been identified as key stakeholders to engage in the assessments. Again although the evidence gathering under the BREF process does not directly concern the assessment of the impacts of BATC, this example helpfully illustrates some of the key risks associated with stakeholder involvement and important lessons learned which should be considered if gap filling is required to facilitate assessment of BATC impacts.

From the experience of the Iron and Steel BREF review, it was evident that within environmental departments of operators, the IED process was placed at the top of the agenda. The response levels from the industry to the BREF reviews were very high. This is driven by the fact that operator responses are informing legal requirements that are ultimately placed on them. The European Council of Vinyl Manufacturers also noted high stakeholder engagement in the BREF process is because operators foresee a direct relation to their work.

The willingness of stakeholders to engage in data collection also depends on their confidence in the processes for handling commercially sensitive information. Competition regulations may limit the extent to which the detailed production and activity data for processes can be shared or published in the public domain. For LCA databases, data are provided by the industry under the terms of a Memorandum of Understanding. Confidentiality issues are resolved through data aggregation.

In the case of LCA data collection, stakeholder engagement highlighted two key drivers for industry involvement:

1. Industrial operators have their own interests in looking at their supply chains, providing benchmarks and reducing emissions as this could also help to drive cost cutting (although the assessment of costs is not straightforward as companies may increase the costs in one part of the supply chain in order to limit the impacts in another part).
2. The attention is also driven by the interest from the European Commission in testing the products’ environmental footprint. In the absence of industrial data, researchers and consultants must make assumptions to inform estimates of performance. Industry therefore has an interest in making sure that data used in relation to their industries is of high quality as (in an agglomerated form) this data is used to inform policy making.
Other considerations

When collecting data, clear guidance needs to be set out to steer operators in their provision of data. An example of this is the EU Life Cycle Database, which defines clear quality requirements set out for the information to be provided. In this case, the data submitted needs to be supported by documentation on what has been excluded / included and describing the application of the data. The data provided by industry is then received and verified by the JRC to ascertain whether the submission is compliant with the quality requirements. If gap filling is required to facilitate the assessment of BATC impacts, the clarity and completeness of guidance is an important consideration to minimise the risk of non-engagement. Establishing minimum quality requirements may be particularly relevant when collecting cost data directly from the operators or technology providers as data collected in this way may vary greatly.

Modelling approaches to gap filling

Approaches to gap filling were explored as part of the case studies. Where there were gaps from collecting primary data, data gaps were attempted to be filled through modelling approaches using existing data.

For example, in the Iron and Steel case study, the emissions of mercury and PCDD/F were not reported in the environmental permit for one installation or in the annual emission report. Emissions were estimated by multiplying the flue gas volume (from the environmental permit) with operating hours (from the emissions report) and the emission concentrations published in the BREF per process/installation. E.g. for a coke oven plant:

- Flue gas volume = 320,000 Nm³/h * 8,760 h/y in 2015 = 2,803,200,000 Nm³/y
- PCDD/F emission concentration from coke oven plant = < 0.1 ng I-TEQ/Nm³
- PCDD/F emissions in 2015 = < 280 g I-TEQ

One can also use gap filling methodologies for activity data, as illustrated by the Iron and Steel case study in Box 16.

Gap-filling methodologies have limitations too. Inherently there is no straightforward way to check if emissions are realistic in the plant specific case. Furthermore, a top-down approach for splitting plant level emissions from country-level data could have an arbitrary nature and will introduce a high degree of uncertainty if limited information is used in the methodology.

Gap filling using modelling approaches was also considered for the Polymer sector. In this case, this method was not considered applicable for two reasons:

1. Precise modelling estimation efforts can be applicable to certain sectors (such as combustion plants, cement, or iron production) where overall plant configuration is known and flue gases can be estimated with a reasonable error. In the case of a polymer manufacturing facility there are a large number of factors which drive variance, including: number and size of raw material and product storage tanks, types of gaskets, process pressure, number of flanges. For channelled process waste gases there are numerous options to generate vacuum (vacuum pumps or ejectors) and many different vent gas condenser types (chilled water, cooling water, freeze condensers and others).

2. There isn’t a validated/accepted estimation model in literature to predict vent gas or waste water flows nor concentrations from each one of the large variety of process configurations.
Box 16 Activity data gap filling example in the Iron and Steel case study

From the production flow approximations for Pig iron, Sinter and Coke activity variables can be derived. The following formulae can be applied:

\[
P_{\text{iron}} = B\text{OF steel} \times 0.93
\]
\[
S\text{inter} = P_{\text{iron}} \times 1.505 \text{ and sinter} < \text{Capacity sinter}
\]
\[
C\text{oke} = P_{\text{iron}} \times [0.39 - 0.45] \text{ and Coke} < \text{Capacity coke}
\]

For Pig iron, the factor 0.93 is calculated from WSA statistics and reflects the fact that in the Blast Oven Furnace (BOF) scrap is added to the melt. The figure is an average for European installations and there might be some slight variations (+/- 5%) between different operators.

For sinter the figure is taken from the literature (see Morfeldt et al., 2014) assuming that sinter is produced completely at the plant. This figure reflects the fact that sinter is an agglomerate of iron ore, and iron ore being a mixture of different iron oxides. The reduction process removes the oxygen, hence there is a loss of mass. For sinter one additional consideration to be made is that it might be easily replaced by purchased pellets. Whereas sinter is prone to transport and therefore produced at the plant, pellets are usually produced near the iron ore mines. So the formula and the applied factor (1.505) can be used as an upper limit when sinter production is used to the full extent, without the consumption of pellets.

The parameter for coke involves some uncertainty because there is some flexibility in process operation. Coke can be replaced partly by other materials with a high carbon content such as coal and even plastics. As coke is more expensive than coal, steel producers will try to minimize coke in the plants. Unlike sinter, coke can be purchased on the market. On the other hand, coke plants will always operate close to maximum capacity. As such the capacity of the coke plant is a good approximation of production.

Use of Life Cycle Assessment data

Data generated for the purpose of life cycle assessment may be considered to fill in the gaps in data on the emission factors. In this section the feasibility of doing so is discussed. There exist two publicly available sources at the EU-level providing data on the life cycle assessment of products:

- The Life Cycle Data Network (LCDN) \(^{42}\) - a web-based infrastructure that provides easy access to the life cycle data. The dataset published is an amalgamation of information provided by any original data owner including industry, specific LCA projects, research organisations and other. Entry-level requirements apply to the data submitted for inclusion in the database. There are also several guidance documents supporting the methodologies.

- The European Life Cycle Database (ELCD) – is a web-based dataset of life cycle inventory data. The purpose of the database is to provide the data required to undertake life cycle assessments of common products free of charge. Entry level requirements adopted for the LCDN apply to the data provided to the ELCD.

Applicability of the information published in the above sources to support assessment of impacts of BATC have been assessed.

The data covered in the Life Cycle Assessment sources above covers all life cycle phases: production phase, use phase and end-of-life phase. The Life Cycle Inventory for the production phase covers not only the actual manufacturing process at an industrial facility but also extraction of the raw materials, production of electricity, production of intermediaries, production of equipment required for production.

ELCD contains 24 entries for the processes in the category “Materials production / Plastics” covering different manufacturing processes. For illustration purposes, the process of “Polyethylene high density granulate (PE-HD); production mix, at plant” has been selected. The Life Cycle inventory for this

---

\(^{42}\) http://eplca.jrc.ec.europa.eu/?page_id=134
process lists inputs and outputs to the three types of flows: elementary flow, product flow and waste flow. An elementary flow is a reference substance or resource emitted or consumed, in an aggregated or partially disaggregated dataset. The inputs/outputs to / out of the manufacturing process of a product – which is covered by scope of BATC, would be covered by the elementary flows.

While the elementary flows are classified into groups such as “resources from ground”, or “emissions to air”, the underlying figures for the given flow are not listed. That means that for example emissions to air of nitrogen dioxide that are expressed as mass emissions in kg per kg of polyethylene high density granulate (PE-HD) would account for emissions from the manufacturing process itself but also for emissions of nitrogen dioxide from extraction of the raw materials, production of electricity, production of intermediaries, production of required equipment. The data published in the ELCD does not allow one to disaggregate the reported emission data into these sub-components. Due to the aggregation issue described above, the aggregated data produced as part of the Life Cycle Assessment is unlikely to be directly applicable for the use in assessment of emission reductions and costs of BAT.

In instances where the input and output data is available at the disaggregated production process level, clarity is required on whether the data covers only the actual process within the boundaries of a single facility, or also inputs and outputs from outside the facility. Table 18 is an extract of the Life Cycle Inventory for the sintering unit used to support Life Cycle Impact Assessment for the iron and steel industry from Olmez et al. (2016). While the inputs and outputs refer to the sintering unit, as the inputs to the process also include electricity, it is unclear whether e.g. CO₂ or NOx in the list of outputs take into account emissions from production of electricity. These complexities could only be clarified by detailed investigation of methodology applied, and/or by direct consultation with the authors of the study.

