Emissions intensity benchmarks for the South African carbon tax

Technical support study

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Summary

South Africa has committed to reducing its greenhouse gas (GHG) emissions by 34% by 2020 and 42% by 2025 below business as usual. To achieve these GHG emission reductions, South Africa is looking at adopting a mix of policy instruments. One of these instruments is a Carbon Tax policy as outlined in May 2013 by South Africa's National Treasury.

The Carbon Tax Policy Paper provides details of the carbon tax design and revenue recycling options. One of the key features of the carbon tax design is the use of GHG benchmarking of selected industries to determine the applicable tax-free threshold under the carbon tax. Companies that perform better as compared to a carbon emissions intensity sector benchmark qualify for a higher than default tax-free threshold.

This study aims:

- To study the carbon tax policy objectives and the role of benchmarking therein; and to translate these into clear guidance for benchmarking in the South African context that meets the policy objectives.
- To assess the applicability of existing international and South African benchmark studies for use in the South African context.
- To design one or more generic fall-back approaches for activities not covered by a specific (sub-sector) product benchmarks.
- To provide recommendations for each sector on the benchmark approach to be used and outlining next steps to finalise benchmark values using the approach suggested.

This study focuses on the following energy-intensive industries which account for a large share of industrial emissions in South Africa: iron and steel, ferroalloys, cement, crude oil production, coal to liquid (CTL), gas to liquid (GTL), chemicals, pulp and paper and sugar.

Based on international experiences, this study concludes that where possible, product benchmarks (defined as emissions per unit of sector output) should be developed. Developing such benchmarks allows all emission reduction options for companies to be taken into account when determining the benchmark approach. Ideally, the majority of emissions of sectors are covered by such product benchmarks so that the sector is treated in a uniform way. The Carbon Tax Policy Paper further makes clear two further criteria to be taken into account in the development of the benchmark approach per sector: that the benchmarks should cover both scope 1 (direct) emissions and scope 2 emissions related to the consumption of electricity, and that the benchmarks should be based on the average performance of the average South African industry.

Using these criteria as a basis, and taking into account the international experiences with benchmarking in the context of carbon pricing initiatives such as the EU, California and Australia, for each sector product, we propose the benchmark approaches and indicative benchmark values listed

in Table 1. This was further informed by research into existing production processes, types of products, emission profile for each sector and other sector characteristics that were relevant for benchmarking for South African sectors. For the emissions that are not covered by these product benchmarks, it is proposed that generic fall-back approaches are applied as follows:

- An electricity consumption benchmark that is related to the South African grid electricity emission factor (an indicative value of 0.94 t CO_{2e}/ MWh has been derived based on 2009 – 2013 data) for the electricity consumed.
- A fuel benchmark that is related to the average fuel emission factor of the South African industry (an indicative value of 90.8 t CO_{2e}/TJ has been derived based on 2010 data) for the fuel used for production processes not covered by the product benchmarks.
- No benchmark approach for the limited number of process emissions that are not covered by a product benchmark.

Under the suggested approach each company in the sectors is studied, and the tax-free emissions threshold is determined by comparing the actual greenhouse emissions with the benchmark greenhouse gas emission, which is based on a combination of applicable product benchmarks and fall-back approaches. A summary of the approach by sector is provided in Table 1.

Table 1: Summary of benchmark approaches for South African Industry Sectors

Sector	Benchmark approaches	Indicative benchmark values (in t CO_{2e} / t product unless otherwise stated)[1]
Iron and Steel	Product benchmark covering more than 80% of emissions: - Coke - Sinter - Hot metal (from BF / BOF) - EAF (carbon steel) - EAF (high alloy steel) - Hot metal (COREX / MIDREX) Fall-back approaches for remainder of emissions. Approach based on benchmark methodology applied in the EU ETS, which can be used to define the benchmarks.	 0.3 – 0.5 0.2 – 0.3 1.4 – 1.7 0.6 – 0.7 0.6 – 0.7 Cannot be determined at this stage

Sector	Benchmark approaches	Indicative benchmark values (in t CO_{2e} / t product unless otherwise stated)[1]
Ferroalloys	Product benchmark covering majority (>80%) of emissions: - Chromium alloys - Manganese alloys (7% C) - Manganese alloys (1% C) - Silicon alloys (assume 65% Si) - Silicon metal Fall-back approach for emissions not covered by product benchmarks. No international experiences. Detailed benchmark definitions to be developed with the sector.	 3.25 – 4.55 3.25 – 4.55 3.75 – 5.25 9.7 15.7
Cement	Product benchmark covering at least 80% of the emissions: - Cement clinker Fall-back approach for emissions not covered by product benchmarks. Benchmark definitions available from existing emission trading schemes, e.g. the EU ETS.	 0.85 – 1.10
Petroleum	Process specific approach covering virtually all emissions: - Complexity Weighted Tonne (CWT) Approach based on benchmark methodology applied in the EU ETS, which can be used as starting point for discussion with the sector.	 0.0295 – 0.035 t CO_2 / CWT
Petroleum (GTL)	Process unit weighted tonne approach covering virtually all emissions. No international methodology available. Methodology to be developed with the sector, CWT approach can be used as blueprint for the approach.	Cannot be determined at this stage

Sector	Benchmark approaches	Indicative benchmark values (in t CO_{2e} / t product unless otherwise stated)[1]
Petroleum (CTL)	Process unit weighted tonne approach covering virtually all emissions. No international methodology available. Methodology to be developed with the sector, CWT approach can be used as blueprint for the approach.	Cannot be determined at this stage
Chemicals	Product benchmark for most important products covering about 80% of the emissions. Fall-back approach for emissions not covered by product benchmarks. Product lists from Australia and EU ETS are a good starting point for the definition of the list of products.	Cannot be determined at this stage
Paper and Pulp	Product benchmark approach covering the majority of emissions (>80%) consisting of the following sub-product groups: - Dry pulp production - Wet recovered paper pulp - Wet pulp in integrated processes - Paper production Fall-back approach for emissions not covered by product benchmarks Approach based on methodology applied in Australia carbon pricing methodology, further specification of product categories to be done with sector, likely to result in installation specific results.	0.8-2 for all products. Product list to be determined with the industry. 1.277 0.471 0.578 0.892 – 2.316

Sector	Benchmark approaches	Indicative benchmark values (in t CO_{2e} / t product unless otherwise stated)[1]
Sugar	Discuss with sector whether product benchmarks for: - Raw sugar - Refined sugar Could cover the majority of the emissions of the sector. As an alternative, consider applying the fall-back approach to the emissions of this sector. No international experiences, detailed benchmark definitions to be developed with the sector.	Cannot be determined at this stage

[1] Benchmark values for South Africa can only be determined based on detailed installation-specific data. The indicative values given here only give an idea of the order or magnitude of the benchmark values that are likely to emerge from a detailed bottom-up data collection process. As such, the values given here should be regarded as indicative only. For an explanation on the sources used to arrive at those values, we refer to the sector chapters.

It should be noted that the benchmark values listed in Table 1 are indicative values based only on a combination of international benchmarks and South African data for products where such indicative benchmark values could be proposed. The data available to this project and data collected by the South African National Treasury during this project has been either at a sector or company level. Although certainly useful to get a better view on the data situation of the sectors concerned, this data cannot be used one-to-one to derive benchmark values for individual products. For the development of such benchmarks, emissions data at the level of individual products is required. Nevertheless, the indicative values as presented above are good starting points for further discussion with the sectors.

As the next step in benchmark development, it is recommended that the findings of this study be discussed with the relevant industry stakeholders. Before further data is collected, it is recommended that the final benchmark approach for each sector first be decided upon. For some sectors (like cement), we expect this to be a relative simple process, while for others, it involves steps to determine which types of products to benchmark (such as products within the chemical sector) or the set-up of sector specific methodologies (such as for the GTL and CTL sectors). In this step, some key methodological choices that apply to all sectors also need to be finalised, such as the choice for base years, the exact treatment of scope 2 emissions, whether or not benchmarks will be updated, and how certain specific issues (such as the production and use of waste gases) will be covered.

Once the benchmark methodologies are fully specified and defined, specific data requests can be sent to the industries in order to collect the data needed for the calculation of the benchmark values. It is clear that support will be required to ensure that data is collected consistently across products and companies. Detailed guidance on data collection will need to be developed given that emissions and energy use data need to be allocated to products rather than the company or operations. In addition, data on company emissions not covered by product benchmarks needs to be collected. All system boundaries, and the treatment of special cases, need to be clearly defined. For some sectors the proposed benchmarking approach requires very specific unit operation data to be collected (e.g. for the CWT approach in refining) which will require collaboration with the industries in question. Given the sensitivity of some of this data in view of confidentiality and in view of the ultimate use for tax purposes, it is essential that all rules and procedures around this data collection and data verification are well defined and embedded in the further policy preparation.

We are confident that this study forms a solid basis towards the further development of final benchmarking methodologies and benchmark values to support carbon tax development in the South Africa.

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1 Introduction

1.1 Background

The World Bank's Partnership for Market Readiness (PMR) programme is set up to support the development of market-based mechanisms to reduce greenhouse gas (GHG) emissions in beneficiary countries (further referred to as implementing countries). A wide range of activities support the preparation of implementing countries for market-based climate change policy instruments. As part of the PMR, implementing countries have to prepare a Market Readiness Proposal (MRP) outlining market readiness components. The MRP also details the existing market readiness capacity and identifies gaps in capacity. South Africa, one of the implementing countries, is currently in the process of preparing an MRP.

South Africa is committed to reducing its GHG emissions by 34% by 2020 and 42% by 2025 below business as usual (conditional on financial assistance, technology transfer and capacity building). To achieve these reductions, South Africa is looking at adopting a mix of policy instruments. At the Cologne PMR Partnership Assembly meeting in May 2012, South Africa presented its Organizing Framework expressing its intention to implement a carbon tax and a complementary domestic offset scheme as the market-based instrument for GHG mitigation.

As part of its preparation to implement a carbon tax, South Africa's National Treasury published a Carbon Tax Policy Paper in May 2013 for public comment, as well as a Carbon Offsets Paper published in April 2014. The taxation policy described in the Carbon Tax paper contains a tax-free threshold adjustment which is dependent on the ratio of a firm's emissions intensity compared to an emissions intensity benchmark.

To support the further development of this approach, the South African National Treasury requested support on benchmarking the emissions intensity of selected industry sectors. Ecofys and The Green House were contracted by the World Bank to assist the South African government in the development of approaches to setting emission intensity benchmarks for several industrial sectors in the context of the South African Carbon Tax Policy.

1.2 Goal of the study

The goal of this study is to provide technical support for the development of benchmarks for the following sectors in South Africa:

- Petroleum (coal to liquid; gas to liquid)
- Petroleum - oil refining
- Iron and steel

* Non-ferrous metals
* Cement
* Chemicals
* Pulp and paper
* Sugar

1.3 Overall approach

The approach taken to achieving the overarching goal of the project included four key tasks (see Figure 1):

1. Defining policy objectives and translating these into guidance for benchmarking in the South African policy context
2. Assessing applicability of existing international and South African product benchmarks for use in the South African context
3. Designing one or more generic fall-back approaches for activities not covered by a specific (sub-sector) product benchmarks
4. Providing a final recommendation for each sector on the benchmark approach to be used and outlining next steps to finalise benchmark values using the approach suggested.

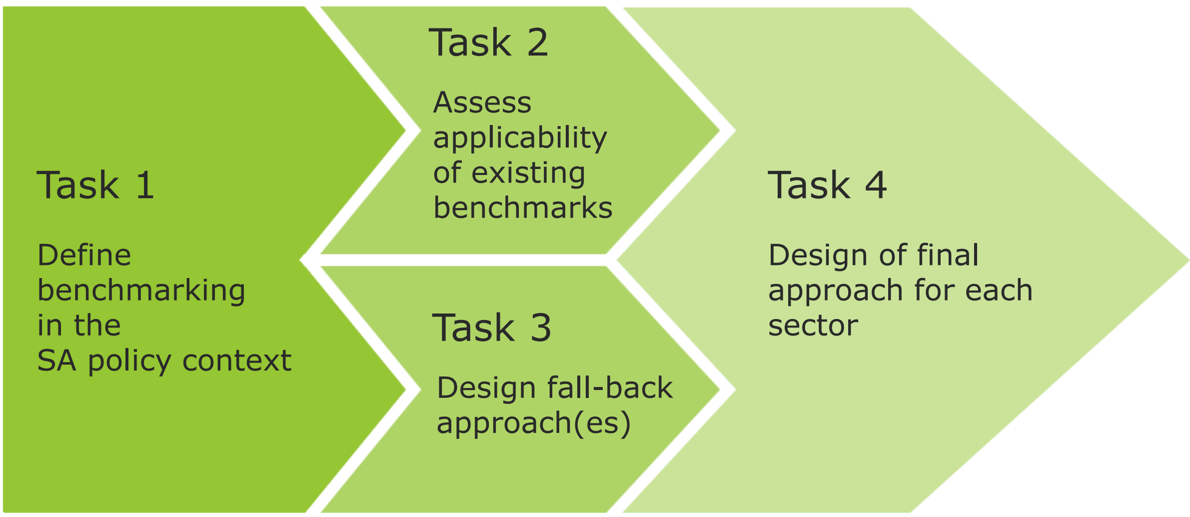

Figure 1: Overall approach to the study

In Task 1, the Carbon Tax Policy Paper of May 2013 is taken as a basis for defining policy objectives. These policy objectives are then translated into guidance for the development of the benchmarking approaches, also taking into account international experience with benchmarking in the context of carbon pricing initiatives. The guidance addresses:

- The technical specifications the product benchmarks and fall-back approaches should meet.
- The activities for which product benchmarks should be developed.
- The approaches to develop these product benchmarks.

In addressing Task 2, existing energy and emissions intensity benchmarks were identified and reviewed. Relevant characteristics of existing international benchmark approaches were obtained mainly from literature sources. Relevant South African sector characteristics were obtained including:

- Number of plants
- Product mix
- Applied production processes
- Emissions intensity
- Fuel mix
- Data availability

The applicability of existing benchmarks to the South African context were assessed by 1) comparing existing benchmarks to South African specifications, 2) identifying required adjustments and 3) assessing the feasibility of the required adjustments. A gap analysis was performed to determine what relevant data was missing. In developing benchmarks, use was made of experience with benchmarking for market-based approaches in other regions, in particular the EU ETS, Australia and California.

In Task 3 different fall-back approaches for the benchmarking in the context of South African Carbon Tax Policy were identified and assessed, and recommendations on what approach(es) to use were presented.

In Task 4 final recommendations were provided on how to treat each sector based on the outcome of the previous tasks and in particular on the policy objectives, technical specifications for South African benchmarks and the framework developed under Task 1.

The outcome of this task consisted of:

- A proposal for which activities should be covered by:
  - An (adjusted) existing product benchmark
  - A new, to-be-developed product benchmark
  - The generic fall-back approaches suggested
- Recommendations on which existing benchmarks can be used, what adjustments need to be made and how these adjustments need to be made
- Recommendations for the development of additional benchmarks

1.4 Outline of this report

Based on the task description given above, this report has the following structure:

- Chapter 2 develops criteria (Section 2.2) and more detailed guidance (Section 2.3) for the development of a benchmarking approach for South Africa taking the Carbon Tax Policy Paper (Section 2.1) as basis. It is the outcome of task 1 of the study.
- Chapter 3 provides an overview of existing international studies containing product benchmarks that are of relevance for the current study (Part of task 2 of this study).
- Chapter 4 describes options for fall-back approaches for activities that cannot be covered via a product benchmark and gives a recommendation for the fall-back approaches to be used (Task 3 of this study).
- Chapter 5 summarizes the overall suggested approach - a combination of product benchmarks and a generic fall-back approach – and summarizes in a generic way the next steps that are required to finalize the benchmark approaches and values (Part of task 4 of this study).
- Chapters 6 to 14 then zoom in on the individual sectors, providing a detailed overview of South African industry sectors and defining the sector specific benchmark approach based on the generic approach and criteria developed in the Chapters 2 – 5 (Part of task 4 of this study).
- A summarizing Chapter 15 presents the key conclusions and recommendations of the study.

2 Benchmark design

The benchmarks that are being developed under this current project are to be used for supporting implementation of the proposed carbon tax. This section therefore begins by listing relevant design features of the proposed carbon tax in Section 2.1 and on that basis defines technical requirements for benchmarks to be developed in Section 2.2. Section 2.3 then uses these requirements to provide guidance for developing benchmarks in the South African carbon tax context.

2.1 Starting point for this study: the Carbon Tax Policy Paper

The development of the methodology for the benchmark definition in this study is based on the design of the carbon tax policy as specified in the Carbon Tax Policy Paper from May 2013 as summarised below. The Carbon Tax Policy Paper proposes a carbon tax levied on scope 1 emissions, (i.e. emissions that result directly from fuel combustion and gasification and industrial process emissions). To manage the transition to a low-carbon economy, a transition period will provide for temporary thresholds below which an exemption from the carbon tax will be granted. The basic tax-free threshold is 60 per cent of a firm's emissions. This share is adjusted based on a firm's performance compared to a sector benchmark. Additional tax-free thresholds are proposed for trade-exposed sectors and for sectors where the potential for emissions reduction is limited for either technical or structural reasons.

Relevant design features of the tax are described below in more detail. Given the scope of this study, this section focuses on design features of the tax that are relevant for benchmarking of industrial processes.[1] The numbers in the text below refer to paragraphs in the Policy Paper.[2]

2.1.1 Coverage of emissions

- Insofar as industrial facilities are concerned, the carbon tax will apply to all direct, stationary sources of emissions from sources that are owned or controlled by the entity (§§174, 175, 184).
- The tax will cover scope 1 emissions; that is, emissions that result directly from fuel combustion and gasification, and from non-energy industrial processes (§§30, 175).
- The tax will cover emissions of carbon dioxide, methane, nitrous oxide, perfluorocarbons, hydrofluorocarbons and sulphur hexafluoride (§§30, 175).

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[1] It should be noted that the currently proposed design does not necessarily reflect final legislation and is subject to an on-going political process. While this section aims to accurately reflect the contents of the Policy Paper, the design features presented in this section should always be seen within the context of the proposal in the Policy Paper

[2] While the Policy Paper formed the basis for the descriptions in this section, the text in this chapter does not literally reflect the contents of that Paper. To improve readability and to provide the proper contexts, sentences have been rewritten and information has been added.

- The tax applies to the entity that generates the GHG emissions. To avoid double-counting, the tax does not cover indirect emissions resulting from a firm's use of purchased electricity, heat or steam.

2.1.2 Monitoring of emissions

- The tax imposed on fuel inputs with GHG emissions is derived from either approved emissions factors for the fuels concerned or an alternative transparent, verified measuring and monitoring procedure. This alternative procedure may be necessary in the case of process emissions resulting from the chemical reactions of certain manufacturing processes, such as cement, glass, aluminium and chemicals production (§172).
- The tax will be supported by a mandatory reporting of GHG emissions for entities and companies.

2.1.3 Temporary tax-free threshold

- To manage the transition to a low-carbon economy, a transition period will provide for temporary thresholds below which an exemption from the carbon tax will be granted. §184).
- During the period (2016–2019)[3], the basic tax-free threshold is 60 per cent of a firm's emissions. The percentage tax-free thresholds will be reduced during the second phase (2020–2025)[3] and may be replaced with absolute emissions thresholds thereafter (§§183, 186).
- Additional tax-free thresholds are proposed for sectors where the potential for emissions reduction is limited for either technical or structural reasons (initial consideration suggests that this will include the cement, iron and steel, aluminium and glass sectors) (§§183, 185, 186).
- Additional tax-free threshold are proposed for trade-exposed sectors (§§183, 185).
- The maximum tax-free threshold is 90% of verified carbon emissions during the first phase (2016–2019)[3]. This maximum threshold will be decreased progressively in subsequent phases (§188).

2.1.4 Adjustment of tax–free threshold making use of benchmarks

- To encourage firms to reduce the carbon intensity (including both scope 1 and scope 2 emissions) the basic tax-free threshold of 60 per cent is adjusted by a Z-factor (§§188, 190).
- The Z-factor is defined as an agreed sector benchmark carbon emissions intensity (including both scope 1 and scope 2 emissions[4]) divided by the average measured and verified carbon intensity (including both scope 1 and scope 2 emissions) of a firm's output. (§190)

[3] Note that these dates refer to those included in the original paper issued in 2013. These periods have subsequently been pushed out.
[4] Scope 1 emissions are direct GHG emissions from sources that are owned or controlled by the entity (e.g. emissions from fuel combustion and industrial processes). Scope 2 emissions are indirect GHG emissions resulting from the generation of electricity, heating and cooling, or steam generated off site but purchased by the entity.

- The Z-factor will result in a higher tax-free threshold for companies with a lower carbon intensity (including both scope 1 and scope 2 emissions) as compared to the benchmark (§190).
- The adjustment will be determined annually based on the company's absolute emissions for that year (§190).
- Adjustments to the 60 per cent basic tax free threshold will be limited to +5 percentage points using the Z-factor adjusted to the benchmarks[5]

Calculation of the Z-factor is proposed in Carbon Tax Policy Paper as follows:

Z = Y / X

Where:

- Y is the agreed benchmark carbon emissions intensity (including both scope 1 and scope 2 emissions) for the sector.
- *X* is the average measured and verified carbon intensity (including both scope 1 and scope 2 emissions) of a firm's output

In addition to the proposed basic tax-free threshold of 60 per cent, an additional tax-free allowance for trade-exposed industrial sectors of up to 10 per cent is introduced. Additional allowances for process emissions are also allocated to the sectors in which most process emissions are expected to take place. An overview of the total thresholds proposed is given in Table 2 (§185). Initially firms will also be able to use verified offsets to reduce their liability by a further 5 or 10 per cent of actual emissions up to the maximum tax-free threshold of 90 per cent.

[5] Peter Janoska, The National Treasury of South Africa. Personal Communication, June 2014.

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Table 2: Tax-free emissions thresholds by sector (%)[6]

Sector	Basic tax-free threshold (%)	Maximum additional allowance for trade exposure (%)	Additional allowance for process emissions (%)	Total (%)	Maximum offset (%)
Electricity	60	–	–	60	10
Petroleum (coal to liquid; gas to liquid)	60	10	–	70	10
Petroleum – oil refinery	60	10	–	70	10
Iron and steel	60	10	10	80	5
Cement	60	10	10	80	5
Glass and ceramics	60	10	10	80	5
Chemicals	60	10	10	80	5
Pulp and paper	60	10	–	70	10
Sugar	60	10	–	70	10
Agriculture, forestry and land use	60	–	40	100	0
Waste	60	–	40	100	0
Fugitive emissions from coal mining	60	10	10	80	5
Other	60	10	–	70	10

2.2 Criteria for benchmark development

In this section, criteria are provided for the development of the benchmark methodology that will be used in the tax-free emissions threshold calculation. These criteria are set upfront to ensure that benchmarks are designed to confirm policy goals and ensure equal treatment of sectors. With the exception of specifications 1 and 2, the specifications listed in this section do not directly follow from the Policy Paper and have been formulated based on experience with benchmarking in other regions, in particular the EU and California[7].

[6] Source: Carbon Tax Policy Paper May 2013. The table might be subject to further revisions.

[7] See in particular: Ecofys, "Methodology for the Free Allocation of Emission Allowances in the EU ETS Post 2012, Ecofys et al. for the European Commission," November 2009 (available at: http://ec.europa.eu/clima/policies/ets/cap/allocation/studies_en.htm; accessed 10/2/14)

CARB, "Appendix J of the Initial Statement of Reasons" of October 2010, California Air Resources Board, October 2010 (available at: http://www.arb.ca.gov/regact/2010/capandtrade10/capandtrade10.htm; accessed 10/2/14)

SEI, "Issues and Options for Benchmarking Industrial GHG Emissions," Stockholm Environment Institute for the Washington Department of Ecology, June 2010 http://www.ecy.wa.gov/climatechange/docs/Benchmarking_White_Paper_Final.pdf; accessed 10/2/14)

The list of criteria has been proposed to and agreed with National Treasury before developing the sector-by-sector methodologies. It should be noted that in practice, as the experience in the EU shows, it may not always be possible to meet all criteria entirely. They should therefore be regarded as starting points instead of strict requirements.

1. *Coverage of emissions*

Benchmark values should cover both scope 1 and scope 2 emissions. Scope 1 emissions should include emissions from the combustion of fuels as well as process emissions.

2. *(Benchmark) carbon intensity values should be undisputable and unambiguous*

Benchmark values should be based on robust data. The covered emissions and related activity levels should be well defined. Methodologies to determine (benchmark) carbon intensity should be simple and transparent. It should be possible to obtain well-defined output data and to determine the emissions associated with the defined output with reasonable accuracy.

3. *Benchmarks should in principle be based on physical indicators*

Emissions are typically related to the occurrence of certain physical activity such as product separations, chemical reactions etc. As a result, benchmarks based on physical indicators provide a better, more robust and less ambiguous measure for the performance of a company with respect to GHG emissions compared to economic indicators. Physical indicators include the production or consumption of products, raw materials, heat and fuel. This study provides recommendations on which indicator is best suited for a particular activity.

4. *Benchmarks should be based on outputs (products) rather than inputs to the extent feasible.*

The fuel mix chosen, the efficiency of heat production and the efficiency of heat end-use are all taken into account in determining the benchmark value and expressing the benchmark as emissions per unit of output. All measures a firm takes to reduce GHG emissions in each of those areas will lead to a higher tax-free threshold. This is not the case for benchmarks based on inputs, where measures taken to reduce the input used do not result in higher tax-free thresholds. Output-based benchmarking may not always be feasible (see point 5 below). This study provides recommendations on when output-based benchmarks are appropriate and how such benchmarks should be defined in such cases.

5. *Products benchmarks should not differentiate by technology, fuel mix, size, age, climatic circumstances or raw material quality, only by type of product.*

This approach is also known as the "one–product, one–benchmark principle" (Ecofys, 2009). If the same output or product is produced by multiple facilities, then this principle leads to benchmarks that cover multiple facilities. In that case, the approach rewards producers that have the lowest emissions per unit of output of a particular product regardless of the technology used, age of the plant, etc.

Facility or technology specific benchmarks bear the risk that inefficient producers are rewarded for specific non-efficient technology or raw material choices. Another drawback of facility-specific benchmarks is that more benchmarks need to be developed, which will require additional effort. It should however be noted that for products that are produced by one facility only, application of the one-product, one-benchmark principle automatically leads to facility-specific benchmarks.

The choice of a one-product, one-benchmark approach may lead to lower taxes for newer more efficient plants, plants that use efficient technology and or raw materials that result in fewer emissions. Since this may have significant competitiveness impacts on individual facilities, it is important that justifications are provided for methodological choices. When using the one-product, one-benchmark approach, it is particularly important that the product produced by the different plants covered by a product benchmark is truly comparable and that the benchmark is thus indeed a fair benchmark for the GHG emissions performance.

6. *Fall-back approaches should be used in cases where product benchmarks are not feasible or worthwhile*

Output-based benchmarking is not feasible if no appropriate measure for output can be defined. This is particularly the case for complex production processes where multiple products are produced simultaneously and in cases where there is a large variety of products within the same product group.

Another limiting factor could be the availability of robust data.

7. *Benchmark values and methodologies need to account for characteristics of South African industry*

For an effective carbon tax it is important that benchmarks take into account the structure and performance of South African industry. South Africa may produce specialty products that should be given special consideration. Also, the value of the benchmark may need to take into account the performance of South African industry such that the tax-free threshold does not become too high or low for a particular sector as a whole in view of overall policy objectives.

8. *Benchmark values should reflect average performance of installations to which the South African tax applies.*

By having the benchmarks reflecting South Africa average performance, the adjustments of the tax-free threshold will be positive based on the firm's performance relative to the sector average. The reference threshold (e.g. 60%) will be the main determinant of the final threshold which allows for easy control of the threshold by the government. In order to reflect actual performance, benchmarks are ideally set based on data from recent years. By basing the benchmarks on data from multiple years, the impact of any specific events will be reduced. Ideally, the same baseline years are used for all sectors since equal treatment is most fair. As a starting point, the period 2010 – 2012 is proposed as baseline period. Reasons may exist to deviate from this starting point in particular cases, e.g. in a case where a plant was not operational in a particular year. In this context, it is noted that shut-downs for the purpose of maintenance are regarded as part of normal operations. It should be noted that this criterion makes the usage of international benchmark values in the South African context limited.

9. *Existing benchmark methodologies should be used where this does not lead to unacceptable conflicts with other specifications.*

Existing international benchmark methodologies could be used for the definition of South African benchmarks in cases where the technological production processes internationally are the same in South Africa. By using existing benchmark methodologies from other regions the amount of effort required to benchmark South African industry can be reduced substantially. However, caution should be taken when using such methodologies for the benchmarks definition as they may not always be appropriate to the South African context.

10. *The same main benchmark methodology should be defined and used for the lion's share of the emissions in a sector insofar this is justifiable and does not lead to complications.*

Using the same benchmark methodology (i.e. product benchmarks or one or multiple fall-back approaches) for a large share of the emissions in a sector ensures a fair and similar treatment for the majority of emissions produced by companies operating in the same competitive playing field (obviously depending on the exact sector definition applied). This will increase sector acceptance of the overall methodology.

11. *Benchmarks should be defined so that they cover as many installations and emissions as possible*

Defining benchmarks with a wide coverage is beneficial for three reasons: it increases the basis for comparison and therefore leads to a better reflection of average performance (see criterion 7). It makes it worthwhile to develop the benchmark and it decreases the overall number of benchmarks to be developed.

Benchmark definition and consequences are discussed in detail in section 2.3.

2.3 Guidance on benchmark development

In this section, we translate the criteria developed in Chapter 2.2 into a step by step guide for the development of an approach for each sector, i.e. an approach to calculate the agreed benchmark carbon intensity for each company to determine the company specific carbon tax-free allowance threshold. The methods described in this section are used to develop the approach for each sector in Chapters 6 to 14. This section therefore serves as a description of the methodology used in this study.

The decision tree (Figure 2) on the development of the benchmarks for each sector was developed based on the specifications for benchmark development outlined in Chapter 2.2. The decision tree assists in defining which approach to be used for which sector.

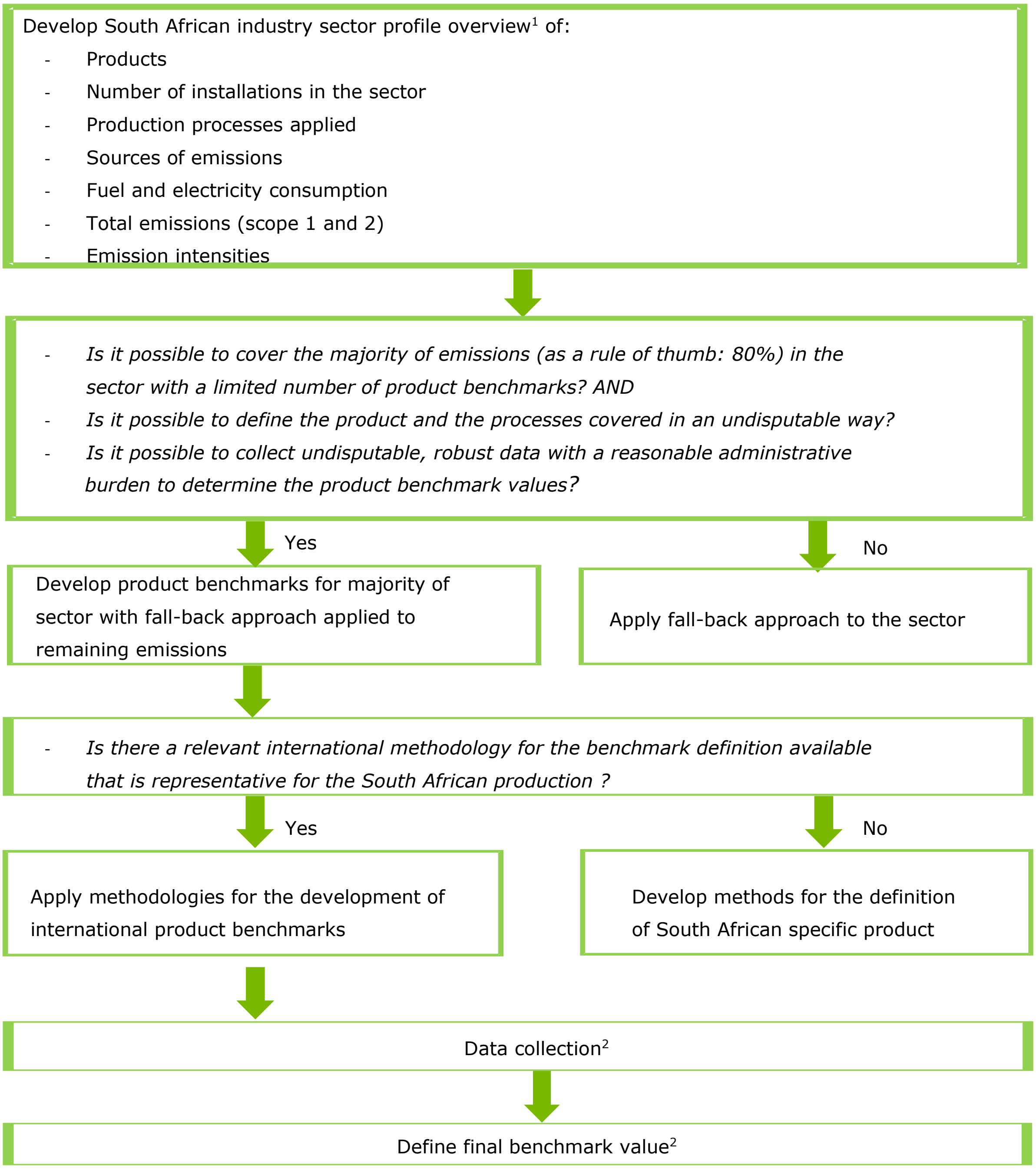

Figure 2: Decision tree for the benchmark development

Notes: [1]For the purpose of creating this sector profile literature research is conducted and a gap analysis is performed to identify missing data; [2] Outside the scope of this study, indicative values are provided in this report.

After obtaining an overview of relevant sector characteristics, the next step is to determine whether it is possible to cover a significant share of the emissions of the sector with a limited number of product benchmarks that can clearly be defined and for which robust, undisputable data can be collected. Typically, it is possible to cover the majority of emissions of a sector with a product benchmarks approach if one or more basic sector products can be defined that are typically produced via similar process steps by all or companies in a sector such as the production of clinker in the cement sector or the production of steel from either iron ore or scrap in the steel sector. It can be challenging for sectors where multiple products are produced simultaneously without a clear basic production process and in cases where there is a large variety of product specifications within the same product group and where these product specifications influences the emissions intensity of production of this product.

Defining the feasibility of a product benchmark approach (done in Chapter 6-14 for each sector) is informed by existing international product benchmarking approaches in countries that went through a similar process of defining a benchmark approach sector by sector (Chapter 3), characteristics of South African industry and the required specifications of benchmarks as listed in the previous section. In some cases it is possible to develop a good product benchmark despite the occurrence of a wide variety of end-products in a sector by:

1. Looking at the intermediate products of a sector only. Comparisons between installations could be improved by considering only processes that they have in common and excluding installation specific processes like waste treatment that are specific for a single installation or downstream processing of a limited number of basic products. For example, this is applied in the approach suggested for the iron and steel sector (where only the upstream basic products are proposed for a product benchmark, Chapter 6) and the cement sector (where a benchmark for clinker production only is suggested, Chapter 8).

2. Grouping similar products into one product benchmark. Product definitions could be defined narrowly or broadly (e.g. red bricks vs. bricks or coated carton board vs. carton board). The grouping of products can lead to unfair comparisons if one product is inherently more emissions intensive to produce than another, but it could be argued that if the products perform the same function they could still be grouped. Grouping similar products with different quality grades (e.g. similar substances with a different purity) can in some cases be facilitated by normalising the output (e.g. relative to a purity of 100%). For example, for the ferro-alloy industry, it should be further discussed with the sector whether an adequate grouping of products could result in a feasible product benchmark approach for the sector (Chapter 7).

In many cases, it will not be possible to cover all the emissions of a certain sector with product benchmarks or it will not be possible to develop a product benchmark approach at all. Given that the calculation of the tax-free threshold should ideally be based on the total output of the companies concerned, it is necessary to develop more generic fall-back approach for the activities not covered by the product benchmark. Options for such fall-back approaches will be discussed in Chapter 4, where a recommendation is also given on the fall-back approach to be used.

Once the basic methodology for each sector is set, the details of each benchmark should be defined, such as the exact boundary and definitions of the production processes included in the product benchmarks, the way indirect scope 2 emissions are included, the treatment of cross-boundary flows of heat, etc. Where possible, internationally developed benchmark methodologies and experiences such as those developed in the context of the EU ETS and the Australian carbon pricing mechanism should be made use of. In this step, it is also important to define whether or not the benchmarks should be updated over time, which base years will be used to determine the benchmarks, etc. If no international methodologies can be used, South Africa specific methods should be developed in consultation with the sectors concerned.

Once the approaches per sector are fully defined and set, the final benchmark values can be set by collecting the necessary detailed data for each company that are required to calculate the average performance of the companies producing the various products for which a benchmark is developed and also to set the values used in the fall-back approaches suggested.

3 Existing product benchmarks

The purpose of this section is to introduce the main benchmarks currently available in the public domain and discuss the intent, underlying methodology and scope of these benchmarks. The main benchmarks reviewed here are the EU ETS cap-and-trade scheme, the California cap-and-trade scheme, the proposed Australian emissions trading scheme, a World Best Practice Energy Intensity publication and the UNIDO Global Industrial Energy Efficiency publication. For each set of benchmarks the following is discussed: the purpose, the basis (e.g. average performance, best practice, etc.), the broad underlying methodology, and the geographical and temporal scopes. The sector-specific methodology in terms of activities and energy use/emissions covered together with the sector-specific benchmark values are presented in the sector specific sections (sections 6 to 14).

It should be noted that these are only the main sources of information that consider multiple benchmark values for a number of industrial sectors. Other sources that are relevant to a single industrial sector will be discussed in the relevant sector specific section.

3.1 EU ETS Benchmarks

The European Union emission trading scheme (EU ETS) is a policy instrument whereby allocation is done by means of benchmarks as part of the third trading period of the EU ETS, which runs from 2013-2020. The EU ETS benchmarks were developed by a consortium of consultants, namely, Ecofys NL, Fraunhofer ISI and the OEKO institute, with ENTEC playing a role in early phases of the development.

Initially sector specific reports were compiled, which describe the underlying methodology and data used to set preliminary benchmarks for each sector. Consultations were held with the informal Technical Working Group on Benchmarking under the WGIII of the Climate Change Committee (CCC), and written comments received from stakeholders and experts from Member States. On the basis of these inputs, the benchmark values were finalised and published as part of the rules for free allocation in the European Commission's 2011 'Benchmarking Decision' (Directorate, European Commission, 2011). In addition to the Benchmarking Decision document, Guidance Document no. 9 (Directorate, European Commission, 2011), (hereafter referred to as “GD9”) was published to assist industry and member states in applying these benchmarks.

The final values provided in the Benchmark Decision and GD9 documents do differ slightly from the initial preliminary benchmarks set in the sector specific reports. The differences between the preliminary benchmarks and those provided in the Benchmarking Decision document are however not documented. For this reason in this current document the methodology and data utilised for the preliminary benchmarks will be discussed for each sector (based on the reports by the consortium of consultants), but with the final benchmark values taken from the Benchmarking Decision. Any large discrepancies between the preliminary and final benchmark values are highlighted.

Benchmark levels were based on the average performance of the top 10% most GHG efficient installations in the European Economic Area in the timeframe 2007 to 2008. A "one-product, one-benchmark" principle was followed, implying that benchmarks were not differentiated by technology, fuel mix, size, age, climatic circumstances or raw material quality. Products were defined based on unambiguous product classifications.

The EU ETS benchmarks cover all product related direct emissions (scope 1). They also include emissions related to the generation of heat consumed for production, irrespective of where this heat was generated (on-site or outside production site boundaries). Emissions related to the production of electricity and to heat exported are not covered under the benchmark. In some special cases where direct fuel use (direct emissions) and electricity (indirect emissions) are interchangeable to a certain extent, the total emissions (including the emissions associated with the generation of electricity) have been considered in establishing the benchmark, although the allocation will only be done based on the share of direct emissions. Where this is the case, it has been discussed in the sector specific benchmark sections.

3.2 California Cap-and-Trade Benchmarks

The purpose of the California Cap-and-Trade Benchmarks is to reduce emissions of greenhouse gases associated with specific entities through the enforcement of the California Greenhouse Gas Cap-and-Trade Program. This program applies an aggregate greenhouse gas allowance budget on covered entities and provides a trading mechanism for compliance instruments.

The program consists of three compliance periods. Starting in 2013, the first is two years long (2013 and 2014) and the second and third are each three years long, covering the periods 2015 to 2017 and 2018 to 2020, respectively. The initial cap was set at the actual projected emissions for 2013, with the caps for each subsequent year reflecting an annual reduction of 2 to 3% of this baseline (IETA, 2012).

Allowance allocations for individual facilities are determined by multiplying total production or energy consumption by an emissions benchmark, a cap adjustment factor and an industry assistance factor. Product output or energy consumed is specific to individual facilities, while the other two variables are specified at the sector level (IETA, 2012).

