Department of Energy & Climate Change

GHG Inventory Research: Use of EU ETS Data - Iron & Steel Sector, Chemical Industry Feedstock Use

Review of UK data on emissions of GHGs from the Iron and Steel sector, and from Chemical Industry Feedstock Use, using EU ETS data in the national inventory

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GHG Inventory Research: Use of EU ETS Data - Iron and Steel Sector

Final Report to the Department of Energy and Climate Change

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Glossary

1996 GLs	1996 IPCC Guidelines for National GHG Inventories
2000 GPG	2000 IPCC Good Practice Guidance
2006 GLs	2006 IPCC Guidelines for National GHG Inventories
BFG	Blast Furnace Gas
BOSG	Basic Oxygen Steel Gas
COG	Coke Oven Gas
CRF	Common Reporting Format
DUKES	Digest of UK Energy Statistics (the UK energy balance)
EA	Environment Agency
ETS	Emissions Trading System (EU)
EU	European Union
EU ETS	European Union Emissions Trading System (ETS)
EUMM	European Union Monitoring Mechanism
GHGI	Greenhouse Gas Inventory
HMRC	Her Majesty's Revenue and Customs
I&S	Iron and steel
IPCC	Intergovernmental Panel on Climate Change
IPPC	Integrated Pollution Prevention and Control
ISSB	Iron & Steel Statistics Bureau
ITT	Invitation to Tender
MS	(European Union) Member States
NAEI	National Atmospheric Emissions Inventory
PI	Pollution Inventory
SEPA	Scottish Environment Protection Agency
SPRI	Scottish Pollutant Release Inventory
TNT	Traded / Non-traded (within and outside of scope of EU ETS)
UNFCCC	United Nations Framework Convention on Climate Change

Executive Summary

The UK Greenhouse Gas Inventory (GHGI) is subject to annual reviews by UN Framework Convention on Climate Change (UNFCCC) experts; this is an important quality assurance mechanism to ensure that the UK GHGI meets international standards and is continually improving to achieve inventory data quality objectives of accuracy, consistency, completeness, comparability (with other reporting nations) and transparency. The UN expert reviewers conduct a range of quality checks, and this includes comparison of the UK inventory against other datasets including the emissions reported via the EU Emissions Trading System (EU ETS).

UNFCCC reviews in recent years have highlighted where the UK GHGI achieves good practice in use of EU ETS data, and has noted opportunities for further use of these data to improve UK emission estimates. There are instances where the UK GHGI estimates are based on EU ETS data in preference to other data sources, such as the Digest of UK Energy Statistics (DUKES). Whilst these deviations have been reviewed and approved by the UNFCCC review teams as providing the best estimate for UK GHG emissions, the need for these deviations from DUKES prompts more questions of UK energy statistics and undermines confidence in the veracity of the UK GHG emissions totals.

This research project has been commissioned to ensure that use of the EU ETS dataset is optimised in the UK GHGI, especially for the iron and steel sector and where process off-gases from chemical and petrochemical feedstock materials are used as an energy source. The research has made recommendations to improve the completeness and accuracy of the UK inventory; minimising inconsistencies between the GHGI, the UK energy balance and EU ETS. These improvements will also improve the transparency and accuracy of the analysis of traded and non-traded emission estimates in the UK economy, which is of growing importance to DECC from a GHG reporting and policy perspective.

The project team has engaged with environmental regulators; industry contacts within trade associations and individual companies; energy statisticians and industry statistical agencies to identify the best available data for use within the UK GHG inventory. Data processing, checking and method development has led to recommendations to revise the UK GHGI through:

- Improved accuracy of UK GHGI emission estimates for the iron and steel sector through recommended revisions to underlying energy and activity data and also access to a larger, more accurate dataset of fuel quality information (calorific values, carbon content, moisture content) and data on process (i.e. non-combustion) emission sources.
- Documenting the flow of source data from operators to environmental regulators and energy statisticians to inventory agency, in order to identify the reasons behind data reporting discrepancies between statistical agencies. E.g. activity data on fuel production and use reported by DECC within the Digest of UK Energy Statistics (DUKES) and by the Iron and Steel Statistics Bureau (ISSB).
- Improved accuracy, completeness and time series consistency of emission estimates for the combustion of process off-gases within the chemical and petrochemical production sectors through access to and use of detailed fuel use data from the EU ETS, Climate Change Agreements and through consultation with industrial operators and regulators.
- Provision of a series of recommendations for DECC to consider for further work to:
    - enhance the flow of data between statistical agencies and remove inconsistencies at source across ISSB, DUKES and the GHGI, and
    - address outstanding issues that could further improve the accuracy of the source-specific estimates presented in the UK GHGI through greater use of the available information from the iron and steel sector in particular (direct from operators or available via EU ETS).

The recommended revisions to the GHGI methodology as a result of this project do not change the UK GHGI emission estimates significantly. In the iron and steel sector, the recommended revisions will increase sector emissions in 1990 by around 2% compared to the 2013 GHGI submission, whilst the change in 2011 is a less than 1% decrease. The recommended revisions to the petrochemical emission estimates will increase sector emissions by around 3% in 1990, but decrease the GHGI estimates for the sector by just over 1% in 2011. In the context of the overall UK GHGI, the recommended changes are less than 0.1% in both 1990 and 2011.

Whilst the recommended revisions do not greatly affect the UK GHGI emission totals, there *has* been a significant improvement in the quality of the data underpinning the estimates in the two sectors, as the UK inventory agency can now access a large dataset of recent fuel analysis data that have been derived using methods that are accredited to the required standards under EU ETS and are third-party verified. Uncertainty in the GHGI estimates for recent years in the iron and steel sector have been reduced by around 30%, whilst 1990 data uncertainty remains higher.

This report provides an overview of the analysis conducted and the explanations of developments in the use of data and the overall inventory estimation method, and forms the underlying reference material for the National Inventory Report to be submitted by DECC to the European Union Monitoring Mechanism and the UNFCCC in 2014.

Supplementary information of a commercially confidential nature has been excluded from this report.

Introduction & Context

The 2012 UNFCCC in-country review of the UK Greenhouse Gas Inventory (GHGI) identified many examples of good practice where EU Emissions Trading System (EU ETS) data have been used to test activity data and emission factors, and to improve the overall inventory data quality. However the reviewers also noted inventory source estimates that were not consistent with EU ETS, and raised concerns regarding possible gaps in the UK energy balance and inventory.

For a number of emission sources, the UK GHGI estimates are based on EU ETS data in preference to other data sources, such as the Digest of UK Energy Statistics (DUKES). These deviations from DUKES improve the accuracy and completeness of the UK inventory, but they also prompt more questions of UK energy statistics and undermine confidence in the veracity of the UK GHG emissions totals.

This research project has been commissioned to ensure that use of the EU ETS dataset is optimised in the UK GHGI, especially for the iron and steel sector and where process off-gases from chemical and petrochemical feedstock materials are used as an energy source.

The research has sought to improve the accuracy of the UK inventory, and to minimise inconsistencies between the GHGI and other data sets such as the Digest of UK Energy Statistics (DUKES) and EU ETS, thereby also improving the accuracy of the analysis of traded and non-traded emissions in the UK economy, which is of growing importance from a GHG reporting and policy perspective, due to the Effort Sharing Decision targets. The main focus of this project is to improve the utilisation of EU ETS data for the iron and steel sector, to identify and where possible resolve any data discrepancies between EU ETS and DUKES, and to recommend further improvements to data provision that may be needed to enable more complete integration between EU ETS, DUKES and the UK GHG inventory datasets. In addition, the study team has researched EU ETS data, Climate Change Agreement data and has consulted with plant operators to improve the UK GHGI estimates of emissions from chemical and petrochemical production sites where process off-gases derived from fossil carbon feedstock materials are used as fuels.

The project has covered the following objectives:

1. Collection and review of EU ETS and other industry data, to compare activity data (against DUKES), and emissions data (against IPPC-reported estimates and previous GHG inventory estimates). Through consultation with regulators, statistical agencies and plant operators, the consistency of data reporting has been assessed to determine the best available data for use in the UK GHGI, and to clarify issues of reporting scope and data uncertainty.
2. To recommend how to address any data inconsistencies in relation to data used in the inventory and the traded/non-traded split.
3. To evaluate whether EU ETS and other industry data could be used for a Tier 3 method for the coke, iron and steel production sector, or if other improvements could be better made to the existing Tier 2 approach using these data.
4. To agree improvement actions with DECC and implement changes in methodology for the 2014 submission of the UK GHGI.

Background: Coke, Iron and Steel Production in the UK

The UK GHGI includes estimates of the emissions from plant that produce iron, steel and coke. In the UK, to a large extent, manufacture of these commodities is limited to a small number of large sites including coke ovens and complex integrated steelworks where several different

sub-processes all contribute to the total GHG emissions. The iron and steel industry also burns diverse fossil fuels in plant ranging in size from the smallest industrial scale to the largest. The fuel combustion sources included in the UK GHGI encompass boilers; heat treatment or melting furnaces; the use of coke in sinter plant and the use of coke oven gas, blast furnace gas and natural gas in the hot stoves used to heat air for blast furnaces and to heat coke ovens. The inventory also includes estimates of other process sources such as emissions from the addition of fuel oil or coke to blast furnaces, emissions of carbon from basic oxygen furnaces and releases from carbon-containing process additives such as limestone and dolomite.

In 1990, at the start of the period covered by the GHGI, the UK had 5 integrated steelworks and 3 independent coke ovens. Following the closure of two steelworks (Ravenscraig closed 1992, Llanwern closed 2001) and two of the coke ovens (in 1992 and 2003) there have since remained three integrated steelworks and one independent coke works operating in the UK:

- Port Talbot Steelworks (British Steel, then Corus UK, now Tata Steel)
- Scunthorpe Steelworks (British Steel, then Corus UK, now Tata Steel)
- Teesside Steelworks (British Steel, then Corus UK, then Tata Steel, now SSI Steel)
- Monckton Coke & Chemicals, Barnsley

The Teesside works was partially mothballed during 2010-2012 during which time most of the operations there were sold by Tata Steel to Sahaviriya Steel Industries UK Ltd (SSI).

The activities and emissions of the sector are detailed in various data sets collected, reported and used by several organisations and exhibiting a range of reporting scopes, formats and periods. This array of reported data needs to be reconciled in order to present complete, accurate emission estimates from this complex economic sector within the UK inventory.

Background: Petrochemical sector emissions and the use of process gases

The UK GHGI includes estimates of emissions from the chemical and petrochemical production industries that are predominantly based on the UK energy statistics published within DUKES, augmented by further information direct from the industry. In many chemical and petrochemical production processes, feedstock materials that contain carbon are converted into products, with the carbon effectively stored in the materials produced (such as plastics, rubber etc.). In the UK energy balances published in DUKES, these feedstock materials are reported as a Non-Energy Use (NEU), as their primary function is to provide the building blocks for UK chemical products.