<table>
<thead>
<tr>
<th>Input/Output</th>
<th>Material</th>
<th>Amount</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inputs</td>
<td>Magnesite</td>
<td>0.002</td>
<td>tonne/tonne sinter</td>
</tr>
<tr>
<td></td>
<td>Iron ore</td>
<td>0.89</td>
<td>tonne/tonne sinter</td>
</tr>
<tr>
<td></td>
<td>Limestone</td>
<td>0.20</td>
<td>tonne/tonne sinter</td>
</tr>
<tr>
<td></td>
<td>Dolomite</td>
<td>0.011</td>
<td>tonne/tonne sinter</td>
</tr>
<tr>
<td></td>
<td>Dunite</td>
<td>0.031</td>
<td>tonne/tonne sinter</td>
</tr>
<tr>
<td></td>
<td>Coke breeze</td>
<td>0.08</td>
<td>tonne/tonne sinter</td>
</tr>
<tr>
<td></td>
<td>Sinter dust</td>
<td>0.69</td>
<td>tonne/tonne sinter</td>
</tr>
<tr>
<td></td>
<td>Pellet dust</td>
<td>0.040</td>
<td>tonne/tonne sinter</td>
</tr>
<tr>
<td></td>
<td>Basic oxygen furnace slag</td>
<td>0.018</td>
<td>tonne/tonne sinter</td>
</tr>
<tr>
<td></td>
<td>Flue dust</td>
<td>0.023</td>
<td>tonne/tonne sinter</td>
</tr>
<tr>
<td></td>
<td>Gas cleaning sludge</td>
<td>0.005</td>
<td>tonne/tonne sinter</td>
</tr>
<tr>
<td></td>
<td>Mill scale</td>
<td>0.027</td>
<td>tonne/tonne sinter</td>
</tr>
<tr>
<td></td>
<td>Service water</td>
<td>1.13</td>
<td>m³/tonne sinter</td>
</tr>
<tr>
<td></td>
<td>Electricity</td>
<td>0.19</td>
<td>GJ/tonne sinter</td>
</tr>
<tr>
<td></td>
<td>Coke oven gas</td>
<td>0.11</td>
<td>GJ/tonne sinter</td>
</tr>
<tr>
<td></td>
<td>Skip sinter</td>
<td>1.0</td>
<td>tonne/tonne sinter</td>
</tr>
<tr>
<td></td>
<td>Sinter dust</td>
<td>0.69</td>
<td>tonne/tonne sinter</td>
</tr>
<tr>
<td></td>
<td>Carbon monoxide</td>
<td>45.1</td>
<td>kg/tonne sinter</td>
</tr>
<tr>
<td></td>
<td>Sulphur dioxide</td>
<td>5.1</td>
<td>kg/tonne sinter</td>
</tr>
<tr>
<td></td>
<td>Nitric oxide</td>
<td>0.80</td>
<td>kg/tonne sinter</td>
</tr>
<tr>
<td></td>
<td>Nitrogen dioxide</td>
<td>1.23</td>
<td>kg/tonne sinter</td>
</tr>
<tr>
<td></td>
<td>Hydrogen chloride</td>
<td>0.01</td>
<td>kg/tonne sinter</td>
</tr>
<tr>
<td></td>
<td>Hydrogen fluoride</td>
<td>0.0005</td>
<td>kg/tonne sinter</td>
</tr>
<tr>
<td></td>
<td>Dioxin</td>
<td>0.0000019</td>
<td>g/tonne sinter</td>
</tr>
<tr>
<td></td>
<td>Furan</td>
<td>0.0000019</td>
<td>g/tonne sinter</td>
</tr>
<tr>
<td></td>
<td>Dust</td>
<td>1.68</td>
<td>kg/tonne sinter</td>
</tr>
<tr>
<td></td>
<td>Carbon dioxide</td>
<td>388</td>
<td>kg/tonne sinter</td>
</tr>
</tbody>
</table>

Table 18 Material inputs and outputs - sintering unit
5 Feasibility analysis of methodologies

5.1 Introduction

The feasibility of the identified methods has been tested at facility level, with a view that this level of assessment provides the most accurate results. In this approach, in order to provide a sectoral estimate of impacts, the results from the individual facilities would need to be summed. While this approach is the most resource intensive approach as requires site by site assessment, it allows assessing the level of effort required in order to obtain the most accurate results. The sections below present a discussion of the results of feasibility testing, specifically considering the trade-offs between the accuracy and resource implications.

The Multi Criteria Analysis (MCA) criteria are repeated in Table 19.

Table 19 Multi-criteria analysis scoring criteria

<table>
<thead>
<tr>
<th>Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Group 1 – Accuracy and uncertainty assessment</strong></td>
</tr>
<tr>
<td>1.1 Are the data modelled or measured?</td>
</tr>
<tr>
<td>1.2 Periodicity of data</td>
</tr>
<tr>
<td>1.3 Granularity of available data (BAT-AELs)</td>
</tr>
<tr>
<td>1.4 Applicability to IED sectors</td>
</tr>
<tr>
<td>1.5 Completeness of data (coverage across Member States)</td>
</tr>
<tr>
<td>1.6 Availability of information across air and water pollutants</td>
</tr>
<tr>
<td><strong>Group 2 – Resource implications</strong></td>
</tr>
<tr>
<td>2.1 Effort / human resource required to extract, process, clean and/or sort existing available data.</td>
</tr>
<tr>
<td>2.2 Effort / resource to operate methodology (in connection to complexity of the approach / time and resource required to understand and run the methodology / time and resource required QAQC)</td>
</tr>
<tr>
<td>2.3 Effort to gather new / primary data to ensure BAT-AEL level of granularity (per stakeholder group)</td>
</tr>
<tr>
<td>2.4 What effort is required to keep the data used (existing and collected) up to date?</td>
</tr>
<tr>
<td>2.5 Financial cost of data (e.g. data licensing)</td>
</tr>
<tr>
<td><strong>Group 3 – Practicality of implementing</strong></td>
</tr>
<tr>
<td>3.1 Compatibility with other methods across other elements of the analysis (emission reduction, costs, benefits)</td>
</tr>
<tr>
<td>3.2 Availability of methodologies</td>
</tr>
<tr>
<td>3.3 IT requirements</td>
</tr>
<tr>
<td><strong>Group 4 – Transparency and acceptability</strong></td>
</tr>
<tr>
<td>4.1 Transparency of the methodology</td>
</tr>
<tr>
<td>4.2 Acceptability of the methodology to stakeholders</td>
</tr>
</tbody>
</table>

The full scoring according to the detailed criteria are presented in Appendix D. The full case studies are presented in Appendix F.
5.2 Results of feasibility analysis of identified methodologies

5.2.1 Establishing baseline for the assessment

Results of the Multi-Criteria Analysis

The methodologies to estimate baseline emissions identified and described in the preceding sections of the report are quite similar to each other in that they rely on the same data sources, and that one method can be used to provide inputs to another. That means that whichever method is selected for the assessment, the data would be sourced from one or combination of the following sources: environmental permits, monitoring reports, E-PRTR, BREF and other literature. An exception from this is method BE5 which is directly used in the GAINS model to calculate emissions at national and sector level. Data from GAINS supported the assessment of method BE5 but not other methodologies.

As a result, methodologies score similarly against the criteria set out in the MCA, as presented in the summary table below.

<table>
<thead>
<tr>
<th>Criteria scoring</th>
<th>BE1</th>
<th>BE2</th>
<th>BE3</th>
<th>BE5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accuracy and uncertainty</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Resource implications</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Practicality of implementing</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transparency and acceptability</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Development of the baseline emissions is the first and one of the most complex elements of the assessment of impacts of BAT-AELs. The accuracy of the baseline data and assumptions made at this early stage of the assessment impacts on the overall assessment results as it defines how close or far from meeting the BAT-AELs a given facility may be. Key findings from conducting sectoral testing for the methods and the MCA are discussed below.

Key conclusions and findings

1. **Ideal data sources for the development of the baseline for the assessment of impacts of BAT-AEL are expressed in the same metric as the actual BAT-AEL, alongside mass emissions (benefits of BAT-AELs are assessed as annual emission loads).** This enables direct comparison between the baseline and BATC scenarios in the latter stages of the analysis (calculation of emission reductions), with minimum need for transformations or complex modelling, and ease of estimation of impacts on emissions.

As presented earlier in the report, BAT-AELs are expressed in various metrics. If data collected for the baseline is expressed in the same unit as the BAT-AEL, the comparison between the two provides immediate indication on whether the plant is already compliant with the BAT-AELs or whether further reductions are needed, and if so at what scale.

The majority of BAT-AELs for the polymer production sector are expressed in emissions per tonne of product (BAT-AELs to air), while for the iron and steel sector in concentrations (to air and water). Thus ideally, the baseline data gathered for the polymer production sector should be expressed in loads (mass emissions), and for the iron and steel sector in concentrations (this can be accompanied by data on loads, or transformed into annual loads using method BE2 if other contextual data is available). Note that mass emissions are ultimately needed for assessing overall health and environmental impacts. Some sectors can face challenges in that installations may have emission sources that can be categorised under two different BREFs (e.g. LVOC and POL), and hence a methodology needs to have sufficient flexibility to cope with such situations. The permit data methodology can get around this.
2. The BE3 method can deliver results for establishing an emission baseline in every installation and unit subject to access to monitoring reports submitted to the authorities or monitoring data from the operators directly. Establishing the baseline is delivered with minimum additional assumptions although there are potential resource implications for accessing such data.

Based on the iron and steel and polymer production case studies, the most accurate emissions and concentration data for the definition of the baseline at facility level is provided by method BE3. This method uses the emissions or concentrations as measured at the plant. In the examples tested, the monitoring data for each facility were sourced from the annual monitoring reports prepared by the operators for the authorities, or directly requested from the operators for the purpose of the study. Use of E-PRTR data was also tested.

The reports submitted by the operators to the inspection authorities present the results of emission monitoring in order for the authorities to verify if a given facility operates in line with the permit requirements. The data in the reports broadly match the granularity at which BAT-AELs are defined, differentiating between emission sources and channelled and fugitive emissions. The details contained in the reports and the ease of accessing them vary depending on the Member State – these reports are generally not published online but are available upon request from the authorities. While the data gathering to inform method BE3 can be resource intensive, it may be suitable for sectors with a smaller number of plants across Europe, for a limited scope of pollutants. It can also utilise the data already collected in the BREF review questionnaires developed by the EIPPCB, thus limiting the scope of additional data that needs to be collected.

Broadly, if a pollutant was covered by a previous BREF under the IPPC regime, it can be assumed that the monitoring data for such pollutant exists. If a BAT-AEL is however defined for a new pollutant, it might be that it has not been monitored widely across the potentially affected sites to date. Data can be expected to be available in facilities for which a pollutant in question was considered important for local environmental quality.

Some stakeholders expressed the view that the data gathered for the method BE3 would require an expert review to assess its robustness and plausibility.

3. While BE3 method provides real monitoring values, data may not be available for all parameters required. Substances monitored are specified in individual permits. These in turn are influenced by requirements introduced in the past at the EU or national level, but also local requirements for environmental protection and technical design of a facility.

This issue was specifically apparent in the polymers production sector, for which assessment was undertaken using draft BAT-AELs in the CWW BREF. While this BREF now applies to the polymer production sector, the pollutants covered by this BREF, such as total suspended solids (TSS), were not required to be monitored under the polymer production BREF previously. Hence the data for TSS was not available in the monitoring reports obtained for the study.

4. Absence of monitoring data is more substantial in cases where wastewater and waste gas streams are combined between multiple facilities.

Absence of monitoring at the granularity level of BAT-AELs was also identified in the case of one iron and steel plant used for testing. In this instance, the emissions to water from individual processes from the plant were not monitored because the wastewater streams were combined with others from other installations in a common wastewater system before treatment and discharge. The concentrations of pollutants in wastewater was only monitored at the point of discharge after treatment. This data could not be compared against the BAT-AELs for individual processes in the steel plant.

Common wastewater systems can be widespread across certain industrial sectors (e.g. chemicals, refining, steelworks). In such instances the load of pollutants can be taken into consideration to decide which BATC prevails or in some cases weighted average(s) of BAT-AELs can be derived for different emission sources.