3.3 Australian Carbon Pricing Mechanism Benchmarks

In 2011, as part of their climate change strategy, the Australian Government released a document titled "Securing a clean energy future: the Australian Government's Climate Change Plan". This plan proposed a carbon pricing mechanism to curb national greenhouse gas emissions. The plan also introduced the Jobs and Competitiveness Program (JCP) in an effort to support jobs and competitiveness in emissions-intensive trade-exposed (EITE) industries (Australian Government, 2012a).

The JCP was designed to assist activities in the economy that are highly exposed to international competition by shielding them from the full impact of the carbon price through issuance of carbon permits. The level of assistance is determined based on a business' productivity level, emissions intensity (compared to a national benchmark), trade-exposure and historic emissions intensity. Historic emissions are included in the calculation to incentivise emission reductions over time. In addition, the assistance rates were to be reduced annually by 1.3% (Australian Government, 2011).

Regulations to establish the framework and implement the details of the JCP were made in the Clean Energy Amendment Regulation 2012 (No.1) (Australian Government, 2012b). This document details the eligible EITE activities, the benchmarks that apply to each activity and the method for calculating the number of free carbon permits. The process that was followed for defining the technical aspects of the activities and the methodology for setting the benchmarks are outlined in the paper titled "Establishing the eligibility of activities under the Jobs and Competitiveness Program" (Australian Government, 2012a).

Benchmarks were defined on per product basis, irrespective of manufacturing technology, and considered both direct emissions and emissions associated with grid electricity usage. Benchmarks were set using historical industry average emissions data per unit of production for the period of 2006–07 to 2007–08 (financial years). A national grid emission factor was also fixed at 1 tonne CO_2e / MWh, subject to adjustment for very large existing electricity supply contracts (Australian Government, 2012a).

It should be noted that, at the time of writing this document, the new Australian Government has repealed the legislation supporting the carbon tax.

3.4 World Best Practice Energy Intensity Benchmarks

The report "World Best Practice Energy Intensity Values for Selected Industrial Sectors" (Worrell, 2008) provides benchmarks for the production of iron and steel, aluminium, cement, pulp and paper, ammonia, and ethylene. These benchmarks represent the most energy-efficient processes that were in commercial use at the time of writing. Here, energy intensity is expressed in energy use per physical unit of output, with output typically being expressed in tonnes.

The report provides energy values for:

- final energy - defined as the energy used at the production facility; and
- primary energy - defined as energy used at the production facility and energy used to produce the electricity consumed at the facility.

Losses associated with conversion of fuels into electricity and losses associated with transmission and distribution of the electricity are included in primary energy, and are assumed to be 67%. Further details of the approach used for calculation of the benchmark values can be found in the report.

3.5 UNIDO Global Industrial Energy Efficiency Benchmarks

In the international benchmarks study by UNIDO (UNIDO, 2010), best practice technologies are assessed for industrial processes, products and industry sectors based on energy efficiency. Processes included in this study are energy-intensive sectors such as iron and steel, chemicals and petrochemicals, as well as a number of light industries and small-scale sectors.

Where information is available, actual company data was compiled to provide energy benchmark curves from which the international benchmarks are derived. Where benchmark surveys do not exist, energy indicators in different regions were compared to provide an estimate for an international benchmark. Energy indicators are estimated from production statistics and international energy statistics found in the open literature, and country-level comparisons are based on an Energy Efficiency Index (EEI) or on the average current Specific Energy Consumption (SEC), which is usually expressed in GJ/tonne product. The EEI of a country is estimated based on the actual energy consumption of the country's production processes relative to that of best practice technology available. With this approach, a country or region will have an EEI of 1 when all its processes for a given sector have adopted best practice technology. The SEC is either specified at the country or regional level, depending on the data availability.

4 Design of fall-back approaches

As described in chapter 2, product benchmarking based on physical indicators is the default and preferred approach taking into account all relevant GHG reduction options. Whenever product benchmarking is not feasible or worthwhile (see section 2.3), fall-back approaches should be used. Fall-back approaches are approaches that can be applied more generally across sectors.

This section first describes fall-back approaches used in other regions (section 4.1) and then evaluates the use of possible approaches for South Africa (section 4.2). On the basis of the evaluation, a fall-back benchmarking approach for South Africa is proposed in section 4.3.

4.1 Overview of fall-back approaches used in other regions

Fall-back approaches for emissions allocation in emissions trading schemes are used in two other regions that use benchmarks: the EU and California. Australia does not apply fall-back approaches because it determined benchmarks for all activities that fall under the jobs and competitiveness program.

4.1.1 Direct, energy related emissions

Both regions that use fall-back approaches make use of energy benchmarking (benchmarking the emissions intensity of consumed energy) for emissions from the combustion of fuels.

Fall-back approaches in the EU Emissions Trading System (EU ETS)
The EU ETS adopted a system of fall-back approaches that are mutually exclusive as they each cover different sources of emissions:

- A heat benchmark is used for emissions relating to production of consumed measurable heat (e.g. steam and hot water). The value of the heat benchmark is 62.3 tCO_2/TJ consumed measurable heat, which is based on the emissions factor of natural gas 56.1 tCO_2/TJ and a conversion (e.g. fuel to steam) efficiency of 90%.
- A fuel benchmark is used for emissions from the combustion of fuels in direct firing applications where no measurable heat is produced (e.g. furnaces and kilns). The value of the fuel benchmark is 56.1 tCO_2/TJ fuel consumed, which is equal to the emissions factor of natural gas.

Fall-back approaches in the California Cap-and-Trade Program
California adopted similar fall-back approaches as the EU ETS. It defined:

- A steam consumption energy benchmark of 6.244×10^{-2} tCO_2/MMBtu steam consumed and;
- A fuel combustion energy benchmark of 5.307×10^{-2} tCO_2/MMBtu fuel consumed.

An important aspect of the use of fall-back approaches in California is that related activity levels (i.e. steam and fuel consumption) are not updated annually to avoid perverse incentives for companies to increase steam/fuel consumption. However, in the case of the product benchmarks, such an update using the actual production levels is used.

An important difference between the application of the fall-back approaches in the EU and California is that in the EU it is very common for a facility to have a mixture of product-based benchmarks and fall-back approaches. In California, a facility is typically covered either completely by a product-based benchmark or completely by fall-back approaches.[8]

4.1.2 Electricity related emissions

Fall-back approaches for electricity related emissions are not needed in the EU ETS and in California, because allocations for electricity related emissions are given to electricity producers (California) to be sold with the revenues distributed to electricity consumers, or no free allocation is given for electricity related emissions (EU ETS).

4.1.3 Process emissions

Process emissions are not separately addressed in the California emission trading allocation system and the EU ETS uses grandfathering (allocation based on historical emissions) as a fall-back approach for the very limited number of process emissions not covered by the product benchmarks.

4.2 Evaluation of possible fall-back approaches

In line with section 2.2, fall-back approaches are needed in cases when product benchmarks are not applied. This is usually the case for complex production processes where multiple products are produced simultaneously and there are a large variety of products within the same product group. Also, fall-back approaches can be applied to sectors with a large number of products produced or where emissions cannot clearly be allocated to the products produced. The decision tree on the development of fall-back approaches is presented in Figure 2. In the context of the South African carbon tax, fall-back approaches need to address both scope 1 and 2 emissions, since the formula to calculate the benchmark-based adjustment of the tax-free emissions threshold is based on scope 1 and scope 2 emissions.

[8] It is noted, that a requirement to completely cover a facility by product benchmarks or by fall-back approaches significantly would substantially reduce the ability to develop product benchmarks that cover multiple facilities and would in many cases lead to facility specific benchmarks. The reason for this is that while facilities may have certain processes in common, they are typically each different from one another.

Taking this into account, the following options for the development of fall-back approaches for different industries in South Africa have been evaluated, based on their feasibility for implementation in the context of the Carbon Tax Policy:

1. **Independent audit:** Under this approach, options to reduce GHG emissions are determined per firm, by means of an independent audit performed by external independent bodies. Based on a transparent methodology which is endorsed and approved by the government, it is established to what extent the firm still has (low cost) options available to reduce emissions, resulting in a higher tax-free emissions threshold (in the case of few options being available) or a lower tax-free emissions threshold (in the case of more options being available). Such an independent audit would cover both scope 1 and scope 2 emissions.

2. **Combination of benchmarking for heat, fuels, process and electricity emissions.** This approach applies heat benchmarking for emissions from the combustion of fuels that result in measurable heat, as well as fuel benchmarking for emissions from the combustion of fuels that do not result in measurable heat. To make the approach all-inclusive, it also includes a benchmark for the electricity consumption and for the actual occurring process emissions. For combustion and process emissions, this is the same approach that is used in the EU ETS (see previous section). The approach will result in a higher tax-free emissions threshold for installations producing measurable heat more efficiently than the benchmark, for installations that use fuel with lower emission factors as compared to the benchmark and/or have electricity-related emissions lower than the benchmark. It will result in a lower tax-free emissions threshold for installations producing measurable heat less efficient than the benchmark, for installations that use fuels with higher emission factors as compared to the benchmark and/or for installations having electricity related emissions higher than the benchmark.

3. **Combination of benchmarking for fuel, process and electricity emissions.** This approach uses fuel benchmarking for all emissions from the combustion of fuels, regardless of whether they are used for production of heat or not, in combination with benchmarking for electricity consumption and process emissions. As compared to the previous option, it does not include a separate benchmark related to the production of heat and as such does not reward companies that produce heat in a more efficient way, because the benchmark is based on the fuels consumed rather than the heat produced by the heat-generating equipment. The approach will result in a higher tax-free emissions threshold for companies using fuels with lower emission factors as compared to the benchmark and/or have electricity related emissions lower than the benchmark. It will result in a lower tax-free emissions threshold for companies that use fuels with higher emission factors as compared to the benchmark and/or for companies having electricity related emissions higher than the benchmark.

4. **No Z-factor calculation for emissions not covered by product benchmarking:** using this approach, no benchmark based deviation to the tax-free emissions thresholds would be applied for emissions that are not included in the product benchmarks.

   An overview of the proposed fall-back approaches and the extent to which the approaches individually assess the GHG emissions performance for the individual emissions sources is presented in Table 3:

Table 3: Overview of the proposed fall-back approaches

Fall-back Approach	Heat production emissions	Fuel Consumption emissions	Process emissions	Electricity emissions
Independent audit	X	X	X	X
Combination of benchmarking for heat, fuel, process and electricity emissions	X	X	X	X
Combination of benchmarking for fuel, process and electricity emissions	X (covered by a single approach)		X	X
No Z-factor	N/A			

The applicability of the proposed above four fall-back approaches in the context of South African carbon tax is evaluated further below on the basis of following criteria:

1. Administrative efforts and costs for authorities and companies
2. Stringency compared to the approach using product benchmarks
3. Consistency with policy objectives
4. Methodological transparency

Independent audit. Individual assessment of the Z-factor can tailor benchmarks to individual sites and set a lower Z-factor for facilities with greater GHG-reduction opportunities. This is in line with §35 of Carbon Tax Policy Paper. This approach is the most accurate amongst the fall-back approaches since the establishment of the benchmark value is based on the data and achievement for each particular facility and can take into account all options to reduce GHG emissions, including efficient use of energy, which is not covered in the other approaches. At the same time it is the most difficult fall-back approach to implement.

Evaluation of options available to reduce emissions for each facility will require a significant amount of administrative effort for authorities and firms, and as a result will be a very costly method. Also, audits will also be subject to debate on the outcomes even if the audits are done using agreed procedures and methodologies.

Combination of benchmarking for heat, fuel, process and electricity emissions approach. This approach comes closest (as compared to the following two options) to product benchmarking in terms of stringency since this approach includes fuel mix choices, combustion process efficiency as well as a benchmark for the efficiency of electricity production. It stimulates low-GHG heat production through fuel choice and boiler efficiency and can be applied to a variety of industrial sectors where the heat is produced in boilers and furnaces (e.g. in the chemical industry). Thus, it is also reasonably in line with the carbon tax policy objectives, although it does not include the efficiency of energy consumption within the facility.

However, the monitoring of heat production is a complicated and a costly procedure. In the EU ETS, the use of heat benchmarking for allocation, including all issues related to monitoring of heat flows etc. resulted in a huge administrative burden.

Combination of benchmarking for fuel, process and electricity emissions. In this benchmarking approach fuel mix choice is taken into account, but the efficiency of heat production and heat end-use efficiency are no longer taken into account. However, the fuel mix used is easier to monitor than heat production. In addition, the calculation of the total emissions from the facility can be based on the amount of fuel used. Therefore this method might be cheaper and simpler to implement than heat benchmarking and it is also methodologically transparent.

No benchmark for emissions not covered by product benchmarking. Under this approach, the Z-factor is calculated only for the part of the emissions for which product benchmarks can be defined. Emissions related to activities for which no product benchmarks are defined, will not receive any adjustment of the carbon-tax exemption threshold as a function of their carbon intensity. As such it is not in line with the policy objective to establish the benchmark-based adjustment as an incentive to reduce emissions, but it is obviously an easy to implement and transparent methodology.

The criteria evaluation of the proposed fall-back approaches is summarized in the following table:

Table 4: Overview of the proposed fall-back approaches and their compliance with the evaluation criteria (where + means criterion is fulfilled, +/- criterion is more fulfilled than not fulfilled, -/+ criterion is more not fulfilled than fulfilled and – criterion is not fulfilled)

Proposed Fall-back Approach	Evaluation criteria			
	Low administrative efforts and costs for authorities and companies	Stringent compared to the approach using product benchmarks	Consistent with policy objectives	Methodologically transparent
Independent audit	-	+	+	-/+
Combination of benchmarking for heat, fuel, process and electricity emissions	-	+/-	+/-	-/+
Combination of benchmarking for fuel, process and electricity emissions	+/-	-/+	-/+	+/-
No Z-factor	+	-	-	+

Based on this table, we propose to use the combination of fuel, electricity and process emissions benchmarks as the default fall-back methodology. The reason for this recommendation are the high administrative burdens related to an independent audit methodology, the high administrative burden related to the monitoring of heat production and consumption and the fact that the last approach (no adjustment for emissions not covered by product benchmarks) is not consistent with the policy objective of giving an incentive to reduce emissions via application of the Z-factor.

4.3 Implementation details of the selected fall-back approaches

Section 4.2 identifies four potential fall-back approaches for use in definition of the Z-factor. Of these four approaches, using a combination of benchmarking for fuel, process and electricity emissions has been identified to be the preferred option.

Fuel Benchmark

Several options can be considered in order to define the fuel benchmark value. One option would be to use a specific reference fuel such as natural gas, which was used in the EU ETS, or a more carbon intensive fuel. However guidance on what to use for benchmarking can be obtained from criterion 8 developed in Section 2.2. Here it was stipulated that the average fuel mix for South Africa should be the basis for the benchmark. In 2012, 72% of South Africa's total primary energy consumption came from coal, followed by oil (22%), natural gas (3%), nuclear (3%), and renewables (less than 1%, primarily from hydropower), according to the BP Statistical Review of Energy 2013[9]. According to the (ABB, 2011) natural gas plays only minor role in the fuel mix of the country (

Figure 3). Thus a benchmark based on natural gas will not depict the current energy supply in South Africa.

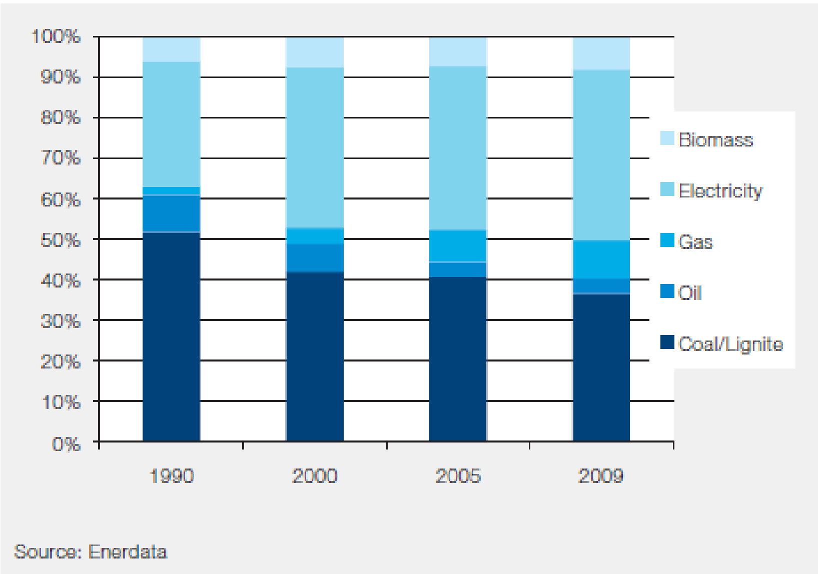

Figure 3: Energy consumption of industry by source in South Africa[10]

A decision is required as to whether the fuel benchmark should be defined at the average level of the total South African industry, at the average level of individual sectors, or even at the level of individual facilities. In this study it is proposed to define fuel mix based on the data for the whole country. This will lead to the definition of only one fuel benchmark value applicable to all industries, which makes the benchmark widely applicable covering a large share of emissions (criterion 11 in Section 2.2). For certain specific processes where the fuel mix choice is directly related to certain raw materials applied in the processes, some of the fuel-related emissions can be regarded as process emissions, which is linked to the definition of process emissions used (see below).

[9] (U.S. Energy Information Administration, 2014)
[10] (ABB, 2011)

For the purpose of the fuel benchmark definition, it is proposed that average energy input from the fuel mix for South African industry be defined based on the most recent data. The energy consumption in GJ for each fuel type will be multiplied by the corresponding IPCC or local (if available) emission factor. As a result, total emissions divided by the fuel energy input will result in the weighted fuel benchmark in tCO_{2e}/GJ. This value will represent average benchmark carbon emissions intensity X based on the fuel mix consumption for the South African industry.

Input data for the calculation of average fuel benchmark value across all industrial sectors is presented in Table 5. The main input data is the total fuel consumption in the South African industry. Data is taken for the industries based on the latest data from the disaggregated energy balance for South African industry for the year 2010.

Table 5: Input data for the calculation of the fuel benchmark value

	Fuel type							
	Anthracite	Bituminous coal	Coke oven	Gasworks gas	Coke oven gas	Blast Furnace gas	Natural gas	Gas Diesel
Industry Sector Final Consumption, TJ [1]	27,711	382,850	6,584	21,597	7,312	15,305	80,674	41,268
Emission Factor, kg CO_{2e}/GJ [2]	98.3	94.6	107.00	44.40	107.0	260.00	56.10	74.10
Emissions, kt CO_{2e}	2,724	36,218	705	959	782	3,979	4,526	3,058
Total emissions, t CO_{2e}	52,950,567							
Total energy consumption, TJ	583,302							
Weighted Emission Factor, tCO_{2e}/GJ	**0.0908**							

[1] Source: Disaggregated energy balance 2010http://www.energy.gov.za/files/media/Energy_Balances.html
[2] Source: IPCC, 2006. 2006 IPCC Guidelines for National Greenhouse Gas Inventories Volume 2 Energy. Available at http://www.ipcc-nggip.iges.or.jp/public/2006gl/vol2.html

The resulting weighted emission factor is 0.0908 tCO_{2e}/GJ or 90.8 tCO_{2e}/TJ. This is a much higher value that than the 56.1 tCO_{2e}/TJ of fuel used in the EU ETS (reference fuel – natural gas) and is slightly lower than emission factor for bituminous coal. To finalize and determine a final value for the fuel benchmark, the following steps are still required:

1. Exclusion of the fuel use that is related to the product benchmark
2. Exclusion of fuel use that is covered via the process emissions approach below

It is recommended that a pragmatic approach with respect to these two steps be taken, in close consultation with the South African industry.

Electricity consumption benchmark:

It is recommended that the benchmark for electricity consumption (the benchmark attributable to the electricity consumption of the company) is based on the emission factor of the grid.

In South Africa there is currently no agreed or standardised methodology for calculating the emissions factor associated with electricity consumption. A standard methodology is required in this context to ensure consistency across companies reporting their scope 2 emissions and for applying an electricity consumption benchmark. Historically, electricity emission factors applied have varied by over 10%. The National Business Initiative published a discussion document highlighting the issues of discrepancy between emission factors currently applied and proposing a new methodology for calculating a country grid emission factor. The main discrepancies relate to the inclusion or exclusion of own usage by Eskom for pumped storage, electricity imports, generation by Independent Power Producer (IPPs), transmission and distribution losses. The proposed methodology is depicted graphically below together with the calculations of emission factors provided by Eskom (Eskom Factor 1 and 2):

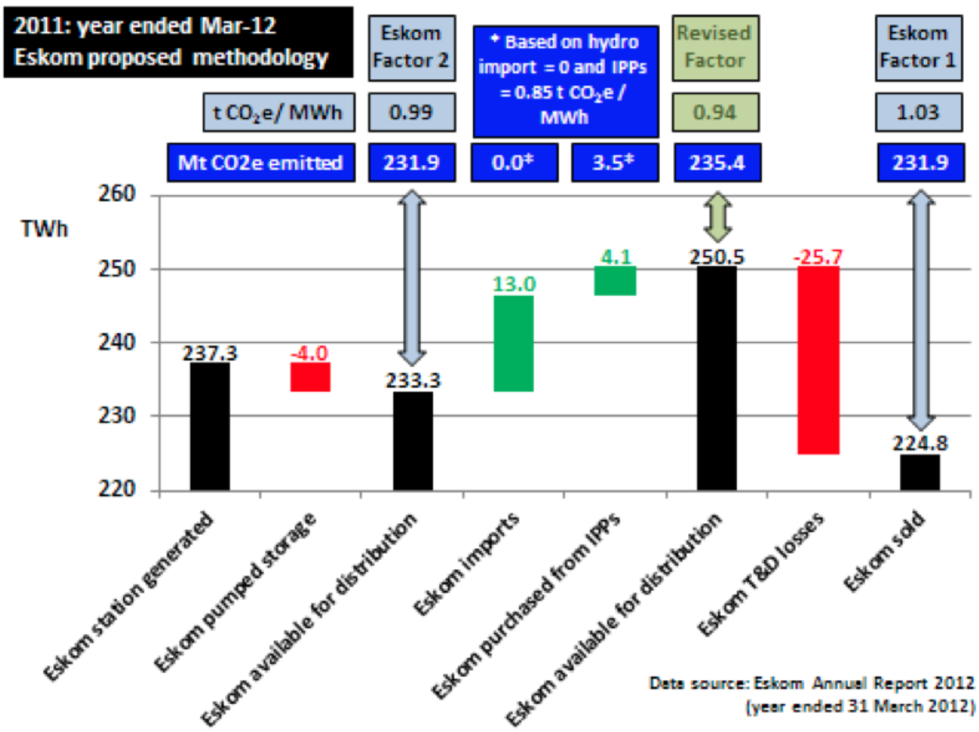

Figure 4: Proposed methodology for calculating the grid emission factor associated with South African electricity consumption (Source: NBI 2013)

The proposed methodology has as the numerator CO_2 emissions from Eskom stations, imported hydro (assumed to be 0) and IPPs which has an assumed emissions factor of 0.85 t CO_2e per MWh.

The denominator includes electricity generated by Eskom stations minus Eskom usage for pumped storage plus imports plus IPP generated electricity. Although this methodology is more correct than previously applied emission factors, some issues remain. These include:

- As the methodology relies on Eskom data, the emission factor is calculated for the Eskom financial year period which runs from the beginning of April to the end of March. This does not align with the calendar year and may not align with company financial years (which typically run from the beginning of March to the end of February).
- The methodology relies on an assumed emissions factor for electricity supplied by IPPs. The number of IPPs is increasing rapidly and the emissions factor should be calculated exactly. In other words the breakdown of IPP generated electricity per technology type is required.
- Although of lesser significance, the methodology appears to only consider CO_2 emissions. Eskom also reports N_2O emissions and these should be included in the calculation of GHG emissions. Similarly, they should be accounted for in the assessment of GHG emissions associated with IPP produced electricity.

Applying the NBI methodology but including N_2O emissions yields the emission factors for the Eskom financial year (April to March) are:

- 2009/2010 0.929 tCO_{2e}/MWh
- 2010/2011 0.935 tCO_{2e}/MWh
- 2011/2012 0.943 tCO_{2e}/MWh
- 2012/2013 0.954 tCO_{2e}/MWh

Based on the data for 2009-2013 presented above, an average emission factor for the electricity grid for South Africa can be calculated as being equal to 0.94025 tCO_{2e}/MWh. However, the calculation of emission factor can be done also for other period of time or using other sources of information on the value of emission factor for the electricity grid. These issues and also the question of how often the value of emission factor shall be updated shall be discussed into more details with the relevant stakeholders.

Process emissions

The definition of process emissions in this report is assumed to be the same as the definition given in EU ETS. EU ETS Monitoring and reporting of greenhouse gas emission regulation define process emissions as "greenhouse gas emissions other than combustion emissions occurring as a result of intentional and unintentional reactions between substances or their transformation, including the chemical or electrolytic reduction of metal ores, the thermal decomposition of substances, and the formation of substances for use as product or feedstock the emissions". Process emissions come mainly from the following processes:

- The chemical or electrolytic reduction of metal compounds in ores, concentrates and secondary materials;
- The removal of impurities from metals and metal compounds;

- The thermal decomposition of carbonates, excluding those for the flue gas scrubbing;
- Chemical synthesis where the carbon bearing material participates in the reaction, for a primary purpose other than the generation of heat;
- The use of carbon containing additives or raw materials for a primary purpose other than the generation of heat;
- The chemical or electrolytic reduction of metalloid oxides or non-metal oxides such as silicon oxides and phosphates.

We propose not to define a separate benchmark for the process related emissions that are not covered by the product benchmarks, but instead to take the actual amount of process emissions into account in the calculation of both X and Y in the formula for determining the Z-factor, as discussed in chapter 2. This is because the emission reduction potential for process emissions is rather limited. As a next step, it is necessary to define in detail which emissions are regarded as process emissions via clear unambiguous definitions.

5 Summary of approach and next steps

5.1 Summary of approach

The approach emerging from Chapters 2 and 4 implies that, for every company, the Z-factor to adjust the default tax-free threshold is calculated based on a combination of the applicable product benchmarks for that company (if any) and the fall-back approach developed in Chapter 4 for the activities not covered by the product benchmarks.

For any reporting year, this means that the following formula will apply for each company:

$$Z= ((\Sigma P_i*Y_{pi}) + FC_j*Y_f + EC_j*Y_e + PE_j) / (FC*X_f + EC*X_e + PE) \qquad \text{Equation 1}$$

where
P_i – Production amount of the product *i* covered by a product benchmark in the reporting year in t
Y_{pi} – GHG emissions intensity benchmark (scope 1 and 2) of the product *i* covered by a product benchmark in tCO_{2e} /t product
FC_j – Actual direct fuel use of activities not covered by a product benchmark in TJ
Y_f – Fuel benchmark in tCO_{2e}/TJ
EC_j – Actual electricity consumption of activities not covered by the product benchmark in the reporting year in MWh
Y_e – Electricity consumption benchmark in tCO_{2e}/MWh
PE_j- Process emissions of activities not covered by the product benchmarks in tCO_{2e}
FC – Fuel use of the company in TJ
X_f – Measured and verified actual emission intensity of direct fuel use of the company in tCO_{2e}/TJ
EC – Total electricity consumption of the company in the reporting year in MWh
X_e – Measured and verified actual emission intensity of electricity consumption of the company in tCO_{2e}/MWh in the reporting year
PE - Process emissions of company in tCO_{2e}

For the fuel benchmark and the electricity consumption benchmark, indicative values of respectively 90.8 t CO_{2e} / TJ (based on 2010 data) and 0.94 tCO_{2e} / MWh (based on a 2009-2013 average value) were calculated in Chapter 4.

The product benchmarks are to be calculated via the following generic equation:

$$Y_{pi}= ((FC_{xi}*X_{fxi}) + (EC_{xi}*X_{exi}) + PE_{xi}) / P_{xi} \qquad \text{Equation 2}$$

where
Y_{pi} – GHG emissions intensity benchmark (scope 1 and 2) of the product *i* covered by a product benchmark in tCO_{2e} /t product

FC_{xi} – Fuel consumption for the production of product *i* in the baseline period x in GJ
X_{fxi} – Measured and verified actual emission intensity of direct fuel use for the production product *i* in the baseline period in tCO_{2e}/GJ
EC_{xi} – Electricity consumption for the production of product *i* in the baseline period x in MWh
X_{exi} – Measured and verified actual emission intensity of electricity consumption for the production of product *i* in the baseline period x in tCO_{2e}/MWh
PE_{xi}- Process emissions from the production of product *i* in the baseline period x in tCO_{2e}
P_{xi} – Production of product *i* covered by product benchmark in the baseline period x

5.2 Base year, electricity emissions, benchmark updates and special cases

The generic methodological description presented so far has not yet explicitly addressed a number of important issues such as:

- The choice of the base year for the calculation of the product benchmarks and fall-back approaches
- The treatment of self-generated rather than grid electricity
- Whether or not the benchmarks should be updated over time
- The treatment of waste gases with a high emission factor

As a general rule, it is recommended to use the years closest to the introduction of the carbon pricing policy as a baseline period and to base the benchmark on an average of two or three years to avoid benchmark values being distorted by incidental years with a lower than normal production that had a negative influence on the emissions intensity, for example. We recommend discussing the base year choice with the industry stakeholders also in relation to the availability of data.

Regarding electricity production on-site, we propose the following formulas for the calculation of the measured and verified actual emission intensity of electricity consumption of activities not covered by a product benchmark in Equation 1 and the measured and verified actual emission intensity of electricity consumption for the production of product *i* in the baseline period in Equation 2:

$$X_e = ((Y_e * EC_{grid}) + (Y_{own} * EC_{own}))/EC \qquad \text{Equation 3}$$

where
EC_{grid} – Electricity consumed from South African electricity grid by the company in the reporting year in MWh
Y_{own} – Emission intensity (emission factor) for own electricity generation in the reporting year in tCO_{2e}/MWh
EC_{own} – Electricity generated and consumed by the company in the reporting year in MWh
EC – Total electricity consumption of the company in the reporting year in MWh

$X_{exi}= ((Y_{ex}* EC_{grid,xi})+ (Y_{own,xi}* EC_{own,x}))/EC_x$ Equation 4

where

Y_{ex} - Electricity consumption benchmark in tCO_{2e}/MWh for the base period x.

$EC_{grid,xi}$ - Electricity consumed from South African electricity grid by the company for the production of product *i* in the baseline period x

$Y_{own,xi}$ - Emission intensity (emission factor) for own electricity generation used for the production of product *i* in the base period x in tCO_2e/MWh

$EC_{own,x}$ - Electricity generated and consumed by the company in the reporting year for the production of product *i* in the base period x in MWh

EC_x -Total electricity consumption of the company in the base period x in MWh

This approach favours the consumption of renewable energy or self-generation of electricity with fuels having emission factors lower than the grid factor. If the company starts to use measurable and verifiable electricity from renewable sources, the emission factor for the electricity consumed X_e will be reduced. This will increase the Z-factor and reward the companies via an increase in the tax-free threshold.

Another important question is whether or not to update the benchmarks over time. Generally speaking, benchmarks should not be updated because it could lead to the perverse incentive to increase emissions. If a firm knows an updated benchmark will be based on future emissions, it could benefit from higher emissions in the years to come. In this discussion, it is, however, important to make a distinction between emissions which are under control of the taxed entities themselves (i.e. the direct scope 1 emissions) and those not under their control (i.e. the scope 2 emissions related to the electricity consumption). In order to avoid companies being negatively influenced by factors that are not under their own control, the policy could update the grid electricity emission factor that is used as electricity consumption benchmark in Equation 1 and is used to calculate the measured and verified actual emission intensity of electricity consumption for the production of the product benchmarks in Equation 4 on an annual basis. This will, however, result in product benchmarks that change over time, depending on this annually updated grid factor. Alternatively, the grid electricity emission factor could be fixed in all calculations during the first taxation period to simplify the system.

A last issue is that of process related waste fuel flows. In some cases, waste gases or other waste fuels with high emission factors are produced in certain production processes, and are subsequently used in other processes and/or are used to produce electricity. This electricity can be subsequently used in the processes where the waste gases originated or in other processes. This raises questions on the way to allocate the emissions between the processes where the waste fuels originate and the processes where they are consumed. For such processes (notably in the iron and steel sector), we propose as the basic approach, to account for waste fuels "traded" between processes using a reference fuel approach. In such an approach the surplus of emissions in the waste fuel (as compared to the reference fuel) are allocated to the waste fuel producer as process emissions and the remaining emissions (i.e. the emissions as if the reference fuel would have been used) to the waste fuel consumer. This approach has also been applied in the EU Emissions trading scheme for setting the benchmark for hot metal where this issue is most prominent. The fuel benchmark calculated for the fall-back approach could be used a reference fuel to create a consistent methodology. A similar approach can be used for electricity production with waste heat which is e.g. applied in the cement sector. Also in this case, exported electricity generated with waste heat could be valued using the electricity consumption benchmark used in the fall-back approach as the reference to create a consistent methodology. The details of this methodology need to be further specified in close consultation with the sectors concerned.

5.3 Next steps

This chapter provided the generic formulas to be used to determine for each company the specific tax-free emissions threshold consisting of a combination of applicable product benchmarks and fall-back approaches. In the next Chapters 6-14, proposals will be done for which product benchmarks to develop for each sector, resulting in a final sector-by-sector approach that can be used.

The data available for this project, and data collected by the South Africa National Treasury during this project, has been available on either sector or company level. Although certainly useful to get a better view on the data situation of the sectors concerned, this data cannot one-to-one be used to derive benchmark values for individual products. For the development of such benchmarks, emissions data at the level of individual products is required. As such, the sector chapters only will give some indicative values based on a combination of international benchmark values and South African data. These indicative values are good starting points for further discussion with the sectors, but not more than that.

As the next step in benchmark development, it is recommended to discuss with the relevant industry stakeholders the findings of this study. Before further data is collected, it is recommended to first decide on the final benchmark approach for each sector. For some sectors we expect this to be a relative simple process, while for others, it involves steps to determine which products to benchmark exactly or the set-up of sector specific methodologies. In this step, some key methodological choices that apply to all sectors also need to be finalised such as the choice for base years, the exact treatment of scope 2 emissions, whether or not benchmarks will be updated and how certain specific issues such as the production and use of waste gases will be covered.

Once the benchmark methodologies are fully specified and defined, specific data requests can be sent to the industries in order to collect the data needed for the calculation of the benchmark values. It is clear that support will be required to ensure that data is collected consistently across products and companies. Detailed data collection guidance will need to be developed given that emissions and energy use data need to be allocated to products rather than the company or operations. In addition, data on company emissions not covered by product benchmarks needs to be collected. All system boundaries, and the treatment of special cases, needs to be clearly defined. For some sectors the proposed benchmarking approach requires very specific unit operation data to be collected (e.g. for the CWT (CO_2 weighted tonne) approach in refining) which will require collaboration with the industries in question. Given the sensitivity of some of this data in view of confidentiality and in view of the ultimate use for tax purposes, it is essential that all rules and procedures around this data collection and data verification are well defined and embedded in the further policy preparation.

6 Iron and Steel

6.1 Introduction

6.1.1 Sector overview

The iron and steel sector includes the production of crude steel, and downstream processing into a variety of products that are either used directly in applications such as construction, or are further processed by the manufacturing sector. It also incorporates the pre-production steps of coke making, sintering and palletisation.

Products that are manufactured in South Africa include primary carbon steel products (billets, blooms, and slabs) and semi-finished products (forgings, light-, medium- and heavy sections and bars, reinforcing bar, railway track material, wire rod, seamless tubes, plates, hot- and cold-rolled coils and sheets, electrolytic galvanised coils and sheets, tinplate and pre-painted coils and sheets) (SAISI, 2013a). South Africa also produces primary stainless steel products and semi-finished products in the form of slabs, plates and hot- and cold-rolled coils and sheets.

The manufacturers in South Africa, location of their production facilities, technologies employed and product ranges are presented in Table 6. More detail on the technology types identified in Table 6 is presented in Section 6.1.2 below and Annex 1.

Table 6: Iron and Steel manufactured by South African companies (SAISI, 2013; Kumba Iron Ore, 2011)

Company	Installation	Technology	Products
ArcelorMittal SA Ltd	Vanderbijlpark	BF/BOF and EAF	Carbon steel, flat products
	Saldanha	Corex/ Midrex	Carbon steel, flat products
	Newcastle	BF/BOF	Carbon steel, long products
	Vereeniging	EAF	Carbon steel, long products
Highveld Steel and Vanadium Corporation Ltd	Witbank	BF	Carbon steel, long and flat products
DAV Steel (Cape Gate Pty Ltd)	Vanderbijlpark	EAF	Carbon steel, long products
Columbus Stainless (Pty) Ltd	Middelburg	EAF	Stainless steel, flat products
Scaw Metals Group	Germiston	EAF	Carbon steel, long products
Cape Town Iron and Steel Works (Cisco)	Kuilsriver, Cape Town	EAF	Currently not operating

Mineral sands companies Tronox and Richards Bay Minerals also produce pig iron as a by-product. However, at a global scale this is an insignificant component of total steel production and it is used only in specific applications (Tronox, 2013).

The South African Iron and Steel Institute (SAISI) is the main sector organisation for the iron and steel sector in South Africa.

6.1.2 Production processes

Carbon steel is produced via three primary production routes in South Africa:

- Blast Furnace/Basic Oxygen Furnace (BF/BOF) route, which makes up the highest proportion of carbon steel production in South Africa and globally;
- Electric Arc Furnace (EAF) (which in some operations is coupled with a Direct Reduced Iron (DRI) furnace); and,
- COREX/MIDREX process at the ArcelorMittal site in Saldanha.

Each of these requires different feedstocks and energy inputs, and gives rise to different emissions profiles. Further detail on the different production routes is provided in Annex 1.

Stainless steel production in South Africa also uses the EAF production route.

6.1.3 Overview of sources of GHG emissions

Iron and steel making gives rise to greenhouse gas emissions (primarily CO_2, but also CH_4 and N_2O) through on-site fuel combustion, the use of carbon-based reductants (process emissions) and generation of electricity. In South Africa the majority of companies make use of grid-based electricity, and hence emissions associated with electricity generation occur off site.

The emissions intensity and split between process emissions, fuel combustion emissions and indirect electricity emissions thus varies widely depending on the process route used and process configuration. Internationally emissions intensities vary from 0.4 t CO_{2e}/t crude steel for EAFs, 1.7 – 1.8 t CO_{2e}/t crude steel for BF/BOF and 2.5 t CO_{2e}/t crude steel for DRI processes (IEA Clean Coal Centre, 2012). No global average data on emissions from stainless steel production could be found, however these may be envisaged to be similar to the production of crude steel via the EAF process route. The South African industry's emissions will be higher than global averages due to the carbon intensity of the local electricity grid.

More detailed information on the individual sources of greenhouse gases emissions from the sector is provided in Annex 1.

6.2 GHG emissions profile of the iron and steel sector in South Africa

6.2.1 Data availability

The data gap analysis for iron and steel is presented in Table 7. A tabular representation all the data that is referred to in this table is included in Annex 2 of this report.

Table 7: Iron and steel data gap analysis

Data availability	Industry wide	ArcelorMittal SA Ltd	Evraz Highveld Steel and Vanadium Corporation Ltd	DAV Steel (Cape Gate Pty Ltd)	Columbus Stainless (Pty) Ltd	Scaw Metals Group	Cape Town Iron and Steel Works (Cisco)
Emissions and energy consumption							
Scope 1 emissions (total) Mt CO_2e	No data available	Data available	Some data available	No data available	Some data available	No data available	Closed in 2010
Scope 1 emissions (fuel) Mt CO_2e	No data available	Requires additional data to be calculated	Requires additional data to be calculated	No data available	No data available	No data available	
Scope 1 emissions (process) Mt CO_2e	Industry wide data available 2000–2010 per production process type	Requires additional data to be calculated	Requires additional data to be calculated	No data available	No data available	No data available	
Fuel consumption GJ	No data available	Data available	Some data available	No data available	No data available	No data available	
Scope 2 emissions Mt CO_2e	No data available	Data available	Some data available	No data available	Some data available	No data available	
Electricity consumption MWh	No data available	Data available	Some data available	No data available	No data available	No data available	
Production							
Liquid steel Mtpa	Total production data from 2000-2010 per production process type.	Data available	Data available	No data available	Data available	Old data (latest 2008)	
Long products Mtpa		Data available	Data available	No data available	No product breakdown	No product breakdo wn	
Flat products Mtpa		Data available	Data available	No data available	No product breakdown	No product	

Data availability	Industry wide	ArcelorMittal SA Ltd	Evraz Highveld Steel and Vanadium Corporation Ltd	DAV Steel (Cape Gate Pty Ltd)	Columbus Stainless (Pty) Ltd	Scaw Metals Group	Cape Town Iron and Steel Works (Cisco)
						breakdo wn	
Intensities							
Scope 1 emissions per tonne liquid steel	No data available	Data available	Can be calculated	No data available	No data available	No data available	
Scope 2 emissions per tonne liquid steel	No data available	Data available	Can be calculated	No data available	No data available	No data available	
Total emissions per tonne liquid steel	Can be calculated	Can be calculated	Some data available	No data available	Data available	No data available	

6.2.2 Current emissions profile of the sector

The split between process emissions and emissions from fuel combustion (other scope 1 emissions) and emissions associated with off-site electricity consumption (scope 2 emissions) is site specific and is a function of the process configuration and the extent to which off-gases are utilised for energy and power generation. As both process emissions and combustion emissions can arise from the same processes, allocation between process emissions and combustion emissions requires detailed mass balance calculations. See, for example, the IPCC methodology (IPCC, 2006).