However, in a number of UK production plant, most notably those producing ethylene, the chemical manufacturing process also results in off-gases or waste residues that are also derived from the carbon-containing feedstock materials and are then used as a support fuel to fire site boilers or furnaces. The use of these process off-gases and residues as a fuel is not reflected in DUKES and therefore could be a gap in the UK GHGI. In recent years, analysis of the EU ETS data for ethylene manufacturers has led to new estimates of emissions being added to the UK GHGI in order to address this potential gap. This research project has enabled a more rigorous review of available data from EU ETS as well as from other data sources such as Climate Change Agreements and through direct consultation with plant operators, to derive more complete and accurate emission estimates for the use of feedstock-derived fuels both for ethylene manufacture and other chemical processes.

Background: Overview of Existing Inventory Datasets and Methods

The primary datasets that are available to the UK GHG inventory agency in compiling the estimates of emissions are[1]:

- The **Digest of UK Energy Statistics (DUKES**) published by DECC, which includes activity data for fuels produced and consumed in energy transformation processes, as well as fuel use in combustion processes and estimates of feedstock to petrochemical processes (allocated to Non Energy Use of fuels, NEU). DUKES also includes data on Gross Calorific Values of fuels. The DUKES data are available for the full GHGI time series, i.e. 1990 onwards.

- The **Iron and Steel Statistics Bureau (ISSB)** compiles and reports energy data and production data for all of the iron and steel sector in the UK, ranging from the primary production of pig iron and crude steel through to all of the secondary processing of metal products. These data also cover the full GHGI reporting time series and provide aggregated (across all sites) data on UK production of commodities by process type, consumption of fuels and a limited regional breakdown of data.

- Energy use, process source activity data, fuel calorific values, carbon emission factors and emission estimates by source and by fuel are available from the **EU ETS** dataset, which is provided to the inventory agency from the regulatory agencies (Environment Agency, Natural Resources Wales and Scottish Environment Protection Agency). Annual Environmental Reports from the EU ETS are available on request, and provide further details. EU ETS operators prepare verified Annual Emissions Reports and submit these to the regulator by 31 March each year. EU ETS regulators then conduct completeness checks by 30 June each year, as this is the deadline for improvement reports. The scope of EU ETS is limited to a sub-set of the total sector emissions, however; the EU ETS data are not comprehensive and comparison against activity data in DUKES is therefore only useful as a quality check. Furthermore the data provided to the inventory agency includes a number of data aggregations (in the case of integrated steelworks), in some cases of fuel / process source blends that are inputted to a specific unit (e.g. sinter plant feed), and in other cases the total emission estimates from a specific fuel (across all units) are presented in one figure, limiting transparency of the data and not enabling direct comparison against estimates of emissions by IPCC sector (within which separate data are needed for reporting of emissions from coke ovens, sinter plant, blast furnaces, basic oxygen furnaces, combustion plant, flaring / losses). Finally, the coverage of EU ETS data is only from 2005 onwards, which limits its usefulness in inventory terms, where time series consistency is key, and the scope of reporting has evolved through several phases: Phase I (2005 to 2007), Phase II (2008 to 2012) and Phase III (2013 onwards).

- The **EU ETS** dataset from regulators includes data for installations across the **iron and steel sector**, but also includes data for the one remaining **independent coke oven** and all of the UK's major **chemical and petrochemical production** plants. The transparency of fuel use within the chemical and petrochemical site data is variable, however; for several such sites all of the emissions are attributed to aggregated "fuel gas" data, which is known to be a mixture of process off-gases and other (bought) fuels

[1] For further information on the scope and detail of reported data through different mechanisms / by different companies / statistical agencies, please see Annex 1.

such as natural gas. Therefore the usefulness of this data (for analysis of feedstock-derived process off-gas carbon emissions) depends on the level of detail provided in the EU ETS and the willingness of plant operators to clarify the content of “fuel gas”.

- Total emissions data across installations are available from the **Pollution Inventory** (for sites in England and Wales) and the **Scottish Pollutant Release Inventory** (for sites in Scotland. These data provide no transparency to the source-specific emissions, but are a useful quality check for overall site emissions, for example to assess the completeness of CO_2 emissions reporting within the EU ETS.

- Data direct from **plant operators** is obtained annually by the inventory agency for many sites in the UK, including the UK’s integrated steelworks.

The UK GHGI method for coke ovens and integrated steelworks is a carbon balance approach, consistent with IPCC guidance for a Tier 2 method. The overall approach has been favourably reviewed by UNFCCC Expert Review Teams and the activity data needed to drive the carbon balance are readily available from DUKES, it provides a route to deriving emission estimates using a method that is consistent across the time series.

Historic comparisons between GHG estimates in the GHGI and the estimates in EU ETS are within the expected uncertainty bounds of the GHGI Tier 2 method, but nevertheless to reduce the disparities and derive a much more accurate inventory estimate is important from a policy and reporting perspective, especially to minimise errors in estimates of non-traded emissions.

Report overview and structure

This research project has enabled the study team to meet with the appropriate industry and statistical experts, learn the details of the data that are available from different sources, and develop an improved emission estimation model for use in the UK GHG inventory to use the best available data and reduce uncertainties.

This report presents the research approach, outlines the data obtained and expert opinions solicited, outlines the key data comparisons and analysis, summarises the recommendations made for improvements to the UK GHGI estimates for the 2014 inventory submission and presents options for further work to address outstanding issues.

Note, however, that due to the limited number of installations and companies operating in the economic sectors under discussion, that the detailed data are excluded from the published report in order to maintain commercial confidentiality.

The research approach is set out within the ***Method*** section, which also outlines the main data sources accessed and analysed by the study team.

The ***Results and Discussion*** section sets out the main findings, including an overview of the data supply systems available to DECC and the inventory agency, as well as specific findings from data analysis to enhance UK inventory methods, emission factors and activity data.

The ***Conclusions and Recommendations*** section outlines the research recommendations for DECC to consider in future inventory compilation and reporting. This comprises recommendations for updates to inventory methods, changes to activity data and emission factors, as well as recommendations to improve data supply chains to DECC and the inventory agency to address reporting inconsistencies at source.

Method

The study team has consulted with several teams of experts within key organisations and accessed a wide range of data for subsequent analysis to derive improved inventory estimates:

- **DECC DUKES**. The team of energy statisticians that compile DUKES provide the primary dataset used within the UK GHG inventory to inform estimates from the Iron and Steel sector, and from the petrochemical sector use of feedstock and fuels. A series of meetings and email exchanges were conducted to clarify the range of data inputs considered in the compilation of DUKES and the scope of reported data across the Commodity Balance tables.
- **Iron and Steel Statistics Bureau.** The project team spent a day with the ISSB energy and emissions statisticians to work through the data collection and reporting systems used for the ISSB annual statistics, reporting annual fuel use and production statistics to DECC (for use within DUKES, using an agreed template) and the EU ETS book-keeping role that ISSB performs for Tata Steel and SSI Steel.
- **Tata Steel.** Following the research with ISSB to assess the ISSB-DUKES data comparisons, the study team spent a day with the Tata Steel energy and GHG reporting experts to further examine the detailed data collection and reporting systems used across the integrated steelworks (and other sites) and to determine the best available data on fuel quality (CEFs, GCVs, moisture data etc.) and activities for use in the GHGI compilation method. The Tata experts also provided numerous clarifications of the basis and scope of the data provided, to minimise analytical errors due to incorrect assumptions by the study team in working with source data.
- **The Environment Agency, Natural Resources Wales.** The regulatory teams for EU ETS within the EA and NRW were both contacted in order to obtain the detailed EU ETS annual environmental reports for the integrated steelworks. These documents provided further clarifications of the reporting approach for each installation, e.g. where data are presented at a more aggregated level in the EA/NRW data outputs that are provided annually to the inventory agency and DECC for use in DUKES and the GHGI.
- **Petrochemical company operators.** The study team contacted plant operators at several of the UK's largest petrochemical complexes in order to update and verify the inventory agency's time series of emission estimates from the use of process off-gases derived from feedstock materials as a fuel.
- **DECC Climate Change Agreements team.** The study team also gained access to the CCA dataset for the chemical industry sector, in order to identify additional sites where process by-products are used as a fuel. The CCA data only provide a limited snapshot of information (2008 and 2010 data only, and not transparent reporting of the specific fuel type) but enabled identification of sites that warranted further research via EU ETS, IPPC permits and regulatory experts.

The research comprised a review of data consistency and extensive data processing including:

- Activity data comparisons between ISSB statistics, EU ETS data (for Monckton) and DUKES, with a series of data clarifications sought via email from DECC and ISSB.
- Analysis of detailed EU ETS data outputs from the ISSB database system, to compare against the installation data from the EA/NRW EU ETS data records, in order to use the (more detailed) ISSB data to provide additional transparency to the EA/NRW dataset. This improvement in data transparency in turn enabled improved resolution of the EU ETS data to report emissions more accurately against individual IPCC source categories.

- Extensive data processing, checking and compilation using the full scope of energy, process source, fuel quality and emissions data from the integrated steelworks via ISSB and Tata Steel-derived datasets, to build a spreadsheet system of industry-sourced data to test against the existing UK GHG inventory carbon balance method for integrated steelworks.
- Review of the scope of reporting of EU ETS as it has evolved through Phases 1, 2 and (from 2013) into Phase 3, and the impact that has on: (i) the data available to inform inventory estimates, and (ii) operator / ISSB data consistency with DUKES.

Extensive data analysis enabled the study team to distil a series of GHGI improvement recommendations for consideration in the UK. Further consultation with colleagues (UNFCCC Lead Reviewers) and DECC GHGI management was conducted to consider the pros and cons of different GHGI method improvement options. This process helped to elaborate the various options available, such as to retain the Tier 2 carbon balance method or to recommend further development towards an installation-specific Tier 3 IPCC method for the I&S sector.

The Results and Discussion section of this report summarises the key recommendations for improvements to GHGI source data and methods, and outlines possible future work to deliver improvements to the UK energy statistics.

Results and Discussion

The project findings impact across many different aspects of the data sources and methods used within the compilation of UK GHG inventory estimates in the Energy and Industrial Process sectors. The main findings are summarised here, with additional details presented in the Annexes. The recommended revisions to the UK GHG inventory and recommendations for future work are summarised in the Conclusions & Recommendations chapter.

The project analysis and recommended improvements for the UK GHG inventory as a result of the research are presented in the following sub-categories:

- Data sources, scope and data flows
- EU ETS scope across reporting phases
- Method selection: Iron and steel sector
- Revisions to emission factors: Iron and steel sector
- Revisions to activity data: Iron and steel sector
- Revisions to GHGI totals: Petrochemical sector
- Uncertainty of UK GHGI estimates

Data Sources, Scope and Data Flows

The primary datasets that are already available to the UK GHG inventory agency in compiling the estimates of emissions have already been described above. In addition, this research project has enabled access to (and analysis of) more detailed data for the **EU ETS** reporting scope that is held by the **ISSB**, on behalf **of Tata Steel and SSI Steel**. Access to outputs from this dataset have proven very useful to provide further insight into the data from the regulators, enabling much greater transparency and disaggregation of data, although still some limitations in detail are evident. In addition, the ISSB hold a database of operator data at a very detailed level (by installation, by process stage, by fuel) from 1999 onwards that can be enquired to derive a wide range of useful data to inform emission estimates for coke ovens, sinter plant, blast furnaces etc. The ISSB database also holds fuel quality information such as carbon content and calorific values. Tata Steel has also provided new data, and this research project has involved a very thorough review of these data, which are a subset of the ISSB statistics. The Tata Steel data on fuel quality and process sources has proven especially useful to unlock the understanding of the EU ETS data (noting that the Tata Steel data cover all sources on their installations not just those that fall within EU ETS).