Accordingly, in order to assess the impacts of a set of new BAT-AELs being introduced for one of these facilities, the following steps would be required:
• Gathering information on the load of each pollutant for which BAT-AELs have been defined from each facility sharing the wastewater treatment plant
• Gathering information on the BAT-AELs applicable to each of the other facilities
• Based on the emission loads calculating weighted average of the BAT-AEL that would be applied to the wastewater treatment plant (BATC scenario)
• Comparing the calculated weighted average BAT-AEL with the baseline emissions / concentrations

The assessment is therefore possible in principle yet it requires additional calculations of weighted averages and additional data collection on the baseline emissions and emission limit values for the other facilities sharing the wastewater treatment plant. In another case study of a steel plant, the only monitoring data obtained from the authorities were emissions from individual processes (thus at the right granularity level) but expressed in loads. In order for the data to be used for the assessment, emission loads had to transformed into concentration values as this is how the BAT-AELs in the iron and steel sector are expressed.

5. Current E-PRTR data has limited applicability for establishing the baseline emissions for the assessment of impacts of BAT

E-PRTR data have not been used successfully in testing with either the polymer production or iron and steel sectors, but can provide useful mass emissions data particularly for larger more polluting plants/sectors where reporting thresholds are much less of an issue. The primary reasons for that are that values reported in E-PRTR correspond to facilities rather than to individual emission sources (stacks), channelled and fugitive emissions to air are reported combined, and reporting thresholds for pollutants apply. If emissions at facility/ installation level are not available, a top-down approach for splitting plant level emissions from E-PRTR to installation or emission source level have an arbitrary character and introduce a high degree of uncertainty unless additional information is used in the methodology. For instance, emissions factors from BREF or other literature could be used for making a split of emissions reported at installation level, but as the ranges of observed emissions factors for air and water pollutants are broad, such a split is highly uncertain and could be far from the real value. This was a key finding from the initial study on this topic (AMEC, 2015).

6. Where monitoring data is incomplete or cannot be accessed, modelling approaches such as BE1 and BE2 can be used to complete the dataset of baseline emissions

Methods BE1 and BE2 represent modelling approaches that could be used to estimate emissions using activity data and emission factors (expressed either as load or concentration). The benefits of these methodologies is that they require relatively fewer data inputs (compared to BE5) and, subject to availability of appropriate data, do not involve complex calculations. Testing with the iron and steel and polymer production sectors demonstrated that the two methodologies cannot be used in place of one another uniformly in every sector.

7. Applicability of method BE2 is limited to sectors where configuration of the plants is generally well-known (e.g. consistent across the sector), and volumes of flue gases or wastewater can be estimated with reasonable certainty. The method cannot however be applied with such accuracy to sectors with a large variety of plant configurations and design options. This method is also more resource intensive compared to BE1 and BE3.

In the case of the polymer production sector it is possible to deploy method BE1 by using plant level load factors and production capacities. However, application of BE2 method which uses concentrations factors and requires flue gas volumes and wastewater flows is limited. In the case of a polymer manufacturing facilities there are too many site specific factors to allow modelling using the method BE2 with any level of accuracy. Some of the factors that would need to be considered include, for example, number and size of raw materials and product storage tanks, types of gaskets, process pressures, amount of flanges. Only the operator of the installation would have sufficient information concerning the plant to allow a reasonable modelling that could come close to the measured emission values. BE2 method could be applied with more confidence at installation and sector level primarily in sectors such as large combustion plants, cement, or iron and steel production where the plant configurations are more standardised and there is a smaller number of larger plants.
8. Method BE5 is more complex compared to other modelling methods.
Method BE5 uses unabated emission factors and then models the impact of the abatement techniques already installed and their uptake in order to calculate baseline emissions. This methodology is applied in the GAINS model at a national and sector level. The advantage of the method when used in the European-wide model such as GAINS, is the ease of building future scenarios by simply modifying assumptions on uptake of abatement techniques in the sector. The accuracy of the method is linked with uncertainties around the modelling of the abatement techniques already fitted in the sector (i.e. their uptake), and the accuracy of using unabated emission factors especially for process emissions. However, solely for the purpose of calculating baseline emissions, this methodology requires greater data collection compared to other methods (specifically on the abatement techniques currently used, their abatement efficiency and uptake). Some stakeholders expressed a view that method BE5 is too theoretical to be used in assessments of the impacts of BAT.

9. Modelling baseline emissions using any of the modelling approaches requires technical expertise, and some sector-specific knowledge.
While methods BE1 and BE2 would typically require relatively fewer data inputs (in comparison to BE5), in the absence of the data on production and emission factors at the level matching BAT-AELs, the modelling of baseline emissions can become less accurate and more complex. Testing with the polymer production sector demonstrated that some additional steps are required: e.g. installation level activity data had to be converted into product sub-categories to match emission factors available in the BREF. Furthermore, an assumption around performance of a site was needed to select appropriate emissions factors from a range of values provided in BREF. In the iron and steel sector, activity data is generally not available at the process level, and rarely can be obtained for the facility as a whole due to commercial sensitivity. In such instances, several additional calculation steps had to be introduced in order to ensure that the production data matches granularity of BAT-AELs; this in turn further reduced accuracy of the modelling and increased its complexity.

Testing of the method BE1 with the polymer production sector demonstrated that in case of emissions to air, it cannot be applied to fugitive emissions (leaks from gaskets, fittings and seals on pipes, pumps and other production devices). These emissions are not proportional to the production rates. Nevertheless, some emission factors available in the BREF or other sources may cover both channelled and diffuse emissions. This decreases the accuracy of the baseline emissions obtained in this way. In the polymer production sector fugitive emissions are a non-trivial source of overall plant emissions thus implications of this issue on the accuracy of the modelling results can be high.

In the complex industrial sectors, these considerations can only be recognised and appropriately captured in the modelling by sector experts with a good knowledge of the processes deployed and emission profiles.

10. The level of effort required in establishing baseline emissions varies depending on the method used, but the difference is primarily driven by the sources of data available and used for the assessment.
Method BE3 is the least resource intensive (where the information is readily available and accessible) and most accurate for undertaking the assessment. This judgment does not consider the way the underlying data is collected; instead it is based on the complexity of the method, and the number of steps that are required to establish the baseline emissions for the pollutants being assessed. It should be recognised that data availability will differ from sector to sector and across Member States. Methods BE1, BE2 and BE5 are modelling methods which rely on combining a number of data inputs together. While they require relatively simple calculations, the level of effort required in their execution increases with the number of data inputs required (e.g. hence method BE1 is considered to require less effort, then BE2 and BE5). Across the modelling methods, method BE5 combines the largest number of variables but does not provide gains in terms of accuracy compared to other modelling approaches. This is because of uncertainties around the modelling of the abatement techniques already fitted in the sector (i.e. their uptake), and the accuracy of using unabated emission factors especially for process emissions.

There is a finite number of data sources that provide the data at sufficient granularity level for the assessment of BAT-AELs. While aggregated emission data at facility level exist in the E-PRTR they cannot be applied in the context of assessment of impacts of BAT-AELs to achieve satisfactory level of
accuracy. Data at lower granularity than installation level are currently not extracted from site specific documentation and systematised across the EU.

11. While the required data is usually available to operators and competent authorities, it requires time and resource to be collected and processed in order to inform sector level assessments of impacts.

As demonstrated with testing of the methodologies with the iron and steel sector, permits and monitoring reports can provide a good level of understanding and data required to determine baseline emissions. However, even just for a single facility as undertaken during sectoral testing, it is resource intensive to extract relevant content from the individual permit documents due to their size, national language, difference in content and lack of standardised formats to present the information (e.g. lack of standardised tables with emission limit values). Another option is to directly request the data from the operators of the industrial facilities. Yet this can be the most burdensome approach, both for the entity undertaking the assessment (in terms of identifying, contacting and managing exchange of data with the operators, compiling the information, quality assuring the data etc.) and the operators who would be required to compile data sets that in some cases may not necessarily already be easily available to them. Even if the above routes are followed, the data from the operators, monitoring reports and permits may still not provide consistent information across the parameters required for the assessment, for example in terms of pollutants they would cover.

12. Data collection for informing baseline development should not be limited to information on emissions. Information on activity, processes and abatement techniques already used across the existing plants should also be gathered to improve accuracy of emission reduction calculations.

BREFs gather sector specific data into a single document and as such provide valuable information on emission factors, process parameters and abatement techniques to support modelling of the baseline at a sector level. The accuracy of the information in BREFs is high, but often presented in ranges or averages for the sector. When used in modelling, use of sector average assumptions decreases the overall accuracy of the results. It also affects decisions on how feasible it is to retrofit the facilities in the sector, and what the associated costs of that would be, in the later stages of the assessments.

5.2.2 Projecting future emissions from the baseline

Results of the Multi-Criteria Analysis

A summary of the MCA for the methodology to project future emissions is presented in Table 21. Only feasibility of method FE1 was assessed in detail. Use of projections developed externally (method FE2 - see section 3.3.3) was not considered appropriate from the outset of the study for either sectors because of lack of sufficient granularity and transparency over the assumptions on BAT compliance already made in such external projections. External projections are also typically only available for emissions to air, and not to water.

Projecting future emissions from the baseline is inherently uncertain as it relies on assumptions about what is likely to happen in the future. These uncertainties may have an impact on acceptability of the assessment, especially if assumptions made about the future changes are made in a non-transparent manner. Nevertheless, projecting the baseline into the future (e.g. into the year the policy starts) is a well-established step in ex-ante policy appraisal. From the resource point of view, projecting the baseline adds a step to the overall assessment, however deriving extrapolations factors for the projections can be relatively simple.

<table>
<thead>
<tr>
<th>Criteria scoring</th>
<th>FE1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accuracy and uncertainty</td>
<td></td>
</tr>
<tr>
<td>Resource implications</td>
<td></td>
</tr>
<tr>
<td>Practicality of implementing</td>
<td></td>
</tr>
<tr>
<td>Transparency and acceptability</td>
<td></td>
</tr>
</tbody>
</table>

Table 21 Summary of assessment according to the MCA criteria for methods to estimate future emissions
Key conclusions and findings

1. **Decision on whether to project baseline emissions into the future should be made on the basis of confidence that future changes in the sector will occur which would have an implication for the assessment of impacts of the BATC.**

   Recognising that projecting future emissions is uncertain, the decision on whether to include this step in the assessment has to be based on the level of confidence that changes are expected in a sector going forward. If there are no major changes predicted, and projecting to the future would solely be based on the changes in the overall economy (i.e. where activity data is extrapolated using forecasted changes in GDP), this step of the assessment may well be omitted. Based on the feedback gathered at the stakeholder workshop, not all Member States with experience in assessing impacts of BATC at sector level projected future emissions.