Based on information contained in the public domain, an indicative, order of magnitude estimate of overall emissions and the split between fuel, process and electricity related emissions could be estimated for the sector. This analysis allows for comparison to order of magnitude estimates for the other sectors, as well as to get an indication of the relative contributors of the individual sources to the overall emissions from the sector. The outcomes of this assessment are shown in the following table.

Table 8: Order of magnitude estimate of emissions from the iron and steel sector (Mt CO_2e)

Emissions	Iron and steel
Total emissions from sector	23
Scope 1: process	12
Scope 1: fuel combustion	4
Scope 2	8

6.2.3 Current activities surrounding own generation in the sector

ArcelorMittal's Vanderbijlpark Works is the only plant at which a 40 MW power plant generates electricity using waste heat from the Works' kilns (ArcelorMittal, 2012b).

6.3 Existing benchmark values

For the Iron and Steel sector five benchmark sets are available. The disaggregation of final benchmark values, based on specific processes or products, differ between the different sets of benchmarks. These benchmark sets, along with the products that they cover, are shown in the following table:

Table 9: Existing benchmarks for the iron and steel sector

Benchmark set	Products for which benchmarks are available
EU ETS Benchmarks	Coke, sintered ore, hot metal, EAF carbon steel, EAF high alloy steel, iron casting
California Cap-and-Trade Benchmarks	Steel production using an electric arc furnace, hot rolled steel sheet production, picked steel sheet production, cold rolled and annealed steel sheet production, galvanized steel sheet production, tin steel plate production
Australian Carbon Pricing Mechanism Benchmarks	**Integrated iron and steel manufacturing:** Dry iron ore sinter, dry iron ore pellets, dry coke oven coke, dry lime, continuously cast carbon steel products and ingots of carbon steel of saleable quality, long products of hot-rolled carbon steel of saleable quality, flat products of hot-rolled carbon steel of saleable quality **Manufacture of carbon steel from cold ferrous feed:** Continuously cast carbon steel products and ingots of carbon steel of saleable quality, long products of hot-rolled carbon steel of saleable quality, flat products of hot-rolled carbon steel of saleable quality
World Best Practice Energy Intensity Benchmarks	**Material Preparation:** Sintering and pelletizing; pelletizing; coking **Iron and Steel making:** Blast furnace and BOF (blast furnace, basic oxygen furnace (BOF), refining); smelt reduction and BOF; EAF (direct reduced iron) **Steel making:** EAF (scrap metal) **Casting and rolling:** Continuous casting and hot rolling; casting and rolling with thin slab casting **Cold rolling and finishing** **COREX:** Coal consumption; electricity; export off-gasses energy value

Benchmark set	Products for which benchmarks are available
UNIDO Global Industrial Energy Efficiency Benchmarks	The report utilised energy indicators from the Worrell, et al. (2008) study, together with production data from the World Steel Association (WSA, 2009), to establish energy efficiency indicators (EEI) for best available technology; global average; selected industrialized countries; selected developing countries.

A full review of the different benchmark sets, as well as the individual benchmark values, is provided in Annex 3.

6.4 Applicability of international benchmarks in South Africa and proposed benchmarking approach

The international benchmark approaches for iron and steel in the context of carbon pricing mechanisms are process specific approaches with separate benchmark sets being developed for primary steel making (the integrated iron and steel production process) and production of steel in electric arc furnaces based on scrap or direct reduced iron. This is justified because the products from these processes are significantly different in terms of quality and type of end products and the two main routes are incomparable in terms of the basic resource used and the resulting emissions profile.

Both in Australia and the EU ETS, the choice has also been made not to benchmark only the final steel product resulting from the integrated iron and steel process, but to define separate benchmarks for the various intermediate products in the integrated iron and steel production like sinter making, coke making etc. For California, this is irrelevant in the absence of integrated iron and steel plants. The choice for benchmarking intermediate products is made to acknowledge that some of the installations also sell part of those intermediate products. Selling part of the intermediate products makes benchmarking only at the product level inappropriate, because the overall emissions intensity per tonne of end product becomes incomparable. The approaches used are thus an example (see Section 2.3) of benchmark approaches where the benchmark focuses on the key intermediate products (the hot metal and crude steel production). This ensures that the majority of emissions are covered without attempting to define separate benchmarks for all the separate steel end-products, since the downstream processes are very diverse in nature.

Although similar in the overall approach, there are differences between the Australian scheme and the EU ETS. In the EU ETS, only one benchmark was developed for sintering (with pellets being covered by fall-back approaches) and the lime production was developed separate from the benchmarks for the steel sector in close consultation with the lime sector and including mainly the stand-alone lime kilns outside the steel sector.

Another difference is the coverage of downstream processes. In the EU ETS the decision was made to cover all those processes via the fall-back approaches whereas in Australia, benchmarks were developed for the first downstream process, the hot rolling process. Also in Australia, no separate benchmarks were developed for high alloy and low alloy steel from cold ferrous feed (i.e. the electric arc process), whereas this has been done in Europe.

What the two schemes have in common is that the product benchmarks cover the vast majority of the emissions of the sector. Based on the EU ETS benchmark sector report for the iron and steel sector, it can be estimated that the benchmarks used in the EU ETS cover more than 90% of the direct emissions of the sector and approximately 70% of the electricity consumption of the sector (Ecofys, 2009d). For Australia, similar ranges can be expected. The approaches followed in Australia and the EU ETS are thus well in line with the criterion developed in Chapter 2 to cover the majority of emissions of a given sector with product benchmarking approaches, and to use product benchmarking as the basic approach when possible.

We therefore propose to use the Australian and EU ETS benchmark approaches as basis for the approach in the South African carbon tax. As a preliminary approach to be discussed with the sector, we propose to follow the EU ETS system by developing the following benchmarks for use in South Africa:

- *Coke*
- *Sinter*
- *Hot metal (from BF / BOF)*
- *EAF (carbon steel)*
- *EAF (high alloy steel)*

and to use the fall-back approaches for the remaining emissions related to the more downstream processing of steel products. Compared to the Australian scheme, the EU ETS approach is simpler because it does not have a separate benchmark for the hot rolling process and for pellets.

In addition we propose to develop a separate benchmark for the unique integrated COREX / MIDREX production process:

- *Hot metal (from COREX / MIDREX)*

The Corex/Midrex process at Saldanha plant is recognised to be unique globally. Thus, it is not covered by the EU ETS, California Cap-and-Trade or Australian Carbon Pricing Benchmark frameworks. Covering this process as part of the hot metal benchmark for blast furnaces/basic oxygen furnaces does not acknowledge the unique character of this process producing both hot metal and electric arc steel in one integrated production process. The approach to develop two separate benchmarks for the integrated production of steel from iron is inconsistent with criterion 5, the one product – one benchmark principle (Section 2.2). We regard this as justified given the special unique character of this process.

The following aspects of the EU ETS and Australian Carbon Pricing Mechanism benchmarking approach can be used to further define the benchmarks in terms of system boundaries and approaches. The product definitions as used in the EU ETS and Australian scheme form an excellent basis to be used also in the South African context. Furthermore, we recommend to carefully study the approach the EU took vis a vis the treatment of carbon containing waste gases (Ecofys, 2009d) that flow between the various processes (see also Chapter 5). The approach consists of defining a reference fuel and possibly also a reference emissions intensity for electricity that can be used to adequately allocate emissions to the processes where the waste gases are originating and the processes where they are finally used.

6.5 Proposed product benchmarking values and next steps

Obviously, none of the international benchmark values can directly be used as representative for the average performance of the South African industry producing this product. Also, the South African industry data that is available does not allow the disaggregation of GHG emission by the technology type and derivation of the product benchmarks for the selected products typical for the South African industry.

At the same time we believe that the EU and Australian technologies used for the production of proposed benchmarked products are similar to the technologies used in South Africa. Based on this assumption, the benchmarks used in these jurisdictions can be used as a first proxy for the South African product benchmark values, (although it should be stated that the EU benchmarks represent the performance of the 10% best installations, rather than the average performance of the installations). The EU ETS and Australian benchmark values for direct emissions are given in Table 9.

Table 10: EU ETS benchmarks for the iron and steel industry[1]

Product Benchmark	EU ETS benchmarks (t CO_{2e} / t product)	Benchmarks in Australian carbon pricing mechanism (t CO_{2e} / t product)
Coke	0.286	0.462
Sintered Ore	0.171	0.227
Hot Metal	1.328	1.560
EAF: Carbon steel	0.283	Not separately distinguished, value of 0.0836 for products from cold ferrous feed.
EAF: high alloy steel	0.352	

[1] System boundaries and treatment of waste gases are not identical in Australia and EU ETS. Value serve only to give an indication of the likely emissions intensity of the South African industry. For more detail on sources, see Annex 3.

The benchmark values given above do not incorporate scope 2 (electricity consumption) emissions. In order to address scope 2 emissions, we have identified electricity consumption for benchmarked products based on the BREF for iron and Steel as cited in Ecofys sectoral report for the iron and steel sector (Ecofys, 2009d) and also provide the benchmarks used in the Australian carbon pricing mechanism. Next, we have multiplied the electricity consumption by the average grid emission factor calculated in Section 4.3 of 0.94 t CO_{2e}/MWh. The results of the calculation of scope 2 emission intensity are presented below:

Table 11: Specific electricity consumption and corresponding emission intensity values for benchmarked products in iron and steel sector

Product Benchmark	Specific electricity Consumption in MWh/t product and (t CO_{2e} / t product)[1,2]	Australian carbon pricing mechanism in MWh/t product and (t CO_{2e} / t product)[2,3]
Coke	0.006 (0.006)	0.0397
Sintered Ore	0.027 (0.025)	0.0397
Hot Metal (from BF / BOF)	0.103 (0.097)	0.145
EAF: Carbon steel	0.44 (0.414)	Not separately distinguished, value of 0.532 (0.500) for products from cold ferrous feed.
EAF: high alloy steel	0.44 (0.414)	

[1] IPPC Best Available documents as used in (Ecofys, 2009d)
[2] applying an emission factor of 0.94 t CO_{2e} / MWh as derived in Chapter 2.
[3] See Annex 3 for source and more details

Summing up the scope 1 and 2 emissions for Europe (representing best practice) and Australia (representing the average performance of the Australian industry) yields an indicative range of values for the South African product benchmarks.

Table 12: Indicative benchmark values for the South African iron and steel sector

Product Benchmark	Indicative benchmark values (in tonne CO_{2e} / tonne product)
Coke	0.3-0.5
Sintered Ore	0.2-0.3
Hot Metal (from BF / BOF)	1.4 -1.7
EAF: Carbon steel	0.6 – 0.7
EAF: high alloy steel	0.6– 0.7

The analysis of the data provided by DEA revealed a higher emission intensity of 1.1 tonne CO_{2e}/tonne for EAF technology, but this can be explained by the inclusion of the downstream processing in this calculation. For the BF/BOF process, an emission intensity value of 1.46 tonne CO_{2e}/tonne product for BF/BOF can be derived which is in the range given above.

For the COREX/MIDREX process product benchmark, we cannot derive an indicative value because literature data only refers to part of the process and is outdated.

In line with the procedure outline in Chapter 5, a first step is to finalise the approach together with the sector.

The system boundary definitions as used in the EU ETS form a good basis to discuss with the sector the methodological definition of the product benchmark proposed, with the notion that the scope 2 emissions related to the electricity consumption should be added to the approach. For the COREX/MIDREX process, the system boundaries need to be defined in close consultation with the companies.

In the discussion with the sector, it is also important to discuss in detail how to deal with the occurrence of waste fuel and waste heat fuel flows between the different processes, taking the approach applied in the EU ETS as basis. Given the complexity of the energy and carbon flows in this sector, both government and industry representatives should be aware that defining the approach for this sector in all its details requires a deep insight into the production processes of the iron and steel sector.

An open point for discussion with the sector is whether the addition of a separate benchmark for pellets, lime and some of the downstream processes would be appropriate and possible in the South African context.

After finalising the approach fully, data needs to be collected to calculate benchmark values reflecting the average performance of the South African industry. As with all sectors, this will require the companies to fully disclose to the relevant authorities their energy and emission data at a detailed process level.

7 Ferroalloys

7.1 Introduction

7.1.1 Sector overview

The ferroalloy sector covers the production of a number of different products in which iron is combined with one or more other elements. The main ferroalloys produced in South Africa are ferrochrome, ferromanganese, ferrosilicon and ferrovanadium.

Table 13 presents an overview of the number of installed plants producing each of these products, the total installed capacities and actual production (DMR, 2013a). In addition to the four main outputs from this sector, the USGS reports South African production of ferronickel of approximately 1,000 tonnes per annum (USGS, 2011).

Table 13: Main Ferroalloys produced in South Africa

Product	Number of Plants	Installed capacity (tonne per annum)	Production (tonne per annum)
Ferrochrome (FeCr)	13	3,700,000	3,061,044
Ferromanganese (FeMn)	4	1,300,000	842,192
Ferrosilicon (FeSi)	3	795,000	125,519
Ferrovanadium (FeV)	3	20,000*	20,245

*Rough estimated figure provided, therefore the slightly higher production than capacity

Each of the main ferroalloys is further classified based on the different alloy contents, carbon content, and other additives. This classification is presented in Table 58 to Table 61 in Annex 1 (DMR, 2013a).

Table 14 presents a list of all the manufacturing companies in South Africa, the location of their operations and the products they produce. In this table, the HC, MC and VC refer to high carbon, medium carbon and low carbon.

Table 14: Plants and products manufactured by ferroalloy production companies in South Africa

Company	Operations	Product
Ferrochrome		
ASA Metals	Dilokong Ferrochrome Works, Mpumalanga	HCFeCr
Assmang (African Rainbow Minerals and Assore Ltd)	Machadodorp Works, Mpumalanga	HCFeCr

Company	Operations	Product
Hernic Ferrochrome	North West	HCFeCr
International Ferro Metals (IFM South Africa)	Mooinooi, North West	HCFeCr
Merafe Resources	Boshoek Works, North West	HCFeCr
Mogale Alloys (Ruukki Group)	West Rand, Gauteng	HCFeCr
Tata Steel KZN (Tata Group)	Richard's Bay, Kwazulu-Natal	HCFeCr
Xstrata SA Chrome Division (Glencore Xstrata plc)	Rustenburg Works, North West	HCFeCr
	Wonderkop Works, North West	HCFeCr
	Lydenburg Works, Mpumalanga	HCFeCr
	Lion Works, Mpumalanga	HCFeCr
Samancor Chrome (International Mineral Resources Group)	Ferrometals, Witbank	HCFeCr MCFeCr
	Middelburg Ferrochrome, Mpumalanga	HCFeCr LCFeCr Silicochrome
	Tubatse Ferrochrome, Steelpoort, Mpumalanga	HCFeCr
Ferromanganese		
Assmang (African Rainbow Minerals and Assore Ltd)	Cato Ridge Works, Kwazulu-Natal	HCFeMn
	Cato Ridge Alloys (JV), Kwazulu-Natal	MCFeMn LCFeMn
Samancor Manganese	Metalloys, Meyerton, Gauteng	HCFeMn MCFeMn
Transalloys (Renova Mining Industries)	Emalahleni, Mpumalanga	SiMn
Ferrosilicon		
Silicon Technology (Glencore Xstrata plc)	Ballengeich, Kwazulu-Natal	FeSi
DMS Powders (Siyanda Inkwali Resources)	Meyerton, Gauteng	FeSi
Silicon Smelters (Ferroatlantica Group) *formerly Rand Carbide owned by Evraz Highveld Steel and Vanadium*	Emalahleni, Mpumalanga	FeSi
Ferrovanadium		
Evraz Vametco Alloys	Brits, North West	FeV and Nitrovan
Vanchem Vanadium Products (Duferco Group)	Witbank	FeV
Xtrata Alloys (Glencore Xstrata plc)	Rhovan Works, North West	FeV

The Ferro-Alloy Producers' Association is the sector organisation for the ferroalloys sector in South Africa. The Steel and Engineering Industries Federation of Southern Africa (SEIFSA) is the umbrella body for this association.

7.1.2 Production processes

Both manganese and chromium-bearing ores undergo similar primary processing steps prior to smelting. Ores are typically upgraded at the mine to produce concentrates through sorting, heavy media or gravity separation, magnetic separation and/or froth flotation. Some South African chromite ores require agglomeration by pelletizing or briquetting before smelting. Similarly, certain South African manganese ores are amenable to agglomeration by sintering. Sintering is achieved by blending fine ore with other materials such as coke, coal, or sludge and additional additives, followed by heating in a furnace. Once cooled, the sinter is crushed and sorted by size prior to smelting.

Both blast furnaces and electric arc furnaces can be used for smelting for ferroalloy production. At the smelter, ore is charged into a furnace, along with fluxes (e.g., limestone, quartzite) and reductants (coke and coal). After conversion, the metal and slag are tapped off separately from the furnace. Slag can be further processed to extract residual metal, whilst the molten metal is cast, cooled and crushed to produce the ferroalloy product.

South Africa’s Ferroalloys Handbook (DMR, 2013a) provides detailed production process descriptions for the main ferroalloys produced in South Africa. These are included in Annex 1.

7.1.3 Overview of sources of GHG emissions

The production of ferroalloys gives rise to direct combustion and process-related GHG emissions, as well as those associated with electricity supply, as follows:

- **Process Emissions:** As the ore, carbonaceous reducing agents, and slag forming materials are heated in a furnace to high temperatures carbon monoxide (CO) and, in the case of ferrosilicon and silicon metal production methane (CH_4), is generated. As the carbon contained in the electrodes is consumed, it combines with oxygen from the metal oxides to form CO, while at the same time reducing and smelting the ore. In a closed-top EAF configuration, CO is either recovered and used for energy production or flared, giving rise to process CO_2 emissions. While these CO_2 emissions may ultimately arise from the energy generation stage, they are typically considered as process emissions as the primary reason for their production was ferroalloy production and not energy recovery (Sjardin, 2003). In semi-open or open-top EAFs, however, the CO burns with air within the furnace, also producing CO_2. Furthermore, when ferrosilicon and silicon metal is produced in semi-open or open-top EAFs, CH_4 and N_2O emissions are also produced (U.S. EPA, 2009).
- **Combustion Emissions:** Combustion emissions are associated with the fuel required to produce heat for drying, melting or casting operations in production steps pre- and post the EAF. The stationary combustion units associated with combustion emissions include furnaces (while noting that EAFs and induction furnaces use electricity and so are not associated with combustion emissions), rotary kilns, casting machines, boilers, and space heaters (U.S. EPA, 2009).

- **Electricity related emissions:** The smelting process is electricity-intensive, with an electricity intensity of up to 4,000 kWh/tonne of metal product (ICDA, 2011), and therefore has large indirect (scope 2) emissions as a result of the emission intensive coal-based grid electricity in South Africa.

Process emissions are reported to be the major source of direct GHG emissions from ferroalloy production (U.S. EPA, 2009).

7.2 GHG emissions profile of the ferroalloys sector in South Africa

7.2.1 Data availability

The data gap analysis for ferrochrome, ferromanganese, ferrovanadium and ferrosilicon is shown in the tables that follow. In general, it is noted that data on energy consumption and emissions are very scarce for this sector. The only companies that report data are Assmang (Assore, 2013), Merafe Resources (Merafe Resources, 2012), and International Ferro Metals (IFM) (IFM, 2013). A tabular representation of all the data that is referred to here is included in Annex 2.

Table 15: Ferrochrome data gap analysis

Data availability	Industry wide	Xstrata SA (Glencore SA)	Samancor (International Mineral Resources)	ASA metals	ASSMANG Ltd (50% ARM, 50% ASSORE)	Hernic Ferrochrome	Merafe resources	International Ferrous Metals South Africa	TATA Steel (Tata group)
Emissions and energy consumption									
Scope 1 emissions (total) Mt CO_2e	No data available	Data available	No data available	No data available	Can be calculated	No data available	Data available	Can be calculated	No data available
Scope 1 emissions (fuel) Mt CO_2e	No data available	Requires additional data to be calculated	No data available	No data available	Requires additional data to be calculated	No data available	Requires additional data to be calculated	No data available	No data available
Scope 1 emissions (process) Mt CO_2e	Process emissions data for 2000 – 2010	Requires additional data to be calculated	No data available	No data available	Requires additional data to be calculated	No data available	Requires additional data to be calculated	No data available	No data available
Fuel consumption GJ	No data available	Data available	No data available	No data available	Data available	No data available	Data available	No data available	No data available

Data availability	Industry wide	Xstrata SA (Glencore SA)	Samancor (International Mineral Resources)	ASA metals	ASSMANG Ltd (50% ARM, 50% ASSORE)	Hernic Ferrochrome	Merafe resources	International Ferrous Metals South Africa	TATA Steel (Tata group)
Scope 2 emissions Mt CO_2e	No data available	Data available	No data available	No data available	Can be calculated	No data available	Data available	Can be calculated	No data available
Electricity consumption MWh	No data available	Data available	No data available	No data available	Data available	No data available	Data available	Data available	No data available
Production									
Ferrochrome ktpa	Data available	Data available	No data available	No data available	Data available	No data available	Data available	Data available	Data available
Intensities									
Scope 1 emissions per tonne FeCr	No data available	Can be calculated	No data available	No data available	Can be calculated	No data available	Can be calculated	Can be calculated	No data available
Scope 2 emissions per tonne FeCr	No data available	Can be calculated	No data available	No data available	Can be calculated	No data available	Can be calculated	Can be calculated	No data available
Total emissions per tonne FeCr	No data available	Data available	No data available	No data available	Can be calculated	No data available	Data available	Can be calculated	No data available

Table 16: Manganese alloys data gap analysis

Data availability	Industry wide	Samancor (BHP Billiton)	ASSMANG Ltd (50% ARM, 50% ASSORE)	Transalloys (Renova Mining Industries)
Emissions and energy consumption				
Scope 1 emissions (total) Mt CO_2e	No data available	Some data available	Can be calculated	No data available
Scope 1 emissions (fuel) Mt CO_2e	No data available	No data available	Requires additional data to be calculated	No data available
Scope 1 emissions (process) Mt CO_2e	Process emissions data for 2000 – 2010 for HCFeMn and LCFeMn	No data available	Requires additional data to be calculated	No data available
Fuel consumption GJ	No data available	No data available	Data available	No data available
Scope 2 emissions Mt CO_2e	No data available	Some data available	Can be calculated	No data available

Data availability	Industry wide	Samancor (BHP Billiton)	ASSMANG Ltd (50% ARM, 50% ASSORE)	Transalloys (Renova Mining Industries)
Electricity consumption MWh	No data available	No data available	Data available	No data available
Production				
Ferromanganese ktpa	Data available	Data available	Data available	No data available
Intensities				
Scope 1 emissions per tonne	No data available	No data available	Can be calculated	No data available
Scope 2 emissions per tonne	No data available	No data available	Can be calculated	No data available
Total emissions per tonne	No data available	No data available	Can be calculated	No data available

Table 17: Ferrovanadium data gap analysis

Data availability	Industry wide	Vanchem Vanadium Products (Duferco group)	Xstrata (Glencore Xstrata)	Evras Vametco Alloys (Strategic minerals corporation)
Emissions and energy consumption				
Scope 1 emissions (total) Mt CO_2e	No data available	No data available	No data available	No data available
Scope 1 emissions (fuel) Mt CO_2e	No data available	No data available	Requires additional data to be calculated	No data available
Scope 1 emissions (process) Mt CO_2e	No data available	No data available	Requires additional data to be calculated	No data available
Fuel consumption GJ	No data available	No data available	Data available	No data available
Scope 2 emissions Mt CO_2e	No data available	No data available	Can be calculated	No data available
Electricity consumption MWh	No data available	No data available	Data available	No data available
Production				
Ferrovanadium ktpa	Some data available	Data available	Data available	No data available
Intensities				
Scope 1 emissions per tonne	No data available	No data available	No data available	No data available
Scope 2 emissions per tonne	No data available	No data available	Can be calculated	No data available
Total emissions per tonne	No data available	No data available	No data available	No data available

Table 18: Ferrosilicon data gap analysis

Data availability	Industry wide	Silicon Smelters (Ferroatlantica group)	Silicon technology (Glencore Xstrata)	DMS powders (Siyanda Inkwali Resources)
Emissions and energy consumption				
Scope 1 emissions (total)	No data available	No data available	No data available	No data available
Scope 1 emissions (fuel)	No data available	No data available	No data available	No data available
Scope 1 emissions (process)	Process emissions data for 2000 – 2010 for FeSi and Si metal	No data available	No data available	No data available
Fuel consumption	No data available	No data available	No data available	No data available
Scope 2 emissions	No data available	No data available	No data available	No data available
Electricity consumption	No data available	No data available	No data available	No data available
Production				
FeSi	Data available	No data available	No data available	No data available
Intensities				
Scope 1 emissions per tonne	No data available	No data available	No data available	No data available
Scope 2 emissions per tonne	No data available	No data available	No data available	No data available
Total emissions per tonne	Can be calculated	No data available	No data available	No data available

7.2.2 Current emissions profile of the sector

The split between process emissions and emissions from fuel combustion (other scope 1 emissions) and emissions associated with off-site electricity consumption (scope 2 emissions) is site specific and is a function of the product being produced and process configuration. As both process emissions and combustion emissions can arise from the same processes, allocation between process emissions and combustion emissions requires detailed mass balance calculations.

Based on information contained in the public domain, an indicative, order of magnitude estimate of overall emissions and the split between fuel, process and electricity related emissions was estimated for the sector. This analysis allows for comparison to order of magnitude estimates for the other sectors, as well as to get an indication of the relative contributors of the individual sources to the overall emissions from the sector. The outcomes of this assessment are shown in the following table.

Table 19: Order of magnitude estimate of emissions from the ferroalloy sector (Mt CO_2e)

	Ferroalloys
Total emissions from sector	>20
Scope 1: process	6
Scope 1: fuel combustion	>2
Scope 2	>12

It is noted that in the United States, the split between process emissions and combustion emissions is 86% process emissions and 14% combustion emissions (U.S. EPA, 2009). This split is somewhat different in the indicative numbers provided in the table above (75% process emissions), which can be attributed to different products, technologies and fuels used.

7.2.3 Current activities surrounding own generation in the sector

International Ferro Metals (IFM) has a co-generation plant that should provide them with approximately 11% of the production facility's energy requirements at full production. There are talks on expanding the existing co-generation plant at IFM, which could see the electricity generation capacity increase by 13.7MW.

Table 20: Electricity generated at the co-gen plant for FY 2012 and FY 2013 (IFM, 2013)

Year	Electricity (GWh)	% of company electricity requirements
FY 2012	28	4.5%
FY 2013	46	6.4%

The Xstrata-Merafe Chrome Venture has conducted feasibility studies on the installation of a waste heat recovery plant to generate electricity at its Wonderkop ferrochrome facility as well as at their Rustenburg ferrochrome plant. The latter would explore the possibility of supplementing the waste heat with landfill gas from the local municipal waste landfill (Merafe Resources, 2012).

7.3 Existing benchmarks

The only publicly available emissions intensity data for the ferroalloy industry are from an article by Holappa (2010) which presents global average emission intensities for non-energy related emissions. Emission factors were adopted from Sjardin (2003) and combined with worldwide production figures of common ferroalloys in 2007 (USGS, 2011). The Intergovernmental Panel on Climate Change Report 2007 (IPCC) also used data from this study.

The figures for FeCr and FeMn include different product grades (high, medium, low carbon) with different emission factors. FeSi also comprises different grades with different Si contents. The final values are weighted mean values based on production figures.

The benchmark values are presented in Annex 3.

7.4 Applicability of international benchmarks in South Africa and proposed benchmarking approach

The ferroalloy industry in South Africa comprises a large number of producers, particularly of ferrochrome. Ferroalloys are also produced using a variety of process configurations at different grades, which make allocation of emissions to different products difficult. The only existing study with benchmark values for ferroalloys considers only non-energy emissions consistent with GHG reporting activities. There is no existing methodology available for benchmarking both the scope 1 and scope 2 emissions of the ferroalloy industry or its products. Furthermore, the benchmark methodology represents international average data and reflects process routes that are not always relevant to South Africa. The benchmarking methodology itself also relies on a fall-back approach to estimate process emissions associated with reductant use and electrode use, which are taken from a European Commission document on best available techniques in the non-ferrous metals industries. Therefore, while there may be some useful information available in these existing benchmark studies, they cannot be applied to the South African context.

This sector is important in terms of emissions and number of companies covered by the tax. Therefore, we propose, as a starting point, developing a product benchmark approach. One possible product categorisation could be based on the product categories used by DEA to collect process emissions data for the national greenhouse gas inventory:

Chromium alloys
Manganese alloys (7% C)
Manganese alloys (1% C)
Silicon alloys (assume 65% Si)
Silicon metal

The fall-back approaches would be used for the emissions not covered by these product benchmarks. It is not possible to accurately determine the share of emissions that will be covered by these product benchmarks, but these product benchmarks are likely to cover the majority of the sector's emissions and include significant shares of process emissions. Given that the processes are relatively simple in process lay-out with a clear final product that can well be defined, we are confident that it is possible to develop a suitable product benchmark approach with cooperation from the sector.

Given the complexity of the sector and the wide variety of product, an alternative could be to determine a more detailed product specification based on the range in emission intensity differences caused by the product specifications. With the current set of data, it is difficult to set the appropriate level of product specification.

The Best Available Technique Reference Document developed in the EU for non-ferrous metal industries[11] might serve as the guideline for the discussion with the industry on the development of the appropriate benchmarking approach, since it is to our knowledge the most detailed study on this sector available (available in the public domain).

7.5 Proposed product benchmarking values and next steps

Public data available in South Africa does not allow for the identification of emission intensities for all installations for the suggested ferroalloys products with product benchmarks. GHG emission data available in public domain is often not disaggregated by product type or does not provide a split between scope 1 and scope 2 emissions. However, based on the DEA data, scope 1 emission intensity values can be calculated for main products.

The analysis of the data in public domain (emissions from the chromium alloys and manganese alloys production for Xstrata-Merafe Chrome Venture and Assmang Operation) shows that the production of ferroalloys is very GHG emission intensive and that scope 2 emissions can be by factor 1.5-2.5 higher than scope 1 emissions. Therefore we have increased the proposed benchmark values for ferroalloys products for chromium and manganese alloys. It should be noted that the electricity consumption data available in public domain is found to be different for different companies and should be treated with caution. For example, electricity data consumption calculated from public sources (see Appendix 4for Assmang Machadodorp Works in 2012 is 4.74 MWh/t charge chrome but for International Ferro Metals (IFM) it is equal to 3.92 MWh/t charge chrome.

Silicon alloys and silicon metal are even more energy intensive. Draft BAT for non-ferrous metal industry (cf. Table 9.5 in (European Comission, 2013)) indicates electrical energy consumption of 8.750 MWh/t for ferro-silicon (75 % Si) and 10.800 – 12.000 MWh/t for silicon metal. Taking into account emission grid value for South Africa we have assumed the indirect emission intensity values of 8.2 tCO_{2e}/t for ferro-silicon (75 % Si) and 10.7 tCO_{2e}/t for silicon metal. An overview of indicative values determined using the data as explained above (including scope 1 and scope 2 emissions) presented in Table 21 below.

[11] http://eippcb.jrc.ec.europa.eu/reference/nfm.html

Table 21: Indicative benchmark values for the South African ferro-alloys sector

Product Benchmark	DEA Data for scope 1 emissions (t CO_{2e} / t product)	Estimate for scope 2 emissions [1] (t CO_{2e} / tonne product)	Indicative benchmark values (t CO_{2e} / tonne product)
Chromium alloys	1.3	1.95 - 3,25	3.25 – 4.55
Manganese alloys (7% C)	1.3	1.95 - 3,25	3.25 – 4.55
Manganese alloys (1% C)	1.5	2.25 – 3.75	3.75-5.25
Silicon alloys (assume 65% Si)	1.5	8.2	9.7
Silicon metal	5	10.7	15.7

[1] Using a factor of 1.5 -2.5 between scope 1 and 2 emissions for chromium and manganese alloys. Values for silicon alloys and silicon metal coming from European Commission (2011)

In line with the procedure outlined in Chapter 5, a first step is to finalise the approach together with the sector. The key issue to be discussed is to define an appropriate product categorisation that takes into account the wide variety of different products from this sector and the influence of these product properties on the greenhouse gas intensity of the production processes, while at the same time not making the methodology more complex than necessary. Another important discussion point is the exact system boundary of the selected product benchmarks. Like in the steel sector, it is probably possible to keep some of the more downstream company specific processes with relatively little contribution to the greenhouse gas emissions of the company outside the scope of the product benchmarks.

After finalising the approach fully, data needs to be collected to calculate benchmark values reflecting the average performance of the South African industry. As with all sectors, this will require the companies to fully disclose to the relevant authorities their energy and emission data at a detailed process level.

8 Cement

8.1 Introduction

8.1.1 Sector overview

The activities included in the cement sector are the production of clinker and the grinding and blending of all grades of cement. There are currently 12 integrated facilities that produce their own clinker and cement, including Sephaku Cement that was due to come online in 2014 (see Table 22). South African Mamba Cement is set to come online in 2015 (ICR Newsroom, 2013). In 2010, the major players in the cement industry in South Africa had sales of 14 million tonnes of cementitious product (ACMP, 2011).

Table 22: Cement production companies in South Africa: Production facilities and overall production capacity.

Company	Type of operation	Location	Cement production capacity (Mtonne/year)
PPC	Production units (integrated)	Hercules	6.1
		Jupiter	
		Dwaalboom	
		Slurry	
		De Hoek	
		Riebeeck	
		Port Elizabeth	
	Milling / blending units	Saldanha (slag only)	
Afrisam	Production units (integrated)	Dudfield	3.8
		Ulco	
	Milling / blending units	Roodepoort (grinding)	
		Vanderbijlpark (Slagment)	
La Farge	Production units (integrated)	Lichtenberg	3.6
	Milling / blending units	Randfontein (grinding)	
		Richard's Bay (grinding)	
NPC-Cimpor	Production units (integrated)	Simuma	2.1
	Milling / blending units	Coedmore, Durban (grinding)	
		Newcastle (blending)	

Company	Type of operation	Location	Cement production capacity (Mtonne/year)
Sephaku Cement*	Production units (integrated)	Aganang	2.6
	Milling / blending units	Delmas (grinding)	
South African Mamba Cement**	Production units (integrated)	Limpopo	-
3rd party extenders[12]	Milling / blending units	IDM Cement Pty Ltd (5 blending facilities in Gauteng); Cemlock (Gauteng) (Pty) Ltd. (Blending facility in Germiston); and others. No information is available on other extenders. The Association of Cementitious Material Producers (ACMP) reports 12 milling/blending units in 2008 and 43 in 2009 and 2010.	2.1

Sources: (Groundwork, 2007; Lafarge, 2012a; NPC-Cimpor, 2010; Sephaku Cement, 2012; PPC, 2007)
* Due to come online in 2014
**To come online in 2015

The main industry associations in the South African cement sector are:

- Association of Cementitious Material Producers (ACMP). The ACMP's member companies are Afrisam, Lafarge South Africa, NPC-CIMPOR, PPC, Cemlock and I.D.M. Cement. The Association acts as an umbrella body, guiding and representing these companies' interests in the fields of environmental stewardship, health and safety practices and community and stakeholder interaction.
- The Concrete Institute (previously known as the Cement and Concrete Institute). The Institute is funded by Afrisam, Lafarge and Sephaku and provides technical services to the industry.

8.1.2 Production processes

The three primary steps in the cement production process are raw meal preparation, clinker production and cement grinding (See Annex 1 for a schematic of the cement production process).

In the first step, limestone and other raw materials are extracted from a quarry and then crushed, homogenised and ground into a powder (Ecofys, 2009b). The raw materials are fed into a rotary kiln together with coal and other fuels, to transform the raw material into lime (CaO) at temperatures in excess of 900°C in a process known as calcination. This process releases CO_2. The calcinated raw meal is heated further along the kiln to temperatures of up to 1,450°C. This allows sintering to form

[12] 3rd Party extenders do not manufacture their own clinker. Clinker is either purchased domestically or imported and other products with cementitious properties are added to the clinker to obtain various grades of cement.

clinker. Clinker is the component of cement that provides it with its binding (or pozzolanic) properties, and clinker production is the most energy-intensive step in the cement production process. Once the clinker is formed, it is rapidly cooled to 100-200°C (Ecofys, 2009b).

Finally, clinker is ground and blended with other materials to produce the final cement product. In Ordinary Portland Cement (OPC), around 5% gypsum is added to the clinker. Blended cements, which consist of a mixture of clinker and other products with cementitious properties, are also produced in South Africa (Ecofys, 2009b).

8.1.3 Overview of sources of GHG emissions

Cement making gives rise to the production of greenhouse gases (primarily CO_2, but also CH_4 and N_2O) through onsite fuel combustion, generation of electricity and by-products of the lime kiln. The main emissions source is a result of *process* emissions and comes from the production of clinker in the manufacturing process. The *on-site stationary combustion* emissions due to the combustion of fuels required to heat material in the kiln is another key source of emissions (ACMP, 2011). In South Africa the majority of companies make use of grid-based electricity, and hence emissions associated with electricity generation occur off site. Where electricity generation occurs on site, these emissions may need to be accounted for as on-site fuel combustion emissions.

Due to the increase in clinker substitute material in South Africa, there has been a steady decrease in CO_2 produced per tonne of cementitious material from approximately 0.83 tonnes CO_2/tonne of cement in 1990 to approximately 0.65 tonnes CO_2/tonne of cement in 2010 (ACMP, 2011).

More detail on the factors that determine the GHG emissions profile is provided in Annex 1.

8.2 GHG emissions profile of the cement sector in South Africa

8.2.1 Data availability

The data gap analysis for cement is shown in the following table. A tabular representation of all the data that is referred to here is included in Annex 2 of this report.

Table 23: Cement data gap analysis

Data availability	units	Industry wide	PPC	Afrisam	Lafarge	NPC-Cimpor	Sephaku Cement
Emissions and energy consumption							
Scope 1 emissions (total)	Mt CO_2e	Combined scope 1 and 2 for 2000-2010	Some data available	No data available	Some data available	No data available	Production only started in 2014
Scope 1 emissions (fuel)	Mt CO_2e	Some data available	Can be calculated	No data available	No data available	No data available	

Data availability	units	Industry wide	PPC	Afrisam	Lafarge	NPC-Cimpor	Sephaku Cement
Scope 1 emissions (process)	Mt CO_2e	Some data available	Can be calculated	No data available	No data available	No data available	
Fuel consumption	GJ	Some data available	Data available	No data available	No disaggregated data	No data available	
Scope 2 emissions	Mt CO_2e	Some data available	Data available	No data available	Some data available	No data available	
Electricity consumption	MWh	Some data available	Data available	No data available	No disaggregated data	No data available	
Production							
Clinker	Mtpa	No data available	Can be calculated	No data available	No data available	No data available	
Portland cement	Mtpa	No data available	Can be calculated	No data available	No data available	No data available	
Fly ash cement	Mtpa	No data available	No data available	No data available	No data available	No data available	
Slag cement	Mtpa	No data available	No data available	No data available	No data available	No data available	
Total cement production	Tonne	2000-2010 data	No data available	No data available	No data available	No data available	
Intensities							
Scope 1 emissions per tonne clinker	tonne CO_2e / tonne clinker	No data available	Can be calculated	No data available	No data available	No data available	
Scope 1 emissions per tonne cement	tonne CO_2e / tonne cement	No data available	Can be calculated	No data available	No data available	No data available	
Scope 2 emissions per tonne clinker	t CO2e / t clinker	No data available	Can be calculated	No data available	No data available	No data available	
Scope 2 emissions per tonne cement	t CO2e / t cement	No data available	Can be calculated	No data available	No data available	No data available	
Total emissions per tonne clinker	t CO2e / t clinker	Some data available	Data available	No data available	No data available	No data available	
Total emissions per tonne cement	t CO2e / t cement	Can be calculated.	Data available	No data available	Some data available	No data available	

8.2.2 Current emissions profile of the sector

Based on information contained in the public domain and heuristics for the sector, an indicative, order of magnitude estimate of overall emissions and the split between fuel, process and electricity related emissions was estimated for the sector. This analysis allows for comparison to order of magnitude estimates for the other sectors, as well as to get an indication of the relative contributors of the individual sources to the overall emissions from the sector. The outcomes of this assessment are shown in the following table.

Table 24: Order of magnitude estimate of emissions from the cement sector (Mt CO2e)

	Cement
Total emissions from sector	7
Scope 1: process	4
Scope 1: fuel combustion	2
Scope 2	1

8.2.3 Current activities surrounding own generation in the sector

None of the cement clinker producers in South Africa currently produce electricity or supply heat to external customers. Having said that, South African Mamba Cement, which is reported to be due to come online in 2015, will include an electricity generation facility, capable of producing 26.8 GWh of electricity from waste heat. This is the first plant on the continent to be able to do so (Okpamen, 2013)

8.3 Existing benchmarks

For the cement sector five existing benchmark sets are reviewed in detail in Annex 3. These benchmarks and the products they cover are as follows:

- EU ETS Benchmarks: Grey cement clinker and white cement clinker
- California Cap-and-Trade Benchmarks: Cement
- Australian Carbon pricing mechanism benchmark: Dry Portland cement clinker of saleable quality
- World Best Practice Energy Efficiency Benchmarks: clinker, Portland Cement, fly ash cement and blast furnace slag cement
- UNIDO Global Industrial Energy Efficiency Benchmarks: Heat use in clinker production and electricity consumption per tonne of cement for selected industrialized countries, selected developing countries, global average, best available technology and international benchmark

8.4 Applicability of international benchmarks in South Africa and proposed benchmarking approach

South African cement manufacturers produce various grades of cement at a number of different sites. Sources of GHG emissions include process emissions from clinker production (which can account for 50% of emissions), emissions from fuel combustion and electricity consumption (particularly in grinding operations).