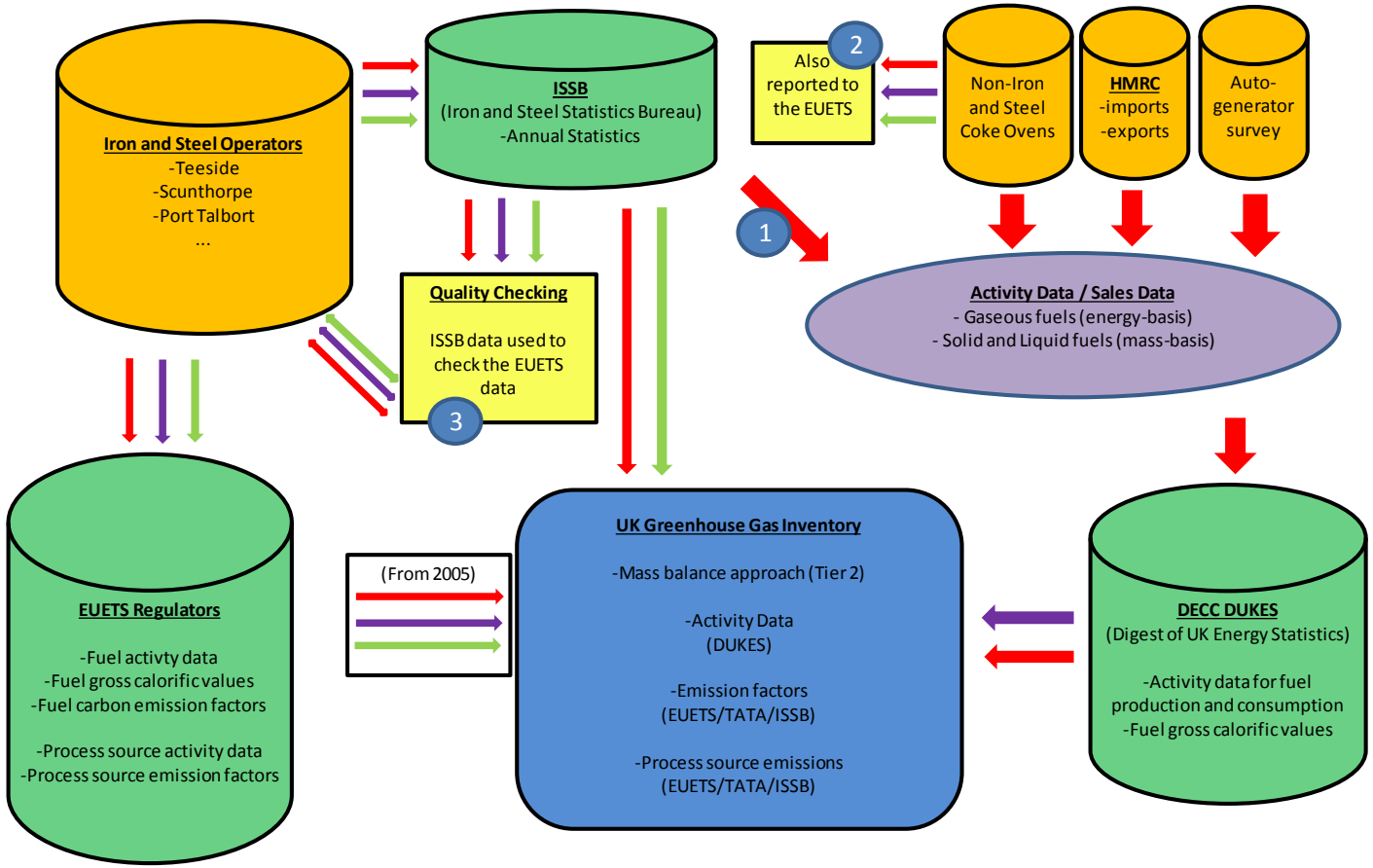
As already stated, the existing GHGI methodology is a carbon balance. This uses data from DUKES and from UK industry but has, until now, not made use of any detailed, plant-specific, data from either EU ETS or Tata. The main barrier to directly using EU ETS and other site-specific data to enhance the UK GHGI carbon balance has been that while the carbon balance model requires data for all of the **primary fuel and process source inputs** to the steel works (i.e. coking coal, fuel oil, natural gas, limestone, dolomite, scrap and so on), the available site-specific data provides details of activities and emissions at the point of final combustion of **secondary fuels** (i.e. coke, coke oven gas, blast furnace gas). In other words, while the GHGI model requires data on the carbon inputs at coke ovens and steelworks, the available data was limited to carbon outputs.

The provision of a much larger dataset of fuel quality data (carbon content, calorific values) by Tata Steel and ISSB during this project has addressed this problem, and allows for the possibility that the carbon balance could be updated with site-, process- and year-specific data on carbon inputs. Before this could be done, however, it was important to examine the existing

and new data provided by ISSB and Tata Steel, to check for any disparities that might indicate inconsistencies or errors in any of the data.

Figure 1 below provides a summary of the data flows that this research has traced, and in the recommendations section there are options for DECC to consider to seek to address the underlying reasons behind the data discrepancies, to further reduce uncertainty in the GHGI.

Figure 1 Summary of the data flows



(1) The ISSB uses a template form from DECC which includes several data assumptions (calorific values, gross to net conversion factors) that differ from data direct from the operators.
(2) Non-iron and steel coke ovens also report to the EUETS, and these data are available for use in DUKES and the UK GHGI.
(3) The iron and steel operators use ISSB as a second-check / book-keeping function to manage their EUETS data, and hence the EUETS data are also held within an ISSB database.

The next section of the report describes specific cases where data comparisons have led to the identification of reporting discrepancies. The study team notes that from a data collection and supply perspective, there are two features where DECC may consider further work to close-out data discrepancies at source:

- ***Review of data provision from ISSB to DECC***. The annual submission from ISSB to DECC that is used in compiling DUKES is a template (item "1" highlighted on **Figure 1**) of activity data (effectively a commodity balance for the iron and steel sector, showing all of the individual fuels, their purchase, sale, production, use). Through discussions with ISSB it is evident that the template has been used for many years and that "standard" or "average" calorific values are used in the template as part of the derivation of activity data for each fuel. In the underlying calculations, there are also embedded assumptions such as gross to net (energy) conversion factors in the handling of calorific values and energy-based activity data. In several cases, these "standards" or embedded assumptions are not entirely consistent with the detailed (year-specific in many cases) data that are available from operators, and these differences play out into discrepancies in the activity data in DUKES compared to the activity data from Tata Steel and SSI Steel. For several fuels these discrepancies are of the order of a 1-2% difference, and whilst such a level of uncertainty can be expected in any statistical reporting system, these discrepancies introduce a small systematic bias to energy data reporting which can be resolved.
  [*The use of the DECC autogenerator survey to define fuel allocations within the I&S sector as part of the DUKES compilation process also leads to differences in the source-specific allocation of fuel use, but this does not impact on the overall comparability of fuel use data from ISSB and within DUKES*.]

- ***Review of EU ETS data provision direct to DECC DUKES***. For the iron and steel sector, aside from the ISSB issue noted above, the access to the EU ETS data should not be a concern. However, for all other source categories, including the data for independent coke works, chemical and petrochemical sites, the provision of the EU ETS data direct to DECC in time for integration of the data to DUKES compilation would help to remove activity data inconsistencies, which (as things stand) have to be addressed in the UK GHGI through a series of deviations from DUKES. Such deviations raise questions annually at the UNFCCC reviews of the UK inventory and undermine confidence in the veracity of the UK GHG emissions totals.

EU ETS scope across reporting phases, EU ETS reporting time-lines

The EU ETS provides a resource of annual fuel quality information, and this is available from 2005 to 2012. The scope of reporting by UK installations within the EU ETS has evolved through the three phases of the EU ETS: phase 1 (2005 to 2007), phase 2 (2008 to 2012) and phase 3 (2013 onwards). This evolution of scope impacts on the data available to inform inventory estimates.

For the chemical and petrochemical installations, the main change will occur within the Phase 3 data (as yet none are reported – the 2013 data will become available in spring 2014). To date, combustion sources have been reported according to the reporting thresholds of the EU ETS Monitoring and Reporting Guidance, but from 2013 emissions from flaring in chemical and petrochemical production facilities will also be included in the EU ETS data.

For the integrated steel works, there is very little change anticipated between Phases 2 and 3, but the scope of reporting for other iron and steel sites will increase in Phase 3, bringing in more activity data and emission estimates from other (smaller) production sites.

In Phase1 (2005-2007), the EU ETS data included (for integrated steelworks and the speciality steel EAF plant at Rotherham): coke, sinter, iron and steel-making plant to continuous casting (concast) plant, plus plant boilers. For other steel sector sites, only emissions from the boiler plant were included.

In Phase 2 (2008 to 2012), the scope for integrated steelworks was expanded to include the furnaces (e.g. reheat furnaces for hot rolling mills) that are downstream of the concast plant, whilst the scope for all other steel sector sites was unchanged.

In Phase 3 (2013 onwards), there is a very small expansion of scope for the integrated steelworks, as a wider interpretation of "combustion" is being applied, which will encompass some of the ancillary operations on site (e.g. fuel use in offices and workshops), but in the context of site emissions this is not expected to have much impact. The same applies to all other steel sector sites, but also the Phase 3 expansion will extend the number of steel sector sites that report to the EU ETS.

Therefore, when the 2013 EU ETS data become available, there will be an opportunity to analyse the new scope of data reported by operators, compare the sector data against DUKES allocations for all fuels, and also to review the information on chemical flaring and use it accordingly within the UK GHGI.

Method selection: Iron and steel sector

The existing GHGI methodology for iron, steel and coke manufacture is based on a carbon balance approach, and this is the recommended Tier 2 approach within IPCC guidance. The carbon balance uses national energy statistics and production statistics as well as country-specific carbon emission factors. The model is detailed and review teams have not previously raised any concerns regarding the accuracy of the model, the level of detail, or with the construction of the model. In previous inventory submissions, the country-specific carbon factor data have been either defaults, kept constant or based on periodic (not annual) operator data varied according to simple calculations (such as basing carbon factors on calorific values published in the UK energy statistics). The UK approach does not therefore make use of the detailed, site-specific and year-specific data that have been collected and reported by operators in EU ETS data returns.

The access to a large dataset of installation-specific activity data and emission factors enables the development of a range of improved estimation methods, and the project team assessed the options available, considering the data quality objectives that underpin inventory reporting. It would be possible to develop a Tier 3 (installation-specific) method based on the EU ETS data, provided that activity data consistency with DUKES could be assured, to avoid any gaps or double-counts within the UK GHGI. However, the EU ETS data are only available from 2005 onwards, and the scope of reported data is not consistent across all years. Therefore, no matter how accurate the data may be for recent years, there would have to be a hybrid method to generate estimates back to 1990, and this would raise concerns over the time series consistency of the approach.