2. **Likelihood of changes is very sector specific and may vary plant by plant. Understanding of future changes in the sector is dependent on data availability.**

   The factors to consider when making a judgement on whether to project emissions include confidence in likely plant closures, investments in the new abatement, change to existing processes, fuel and raw materials used etc. In some sectors, future changes are well known, e.g. in the Large Combustion Plant sector there is existing knowledge of the plants due to close in the short-term due to legislative requirements. However, projecting with accuracy over the longer period is more uncertain.

   In contrast, in the polymer production sector, there is little certainty of the anticipated changes moving forward. Given these gaps, when testing the methodology, the emission factors were kept constant at the same level as in the baseline, while activity was projected to reflect economic growth. The activity data was extrapolated in to the future based on the trends in the historic production data published in Eurostat. However, in the iron and steel sector a simple relationship between steel production and GDP does not exist. Therefore, in the absence of any specific information on the changes to the plants used for testing, emissions were not projected into the future.

3. **Uncertainty of results to the assumptions used for development of future emission projections should be quantified using sensitivity analysis**

   Projecting future emissions has large uncertainties hence there is no added benefit of considering too many potential change factors in such assessments. Some stakeholders consulted in the study suggested therefore that only key changes should be reflected when projecting future emission (as discussed above). Furthermore, data on future changes in some sectors may be subject to competition laws. Given the uncertainties of projecting future changes at plant and sector level, the results of the assessment should be tested for sensitivity to the assumptions made. The extent to which a change in the sector can be determined is based on data availability and how well the sector has been studied.

### 5.2.3 Calculating emission reductions

**Results of the Multi-Criteria Analysis**

Summary of the MCA for the methodologies to calculate emission reductions is presented in Table 22 below. Methodologies ER1 and ER2 are both based on calculating the difference between the future scenario assuming compliance with the BAT-AELs, and future emissions in the absence of the BAT-AELs or the baseline – as such the MCA for the two methods has been conducted together.

<table>
<thead>
<tr>
<th>Criteria scoring</th>
<th>ER1 &amp; 2</th>
<th>ER3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accuracy and uncertainty</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Resource implications</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Practicality of implementing</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transparency and acceptability</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Key conclusions and findings

1. **Methods ER1/ER2 when undertaken at a sector level can result in low accuracy; specifically underestimating the emission reductions achieved by BAT-AELs as they assume strict compliance with the limit values, i.e. they do not capture potential emission reductions beyond the limit value as a result of new abatement being installed.** However, such overshoot may be significant only in the first few years of operation of the abatement technique. The main difference in application of ER1/2 and ER3 in terms of accuracy is that the first two methods assume strict compliance with BAT-AELs, e.g. that emission loads or concentrations will be reduced to the level of the BAT-AEL but not further. In reality, in an industrial process it will be difficult to reduce emission levels precisely to the BAT-AEL. Installation of new abatement techniques is likely to achieve emissions / concentrations lower than specified by BAT-AELs (i.e. it is likely to overshoot the limit value). In contrast method BE3 is likely to be more accurate in estimating real life emission reductions as it will capture potential overshoot.

2. **Methods ER1/ER2 are less resource intensive to execute as they do not require identification of specific abatement equipment that will be installed in order to meet BAT-AELs (although this may still be required for estimating costs).** Methods ER1/ER2 use BAT-AELs directly to develop future compliance scenarios. They are therefore relatively easy to apply and do not require particular technical or sector specific expertise. Method ER3 however requires determination of the action that will be undertaken by the operator in order to meet BAT-AELs, for example an abatement technique that needs to be applied at the plant in order to meet BAT-AELs. This is a more resource intensive process as there may be more than one way to meet BAT-AELs, e.g. operator may make changes to the process, may install abatement equipment in addition to the one already present, may replace existing equipment with the more efficient one. Selection of the appropriate abatement technique, which is core to the method ER3, requires specific contextual information. Selection of a technique needs to be informed by what abatement is already in place and consider if the new abatement technique could be installed in addition or as an alternative.

One assumption to be made in calculating impacts on emission reductions (irrespective of the method) is the level of BAT-AEL that should be selected for the assessment, given these are commonly expressed as ranges. For the sector level assessments and ahead of implementation of the BAT, it is not possible to predict this with certainty. Modelling using upper BAT-AELs may underestimate the assessment result if the permitting authorities are likely to set stricter limit values in the permit conditions. On the other hand, modelling the lower BAT-AELs may lead to overestimation. Evidence gathered in the study suggested that mostly upper BAT-AEL levels have been used in the assessments undertaken to date.

Sensitivity analysis is important to understand how much the overall results depend on these assumptions. It is recognised however that in the case of method ER3 specifically, moving from upper-end BAT-AEL to lower-end BAT-AEL may require identification of different abatement techniques; thus increasing resource implications (and costs of compliance).

5.2.4 **Calculating costs of achieving emission reductions**

Results of the Multi-Criteria Analysis

A summary of the MCA for the methodologies to calculate costs of achieving emission reductions is presented in Table 23 below. The main difference between the methods CO1 and CO2 is accuracy – the results obtained using CO1 are far less accurate, yet the method is quick to execute. On the contrary method CO2 is more complex and resource intensive but provides greater accuracy of results and is linked to actual action that may be put in place in order to reach compliance with BAT-AELs. Costing methodologies appear to be more straightforward (although not necessarily less uncertain) compared to methodologies related to emissions.
Table 23 Summary of assessment according to the MCA criteria for methods to calculate costs of compliance with BAT-AELs

<table>
<thead>
<tr>
<th>Criteria scoring</th>
<th>CO1</th>
<th>CO2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accuracy and uncertainty</td>
<td>Red</td>
<td>Yellow</td>
</tr>
<tr>
<td>Resource implications</td>
<td>Green</td>
<td>Red</td>
</tr>
<tr>
<td>Practicality of implementing</td>
<td>Green</td>
<td>Green</td>
</tr>
<tr>
<td>Transparency and acceptability</td>
<td>Green</td>
<td>Yellow</td>
</tr>
</tbody>
</table>

Key conclusions and findings

1. **Selection of the appropriate method for calculating costs can depend on the methodologies selected in the preceding steps.**

Selection of a suitable methodology to estimate costs can be influenced by the earlier steps in the assessment. In practice if the method ER3 is used to calculate emission reductions, the most resource intensive aspect of methodology CO2 i.e. selection of abatement technique, is already completed. Costing the abatement technique using capital (CAPEX) and operational (OPEX) expenditure is then relatively straightforward and can be supported by cost information from the literature or requested from equipment manufacturers. If instead methods ER1 and ER2 are used to calculate emission reductions, choosing the ER3 methodology would mean additional effort is required to identify abatement techniques.

2. **Method CO1 using marginal abatement cost provides a high-level indication of the possible costs of meeting BAT-AELs. Its accuracy is questionable as it uses averaged cost figures derived for a country, pollutant, sector or technology.**

Method CO1 which uses costs expressed per tonne of pollutant abated can provide a first estimate of the cost and is more suitable for assessments at sector or national level, rather than facility level. It is attractive from the resource perspective as it involves simple calculation and minimum data collection efforts (in this method it is assumed that the cost per tonne of pollutant abated will be taken from literature, not derived from individual cost components). However, it is likely to be less accepted by stakeholders as it is sometimes not tied to the specific techniques implied in BATC and/or does not take into account existing uptake of techniques across a sector. Indeed, some stakeholders consulted in the course of this study expressed concerns over the source of such cost information. Data on the marginal abatement costs may also not always be fully compatible with the calculated emission reduction figures. When testing method CO1 using data from GAINS, the costs were expressed per tonne of PM$_{2.5}$ reduced, while the emission reductions were calculated for total PM. To calculate the costs, the emission reductions to which marginal abatement cost is applied need to be scaled down to only account for the PM$_{2.5}$ share of total PM emissions.

Method CO1 can work better in cases where there is only one abatement technique (or a very limited number) that can be fitted across the sector, and/or when the understanding of current installed abatement across the plants is very weak (thus meaning that at sector level it is impossible to determine what the likely uptake of BAT will be). In the latter case using a range of marginal abatement costs reflecting different techniques may provide an indication of the likely cost for the sector at a similar level of uncertainty as if poorly informed assumptions are made when executing method ER3.

3. **Results of the cost assessments should be expressed in the context of either environmental benefits achieved, production costs or another value which allows judgment to be made on whether the costs are low or high.**

The study did not test a detailed application of the benefits assessment methods to the two selected sectors. As a result, the cost results obtained in the case study were difficult to interpret in the wider context – specifically it was not possible to conclude whether the resulting cost estimates are low, high, proportionate or excessive. Some stakeholders supported a view that when presenting the results of
the cost assessment it is important to set them in perspective (as relative rather than absolute costs) to understand whether they are proportionate. Providing absolute values alone is not necessarily meaningful for the purpose of decision making. It was suggested that the context for the estimated cost figures could be provided either by setting the costs against the benefits (i.e. damages avoided) or, for example, by expressing costs of compliance per unit produced and comparing these to the production costs of unit of product. When presenting costs in the context of environmental and human health benefits, some stakeholders called for caution highlighting that not all benefits of BATC can be monetised thus the benefits are likely to be systematically underestimated.

5.2.5 Using the GAINS model for the purpose of assessing emission reductions and costs of meeting BAT-AELs

The GAINS model (IIASA, 2016) provides an integrated assessment framework allowing the exploration of cost-effective strategies to reduce emissions of air pollutants in order to meet specified environmental targets. It models possible control measures and their simultaneous impact on emissions of different pollutants across the EU Member States (and others). The GAINS model has been widely applied to policy analyses in the European Union, including the assessments of impacts of revisions to the Gothenburg Protocol and to the EU Thematic Strategy on Air Pollution (including the revision of the National Emission Ceilings Directive). The assessments are done at sector level for each Member State. GAINS does not undertake facility level assessments. This section reviews the applicability of a modelling approach based on the GAINS model and on the data available from the online version of the GAINS ("GAINS online") model in the context of the assessment of impacts of BAT-AELs.

The review of applicability of GAINS in the context of BATC has comprised the same elements of assessment as presented in section 3.2, starting with the calculation of baseline emissions and then emission reductions assuming compliance with the BATC. Currently, “GAINS online” does not provide specific BAT compliance scenarios that would enable the assessment of the impacts of BATC. The examples below are presented using a reference scenario in GAINS as a “future emissions” scenario in the terminology developed in this study and then by altering the future control strategy in the specific GAINS sectors to represent the uptake of BAT.