The methodologies to establish benchmarks for clinker are relatively straightforward, but benchmarks for cement give rise to a number of complicating factors related to blending, clinker substitutes and quality differences between cement products as well as trade with the intermediate clinker product. The EU ETS as well as the Australian Carbon Pricing Mechanism and the Californian cap and trade system have therefore chosen an approach based on a clinker benchmark. We suggest South Africa to follow this practice and propose one product benchmark for c*ement clinker* for this sector that will cover the vast majority (over 80%) of the sectors emissions.

The fall-back approaches proposed are to be used for the (very small) emissions not covered by this benchmark such as product blending etc. The system boundary definitions as used in the EU ETS are a good starting point for a discussion with the sector on the exact scope of the product benchmark with the notion that the scope 2 emissions related to the electricity consumption should be added to this approach. There may be difficulties allocating the electricity consumption of operations of the facilities to individual processes (i.e. clinker making and other processes). Therefore, the choice could be made to exclude electricity consumption from the product benchmark but to cover all electricity related emissions with the fall-back approach. We however do recommend first trying to develop a product benchmark including the scope 2 emissions. If in South Africa, as in Europe, smaller amounts of white clinker are produced, it could be envisioned to either cover this production via the fall-back approach or to develop a separate product benchmark for this product, which is inherently more emissions intensive as discussed in Ecofys (Ecofys, 2009d).

8.5 Proposed product benchmarking values and next steps

As reported in Annex 3, the EU ETS benchmark for clinker production is 0.766 t CO_{2e}/t clinker and Ecofys (Ecofys, 2009d) reports an electricity consumption of 100 – 110 kWh/t clinker for OECD Europe, which results in a product benchmark including scope two emissions of 0.86 – 0.87 taking the South African grid electricity factor 0f 0.94 t CO_{2e}/MWh (Chapter 2). This can be considered as the lower range of what can be expected as the average in South Africa given that the European benchmark is based on the 10% most efficient installations. The Australian benchmark is 0.95 t CO_{2e}/t clinker.

According to the data available in public domain, the largest cement producing company in South Africa, PPC South Africa, indicated an emission intensity of 1.05-1.08 tCO_{2e}/t clinker in 2010-2013, although the exact methodology used to calculate this intensity is not completely clear. Based on these values, a clinker benchmark based on the average performance of the South African industry will likely lie at the upper side of the 0.85 – 1.10 t CO_{2e}/t clinker range.

In line with the procedure outline in Chapter 5, a first step is to finalise the approach together with the sector and to confirm that a clinker benchmark is the most suitable approach for South Africa. As with all sectors, defining benchmark values for the average performance of the South African companies producing cement clinker, will require that these companies fully disclose to the relevant authorities their energy and emission data at a detailed process level. The Cement Sustainability

Initiative has published guidelines on CO_2 accounting and reporting in the cement industry, which might be a useful guide in the process of data collection.

9 Petroleum (crude oil refineries)

9.1 Introduction

9.1.1 Sector overview

Petroleum refining involves the conversion of crude oil into multiple refined products. These products include liquefied petroleum gas (LPG), petrol, paraffin, aviation fuel, diesel, heavy fuel oils and lubricating oils. Apart from these final products many intermediate products are produced which serve as a feedstock to the petrochemical industry (US EPA, 1995).

South Africa has four crude oil refineries, with ownership, location and capacity as shown in Table 25. Table 26 shows total refining capacity per product type.

Table 25: Production capacities for South African refineries (SAPIA, 2012)

Refinery	Ownership	Location	Capacity of refinery [bbl/ day]
Sapref	Shell SA/ BP SA (50%/ 50%)	South Durban Basin (SDB)	180 000
Enref	Engen Petroleum	Durban	120,000
Chevref	Chevron South Africa	Cape Town	110,000
Natref	Sasol/ Total SA (64%/ 36%)	Sasolburg	108,000

Table 26: SA Refined product capacity for 2012 (SAPIA, 2012)

Description	Value	Unit
Petrol refining capacity, total	10,550	million litres / year
Diesel refining capacity, total	9,657	million litres / year
Kerosene refining capacity, total	2,979	million litres / year

The South African Petroleum Industry Association (SAPIA) represents the collective interests of its members that are BP Southern Africa (Pty) Ltd, Chevron South Africa (Pty) Ltd, Engen Petroleum Limited, PetroSA (Pty) Ltd, Sasol Limited, Shell SA (Pty) Ltd and Total South Africa (Pty) Ltd.

9.1.2 Production processes

The key processes in the production of mineral oil products from crude oil are as follows (Ecofys, 2009f) (US EPA, 1995):

- Separation processes: Crude oil is essentially a mixture of paraffinic, naphthenic and aromatic hydrocarbons. Impurities, such as sulphur, nitrogen, oxygen and metals are also present in small quantities. The first phase in refining involves separation of the input stream into its major constituents, grouped by boiling point. Separation processes include atmospheric distillation, vacuum distillation, and gas processing for light ends recovery.
- Conversion processes: After separation, and in order to produce high value desired liquid fuel products, residual oils, fuel oils, light ends and other components are converted either via cracking, coking and visbreaking or via polymerisation and alkylation. The former processes break down large hydrocarbon chains into shorter ones, whereas in the latter processes smaller molecules are combined. Conversion processes also include isomerization and reforming which change the structure of the resulting molecules to meet product specifications.
- Treating processes: In these processes, liquid fuel products are stabilised and upgraded. This also includes the removal of impurities.
- Other processes: Further processing of the treated products may be required to achieve the desired end products in terms of quality. In addition, the refinery contains a number of supporting processes that are not involved directly in refining, but are necessary to the process. These include all auxiliary processes involving water, heat and steam as well as wastewater treatment facilities, hydrogen plants and sulphur recovery operations.

Given the differing composition of crude oils and end-product requirements, as well as available technology choices, all refineries will have different configurations of the processes listed above. A typical process flow diagram for a crude oil refinery is presented in Annex 1.

9.1.3 Overview of sources of GHG emissions

There are numerous sources of CO_2 emissions in refineries, although the main processes which give rise to direct emissions on site are (Ecofys, 2009f):

- Furnaces and boilers used for the production of process heat, electricity and steam;
- Coke combustion in catalytic crackers and reformers;
- Production of hydrogen and synthesis gas;
- Calcination of petroleum coke;
- Post-combustion furnaces;
- Gasifiers of heavy fractions; and
- Flaring.

Furthermore, refineries use electricity from the grid, giving rise to indirect greenhouse gas emissions.
The table below shows the average global contribution of the various sources of emissions to refineries' emissions in the year 2000.

Table 27: Contribution of different sources to overall refinery GHG emissions, average and range on a CO_{2e} basis for worldwide operations in the year 2000 (Öko Institut and Ecofys , 2008).

Contribution to overall GHG emissions (%, CO_{2e} basis)	Average	Minimum	Maximum
Direct combustion	85	56	100
- FCC Coke on Catalyst - Other fuels	19	0	61
Indirect energy	66	23	99
Hydrogen generation	8	0	35
Flare loss	4	0	29
Methane	3	0	19
Direct combustion	<1	0	1

9.2 GHG emissions profile of the crude oil refinery sector in South Africa

9.2.1 Data availability

The following is a summary of the available data on production, energy consumption and greenhouse gas emissions from crude oil refineries in South Africa. A tabular representation of the data gap analysis, along with all the data that is referred to here is included in Annex 2 of this report.

Industry-wide electricity consumption and total emissions data is available for crude refining for 2006 to 2011, along with the 2012 petrol, diesel, and kerosene production in litres (SAPIA, 2012). Confidential data for energy consumption per refinery was also obtained from the DEA for 2000-2010.

Sapref's sustainability report provides the fuel and electricity consumption for 2011 and the production output in percentages for 2011 are reported, but not the actual product specific production per year (Sapref, 2011). Sapref's sustainability report also provides the scope 1 emission intensity for 2007-2011 (Sapref, 2011).

No electricity consumption data is available for Natref, Enref and Chevref, but the total energy consumption of the Engen refinery (Enref) is available for 2008-2011 in Engen's Sustainability Report (Engen, 2011). Scope 1 emissions available for Natref for relevant years (2010-2013) can be derived from Sasol Oil data from Sasol Annual reports (Sasol, 2010a; Sasol, 2011a; Sasol, 2013b). Total refinery emissions data is available for some years for Sapref (2007-2011) and Enref (2008-

2011) (Engen, 2011; Sapref, 2011). Natref, Sapref and Enref account for approximately 80% of the current market.

No scope 2 emission data was found to be available for industry or company level.

9.2.2 Current emissions profile of the sector

Information available in the public domain was analysed to determine whether it would be possible to obtain an order of magnitude estimate of the current emissions from the sector broken down into process, fuel and electricity emissions. Given the complexity of the sector and lack of data, insufficient information was available to provide a breakdown of emissions by source, although based on the data that was available, it was estimated that emissions from the sector are to the order of 3 Mt CO_{2e} per annum, including both scope 1 and 2 emissions.

9.2.3 Current activities surrounding own generation and energy recovery in the sector

Refineries can theoretically export heat (in the form of steam) and electricity, but this is not currently done by any of the South African refineries. Most refineries both produce electricity on site and import additional electricity, leading to indirect emissions.

9.3 Existing benchmarks

Due to the wide range of petroleum products produced and ability of refineries to change the product mix and grades, setting of benchmarks are very complex in the petroleum industry. Identical benchmarks were chosen for the EU ETS and Californian cap-and-trade schemes' petroleum sector benchmarks. In both the EU ETS and California benchmark frameworks, the Solomon "CO_2 weighted tonne" (CWT) approach forms the basis of the benchmarking methodology. In this approach, each unit operation in the refinery is identified and assigned a CWT factor. These CWT factors are based on an extensive global database and the current values have been applied in various benchmarking approaches since 2006. The CWT factor represent the average emission intensity of the unit operation as compared to the average emission intensity of the crude distillation unit of the refinery, which by default has a CWT of 1.

To benchmark refineries, the throughput of each unit is multiplied by the corresponding CWT factor and totalled. Each refinery's total CWT will be different, and reflects the particular processes involved. The importance the various units is based on the typical emissions intensity of those units. Units with on average a higher emission intensity get a higher CWT factor, and units with a lower emissions intensity get a lower CWT factor. The units are thus weighted based on their average emissions intensity allowing to compare complex refineries (that will have a higher number of CWT's) and simple refineries (that will have a lower number of CWT's). The CWT method also includes a standard method to account for the small emissions related to non-process related emissions (such as office buildings etc.) and the calculations applied also correct for issues such as imported versus own produced electricity etc.

A benchmark curve can be produced by comparing the resulting emissions per CWT between refineries. A complex and a simple refinery that both operate exactly at the average emissions intensity that formed the basis for the weighing of the units, will have identical emissions per CWT, although their total emissions and emissions per tonne crude will be quite different.

The final benchmark (expressed as t CO_{2e} / CWT) can be set at the average emissions per CWT, the 10% best or any other point on the benchmark curve.

The Australian Carbon Pricing Benchmarks provide direct emissions and electricity usage for combined stabilised crude petroleum oil, condensate, tallow, vegetable oil and eligible petroleum feedstocks (at 15^{o}C and 1 atmosphere).

The only other data available were energy efficiency indicators from the UNIDO study that provides energy efficiency indicators (EEI) for the petroleum sector (UNIDO, 2010).

These benchmarks are all reviewed in detail in Annex 3.

9.4 Applicability of international benchmarks in South Africa and proposed benchmarking approach

South Africa has four refineries, with each refinery producing a different product mix, which can change according to local demand. Production processes in the refinery sector are complex with multiple links between the inputs used and the different shares of outputs produced. As the EU experience shows, this makes product benchmarking difficult. A simple approach based on a single output or input parameter cannot properly take into account this complexity.

Australia developed an input-based benchmark for its four facilities based on data received from the facilities. Given that the structure of the South African industry is similar to the Australian industry, such a benchmarking approach may be appropriate, but we do expect such an approach to result in significant opposition from the refineries involved given that the input basis can never correct for the different refinery configurations the South African refineries will have.

To overcome the difficulties associated with developing a product benchmark the EU applied the CO_2 weighted tonne (CWT) approach for benchmarking refineries, which can be seen as a more process specific approach. This methodology could equally be applied in South Africa. While the EU methodology had to make a correction for electricity use and production, this would not be necessary for the South African context as a scope 1 and scope 2 benchmark is required.

Due to the absence of suitable international benchmarking methodology for petroleum sector which could be directly applied, we propose approach, applying the CWT approach for the refinery sector in South Africa as well. The CWT methodology for setting GHG emission intensity benchmarks for the sector, including definitions of system boundaries, is available (presented in the Report No. 09/12 available at https://www.concawe.eu). As explained in the next paragraph, as the first step we suggest to discuss with the sector whether or not they agree with the suggested approach to use the CWT approach as benchmark approach for the refinery sector and if so, the necessary steps to make it fully applicable to the South African refinery sector.

This CWT South African approach can cover almost 100% of all emissions related to refinery operations (including the limited number of process emissions occurring at refineries), with the possible exception of a small number of chemical production processes at refineries that should be treated identical to the approaches developed for the chemical sector in line with the one product, one benchmark criteria.

If, for any reason, full application of the CWT approach is not possible, more simplified methodologies could be applied, such as the methodology developed in Australia, but we expect any simplified methodology to result in opposition from the refinery sector.

9.5 Proposed product benchmarking values and next steps

The only CWT benchmark value available for the refinery sector is the 0.0295 tonne CO_{2e}/CWT value applied in Europe which is based on the 10% most efficient installations in the EU. In the sector report, Ecofys reports an average value of 0.035 for European refineries showing that there is a relatively limited spread in the emissions of the various refineries (Ecofys, 2009f). These values can be used as starting point for the discussion with the South African refinery sector, together with the publicly available weighing factor for the various process units.

It is likely that in working out the details of the approach, it will be necessary to discuss with SOLOMONS, the owner of the underlying data base and benchmark methods that were used to develop the CWT approach. This will for example be needed in case an update to the current version or South Africa specific version of the CWT weighing factors between processes would be considered. For example, an update may reflect the different grid emission factor of electricity. Revisions of the weighing factor can only be based on the global database on refinery performances. The simpler alternative would be to use the weighing factors as they were used in Europe without any changes in which case the method can in principle be applied with consulting SOLOMONS.

As with all sectors, defining benchmark values for the average performance of the South African refineries (i.e. the t CO_{2e}/CWT value) will ultimately require that these companies fully disclose to the relevant authorities their energy and emission data at a detailed process level.

10 Petroleum (GTL) sector

10.1 Introduction

10.1.1 Sector overview

The GTL process converts natural gas or other gaseous hydrocarbons into longer-chain hydrocarbons such as gasoline or diesel fuel. There is a large overlap between the products manufactured in GTL, CTL, petroleum refineries, and the chemicals sector.

PetroSA operates South Africa's only gas-to-liquid (GTL) refinery, which is situated in Mossel Bay. Of the five commercially operating facilities globally, this was the first (built in 1992) and it is the third largest globally (PetroSA, undated). PetroSA's product suite includes (PetroSA, 2012):

- Petrol, unleaded (53%)
- Diesel, 50 ppm (6%)
- Kerosene (11%)
- Fuel oil (4%)
- Propane and LPG (8%)
- Distillates (12%)
- Alcohols (6%)

PetroSA's GTL facility has a capacity of 45,000 bbl/day[13]. This accounts for roughly 6% of South Africa's liquid fuels production capacity (SAPIA, 2012).

PetroSA is represented by the South African Petroleum Industry Association (SAPIA), which represents the collective interests of its members (BP Southern Africa (Pty) Ltd, Chevron South Africa (Pty) Ltd, Engen Petroleum Limited, PetroSA (Pty) Ltd, Sasol Limited, Shell SA (Pty) Ltd and Total South Africa (Pty) Ltd).

10.1.2 Production process

The GTL conversion process consist of 3 main process steps (PetroSA, 2012; Knottenbelt & Ntshabele, 2005):

- Gas reforming – natural gas is converted to syngas (mainly carbon monoxide and hydrogen); the carbon monoxide to hydrogen ratio is adjusted using the water gas shift reaction and excess carbon dioxide is removed in an aqueous solution of alkanolamine.

[13] crude oil equivalent

- Gas-to-liquids – syngas is chemically reacted in the Fischer-Tropsch process over an iron or cobalt catalyst to produce liquid hydrocarbons and other byproducts, ranging from methane to waxes.
- Olefin oligomerization – the light olefins are converted into longer chain gasoline and distillate fuels.

Petro SA operates 3 different GTL technologies at its Mossel Bay Plant (Knottenbelt & Ntshabele, 2005)

- High Temperature Fischer Tropsch Technology (Synthol) (Sasol Technology) – 22,500 bbls/day
- Catalytic Conversion of Olefins to Distillates (COD) (PetroSA/ Central Energy Fund technology) – 8,000 bbls/day
- Low Temperature Fischer Tropsch Technology (Statoil/ PetroSA Technology) – 1,000 bbls/day

Relevant process flow diagrams are included in Annex 1.

10.1.3 Overview of sources of GHG emissions

Similarly to crude oil refining, process emissions arise from various unit processes in addition to significant combustion related emissions to provide heat, steam and generate electricity on-site. However, due to the nature of the feedstock, emissions from GTL are similar to or lower than emissions from crude oil refining (Five Winds International , 2004). The GTL process does have a higher primary energy requirement than a crude oil refinery, which suggests that the level of process emissions is lower than for conventional refining.

Emissions from off-site electricity generation are also seen in this sector.

10.2 GHG emissions profile of the GTL sector in South Africa

10.2.1 Data availability

Petro SA's Mossgas facility in Mossel Bay is currently the only GTL refinery in South Africa. Confidential Scope 1 emission data for 2000 to 2010 was obtained from the DEA. Further data collected by National Treasury includes the 2010, 2011, 2012 production volumes of hydrocarbon products, process emissions and disaggregated fuel use, electricity consumption (total) and details of own generation for the years of interest.

10.2.2 Current emissions profile of the sector

Based on information contained in the public domain, an indicative, order of magnitude estimate of overall emissions and the split between fuel, process and electricity related emissions was estimated for PetroSA, who owns the only operating GTL plant in the country. This analysis allows for comparison to order of magnitude estimates for the other sectors, as well as to get an indication of the relative contributors of the individual sources to the overall emissions from the sector. The outcomes of this assessment are shown in the following table.

Table 28: Order of magnitude estimate of emissions from GTL (Mt CO_{2e})

	GTL
Total emissions from sector	>2
Scope 1: process	>1
Scope 1: fuel combustion	<1
Scope 2	<1

To calculate the split between process emissions and combustion emissions for PetroSA requires additional data to be collected, in particular the emissions factors for fuels used in the process.

10.2.3 Current activities surrounding own generation and energy recovery in the sector

The refinery generates electricity and heat from natural gas, using combined-cycle gas turbine. The rated electrical capacity is 90 MW and some exhaust steam is utilized in the refinery processes (Dingle, 2013).

PetroSA also has a 4.2 MW biogas-to-electricity plant on site, commissioned in 2007, that operates on process wastewater from the GTL process. The wastewater is passed through the anaerobic digesters, where the methane is captured, and returned to the refinery. This project was successfully registered with the international CDM board for carbon credits (BioTherm, undated).

10.3 Existing benchmarks

There are no internationally available benchmarks for GTL.

10.4 Applicability of international benchmarks in South Africa and proposed benchmarking approach

The GTL process has only relatively recently been undertaken at commercial scale with only a handful of plants operational worldwide, including the PetroSA refinery. As with other refineries the product mix in the sector is complex and can change, which makes defining a product benchmark complex.

As such, there are no international benchmarking methodologies for GTL industry available. The GTL process is similar to the refinery sector in the sense that there are multiple links between the inputs used and the (shares of) the various outputs of the processes. As such, developing a true product benchmark approach as recommended in Chapter 2 is difficult for sectors like this, which resulted in the EU's choice to apply a more process specific benchmark approach, the CWT approach.

The CWT approach allows weighting of the various process units due to their relative emission intensity and can be useful for the GTL sector as well, albeit that the sample size to determine these typical emission intensity will be based on the South African plant only. The benchmark could be set at the emissions per process unit weighted tonne in the base year. Over time, the relative performance as compared to this benchmark can be used as a basis for the tax-free emissions threshold.

An alternative could be to bring the process units of the GTL operations into the CWT approach that is already developed for refineries, but this would require detailed consultations with SOLOMONS who developed the weighing factors between process units on the basis of a global database with performance data of the relevant process units.

Based on our analysis, we therefore recommend exploring the possibility to develop a process unit weighted tonne approach specific for the South African GTL sector. We propose to develop such approach on the basis of the approach applied in the CWT approach for refineries, i.e. weighting of the individual process steps in the gas to liquid processes based on their emission intensity in a certain base period. Such South African specific approach, including also the share of the emissions that can be regarded as process emissions, can cover almost 100% of the emissions from this sector.

10.5 Proposed product benchmarking values and next steps

Based on the data available it is not possible to give any meaningful value for the different weighting factors of individual process units in the GTL sector and thus to give a meaningful indicative benchmark value if such an approach would be developed.

We recommend exploring with the sector whether a process unit weighted approach could indeed be developed for the South African GTL sector that would allow to adequately incorporate changes in the product mixes produced over time. For the development of such an approach, it could be worthwhile to discuss with SOLOMONS, who developed the benchmark methodologies for the refinery sector that formed the basis for the CTW approach, which steps are typically required to develop a similar approach to the GTL sector given their longstanding experience with benchmark approach for such sectors.

As with all sectors, defining the final benchmark values for the average performance of the South African GTL sector will ultimately require that these companies fully disclose to the relevant authorities their energy and emission data at a detailed process level.

11 Petroleum (CTL) sector

11.1 Introduction

11.1.1 Sector overview

The Sasol complex in Secunda is the world's only commercial coal-based synthetic fuels manufacturing facility (Coal to Liquids (CTL) facility). This technology converts syngas into synthetic fuel components, pipeline gas and chemical feedstock for the downstream production of solvents, polymers, co-monomers and other chemicals (Sasol, undated). There is a large overlap between the products manufactured in CTL, GTL, petroleum refineries, and the chemicals sector.

Sasol Synfuels' products include (Sasol, undated):

- Fuel components for the manufacture of automotive fuels, aviation jet fuel, illuminating paraffin and liquefied petroleum gas
- Ammonia
- Carbon products including green and calcined pitch/hybrid and waxy oil cokes
- Feedstock for the manufacture of ethylene, propylene, hexene, pentene, octene, detergent alcohols, phenol, solvents
- Krypton/xenon mixture
- Methane-rich gas
- Heavy refinery fuels for the manufacture of fuel oils
- Sodium sulphate
- Sulphur
- Wet sulphuric acid

Sasol is represented by the South African Petroleum Industry Association (SAPIA). Other members include BP, Chevron, Engen, PetroSA, Shell and Total.

The CTL facility in Secunda converts roughly 40 Mt of coal per annum into a 150,000 bbl/day of liquid fuels[14]. This accounts for roughly 21% of South Africa's liquid fuels production capacity (SAPIA, 2012). Table 29 provides a breakdown of the Sasol Synfuels production by CTL at Secunda.

[14] crude oil equivalent

Table 29: Sasol Synfuels product mix (thousand tonnes per year) (Sasol, 2013a)

Product	2013	2012	2011	2010	2009
Refined products	3,740	3,574	3,657	3,912	3,803
Heating fuels	652	680	607	620	621
Alcohols and ketones - feedstock	597	554	577	628	582
Other chemical feedstocks	1,737	1,647	1,576	1,562	1,468
Gasification products	574	558	530	517	501
Other products	143	155	141	141	128
Total synfuels production	**7,443**	**7,168**	**7,088**	**7,380**	**7,103**

11.1.2 Production process

Sasol's CTL process includes four main stages: gasification of coal to produce syngas, gas purification, Fischer-Tropsch synthesis and product workup.

Sasol sources its coal from 5 mines in Mpumalanga. This coal is crushed and blended to obtain an even quality distribution before it is fed into the CTL process. Electricity is used to convert the coal to syngas in the gasification process at temperatures of around 1,300°C. This electricity is produced from steam generated from coal and natural gas. In addition to syngas, gas-water and tar oil streams are produced during the gasification process. These products are refined into ammonia and various grades of coke (Sasol, undated).

The syngas is fed into two types of reactors – a circulating fluidised bed and Sasol's Advanced Synthol™ reactors. Depending on which reactor is used, different components are produced for making synthetic fuels as well as various chemicals (Sasol, undated). A simplified process flow diagram is presented in Annex 1.

11.1.3 Overview of sources of GHG emissions

The CTL process gives rise to the production of greenhouse gases from the production process as well as from electricity and steam production. The main source of *process* emissions is in the syngas production stage, resulting in the emissions of mainly CO_2 and H_2S (Jaramillo, et al., 2008; World Coal Institute, 2006). On-site steam is generated from the combustion of coal and natural gas, resulting in the main source of on-site stationary combustion emissions (Sasol, undated). Any additional electricity requirements are met by grid-based electricity, and hence emissions associated with this electricity generation occur off site.

The conversion of any feedstock to liquid fuels is energy intensive, but the CTL process is significantly more CO_2 intensive than conventional oil refining (World Coal Association, undated). In the overall CTL process, the maximum theoretical carbon efficiency is 52%, which suggests that 3 tonnes of CO_2 is produced for every tonne of product manufactured (Mulder, 2009). The overall CTL process has very limited potential for significant CO_2 reduction potential due to the nature of the process, although it needs to be recognised that new plants could achieve great efficiencies than older production facilities.

11.2 GHG emissions profile of CTL in South Africa

11.2.1 Data availability

The Sasol Synfuels facility at Secunda is currently the only CTL production facility in South Africa.

Sasol Synfuels refinery production data is provided for 2009 to 2013 in its annual Analyst Handbook (Sasol, 2013a) and scope 1 emissions are available for 2010 to 2013 from Sasol Annual reports (Sasol, 2010a; Sasol, 2011a; Sasol, 2013b). Fuel and process emissions are also provided for 2000 to 2010 from confidential DEA data. This data is however for Sasol CTL and GTL combined.

No scope 2 emissions and fuel/electricity consumption data is available, only Sasol South Africa data is available from CDP reports (Sasol, 2011c; Sasol, 2012b; Sasol, 2013c). Scope 1 emission intensity can be calculated from available data, but only for total production and not for specific products due to lack of disaggregated emission data.

11.2.2 Current emissions profile of the sector

Based on information contained in the public domain, an indicative, order of magnitude estimate of overall emissions and the split between fuel, process and electricity related emissions was estimated for CTL, while recognising that allocation within this sector is particularly challenging due to the wide variety of products and the linkages with petrochemicals. The numbers in the following table are for Sasol synfuels production only, and thus include any liquid fuels produced by Sasol via GTL, but excluded chemicals which are considered in the following section. This analysis allows for comparison to order of magnitude estimates for the other sectors, as well as to get an indication of the relative contributors of the individual sources to the overall emissions from the sector, although consultation with Sasol is critical to assess the accuracy of these numbers.

Table 30: Order of magnitude estimate of emissions from CTL (liquid fuels only) (Mt CO_{2e})

	CTL
Total emissions from sector	<47
Scope 1: process	24
Scope 1: fuel combustion	<20
Scope 2	>3

11.3 Existing benchmarks

There are no existing international benchmarks for CTL.

11.4 Applicability of international benchmarks in South Africa and proposed benchmarking approach

South Africa has the only commercial CTL facility in the world. As such, to our knowledge, there are no international benchmarking methodologies for CTL available. As with other refineries the product mix is complex and can change, which makes defining a product benchmark complex. The CTL process is similar to the refinery sector in the sense that there are multiple links between the inputs used and the (shares of) the various outputs of the processes. As such, developing a true product benchmark approach as recommended in Chapter 2 is difficult for sectors like this, which resulted in Europe to the choice to apply a more process specific benchmark approach.

Similar to the case of GTL industry, the approach taken in the CWT approach of weighting the various process units with their relative emission intensity can be useful for the CTL sector as well, albeit that the sample size to determine these typical emission intensity will be based on the South African plant only. The benchmark could be set at the emissions per process unit weighted tonne in the base year. Over time, the relative performance as compared to this benchmark can be used as a basis for the tax-free emissions threshold.

An alternative could be to bring the process units of the CTL operations into the CWT approach that is already developed for refineries, but this would require detailed consultations with SOLOMONS who developed the weighing factors between process units on the basis of a global database with performance data of the relevant process units.

Based on our analysis, we therefore recommend exploring, along with the sector, the possibility to develop a process unit weighted tonne approach specific for the South African CTL sector. We propose to develop such approach on the basis of the approach applied in the CWT approach for refineries, i.e. by weighting of the individual process steps in the coal to liquid processes based on their emission intensity in a certain base period. Such South African specific approach, including also the share of the emissions that can be regarded as process emissions, can cover almost 100% of the emissions from this sector.

11.5 Proposed product benchmarking values and next steps

Based on the data available it is not possible to give any meaningful value for the different weighting factors of individual process units in the CTL sector and thus to give a meaningful indicative benchmark value if such an approach would be developed.

We recommend exploring with SASOL whether a process unit weighted approach could indeed be developed for the South African CTL sector that would allow for the adequate incorporation of changes in the product mixes produced over time. For the development of such an approach, it could be worthwhile to discuss with SOLOMONS, who developed the benchmark methodologies for the refinery sector that formed the basis for the CTW approach, which steps are typically required to develop a similar approach to the CTL sector given their longstanding experience with benchmark approach for such sectors.

As with all sectors, defining the final benchmark values for the average performance of the South African CTL sector will ultimately require that these companies to fully disclose to the relevant authorities their energy and emission data at a detailed process level.

12 Chemicals

12.1 Introduction

12.1.1 Sector overview

A wide range of chemicals is manufactured in the South African chemicals sector. The companies include both dedicated chemical companies as well as petrochemical companies where chemical manufacturing is integrated with petroleum refining, coal-to-liquids and gas-to-liquids processes. The SIC codes relevant to products from the chemicals sector are presented in Annex 1.

As the approach to benchmark development in the chemicals sector is still to be determined, including whether it will be product- or process-based, and due to the vast number of products and different production processes in South Africa as well as a lack of industry-wide energy and emissions data, a method was required to shortlist the chemicals for consideration here. To this end, the chemical products identified in the EU ETS benchmarks were used as an initial filter to assist in identifying South African chemical manufacturers that might be included under the carbon tax (Directorate, European Commission, 2011). These chemicals contribute most to the total emissions of the chemical industry according to EU data:

- Adipic acid
- Ammonia
- Aromatics
- Carbon black
- Ethylene glycol
- Ethylene oxide
- Hydrogen
- Methanol
- Nitric acid
- Phenol/ acetone
- S-PVC
- Soda ash
- Steam cracking (high value chemicals)
- Styrene
- Vinyl chloride monomer (VCM)

A list of companies that manufacture these chemicals in South Africa was obtained from the Chemissa website database[15]. This database provides information on the chemicals sector in

[15] http://www.caia.co.za/chemissa/companies.php

Southern Africa including contact details, subsidiaries and other related companies and chemicals that are manufactured, imported and exported (Chemissa & CAIA, 2014).
Table 31 lists the companies that manufacture and/or import or export the products identified above. Chemicals that are imported or exported are marked with an asterisk in the table. Companies that only import or export chemicals were not considered further. It is noted that no manufacturers of adipic acid or soda ash in South Africa were identified.

Table 31: South African manufacturers of energy intensive products

Company	Product
AEL Mining Services (Division of AECI Group)	Nitric Acid
AECI (Speciality Chemicals) (Division of AECI Group)	Ammonia, Aromatics, Ethylene glycol*, Methanol, Nitric Acid, Phenol/Acetone, Soda ash*
African Oxygen Limited (Afrox)	Hydrogen, Methanol
Air Products	Ammonia, Ethylene oxide, Hydrogen, Methanol, Steam Cracking (High value chemicals), Vinyl chloride monomer (VCM)
Algorax (Pty) Ltd t/a Orion Engineered Carbon	Carbon Black
Carst & Walker (Pty) Ltd	Aromatics*, Carbon Black*, Styrene*
Chemetall (Pty) Limited	Polyvinyl chloride
Chemfit Ind. Holdings (Pty) Limited	Aromatics*, Phenol/Acetone*, Polyvinyl chloride*, Vinyl chloride monomer (VCM)*
Chemimpo SA (Pty) Ltd	Aromatics*, Carbon Black*, Polyvinyl chloride*, Steam Cracking (High value chemicals)*, Styrene*, Vinyl chloride monomer (VCM)*
Chemplast Marc Etter (Pty) Ltd (Quadrant Chemplast)	Polyvinyl chloride, Steam cracking (High value chemicals)
CJ Petrow Chemicals & Spices	Adipic acid*, Aromatics*, Ethylene glycol*, Manganese dioxide*, Methanol*, Phenol/ acetone*, Soda ash*, Steam cracking (High value chemicals)*, Titanium dioxide*
Dow	Manganese dioxide, Nitric Acid
Engen Limited	Aromatics
Industrial Distillers & Refiners	Aromatics, Phenol/Acetone
Merck (Pty) Limited	Adipic Acid*, Ammonia*, Aromatics*, Ethylene glycol*, Methanol*, Nitric Acid*, Phenol/Acetone*, Styrene*, Titanium dioxide*
NCP Chlorchem	Chlorine, Sodium hydroxide (caustic soda), Chlor alkali derivatives, Sodium hypochlorite
Omnia	Adipic Acid*, Ammonia*, Aromatics*, Ethylene glycol*, Methanol*, Nitric Acid, Phenol/Acetone*, Soda ash*, Styrene*
Sasol Polymers	Polyvinyl chloride Vinyl chloride monomer (VCM)
Sasol Solvents (Methanol is a co-product of Sasol wax production process)	Methanol
Sasol Merisol (international)	Aromatics ,Ethylene glycol, Phenol/Acetone
Sasol Infrachem	Hydrogen (low purity)
Sasol Nitro	Ammonia, Nitric Acid
Sasol Olefins and Surfactants (international)	Ethylene oxide
T & C Chemical Ind (Pty) Ltd	Aromatics, Carbon black, Ethylene, Hydrogen, Steam cracking (High value chemicals)

*Chemicals not manufactured in South Africa; imported and distributed.

In addition to the companies identified from the Chemissa database, further companies that give rise to either significant energy related or process emissions were identified through the consultants' own experience. Companies not already included in Table 31 are shown in Table 32, together with the main chemicals they manufacture.

Table 32: Additional chemical manufacturers in South Africa with significant process or energy-related emissions

Company	Product
Delta EMD (Pty) Ltd[16]	Electrolytic manganese dioxide (EMD)
Huntsman-Tioxide	Titanium-dioxide pigments
Karbochem Holdings (Pty) Ltd	Styrene-butadiene rubber
Safripol (Pty) Ltd	Polypropylene (PP), High Density Polyethylene (HDPE)
Sasol Polymers	Polypropylene (PP), Polyethylene (linear low density) (lldpe), Polyethylene (low density) (ldpe)
T & C Chemical Ind (Pty) Limited	Polypropylene (PP)

The following sections provide further information on the production processes used for the key chemicals, as well as the main manufacturers and their operating locations in South Africa.

12.1.2 Production processes and manufacturers: Ammonia (anhydrous)

Ammonia is produced via the Haber-Bosch process according to the following reaction equation:

$N_2 + 3H_2 \rightarrow 2NH_3$

This reaction is exothermic and no greenhouse gases are emitted directly. However, ammonia plants are typically integrated with hydrogen production, which is considered to be part of the ammonia production process. Hydrogen production is very energy- and emission-intensive. The production steps that precede the Haber-Bosch process are:

- production of synthesis gas (syngas, a mixture of hydrogen and carbon monoxide) via steam reforming or partial oxidation to generate hydrogen for the process;
- separation of nitrogen from air; and
- CO shift conversion to CO_2 and its capture.

More detail on the production processes is presented in Annex 1.

[16] According to their website (http://www.deltaemd.co.za/index.php/skills-development-and-training) Delta EMD will discontinue operation in 2014 and 2015. Therefore, the production of electrolytic manganese dioxide is not considered further here.

Table 33 lists dedicated ammonia manufacturers in South Africa, as well as their plant locations. Ammonia is also manufactured by ArcelorMittal as a by-product to the coke oven gas clean-up process, and by Sasol Synfuels as a by-product of the coal-to-liquid process.

Table 33: Ammonia producers in South Africa

Company	Location
AECI Speciality Chemical Cluster	Modderfontein
Air Products SA (Pty) Ltd	Manufacturing facility in Newcastle and Witbank
ArcelorMittal	Ammonia produced as a by-product of its coke oven gas cleaning plants in Newcastle, Vanderbijlpark and Pretoria
Sasol Infrachem (ammonia division of Sasol Nitro) and Sasol Synfuels	Sasolburg (natural gas) and Secunda (coal)

Grain SA's 2011 Fertilizer Report states that Sasol supplies most of the country's ammonia, with some produced by ArcelorMittal, while the rest of the ammonia demand is met by imported product (Grain SA, 2011). It is inferred that production by AECI Speciality Chemicals and Air Products SA is at a smaller scale.

12.1.3 Overview of sources of GHG emissions: Ammonia (anhydrous)

The production of ammonia results in both process emissions and emissions as a result of heat and steam generation. CO_2 is a product of the steam reforming process for the production of syngas. The necessary heat for the steam reforming process is generated by combustion of a part of the feedstock, which also results in CO_2 emissions. For Sasol this feedstock is natural gas. A requirement for electricity inputs is also seen.

In some ammonia plants globally the CO_2 is captured from the process gas and used as feedstock for urea production. The total CO_2 emissions from ammonia plants with downstream urea plants are therefore lower than those without urea plants. There are, however, no urea production facilities in South Africa.

12.1.4 Production processes and manufacturers: Aromatics

Benzene, Toluene and Xylenes (ortho, meta and para) are the basic aromatic intermediates used for the manufacture of other chemicals. Reformate which is produced in unit processes known as reformers that are integral to refineries provides a large proportion of the overall aromatics production. Pyrolysis gasoline produced from steam crackers is a second source of aromatics. Aromatics can also be produced in coke oven operations, but this represents a minor fraction of aromatics production and is not identified as playing a role in the South African chemicals sector (Ecofys, 2009c). Annex 1 includes a process flow diagram of the production of the three main aromatics from catalytic reforming.

Table 34 lists the companies identified as producing aromatic chemical compounds in South Africa. As limited disaggregated production statistics are available it is not possible to determine market share.

Table 34: Companies producing aromatics and their plant locations

Company	Location
AECI Speciality Chemical Cluster	AECI has major sites in Johannesburg and Durban, with a number of smaller operations country-wide.
Engen Limited	Engen Refinery (Enref) is situated in Durban
Sasol Chemical Industries (Pty) Limited	Secunda and Sasolburg

12.1.5 Overview of sources of GHG emissions: Aromatics

The production of aromatics requires heat (or steam) and electricity, with the volumes required depending on the process route. Heat, and sometimes electricity, is typically generated on site, which results in direct combustion related CO_2 emissions. Purchased electricity carries with it indirect emissions. Due to the number of products and integration of the production processes into refineries, allocating emissions to specific products is complex. Therefore, no split between process emissions and combustion related scope 1 emissions is available without detailed data from industry.

12.1.6 Production processes and manufacturers: Carbon black

The production technologies available for the manufacture of carbon black are summarised in Table 35. From confidential data it appears as if the furnace black process is that used in South Africa.

Table 35: Carbon black manufacturing technologies

Chemical process	Manufacturing method	Main raw materials
Thermal-oxidative decomposition	Furnace black process Gas black process Lamp black process	Aromatic oils on coal tar basis or mineral oil, natural gas Coal tar distillates Aromatic oils on coal tar basis or mineral oil
Thermal decomposition	Thermal black process	Natural gas (or mineral oils)

For the production of carbon black, hydrocarbons are split into their constituent elements (hydrogen and carbon) by either a thermal or thermal-oxidative (partial combustion) process. The thermal-oxidative route is the predominant method used today, seeing as it is the most economical method with the hydrocarbons both serving as a source of heat and carbon.

The two carbon black manufacturers identified in South Africa are identified in the table below. It is noted that it is not clear if T&C Chemicals manufacture carbon black or are primarily involved in its trade.

Table 36: Carbon black manufacturers in South Africa

Company	Location
Algorax (Pty) Ltd t/a Orion Engineered Carbons	Carbon Black plant, Port Elizabeth
T & C Chemical Ind (Pty) Limited	Manufacturing facility in Gauteng, South Africa

12.1.7 Overview of sources of GHG emissions: Carbon black

Direct emissions arise from the carbon black production process as a result of the combustion of fuel (primary and secondary feedstock) and when the carbon-rich tail gas is burnt either for energy recovery or flared. In most installations in Europe the tail gas from the production process is utilised to produce steam, hot water or electricity for sale (Ecofys, 2009c).