Therefore, the project team recommends implementing an improved Tier 2 method, retaining the carbon balance approach, but integrating the available fuel quality data provided by plant operators and from the EU ETS. This ensures a consistent method can be applied across the time series for this high-emitting sector of the UK economy, and makes the best use of available data. In the majority of cases, the inventory agency should retain the use of the DUKES activity data, and the site-specific emissions data from EU ETS/EPRTR data can be used to cross check/validate the resulting modelled emission estimates. This Tier 2 approach provides a well-founded set of estimates that can be reconciled with energy balance data and draws upon high quality country-specific data sources on fuel quality.

The recommended approach is summarised as follows:

1. Use plant specific data (such as EU ETS returns) to provide accurate and up-to-date data on the carbon contents and other characteristics of the input fossil fuels i.e. to generate country-specific EFs from EU ETS data;
2. Apply the country-specific EFs to the energy balance (or other national statistics) data on the flow of fuels through the iron and steel process. This ensures completeness by ensuring that all fuel reported in the national energy statistics is captured and also ensures accuracy by ensuring that the most up-to-date understanding of fuel parameters is being drawn from any plant-specific analysis.
3. Compare the EU ETS/industry reported emissions for the sector with the output from the carbon balance, either broken down by sub-source (e.g. energy-related, process-related) or combined, depending on how easy the industry data can be split in the same way. The comparison can be presented as a cross-check on the accuracy of the Tier 2 method, with explanations given where possible for any differences.
4. Address time series consistency by considering the variability in the country-specific EFs and other parameters derived for the 2005 – 2012 years of the time series and deciding whether to apply an average (if there is no clear trend or variability) or to use a splicing technique (if there seems to be a trend) to the years 1990 – 2004.

Recommended revisions to emission factors: Iron and steel sector

The project involved the collection of significant quantities of new data. The new data and their usefulness in developing the UK GHGI estimates are summarised here:

- Detailed EU ETS data for the 3 steelworks, compiled by ISSB, which underpin the summarised form of the EU ETS data which are made available to the inventory agency from the Environment Agency and Natural Resources Wales. The more detailed data from ISSB provides a more detailed breakdown of fuel by process stage / process plant, improving data accuracy (by source) and transparency.
- Energy data compiled by ISSB can be compared with DUKES commodity balances and with energy data available from the EU ETS. These data only cover the 3 steelworks, whilst energy data for the Monckton coke works are available directly from the EU ETS. The analysis has helped to clarify the activity data allocations across different economic sectors within DUKES, and therefore to clarify where different emission factors (e.g. for I&S-grade coke compared to other industry coke) could be applied, improving the accuracy of the GHGI method.
- Carbon factors for fuels, feedstock materials (e.g. limestone and dolomite, scrap metal), products and wastes, available as annual figures from Tata Steel for 2007-2012. These provide new data to consider in inventory method updates, to replace defaults or to improve the industry data time series.
- Tata Steel data on production of various fuels and products, for 2007-2012, which have helped significantly in the improved understanding of the material, energy and carbon flows through the integrated steelworks. These are useful to assess the derived carbon factors for intermediate and final products in the carbon balance or to set some of these parameters to re-configure carbon flows and estimates within the UK I&S model.

The key findings from the analysis of these new data are as follows:

- **Coking coal carbon content.** The coking coal quality is closely regulated by the coke oven operators, as they seek to optimise the coking process using a blend of coals. As a result, for each of the coke ovens operated by Tata Steel / SSI, there is a comprehensive dataset available using reported monthly average data for each coke oven. Tata Steel provided these data for their installations from 2007 onwards, together with activity data. Monckton coke oven data on coking coal carbon content are reported in the EU ETS, as the method used is a carbon balance approach. Hence through the provision of a time series of activity data and carbon content of coals at all UK coke ovens, a weighted average UK carbon emission factor can be derived. This analysis indicates that the range of coal quality for a given installation is narrow, and therefore that extrapolating the aggregate carbon emission factor back across the time series is a reasonable approach. Applying this revised time series of emission factors will lead to small percentage changes in each year (~2% higher in 1990 and ~1% higher in 2012 compared to the data and method in the 2013 submission).
- **Carbon factors for coke oven gas and coal tars and benzoles.** The current inventory method applies a constant factor in the carbon balance model for the carbon content of coke oven gas, coal tars and benzoles. Tata Steel have provide a time series of the carbon content of these coke oven products, again at a site-specific level and from 2007 to 2012. Together with the site-specific activity data, industry aggregate annual carbon emission factors have been derived. It is recommended that these new factors be applied in the UK GHGI method and that the 5-year average over 2007 to 2011 be extrapolated back to 1990.
- **Carbon factors for limestone and dolomite**. The current inventory method applies a constant factor in the carbon balance model, based on information provided by Corus in 2005. Tata Steel have now provided annual figures for both carbonate minerals based on the data they collect for EU ETS purposes, covering 2007-2012. Using the facility-specific activity data that is also available, an industry weighted-average figure for each year has been derived. Given the narrow range of these factors, it is recommended that these new factors be applied in the UK GHGI method and that the 2007 factors are extrapolated back to 1990 as the best estimate for the earlier years.
- **Blast furnace coal carbon content**. The current inventory method applies a constant factor in the carbon balance model, based on the assumption that the carbon content for coal used in blast furnaces is identical to that for coking coal. However, Tata Steel have again provided a comprehensive dataset of facility-specific carbon factors and activities over 2007-2012, from which an annual weighted average factor can be calculated. These factors show that the fuel quality for blast furnaces differs markedly from coking coal. It is recommended that these new industry carbon factors be applied in the UK GHGI method and that the 5-year average over 2007 to 2011 be extrapolated back to 1990.
- **Blast furnace gas carbon content**. For blast furnace gas (BFG), a similar situation exists as for coke oven gas (COG): a single value is used in the existing model for all years, whereas Tata have now provided installation-specific data for the period 2007-2012. The model could now be updated to include this time series of sector weighted-average carbon content, with a five-year average figure (2007 to 2011) extrapolated back to 1990.
- **Carbon content of pig iron, scrap and steel.** Tata Steel has provided annual data for the carbon content of pig iron, oxygen steel and scrap. In all cases the current approach uses a constant value based on data provided by Corus. For oxygen steel and scrap, it is recommended that the new industry annual data are applied and that the weighted-average from the time series for 2007 to 2012 is extrapolated back to 1990. For pig iron,

the current approach assumes a constant level of carbon in pig iron tapped from the blast furnace and a constant proportion of that carbon removed in the form of kish (so therefore a constant level of carbon in pig iron fed to the oxygen converter as well). Tata have provided a single set of carbon factors for pig iron and it is not clear whether these are for metal pre- or post-removal of kish and therefore the previous default factors for pig iron should be retained. Consultation with Tata Steel may enable an update to use more current data in future submissions.

Table 1: Summary of recommended revisions to carbon emission factors for coke, iron & steelmaking

Parameter	Recommended revisions to Carbon Emission Factors
Coking coal	Replace the existing time series with industry values for the period 2005-2012, using the average of the industry data for the five year period 2005-2009 for all earlier years
Coke oven gas, coal tar, benzoles	Replace the existing single value with industry time series for the period 2007-2012, using the average of the industry data for the five year period 2007-2011 for all earlier years
Limestone and Dolomite	Replace the existing single value with industry time series for the period 2007-2012, using the 2007 value for all earlier years
Blast furnace coal	Replace the existing time series with industry values for the period 2007-2012, using the average of the industry data for the five year period 2007-2011 for all earlier years
Blast furnace gas	Replace the existing single value with industry time series data for the period 2007-2012, using the average of the industry data for the five year period 2007-2011 for all earlier years
Pig iron	Retain the existing emission factors.
Oxygen steel	Replace the existing single value with industry time series data for the period 2007-2012, using the 2007 value for all earlier years
Scrap steel	Replace the existing single value with industry time series data for the period 2007-2012, using the 2007 value for all earlier years

Recommended revisions to activity data: Iron and steel sector

The review of activity data involved several extensive stages of data processing, quality checking and comparison between different datasets, including:

- **Comparison of the ISSB annual activity data templates against DUKES commodity balance tables**. This was conducted in detail for 2009 to 2012, to assess whether there were any systematic differences, with analysis then across the full time series as required. Through consultation with ISSB and the DUKES team, the following issues were identified:
    - The ISSB template used to report activity data to DUKES uses historic default GCV data and gross to net energy conversion factors that differ from the operator-reported factors. However, it is unclear why these simplistic assumptions should lead to any reporting inconsistencies between ISSB and DUKES, as all solid and liquid fuels are reported on a mass basis by both ISSB and DECC, whilst all gaseous fuels are reported on an energy basis. Therefore there are no mass to

energy conversion calculations that should be required in order to populate DUKES using ISSB data;

- DUKES commodity balance tables are constructed using a range of data inputs, to the tables where iron and steel data activity data are reported. Data from other coke oven operators, HMRC import and export data, and cross-cutting datasets such as the DUKES autogeneration survey, all impact upon the DUKES allocations. Therefore it is not a straightforward or transparent system to analyse directly against the “iron and steel sector” source data.
- In some instances, ISSB data alone are higher than the DUKES data. This is notable for 2009 across several sources and fuels. There appears to be no basis for this discrepancy. The DUKES activity data ought to be higher than ISSB data in all years and categories. Therefore it is recommended that the ISSB data should be used in preference to the DUKES data in those instances, in order to derive a conservative estimate of total emissions in the UK GHGI.
- In 2012, several data discrepancies between ISSB and DUKES annual fuel use estimates are evident. This has been traced to revisions to the ISSB dataset (since an initial annual template was submitted and used in DUKES compilation). The later version of the ISSB template (as provided to the study team) includes corrections for data from one of the UK integrated steelworks, and therefore provides a more accurate representation of sector activity in 2012. For this reason, again it is recommended that the ISSB data should be used in preference to the DUKES data in that instance (i.e. coke breeze use in Blast Furnaces and in I&S combustion plant);
- Due to the availability of coking coal activity data from all coke ovens in the UK back to 2000 (from EU ETS data and direct from operators), comparison of the industry data against DUKES data indicates differences (higher data in DUKES in most years) back to 2004. Differences are small during 2004 to 2008 but from 2009 onwards there is a much larger difference between the industry and DUKES data. This is mainly due to a new line in DUKES for anthracite use in the coke ovens, which is not evident in the industry data. Therefore it is recommended that the ISSB and Monckton data be used to over-write the DUKES estimates for 2004 to 2012. In order to maintain the overall consumption total for the commodity balances, an equal and opposite correction should be made to the unclassified industry coal allocation (i.e. use the coal allocation to 1A2f Other Industry as the balancing amendment to maintain overall coal consumption as reported in DUKES). A similar issue is evident for the blast furnace coal allocation in 2009, where the sum of operator data is markedly different from the DUKES data, and therefore the same approach is recommended, i.e. to use the ISSB data and amend other industry coal also;
- A range of other data inconsistencies are also evident, for a number of other fuels and sources. In all cases, however, the study team is not in possession of all the required data to determine if there is an error to be resolved. These are issues for DECC to consider in future DUKES compilation. There are several differences in reported **coke oven coke** use, including an apparent under-report in 2009 in DUKES (i.e. ISSB > DUKES). **COG** data from Monckton are not available for most years and therefore no comparisons can be drawn. Industry data for **coal tars and benzoles** are consistently different to the data published in DUKES. Since they are a relatively insignificant component of the carbon balance, it is recommended that the DUKES data should be retained, but these data warrant further review. For **blast furnace gas** (BFG), industry data on consumption within steelworks are, with the exception of an unexplained difference for 2009, very close to the figures given

in DUKES for overall demand and therefore the DUKES data should be retained. Industry and DUKES data for coal used in blast furnaces are very close and we recommend that DUKES data be retained with the exception of the 2009 data point as outlined above.