Sector coverage and scope of the GAINS method review

Emissions from industrial sectors in GAINS are divided into combustion and process emissions. Within these two broad categories, the following industries are distinguished: cement, lime, glass, pulp, refining, paper, coke production, sintering, basic oxygen furnace, and pig iron. The remaining industrial sectors are aggregated in the “other” category. Only for the iron and steel sector, the GAINS model disaggregates an industry sector into process level aligned with some of the BAT-AELs and this sector was therefore used to review applicability of the model in the context of BATC.

The GAINS model covers air emissions of the following pollutants: Carbon dioxide (CO₂), Methane (CH₄), Ammonia (NH₃), Nitrogen oxides (NOₓ), Nitrous oxide (N₂O), Particulate matter (TSP, PM₁₀, PM₂.₅ and PM₁), Sulphur dioxide (SO₂) and Volatile organic compounds (VOC).

From that list, BAT-AELs for the iron and steel sector have been established for nitrogen oxides, sulphur dioxide and dust (total suspended particles). The review presented below focuses on these three pollutants.

Calculation of baseline emissions with GAINS

Calculation of emissions in the GAINS model is undertaken using unabated emission factors, activity data, abatement efficiency of the control strategy already in place, and share of the activity in which the control strategy is already applied (i.e. uptake of emission reduction measures) (referred to as BE5 in this report). This calculation is shown in Box 17.
Box 17 Calculation of emissions in the GAINS model

The GAINS model uses the following equation to calculate emissions for a given sector / activity in a country:

\[ E_{i,p} = \sum_k \sum_m A_{i,k,m} e_{i,k,m,p} x_{i,k,m,p} \]

where:
- \( i, k, m, p \): Country, activity type, abatement measure, pollutant, respectively
- \( E_{i,p} \): Emissions of pollutant \( p \) (for \( S_0, NO_x, VOC, NH_3, PM2.5, CO_2, CH_4, N_2O, \) etc.) in country \( i \)
- \( A_{i,k} \): Activity level of type \( k \) (e.g., coal consumption in power plants) in country \( i \)
- \( e_{i,k,m,p} \): Emission factor of pollutant \( p \) for activity \( k \) in country \( i \) after application of control measure \( m \)
- \( x_{i,k,m,p} \): Share of total activity of type \( k \) in country \( i \) to which a control measure \( m \) for pollutant \( p \) is applied.

As an example, Table 24 presents the results of the calculations of the total PM emissions from the basic oxygen furnaces and coke ovens in Italy in 2010, using the methodology and data from GAINS.

Table 24 Example of calculation of baseline PM emission using data and methodology in GAINS

<table>
<thead>
<tr>
<th>Sector</th>
<th>Technology</th>
<th>Sectoral activity [Mt]</th>
<th>Unabated emission factor [kt/Unit]</th>
<th>Removal efficiency [%]</th>
<th>Abated emission factor [kt/Unit]</th>
<th>Capacities controlled [%]</th>
<th>Emissions [kt]</th>
</tr>
</thead>
<tbody>
<tr>
<td>PR_SINT</td>
<td>PR_ESP1</td>
<td>7.5</td>
<td>8.6</td>
<td>97</td>
<td>0.3</td>
<td>61</td>
<td>1.3</td>
</tr>
<tr>
<td>PR_SINT</td>
<td>PR_ESP2</td>
<td>7.5</td>
<td>8.6</td>
<td>100</td>
<td>0.0</td>
<td>39</td>
<td>0.0</td>
</tr>
<tr>
<td>PR_BAOX</td>
<td>PR_ESP2</td>
<td>8.6</td>
<td>20.9</td>
<td>98</td>
<td>0.5</td>
<td>3</td>
<td>0.1</td>
</tr>
<tr>
<td>PR_BAOX</td>
<td>PR_HED</td>
<td>8.6</td>
<td>20.9</td>
<td>99</td>
<td>0.1</td>
<td>97</td>
<td>0.9</td>
</tr>
<tr>
<td>PR_COKE</td>
<td>PR_ESP1</td>
<td>4.0</td>
<td>5.0</td>
<td>95</td>
<td>0.3</td>
<td>15</td>
<td>0.2</td>
</tr>
<tr>
<td>PR_COKE</td>
<td>PR_ESP2</td>
<td>4.0</td>
<td>5.0</td>
<td>98</td>
<td>0.1</td>
<td>85</td>
<td>0.3</td>
</tr>
</tbody>
</table>

PR_SINT – Industrial process: Sinter
PR_BAOX – Industrial Process: Basic oxygen furnace
PR_COKE – Industrial Process: Coke oven
PR_HED - High efficiency deduster
PR_ESP1 - Electrostatic Precipitator 1 field
PR_ESP2 - Electrostatic Precipitator 2 fields

Calculation of Future emissions with GAINS

Future emissions in GAINS are estimated according to the above equation, by varying the activity levels and by adjusting the uptake rates of abatement technologies.

Calculation of emission reductions associated with BAT-AELs with GAINS

Identifying BAT-AELs corresponding to GAINS emission sources

BAT-AELs for the iron and steel sector are expressed as concentrations. The first step in assessing impacts of BAT-AELs on emissions is matching specific BAT-AELs to the emission sources they apply to. In the case of the iron and steel sector, BAT-AELs are defined for specific abatement techniques that are installed in a plant. In addition to identifying the emissions from individual processes, it is therefore also a requirement to understand what abatement is installed already.

Control strategies used in GAINS are not always defined by specific abatement technologies. For process emissions – where emissions cannot be directly linked to the energy use, GAINS in many cases assumes that emissions can be controlled in three stages represented by typical removal efficiencies
with increasing marginal costs of abatement – an example of the control strategies for sulphur dioxide emissions from the processes involved in steel production are illustrated in Table 25. The reason for this is related to the range of potential techniques that could be applied so generic categories have been developed that should encompass all of the main options.

Such definition of control strategies is a problem in the context of matching corresponding BAT-AELs defined for specific abatement techniques. In the case of sulphur dioxide emissions from sinter plants, BAT-AELs are defined for example for the use of “Iron ore with low sulphur content”, "Injection of adsorption agent before dedusting by bag filter" or “Wet desulphurisation or regenerative active coal (RAC) process”. It is not possible to directly match these technologies to the stage 1, stage 2 and stage 3 process emission controls in GAINS. An approach to overcome this is to use the abatement efficiencies for the control strategies in GAINS and compare them to abatement efficiencies of specific technologies. Such comparison helps inform an assumption on what BAT-AEL is most likely to correspond to each emission source in GAINS.

**Table 25 Matching BAT-AELs with the control strategies in GAINS model**

<table>
<thead>
<tr>
<th>Sector</th>
<th>Abatement description</th>
<th>Abatement efficiency (%)</th>
<th>Assumed abatement technique used based on the abatement efficiency in GAINS</th>
</tr>
</thead>
<tbody>
<tr>
<td>PR_COKE Stage 1 - Process SO₂ control</td>
<td>50</td>
<td>Unclear. Desulphurisation of coke oven gas is usually applied with higher efficiencies than assumed in GAINS.</td>
<td></td>
</tr>
<tr>
<td>PR_COKE Stage 2 - Process SO₂ control</td>
<td>85</td>
<td>Desulphurisation of coke oven gas.</td>
<td></td>
</tr>
<tr>
<td>PR_SINT Stage 1 - Process SO₂ control</td>
<td>50</td>
<td>Injection of adequate adsorption agents into the waste gas duct of the sinter strand before dedusting by bag filter.</td>
<td></td>
</tr>
<tr>
<td>PR_SINT Stage 2 - Process SO₂ control</td>
<td>70</td>
<td>Wet desulphurisation or regenerative active carbon.</td>
<td></td>
</tr>
</tbody>
</table>

Inevitably, uncertainty is introduced into the assessment at this early step. Furthermore in some instances it is not possible to match BAT-AELs to the GAINS emission source. For example, in case of dust emissions from coke ovens, the BAT-AELs are defined for:

- Emissions from coal grinding
- Emissions from storage and handling pulverised coal
- Emissions from charging coke oven chambers
- Emissions from coke oven underfiring
- Emissions from coke pushing (using bag filters and other cases)
- Emissions from coke quenching (dry quenching, conventional wet quenching, coke stabilisation quenching)
- Emissions from coke grading and handling

In GAINS, data is presented at 'coke oven' level, therefore it is not possible to match the corresponding BAT-AEL with any certainty.
Calculating emission reductions

Since for the iron and steel sector GAINS provides baseline process emissions as loads, while BAT-AELs are defined as concentrations, there exist two options to approach calculation of impacts of BAT-AELs on emission reductions using data from GAINS:

- Option 1: Calculation of annual emission loads associated with BAT-AELs concentrations and their comparison with the baseline emissions (expressed in loads) in GAINS
- Option 2: Identification of the abatement techniques required to meet concentrations of BAT-AELs and calculation of the emission reductions using the abatement efficiency

The examples below have been generated using data downloaded from GAINS, rather than by running new scenarios within GAINS. Modelling undertaken within the GAINS model is based on the same principles as option 2 above i.e. the impact on emissions resulting from a policy scenario is calculated by changing the uptake of the abatement measures that are assumed to be implemented under the modelled scenario.

1. **Calculation of annual emission loads associated with BAT-AELs concentrations and their comparison with the baseline emission in GAINS**

In order to calculate the emission loads (in tonnes per annum) associated with BAT-AELs defined as concentrations, annual volume of the flue gas needs to be assumed. These can be approximated using the activity data in GAINS for specific process, and indicative flue gas volumes from the BREF. An example of these calculations for dust BAT-AELs from sinter production, are presented below. In the example provided, the remaining 39% of activity are controlled by electrostatic precipitator with 2 fields which in GAINS is assumed to already achieve 100% abatement efficiency of dust and thus comply with the BAT-AEL.

<table>
<thead>
<tr>
<th>Table 26 GAINS ER calculation Option 1 – part 1</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Data inputs</strong></td>
</tr>
<tr>
<td>Flue gas volume per tonne of sinter</td>
</tr>
<tr>
<td>Activity data in GAINS</td>
</tr>
<tr>
<td>Share of activity controlled by specific control strategy:</td>
</tr>
<tr>
<td>- Electrostatic precipitator 1 field</td>
</tr>
<tr>
<td><strong>Results</strong></td>
</tr>
<tr>
<td>Total flue gas volume from sinter production</td>
</tr>
<tr>
<td>Total flue gas volumes corresponding to specific control strategies:</td>
</tr>
<tr>
<td>- Electrostatic precipitator 1 field</td>
</tr>
</tbody>
</table>

The lower and higher end of the flue gas volume per tonne of sinter range provided in the BREF can be used for the sensitivity analysis of the calculated flue gas volumes.