Parameters like temperature and degree of quenching can be changed to get different grades of carbon black. The yield of carbon black, and thus energy consumption and specific carbon dioxide emissions, will vary from one facility to the next (Ecofys, 2009c).

12.1.8 Production processes and manufacturers: Ethylene oxide

Ethylene Oxide is a basic petrochemical and precursor to a number of solvents, amines, surfactants and related materials, as well as mono-ethylene glycol. Ethylene oxide is produced by direct oxidation of ethylene with air or oxygen (Ecofys, 2009c). After passing through the reactor, the reactor product has to be stripped of CO_2 and by-products in a scrubber, to a de-sorber to remove water and to stripping and distillation.

The Chemissa database identifies Air Products as a manufacturer of ethylene oxide in South Africa, with facilities in Newcastle and Witbank. However, production could not be confirmed due to the lack of available data on the company and its operations.

12.1.9 Overview of sources of GHG emissions: Ethylene oxide

In addition to energy related emissions associated with the purification steps and the cooling required for the reactor (as the process is exothermic), the ethylene oxide reaction gives rise to CO_2 as a by-product which is released to the atmosphere. Furthermore, other by-products produced in the reaction may be burned for energy recovery, giving rise to further CO_2 emissions. Emissions are also associated with feedstock supply, which in South Africa will be from Sasol and potentially crude oil refineries. The split between process emissions and combustion-related emissions requires additional data.

12.1.10 Production processes and manufacturers: Ethylene glycol

In the direct oxidation route, which is the most common route for producing ethylene glycol, ethylene oxide is first produced by oxidation of ethylene (see Section 12.1.8) in the presence of oxygen or air. The next step in the process is the hydrolysis of EO with water under pressure and in the presence of heat or a catalyst, which gives rise to an ethylene glycol and water mixture. This stream is fed to evaporators where the water is recovered and recycled. Fractional distillation under vacuum is used to separate the monoethylene glycol from diethylene and triethylene glycols (ICIS, 2007).

The Chemissa database identifies T&C chemicals as a manufacturer of ethylene glycol in South Africa. However, production could not be confirmed due to the lack of available data on the company and its operations.

12.1.11 Overview of sources of GHG emissions: Ethylene glycol

Energy related emissions are associated with supply of energy for the reaction (as it takes place at elevated temperatures), and with distillation. Emissions are also associated with feedstock supply, which in South Africa will be from Sasol and potentially crude oil refineries. The split between process emissions and combustion-related emissions in the South African context requires additional data, including an allocation of process emissions from CTL and GTL processes to downstream products.

12.1.12 Production processes and manufacturers: Hydrogen

Synthesis gas (syngas) is classified as a gas mixture consisting of anything from pure CO to pure H_2; an average syngas product has a H_2:C ratio of 1.8 (Ecofys, 2009c). Syngas/H_2 is manufactured by steam reforming or partial oxidation processes, which are similar to the initial step in ammonia production, as described in Section 12.1.2 (Ecofys, 2009c).

There are manufacturers both in the chemical and refinery sectors producing syngas/H_2. The first three types of manufacturers are classified as part of the chemical sector:

- Captive within the chemical sector
- Gas producers supplying the chemical industry
- Gas producers supplying refineries
- Captive within the refinery sector

Table 37 identifies the companies involved in hydrogen production in South Africa.

Table 37: Hydrogen manufacturers in South Africa

Company	Location
African Oxygen Limited (Afrox)	Gas Equipment Factory, Germiston
Air Products SA (Pty) Ltd	Manufacturing facility in Newcastle and Witbank
T & C Chemical Ind (Pty) Limited	manufacturing facility in Gauteng, South Africa
Sasol	Secunda and Sasolburg

12.1.13 Overview of sources of GHG emissions: Hydrogen production

Refer to Section 12.1.2

12.1.14 Production processes and manufacturers: Methanol

In the Sasol process, methane is reacted with water to provide synthesis gas that consists of carbon monoxide and hydrogen. Although most of this gas is used for fuels and other products, a small percentage of the stream is diverted to a catalytic reactor to produce methanol, via the reaction (Cambray, 2007):

$$CO + 2H_2 \rightarrow CH_3OH$$

Sasol Solvents in Sasolburg is the primary producer of methanol in South Africa. The plant produces 140,000 tons per year of methanol as a co-product of its wax division. The Chemissa database identifies other manufacturers, but production could not be confirmed due to the lack of data.

12.1.15 Overview of sources of GHG emissions: Methanol

As with all of Sasol's processes, there are emissions associated with the entire process, and allocation to the various product streams needs to be considered. The steam reforming process gives rise to CO_2 emissions, and the methanol purge from the process contains hydrogen and methane as well as non-methane volatile organic compounds, which are typically burned for energy recovery (thus giving rise to CO_2 emissions) (IPCC, 2006). In addition, electricity is required to operate the process, which results in indirect emissions.

12.1.16 Production processes and manufacturers: Nitric acid

Two categories of nitric acid products are available, being weak acids of 30-65% HNO_3 by weight and strong acids which have 70% or more HNO_3 by weight. Strong acid is manufactured by concentrating weak nitric acid via an energy intensive extractive distillation process. The global market for strong acid covers only 10% of the total nitric acid market. As all strong acid production is done via an add-on to weak acid production, only weak acid production is described here.

The most common production process for nitric acid production is the Ostwald Process (see Annex 1 for the process flow diagram). It entails high-temperature catalytic oxidation of ammonia, nitric oxide oxidation and absorption (Ecofys, 2009c).

Nitric acid manufacturers identified by the Chemissa database are listed in Table 38.

Table 38: Nitric acid manufacturers in South Africa

Company	Location
AECI Specialty Chemical Cluster	
African Explosives Ltd	Two nitric acid plants at Modderfontein, Gauteng
Omnia	Two nitric acid plants in Sasolburg
Sasol Nitro	Major production facilities are at Bronkhorstspruit, Rustenburg, Sasolburg and Secunda, all in South Africa.

12.1.17 Overview of sources of GHG emissions: Nitric acid

Tail gas streams for the nitric acid production process contain NO, NO_2, N_2O, O_2, and H_2O, which are produced as by-products, depending on the process conditions. Of these, N_2O is a greenhouse gas. In the last few decades the combustion pressure for the reaction has increased from 1 to 5 bar, which has resulted in increased N_2O emissions (Ecofys, 2009c). Plant performance and greenhouse gas emissions are affected by a number of parameters including plant configuration, reactor pressure, reactor design, absorption chamber structure and type of catalyst. Due to these varying parameters, it is not easy to compare the performance of one plant to another. Emission mitigation techniques are also not applicable to all units (Ecofys, 2009c).

In South Africa, nitric acid production facilities have installed nitrous oxide abatement technologies, with funding through the Clean Development Mechanism. Omnia installed the EnviNOx® emissions mitigation technology at both its new and old nitric acid plants in Sasolburg. This technology eliminates 98% of greenhouse gas emissions, for which Omnia is receiving carbon credits. When the new plant is running at full capacity, waste steam from the production process piped through a turbine generates approximately 50% of the total electricity demand for the entire Sasolburg site (Omnia, undated). Sasol Nitro also sells carbon credits from the mitigation of N_2O emissions from their nitric acid plant to the order of 1 Mt CO_2eq per year (Louw, 2011). However, given that these emission reductions have been sold, the South African nitric acid industry cannot also be credited with these emission reductions. The Treasury Carbon Offsets Paper provides clarity on this issue in relation to the carbon tax.

12.1.18 Production processes and manufacturers: Phenol/acetone

The most widely process used for producing phenol and acetone is a two-step process known as the Hock process. The raw material for production is isopropylbenzene (otherwise known as cumene), which is made from benzene that has been alkylated with propylene, both feedstocks that have been obtained from crude oil and refined fuels. In the first step, the cumene is oxidised to form cumene hydroperoxide. The hydroperoxide is then concentrated and decomposed into acetone and phenol. After the reaction, the catalyst is removed and the solution is neutralised before high purity phenol and acetone are recovered by distillation. By-products that include alpha-methyl-styrene and acetophenone are sometimes recovered as useful products (Ecofys, 2009c).

The following companies produce phenol and acetone in South Africa.

Table 39: Phenol / acetone manufacturers in South Africa

Company	Location
AECI Speciality Chemical Cluster	AECI has major sites in Johannesburg and Durban, with a number of smaller operations country-wide.
Industrial Distillers & Refiners	Alrode, Gauteng
Sasol Chemical Industries (Pty) Limited	Secunda and Sasolburg

12.1.19 Overview of sources of GHG emissions: Phenol/acetone

Neither the production of cumene from benzene, nor the chemical reaction of conversion of cumene to phenol and acetone, gives off any direct process emissions. Energy requirements to achieve the temperatures and pressures required for the reaction, as well as for distillation of the products will, however, give rise to energy-related GHG emissions.

12.1.20 Production processes and manufacturers: Vinyl chloride monomer (VCM)

There are two ways to manufacture VCM from ethylene (which is obtained from cracking – see Section 12.1.24), being the direct chlorination method and oxychlorination method. Under the direct chlorination method, ethylene and chlorine (which has been obtained from electrolysis of salt) react within a catalyst-containing reactor to form an intermediate product called 1,2-dichloroethane (EDC). EDC is then thermally cracked to yield VCM at a few hundred degrees Celsius.

Hydrogen chloride produced as by-product from this reaction can then be further reacted with ethylene in the presence of catalyst and air (or oxygen) to produce further EDC, in what is called the oxychlorination process. VCM is then produced by dehydrating the EDC and thermally cracking it, together with the EDC from the direct chlorination process. These two methods are usually combined at the major VCM plants in Europe.

Sasol Polymers is the main supplier of VCM in South Africa. The Chemissa website (2014) suggests that Air Products also supplies VCM, although no evidence thereof could be found on the company's website.

12.1.21 Overview of sources of GHG emissions: Vinyl chloride monomer

CO_2 is produced as a by-product of the oxychlorination process, as well as in the flaring of unconverted ethylene from the process. Emissions are also produced from supply of energy required for electrolysis of salt, and for driving the remainder of the process (particularly for thermal cracking which takes place at temperatures of around 500°C and high pressures). Given the lack of data availability, together with the lack of information regarding process emissions allocated to the feedstock, it is not possible to determine the split between process emissions and energy related emissions for VCM.

12.1.22 Production processes and manufacturers: Polyvinyl chloride

The raw material for PVC production is the vinyl chloride monomer (VCM). In the most widely used production process, the raw material is pressurised and liquefied, and fed into a polymerisation reactor, which contains water and suspending agents. The VCM is mixed at high speed to obtain small particle sizes, before introducing an initiator for polymerisation, which occurs at 40 - 60°C under slight induced pressure. The PVC formed by this process is in a slurry which is then separated and processed to provide the PVC product in the form of a white powder. This powder is then heated and formed into a wide variety of products (PVC.org, n.d.). Alternative, although less widely used, processes for PVC production are bulk polymerisation and emulsion polymerisation (PVC.org, n.d.).

Sasol polymers is the main company producing polyvinyl chloride (PVC) in South Africa.

12.1.23 Overview of sources of GHG emissions: Polyvinyl chloride

The manufacture of PVC from VCM does not incur any direct process emissions, although electricity-related emissions will result from the energy used in heating and pressurising for the process. There are, however, emissions associated with manufacture of VCM as discussed in Section 12.1.20. Thus, for this process all scope 1 emissions will be from fuel combustion.

12.1.24 Production processes and manufacturers: High value chemicals

High value chemicals include acetylene, ethylene, propylene, butadiene, benzene and hydrogen that are all produced by breaking long-chain hydrocarbons into shorter-chain products. Ethylene is the product produced in the greatest volumes in the EU, and is the basic building block of about one third of all other petrochemicals.

Steam cracking is the primary route used globally to produce basic chemicals. In the EU ethylene, butadiene and most of the propylene demand is met by steam cracking. Two thirds of benzene demand is met from steam cracking, and the remainder from reforming (Ecofys, 2009c). Steam reforming is often used to provide hydrogen from natural gas. In steam cracking, the feedstock is mixed with steam and piped through furnace tubes at a temperature of 700°C to 900°C. The tubes are heated by burning fuel in external burners.

Choice of feedstock influences the product mix, specific energy consumption and specific CO_2 emissions. The lighter the feedstock, the higher the share of ethylene in the product mix (Ecofys, 2009c). In Europe naphtha is the most widely used feedstock, followed by gas oil and gaseous feedstocks including LPG and ethane.

In the Sasol process, however, which is the primary producer of these products in South Africa, ethylene and propylene are recovered as by-products of the Sasol Synfuels process which converts coal into liquids.

The companies shown in the Table below are the main producers of these products in South Africa.

Table 40: South African companies manufacturing high value chemicals

Company	Location	Products
Air Products SA (Pty) Ltd	Facilities all over South Africa	Acetylene
Sasol Polymers	Sasolburg and Secunda	Ethylene, propylene

The Chemissa website (2014) suggests that Air Products supplies a number of other gases such as ethylene, propylene, butadiene and hydrogen, although no evidence thereof could be found on the company's website.

12.1.25 Overview of sources of GHG emissions: High value chemicals

Steam cracking is an endothermic reaction and thus requires a supply of energy for steam generation and heating the process, giving rise to combustion-related CO_2 emissions. Process emissions are associated with feedstock supply and CO_2 released during the combustion for energy recovery or flaring of any light products from the process.

The Sasol Synfuels process is a significant source of greenhouse gas emissions, although as decisions need to be made as to how these emissions are allocated across products from the process. Therefore, it is not possible to provide a split between process emissions and combustion related scope 1 emissions for these products.

12.1.26 Production processes and manufacturers: Titanium dioxide

Titanium dioxide feedstock is the most important product from mineral sands, and is mostly used to produce white titanium dioxide pigment. Pigment can be produced by two different processes. The sulphate process is an older technology that can utilise lower-grade feedstock, and is the technology in operation in South Africa. It produces a lower grade of pigment and produces gypsum as a by-product. A newer technology, the chloride process, is cheaper and produces higher-grade pigments, but the access to the technological know-how is difficult (DMR, 2013; Tronox, 2012). A number of companies use the chloride process elsewhere in the world, including Tronox, one of the two companies mining in South Africa (Tronox, 2012).

Huntsman tioxide is the only producer of titanium dioxide identified in South Africa.

12.1.27 Overview of sources of GHG emissions: Titanium dioxide

The titanium dioxide production sulphate process does not give rise to process emissions. Process emissions arise upstream with the production of the titanium slag. This process is a significant consumer of various forms of energy including electricity, steam, gas and coal. Indicative energy use for the sulphate process (based on German production) is given in the table below. Given the lack of data availability as well as the unclear boundaries of the TiO_2 production vs. feedstock production, determining the split between process emissions and combustion related emissions is not possible without additional data.

Table 41: Indicative (minimum and maximum) energy consumption data for the sulphate production process of titanium dioxide (Federal Environmental Agency, 2001)

	TiO_2 manufacture	Follow up treatment	Acid concentration and filter salt decomposition	Total
Electrical energy (GJ/tonne)	1.5 – 2.31	0.6 – 1.46	0.13 – 1.3	
Steam (GJ/tonne)	3.7 – 7.7	6.7 – 10.47	0 – 5.07	
Gas (GJ/tonne)	7.3 – 11.85	2.37 – 4.22	0 – 0.1	
Coal (GJ/tonne)			5.8 – 8.5	
Total energy consumption (GJ/tonne)	12.6 – 20.5	9.9 – 14.3	5.93 – 15.17	32.7 – 40.9

12.1.28 Production processes and manufacturers: Styrene-butadiene rubber

There are two polymerization process routes for the production of styrene-butadiene rubber (SBR), being emulsion polymerization and solution polymerization. A flow diagram of the emulsion process is given in Annex 1. The main production step is polymerization of the styrene and butadiene raw materials which takes place in a series of reactors. After polymerization, the resulting emulsion (latex) is sent to flash tanks where unreacted butadiene is recovered, compressed and condensed and recycled back into the process. Following this, unreacted styrene is recovered in a steam stripping process. The pure latex product is either sent to storage tanks or is further processed through coagulation with dilute sulphuric acid and sodium chloride to produce a crumb product. Rinsing and dewatering, and drying steps follow to produce a saleble styrene-butadiene rubber crumb. The product from the emulsion process can either be in a granular solid form or in liquid form (latex).

Karbochem is a South African manufacturer of synthetic rubber (styrene-butadiene rubber) and latex with its plant located at Sasolburg. It is not clear if Karbochem also produce the raw materials styrene and butadiene, or if these are obtained from refining operations (e.g. Sasol). However, only the styrene-butadiene rubber production is described here, with the acknowledgement that styrene production, in particular, is energy intensive.

12.1.29 Overview of sources of GHG emissions: Styrene-butadiene rubber

The process emissions related to SBR production are typically VOCs as opposed to greenhouse gases. Energy is required in the form of heat and steam and for pumping. Thus it is assumed that all scope 1 emissions are associated with fuel combustion.

12.1.30 Production processes and manufacturers: Polymerisation of monomers (propylene and ethylene)

Polymerisation is the process by which monomer raw materials (ethylene and propylene) are combined to form long chain like structures or polymers. Polyethylene is produced in slurry phase reactors (either double loop or stirred tank reactors) or gas phase fluidised bed reactors or in a combination of both reactor types in series (Guichon Valves, 2011).

The companies involved in production of polypropylene and polyethylene in South Africa are identified in the following table.

Table 42: Additional chemical manufacturers in South Africa with significant process or energy-related emissions

Company	Product
Safripol (Pty) Ltd	Polypropylene (PP) High Density Polyethylene (HDPE)
Sasol Polymers	Polypropylene (PP) Polyethylene (linear low density) (lldpe) Polyethylene (low density) (ldpe)
T & C Chemical Ind (Pty) Limited	Polypropylene (PP)

Sasol is the source of raw materials (through their CTL and GTL processes) and are also involved in the production of polymers as well as supply of monomers to other companies.

12.1.31 GHG emissions: Polymerisation of monomers (propylene and ethylene)

The polymerisation process is energy intensive, although less so than other upstream production processes in the chemicals value chain. However, the volume of polymers produced can mean that the sub-sector is a significant emitter due to scale. Historically the process took place at high temperatures and pressures, but newer processes employ catalysts that have reduced the required energy input. There are no process emissions associated with polymerisation. There is no information on the technologies employed in South Africa or their energy requirements. It is noted that feedstocks, where derived from Sasol, will be associated with process emissions from the CTL/GTL process. Allocation is thus required to determine the split between process and combustion emissions for these chemicals.

12.2 GHG Emissions profile of the chemicals sector in South Africa

12.2.1 Data availability

As noted in the introduction, the sector is characterised by an extensive lack of process-specific data. What data is available is summarised below for each of the chemicals identified. A tabular representation of the data gap analysis and the data referred to here being presented in Annex 2.

12.2.1.1 Ammonia

The DEA supplied confidential process emission data (CO_2 and CH_4) for the ammonia manufacturing industry for 2000-2010.

In terms of company specific production data, Sasol Nitro reports only its global ammonia production for 2009-2012, but not that produced in South Africa (DMR, 2013). No production data is available for AECI.

AECI reports the electricity consumption for its South African Special Chemicals Cluster for 2012 only (AECI, 2013). No fuel consumption data is provided for either Sasol Nitro or AECI. Sasol Nitro only reports its global scope 1 emissions for 2010-2011 from the Sasol annual reports (Sasol, 2010a; Sasol, 2011a; Sasol, 2013b) and AECI reports both the scope 1 and 2 emissions for its South African Chemical Cluster for 2010-2012 in their CDP report (AECI, 2013).

No emission intensity data is available. Furthermore, it is not possible to determine the split between process emissions and combustion emissions based on available data and without an allocation of upstream process emissions to products.

12.2.1.2 Aromatics

The global sales volumes for Sasol's Merisol Division are available for 2009-2012 from Sasol's Analyst Book (Sasol, 2013a). There is no specific production data available for Engen's refinery (Enref) or for the AECI Speciality Chemicals Cluster.

The total refinery energy consumption is available for Enref for 2008-2011 from Engen 's Sustainability Report (Engen, 2011). AECI reports electricity consumption for its entire South African Special Chemicals Cluster for 2012 only (AECI, 2013).

The scope 1 emissions of Engen's refinery are available for 2008-2011 (Engen, 2011) and AECI reports both the scope 1 and 2 emissions for its South African Chemical Cluster for 2010-2012 in their CDP report (AECI, 2013).

No emission intensity data is available nor can it be calculated from available data.

12.2.1.3 Carbon black

The DEA supplied confidential production and process emission data for the carbon black manufacturing industry for 2000-2010.

The only company specific data available for carbon black manufacturing in South Africa is the production capacity for Algorax (Pty) Ltd t/a Orion Engineered Carbon (SA Plastics, 2010).

12.2.1.4 Ethylene oxide

The total global sales and production data is available for Sasol's Olefin and Surfactant Division from Sasol's Analyst Book and Annual Reports (Sasol, 2010a; Sasol, 2011a; Sasol, 2013b; Sasol, 2013a).

The scope 1 emissions for Sasol's Olefin and Surfactants Division are reported for 2009-2013 on the same level as the production data (Sasol, 2010a; Sasol, 2011a; Sasol, 2013b).

No emission intensities are, however, reported.

12.2.1.5 Ethylene glycol

The global sales volumes for Sasol's Merisol Division are available for 2009-2012 from Sasol's Analyst Book (Sasol, 2013a). No further energy or emissions data is available.

12.2.1.6 Hydrogen

The total global production data is available for Sasol Infrachem for 2009-2012 from Sasol's Analyst Book (Sasol, 2013a). This is not disaggregated to South African operations and in addition no disaggregated energy or emissions data is available.

Both the electricity consumption and scope 1 and 2 emissions data are available for African Oxygen Limited (Afrox) for 2010-2012 (Afrox, 2012). However, production is not noted and thus it is not possible to determine energy or emission intensities.

12.2.1.7 Methanol

The total global methanol sales and production figures are available for Sasol Solvents for all years (2009-2013) from Sasol's Analyst Book and Sasol Annual Reports (Sasol, 2010a; Sasol, 2011a; Sasol, 2013a; Sasol, 2013b).

Electricity consumption data is available for African Oxygen Limited (Afrox) for 2010-2012 from Afrox annual report (Afrox, 2012) and the AECI for its entire South African Special Chemicals Cluster for 2012 only (AECI, 2013).

Sasol Solvents reports only its global scope 1 emissions for 2009-2013 data in the Sasol annual reports (Sasol, 2010a; Sasol, 2011a; Sasol, 2013b). Scope 1 and 2 emissions are available for African Oxygen Limited (Afrox) for 2010-2012 from Afrox annual report (Afrox, 2012) and the AECI Special Chemicals Cluster for 2010-2012 from the CDP reports (AECI, 2011; AECI, 2012; AECI, 2013).

No data on emission intensities are available.

12.2.1.8 Nitric acid

The DEA supplied confidential production and process emission data (N2O) for the nitric acid manufacturing industry for 2000-2010. Sasol Nitro's global production is provided in Sasol's Analyst Handbook for 2009-2012 (Sasol, 2013a).

The Omnia Group provides only its total energy consumption for 2010-2013 in its annual reports (Omnia, 2011; Omnia, 2012; Omnia, 2013), but does not disaggregate into the divisions. Electricity consumption is available for AECI for its entire South African Special Chemicals Cluster for 2012 only (AECI, 2013).

Sasol Nitro reports only its global scope 1 emissions for 2010-2011 in the Sasol annual reports (Sasol, 2010a; Sasol, 2011a; Sasol, 2013b). Scope 1 and 2 emissions are available for African

Explosives Limited (AEL) for 2010 from AECI's CDP report (AECI, 2011) and for the AECI Group for 2010-2012 from CDP reports (AECI, 2011; AECI, 2012; AECI, 2013).

No data on emission intensities is available.

12.2.1.9 Phenol/ acetone

Sasol Merisol's global production is provided in Sasol's Analyst Handbook for 2009-2012 (Sasol, 2013a).

Electricity consumption data is available for AECI for its entire South African Special Chemicals Cluster for 2012 only (AECI, 2013). Scope 1 and 2 emissions are available for the AECI Group for 2010-2012 from CDP reports (AECI, 2011; AECI, 2012; AECI, 2013).

No data on emissions intensities are available.

12.2.1.10 Vinyl chloride monomer (VCM)

Sasol Polymers global sales and production data is available for 2009-2012 in Sasol's Analyst Handbook and Annual Reports (Sasol, 2010a; Sasol, 2011a; Sasol, 2013a; Sasol, 2013b).

No fuel or electricity data associated with VCM production is available. The global scope 1 emissions are available for Sasol Polymers for 2009-2013 from Sasol Annual Reports (Sasol, 2010a; Sasol, 2011a; Sasol, 2013b). However, as expected, no allocation to products is presented and no product specific emission intensities are available.

12.2.1.11 S-PVC

Sasol Polymers global sales and production data is available for 2009-2012 in Sasol's Analyst Handbook and Annual Reports (Sasol, 2010a; Sasol, 2011a; Sasol, 2013a; Sasol, 2013b).

No fuel or electricity data associated with S-PVC production is available.

The global scope 1 emissions are available for Sasol Polymers for 2009-2013 from Sasol Annual Reports (Sasol, 2010a; Sasol, 2011a; Sasol, 2013b). However, as expected, no allocation to products is presented and no product specific emission intensities are available.

12.2.1.12 Steam cracking (high value chemicals)

No data is available.

12.2.1.13 Titanium dioxide

No data could be found relating to Huntsman Tioxide operations. Confidential DEA data is available on the process emissions associated with titanium dioxide production for 2000 to 2010, but the associated production figures are not provided.

12.2.1.14 Styrene Butadiene Rubber

The only available data for Karbochem is the 2011 capacity of styrene, pure acrylics and carboxylated styrene butadiene latices of 35,000 tonnes (Bus-Ex, 2011).

12.2.1.15 Polymer production

For Safripol, the only data available is an undated production capacity listed on the company website of 115,000 tonnes and 160,000 tonnes of polypropylene and polyethylene respectively (Safripol, undated).

Sasol Polymers global sales and production data is available for 2009-2012 in Sasol's Analyst Handbook and Annual Reports (Sasol, 2010a; Sasol, 2011a; Sasol, 2013a; Sasol, 2013b).

No fuel or electricity data associated with polymer production is available.

The global scope 1 emissions are available for Sasol Polymers for 2009-2013 from Sasol Annual Reports (Sasol, 2010a; Sasol, 2011a; Sasol, 2013b). However, as expected, no allocation to products is presented and no product specific emission intensities are available.

12.2.1.16 Other chemicals

NCP chlorchem is identified as a South African chemicals company with significant energy use and emissions. It produces chlorine, caustic soda, chlor alkali derivative and sodium hypochlorite. No data on capacities, production, energy use or emissions could be sourced for this company.

12.2.2 Current emissions profile of the sector

Ascertaining the overall emissions, and emissions by source (fuel, process, electricity) is very difficult for this sector given the wide range of products and number of producers. However, a large contribution to emissions from this sector can be attributed to petrochemicals production. It is also noted that a number of large emitters (e.g. fertiliser manufacturers) have installed abatement technologies to reduce process emissions, with credits being sold on the CDM markets. The table below presents some indication of the volume of process, fuel and electricity emissions from this sector, associated largely with petrochemicals production via the Sasol CTL/GTL process.

Table 43: Order of magnitude estimate of emissions from chemicals (Mt CO_{2e})

	Chemicals
Total emissions from sector	unknown
Scope 1: process	>22
Scope 1: fuel combustion	>>18
Scope 2	>>4

12.3 Existing benchmarks

The benchmarks available for the chemical sector are as shown in the table below, and are all product specific. These benchmarks are reviewed in detail in Annex 3.

Table 44: Product benchmarks available in other cap and trade systems and key studies.

Benchmark	Products covered
EU ETS	Nitric Acid, Ammonia, Adipic Acid, Hydrogen, Synthesis Gas, Soda ash, Aromatics, Carbon Black, Phenol/Acetone, Ethylene oxide (EO)/Ethylene glycols (EG), S-PVC, Styrene, Vinyl chloride monomer (VCM), Steam Cracking (High value chemicals)
California Cap-and-Trade	Nitric Acid, Calcium Ammonium Nitrate Solution, Mining and Manufacturing of Soda Ash and Related Products, Gaseous Hydrogen Production, Liquid Hydrogen Production
Australian Carbon Pricing Mechanism	Production of methanol, Production of carbon black, Production of ethane (ethylene), Production of sodium carbonate (soda ash) and sodium bicarbonate, Production of ammonium nitrate, Production of ammonia, Production of white titanium dioxide pigment, Production of polyethylene
World Best Practice Energy Intensity Benchmarks	Ammonia: Haber-Bosch process, natural gas feedstock in steam reforming for synthesis gas production Ammonia: Haber-Bosch process, coal feedstock for synthesis gas production Ethylene (and other high value chemicals): Ethane cracking Ethylene (and other high value chemicals): Naphtha cracking
UNIDO Global Industrial Energy Efficiency Benchmarks	High value chemicals, ammonia and methanol for Selected industrialized countries, Selected developing countries, Global average, Best available technology, and International benchmark

12.4 Applicability of international benchmarks in South Africa and proposed benchmarking approach

A number of international product benchmarking approaches could be applicable for South African chemical industry. However, a better understanding of the South African chemicals sector is required in order to establish which products are associated with large shares of emissions (scope 1 and scope 2). In Europe, ultimately a product category list was used that covered approximately 80% of the sector's emissions which is well in line with the criteria developed in Chapter 2 to develop a product benchmark approach for a large share of the sectors' emissions.

Given the importance of the sector in terms of overall emissions, we proposed following the European approach and to develop benchmarks for the products in South Africa that are responsible for the largest share of the emissions of the sector in such a way that the product benchmarks cover the majority (e.g. 80%) of emissions of the sector. Experience in the EU ETS made clear that the 80% coverage can be achieved with a relatively limited number of product benchmarks (typically less than 20). For the remaining emissions, the fall-back approach can be applied.

A first data collection, together with the sector, could aim to determine the relative performance of the various products in the sector's emissions to ensure that the correct products and processes are considered for benchmarking. The list of products from the EU ETS in combination with the sector overview developed in this Chapter can serve as a starting point for discussion with the sector, but this list is unlikely to be fully representative in the South African context.

Once a list of products for which product benchmark are to be developed is established, use can be made of existing benchmark methodologies to set the exact methodological approach for determining scope 1 and scope 2 emissions for the various products. For some products, approaches used in the EU ETS and/or Australian scheme can be used, whereas for some other products, new methodologies need to be developed. Given the complexity of the chemical sector in terms of energy and carbon flows, it is recommended to take these steps in close consultation with the sector.

The overview of international benchmarks given in Table 44 gives insight on the availability of benchmark methodologies (i.e. system boundary descriptions etc.).

12.5 Proposed product benchmarking values and next steps

We recommend first developing a list of the most important products in terms of their contribution to the total greenhouse gas emissions of the sector, so that the product benchmark approach covers about 80% of the sectors emissions. Given that this selection can not currently be made, giving indicative benchmark values is of little use. Once the list of products is established in close consultation with the sector, the internationally available benchmarks can be used as first proxy value for the South African benchmark values to be expected.

As with all sectors, defining the final benchmark values for the average performance of the South African companies producing the various products will then require that these companies fully disclose to the relevant authorities their energy and emission data at a detailed process level.

13 Pulp and paper

13.1 Introduction

13.1.1 Sector overview

The pulp and paper industry sector involves the production of virgin and recycled pulp and the subsequent production of a variety of paper and board products. Virgin pulp production is typically integrated with paper production. Stand-alone paper mills, that source pulp from local or international sources to produce specific paper products are also common.

The following products are manufactured in South Africa (Dept. of Labour, 2008):

- Pulp (chemical pulp, dissolving pulp, mechanical pulp, semi-chemical pulp);
- Printing and writing paper (uncoated paper, coated paper, newsprint and telephone directory paper, specialised cellulose mechanical and light weight coated paper);
- Packaging papers and board (liner board, fluting, Kraft wrapping and packaging, other wrapping papers, other Kraft paperboard and fibreboard); and,
- Tissue paper.

The local paper and pulp sector is typically highly integrated, with the major enterprises spanning the entire value chain owning plantation forests, pulp milling, and paper mills.

In South Africa, Sappi and Mondi are the only pulp producers, with a market share of 60% and 40% respectively. The total pulp production in 2005 was 2.69 million tonnes from Sappi's five pulp mills and Mondi's four mills (Pogue, 2008). The breakdown in terms of types of pulp is given below (Pogue, 2008):

- Chemical pulp: 59%
- Dissolving pulp (primarily exported and used in textile and chemicals industries): 22%
- Mechanical pulp (used to produce newsprint and magazine grade paper): 12%
- Semi-chemical pulp (used to produce linerboard, fluting and low-cost printing paper): 7%

Mondi and Sappi also dominate South Africa's paper milling capacity, together owning 87% of the total domestic paper milling capacity. There are few other companies with significant paper milling capacity for which details are provided in Table 45.

Table 45: Paper and pulp plants, mill types, and share of milling capacity in South Africa

Company	Plant	Mill type	Pulp milling capacity (% of total SA capacity)	Paper milling capacity (% of total SA capacity)
Mondi	Richards Bay	Integrated pulp and paper	40%	47%
	Durban	Paper		
Mpact (formerly Mondi Packaging SA)	Piet Retief	Integrated pulp and paper		
	Felixton	Integrated pulp and paper		
	Springs	Integrated pulp and paper		
Sappi	Saiccor	Integrated pulp and paper	60%	40%
	Ngodwana	Integrated pulp and paper		
	Stanger	Integrated pulp and paper		
	Tugela	Integrated pulp and paper		
	Sappi Refibre	Integrated pulp and paper		
	Enstra	Paper		
	Cape Kraft	Paper		
Nampak	Bellville	Paper	-	4%
	Verulem	Paper		
	Kliprivier	Paper		
	Rosslyn	Paper		
Kimberley-Clark	Enstra Mill (Gauteng)	Paper	-	2%
	Cape Town	Paper		
Gayatri Paper Mills	Germiston	Paper	-	2%
Lothlorien Group of Companies	Wadeville (Germiston)	Paper	-	1%
South African Paper Mills (Pty) Ltd	Durban	Paper	-	1%
Other paper mills	12 smaller mills	Paper	-	3%

Sources: (Mondi, 2013a; Mpact, 2011; Sappi, 2012a; Nampak, 2014; Kimberley-Clark SA, 2008; PRASA, undated; SA Paper Mills, undated; Pogue, 2008)

The South African paper and pulp sector is represented by 3 main organisations:

- Paper Recycling Association of South Africa (PRASA)
- Paper Manufacturers of South Africa (PAMSA)
- Technical Association of the Pulp and Paper Industry of South Africa (TAPPSA)

13.1.2 Production process

The production of pulp and paper can be divided into three main operations:

- Virgin pulp making
- Recovered paper processing
- Paper production

Depending on the production facility, these processes may be integrated in one installation. The main activities are supported by a number of associated activities such as power and steam generation, wood handling, water treatment, waste handling and storage handling of chemicals and converting paper into paper articles.

More detail on the production processes is presented in Annex 1.

13.1.3 Overview of sources of GHG emissions

The main sources of GHG emissions steps in pulp and paper production are as follows. The pulping process gives rise to the production of greenhouse gases (primarily CO_2, but also CH_4 and N_2O) through onsite fuel combustion, generation of electricity and by-products of the lime kiln (EPA, 2010). The key process emissions come as a by-product from chemical reactions that occur in the lime kiln, with additional emissions from onsite landfills (EPA, 2010). The main sources of on-site stationary combustion emissions are the combustion of fuel for the production of steam in the Kraft process, to fire the lime kiln and for the production of on-site electricity (Brown, et al., 1996). Additional electricity may also be supplied from the grid; which is often the case in South Africa, and hence emissions associated with this electricity generation occur off site.

The paper production process gives rise to the production of greenhouse gases through onsite fuel combustion and electricity generation. The *on-site stationary combustion* emissions are due to the combustion of fuel for the generation of steam, the generation of electricity, the use in Yankee cylinders and the dryers for coating. Similarly to the pulping process, if the electricity is not supplied by onsite fuel combustion, it may be supplied from the grid, and hence emissions associated with this electricity generation occur off site. Energy use in paper production is a function of the specific grade of paper manufactured and the fibre quality (Ecofys, 2009e).

13.2 GHG emissions profile of the pulp and paper sector in South Africa

13.2.1 Data availability

The following is a summary of the available data on production, energy consumption and greenhouse gas emissions from the pulp and paper sector in South Africa. A tabular representation of all the data that is referred to here is included in Annex 2 of this report.

Table 46: Pulp and paper data gap analysis

Data availability	Industry wide	Mondi and Mpact (formerly Mondi Packaging SA)	Sappi	Nampak	Kimberley-Clark	Gayatri Paper Mills	Lothlorien Group of Companies	South African Paper Mills (Pty) Ltd	Other paper mills
Emissions and energy consumption									
Scope 1 emissions (total)	No data available	Data available	Data available	Data available	No data available	No data available	No data available	No data available	No data available
Scope 1 emissions (fuel)	No data available	No data available	No data available	No data available	No data available	No data available	No data available	No data available	No data available
Scope 1 emissions (process)	No data available	No data available	No data available	No data available	No data available	No data available	No data available	No data available	No data available
Fuel consumption	No data available	Data available	Data available	Some data available	No data available	No data available	No data available	No data available	No data available
Scope 2 emissions	No data available	Data available	Data available	Data available	No data available	No data available	No data available	No data available	No data available
Electricity consumption	No data available	Data available	Data available	Data available	No data available	No data available	No data available	No data available	No data available
Production									
Product data	Some data available	Data available	Data available	No data available	No data available	No data available	No data available	No data available	No data available
Intensities									
Scope 1 emissions per tonne product	No data available	Can be calculated, but requires allocation to products	Can be calculated, but requires allocation to products	No data available	No data available	No data available	No data available	No data available	No data available

Data availability	Industry wide	Mondi and Mpact (formerly Mondi Packaging SA)	Sappi	Nampak	Kimberley-Clark	Gayatri Paper Mills	Lothlorien Group of Companies	South African Paper Mills (Pty) Ltd	Other paper mills
Scope 2 emissions per tonne product	No data available	Can be calculated, but requires allocation to products	Can be calculated, but requires allocation to products	No data available	No data available	No data available	No data available	No data available	No data available
Total emissions per tonne product	No data available	Can be calculated, but requires allocation to products	Can be calculated, but requires allocation to products	No data available	No data available	No data available	No data available	No data available	No data available

13.2.2 Current emissions profile of the sector

The split between direct and indirect emissions (associated with purchased electricity) varies between different facilities depending on how much energy generation happens on site, the fuel source utilised, and how much grid electricity is imported. Integrated pulp and paper mills can also be more energy efficient and therefore have lower emissions.

Based on information contained in the public domain and heuristics for the sector, an indicative, order of magnitude estimate of overall emissions and the split between fuel and electricity related emissions was estimated for the sector. This sector gives rise to negligible process emissions. The analysis presented here allows for comparison to order of magnitude estimates for the other sectors, as well as to get an indication of the relative contributors of the individual sources to the overall emissions from the sector. The outcomes of this assessment are shown in the following table.

Table 47: Order of magnitude estimate of emissions from the pulp and paper sector (Mt CO_{2e})

	Pulp and paper
Total emissions from sector	6
Scope 1: process	0
Scope 1: fuel combustion	4
Scope 2	2

13.2.3 Current activities surrounding own generation and energy recovery in the sector

The electricity/steam consumption ratio at paper mills enables efficient use of co-generation of heat and power (CHP) and CHP is therefore widely applied in the paper industry.

In South African operations, renewable energy accounts for 38% of Sappi’s energy requirements. The main source of renewable energy is black liquor, accounting for 95%, with the remainder being bark. Black liquor is used to generate on-site electricity and steam. Electricity generated can often be surplus to requirements. For example, Sappi’s Ngodwana mill in South Africa supplies electricity to the national grid (Sappi, 2012a; Sappi, 2012b).

Mondi reports that globally, renewable resources meet 57-58% of energy demand, while only 7% of total energy requirements are imported from the grid. Mondi also generates electricity, with plans to expand generation capacity that would result in approximately 27 MW available for export to the grid. Electricity generation is a mix of renewables and coal-based generation (Mondi, 2012b).

13.3 Existing benchmarks

For the pulp and paper sector, benchmarks are available from cap-and-trade schemes and from other best practice values for energy intensity. The wide range of products produced in the different production processes in this sector resulted in multiple benchmarks from various sources. All benchmarks obtained, which are presented in detail in Annex 3, are product specific. It is important to highlight the different choices made in the Australian carbon pricing mechanism and the EU ETS regarding the treatment of stand-alone and integrated pulp and paper mills. In the EU ETS, separate benchmarks are defined for three types of dry pulp, recovered paper pulp and six paper types, which were based on data from non-integrated mills. For integrated mills, the benchmark decision contains a provision on the further processed pulp being excluded from the calculations, but it is not entirely clear how this is done exactly in practice.

In the Australian carbon pricing mechanism, benchmarks for five paper types were developed which each consist of two sub-activities: wet pulp manufacturing (applying to integrated mills) and the paper making (applying to both integrated and non-integrated mills). In addition, a benchmark was developed for non-integrated dry pulp manufacturing. In Australia, the wet pulp benchmark does not distinguish between different types of pulp.