- **Comparison of EU ETS data held by the ISSB against EU ETS data held by the EA.** The ISSB database holds the Tata Steel EU ETS data at a greater level of resolution than is available from the EA. In the EU ETS data held by the EA, the I&S installation data are in some cases aggregated across sources and fuels; the ISSB data provides a more detailed breakdown of the emissions by source. The study team have an extensive working knowledge of the EA data, whilst the ISSB dataset was a new dataset that required some resource-intensive manipulation and assumptions (e.g. application of conversion factors, re-formatting) to be used in this project. An extensive amount of data quality checking was undertaken to compare these two datasets. The main output of this process was a rigorous quality check for the EU ETS data and significant improvement in the study team's understanding and interpretation of the ISSB data. Furthermore, the ISSB data can be used to provide additional detail to the (more aggregated) EA dataset; this improvement in data transparency enables most (but not all) of the EU ETS emissions data to be more accurately allocated to a specific IPCC source category. There remain some aggregated data for fuels (across sources) and for blended fuel/process inputs, but a much greater level of data resolution is now achievable. As a consequence of the study team's quality checking, an error in the ISSB data processing was identified; a small under-report for gaseous fuels was identified, where Tata Steel sells gases on to adjacent installations. It is recommended that the activity data used in the carbon balance model should be amended for coke oven gas to correct this omission from ISSB statistics (and hence from DUKES), although this will not impact upon the UK emissions total (as the total carbon content of COG – no matter where it is consumed - is addressed within the carbon balance, and therefore the increase in AD leads to a commensurate reduction in the COG carbon factor calculated within the model).

Table 2: Summary of recommended revisions to activity data for coke, iron & steelmaking

Parameter	Activity data summary and recommended revisions
Coking coal use in coke ovens	There are small but significant differences between industry & DUKES data. Replace the DUKES data for 2004-12 with the industry data, and apply an equal and opposite amendment for Other Industry coal in order to retain consistency with the overall coal balance for the UK. Industry fuel use data are also available for earlier years, but these are closely consistent to data given in DUKES, and hence DUKES data should be retained for 1990-2003.
Coke oven coke production	Retain DUKES data except in the case of 2009, where industry data deviate from the figure given in the UK energy statistics.
Coke oven gas production	Retain DUKES data.
Benzole and tar production	Retain DUKES data, but review these data in future.
Other fuels used in coke ovens	EU ETS data indicates that some fuels used in coke ovens are not reported as used in that source, within DUKES. DECC should consider revising the DUKES data and the GHGI.
Limestone/dolomite	*The study team has not accessed any new data on limestone and*

Parameter	Activity data summary and recommended revisions
consumption	*dolomite use and therefore existing estimates should be retained.*
Blast furnace coal	Retain DUKES data.
Blast furnace gas production	Retain DUKES data.
Blast furnace gas use – other sites	BFG is supplied to other users by the steelworks' operators and ISSB provide data but these are not currently included in DUKES. It is recommended that DECC consider including these data within DUKES and the GHGI. *Note that this does not impact on GHGI emissions totals, due to the use of the carbon balance approach in the inventory compilation.*

Recommended revisions to GHGI estimates for the petrochemical sector

Petrochemicals have been manufactured in the UK across the full GHGI time series, i.e. since 1990; although the number of sites has decreased with time and installations have altered in capacity and manufacturing processes. Within the 2013 Inventory submission, estimates are included for the 5 largest petrochemical complexes that have operated in the UK during this period, where the use of feedstock-derived process off-gases as a fuel has been assessed and reported. Two of these sites are now closed or mothballed. Consultation with operators at the three operational sites has provided new information and clarifications of the data available from the EU ETS, PI and SPRI data. This information enables more accurate estimates to be derived for emissions that should be attributed to process off-gases. The recommended revisions to source estimates across the time series will lead to a decrease in emissions estimated for some years, and increases in other years.

This study has also identified a number of other sites where data reported within the EU ETS and Climate Change Agreement data indicates that by-products (residues, off-gases) are being used as fuels, but on a scale that is far less significant than the 5 large sites already accounted for within the UK GHGI. Available datasets do not provide sufficient detail to fully quantify these smaller contributing emitters:

- The Pollution Inventory (PI), Scottish Pollutant Release Inventory (SPRI) and Northern Ireland Inventory of Statutory Releases (ISR) contain emissions data for all IPPC-regulated chemical manufacturing sites in the UK. Only total emissions are reported; no source-specific breakdown is available and no activity data (fuel use or production statistics) are in the public domain. Therefore it is not possible to use these data to discern whether emissions are derived from combustion, flaring, process sources, waste disposal activities or from purchased fuels or by-products from processes on site.
- EU ETS data for chemical and petrochemical sites is limited to combustion in boilers, gas turbines and engines, plus some process furnaces only. Emissions of flaring on chemical sites will be included within EU ETS data returns in Phase III (2013 data onwards). In many cases it is possible to identify fuels from EU ETS returns, but in some cases the fuel data are aggregated (e.g. where a common ring main of fuel gas is used on a site and fed by a range of sources including process off-gases).
- The study team has also reviewed the Chemical Industry Association Climate Change Agreement (CCA) dataset to identify sites that use by-products as fuels. There is a very limited dataset from the CCA records, which comprise energy-based data on by-products used as a fuel, with no indication of the precise fuel type. The CCA data are therefore not directly useful as a source of activity or emissions data.

However, the CCA and EU ETS data have been used together to identify four additional sites and to quantify the CO_2 emissions that arise due to use of by-products. These emission estimates have been extrapolated back across the time-series as all sites were operational since 1990; in general it has been assumed that emissions in earlier years are the same as reported in EU ETS (see Annex 3 for details of the methodology applied for each site). The emissions from these additional sites are small in comparison to emissions at the 5 large sites included to date; this is consistent with available qualitative information from industry sources that have outlined that the main bulk of emissions from combustion of process off-gases will be focused within the 5 main petrochemical complexes included in the 2013 inventory submission.

Finally, in response to UNFCCC Expert Review Team comments, it is recommended that the emission estimates from this activity should be re-allocated within the UK GHGI to the 1A2c Chemicals sector, rather than the 1A2f Other Industry sector that was reported in the 2013 submission.

Table 3 below summarises the emission estimates for all sites within the 2013 submission and the revisions recommended for the 2014 UK GHGI submission.

Table 3: Recommended revisions to UK emission estimates for petrochemical sector use of waste products as fuel (ktonnes of CO_2)

Emission Year	2013 GHGI Submission (Current) ktonnes CO_2	2014 GHGI Submission (Recommended) ktonnes CO_2	% Change
1990	2806	2903	+ 3.5%
1995	2799	2856	+ 2.0%
2000	3545	3496	- 1.4%
2005	3520	3480	-1.1%
2006	3389	3503	+ 3.4%
2007	3445	3608	+ 4.7%
2008	3052	3015	-1.2%
2009	3036	2981	-1.8%
2010	3256	3203	-1.6%
2011	3095	3057	-1.2%
2012	n/a	3153	n/a

Uncertainty of UK GHGI estimates: Iron and Steel Sector

The use of data derived from fuel analysis conducted annually for the EU ETS reporting system has enabled an improvement in understanding of the carbon flows through the integrated steelworks and independent coke oven in the UK and improved the emission estimates for these processes.

Uncertainties in the emission estimates derived from the use of the EU ETS data within the UK inventory carbon balance method remain due to:

- Discrepancies in activity data reported through the ISSB and DUKES, compared to the activity data reported directly by the operators of the three integrated steelworks to the inventory agency *(not all such issues have been fully resolved)*.
- Uncertainties concerning the use of emission factors for various fuels which are derived from data for the three integrated steelworks and independent coke oven that are then applied to (i) other I&S and non-I&S coke works at sites which are now closed such as the Llanwern & Ravenscraig steelworks, and the Cwm coke works; ii) imported coke. *However, we note that the differences in the specification of cokes and fuel gases produced at different sites are relatively small, and that the use of these site-specific data is, in any case, the best available method, minimising uncertainty.*

Overall, compared with many other sectors in the UK inventory the estimates for the iron and steel sector, taking account of the recommended improvements from this study for the 2014 submission, are associated with a relatively low uncertainty; there are only a handful of sites, with only a few operators. There are good quality activity data and the inventory agency has access to a large, well-documented, third-party-verified dataset to derive country-specific emission factors to apply within the carbon balance model.

Whilst in some years the recommended improvements may not alter the actual emission estimates greatly, the revisions will result in a big improvement in data quality, as the GHGI method will be able to reference a large dataset of recent fuel analysis data that have been derived using methods that are accredited to the required standards under EU ETS and are third-party verified. We note also that the proposed revised method is consistent with the good practice approaches exhibited by many other EU Member States.

In the uncertainty analysis carried out for the GHGI 2013 submission, the uncertainty in 2011 on emission factors for key fuels is estimated as: coke (6%), COG and BFG (12%), and coking coal (2%). The overall output from the Monte Carlo analysis gives a sector uncertainty of around 4.2%.

The revisions recommended through this project are estimated to reduce the uncertainty associated with emission factors to around 2-3% for all fuels and less for coking coal, as the source data are based on EU ETS data that have an overall uncertainty limit of 2.5% for the higher tier data. Note that the uncertainty estimates for activity data will be unchanged as the GHGI method still uses a carbon balance approach using (predominantly) DUKES data, and therefore the use of DUKES statistical differences to estimate uncertainty on activity data will be retained and unchanged. Overall therefore, the iron and steel sector uncertainty will be reduced to around 3%.

The uncertainty in 1990 will be slightly higher as we do not have the same level of reliable data on carbon emission factors and are using extrapolated data back to 1990. However, the research has shown that the variability of emission factors for each fuel type is very narrow, and therefore the main source of additional uncertainty is the applicability of emission factors (derived from operating plant in later years) for activities in steelworks and coke ovens that are no longer operating, but that were open in 1990 (e.g. Llanwern, Cwm and Ravenscraig).

Uncertainty of UK GHGI estimates: Petrochemical Sector

The revisions reported here to UK GHGI estimates for the petrochemical sector are restricted to i) the addition of some small sites that were previously not included, and ii) some minor refinements to the time series data for those sites that had been previously included. The basic methodology has not been changed, but some additional data have been collected which supplements the EU ETS, PI and SPRI data previously available. As a result, revisions have

been recommended to the annual time series data of between 1% and 5% each year, those changes sometimes being an increase relative to the 2013 submission, and sometimes a decrease. Because most of the components used to generate the emission estimates are unchanged, the accuracy of the emission estimates is also largely unchanged. However, this work provides more confidence in the completeness of the inventory, since the study team has reviewed multiple data sets covering much of the chemical sector, and identified sites missing from previous estimates, and has verified with industry experts that they are not aware of any additional emission sources.