BAT-AEL for dust associated with the use of electrostatic precipitator in sinter production is < 20-40 mg/Nm³. The annual emission loads from sintering associated with this BAT-AEL are calculated by multiplying the lower and upper end of the BAT-AEL range by the flue gas volumes corresponding to each control strategy:

---

43 It is recognised that for other emission sources, such as combustion, GAINS also provides information on the concentrations values, thus matching granularity of BAT-AELs expressed as concentrations.
Table 27 GAINS ER calculation Option 1 – part 2

<table>
<thead>
<tr>
<th>Data inputs</th>
<th>Value</th>
<th>Units</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>BAT-AEL (lower)</td>
<td>20</td>
<td>mg/Nm³</td>
<td>I&amp;S BATC</td>
</tr>
<tr>
<td>BAT-AEL (upper)</td>
<td>40</td>
<td>mg/Nm³</td>
<td>I&amp;S BATC</td>
</tr>
<tr>
<td>Flue gas volume from sinter production controlled by electrostatic precipitator 1 field</td>
<td>9608</td>
<td>million Nm³</td>
<td>calculated</td>
</tr>
</tbody>
</table>

Results

For the share of activity controlled by electrostatic precipitator 1 field

| Emissions associated with BAT-AEL (lower) | 0.19  | ktonnes | calculated |
| Emissions associated with BAT-AEL (upper) | 0.38  | ktonnes | calculated |

The resulting emissions are then compared with the baseline emissions for each control strategy to establish whether further emission reductions can be obtained. The example below presents calculation for the share of activity to which electrostatic precipitator with 1 field is applied.

Table 28 GAINS ER calculation Option 1 – part 3

<table>
<thead>
<tr>
<th>Data inputs</th>
<th>Value</th>
<th>Units</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emissions associated with BAT-AEL (lower)</td>
<td>0.19</td>
<td>ktonnes</td>
<td>calculated</td>
</tr>
<tr>
<td>Emissions associated with BAT-AEL (upper)</td>
<td>0.38</td>
<td>ktonnes</td>
<td>calculated</td>
</tr>
<tr>
<td>Baseline emissions</td>
<td>1.34</td>
<td>ktonnes</td>
<td>calculated / from GAINS</td>
</tr>
</tbody>
</table>

Results

Emissions reductions associated with BAT-AEL (lower) | 1.15 ktonnes | calculated |
Emissions reductions associated with BAT-AEL (upper) | 0.96 ktonnes | calculated |

The above results can be interpreted as follows:

- Further reductions in dust emissions from sintering can be achieved in 61% of the activity.
- The current abatement technology fitted to this activity is electrostatic precipitator with 1 field, which in GAINS is assumed to achieve 97% abatement efficiency.
- It is possible to approximate annual emissions that would be associated with meeting dust BAT-AELs, using the average flue gas volumes and activity data.
- Baseline dust emissions corresponding to the above activity are higher than the emissions associated with BAT-AELs. The abatement efficiency of the abatement techniques is less than 100% hence there is scope to further abate the emissions.
- The minimum emission reductions associated with compliance with BAT-AELs are 0.96 ktonnes – this assumes compliance with upper BAT-AEL. As the lower end of the BAT-AELs range is expressed as “less than 20 mg/Nm³” compliance with the lower end of BAT-AEL range is expected to achieve between 1.15 ktonnes (reductions associated with meeting 20mg/Nm³) and 1.34 ktonnes (reductions associated with full abatement of baseline emissions).

As discussed above, this approach is sensitive to the assumption on the flue gas volumes.
2. Identification of the abatement techniques required to meet concentrations of BAT-AELs and calculation of the emission reductions using the abatement efficiency

In this approach the starting point is to understand what abatement techniques would need to be fitted in order to meet BAT-AELs. For the iron and steel sector in which the BAT-AELs are expressed in concentrations, this would normally be done by comparing baseline concentrations with BAT-AELs to calculate the minimum additional abatement efficiency that is required to reach compliance. As GAINS does not contain information on the baseline concentrations, the baseline emissions are compared to the emissions associated with BAT-AELs calculated in the example above.

Table 29 GAINS ER calculation Option 2

<table>
<thead>
<tr>
<th></th>
<th>Value</th>
<th>Units</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Data inputs</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Emissions associated with BAT-AEL (lower)</em></td>
<td>0.19</td>
<td>ktonnes</td>
<td>calculated</td>
</tr>
<tr>
<td><em>Emissions associated with BAT-AEL (upper)</em></td>
<td>0.38</td>
<td>ktonnes</td>
<td>calculated</td>
</tr>
<tr>
<td>Baseline emissions</td>
<td>1.34</td>
<td>ktonnes</td>
<td>calculated / from GAINS</td>
</tr>
<tr>
<td><strong>Results</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Emission abatement efficiency - upper BAT-AEL</em></td>
<td>72</td>
<td>%</td>
<td>calculated</td>
</tr>
<tr>
<td><em>Emission abatement efficiency – lower BAT-AEL</em></td>
<td>86</td>
<td>%</td>
<td>calculated</td>
</tr>
</tbody>
</table>

For the example of dust emissions from sintering, as presented above, compliance with BAT-AELs requires a control strategy that would achieve minimum 72% abatement efficiency. As described in the section above on future emissions, in GAINS different abatement scenarios can be modelled by manipulating the share of activity and uptake rates. In the analysed example of dust emissions from sintering, the share of activity fitted with ESP with 1 field (97% reduction efficiency), could instead be fitted with ESP with 2 fields (100% reduction efficiency) as presented below. The share of activity fitted with ESP with 2 fields achieves maximum abatement efficiency already and is compliant with BAT-AELs.

Table 30 Manipulating GAINS scenarios to model compliance with BAT-AELs – dust emissions from sintering

<table>
<thead>
<tr>
<th>Sector</th>
<th>Abatement description</th>
<th>Abatement efficiency (%)</th>
<th>Capacities controlled (%)</th>
<th>Baseline emissions (kt)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Baseline scenario</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PR_SINT Electrostatic Precipitator 1 field</td>
<td>97</td>
<td>61</td>
<td>1.3</td>
<td></td>
</tr>
<tr>
<td>PR_SINT Electrostatic Precipitator 2 fields</td>
<td>100</td>
<td>39</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td><strong>BATC scenario</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PR_SINT Electrostatic Precipitator 1 field</td>
<td>97</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>PR_SINT Electrostatic Precipitator 2 fields</td>
<td>100</td>
<td>100</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

The same approach can also be applied to emissions of other pollutants from other processes. In the example presented in the table below, the share of activity to which “Stage 2 - Process SO₂ control” has been applied is already compliant with the BAT-AELs (established by comparing the emissions associated with concentration BAT-AELs and the baseline emissions levels). Applying “Stage 2 - Process SO₂ control” to the remaining 30% of activity models compliance of the cokes ovens with the BAT-AELs.
Table 31 Manipulating GAINS scenarios to model compliance with BAT-AELs – sulphur dioxide emissions from coke ovens

<table>
<thead>
<tr>
<th>Sector</th>
<th>Abatement description</th>
<th>Abatement efficiency (%)</th>
<th>Capacities controlled (%)</th>
<th>Emissions (kt)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Baseline scenario</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PR_COKE</td>
<td>Stage 1 - Process SO₂ control</td>
<td>50</td>
<td>30</td>
<td>0.78</td>
</tr>
<tr>
<td>PR_COKE</td>
<td>Stage 2 - Process SO₂ control</td>
<td>85</td>
<td>70</td>
<td>0.55</td>
</tr>
<tr>
<td>TOTAL</td>
<td></td>
<td></td>
<td></td>
<td>1.33</td>
</tr>
<tr>
<td><strong>BATC scenario</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PR_COKE</td>
<td>Stage 1 - Process SO₂ control</td>
<td>50</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>PR_COKE</td>
<td>Stage 2 - Process SO₂ control</td>
<td>85</td>
<td>100</td>
<td>0.78</td>
</tr>
<tr>
<td>TOTAL</td>
<td></td>
<td></td>
<td></td>
<td>0.78</td>
</tr>
<tr>
<td><strong>EMISSION REDUCTIONS</strong></td>
<td></td>
<td></td>
<td></td>
<td>0.55</td>
</tr>
</tbody>
</table>

5.2.5.1 Estimating costs of emission reductions associated with BAT-AELs

GAINS can output cost information for a given control strategy expressed either as cost per tonne of pollutant abated, or as cost per unit of activity abated. These are calculated based on detailed CAPEX and OPEX input data for each technique. However, these underlying data are not however available for download from the “GAINS online” model. For that reason, the cost values expressed in EUR per tonne of pollutant abated or per unit of activity abated have been used.

Table 32 presents cost information provided in GAINS for the control strategies used in the above examples, i.e. dust control strategies for sintering plants, and sulphur dioxide control strategies for coke ovens. Examples of the calculations are elaborated below.

Table 32 Example cost data in GAINS

<table>
<thead>
<tr>
<th>Sector</th>
<th>Abatement description</th>
<th>Cost (million EUR per unit of activity)</th>
<th>Cost (EUR per tonne of pollutant abated)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PR_SINT</td>
<td>Cyclone</td>
<td>0.2</td>
<td>1,456</td>
</tr>
<tr>
<td>PR_SINT</td>
<td>ESP 1 field</td>
<td>0.3</td>
<td>641</td>
</tr>
<tr>
<td>PR_SINT</td>
<td>ESP 2 field</td>
<td>0.4</td>
<td>746</td>
</tr>
<tr>
<td>PR_SINT</td>
<td>High efficiency deduster</td>
<td>0.5</td>
<td>834</td>
</tr>
<tr>
<td>PR_COKE</td>
<td>Stage 1 - Process SO₂ control</td>
<td>0.2</td>
<td>354</td>
</tr>
<tr>
<td>PR_COKE</td>
<td>Stage 2 - Process SO₂ control</td>
<td>0.4</td>
<td>348</td>
</tr>
<tr>
<td>PR_COKE</td>
<td>Stage 3 - Process SO₂ control</td>
<td>0.5</td>
<td>431</td>
</tr>
</tbody>
</table>

Where emission reductions are calculated using option 1 as presented above, there is no basis for calculation of costs of achieving them – e.g. specific abatement techniques are not identified and the share of total activity that needs to be abated is also unknown. An average cost per unit of activity or tonne of pollutant abated across all control strategies could be used instead. However, the cost per tonne of pollutant abated is expressed per tonne of PM₂.₅, while the BAT-AELs are expressed for “dust” and calculations of emission reductions has been undertaken for total particulate matter (i.e. all PM fractions combined). Hence without converting TSP to PM₂.₅ using fractionation assumptions the costs of achieving the required emission reductions will be overestimated.