In California, finally, no pulp is produced and benchmarks are defined for four paper products.

13.4 Applicability of international benchmarks in South Africa and proposed benchmarking approach

The pulp and paper sector is difficult to benchmark given the variety of products produced and the different process configurations. A particular issue is integrated versus stand-alone paper production, which while potentially producing similar products, can have different emissions profiles. In our view, the methodology applied in Australia is best suited to deal with this complexity by defining separate benchmarks:

- Dry pulp production
- Wet recovered paper pulp
- Wet pulp in integrated processes
- Paper production

It should be noted that this approach is not consistent with the one-product, one-benchmark criterion as listed in Chapter 2, because it will result in different benchmarks for the same product that is produced in respectively an integrated mill or two stand-alone pulp and paper mills. Also it will result in different benchmarks for the same product produced by respectively virgin pulp and recovered paper.

For pragmatic reasons, we nevertheless propose following the Australian methodology and determine benchmarks for the four product types given above. Given the data availability, it is not possible to determine at this moment how many different types of dry pulp, wet pulp and paper need to be distinguished in the South African context. We recommend discussing this further with the sector. Given that none of the products is produced by more than one or two mills, it is likely that the methodology implies that basically for each mills a specific benchmark needs to be developed containing one or more of the main sub-product categories as listed above (i.e. wet pulp production and paper for integrated mills, dry pulp production for mills selling pulp and recovered paper pulp and paper production for mills using recovered paper). Over time, facilities can improve relative to this base year level, giving them a higher tax exemption threshold.

In doing so, the vast majority of the emissions could be covered by these benchmarks with possible fall-back approaches applied for downstream paper conversion processes and possibly also for smaller multi-purpose mills that can produce different types of paper via the same paper machine.

13.5 Proposed product benchmarking values and next steps

As a very first proxy, we list in Table 48, the (range of) benchmarks that apply in the Australian carbon pricing mechanism to give an indication of the typical benchmark values that can be expected when this approach is followed.

Table 48 Indicative benchmark values for the South African paper sector

Product Benchmark	Direct emissions (t CO_{2e} / t product)	Indirect emissions (t CO_{2e} / tonne product)	Indicative benchmark values (t CO_{2e} / tonne product)
Dry pulp production	0.873	0.404	1.277
Wet recovered paper pulp	0.0404	0.431	0.471
Wet pulp in integrated processes	0.130	0.448	0.578
Paper production	0.338 – 0.866	0.554 – 1.67	0.892 – 2.316

The benchmark values for direct emissions in the EU ETS are lower as compared to these values which is understandable given that these benchmarks are based on the top 10% most efficient installations, while the values in the Californian system are in the same order of magnitude.

In order to define the installation specific final product benchmark values for South Africa, detailed disaggregated data on GHG emissions for each product produced at each facility is needed.in the public domain does not allow for very accurate estimates for each of the sub-products distinguished above. However, very preliminary estimates for two stand-alone mills producing respectively market pulp and recovered paper based paper indicate that the emissions intensity of these mills are in the same order of magnitude as the values given above.

As a next step, it is first important to agree with the sector on the basic approach taken (i.e. distinguishing the four product categories as listed above). Next, it should be decided how many types of products should be distinguished under each of those categories in order to reflect differences in product types and product quality that result in differences in emissions intensity. The product lists for Australia (one pulp type, six paper types), California (four paper types) and Europe (3 pulp types, six paper types) can be a good starting point for those discussions.

As with all sectors, defining final benchmark values for the average performance of the South African companies producing the various products will then require that these companies fully disclose to the relevant authorities their energy and emission data at a detailed process level.

14 Sugar

14.1 Introduction

The sugar sector covers the production of sugar over the entire value-chain and includes the following activities:

- Juice extraction from cane (cane milling)
- Sugar production (refined and unrefined sugar)
- Molasses production
- Production of sugar syrups

In South Africa there are a total of 14 sugar mills, of which five produce their own refined sugar (known as “white-end” mills). On average, the South African sugar industry produces 1.84 million tonnes of saleable sugar per season (white, brown and raw sugar) (SASA, 2013). Table 49 shows the sugar mills, their owners and production for the 2011-2012 season.

Table 49: Sugar mills, mill types, and production for the 2011-2012 season

Company	Sugar Mill	Mill type	Sugar Production for 2011-2012 season (tonnes)
THS Ltd	Felixton	Raw sugar mill	193,440
	Amatikulu	Raw sugar mill	124,732
	Darnall	Raw sugar mill	89,408
	Maidstone	Raw sugar mill	79,048
	Durban	Central refinery	-
Illovo Sugar Ltd	Noodsberg	"White end" mills (incl. refinery)	113,138
	Eston	Raw sugar mill	122,165
	Sezela	Raw sugar mill	198,899
	Umzimkulu (closed)	Raw sugar mill	-
TSB Ltd	Malelane	"White end" mills (incl. refinery)	199,638
	Komati	Raw sugar mill	290,812
	Pongola	"White end" mills (incl. refinery)	128,426
Gledhow (Pty) Ltd	Gledhow	"White end" mills (incl. refinery)	107,791
UCL Company Ltd	Union (Dalton)	Raw sugar mill	67,506
USM (Pty) Ltd	Umfolozi	Raw sugar mill	127,139

Organisations representing the Sugar Industry in South Africa are:

- South African Sugar Association (SASA)
- Sugar Milling Research Institute (SMRI)
- South African Sugar Millers Association (SAGMA)

14.1.1 Production process

Sugar production consist of five main steps (Tongaat Hulett, 2014):

- Juice extraction from cane: In this step, the sugar cane is shredded and crushed and the resulting juice separated. A by-product from this step is bagasse (sugar cane stalks), which is used for on-site energy generation co-fired with coal or wood in boilers or exported to other users (e.g. pulp and paper industry).
- Purification of juice: This step involves heating and the addition of lime. A clarifier removes suspended matter to produce a clear juice.
- Crystal growth: The clear juice is concentrated in a series of evaporators to form a syrup. Seeded crystalline sugar is added to the syrup and the mixture is boiled to produce raw sugar crystals and molasses. Cooling results in formation of additional crystals.
- Separation of crystals from molasses: Separation of the raw sugar crystals is achieved in centrifuges, after which the crystals are washed to remove remaining molasses. The crystals are also dried in this stage before proceeding to refining.
- Sugar refining: Sugar refining involves dissolving the raw sugar, removing the colour through carbonation and ion exchange steps and recrystallisation.

A schematic of the sugar production process is included in Annex 1.

14.1.2 Overview of sources of GHG emissions

GHG emissions associated with sugar production are dominated by direct emissions from coal combustion in boilers (steam and power generation) and indirect emissions from purchased electricity use. The majority of South African mills use bagasse for electricity and steam generation, some mills more efficiently than others due to the surplus of bagasse. Due to the seasonality of the bagasse supply and the inefficiency of the mill boilers, coal and/or wood is typically used to supplement the boiler fuel (SMRI, 2012) and electricity is still purchased from the grid when required. Sugar production does not give rise to any material process GHG emissions.

14.2 GHG emissions profile of the sugar sector in South Africa

14.2.1 Data availability

The following is a summary of the available data on production, energy consumption and greenhouse gas emissions from the sugar sector in South Africa. A tabular representation of all the data that is referred to here is included in Annex 2.

Table 50: Sugar data gap analysis

Data availability	Industry wide	TSB Sugar Holdings (Pty) Ltd	Tongaat Hulett Sugar Ltd	Illovo Sugar Limited	Umfolozi Sugar Mill (Pty) Ltd	Gledhow Sugar Company (Pty) Ltd	UCL Company Ltd
Emissions and energy consumption							
Scope 1 emissions (total)	No data available	Some data available	Some data available	Some data available	No data available	No data available	No data available
Scope 1 emissions (fuel)	No data available	No data available	No data available	No data available	No data available	No data available	No data available
Scope 1 emissions (process)	No data available	No data available	No data available	No data available	No data available	No data available	No data available
Fuel consumption	Some data available	Some data available	Some data available	Some data available	Some data available	Some data available	Some data available
Scope 2 emissions	No data available	Some data available	Some data available	Some data available	No data available	No data available	No data available
Electricity consumption	No data available	No data available	No data available	No data available	No data available	No data available	No data available
Production							
Sugar	Data available	Data available	Data available	Data available	Data available	Data available	Data available
Intensities							
Scope 1 emissions per tonne product	No data available	No data available	Can be calculated	Can be calculated	No data available	No data available	No data available
Scope 2 emissions per tonne product	No data available	No data available	Can be calculated	Can be calculated	No data available	No data available	No data available
Total emissions per tonne product	No data available	No data available	Some data available	Some data available	No data available	No data available	No data available

14.2.2 Current emissions profile of the sector

The split between direct and indirect emissions (associated with purchased electricity) varies between different facilities depending on how much energy generation happens on site, the fuel source utilised, and how much grid electricity is imported. Based on information contained in the public domain and heuristics for the sector, an indicative, order of magnitude estimate of overall emissions and the split between fuel and electricity related emissions was estimated for the sector. This sector gives rise to negligible process emissions. The analysis presented here allows for comparison to order of magnitude estimates for the other sectors, as well as to get an indication of the relative contributors of the individual sources to the overall emissions from the sector. The outcomes of this assessment are shown in the following table.

Table 51: Order of magnitude estimate of emissions from the sugar sector (Mt CO_{2e})

	Sugar
Total emissions from sector	1
Scope 1: process	0
Scope 1: fuel combustion	0.7
Scope 2	0.3

14.2.3 Current activities surrounding own generation and energy recovery in the sector

Most sugar mills produce their own electricity and some also export electricity to the grid (Table 52). Electricity generation by mills can be increased by as much as a factor of five through interventions such as increasing efficiency of generation, improving the efficiency of the mill's steam production, and introduction of high efficiency generation using bagasse and sugarcane leaves. The use of bagasse for the production of electricity typically provides a supplementary product, and does not substitute the production of sugar (Conningarth Economists, 2013). However, the global sugar industry has seen a shift in recent years, as increasing quantities of sugarcane are used for renewable electricity generation and ethanol production (Tongaat Hulett Sugar, 2014).

Table 52: Global electricity generation from renewable sources by sugar manufacturers that operate in South Africa

Company	Description	Value	Units (GWh annum)	Year	Reference
Illovo Sugar Ltd	Renewable electricity	9,124	GWh	2012	(Illovo, 2013b)
Tongaat Hulett Sugar Ltd	Bagasse-based electricity	427	GWh	Apr 2012 - Mar 2013	(DMR, 2006a)
TSB Sugar Holdings (Pty) Ltd	Bagasse-based electricity exports to the grid	190	GWh	Jul 2011 - Jun 2012	Remgro Ltd (2013) CDP Disclosure

14.3 Existing benchmarks

The only publicly available energy or emissions intensity data for the sugar industry is from the UNIDO study. The data utilised is country specific data from Brazil, Thailand, and selected EU countries. The final energy intensity value given for industrialised countries is 5.9 GJ/tonne refined sugar (UNIDO, 2010).

14.4 Applicability of international benchmarks in South Africa and proposed benchmarking approach

The South African sugar industry is made up of three companies with multiple mills and three companies operating single mills. There is a mix of process configurations including integrated sugar mills with refineries, standalone mills and a standalone refinery. The sugar industry is also associated with significant biomass use for energy and electricity generation.

There are no applicable international benchmarking methodologies which can be used for the South African sugar industry. UNIDO energy intensity value for sugar industry represents other developing and developed countries and therefore can not be used in South Africa. Therefore, for sugar industry we propose developing a South African specific methodology (in terms of system boundaries etc) in close cooperation with the industry. Given that production process are likely to be similar for all types of mills, and that all mills produce either the intermediate raw sugar and/or the refined sugar as output, a methodology consisting of two product benchmarks might work out for this sector with the two product benchmarks being:

Raw sugar
Refined sugar

For the emissions of auxiliary processes and process not directly linked to the key production process, a fall-back approach could be developed. It should be noted, however, that it is difficult to draw very robust conclusions for this sector without a more detailed view on the emissions per sub-process etc. and as such it is also hard to estimate which part of the emissions would be covered by these product benchmarks. As an alternative, given also that the total number of emissions from this sector is relatively small, it could be considered applying the fall-back approaches to the total emissions of this sector.

A special point of attention are the scope 2 emissions related to electricity given that many sugar mills do generate on-site electricity which is partly also exported to the grid. It should be discussed with the stakeholders of the sugar industry which share of the electricity produced and consumed can be allocated to the raw and refined sugar production and how to account for the related emissions in line with the approaches suggested in Chapter 5.

14.5 Proposed product benchmarking values and next steps

For two producers, emissions intensity data is available. Illovo Sugar Ltd reports an emission intensity of 0.32 tonnes CO_{2e}/tonne sugar for 2012 and 2013 and Tongaat Hulett Sugar Ltd report value of 0.59 for 2013 and 0.62 tonnes CO_{2e}/tonne sugar for 2011 and 2013, with lower value of 0.31 tonnes CO_{2e}/tonne sugar in 2012 The UNIDO benchmark value of 5.9 GJ/tonne refined sugar multiplied by the weighted emission factor of 90.8 tCO_{2e} / TJ as defined in Table 5 would result in a benchmark value of 0.58 tCO_{2e} /tonne refined sugar. Based on this evidence, it can be expected that the benchmark for the final refined sugar product will be in the order of magnitude of 0.3-0.6 t CO_{2e} /refined sugar, but this includes the emissions related to the intermediate raw sugar production. It is not possible to give reasonable estimates for the two steps in the production separately.

As a next step, it is for this sector very important to discuss possible benchmark approaches with the sector in more detail by looking at similarities and differences in production processes and products produced. International experience is of little help in this respect as hardly any international benchmark methodologies could be found for this sector. As with all sectors, defining benchmark values for the average performance of the South African companies producing the various products will require that these companies fully disclose to the relevant authorities their energy and emission data at a detailed process level.

15 Conclusions

This study developed a benchmark approach for nine industrial sectors in South Africa that can be used to determine the applicable tax-free threshold under the proposed South African carbon tax. In Table 53, we provide an overview of the nine sectors in terms of the overall emissions and the contribution of scope 1, scope 2 and process emissions to this total based on the research into the characteristics of the sectors as conducted as part of this project. Based on information contained in the public domain and heuristics for each sector, an indicative, order of magnitude estimate of overall emissions and the split between fuel, process and electricity related emissions was estimated for each sector. More information can be found in the subchapters on current emission profiles for the sector. Insufficient information is available to provide a very accurate estimate, but the values as given provide some indication of the order of magnitude of the emissions from each sectors. While not definitive, these allow for some comparison to be made between the sectors and the different fuel sources.

Table 53: Indication of emissions from the different sectors included in the study

Sector	Total emission (Mt CO_2)	Scope 1 emissions : Process emissions (Mt CO_2)	Scope 1 emissions: Fuel combustion (Mt CO_2)	Scope 2 emissions (Mt CO_2)
Iron and steel	23	12	4	8
Ferro-alloys	>20	6	>2	>12
Cement	7	4	2	1
Petroleum (crude oil refineries)	3	Unknown	Unknown	Unknown
Petroleum (GTL)[1]	>2	>1	<1	<1
Petroleum (CTL)[2]	<47	24	<20	>3
Chemicals[3]	Unknown	>22	>18	>4
Pulp and paper	6	0	4	2
Sugar	1	0	0.7	0.3

[1] PetroSA
[2] Sasol CTL and GTL Petroleum
[3] Only SASOL CTL / GTL emissions allocated to chemicals

Based on international experiences, we conclude that where possible the approach for each sector should account for the majority of emissions based on product benchmarks. This will allow all companies to reduce emissions taking into account in the benchmark values. The design of the carbon tax further prescribes that the benchmarks should cover both direct scope 1 and scope 2 emissions, which provided further criteria used in the development of the approach per sector. For the emissions that cannot be covered via product benchmarks, it is proposed to apply the following generic fall-back approaches:

- An electricity consumption benchmark that is related to the South African grid electricity emission factor (an indicative value of 0.94 t CO_{2e}/ MWh has been derived based on 2009 – 2013 data) for the electricity consumed.
- A fuel benchmark that is related to the average fuel emission factor of the South African industry (an indicative value of 90.8 t CO_{2e}/TJ has been derived based on 2010 data) for the fuel used for production processes not covered by the product benchmarks.
- No benchmark approach for the limited number of process emissions that are not covered by a product benchmark.

The approach suggested means that for each company in the sectors studied, the tax-free emissions threshold is determined by comparing the actual greenhouse emissions with the benchmark greenhouse gas emission, which is based on a combination of applicable product benchmarks and fall-back approaches. A summary of the approach for each sector is provided in Table 54.

Table 54: Summary of benchmark approaches for South African Industry Sectors

Sector	Benchmark approaches	Indicative benchmark values (in t CO_{2e} / t product unless otherwise states) [1]
Iron and Steel	Product benchmark covering more than 80% of emissions:	
	- Coke	0.3 – 0.5
	- Sinter	0.2 – 0.3
	- Hot metal (from BF / BOF)	1.4 – 1.7
	- EAF (carbon steel)	0.6 – 0.7
	- EAF (high alloy steel)	0.6 – 0.7
	- Hot metal (COREX / MIDREX)	Cannot be determined at this stage
	Fall-back approaches for remainder of emissions. Approach based on benchmark methodology applied in the EU ETS, which can be used to define the benchmarks.	

Sector	Benchmark approaches	Indicative benchmark values (in t CO_{2e} / t product unless otherwise states) [1]
Ferroalloys	Product benchmark covering majority (>80%) of emissions: - Chromium alloys - Manganese alloys (7% C) - Manganese alloys (1% C) - Silicon alloys (assume 65% Si) - Silicon metal Fall-back approach for emissions not covered by product benchmarks. No international experiences, detailed benchmark definitions to be developed with the sector.	 3.25 – 4.55 3.25 – 4.55 3.75 – 5.25 9.7 15.7
Cement	Product benchmark covering at least 80% of the emissions: - Cement clinker Fall-back approach for emissions not covered by product benchmarks Benchmark definitions available from e.g. the EU ETS.	 0.85 – 1.10
Petroleum	Process specific approach covering virtually all emissions: - Complexity Weighted Tonne (CWT) Approach based on benchmark methodology applied in the EU ETS, which can be used as starting point for discussion with sector.	 0.0295 – 0.035 t CO_{2e} / CWT
Petroleum (GTL)	Process unit weighted tonne approach covering virtually all emissions. No international methodology available, methodology to be developed with the sector, CWT approach can be used as blueprint for the approach.	Cannot be determined at this stage

Sector	Benchmark approaches	Indicative benchmark values (in t CO_{2e} / t product unless otherwise states) [1]
Petroleum (CTL)	Process unit weighted tonne approach covering virtually all emissions. No international methodology available, methodology to be developed with the sector, CWT approach can be used as blueprint for the approach.	Cannot be determined at this stage
Chemicals	Product benchmark for most important products covering about 80% of the emissions. Fall-back approach for emissions not covered by product benchmarks. Product lists from Australia and EU ETS is good starting point for the definition of the list of products.	Cannot be determined at this stage
Paper and Pulp	Product benchmark approach covering the majority of emissions (>80%) consisting of the following sub-product groups: - Dry pulp production - Wet recovered paper pulp - Wet pulp in integrated processes - Paper production Fall-back approach for emissions not covered by product benchmarks Approach based on methodology applied in Australia carbon pricing methodology, further specification of product categories to be done with sector, likely to result in installation specific result.	0.8-2 for all products. Product list to be determined with the industry. 1.277 0.471 0.578 0.892 – 2.316

Sector	Benchmark approaches	Indicative benchmark values (in t CO_{2e} / t product unless otherwise states) [1]
Sugar	Discuss with sector whether product benchmarks for: - Raw sugar - Refined sugar Could cover the majority of the emissions of the sector. As an alternative, consider applying the fall-back approach to the emissions of this sector. No international experiences, detailed benchmark definitions to be developed with the sector.	Cannot be determined at this stage

[1] Benchmark values for South Africa can only be determined based on detailed installation-specific data. The indicative values given here only give an idea of the order or magnitude of the benchmark values that are likely to emerge from a detailed bottom-up data collection process. As such, the values given here should be regarded as indicative only. For an explanation on the sources used to arrive at those values, we refer to the sector chapters.

It should be noted that the benchmark values listed in Table 1able 54 are indicative values only based on a combination of international benchmark and South Africa data for products. The data available to this project and data collected by the South Africa National Treasury during this project has been either sector or company level. Although certainly useful to get a better view on the data situation of the sectors concerned, this data cannot one-to-one be used to derive benchmark values for individual products. For the development of such benchmarks, emissions data at the level of individual products is required. Nevertheless, the indicative values as presented above are good starting points for further discussion with the sectors.

As the next step in benchmark development, discussion of the findings of this study with the relevant industry stakeholders is recommended. Before further data is collected, it is recommended to decide first on the final benchmark approach for each sector. For some sectors (like cement), we expect this to be a relative simple process, while for others, it involves steps to determine which products to benchmark exactly (like chemicals) or the set-up of sector specific methodologies (such as for the GTL and CTL sectors). In this step, some key methodological choices that apply to all sectors need to be finalised, such as the choice for base years, the exact treatment of scope 2 emissions, whether or not benchmarks will be updated, and how certain specific issues such as the production and use of waste gases will be covered.

Once the benchmark methodologies are fully specified and defined, specific data requests can be send to the industries in order to collect the data needed for the calculation of the benchmark values. It is clear that support will be required to ensure that data is collected consistently across products and companies. Detailed data collection guidance will need to be developed given that emissions and energy use data need to be allocated to products rather than the company or operations. In addition, data on company emissions not covered by product benchmarks also needs to be collected. All system boundaries, and the treatment of special cases, need to be clearly defined. For some sectors the proposed benchmarking approach requires very specific unit operation data to be collected (e.g. for the CWT approach in refining) which will require collaboration with the industries in question. Given the sensitivity of some of this data in view of confidentiality and in view of the ultimate use for tax purposes, it is essential that all rules and procedures around this data collection and data verification are well defined and embedded in the further policy preparation.

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I Annex 1: Further information on individual sectors

This annex contains the following information:

- SIC codes for the activities covered by the different sectors included in this report, and additional product information where relevant.
- Further detail on production processes where additional information is required to that provided in the main body of the text, as well as all process flow diagrams.
- Further detail on typical GHG emission sources from the sector, including that information that is available on the split between direct fuel emissions, process emissions and electricity-related emissions. The analysis of what information is available in South Africa is included in Annex 2.

A.1.1. Iron and steel

A.1.1.1. Products from the sector

The range of activities and products that are included in the iron and steel sector, along with the relevant SIC codes, is provided in Table 55.

Table 55: SIC codes for coke making, sintering, and iron and steel manufacturing (Statistics South Africa, 2005)

1910	***Manufacture of coke oven products***
19100	Manufacture of coke oven products
19100	Operation of coke ovens
19100	Production of coke and semi-coke
19100	Production of pitch and pitch coke
19100	Production of coke oven gas
19100	Production of crude coal
19100	Production of lignite tars
19100	Agglomeration of coke
2592	***Treatment and coating of metals; machining***
25910	Powder metallurgy: production of metal objects directly from metal powders by heat treatment (sintering) or under pressure (for production of metal powder, see 2410, 2420)
2410	***Manufacture of basic iron and steel***
24101	Basic iron and steel industries; except steel pipe and tube mills
24101	Manufacture of basic iron and steel
24101	Operation of blast furnaces
24101	Operation of steel converters
24101	Operation of rolling mills

24101	Operation of finishing mills
24101	Production of pig iron and spiegeleisen in pigs, blocks or primary forms
24101	Production of ferro-alloys
24101	Production of ferrous products by direct reduction of iron and other spongy ferrous products
24101	Production of iron of exceptional purity by electrolysis
24101	Production of iron of exceptional purity by other chemical processes
24101	Production of granular iron
24101	Production of iron powder
24101	Production of steel in ingots
24101	Production of steel in other primary forms
24101	Remelting of scrap ingots of iron
24101	Remelting of scrap ingots of steel
24101	Production of semi-finished products of steel
24101	Manufacture of hot-rolled and cold-rolled flat-rolled products of steel
24101	Manufacture of hot-rolled bars of steel
24101	Manufacture of hot-rolled rods of steel
24101	Manufacture of hot-rolled open sections of steel
24101	Manufacture of steel bars and solid sections of steel by cold drawing, grinding or turning
24101	Manufacture of open sections by progressive cold forming on a roll mill or folding on a press of flat-rolled products of steel
24101	Manufacture of wire of steel by cold drawing or stretching
24101	Manufacture of sheet piling of steel and welded open sections of steel

Two broad categories of steel products are produced in South Africa, being carbon steel and stainless steel. Stainless steel is an alloy with a chromium content of at least 11%, as compared to carbon steel which has no minimum chromium content (Columbus, 2014a). The chromium in the product forms a chromium oxide (CrO) layer on the surface that prevents oxygen from reacting with the iron at the surface to form iron oxide or rust (Columbus, 2014a).

A.1.1.2. Production processes

Carbon steel is produced via three primary process routes in South Africa:

- Blast Furnace/Basic Oxygen Furnace (BF/BOF);
- Electric Arc Furnace (EAF) (which in some operations is coupled with a Direct Reduced Iron (DRI) furnace); and,
- COREX/MIDREX process (which is only used at the ArcelorMittal site in Saldanha).

The processes differ in terms of energy input and emissions, as well as in the quality of and uses for the products.

At integrated steel mills, BF/BOF steel is produced via the production of hot metal in a blast furnace (BF), followed by conversion of the hot metal to crude steel in a basic oxygen furnace (BOF) (**Error! eference source not found.**). The production process begins with the processes of coke making and sintering. Coke making involves the conversion of coal to coke by heating of coal in absence of air (or oxygen) to remove volatile components and other substances like tars, which are removed with the coke oven gas. During sintering, iron ores of different grain sizes are agglomerated with additives to produce a feed for the BF with improved permeability and reducibility. To produce hot metal, iron ore (sinter) is added to the furnace along with coke (which meets the majority of the energy demand for the process), and a variety of fluxes and other materials. Air is injected into the bottom of the furnace, and the burning coke raises furnace temperatures to over 2,000°C (US EPA, 2010; Stahl, undated). The coke generates heat and at the same time chemically transforms iron oxides in the ore into metal, and the molten metal product separates from the non-metallic mineral slag. Carbon-rich liquid metal is drawn off from the bottom of the furnace. This is treated in the BOF to burn off excess carbon, resulting in the production of raw steel. A relatively small quantity of scrap metal (typically 10 to 25%) is added to regulate furnace temperatures. No net input of energy is required for the process, and there is typically the opportunity for recovering energy from the BOF gas and steam.

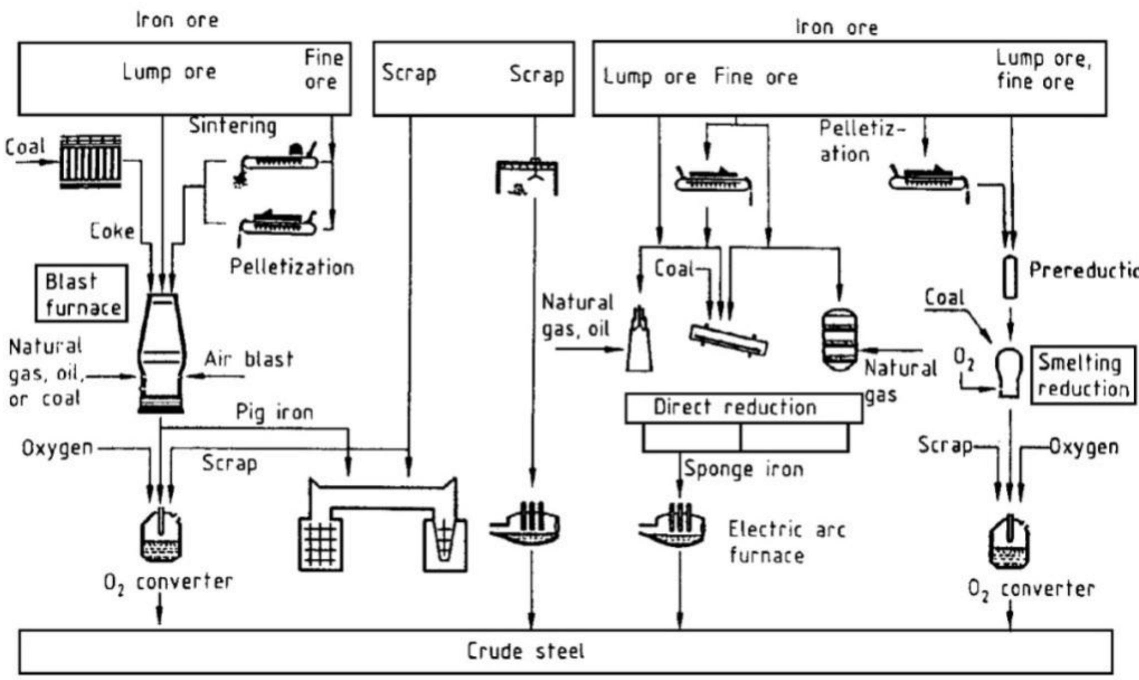

Figure 5: Crude steel production processes (Ullmann, 1999)

An Electric Arc Furnace (EAF) cannot produce steel directly from iron ore and requires a feed of recycled or scrap steel. The feedstock is converted to liquid steel through application of an electric current that is passed through the feedstock using electrodes. If sufficient scrap is not available, iron ore can be converted into metallic iron and used as an input for the EAF. This conversion is done via a direct reduction process, with the intermediate product often being referred to as "direct reduced iron (DRI)" or "sponge iron".

Finally, the COREX/MIDREX route is as shown in **Error! Reference source not found.**. In the IDREX process, iron oxides pellets or lump ores are converted into DRI in a gas-based shaft furnace process. The COREX plant uses a melter/gasifier to simultaneously produce hot metal and a by-product synthesis gas that feeds gas into the MIDREX Shaft Furnace. ArcelorMittal's Saldanha Works plant is the world's first application of coal gasification to produce DRI in a MIDREX Plant (Midrex Technologies, Inc. , 2012).

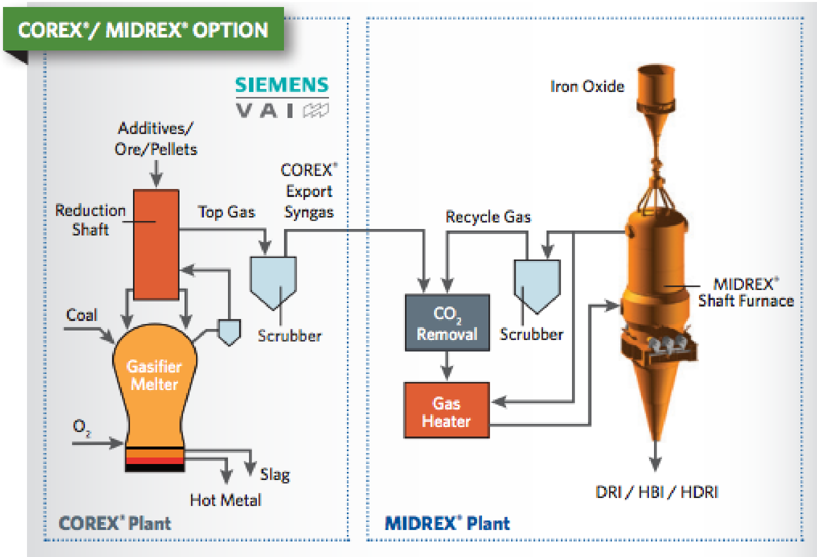

Figure 6: COREX/MIDREX production process (Midrex Technologies, Inc. , 2012)

In stainless steel production in South Africa, the inputs are first melted in an EAF to produce a molten metal, and further refined in an Argon-Oxygen Decarburiser (AOD) by blowing oxygen, argon and nitrogen into the molten steel (Columbus, 2014b). The refined product is then processed through a continuous casting machine to produce stainless steel slabs, with any surface defects removed via surface grinding (Columbus, 2014b).

Regardless of the processing route, semi- finishing of crude and stainless steel is typically conducted on-site using a continuous casting process. Finished end products are produced via various foundry, casting, hot and cold rolling and finishing steps. The latter includes annealing, pickling, coating, welding, etc. These products are either used directly (for example in construction) or are further processed in the manufacturing sector.

Table 56 provides the production capacity per production route for various companies in South Africa.

Table 56: Production capacities of South African iron and steel and stainless steel facilities (million tonnes per year) (Kumba Iron Ore, 2011; Columbus, 2013a)

Company/ plant/ region Capacity	EAF	Blast furnace	Midrex and Corex	Total
ArcelorMittal SA	0.4	4.9	1.3	6.6
Highveld Steel and Vanadium Corporation Ltd	-	1.0	-	1.0
Columbus Stainless	1.0	-		1.0
Scaw Metals	0.6	-	-	0.6
CISCO	0.3	-	-	0.3
DAV Steel	0.6	-	-	0.6
Total	2.9	5.9	1.3	9.1

A.1.1.3. Sources of GHG emissions from iron and steel production

The following is a summary of how the different processes give rise to direct CO_2 emissions. Emissions associated with off-site electricity generation are not included in this summary.

CO_2 emissions from coke production arise from the fuel used for under-firing. The fuel requirement and associated emissions can be reduced in integrated plants by utilising heat from the blast furnace gas in the production of coke. Fuel use for steam generation, which is needed for by-product plants and controlling the moisture of the coal, also gives rise to emissions.

In sinter production, CO_2 emissions originate from fuel use, recycling of residue materials and as process emissions from limestone calcination. In the blast furnace, CO_2 emissions arise from fuel use, as well as from the carbon in the coke and coal inputs that is transferred to the BF gas. **Error! eference source not found.** Figure 7 presents a schematic of the sources of emissions from a typical BF steel mill. The conversion of hot metal to crude steel in the basic oxygen furnace also leads to direct CO_2 emissions from fuel use. Finally, carbon contained in the hot metal feed to the basic oxygen furnace is transferred to BOF gas (Worrell, 2008).

In addition to CO_2 emissions, production of coke and hot metal in blast furnaces and basic oxygen furnaces gives rise to high volumes of waste gas containing partially oxidised carbon. The gas includes carbon monoxide (CO) and waste gases from coke oven plants, some methane (CH_4) and hydrogen (H_2). These streams are typically not directly emitted to the atmosphere but are recovered and used for electricity production, for blast furnaces stoves, for under-firing of coke oven plants, ignition of sinter stands and furnace reheating (Worrell, 2008). If not recovered, these waste gases are flared.

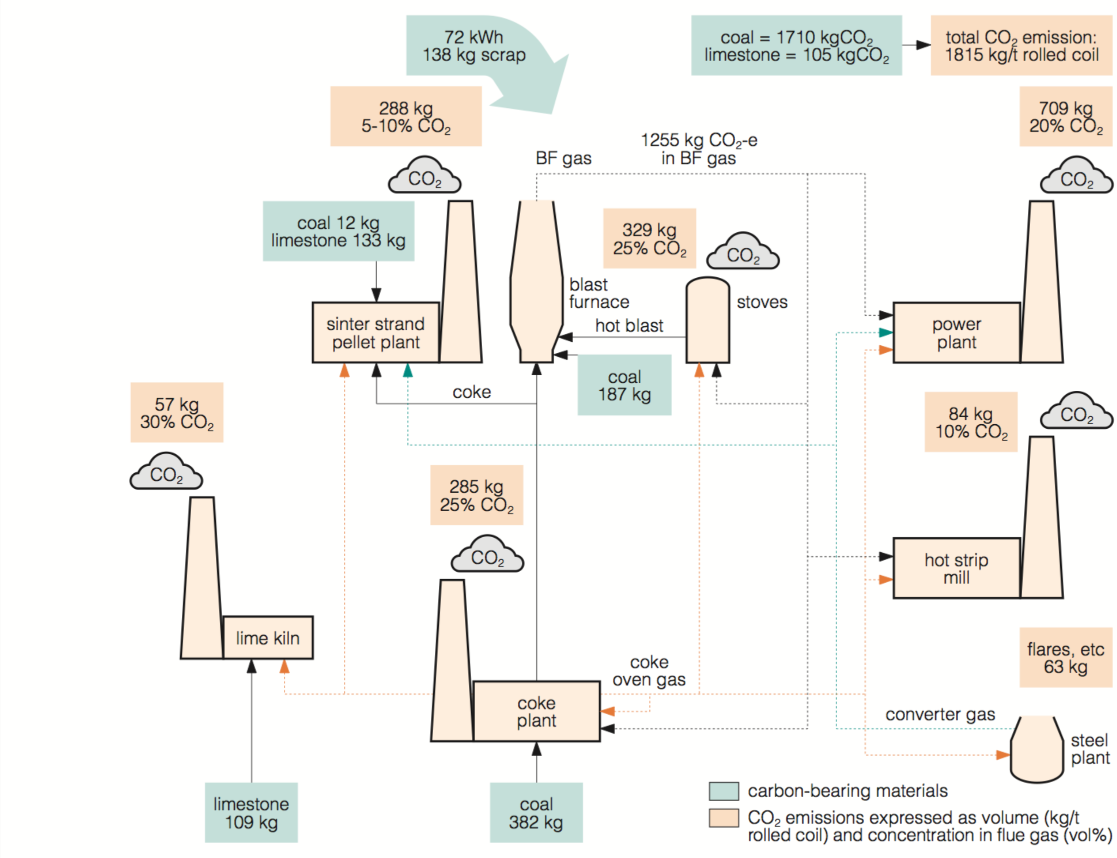

Figure 7: CO_2 emissions from a typical BF steel mill (IEA Clean Coal Centre, 2012)

In production of crude steel via EAF, CO_2 emissions arise from fuel use, as well as from oxidation of electrodes and scrap in the furnace. In the production of high alloy steels, CO_2 emissions arise from ferroalloys rather than from scrap, as the scrap grades fed in the EAF for this type of production have low carbon contents (Worrell, 2008).

Casting, rolling, surface treatment and further processing of steel all require fuel inputs which gives rise to CO_2 emissions, as does meeting the steam requirement for certain processes (Worrell, 2008).

As noted previously, the split between process emissions and emissions from fuel combustion (other scope 1 emissions) and emissions associated with off-site electricity consumption (scope 2 emissions) is site specific and is a function of the process configuration and the extent to which off-gases are utilised for energy and power generation. As both process emissions and combustion emissions can arise from the same processes, allocation between process emissions and combustion emissions requires detailed mass balance calculations. See, for example, the IPCC methodology (IPCC, 2006).

A.1.2. Ferroalloys

A.1.2.1. Products from the sector

The relevant SIC codes to the ferroalloys sector are provided in the table below.

Table 57: SIC codes for ferroalloy production (Statistics South Africa, 2005)

SIC Code	Description
24	Manufacture of basic metals
241	Manufacture of basic iron and steel
2410	Manufacture of basic iron and steel
24101	Production of ferro-alloys
24202	Production of alloys of chrome
24202	Production of alloys of manganese
24202	Production of alloys of nickel

Each of the main categories of ferroalloys produced (ferrochrome, ferromanganese, ferrosilicon and ferrovanadium) is further classified based on the different alloy contents, carbon content, and other additives as shown in Table 58 to Table 61 (DMR, 2013a).

Table 58: Grades of Ferrochrome

Ferrochrome Grades	Chrome	Carbon	Phosphorous	Sulphur	Silicon
High carbon ferrochrome (HCFeCr) (charge chrome: ChCr)	48 – 65%	4 – 8%	0.04% (max)	0.05% (max)	1% (max)
Medium carbon ferrochrome (MCFeCr)	55 – 65%	2% (max)	0.04% (max)	0.01% (max)	1.5% (max)
Low carbon ferrochrome (LCFeCr)	60 – 65%	0.03 - 0.2%	0.04% (max)	0.01% (max)	1.5% (max)

Table 59: Grades of Ferromanganese

Ferromanganese Grades	Manganese	Carbon	Silicon	Phosphorous	Sulphur
High carbon ferromanganese (HCFeMn)	65 – 79%	8% (max)	2% (max)	0.5% (max)	0.03% (max)
Silico-manganese	57 – 77%	0.1 - 3.5% (min)	10-35%	0.05-0.35% (max)	0.03% (max)
Refined ferromanganese (medium or low carbon) (MCFeMn, LCFeMn)	80 – 81%	0.1 – 2% (max)	2% (max)	0.15-0.35% (max)	0.03% (max)

Table 60: Grades of Ferrosilicon

Ferrosilicon Grades	Silicon	Carbon	Sulphur	Phosphorous	Aluminium
Stabilised/Unstabilised	43 – 47%	0.10%	0.03%	0.03%	1.5%
Atomised	43 – 47%	0.10%	0.05%	0.05%	2.0%
Steel	> 72%	0.15%	0.05%	0.05%	1.5%

Table 61: Grades of Ferrovanadium

Ferrovanadium Grades	Carbon	Aluminium	Silicon	Phosphorous	Sulphur
50 – 60% V	0.2%	2% (max)	1% (max)	0.05% (max)	0.05% (max)
70 – 80% V	-	1% (max)	2.5% (max)	0.05% (max)	0.1% (max)
77 – 83% V	0.5%	0.5% (max)	1.25% (max)	0.05% (max)	0.05% (max)

A.1.2.2. Production processes

South Africa's Ferroalloys Handbook (DMR, 2013a) provides detailed production process descriptions for the main ferroalloys produced in South Africa.