The time series data for recent years relies heavily upon verified data from EU ETS, while the middle part of the time series relies upon less certain, but good quality data from the PI and SPRI. For the earliest part of the time series, estimates are much more uncertain because of the need to extrapolate from later data, and assuming that emissions are linked to plant capacity (in the absence of data on actual production). The lower quality of the estimates for the earlier years of the inventory time series is reflected in the uncertainty analysis for the GHGI 2013 submission, where the uncertainty in the activity data is judged to be +/-50% and that for the emission factor, +/-20%. No revision to the assumptions for uncertainty in 1990 is recommended, but the uncertainty for the latest inventory year is much lower at around +/-10%.

Conclusions and Recommendations

This chapter presents the summary of the recommended improvements to the UK GHG inventory as a result of the research, and outlines remaining issues for further consideration by DECC where additional research and action could further reduce uncertainty in the GHGI.

Conclusions: Summary of GHGI Improvement Recommendations

Recommended Recalculations of GHGI Emission Estimates: Coke, Iron and Steelmaking

The emissions from the UK GHGI carbon balance for coke manufacture and integrated iron and steel works have been recalculated based on new data provide by Tata Steel, the ISSB and the Environment Agency. These recalculations are recommended for the 2014 UK GHGI submission, in order that the UK inventory method utilises data that are closely consistent with the EU ETS, whilst retaining (in most cases) a time series of energy statistics that are consistent with DUKES and the existing Tier 2 carbon balance method. The emission estimates in the 2013 submission compared to the recommended recalculations are summarised in the table below, presenting the changes across all affected sources in the UK GHGI. For more information on the changes to iron and steel sector estimates, please see Annex 2.

The revisions are driven primarily by access to a much better dataset on fuel quality data (carbon emissions factors) for coking coal and derived fuels within the integrated steel works. These are combined with the impacts of revisions to activity data within DUKES and on the basis of information from the ISSB. The revisions affect the total GHGI estimates and also the emission source allocation.

Table 4: Recalculations of GHGI Emissions: I&S Sector, Other Sources, Overall GHGI

Year	I&S total (old)	I&S total (new)	I&S sector change	Other sources (old)	Other sources (new)	Other sources change	Overall GHGI change	Overall GHGI change	Coking coal carbon factor change
	kt CO_2	kt CO_2	kt CO_2	kt CO_2	kt CO_2	kt CO_2	kt CO_2	%	%
1990	25,934	26,487	553	3,934	3,949	15	568	101.9%	102.2%
1995	23,820	24,127	307	2,070	2,078	9	316	101.2%	101.5%
2000	22,049	23,011	962	1,638	1,670	32	994	104.2%	104.8%
2005	19,693	20,606	914	366	399	33	947	104.7%	105.3%
2006	20,756	21,668	912	326	331	5	917	104.4%	104.7%
2007	21,436	22,282	847	346	382	35	882	104.0%	104.8%
2008	21,003	21,463	460	357	419	62	522	102.4%	102.6%
2009	16,130	16,185	56	325	62	-264	-208	98.7%	98.7%
2010	15,093	15,063	-30	236	862	627	597	103.9%	103.6%
2011	14,080	13,650	-430	174	585	411	-19	99.9%	99.5%
2012	15,425	14,968	-457	156	736	580	123	100.8%	100.8%

Summary of Data and Methodological Changes: Coke, Iron and Steelmaking

The current UK GHG inventory method for the I&S sector uses a carbon balance approach across the time series and it is recommended to maintain that approach as it provides the best route to maintaining a method and emission estimates that are consistent across the time series. The recommended revisions to inventory estimates are therefore based on the previous GHGI method (which is consistent with IPCC Guidelines and Good Practice GLs), but to integrate as far as possible the new information derived during this research project.

The following are the key factors that influence the recommended changes to the GHGI emission estimates for the I&S sector:

- **Use of a new, up to date and much larger dataset on coking coal carbon content.** The method in the 2013 submission extrapolates forward estimates of carbon content of coking coal based on a very limited dataset and DUKES GCV information. We now have a large dataset of coking coal carbon content, at a site-specific level and based on monthly data from each of the three integrated steel works since 2007. *This change has the greatest impact on the overall emission estimates for I&S and other sources that use fuels from the I&S sector.*
- **Activity Data revisions.** The study has identified several recommended revisions to DUKES data in recent years. In addition, we recommend correction of activity data allocation errors within DUKES to correct: (i) the fuel use total within the I&S sector (re-allocating fuel use between I&S and other sources), and (ii) the distribution of emissions between coke oven and I&S emission sources. *This change affects the overall emission estimates and the split between I&S and other sources*.
- **Carbon content information for other fuels, feedstock and outputs.** In addition to the change to coking coal, we recommend use of a large new dataset of carbon content of many of the inputs and outputs from the coke ovens and iron and steel-making processes, including: secondary gases (COG, BFG), scrap, coal tars, benzoles, pig iron, reverts, steel, coke. *The main impact of these changes is to revise the allocation of emissions within the I&S works*.

Summary of Data and Methodological Changes: Petrochemical Sector

The study team makes no specific methodological recommendations for the petrochemical sector. The main outcomes of the research are to recommend:

- Re-allocation of the emissions to IPCC source category 1A2c from 1A2f.
- Revision of the time series of emission estimates to encompass new estimates of emissions from an additional 4 chemical / petrochemical production facilities, based on estimates derived from EU ETS, CCA data and consultation with operators.

Recommendations: Further Work

Revisions to Source Data Inputs to the GHGI methods

- The carbon balance model has been modified with new industry data, but the study team has only recommended that changes be made where we have the most confidence in the new data and where the changes will have a tangible impact on the inventory. There are other parameters where new industry data could be used in preference to the current values, including for:
    - Benzole and coal tars production
    - Pig iron carbon content
    - Addition of fuels for coke manufacture that are not reported in DUKES

  - Industry activity data (e.g. coal use in blast furnaces, coke oven coke production) across the time series

- The carbon balance is a model that is currently set up so that emissions due to the removal of carbon from the pig iron in the oxygen converters are all treated as contained in the combined BOSG/BFG fuel and therefore emitted from combustion sources, i.e. reported under 1A2a. However, emissions data from operators suggest that most of this carbon is vented to atmosphere without energy recovery and would therefore more properly be reported under 2C1. For example, in 2008 the three steelworks reported emissions of about 1.5 Mtonnes of CO_2 from their basic oxygen furnaces, whereas the GHGI only treats 0.12 Mtonnes of CO_2 as being directly released from the oxygen furnaces. This needs clarification with the operators, and if appropriate a re-allocation of emissions could be addressed in future submissions. Note that this will have no impact on the overall GHGI emission estimates – merely the allocation.
- ISSB have also provided data on fuels used by 'non-oxy' works, i.e. iron and steel sites other than the integrated oxygen steel works. These sites were outside of the scope of the current work, and the data have not been analysed in detail. Although they do not give a complete picture of the emissions within the 'non-oxy' iron & steel sector, they could be reviewed with the aim of incorporating the site-specific data into DUKES and the GHGI.
- Furthermore, when Phase III EU ETS data become available in spring 2014, it is recommended that the data for new sites (several in the steel sector) and new sources (such as chemical flaring) are analysed and incorporated into DUKES and the GHGI. This may lead to either revisions to emission totals and/or source re-allocations.
- Future compilation of the UK GHGI for the iron and steel sector should seek to draw upon the more detailed data that are available from ISSB and plant operators. The ISSB database queries that have been set up to provide the data used in this project have been saved in an ISSB directory and therefore will be straightforward to run to obtain the necessary annual data. Some further consultation is needed with plant operators to secure access to the detailed fuel-specific quality data. Periodic (rather than annual) updates to these parameters would be acceptable given the narrow range of carbon factors and calorific values that are evident from the recent data.
- Coke CEFs output from the carbon balance model could be applied at a more detailed source-specific level due to potential differences in the coke quality for steel production compared to coke quality in other economic sectors. However, whilst this is a possible avenue for further work, the additional improvements to emission estimates are expected to be very small and it is therefore considered to be a low priority.

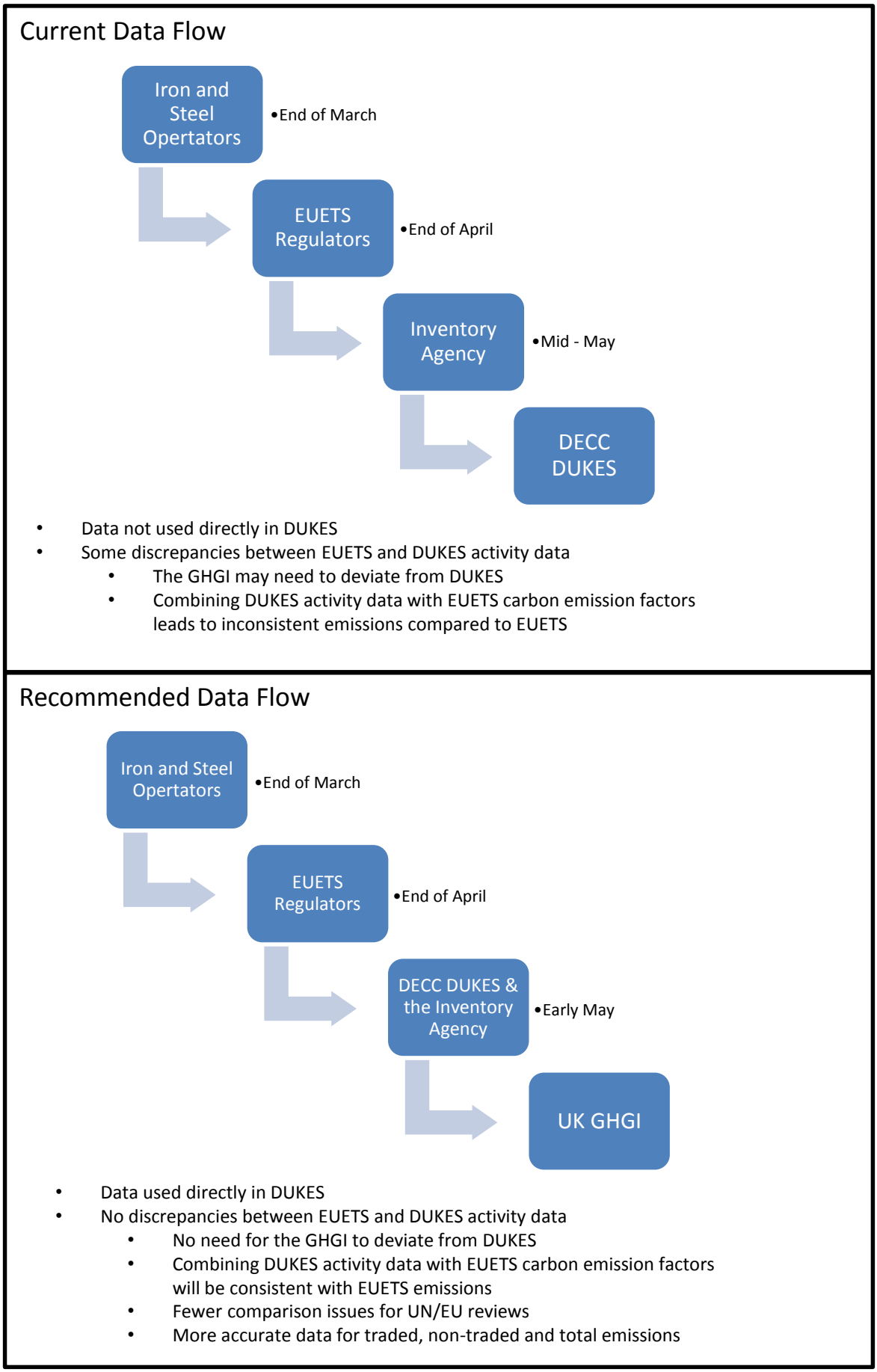
<u>Issues for further consideration by DECC within the compilation of the UK energy balance</u>