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44 While the GAINS methodology uses CAPEX and OPEX based methodology (CO2) to estimate costs of emission control strategies, an output can be downloaded in GAINS is expressed in EUR per pollutant abated (data input to method CO1).

45 For sintering, this is expressed per tonne of PM₂.₅.
Box 18 Use of costs expressed in Euros per tonne of pollutant abated

*Cost of achieving dust emission reductions in sinter plants*

Average cost per tonne of pollutant abated is calculated using cost information for three possible technologies: Cyclone, ESP 2 field, High efficiency deduster. ESP1 is excluded from the calculation of the average cost per tonne of pollutant abated as this is the control option in which greater emission reductions need to be achieved in order to comply with BAT-AELs.

The resulting average cost of abating PM$_{2.5}$ emissions from sinter plants is €1,012/tonne.

Using that value, the costs of achieving the lower BAT-AEL (requiring reduction of 1.15kt) would be €1.17m, and upper BAT-AEL (requiring reduction of 0.96kt) would be €0.97m.

**Limitations:**
- Cost is expressed per tonne of PM$_{2.5}$ while the emission reductions are calculated for total PM. This limitation would not apply to assessments of BAT-AELs for nitrogen or sulphur dioxides.
- Cost not linked to a single abatement technique.

Where emission reductions are calculated using option 2 as presented above, specific abatement technique required to meet the emission reductions are identified. This presents two sub-options:

Box 19 Use of costs expressed in Euros per tonne of pollutant abated

*Cost of achieving dust emission reductions in sinter plants*

Using option 2, electrostatic precipitator with 2 fields, achieving 100% abatement efficiency has been applied to meet BAT-AELs. The cost of applying this technique to sinter plants according to GAINS is €746/t PM$_{2.5}$. Assuming reductions of 1.34kt, the resulting cost of achieving BAT-AELs is €1m.

**Limitations:** Cost is expressed per tonne of PM$_{2.5}$ while the emission reductions are calculated for total PM. This limitation does not apply to assessments of other pollutants.

*Cost of achieving sulphur dioxide emission reductions in coke oven plants*

Using option 2, stage 2 process SO$_2$ control is applied instead of stage 1 controls. This leads to 0.55kt of SO$_2$ emission reductions. The cost is €410/t SO$_2$ abated; resulting in the overall cost of achieving emission reductions of €0.23m.

Box 20 Use of costs per unit of activity abated

*Cost of achieving dust emission reductions in sinter plants*

Using option 2, electrostatic precipitator with 2 fields has been applied to meet BAT-AELs. The technology is applied to 4.6 Mt of sinter produced. The cost of applying this technique to sinter plants according to GAINS is €0.4m per unit of activity. The resulting total costs of achieving the emission reductions is €1.8m.

*Cost of achieving sulphur dioxide emission reductions in coke oven plants*

Using option 2, stage 2 process SO$_2$ control is applied instead of stage 1 controls. This change is applied to activity of 1.2 Mt of coke. Resulting overall cost of emission reductions is €0.46 m.
5.2.5.2 Conclusions on the use of GAINS for the assessment of emission reductions and costs of BAT-AELs

GAINS serves as a valuable source of EU-wide assumptions for the following inputs to the assessment of impacts of BAT Conclusions:

- **Activity data** – activity data for coke production, pig iron production, sinter and steel is expressed in Million tonnes and is available in GAINS for the EU-28 broken down by MS. Ratios between activity data for different processes can also be applied to steel production data from elsewhere in order to obtain corresponding activity values for coke oven, sinter and pig iron production. Similar activity data are available for other sectors in the model (although there are limitations regarding sectoral/process mapping).

- **Future activity and emission data** - projections on sector's future activity in the reference scenarios within GAINS model assume impacts of existing legislation on the sector. These are consistent with other European wide models such as PRIMES. Projections made in GAINS reference scenarios could therefore be valuable when projecting the baseline (creating the future emissions scenario using method FE1).

- **Unabated emission factors** – unabated emission factors are used in GAINS to calculate emissions for each sector, before the control strategy is applied. These emissions factors compared to emission factors calculated from reported emissions, can be used to estimate abatement efficiency of equipment already fitted at individual facilities. While this approach is uncertain, it may be a valid gap filling technique in the absence of contextual site specific data.

- **Information on the current – and projected future – uptake of abatement techniques** – while the control strategies for process emissions in GAINS are often aggregated into groups such as stage 1, 2 and 3 process control, using abatement efficiency as a guidance allows estimating existing and projected future uptake of abatement measures within the sector. GAINS model is one of very few sources that projects the uptake of technologies within the sector.

- **Costs of control strategies** – one of the output of the GAINS model are costs of control strategies expressed per unit of pollutant abated, or per unit of activity abated as outputs. While these costs also have the same limitation as the uptake information (i.e. in terms of aggregation), they provide least resource intensive method to calculate potential abatement costs.

As demonstrated above, it has been possible to estimate the impact on emission reductions and costs of BAT Conclusions using data available from the GAINS model. Undertaking such assessment has relatively low resource implications as it is undertaken at sector level. However, the approaches tested using the GAINS data have some limitations:

- **Iron and steel** is a unique industrial sector within GAINS given it is disaggregated to process level. Despite that, this disaggregation often is not sufficient to correlate clearly to BAT-AELs, hence the assessment of impacts of BAT-AELs using GAINS is incomplete in terms of processes and pollutants.

- **Given lack of concentration data in GAINS, assessment of emission reductions relies on the estimation of loads associated with concentrations set out in BAT-AELs. This calculation requires information on the total flue gas volumes in the sector which is uncertain. While the I&S BREF provides default waste gas flow rates for individual processes, the value ranges are wide.**

- **Different options tested to calculate emission reductions using data from GAINS yield different results. Option 1 which uses the BAT-AELs directly to calculate emission reductions, without the need to identify emission abatement techniques, can underestimate emissions reductions because it assumes strict compliance with the limit values (i.e. that emissions will be reduced exactly to the BAT-AEL limit and no further). In reality, it is likely that upgrade of abatement equipment in order to comply with BATC will result in greater emission reductions than specified by BAT-AELs. This finding is supported by testing of the two options for dust emissions from sinter plants – e.g. use of BAT-AELs directly to calculate emission reductions (option 1) resulted.
in a lower estimate of emission reductions than calculating the emission reductions by identifying potential technologies required (option 2).

- GAINS does not allow estimating the impact of individual BAT because the control strategies applied to process emissions are often an aggregate of several techniques. Not knowing what stage 2 or stage 3 control strategies actually mean in terms of technical solutions, increases the risk of making a mistake in assuming that emissions can be abated further. For example, in case of coke ovens, emission reduction technologies can only easily be installed in new plants, as it is impossible to stop production in existing coke ovens. As it is unclear what the stage 2 process control actually implies in the context of coke ovens, it is impossible to judge whether upgrade from stage 1 to stage 2 controls is feasible in existing plants.
6 Recommendations on methodologies to assess emission reductions and costs of BATC

The study has identified a range of methodologies and data sources which can support the assessment of BATC impacts at Member State or EU level. The selection of a suitable methodology to calculate emission reductions and costs is governed by the required or acceptable level of accuracy versus the level of effort required and available to undertake the assessment. Figure 15 presents an indicative summary of the assessment of identified methodologies against the accuracy and efforts required.

Figure 15 Indicative accuracy and effort associated with assessment methodologies

Some stakeholders consulted in the study expressed a preference for more accurate results with concerns raised regarding the use of less resource intensive and less accurate methods to inform policy decisions.

Testing methodologies for specific installations in two selected sectors in selected MS has provided some insights into data sources and data availability. This testing with case studies has generated, based on the data gathered for specific installations, recommendations on methodologies suitable for those sectors. However, it must be noted that data availability for installations in those tested sectors may differ across other MS, and so this lowers the confidence in the conclusions.

Since the testing has been with only specific sectors, in order to generate a recommendation on suitable methodologies for assessing the costs and impacts of BAT conclusions for other sectors, we have relied upon our own experience and knowledge of other sectors. In addition, other views, including from experts attending the workshop, were taken into account for formulating the recommendations below.

As the study did not focus on methodologies to assess potential cross media effects, no recommendations are made on how the cross media effects of the full implementation of BAT conclusions at sector level should be accounted for. However, this does not mean that the recommended methodology precludes the ability to assess cross media effects.

Instead the recommendations are formulated to inform sector level assessments of impacts on emission reductions and costs associated with compliance with BAT-AELs for air and water.
Based on the conclusions reached for the two sector case studies, which are presented in the case study annexes, our overall recommendations on methodologies to assess emission reductions and compliance costs of BAT-AELs at the sector level are as follows:

1. Accounting for the similarities and diversities among IED sectors, each sector will need to have a bespoke approach to the assessment of impacts, selecting the most appropriate approach from the options identified in this study. The choice of approach will be influenced by the metric(s) that BAT-AELs are expressed in, how the sector is split into subsectors or plant types, the number and spread of installations across MS, data availability, any overlap(s) with other BREFs and BATC, as well as time and resource implications of different approaches. Whilst a general framework can be prescribed to guide the assessment of impacts for one sector, there will be aspects associated with most sectors that require the selection of methodology to account for elements specific to the sector. Operators, industry associations and other sector experts are well placed to inform selection of the methodology for their respective sectors. The initial set up of the analysis will need to be adapted to the sector under consideration and format and disaggregation (in terms of the emissions sources they apply to) of the BATC. Once set up for a particular sector then there are likely to be a series of approaches for some impacts that may be common between sectors.

2. It is recommended that the first part of any assessment should be a scoping phase. The scoping phase should determine which aspects and impacts are important to take into account and which are feasible to take into account – a prioritisation exercise using a series of criteria such as identifying which of the BAT are likely to have the largest impacts. Industry stakeholders consulted in the course of this study stressed the importance of involving sector experts in that phase. This feasibility should consider for example data availability and where there are known data gaps or limitations that will otherwise dictate the choice of methodology. For example, it may need to be determined for LVOC installations what proportion of installations share common waste water treatment facilities with an adjacent refinery, and for these combined sites if this means that data on pollutant concentrations in water would only be available in aggregated form. The scoping phase should consider time and resource implications to undertake a worthwhile assessment. It should closely involve the stakeholders relevant to the sector to agree on BATC prioritisation, confirm data availability and data quality, as well as consider the potential to improve / gather other data from existing sources. Overall, the scoping phase balances which impacts to assess and what specifics of the sector to take into account against the data availability and resource implication constraints, and then selects which methodology is most appropriate. Results of a streamlined assessment as described in recommendation 4, could provide a basis for narrowing the scope of a full assessment to certain pollutants. While it will not allow for a comprehensive assessment of the sector it would allow an in-depth analysis of benefits and costs of those BAT-AELs considered the most critical for the industry.