Ferrochrome production

A generalized process flow diagram, which indicates the most common process steps utilized by the South African FeCr producers, is shown in Figure 8. Four process combinations can be identified in the South African FeCr sector, namely:

- Conventional semi-closed furnace with bag filter off-gas treatment;
- Closed furnace;
- Closed furnace with pre-reduced pelletized feed; and
- Electric arc furnace (EAF).

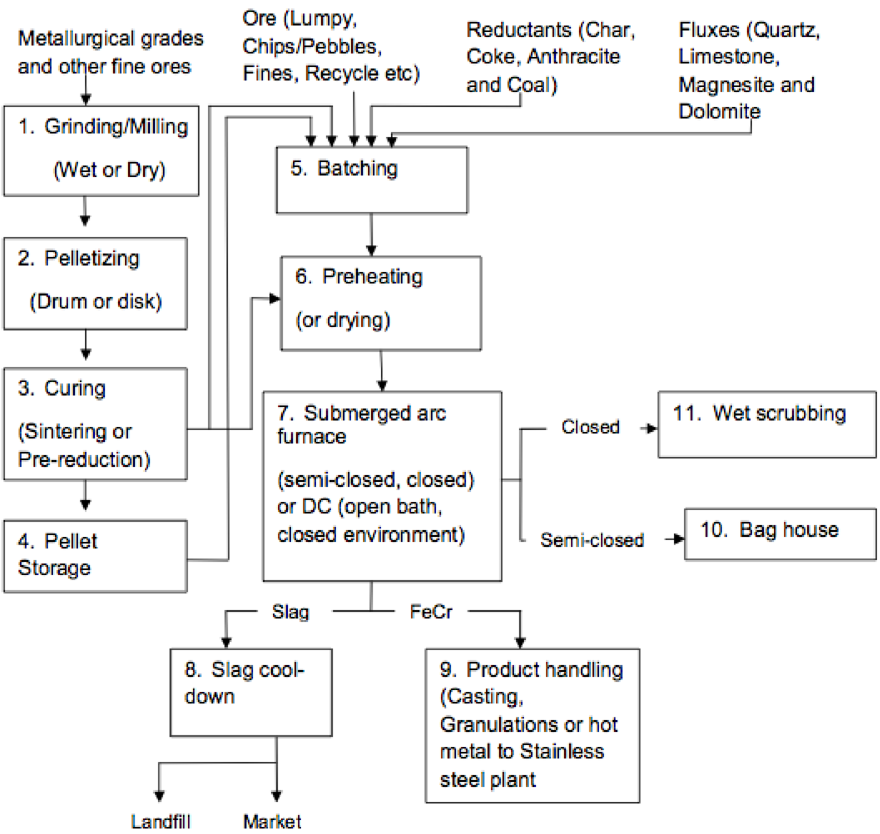

Figure 8: Ferrochrome alloy production process flow diagram (DMR, 2013a)

Ferromanganese production

In South Africa there are two main process routes for the production of manganese alloys, namely, blast furnace and submerged electric arc furnace. These process routes are illustrated in Figure 9**Error! Reference source not found.**.

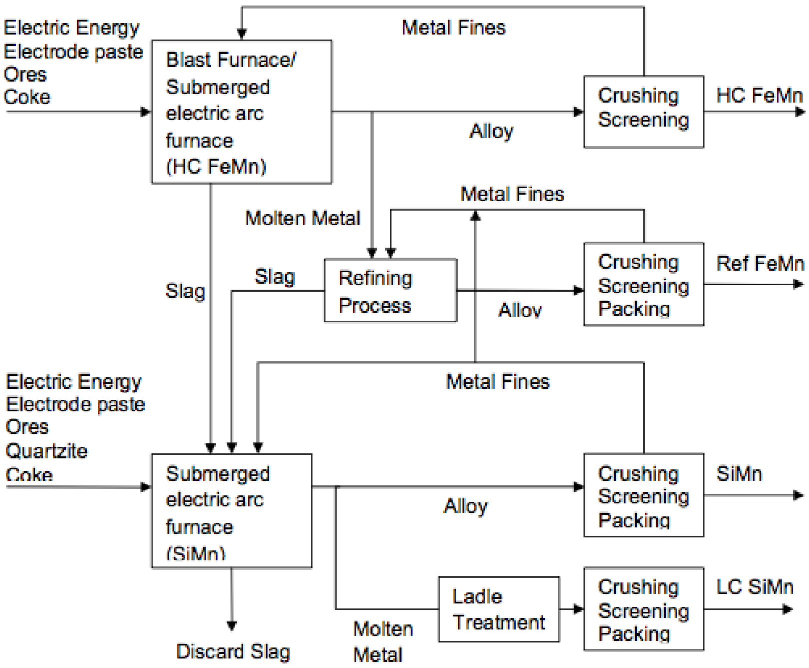

Figure 9: Manganese alloys production process flow diagram (DMR, 2013a)

Ferrosilicon production

Ferrosilicon is produced in either blast furnaces (for alloys with Si content of less than 15%) or in electric arc furnaces (for alloys with Si content greater than 15%) (DMR, 2013a).

Ferrovanadium production

Ferrovanadium is produced in an exothermic process with aluminium as the reductant. For some grades of FeV (with V content > 80%), additional electrical energy is required, which is supplied by an electric arc furnace.

A.1.2.3. Sources of GHG from ferroalloy production

Section 7.1.3 provides an overview of sources of GHG emissions from ferroalloy production, and no further information is included here.

A.1.3. Cement

A.1.3.1 Products from the sector

The relevant SIC codes for the cement sector are provided in the following table.

Table 62: SIC codes for manufacturing relevant to the cement sector (Statistics South Africa, 2005)

SIC Code	Description
2394	*Manufacture of cement, lime and plaster*
23940	Manufacture of cement, lime and plaster
23940	Manufacture of quicklime
23940	Manufacture of slaked lime
23940	Manufacture of hydraulic lime
23940	Manufacture of plasters of calcined gypsum
23940	Manufacture of plasters of calcined sulphate
23940	Manufacture of calcined dolomite
23940	Manufacture of clinkers and hydraulic cements, including Portland cement (for manufacture of refractory mortars, concrete etc., see 2391) (for manufacture of ready-mixed and dry-mix concrete and mortars, see 2395)
23940	Manufacture of clinkers and hydraulic cements, including aluminous cement (for manufacture of refractory mortars, concrete etc., see 2391) (for manufacture of ready-mixed and dry-mix concrete and mortars, see 2395)
23940	Manufacture of clinkers and hydraulic cements, including slag cement (for manufacture of refractory mortars, concrete etc., see 2391) (for manufacture of ready-mixed and dry-mix concrete and mortars, see 2395)
23940	Manufacture of clinkers and hydraulic cements, including slag superphosphate cement (for manufacture of refractory mortars, concrete etc., see 2391) (for manufacture of ready-mixed and dry-mix concrete and mortars, see 2395)

A.1.3.2 Production processes

The cement production process is described in section 8.1.2. Figure 10 presents a schematic representation of the process.

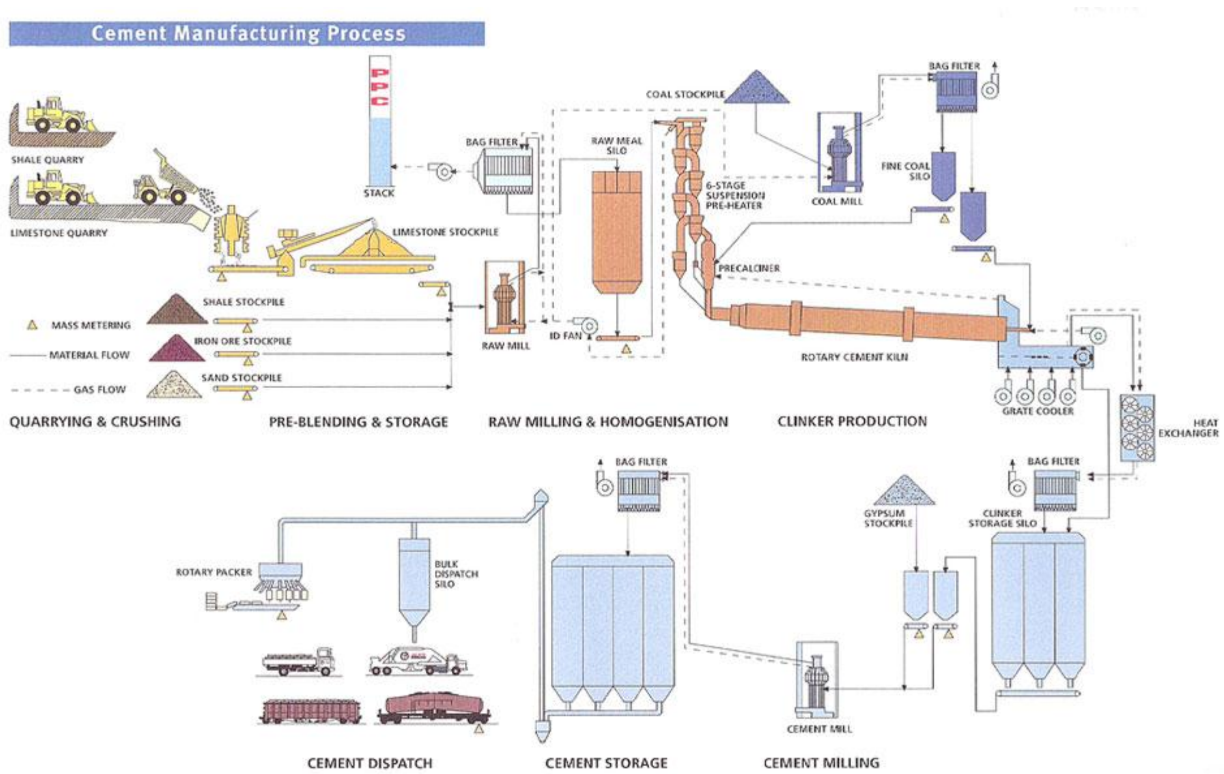

Figure 10: Cement production process flow diagram (ACMP, 2009)

A.1.3.2 Sources of GHG from cement production

The main emission sources in the manufacturing process are (ACMP, 2011):

- Process emissions from clinker production (i.e. calcination of limestone): 50%
- Combustion emissions from fuels required to heat material in kiln (primarily coal is used in South Africa): 40%
- Scope 2 emissions from electricity use (mostly for grinding) and emissions associated with transportation: 10%

The specific CO_2 emissions (emissions per tonne of cement) are, however, influenced by various factors. The three factors with the largest impact are the clinker content in cement, kiln technology and size, and the fuel mix used to provide the required energy (Ecofys, 2009b):

- **Clinker substitutes:** Reducing the clinker content of cement products by adding fillers such as sand, slag, limestone, fly-ash and other pozzolans during grinding reduces the energy and emissions per tonne of cement, through reducing the need for clinker production. Ordinary

Portland Cement typically contains 95% clinker, while blended cements can contain up to 65% of slag or 35% of fly ash. Blended cements are already widely used globally, and can substitute Ordinary Portland Cement in most applications, achieving similar product strengths. However, certain cement characteristics can be impacted by the use of additives, such as initial strength, drying time and seawater resistance. Quality standards are thus used to distinguish cements on the basis of their contents of clinker substitutes.

- **Fuel mix:** The three main types of conventional, fossil fuels that are used as fuel in cement kilns are pulverized coal and petcoke, (heavy) fuel oil and natural gas, each of which provides a different CO_2 intensity. Conventional fuels are increasingly being substituted by non-conventional, non- fossil, alternatives, leading to lower fossil CO_2 emissions. For example, up to 40% of the fuel can be replaced by biomass. Cement kilns also present an alternative option for incinerating combustible wastes.
- **Kiln technology and size:** In South Africa a combination of older long dry kilns and modern short dry kilns with preheating are used. The best available technology for the production of cement clinker today is a dry process kiln with multi-stage preheating and precalcination. These technologies are the most economically feasible option (Karstensen, 2007). In addition to kiln technology, kiln capacity is an important factor influencing the energy efficiency of a cement plant. Large kilns have lower heat losses per unit of clinker and consequently have lower specific heat consumption and CO_2 emissions as compared to smaller kilns.

In addition to the above, there are various energy efficiency measures that can be implemented in the cement manufacturing process to reduce emissions (EPA, 2010).

A.1.4. Petroleum (crude oil refineries)

Products from the sector

The relevant SIC code for the activities in petroleum refining are provided in the following table.

Table 63: SIC codes for petroleum refining (Statistics South Africa, 2005)

SIC Code	Description
192	*Manufacture of refined petroleum products*
1920	Manufacture of refined petroleum products
19200	Manufacture of refined petroleum products
19200	Production of motor fuel: gasoline, kerosene etc.
19200	Production of fuel: light, medium and heavy fuel oil, refinery gases such as ethane, propane, butane etc.
19200	Manufacture of oil-based lubricating oils or greases, including from waste oil
19200	Manufacture of products for the petrochemical industry
19200	Manufacture of products for the manufacture of road coverings
19200	Manufacture of various products: white spirit, Vaseline, paraffin wax, petroleum jelly etc.
19200	Manufacture of hard-coal fuel briquettes
19200	Manufacture of lignite fuel briquettes
19200	Manufacture of petroleum briquettes
19200	Blending of biofuels, i.e. blending of alcohols with petroleum (e.g. gasohol)

Production processes

The production of petroleum from crude oil is described in section 9.1.2. A typical process flow diagram for a crude oil refinery is presented in Figure 11, although it is identified that significant variation in refinery layouts is seen between installations.

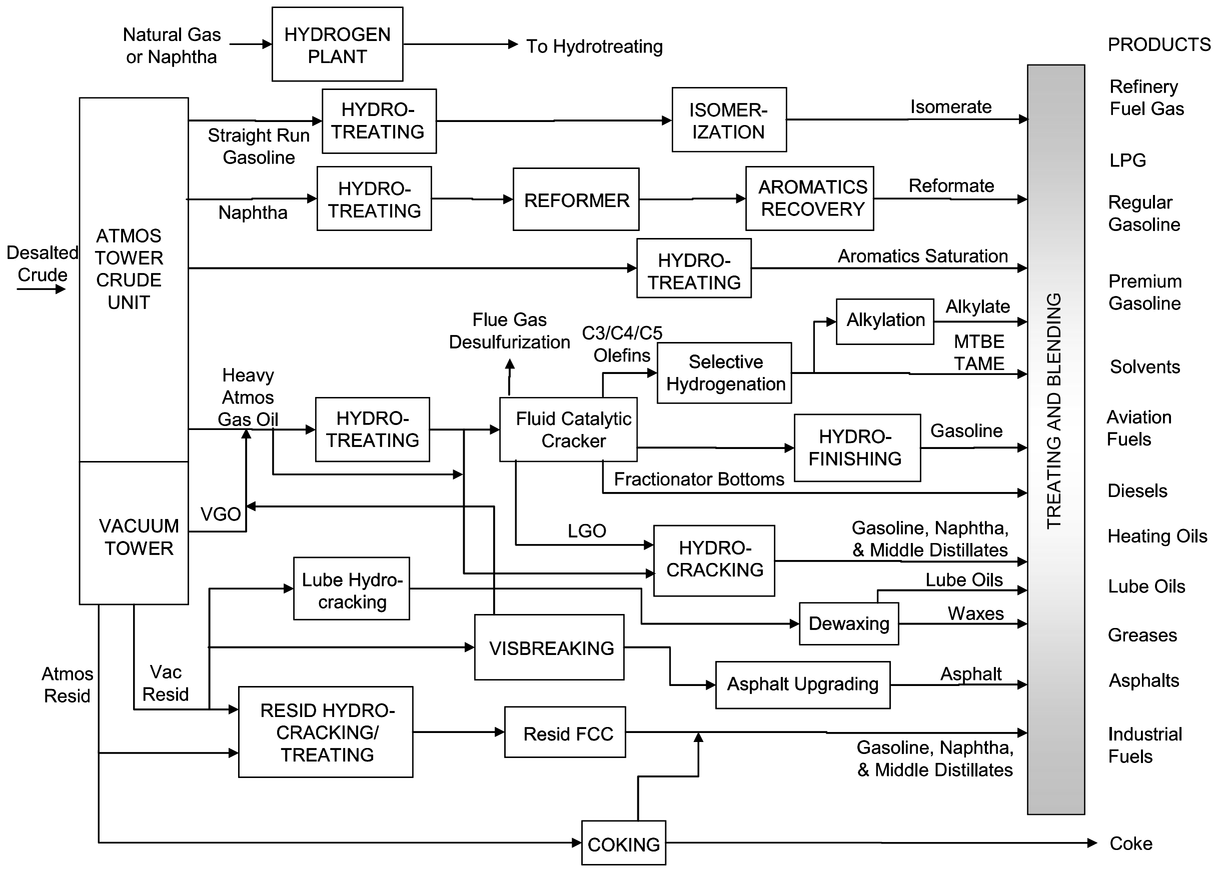

Figure 11: Simplified petroleum production flow diagram (Energetics Incorporated, 2007)

A.1.4.1 Sources of GHG from crude oil refineries

Sources of GHG emissions from crude oil refining are reviewed in section 9.1.3 and no further information is provided here.

A.1.5. Petroleum (GTL)

A.1.5.1. Products from the sector

The SIC codes for activities in GTL are the same as those for petroleum refineries presented in Table 63.

A.1.5.2. Production processes

The production of petroleum via the GTL route is described in section 9.1.2. The diagrams below present the process flow diagrams for the high and low temperature Fischer Tropsch production routes.

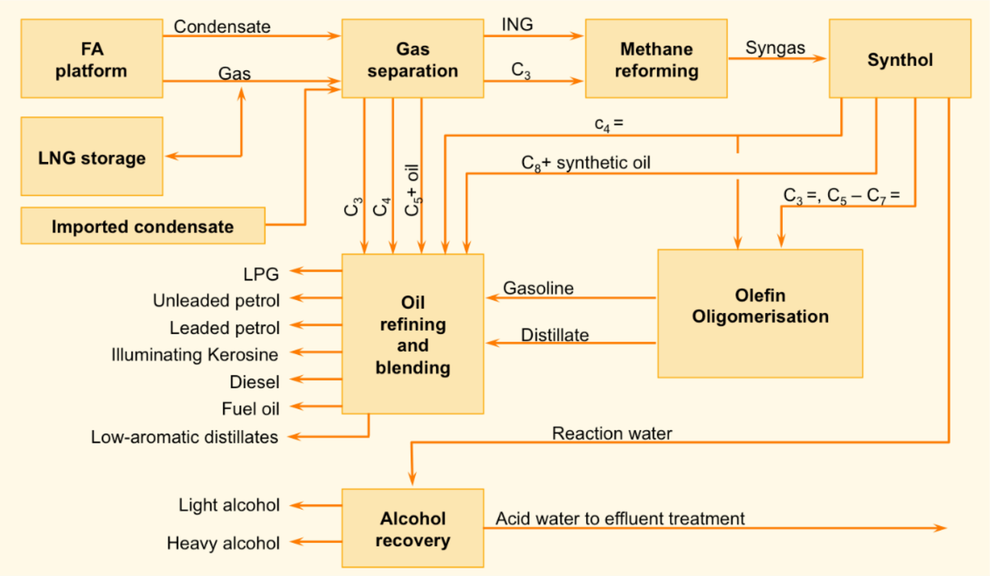

Figure 12: High Temperature Fischer Tropsch Technology process flow diagram (PetroSA, undated)

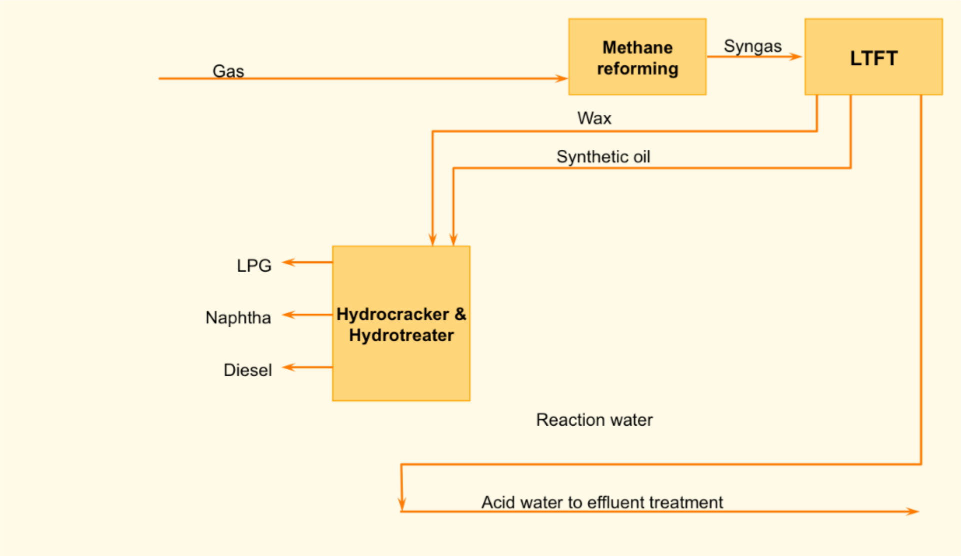

Figure 13: Low Temperature Fischer Tropsch Technology process flow diagram (PetroSA, undated)

A.1.5.3. Sources of GHG from GTL

Sources of GHG from GTL are described in Section 10.1.3. No further detail is available here.

A.1.6. Petroleum (CTL)

A.1.6.1. Products from the sector

The SIC codes for activities in CTL are the same as those for petroleum refineries presented in Table 63.

A.1.6.2. Production processes

The production process is described in Section 11.1.2. The figure below presents a simplified process flow diagram of the CTL production route.

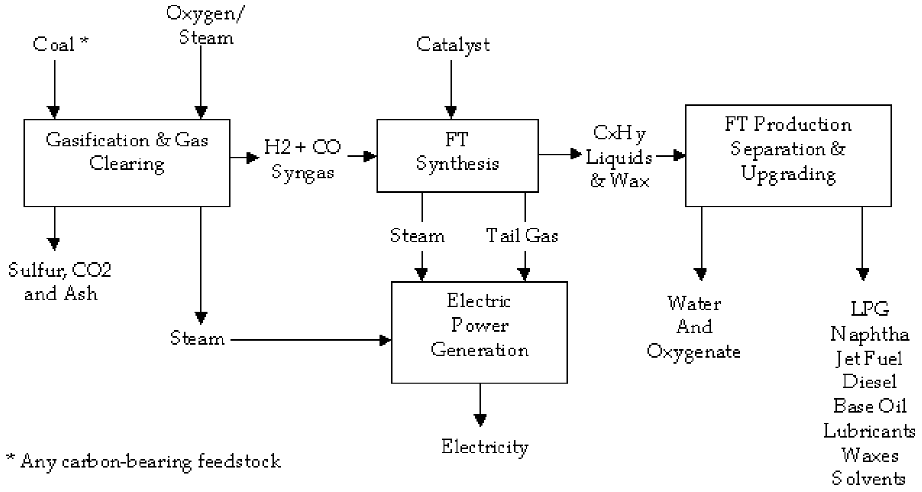

Figure 14: Simplified indirect liquefaction CTL process (InfralineEnergy, 2014)

A.1.6.3. Sources of GHG from CTL

Sources of GHG emissions are described in Section 11.1.3. No further information is provided here.

A.1.7. Chemicals

A.1.7.1. Products from the sector

The relevant SIC codes for activities in the chemicals sector are provided in the following table.

Table 64: SIC codes for chemical manufacturing (Statistics South Africa, 2005)

SIC Code	Description
20	Manufacture of chemicals and chemical products
201	*Manufacture of basic chemicals, fertilizers and nitrogen compounds, plastics and synthetic rubber in primary forms*
2011	Manufacture of basic chemicals
2012	Manufacture of fertilizers and nitrogen compounds
2013	Manufacture of plastics and synthetic rubber in primary forms
202	*Manufacture of other chemicals products*
2021	Manufacture of pesticides and other agrochemical products
2022	Manufacture of paints, varnishes and similar coatings, printing ink and mastics
2023	Manufacture of soap and detergents, cleaning and polishing preparations, perfumes and toilet preparations
2029	Manufacture of other chemical products n.e.c.
203	*Manufacture of man-made fibres*
2030	Manufacture of man-made fibres

A.1.7.2. Production processes

Note that relatively short descriptions have been provided for products from the chemicals sector, given the substantial number of products to be included here. In this Annex, only a selection of these have been included where it was considered desirable to present additional information or a flow diagram. For further descriptions, and description of the processes not covered in this Annex, please refer to the main body of the text.

A.1.1.1 Ammonia

As indicated in the main body of the report, ammonia is produced via the Haber-Bosch process according to the following reaction equation:

$N_2 + 3H_2 \rightarrow 2NH_3$

This reaction is exothermic and no greenhouse gases are directly emitted. However, ammonia plants are typically integrated with hydrogen production, which is considered to be part of the ammonia production process. Hydrogen production is a very energy- and emission-intensive process.

Normally, in the plant where ammonia is produced, the following preceding production steps are also conducted as one integrated process:

- production of synthesis gas (syngas, a mixture of hydrogen and carbon monoxide) which is used in the production of hydrogen
- separation of air (nitrogen)
- CO shift conversion to CO_2 and its capture

Hydrogen is produced via one of two different processes: steam reforming or partial oxidation.

Steam reforming

Methane (contained in natural gas) is reacted in a highly endothermic reaction with steam over a catalyst at high temperatures and pressures (800-1000°C, 20-30 atm) to form CO and H_2. Some of the CO formed reacts further with the steam to yield CO_2 and more H_2 (this is known as the water gas shift reaction) (Olah, et al., 2011).

As mentioned, Sasol is one of the largest suppliers of ammonia in South Africa. Natural gas is used as feedstock at Sasolburg for the steam reforming process in two auto thermal reformers (ATRs) to produce synthetic gas (syngas) (Sasol, undated).

Partial Oxidation

Heavy hydrocarbons, such as heavy fuel oil or coal, are used as feedstock for this process. The feedstock is converted to syngas by gasification, a process combining partial oxidation and steam treatment. As this process is exothermic, no additional fuel is required and all CO_2 emissions from this step are process emissions (Ecofys, 2009c).

Sasol produces ammonia as a by-product at its Secunda based coal-to-liquids (CTL) facility. This partial oxidation process commences in the multi-unit gasification plant where coal is converted, with the aid of heat, pressure, steam and oxygen, into syngas. Once cooled and recovered from the gas stream, the gasification condensates yield the first generation of co-products: tars, oils and pitches, as well as ammonia, sulphur and phenols. The ammonia is produced through the refining of the gas water stream emanating from the gasification process. CTL is described more fully in Section 11.

Other industry by-product

ArcelorMittal also produces ammonia as a by-product of its coke oven gas cleaning plants in Newcastle, Vanderbijlpark and Pretoria. A flow diagram of the coke oven gas cleaning circuit is provided in the figure below. Hot crude coke oven gas is cooled down by spraying it with coal water. Coal water from the gas cleaning plant is then routed to an ammonia liquor storage tank, while ammonia and hydrogen sulphide is scrubbed form the coke oven gas (SE Solutions, 2010).

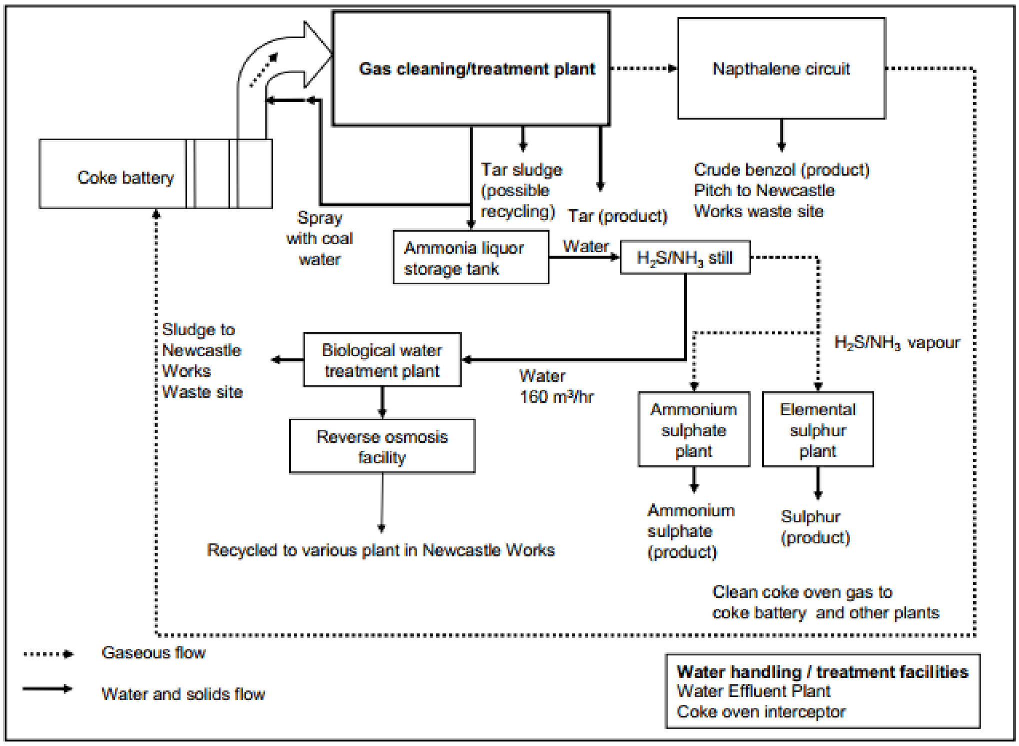

Figure 15: Process flow diagram of coke oven gas cleaning process and water circuit (SE Solutions, 2010)

A.1.1.2 Aromatics

Figure 16 illustrates the production of the three main aromatics (benzene, toluene and xylene) from catalytic reforming.

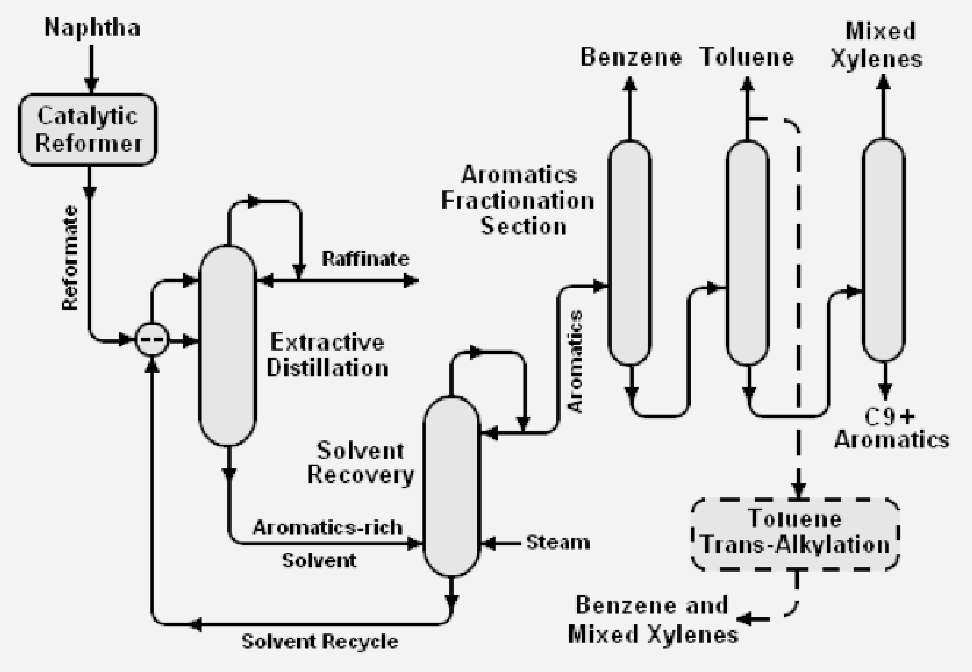

Figure 16: Process flow diagram for production of benzene, toluene and xylene via catalytic reforming (Hu, 2013)

A.1.1.3 Carbon black

Figure 17 presents a schematic of the furnace black process, which is the most commonly used process and that considered to be used in South Africa. The process utilises liquid and gas hydrocarbons as feedstock and heat source. The carbon black is formed in a refractory-lined furnace where the heat source (generated by natural gas) is sprayed with the liquid hydrocarbons. The carbon black loaded gas exiting the furnace passes through a heat exchanger for cooling, while heating up the required process air utilised in the furnace. A bag filter system separates the carbon black particles from the gas stream. The carbon black collected has a very low bulk density and is usually pelletized or densified for further handling.

This method has the lowest emissions, and is also the cheapest manufacturing process of carbon black. Technically this method is also very flexible and allows for the production of various grades of carbon blacks for various applications without changing the process (Orion Engineered Carbon, 2013).

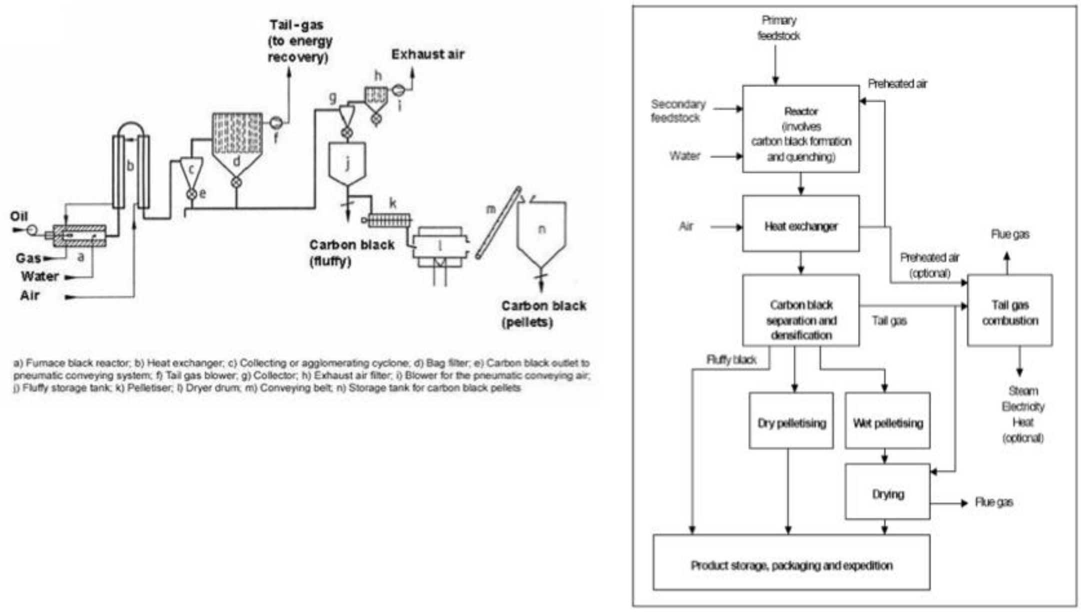

Figure 17: Process flow diagram for the furnace black process for the production of carbon black (Ecofys, 2009c)

A.1.1.4 Nitric acid

The most common production process for nitric acid production is the Ostwald Process shown in the following process flow diagram). It entails high-temperature catalytic oxidation of ammonia via the following 3 steps: ammonia oxidation; nitric oxide oxidation; and absorption (Ecofys, 2009c).

Ammonia oxidation
In the oxidation section, NH_3 is reacted with air over a catalyst (the most common catalyst being a 90% Palladium / 10% Rhodium gauze) to form nitric oxide and water.

$4NH_3 + 5O_2 \rightarrow 4NO + 6H_2O$

Nitric oxide oxidation
The nitric oxide is cooled to a temperature of 38°C at a pressure up to around 7.8 bar. The nitric oxide reacts (non-catalytically) with oxygen to form nitrogen dioxide and dinitrogen tetroxide.

$4NO + 2O_2 \rightarrow 2NO_2 + N_2O_4$

Temperature and pressure determines the progress of this reaction. High pressures and low temperatures favour the production of nitrogen dioxide, which is preferred to dinitrogen tetroxide.

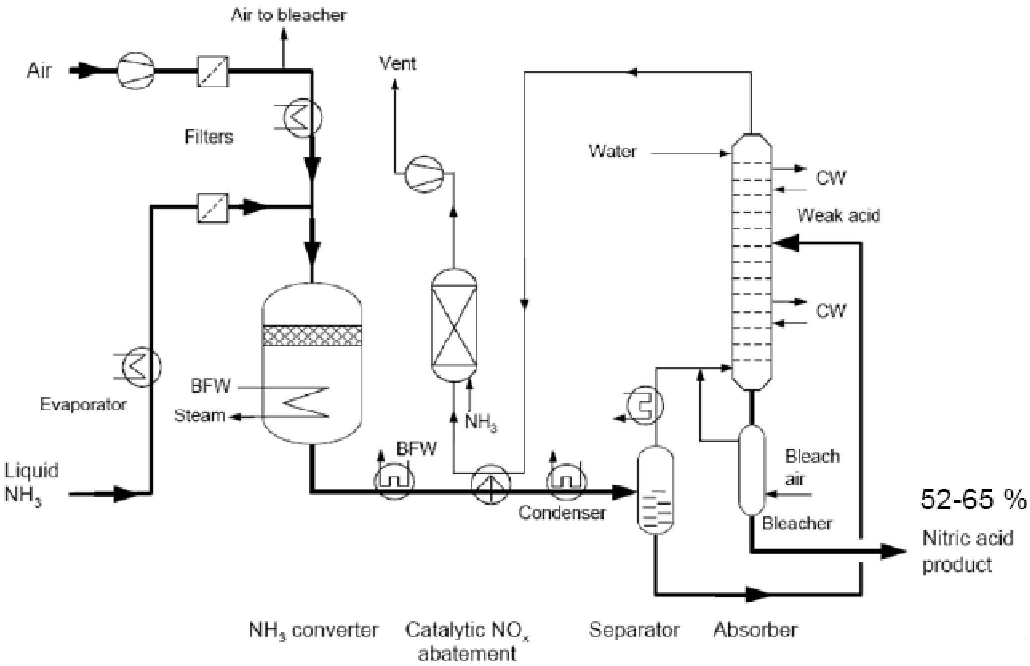

Figure 18: Simplified view of Ostwald-process plant for weak nitric acid production (Ecofys, 2009c)

Absorption

The nitrogen dioxide and the tetroxide mixture is cooled and entered into the absorption column. The gaseous mixture is introduced at the bottom of the column while liquid dinitrogen tetroxide and deionised water enter at the top. In this chamber, the absorption takes place on the (bubble cap) trays and oxidation takes place between the trays.

$3NO_2 + H_2O \rightarrow 2HNO_3 + NO$

In order to further oxidise the NO and to remove the NO_2 from the weak nitric acid, secondary air is fed into the column. Weak acid produced typically has a concentration of 55-65% (weight basis), depending on the temperature, pressure and the number of absorption stages. Some nitrous acid (HNO_2) formation is possible during the NO_2 absorption process (Ecofys, 2009c).

A.1.1.5 Titanium dioxide

The sulphate production process for titanium dioxide production is shown in the figure below. The process steps are as follows:

- Drying: The raw materials (ilmenite or titanium slag) are dried to avoid premature reaction with the sulphuric acid. The dried materials are ground in a ball mill.
- Digestion: The ground materials are mixed with concentrated sulphuric acid, water and steam in a batch reaction tank. The hydration heat of the sulphuric acid gives rise to heat

which is increased due to the exothermic reaction ($FeTiO_3 + 2\ H_2SO_4 \rightarrow TiOSO_4 + FeSO_4 + 2\ H_2O$). The resulting cake is left to set, before being re-dissolved at lower temperatures in water or dilute acid. Air may be added throughout the digestion process to accelerate the process.

- Separation, crystallization, hydrolysis: In this stage, all insoluble solids are removed by thickening and filtration processes. The titanium oxide hydrate is then selectively precipitated at higher temperatures with the addition of steam under the following reaction: $TiOSO_4 + 2H_2O \rightarrow TiO(OH)_2 + H_2SO4$. In South Africa, the spent acid is neutralized and gives rise to a gypsum by-product.
- Filtration: The hydrate product goes through a number of washing and filtering steps to remove residual metals and impurities.
- Calcination: This optional step produces high purity TiO_2 whereby the hydrate together with various additives are calcined in a furnace at high temperatures. The resulting clinker is air-cooled and ground.
- Treatment: Finally, various additives are added to produce required products.