- It is recommended that DECC reviews the allocation of coal tars and benzoles within the DUKES Commodity Balance tables to the Non-Energy Use line. This activity is currently allocated to "unclassified industry", inferring that the coal tars and benzoles are used in a combustion process. Based on consultation with Tata Steel and Koppers UK Ltd, it is our understanding that none of the coal tars and benzoles are used as a fuel, but rather they are distilled and used in a range of Non-Energy Use applications, primarily in the manufacture of anodes and speciality chemicals.
- It is recommended that DECC reviews the activity data discrepancies that have been highlighted through comparison with ISSB annual summary data. The ISSB data are higher for some fuels and sources in 2009 and 2012, whilst the DUKES allocation of

anthracite to coke oven use since 2009 does not appear to be correct, based on industry information.

- The research indicates that some very small gaps in activity data may exist within the ISSB and DUKES sector totals, where co-located plants at integrated steelworks use some of the COG and BFG in combustion processes. It is recommended that DECC and ISSB review the data provision that informs DUKES activity data, to ensure that the UK energy statistics are complete.
- The analysis of activity data from plant operators, ISSB and DUKES has not been able to compare comprehensive source data (i.e. the scope of DUKES data is typically wider than the industry-specific data that the study team have accessed). However, for some fuels (e.g. BFG, COG, coke) and for some sources (Blast Furnaces, Coke ovens) the available data from EU ETS and operators is comprehensive and directly comparable to DUKES. Despite the small number of data sources (small number of sites and companies involved) there still exist data discrepancies between operator / ISSB and DUKES data. In the most part these are trivial and can be accommodated within expected uncertainty limits for the GHGI carbon balance approach, but the inconsistencies seem to derive from relatively minor issues such as not updating annual operator data for fuel calorific values and gross to net conversion factors and therefore could be resolved easily and to every data user's benefit.
- Similarly, differences between EU ETS data and DUKES create problems in both the UK GHGI but also in the analysis of traded/non-traded components of the inventory. Figure 2 shows the current flow of data for EU ETS data and indicates the potential benefits of integrating the EU ETS data directly into the UK energy statistics. Resolving the data discrepancies will remove the need for the UK National Inventory Report to list a series of deviations from DUKES and the associated explanations. These issues understandably attract UNFCCC Expert Reviewer comments, creating additional burdens on the inventory agency and DECC, undermining confidence in the UK inventory data.
- EU ETS data show that some fuels are used at coke ovens that are not recorded in DUKES. We recommend that DECC review these data for inclusion into DUKES commodity balance tables. (Note that the activity data in EU ETS are Commercial in Confidence, and hence further details are excluded.)

Figure 2. Source Data Flows: Current and Recommended



Acknowledgements

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- Donna Leach of the Iron and Steel Statistics Bureau for providing extensive information and data across all ISSB and related EU ETS submissions by operators, and for liaising directly with the industry sector contacts to secure data access for the research;
- Mick Briggs and Bob Lewis of Tata Steel for providing detailed insight into the integrated steelworks energy flows, data reporting systems, and for providing extensive information for the Ricardo-AEA research team to improve UK GHGI estimates;
- Alison Judd, Mita Kerai and James Hemingway from the DECC team of energy statisticians, for all of their work to provide details of fuel use allocations and source data that underpin the UK GHG inventory estimates for the iron and steel sector;

Annexes

Annex 1: Data Sources Available for use in the GHGI, and Summary of Emissions Data for Steelworks and Monckton Coke Ovens

Annex 2: Detailed Analysis of EU ETS and Other Industry Data

Annex 3: Derivation of Emission Estimates for Petrochemical Sites

Annex 1: Data Sources Available for use in the GHGI, and Summary of Emissions Data for Steelworks and Monckton Coke Ovens

[This annex provides more details of the scope and basis for activity and emissions data (as summarised in the Results and Discussion section of the report) and also provides an overview of the data available for specific installations, to illustrate the variability of the different datasets.]

Activity data are available from the Iron & Steel Statistics Bureau (ISSB) and from EU ETS returns, as well as from DUKES and other official UK statistics. Emissions data are available from EU ETS, from the Environment Agency Pollution Inventory (PI), and in data sets provided directly by some of the operators.

All of the integrated steel works and the Monckton coke works are included in the EU ETS data set. These data cover the period from 2005 to 2012, although there is a step change in the scope of data and, in the case of some sites, the quality and level of detail of data between the first (2005-2007) and second phase (2008-2012) of the EU ETS. During phase 1, the scope of ETS did not extend to the reheat furnaces at the 3 steelworks. For that 3 year period, the data covered the coke ovens, sintering, blast furnaces, basic oxygen furnaces, and the site boilers at the steelworks, while from 2008 onwards, reheat furnaces were also included.

Scope of reporting at the coke oven remained unchanged over the entire period. One problem with the EU ETS data available prior to this work was the aggregation of some of the data so that, most crucially, fuel consumption and emissions data were combined for the site boilers, other combustion plant, and the blast furnaces. Combustion plant and blast furnace emissions need to be reported separately in the GHGI and so this combining of data was problematic for the inventory.

The ISSB publish detailed activity statistics for the UK iron and steel industry on an annual basis. Their statistics cover production of pig iron, oxygen steel and electric steel as well as the manufacture of various steel products such as ingots, bars and flat products. The statistics do not cover the independent coke oven which is of interest for this study. The statistics cover energy use and fuel production as well as the consumption and production of other materials such as metals. While the statistics available are sector-wide rather than installation-specific, they are sufficiently detailed to match very well with the reporting needs of the GHGI, providing information on fuels, feedstocks and products used in many of the production stages at steelworks.

ISSB data are used by the DECC DUKES team in the derivation of energy statistics for the iron and steel industry. The energy data in DUKES is however structured slightly different to the data in ISSB publications, there are differences in scope and in units used, and the DUKES data will also reflect data available from other sources. Thus, although in some cases it is possible to trace the data published in DUKES back to numbers given in the ISSB statistics, in other cases there are either small differences in numbers, or else the statistics are not directly comparable.

Tata Steel and SSI provide facility-level emissions data each year for each steelworks, with Tata having done so since 2000. The data are supplied in an agreed form and include separate facility-level figures for coke ovens, sintering, blast furnaces, basic oxygen furnaces, power plant (boilers), reheat furnaces, and flaring of COG, BFG & BOSG. The figures from 2005 onwards are essentially consistent with the ETS data, allowing for the fact that the data

for 2005-2007 contain extra emissions – for the reheat furnaces. Unlike EU ETS data, however there is no breakdown by fuel type.

The Environment Agency provides the Pollution Inventory (PI) which contains emissions data for facilities regulated under IPPC in England and Wales. This contains facility-level emissions data for the years back to 1998. Because the PI only includes a total emission for each facility, with no breakdown by fuel or by process, it is not very useful for inventory purposes for the 3 steelworks, however the data for the Monckton coke works is useful, and extends back our information on emissions at that site to before the ETS data in 2005. Emissions data are available for the now-closed Llanwern steelworks from Tata for 2001-2002, and from the PI for 1998-2003 and for the Cwm coke works for which PI data are available for 1998-2002.

The differences between the emissions data from ETS and that from other sources is partially understood in that major differences in scope between ETS, PI, and Tata/SSI data are known. But some small differences in recent years are not accounted for, and may simply relate to the use of provisional data for some data sets, and revised/final data for other data sets. Since the EU ETS data have to be verified independently, in theory these data ought to be treated as the most reliable. However, note that to a large extent we believe that the various data sets largely use the same 'EU ETS' data, albeit with some small modifications for the PI and Tata/SSI data to incorporate differences in scope or other revisions so the quality of all three data sets can largely be assumed to be the same.

There is a difference in the level of detail provided in the data sets, with the PI data only giving a facility-wide total emission of CO_2. The EU ETS and Tata/SSI data are more detailed, though neither gives sufficient detail to provide full transparency and accuracy for all reporting needs of the UK inventory (i.e. by fuel, by source).

Differences between the three data sources are summarised below:

Data Source	Scope / Comments
EU ETS	Excludes bio-carbon (though not likely to be important for these facilities anyway). For steelworks, covers coke ovens, sintering, blast furnaces, oxygen furnaces, boilers, reheat furnaces (2008 onwards only) and flaring but does not necessarily report emissions from these different sources separately. The level of detail at facility-level varies from year to year and from one facility to another but is largely defined in terms of fuel types e.g. emissions are reported separately for coke, coke oven gas, fuel oil etc. But some data are ambiguous, may relate to mixed fuels (or even fuels plus carbonates), and data cannot easily be allocated to NAEI and CRF source or fuel categories. Data for Monckton is based on a carbon balance and is broken down into carbon inputs and outputs in a number of fuels and products. Data can be allocated to NAEI & CRF source category and possibly to NAEI/CRF fuel categories to some extent.
Tata/SSI	Integrated steelworks only. Excludes bio-carbon. Covers coke ovens, sintering, blast furnaces, oxygen furnaces, boilers, reheat furnaces and flaring with separate emission totals for each source category at each facility. Emissions data have followed the same format since 2001 and the scope of data should be the same for all years. Apart from the flaring emissions (which are given by gas type), the emissions are not broken down by fuel type or into

Data Source	Scope / Comments
	fuel-related and process-related so, for example, emissions are not split into emissions from the coke breeze and other fuels/reductants and emissions from the limestone and dolomite also used. Data can be allocated to NAEI source category and CRF source category, but not easily to NAEI and CRF fuel categories.
PI and SPRI	Includes bio-carbon (if appropriate for these facilities). Covers coke ovens, sintering, blast furnaces, oxygen furnaces, boilers, reheat furnaces and flaring at the steelworks and coke-making at Monckton. Facility-wide emission estimate only with no information on individual sources or fuels etc. Cannot be allocated to NAEI and CRF categories.