3. Notwithstanding the above conclusion that each sector will need to have a bespoke assessment and includes its own scoping exercise, from the case studies completed, our own experience and feedback gathered from stakeholders, the framework for assessment of the costs and benefits of BATC across all sectors should include the following steps as best practice:

   - **Estimate baseline emissions.** It is recommended this is based on reported emissions or concentrations where appropriate for the specific sector (method: BE3), in order to have data that are both accurate and which represent the real situation of installation performance with sufficient granularity so that they can be compared to the BAT-AELs. Some consideration may need to be made for data sources that have reporting thresholds, especially if the data for certain plants are extrapolated to represent the wider sector. Data supporting the development of the baseline scenario should cover information on the existing facilities, processes and abatement techniques used in the sector.

   - **Estimate future emissions:** it is recommended to make an assessment for the sector in question of whether relevant changes are expected for the sector over time, and only if this is the case to adjust the baseline emissions and so estimate future emissions. There is no specific recommendation of whether to adopt method FE1 or FE2 in this case, although preference may
be given to projections that specifically consider changes in emissions. GAINS or PRIMES could be relevant here; however, stakeholders consulted in this study expressed mixed views on the appropriateness of using estimates from these models for their specific sectors.

- **Estimate emission reductions that would occur if BAT-AELs were applied**: it is recommended that if the assessment is carried out in parallel with the cost estimation, emission reductions calculations take into account the impacts of specific techniques (method: ER3). This method has the advantage of being a more specific depiction of changes that would occur at installations in the sector than a method that assumes that emissions reduce just to the level of BAT-AEL, which enables also a cost assessment. One stakeholder expressed the view that the greater accuracy of method ER3 is only relevant in the short-term (initial years following installation of the technique) and that if assessed over time, methods ER1, ER2 and ER3 would yield similar results due to degradation of equipment over time. However proper maintenance of abatement equipment should prevent or minimise the deterioration of its efficiency over time. Assumptions are ideally made at plant/process level, but could also be at a more aggregate level such as at Member State level. If no cost assessment is required, simpler methods (ER1 or ER2) are recommended alternatives.

- **Estimate the costs of meeting BAT-AELs**: it is recommended that this assessment is carried out in parallel with the emission reduction estimation by accounting for the costs of specific techniques needed to comply with BAT-AELs (method: CO2). This method enables a transparent assessment of costs, and is particularly suitable to those sectors with more straightforward or standardised plant designs for which it can be easier to characterise the available abatement techniques. However, there can remain obstacles to accurately estimating the costs of techniques to meet BAT-AELs. For example, to estimate the sizing or dimensioning of the technique(s) technical data which are not currently reported such as waste gas flow rates may be needed. If the data collected during the BREF review for the sector is incomplete or cannot be accessed, it would need to be newly gathered directly from the operators and/or competent authorities. Also, in those sectors where industrial plant designs can be very different (such as POL or LVOC) and where there is a business commercialising those designs (process licenses, catalyst, etc.) there is a risk in assessing emission reductions to meet BATC to focus only on secondary techniques and not on primary plant design or techniques which could have larger emission impacts. Wider cost impacts can also be considered in addition to those associated with air pollutant reduction techniques such as meeting monitoring requirements, or the quantification of impacts from changes in GHG emissions that can be quantified alongside changes in air pollutant emissions.

For some sectors it is much more challenging to simply model abatement options and impacts for each emission source as they depend on the process as a whole, taking into account raw materials used and so on. For the intensive livestock sector as an example, control options for housing and manure storage cannot be modelled independently as the nutrient content is linked to a number of factors through the process such as feedstock, manure storage. For these sectors CO2 could still be applied, with the caveat that higher uncertainties in the modelling would be expected, although it may be more effective to assess multiple BAT together as part of an integrated evaluation so that interactions between different stages are taken into account e.g. for intensive livestock assess the costs and benefits of BAT across the whole lifecycle from feed stock to manure storage and spreading.

- **Estimate benefits associated with the emission reductions if a case for action vis-à-vis as a comparison with costs is required**: whilst this study has not carried out a full comparison of benefits methodologies, from the recommended approach to estimating emission impacts, it is most straightforward to estimate benefits through the use of damage costs per tonne of pollutant abated (ABE2) for emissions to air.

However, given that damage cost functions do not monetise all impacts of pollution, the monetary cost benefit analysis may remain biased which has to be considered in any decision making. Several stakeholders consulted in the study expressed their concerns about that issue, noting that the aim of the BATC is to ensure a high level of environmental protection, and the human health impact primarily monetised in damage cost functions is only a fraction of the
overall benefits. Therefore, when interpreting the cost benefit ratios, the following should be considered:

- If the costs exceed the benefits, the limitation of benefits not being fully monetised increases uncertainty of any conclusions to be made, i.e. would the ratio of costs and benefits be the same if all benefits were monetised to the same extent as costs?
- If the value of benefits exceeds the costs, there is a higher certainty that an intervention considered brings overall benefits.

Furthermore, to date, the transboundary impact of BAT have not been widely accounted for across Member States in national derived damage cost functions and BAT assessments. That considers both the impact of resulting emission reductions in a country on the neighbouring Member States, and the impact on a country from emission reductions in other Member States.

Whilst a number of methodologies have been identified for monetising the benefits associated with good water quality status, no particular methodology is recommended. No method feasible in sector level assessments has been identified to quantitatively assess the impact on water quality due to emission reductions from industrial installations. Valuation of impacts of emission reductions to water requires understanding of the quality status of affected water body and its use (e.g. for recreational purposes). It is therefore more feasible to undertake such valuation in facility-level assessments, where characteristics of the local water bodies are known.

- **Test sensitivity of the results against key assumptions**: irrespective of the combination of methodologies used, sensitivity of the results against the key assumptions made should be tested. This could consider, among others:
  - Baseline assumptions, such as variation in the level of emissions across the plants and abatement equipment already fitted
  - Assessing the difference in results between different levels of BAT-AELs to account for variation in the way BAT-AELs may be translated into permits
  - Investigating lower and higher cost estimates if the data gathered from different sources results in a wide range

Developing a range of sensitivity scenarios at the sector level to illustrate the likely scale of impacts under different assumptions and circumstances could be an efficient alternative to a more time consuming, full plant-by-plant assessment.

4. The best practices identified in recommendation 3 may need to be simplified to account for the available resources or time to undertake an assessment. In such cases, a simpler high level assessment, which could also form part of the scoping exercise (recommendation 2), could be carried out; recognising the need for an acceptable level of accuracy. It should be noted that this may differ depending on the sector and Member State, however some stakeholders expressed their concerns whether a more top-down approach would provide sufficiently reliable results. A high level methodology would be suitable for a streamlined assessments of impacts, for example when carrying out rapid high-level assessment across all BAT before prioritising (for the focussed approach) particular BAT considered to be at risk of costs exceeding benefits. This comprises the use of any of the baseline emissions methodologies, subject to best data availability, followed by the assessment of emission reductions using ER1 and ER2 methodologies. The high level assessment ought to also include an indication of costs. However, a sufficient level of accuracy may not be possible using a streamlined method CO1, as it does not provide flexibility to reflect differences across the facilities and whether retrofitting the equipment is feasible.

5. Technical and economic expertise is needed for all methodologies, such as assessing the technical applicability of emission reduction techniques, and for assessing the marginal additional costs compared to a status quo. Any assumptions and calculations made should be well-documented and transparent to allow review by stakeholders. This should include economic parameters used in the assessment such as discount rate, method of annualisation of capital costs and key assumptions behind the damage cost functions (if used) such as the value of life lost.
6. Accounting for the reality that there may be difficulties in obtaining large amounts of data required for a particular sector to carry out the recommended methodology, some alternatives/variants have been identified. These include gathering smaller quantities of data for selected installations, and extrapolating the impacts of the BAT based on the assessment of impacts for these selected installations. The viability of this approach will vary by sector, according to the availability of data for the specific installations, diversity or similarity among installations within the sector (characterised principally in terms of emissions performance), and the ease with which the rest of the sector can be extrapolated. According to stakeholder feedback, for some sectors it may be more appropriate to attempt to collect data from all installations, to ensure the data collected is sufficiently representative of the characteristics of the sector. Some difficulties in data collection can be experienced given commercial sensitivity of information to be collected. In the past this has been successfully overcome by having an independent third party collating and analysing the data which otherwise would be considered confidential.

7. Data required for the assessments of potential industrial emissions reductions and compliance costs of BATC at sector level remain a key challenge. The consideration of developing future data sources to support the methodologies at sector level could take into account:

- That the Member States' reporting on implementation of the IED by September 2017 will include for all permitted installations: a web link to the active permit, information on application of the Article 15(4) derogation and on the preparation of the baseline report. In addition, Member States will be reporting data on the permit conditions, limit values and monitoring for the iron and steel and manufacture of glass sector.

- Whether the development of a pan-European system to systematise all permit information across Member States is feasible. Such a system could include information on ELVs applied, derogations granted, as well as process-level information such as information on the abatement equipment already installed on sites.

- The data sought via questionnaires as part of the existing ‘Sevilla’ process.

The level of effort required to develop future data sources may be minimised if the key data from permits is extracted during already-planned permit reviews (rather than retrospectively for all industrial sectors). The information for a given sector would then be available for the next time the BREF is reviewed. Making permit data more accessible could also facilitate the identification and definition of Key Environmental Issues (KEI) at the start of the BREF review process.
7 References

Note: Methodology-specific references have been cited by [number] in this report for brevity. These numbered references are listed in Appendix A. References to websites have been provided in footnotes. In addition to these, the references in this section are cited by name in this report.


AMEC (2015) Service contract for assessing the potential emission reductions delivered by BAT conclusions adopted under the directive on industrial emissions (IED).

AMEC (2016) Summary report Workshop on the evaluation of the European Pollutant Release and Transfer Register. https://circabc.europa.eu/w/browse/3b1bc3f5-ee9a-4e4e-a5bc-fffeba8aac59


Pöyry, 2013, Cost analysis of reducing flue gas emissions to achieve the BAT emission levels in peak load boilers using liquid fuels and natural gas


Appendices

Appendix A: Literature register
Appendix B: Consultation summary
Appendix C: Completed templates for methodology and data source assessments
Appendix D: Feasibility assessment of individual methodologies (MCAs)
Appendix E: Overview of the structure and metrics for BAT-AELs
Appendix F: Case studies