The existing GHGI methodology uses a carbon balance approach to estimate all outputs from coke making and steelmaking. Carbon inputs are calculated from national energy/activity data and assumed carbon factors, and these estimated carbon inputs are then allocated between the various outputs (direct emissions, wastes, products, produced fuels) from coke ovens and steelworks. In other words, the overall carbon output is dependent on the activity data for carbon inputs (principally coking coal) and the assumed carbon content of those inputs. The carbon outputs are however split across multiple flows including emissions from each part of the coke and steelmaking process, as well as carbon containing in steel, wastes, and produced fuels, and the quantity of carbon in any one of the outputs depends upon the activity data and assumptions used in the carbon balance. Each carbon output is calculated/modelled, with no use of facility-level measured data. The methodology is consistent with the IPCC Tier 2 approach for coke ovens and steelmaking.

The assumptions regarding carbon contents used in the carbon balance were based on a methodology that pre-dated the ETS data, and which required only the use of default values and values updated using national energy statistics. No site-specific ETS, PI or operator data are incorporated each year. The methodology allowed a consistent set of calculations to be used across the full time-series from 1990 onwards.

A comparison of sector emissions based on ETS returns for the 3 steelworks and the coke oven, with approximately comparable data from the GHGI (2013 submission) is given below:

Year	EU ETS, ktonnes CO_2	GHGI, ktonnes CO_2	EU ETS / GHGI
2005	18,550	17,688	1.049
2006	19,919	19,049	1.046
2007	20,486	19,220	1.066
2008	20,072	18,358	1.093
2009	15,811	15,264	1.036
2010	14,454	13,597	1.063
2011	13,337	12,907	1.033

The scope of the two sets of figures is not identical, and the scope of the ETS figures also changes over time, being more limited during the 2005-2007 period. But there is a consistent feature in that the EU ETS emission is higher for all years. The difference does vary from one year to another, with the ETS data between 3% and 9% higher, but if anything, the scope of the ETS numbers is marginally more limited of the two, so one might expect the GHGI figures to actually be the higher, rather than the lower. As a result, one might conclude that the GHGI methodology systematically underestimates emissions from the sector.

Data Overview: Installation Data from different reporting mechanisms

The tables below summarise emissions data for the 3 integrated steelworks currently in operation in the UK, and the Monckton coke works.

Table A1.1. Summary of emissions data for Port Talbot Steelworks (ktonnes CO_2)

Year	EU ETS	Tata Steel	Pollution Inventory
1998	NA	NA	6389
1999	NA	NA	5681
2000	NA	NA	6218
2001	NA	5545	5846
2002	NA	4184	4304
2003	NA	6549	6550
2004	NA	6947	6631
2005	6133	6994	6391
2006	6589	7016	6832
2007	7059	7555	7349
2008	6921	6877	6916
2009	5295	5295	5295
2010	7306	7306	7306
2011	6619	6619	6590
2012	5080	5091	5121

Table A1.2. Summary of emissions data for Scunthorpe Steelworks (ktonnes CO_2)

Year	EU ETS	Tata Steel	Pollution Inventory
1998	NA	NA	7351
1999	NA	NA	6798
2000	NA	NA	6948
2001	NA	6698	6702
2002	NA	7033	7003
2003	NA	7091	7094
2004	NA	7386	7176
2005	6000	7457	7439
2006	7051	7688	8097
2007	7172	7827	8081
2008	6880	6886	6985
2009	5057	5057	5070
2010	5913	5990	5751
2011	6107	6107	5895
2012	5263	5231	3756

Table A1.3. Summary of emissions data for Teesside Steelworks (ktonnes CO_2)

Year	EU ETS	Tata Steel / SSI	Pollution Inventory
1998	NA	NA	6104
1999	NA	NA	5858

2000	NA	NA	4043
2001	NA	6186	5912
2002	NA	5969	5969
2003	NA	6497	6497
2004	NA	6479	6551
2005	6370	6464	6440
2006	6231	6296	6650
2007	6210	6295	6298
2008	6223	6222	6181
2009	5412	5412	5412
2010	1189	1193	1183
2011	565	502	563
2012	4238	4657	4238

Table A1.4. Summary of emissions data for Barnsley Coke works (ktonnes CO_2)

Year	EU ETS	Pollution Inventory
1998	NA	30.8
1999	NA	57.0
2000	NA	52.7
2001	NA	36.2
2002	NA	55.0
2003	NA	50.5
2004	NA	55.0
2005	46.9	47.0
2006	47.8	60.0
2007	45.4	50.0
2008	47.9	50.0
2009	46.5	46.9
2010	47.1	47.6
2011	45.4	47.5
2012	40.5	45.5

Annex 2: Detailed Analysis of EU ETS and Other Industry Data

Due to the limited number of installations and companies operating in the economic sectors under discussion, the detailed data are excluded from the published report in order to maintain commercial confidentiality.

Overall Recalculations to the Iron and Steel Sector in the GHGI

Incorporating all of the revisions to activity data and emission factors into the existing carbon balance model produces changes in GHGI emission estimates as shown in the table below:

Emission Source	1990	1995	2000	2005	2006
2013 GHGI Submission, ktonnes of CO_2					
Coke ovens	2,052	1,616	1,805	894	1,148
Sintering	3,407	3,510	3,227	2,991	2,885
Blast furnaces	4,813	5,334	4,948	4,167	4,475
Oxygen furnaces	129	142	152	109	118
Flared gases	1,941	1,562	1,523	1,919	1,609
Combustion plant	13,604	11,657	10,395	9,609	10,518
Fuels sold	3,934	2,070	1,638	366	326
Total	29,880	25,890	23,688	20,056	21,079
Recommended 2014 GHGI Submission, ktonnes of CO_2					
Coke ovens	2,063	1,619	1,840	900	1,165
Sintering	3,522	3,610	3,404	3,157	3,038
Blast furnaces	4,882	5,381	5,148	4,345	4,658
Oxygen furnaces	135	149	159	114	123
Flared gases	1,971	1,577	1,587	2,004	1,676
Combustion plant	13,907	11,791	10,872	10,086	11,008
Fuels sold	3,949	2,078	1,670	340	302
Total	30,435	26,205	24,682	20,946	21,971
Difference, ktonnes of CO_2					
Coke ovens	+11	+4	+35	+6	+17
Sintering	+116	+100	+178	+166	+153
Blast furnaces	+75	+47	+200	+177	+183
Oxygen furnaces	+6	+6	+7	+5	+5
Flared gases	+30	+14	+64	+85	+67
Combustion plant	+303	+134	+478	+477	+490
Fuels sold	+15	+9	+32	-26	-23
Total	+555	+315	+994	+890	+892

Emission Source	2007	2008	2009	2010	2011
2013 GHGI Submission, ktonnes of CO_2					
Coke ovens	1,318	1,329	1,152	1,321	1,241
Sintering	2,974	2,608	1,980	1,759	1,642
Blast furnaces	4,656	4,734	3,753	3,208	2,978
Oxygen furnaces	131	114	101	109	98
Flared gases	2,125	2,586	830	1,460	1,139
Combustion plant	10,231	9,633	8,316	7,236	6,984
Fuels sold	346	357	325	236	174
Total	21,782	21,361	16,457	15,330	14,255
2014 GHGI Submission, ktonnes of CO_2					
Coke ovens	1,335	1,310	1,182	1,322	1,184
Sintering	3,127	2,699	1,988	1,765	1,624
Blast furnaces	4,822	4,829	3,734	3,180	2,874
Oxygen furnaces	137	120	105	114	102
Flared gases	2,204	2,640	825	1,448	1,096
Combustion plant	10,656	9,865	8,351	7,234	6,771
Fuels sold	320	326	276	193	130
Total	22,602	21,788	16,461	15,256	13,780
Difference, ktonnes of CO_2					
Coke ovens	+17	-19	+30	+1	-57
Sintering	+154	+91	+8	+6	-19
Blast furnaces	+166	+95	-19	-28	-103
Oxygen furnaces	+6	+5	+5	+5	+4
Flared gases	+79	+54	-5	-12	-43
Combustion plant	+425	+232	+35	-3	-213
Fuels sold	-27	-32	-49	-43	-44
Total	+820	+427	+5	-74	-475

Annex 3: Derivation of Emission Estimates for Petrochemical Sites

Based on the review of data available for chemical and petrochemical sites within EU ETS and the CCA datasets, the study team has derived revised estimates for the emissions in the UK from the use of feedstock-derived process off-gases as a fuel within the sector. The emission estimates included in the UK GHGI are conservative estimates of the emissions from combustion activity that are not reported within DUKES; these estimates reflect the emissions of carbon derived from chemical feedstocks that are allocated to Non-Energy Use in DUKES.

It is recommended that emission estimates are included in the UK GHGI for the following nine sites:

Site	Product	Years of operation	Feedstock commodities	Already included in the inventory
1	Ethylene	1990-2012	Naphtha / Heavy gas oil	✓
2	Ethylene	1990-2012	Naphtha / LPG	✓
3	Ethylene	1990-2012	Naphtha, butane, propane, ethane	✓
4	Ethylene	1990-1993	Naphtha	✓
5	Ethylene	1990-2012	Natural gas liquids	✓
6	Polypropylene	1990-2012	Propylene	
7	Acrylonitrile	1990-2012	Propylene	
8	Acetyls	1990-2012	Naphtha, natural gas liquids	
9	Tetra acetyl ethylene diamine	1990-2012	Acetyls	

Estimates of emissions from the five ethylene sites were reported within the 2013 inventory submission and therefore the methodology for those sites is not described here but can be found in the 2013 NIR. For the four newly included sites, emissions data from the EU ETS were used for the period 2008-2012, in conjunction with by-product fuel use energy data reported in the 2008 and 2010 Climate Change Agreement data. The EU ETS data includes details of the fuels being burnt, and the emissions data selected were only those that related to the combustion of waste-chemical based fuels (generally process off-gases or process residues), i.e. those fuels that are not reported within DUKES directly.

In the case of Site 8, where the level of activity has decreased markedly in recent years, a time-series for the period 2001-2007 was created by extrapolation from the 2008 EU ETS emissions data, varying this in proportion to deliveries of feedstock to the plant which are available from the DECC Petroleum Production Reporting System (PPRS) data. This ensures that the estimates take into account that some sections of the plant were closed in 2005/6, before EU ETS data were available.

For all other years i.e. 1990-2000 for site 8, and 1990-2007 for the other 3 sites we assume that annual emissions are equal to the average figure for the first 5 years were we have more robust data. That is the five years of EU ETS data for sites 6, 7 and 9, and the PPRS-based estimates for 2001-2005 in the case of site 8.

Our research considered other sites that might have used by-product gases as fuels, but found no evidence in EU ETS or CCA data that this was the case. The extension of EU ETS reporting in Phase 3 (2013 data reporting onwards) may lead to further data and additional sites being identified. Perhaps more likely though is that emissions may have occurred from other plant that closed before the beginning of EU ETS reporting in 2008. Many petrochemical sites that were operating in the UK in 1990 have since closed, and it is possible that some could have used by-products as fuels. However, since the ethylene plant already included in the estimates are known to have been by far the most significant users of chemical feedstock, it is unlikely that any emissions from sites that are not accounted for, will be comparable in scale to the emissions from those sites included in the estimates.

Uncertainty in the estimates for recent years is judged to be low (2-3%), while estimates for earlier years are much more uncertain due to the lack of data and the assumption of unchanged emissions over long time periods. The estimates for the earlier part of the time series could be as high as +/- 50%; we will review this judgement as further information is obtained from contacts with regulators or industry.

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