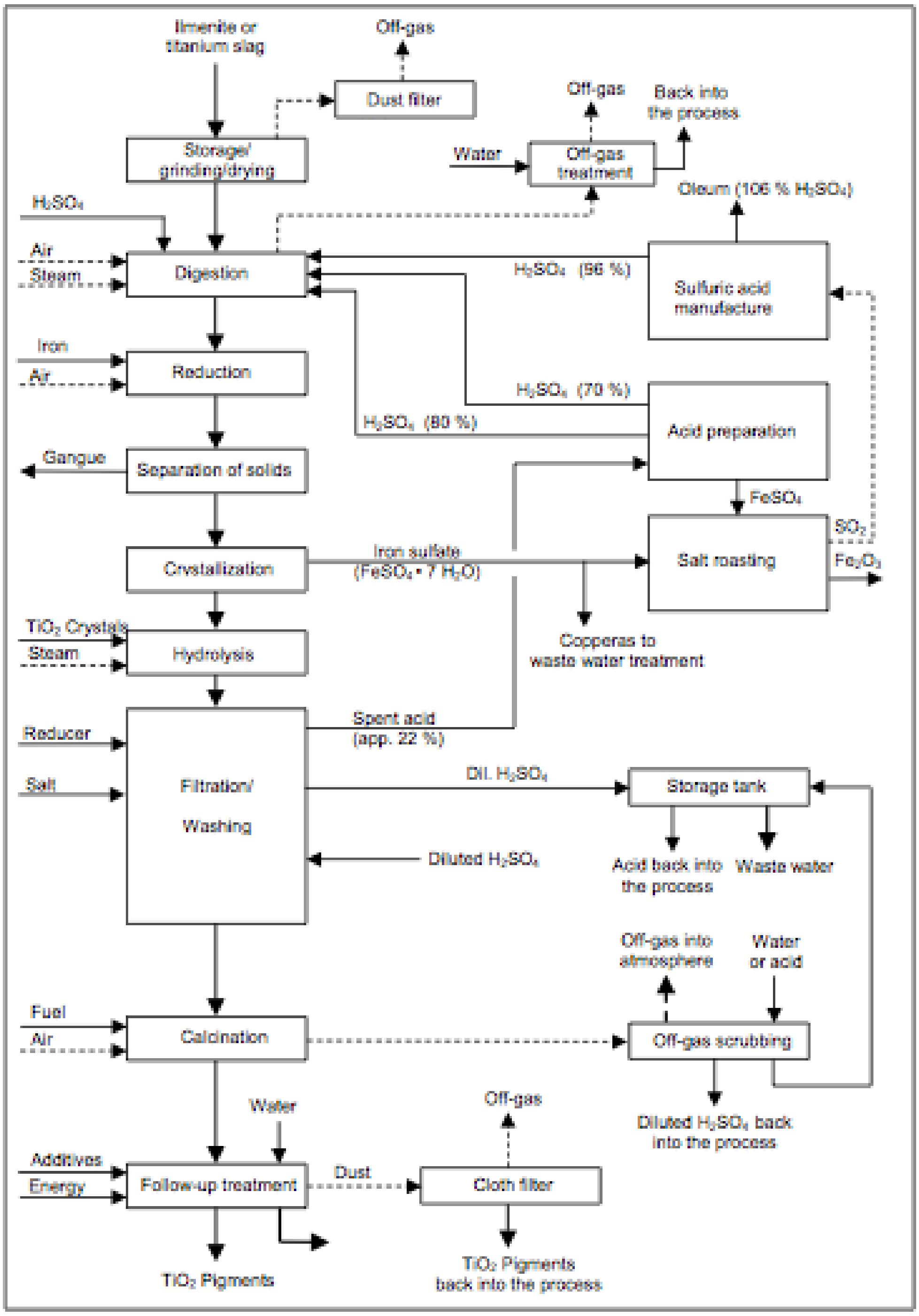

Figure 19: Titanium dioxide pigment production via the sulphate process (Federal Environmental Agency, 2001)

A.1.1.6 Styrene-butadiene

The flow diagram for styrene-butadiene is shown in the figure below.

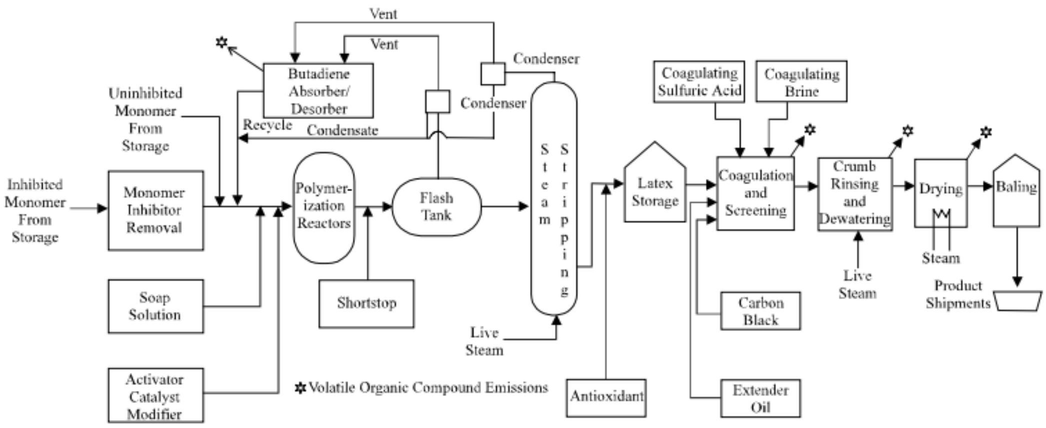

Figure 20: SBR production by emulsion polymerisation (Ecofys, 2009c)

A.1.1.7 Polymerisation of monomers (propylene and ethylene)

A typical flow diagram for monomer polymerisation is shown below.

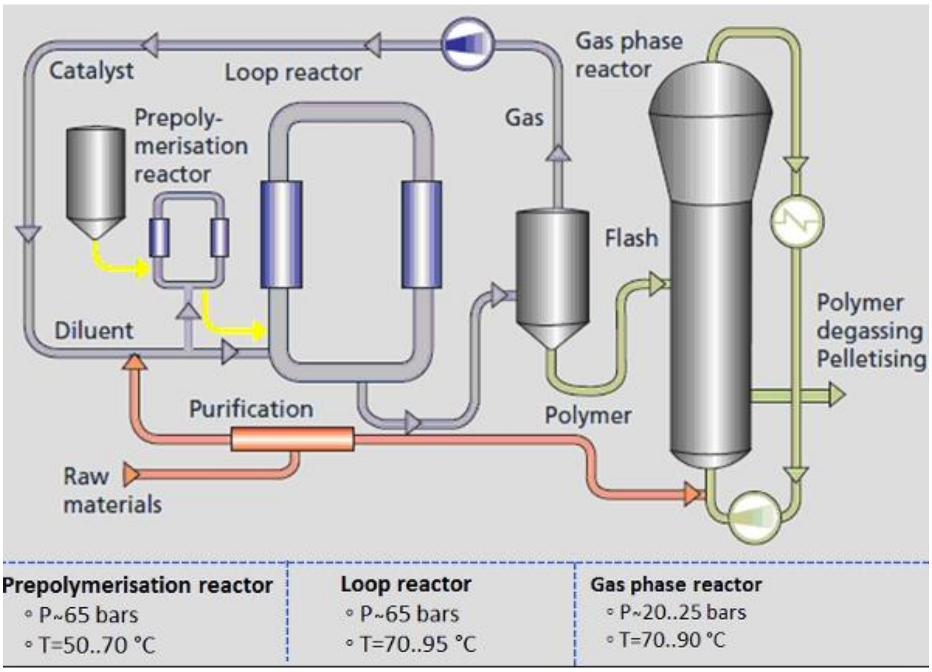

Figure 21: Polymerisation process – Borstar process (Guichon Valves, 2011)

A.1.7.3. Sources of GHG from chemicals production

Sources of GHG from chemicals production are discussed in the relevant sections in the main body of the report.

A.1.8. Pulp and paper

A.1.8.1. Products from the sector

The relevant SIC code for the activities in the pulp and paper sector are provided in the following table.

Table 65: SIC codes for paper and pulp manufacturing (Statistics South Africa, 2005)

SIC Code	Description
17	Manufacturing of paper and paper products
1701	*Manufacture of pulp, paper and paperboard*
17010	Manufacture of pulp, paper and paperboard
17010	Manufacture of bleached paper pulp by mechanical processes
17010	Manufacture of bleached paper pulp by chemical (dissolving or non-dissolving) processes
17010	Manufacture of bleached paper pulp by semi-chemical processes
17010	Manufacture of semi-bleached paper pulp by mechanical processes
17010	Manufacture of semi-bleached paper pulp by chemical (dissolving or non-dissolving) processes
17010	Manufacture of semi-bleached paper pulp by semi-chemical processes
17010	Manufacture of unbleached paper pulp by mechanical processes
17010	Manufacture of unbleached paper pulp by chemical (dissolving or non-dissolving) processes
17010	Manufacture of unbleached paper pulp by semi-chemical processes
17010	Manufacture of cotton-linters pulp
17010	Removal of ink from waste paper
17010	Manufacture of pulp from waste paper
17010	Manufacture of paper intended for further industrial processing
17010	Manufacture of paperboard intended for further industrial processing
17010	Further processing of paper and paperboard: coating, covering and impregnating of paper and paperboard
17010	Further processing of paper and paperboard: manufacture of crêped or crinkled paper
17010	Further processing of paper and paperboard: manufacture of laminates and foils, if laminated with paper or paperboard

SIC Code	Description
17010	Manufacture of handmade paper
17010	Manufacture of newsprint and other printing or writing paper
17010	Manufacture of cellulose wadding and webs of cellulose fibres
17010	Manufacture of carbon paper in rolls or large sheets
17010	Manufacture of stencil paper in rolls or large sheets
1702	*Manufacture of corrugated paper and paperboard and of containers of paper and paperboard*
17021	Manufacture of corrugated paper and paperboard
17022	Manufacture of containers of paper and paperboard
17022	Manufacture of containers of corrugated paper or paperboard (for manufacture of moulded or pressed articles of paper pulp (e.g. boxes for packing eggs, moulded pulp paper plates), see 1709)
17022	Manufacture of folding paperboard containers (for manufacture of moulded or pressed articles of paper pulp (e.g. boxes for packing eggs, moulded pulp paper plates), see 1709)
17022	Manufacture of containers of solid board
17022	Manufacture of other containers of paper and paperboard
17022	Manufacture of sacks and bags of paper
17022	Manufacture of office box files and similar articles (for manufacture of envelopes, see 1709)
1709	*Manufacture of other articles of paper and paperboard*
17090	Manufacture of other articles of paper and paperboard
17090	Manufacture of household and personal hygiene paper and cellulose wadding products
17090	Manufacture of cleansing tissues
17090	Manufacture of household and personal hygiene paper and cellulose wadding products: handkerchiefs
17090	Manufacture of household and personal hygiene paper and cellulose wadding products: towels
17090	Manufacture of household and personal hygiene paper and cellulose wadding products: serviettes
17090	Manufacture of toilet paper
17090	Manufacture of household and personal hygiene paper and cellulose wadding products: sanitary towels and tampons, napkins and napkin liners for babies
17090	Manufacture of cups (made of paper or paperboard)
17090	Manufacture of dishes (made of paper or paperboard)
17090	Manufacture of trays (made of paper or paperboard)
17090	Manufacture of textile wadding and articles of wadding: sanitary towels, tampons etc.
17090	Manufacture of printing paper ready for use
17090	Manufacture of writing paper ready for use
17090	Manufacture of computer printout paper ready for use
17090	Manufacture of self-copy paper ready for use

SIC Code	Description
17090	Manufacture of duplicator stencils and carbon paper ready for use
17090	Manufacture of gummed or adhesive paper ready for use
17090	Manufacture of envelopes
17090	Manufacture of letter-cards
17090	Manufacture of registers, accounting books, binders, albums and similar educational and commercial stationery
17090	Manufacture of boxes, pouches, wallets and writing compendiums containing an assortment of paper stationery
17090	Manufacture of wallpaper and similar wall coverings, including vinyl-coated and textile wallpaper
17090	Manufacture of labels (paper)
17090	Manufacture of filter paper and paperboard
17090	Manufacture of paper and paperboard bobbins, spools, cops etc.
17090	Manufacture of egg trays and other moulded pulp packaging products etc.
17090	Manufacture of paper novelties

A.1.8.2. Production processes

The production of pulp and paper can be divided into three main operations:

- Virgin pulp making
- Recovered paper processing
- Paper production

Depending on the production facility, these processes may be integrated in one installation. The main activities are supported by a number of associated activities such as power and steam generation, wood handling, water treatment, waste handling and storage handling of chemicals and converting paper into paper articles.

Virgin pulp making

In the pulping process the raw cellulose-bearing material is broken down into individual fibres. This is achieved through a combination of chemical, thermal and mechanical treatment of the fibres. Heating is often employed in both chemical and mechanical paths. The three main types of processes for virgin pulp production are (Ecofys, 2009e) (Ras & Lewis, 2012):

- Kraft (sulphate) pulping: treatment of wood chips with a chemical solution of sodium hydroxide and sodium sulphide, known as "white liquor", at high temperature (the cooking process). This breaks the bonds that link lignin to the cellulose, thereby liberating the fibres from the wood matrix. The pulp liquor from the cooking process in the digester subsequently undergoes washing and filtration to separate out a "black liquor" stream. The remaining pulp undergoes further physical processing before it is bleached, dewatered and dried into a marketable pulp for paper production (Brown, et al., 1996). A parallel process is operated to recover chemicals from the black liquor stream. The black liquor undergoes intensive processing in a recovery boiler to yield a "green liquor", which is further reacted with slaked lime for the recovery of caustic material to regenerate white liquor (Ragauskas, undated). The lime is provided through the operation of a lime kiln (Brown, et al., 1996).

- Sulphite pulping: the chemical solution used in the cooking process is aqueous sulphur dioxide (SO_2). Various salts of sulphurous acid are used to extract the lignin from wood chips.
- Mechanical pulping: Here wood fibres are physically separated from each other using mechanical energy applied to the wood matrix, rather than by using a chemical solution. Fibrous material is broken down predominantly in grinders through abrasion, but may be accompanied by heat treatment and chemical treatment (IFC, 2007c).

The Kraft process route dominates the production of pulp, with 80% of global pulp production (Ecofys, 2009e).

Dissolving pulp (as produced by Sappi's Saiccor Mill) is made from the sulphite process or the Kraft process with an acid pre-hydrolysis step to remove hemicelluloses.

Recovered paper processing

Processing of recovered paper prior to the paper production process requires some removal of contaminants prior to use and may involve de-inking depending upon the quality of material recycled and the requirements of the end product (e.g. tissue, carton board and newsprint). For the processing of recycled fibre, fossil fuels are used.

Paper production

Virgin pulp or processed recovered paper forms the feedstock to paper production. Often a combination of different types of pulp is used. Paper production from pulp is achieved through a sequence of screening (to remove fine pulp); thickening, pressing and drying (to remove water); as well as refining through the addition of chemicals. Paper is finally wound, cut and trimmed into appropriate sizes and dimensions (Brown et al., 1996). Most paper mills are able to make multiple paper grades depending on feedstocks and requirements.

Error! Reference source not found. Figure 22 shows the process flow diagram for an integrated aper making process.

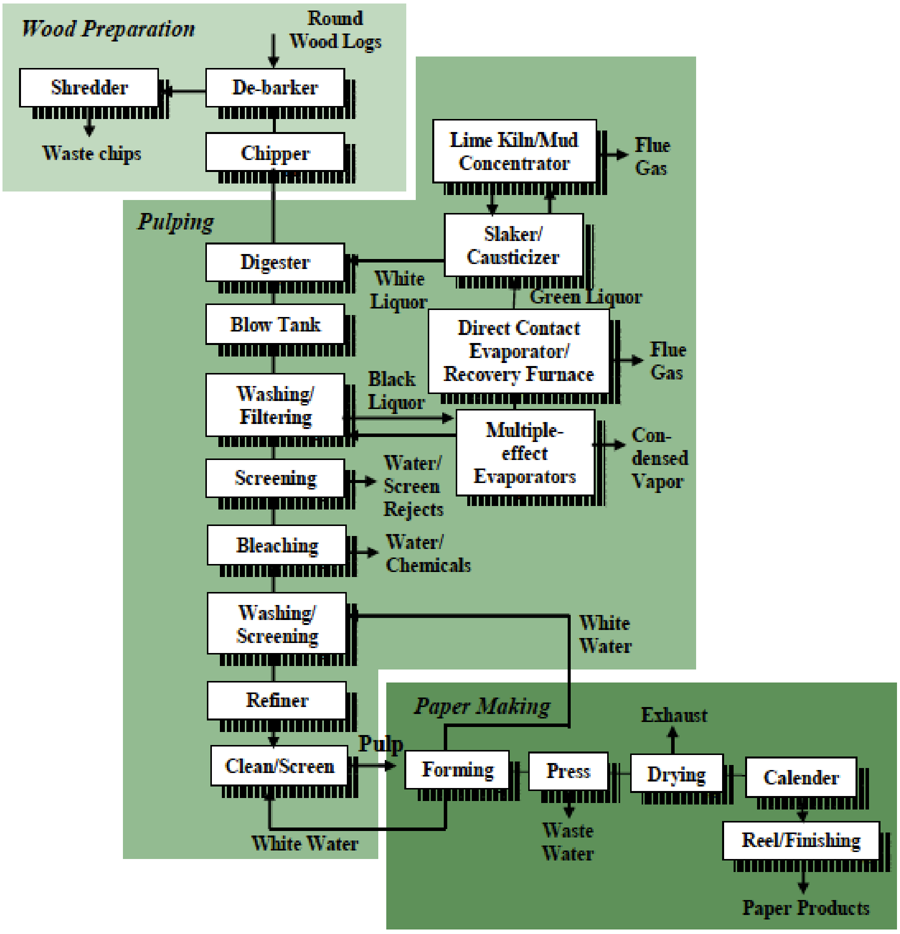

Figure 22: Process flow diagram for an integrated paper making process (Ras & Lewis, 2012)

A.1.8.3. Sources of GHG from pulp and paper production

Sources of GHG from pulp and paper production are discussed in section 13.1.3 and no further information is offered here.

A.1.9. Sugar

A.1.9.1. Products from the sector

The relevant SIC code for the activities in this sector are provided in the table below.

Table 66: SIC codes for sugar manufacturing (Statistics South Africa, 2005)

SIC Code	Description
1072	*Manufacture of sugar*
10720	Manufacture of sugar
10720	Manufacture or refining of sugar (sucrose) and sugar substitutes from the juice of cane, beet, maple and palm
10720	Manufacture of sugar syrups (for manufacture of glucose, glucose syrup, maltose, see 1062)
10720	Manufacture of molasses
10720	Production of maple syrup and sugar

A.1.9.2. Production processes

The sugar production process is described in section 14.1.1. The figure below illustrates the flow diagram of a typical mill. For every 100 tonnes of cane crushed, 30 tonnes of fibrous residue (bagasse), about 12 tonnes sugar and 4 tonnes molasses are typically produced.

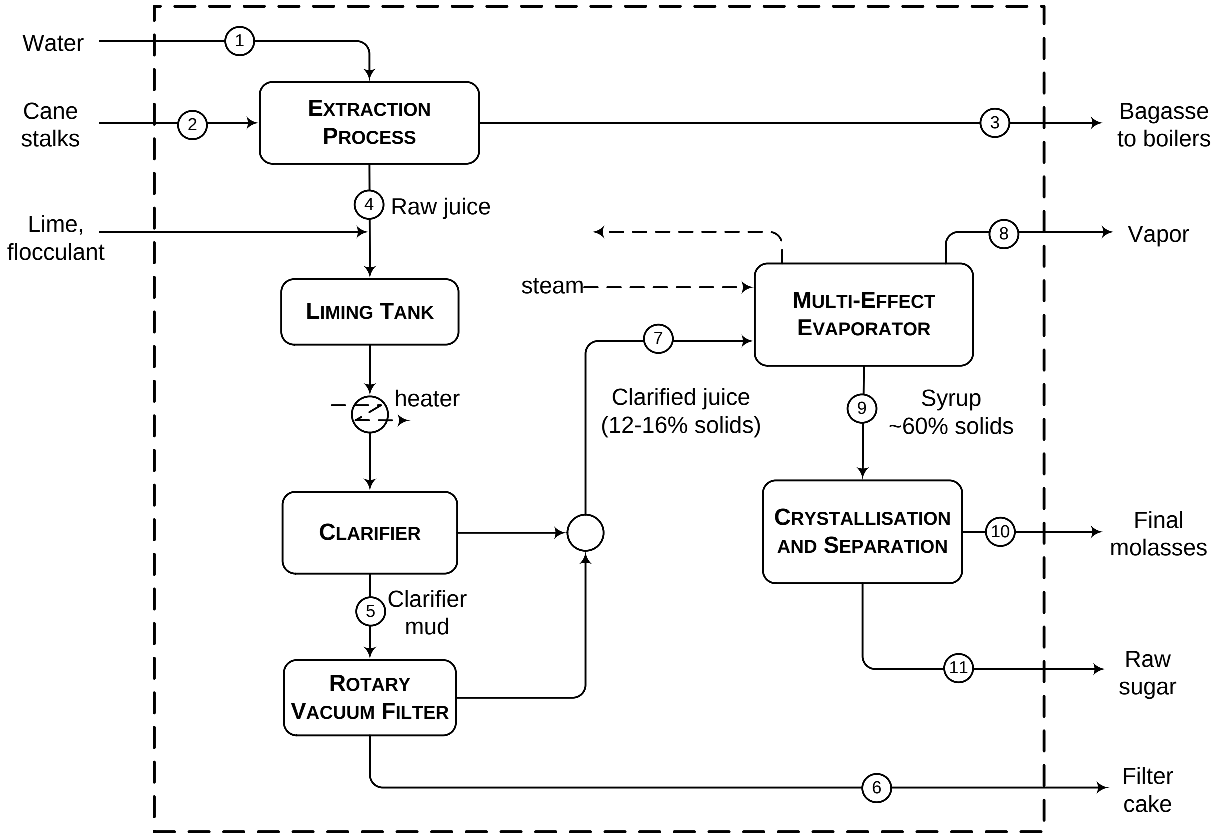

Figure 23: Sugar production process (Patel & Notten, 2013)

A.1.9.3. Sources of GHG from sugar production

II Annex 2: Data availability and data summaries

This Annex summarises the data that is available in the public domain for the different sectors. It is noted that the data presented here is not necessarily that that can be used to develop an output based benchmark or for any fall back approaches.

A.2.1 Iron and steel

Publically available data for iron and steel is provided in the table below.

Table 67: Publically available company data on production, fuel and electricity use (including own generation), emissions and emissions intensity for the iron and steel sector

Company/ plant/ region	Description	Value	Units	Year	Reference
Production					
South Africa	Crude steel production	7.60	million tonnes	2010	World Steel (2012) World Steel in Figures 2012
South Africa	Crude steel production	7.50	million tonnes	2011	World Steel (2013) World Steel in Figures 2013
South Africa	Crude steel production	6.90	million tonnes	2012	World Steel (2013) World Steel in Figures 2013
South Africa	Pig iron production	5.40	million tonnes	2010	World Steel (2012) World Steel in Figures 2012
South Africa	Pig iron production	4.60	million tonnes	2011	World Steel (2013) World Steel in Figures 2013
South Africa	Pig iron production	4.60	million tonnes	2012	World Steel (2013) World Steel in Figures 2013
South Africa	Direct reduced iron production	1.10	million tonnes	2010	World Steel (2013) World Steel in Figures 2013
South Africa	Direct reduced iron production	1.40	million tonnes	2011	World Steel (2013) World Steel in Figures 2013
South Africa	Direct reduced iron production - estimate	1.50	million tonnes	2012	World Steel (2013) World Steel in Figures 2013
Highveld Steel and Vanadium Corporation Ltd	Hot metal produced	777,190	tonnes	2010	Evraz Highveld (2012) Integrated Annual Report
Highveld Steel and Vanadium Corporation Ltd	Hot metal produced	659,603	tonnes	2011	Evraz Highveld (2012) Integrated Annual Report
Highveld Steel and Vanadium Corporation Ltd	Hot metal produced	620,035	tonnes	2012	Evraz Highveld (2012) Integrated Annual Report
Highveld Steel and Vanadium Corporation Ltd	Continuously cast blocks	733,646	tonnes	2010	Evraz Highveld (2012) Integrated Annual Report
Highveld Steel and Vanadium Corporation Ltd	Continuously cast blocks	670,880	tonnes	2011	Evraz Highveld (2012) Integrated Annual Report
Highveld Steel and Vanadium Corporation Ltd	Continuously cast blocks	571,787	tonnes	2012	Evraz Highveld (2012) Integrated Annual Report
Highveld Steel and Vanadium Corporation Ltd	Rolled products	554,403	tonnes	2010	Evraz Highveld (2012) Integrated Annual Report

Company/ plant/ region	Description	Value	Units	Year	Reference
Highveld Steel and Vanadium Corporation Ltd	Rolled products	512,755	tonnes	2011	Evraz Highveld (2012) Integrated Annual Report
Highveld Steel and Vanadium Corporation Ltd	Rolled products	447,537	tonnes	2012	Evraz Highveld (2012) Integrated Annual Report
ArcelorMittal SA	Liquid Steel production	5,674	thousand tonnes	2010	ArcelorMittal (2012) Financial report 2012
ArcelorMittal SA	Liquid Steel production	5,453	thousand tonnes	2011	ArcelorMittal (2012) Financial report
ArcelorMittal SA	Liquid Steel production	5,090	thousand tonnes	2012	ArcelorMittal (2012) Financial report
ArcelorMittal SA	Flat products	3,814	thousand tonnes	2010	ArcelorMittal (2012) Financial report 2012
ArcelorMittal SA	Flat products	4,060	thousand tonnes	2011	ArcelorMittal (2012) Financial report
ArcelorMittal SA	Flat products	3,554	thousand tonnes	2012	ArcelorMittal (2012) Financial report
ArcelorMittal SA	Long products	1,860	thousand tonnes	2010	ArcelorMittal (2012) Financial report
ArcelorMittal SA	Long products	1,393	thousand tonnes	2011	ArcelorMittal (2012) Financial report
ArcelorMittal SA	Long products	1,536	thousand tonnes	2012	ArcelorMittal (2012) Financial report
Columbus	Stainless steel production	481	thousand tonnes	2010	Acerinox (2012) Annual report
Columbus	Stainless steel production	446	thousand tonnes	2011	Acerinox (2012) Annual report
Columbus	Stainless steel production	506	thousand tonnes	2012	Acerinox (2012) Annual report
					Fuel and electricity consumption
ArcelorMittal SA	Coal use	4,418,984	tonnes	2010	ArcelorMittal (2012) Annual sustainability report
ArcelorMittal SA	Coal use	3,984,744	tonnes	2011	ArcelorMittal (2012) Annual sustainability report
ArcelorMittal SA	Coal use	4,572,542	tonnes	2012	ArcelorMittal (2012) Annual sustainability report
ArcelorMittal SA	Electricity (purchased)	4.31	TWh	2010	ArcelorMittal (2012) Annual sustainability report
ArcelorMittal SA	Electricity (purchased)	4.38	TWh	2011	ArcelorMittal (2012) Annual sustainability report
ArcelorMittal SA	Electricity (purchased)	3.78	TWh	2012	ArcelorMittal (2012) Annual sustainability report
ArcelorMittal SA	Electricity	4,053,104	MWh	2010	ArcelorMittal (2011) CDP Disclosure
ArcelorMittal SA	Electricity	4,036,081	MWh	2011	ArcelorMittal (2012) CDP Disclosure
ArcelorMittal SA	Electricity	3,490,045	MWh	2012	ArcelorMittal (2013) CDP Disclosure
ArcelorMittal SA	Bitumous coal	30,718,114	MWh	2010	ArcelorMittal (2011) CDP Disclosure
ArcelorMittal SA	Bitumous coal	29,803,657	MWh	2011	ArcelorMittal (2012) CDP Disclosure

Company/ plant/ region	Description	Value	Units	Year	Reference
ArcelorMittal SA	Bitumous coal	30,261,436	MWh	2012	ArcelorMittal (2013) CDP Disclosure
ArcelorMittal SA	Diesel/ gas oil	73,911	MWh	2010	ArcelorMittal (2011) CDP Disclosure
ArcelorMittal SA	Diesel/ gas oil	62,515	MWh	2011	ArcelorMittal (2012) CDP Disclosure
ArcelorMittal SA	Diesel/ gas oil	76,900	MWh	2012	ArcelorMittal (2013) CDP Disclosure
ArcelorMittal SA	Liquefied Petroleum gas (LPG)	278,670	MWh	2010	ArcelorMittal (2011) CDP Disclosure
ArcelorMittal SA	Liquefied Petroleum gas (LPG)	208,579	MWh	2011	ArcelorMittal (2012) CDP Disclosure
ArcelorMittal SA	Liquefied Petroleum gas (LPG)	163,687	MWh	2012	ArcelorMittal (2013) CDP Disclosure
ArcelorMittal SA	Natural gas	2,380,662	MWh	2010	ArcelorMittal (2011) CDP Disclosure
ArcelorMittal SA	Natural gas	2,351,791	MWh	2011	ArcelorMittal (2012) CDP Disclosure
ArcelorMittal SA	Natural gas	2,201,133	MWh	2012	ArcelorMittal (2013) CDP Disclosure
Evraz Highveld Steel and Vanadium	Diesel/Gas oil	30,142	MWh	2010	Evraz Highveld (2011) CDP Disclosure
Evraz Highveld Steel and Vanadium	Diesel/Gas oil	11,845	MWh	2011	Evraz Highveld (2012) CDP Disclosure
Evraz Highveld Steel and Vanadium	Other: Gascor Gas	669,429	MWh	2010	Evraz Highveld (2011) CDP Disclosure
Evraz Highveld Steel and Vanadium	Other: Gascor Gas	574,633	MWh	2011	Evraz Highveld (2012) CDP Disclosure
Evraz Highveld Steel and Vanadium	Other: Metallurgical coal	5,852,599	MWh	2010	Evraz Highveld (2011) CDP Disclosure
Evraz Highveld Steel and Vanadium	Other: Metallurgical coal	4,529,705	MWh	2011	Evraz Highveld (2012) CDP Disclosure
Evraz Highveld Steel and Vanadium	Other: Duff coal/ waste coal	1,338,167	MWh	2010	Evraz Highveld (2011) CDP Disclosure
Evraz Highveld Steel and Vanadium	Other: Duff coal/ waste coal	1,293,657	MWh	2011	Evraz Highveld (2012) CDP Disclosure
Evraz Highveld Steel and Vanadium	Electricity	1,758,741	MWh	2010	Evraz Highveld (2011) CDP Disclosure
Evraz Highveld Steel and Vanadium	Electricity	1,471,553	MWh	2011	Evraz Highveld (2012) CDP Disclosure
					Electricity generated and/or exported
ArcelorMittal SA, Vanderbijlpark Works	Internal electricity generation, 40 MW plant, using waste heat from kilns	29	MW	2011	ArcelorMittal (2011) CDP Disclosure
					Annual emissions
ArcelorMittal SA	Scope 1 emissions	11.85	Mt CO_2e	2010	ArcelorMittal (2012) Annual sustainability report
ArcelorMittal SA	Scope 1 emissions	10.96	Mt CO_2e	2011	ArcelorMittal (2012) Annual sustainability report
ArcelorMittal SA	Scope 1 emissions	11.32	Mt CO_2e	2012	ArcelorMittal (2012) Annual sustainability report

Company/ plant/ region	Description	Value	Units	Year	Reference
ArcelorMittal SA	Scope 2 emissions	4.44	Mt CO_2e	2010	ArcelorMittal (2012) Annual sustainability report
ArcelorMittal SA	Scope 2 emissions	4.49	Mt CO_2e	2011	ArcelorMittal (2012) Annual sustainability report
ArcelorMittal SA	Scope 2 emissions	3.90	Mt CO_2e	2012	ArcelorMittal (2012) Annual sustainability report
ArcelorMittal SA	Total emissions	16.29	Mt CO_2e	2010	ArcelorMittal (2012) Annual sustainability report
ArcelorMittal SA	Total emissions	15.44	Mt CO_2e	2011	ArcelorMittal (2012) Annual sustainability report
ArcelorMittal SA	Total emissions	15.22	Mt CO_2e	2012	ArcelorMittal (2012) Annual sustainability report
ArcelorMittal SA, Flat steel products	Scope 1 emissions	8,155,464	tonnes CO_2e	2010	ArcelorMittal (2011) CDP Disclosure
ArcelorMittal SA, Flat steel products	Scope 1 emissions	8,260,314	tonnes CO_2e	2011	ArcelorMittal (2012) CDP Disclosure
ArcelorMittal SA, Flat steel products	Scope 1 emissions	8,264,512	tonnes CO_2e	2012	ArcelorMittal (2013) CDP Disclosure
ArcelorMittal SA, Long steel products	Scope 1 emissions	3,783,388	tonnes CO_2e	2010	ArcelorMittal (2011) CDP Disclosure
ArcelorMittal SA, Long steel products	Scope 1 emissions	2,701,593	tonnes CO_2e	2011	ArcelorMittal (2012) CDP Disclosure
ArcelorMittal SA, Long steel products	Scope 1 emissions	3,053,565	tonnes CO_2e	2012	ArcelorMittal (2013) CDP Disclosure
ArcelorMittal SA, Flat steel products	Scope 2 emissions	3,493,354	tonnes CO_2e	2010	ArcelorMittal (2011) CDP Disclosure
ArcelorMittal SA, Flat steel products	Scope 2 emissions	3,709,913	tonnes CO_2e	2011	ArcelorMittal (2012) CDP Disclosure
ArcelorMittal SA, Flat steel products	Scope 2 emissions	3,036,460	tonnes CO_2e	2012	ArcelorMittal (2013) CDP Disclosure
ArcelorMittal SA, Long steel products	Scope 2 emissions	949,742	tonnes CO_2e	2010	ArcelorMittal (2011) CDP Disclosure
ArcelorMittal SA, Long steel products	Scope 2 emissions	777,285	tonnes CO_2e	2011	ArcelorMittal (2012) CDP Disclosure
ArcelorMittal SA, Long steel products	Scope 2 emissions	862,071	tonnes CO_2e	2012	ArcelorMittal (2013) CDP Disclosure
Columbus	Total emissions	205	Mt CO_2e	2010	Acerinox (2012) Annual report
Columbus	Total emissions	190	Mt CO_2e	2011	Acerinox (2012) Annual report
Columbus	Total emissions	196	Mt CO_2e	2012	Acerinox (2012) Annual report
Evraz Highveld Steel and Vanadium	Scope 1 emissions	2,799,579	tonnes CO_2e	2010	Evraz Highveld (2011) CDP Disclosure
Evraz Highveld Steel and Vanadium	Scope 1 emissions	2,432,193	tonnes CO_2e	2011	Evraz Highveld (2012) CDP Disclosure
Evraz Highveld - Steelworks	Scope 1 emissions	2,796,146	tonnes CO_2e	2010	Evraz Highveld (2011) CDP Disclosure
Evraz Highveld - Steelworks	Scope 1 emissions	2,421,249	tonnes CO_2e	2011	Evraz Highveld (2012) CDP Disclosure

Company/ plant/ region	Description	Value	Units	Year	Reference
Evraz Highveld - Mapochs mine	Scope 1 emissions	3,433	tonnes CO_2e	2010	Evraz Highveld (2011) CDP Disclosure
Evraz Highveld - Mapochs mine	Scope 1 emissions	10,944	tonnes CO_2e	2011	Evraz Highveld (2012) CDP Disclosure
Evraz Highveld Steel and Vanadium	Scope 2 emissions	1,811,503	tonnes CO_2e	2010	Evraz Highveld (2011) CDP Disclosure
Evraz Highveld Steel and Vanadium	Scope 2 emissions	1,555,882	tonnes CO_2e	2011	Evraz Highveld (2012) CDP Disclosure
Evraz Highveld - Steelworks	Scope 2 emissions	1,800,841	tonnes CO_2e	2010	Evraz Highveld (2011) CDP Disclosure
Evraz Highveld - Steelworks	Scope 2 emissions	1,546,492	tonnes CO_2e	2011	Evraz Highveld (2012) CDP Disclosure
Evraz Highveld - Mapochs mine	Scope 2 emissions	10,662	tonnes CO_2e	2010	Evraz Highveld (2011) CDP Disclosure
Evraz Highveld - Mapochs mine	Scope 2 emissions	9,390	tonnes CO_2e	2011	Evraz Highveld (2012) CDP Disclosure
					Emissions intensity
ArcelorMittal company average	Emissions intensity	2.89	tonnes CO_2e/ tonne steel	2010	ArcelorMittal (2011) CDP Disclosure
ArcelorMittal company average	Emissions intensity	2.77	tonnes CO_2e/ tonne steel	2011	ArcelorMittal (2012) CDP Disclosure
ArcelorMittal company average	Emissions intensity	2.98	tonnes CO_2e/ tonne steel	2012	ArcelorMittal (2013) CDP Disclosure
ArcelorMittal company average	Scope 1 emissions intensity	2.09	tonnes CO_2e / tonne liquid steel	2010	ArcelorMittal (2012) Annual sustainability report
ArcelorMittal company average	Scope 1 emissions intensity	1.96	tonnes CO_2e / tonne liquid steel	2011	ArcelorMittal (2012) Annual sustainability report
ArcelorMittal company average	Scope 1 emissions intensity	2.22	tonnes CO_2e / tonne liquid steel	2012	ArcelorMittal (2012) Annual sustainability report
ArcelorMittal company average	Scope 2 emissions intensity	0.78	tonnes CO_2e / tonne liquid steel	2010	ArcelorMittal (2012) Annual sustainability report
ArcelorMittal company average	Scope 2 emissions intensity	0.85	tonnes CO_2e / tonne liquid steel	2011	ArcelorMittal (2012) Annual sustainability report
ArcelorMittal company average	Scope 2 emissions intensity	0.76	tonnes CO_2e / tonne liquid steel	2012	ArcelorMittal (2012) Annual sustainability report
ArcelorMittal Vanderbijlpark	Scope 1 emissions intensity	2.18	tonnes CO_2e / tonne liquid steel	2010	ArcelorMittal (2012) Annual sustainability report
ArcelorMittal Vanderbijlpark	Scope 1 emissions intensity	1.98	tonnes CO_2e / tonne liquid steel	2011	ArcelorMittal (2012) Annual sustainability report
ArcelorMittal Vanderbijlpark	Scope 1 emissions intensity	2.52	tonnes CO_2e / tonne liquid steel	2012	ArcelorMittal (2012) Annual sustainability report
ArcelorMittal Vanderbijlpark	Scope 2 emissions intensity	0.80	tonnes CO_2e / tonne liquid steel	2010	ArcelorMittal (2012) Annual sustainability report
ArcelorMittal Vanderbijlpark	Scope 2 emissions intensity	0.77	tonnes CO_2e / tonne liquid steel	2011	ArcelorMittal (2012) Annual sustainability report
ArcelorMittal Vanderbijlpark	Scope 2 emissions intensity	0.70	tonnes CO_2e / tonne liquid steel	2012	ArcelorMittal (2012) Annual sustainability report
ArcelorMittal Saldanha	Scope 1 emissions intensity	2.03	tonnes CO_2e / tonne liquid steel	2010	ArcelorMittal (2012) Annual sustainability report
ArcelorMittal Saldanha	Scope 1 emissions intensity	1.87	tonnes CO_2e / tonne liquid steel	2011	ArcelorMittal (2012) Annual sustainability report

Company/ plant/ region	Description	Value	Units	Year	Reference
ArcelorMittal Saldanha	Scope 1 emissions intensity	1.93	tonnes CO_2e / tonne liquid steel	2012	ArcelorMittal (2012) Annual sustainability report
ArcelorMittal Saldanha	Scope 2 emissions intensity	1.28	tonnes CO_2e / tonne liquid steel	2010	ArcelorMittal (2012) Annual sustainability report
ArcelorMittal Saldanha	Scope 2 emissions intensity	1.24	tonnes CO_2e / tonne liquid steel	2011	ArcelorMittal (2012) Annual sustainability report
ArcelorMittal Saldanha	Scope 2 emissions intensity	1.17	tonnes CO_2e / tonne liquid steel	2012	ArcelorMittal (2012) Annual sustainability report
ArcelorMittal Newcastle	Scope 1 emissions intensity	2.29	tonnes CO_2e / tonne liquid steel	2010	ArcelorMittal (2012) Annual sustainability report
ArcelorMittal Newcastle	Scope 1 emissions intensity	2.39	tonnes CO_2e / tonne liquid steel	2011	ArcelorMittal (2012) Annual sustainability report
ArcelorMittal Newcastle	Scope 1 emissions intensity	2.28	tonnes CO_2e / tonne liquid steel	2012	ArcelorMittal (2012) Annual sustainability report
ArcelorMittal Newcastle	Scope 2 emissions intensity	0.40	tonnes CO_2e / tonne liquid steel	2010	ArcelorMittal (2012) Annual sustainability report
ArcelorMittal Newcastle	Scope 2 emissions intensity	0.65	tonnes CO_2e / tonne liquid steel	2011	ArcelorMittal (2012) Annual sustainability report
ArcelorMittal Newcastle	Scope 2 emissions intensity	0.45	tonnes CO_2e / tonne liquid steel	2012	ArcelorMittal (2012) Annual sustainability report
ArcelorMittal Vereeniging	Scope 1 emissions intensity	0.38	tonnes CO_2e / tonne liquid steel	2010	ArcelorMittal (2012) Annual sustainability report
ArcelorMittal Vereeniging	Scope 1 emissions intensity	0.37	tonnes CO_2e / tonne liquid steel	2011	ArcelorMittal (2012) Annual sustainability report
ArcelorMittal Vereeniging	Scope 1 emissions intensity	0.42	tonnes CO_2e / tonne liquid steel	2012	ArcelorMittal (2012) Annual sustainability report
ArcelorMittal Vereeniging	Scope 2 emissions intensity	1.09	tonnes CO_2e / tonne liquid steel	2010	ArcelorMittal (2012) Annual sustainability report
ArcelorMittal Vereeniging	Scope 2 emissions intensity	1.04	tonnes CO_2e / tonne liquid steel	2011	ArcelorMittal (2012) Annual sustainability report
ArcelorMittal Vereeniging	Scope 2 emissions intensity	1.02	tonnes CO_2e / tonne liquid steel	2012	ArcelorMittal (2012) Annual sustainability report
Columbus	Emissions intensity	0.43	tonnes CO_2/ tonne steel	2010	Acerinox (2012) Annual report
Columbus	Emissions intensity	0.43	tonnes CO_2/ tonne steel	2011	Acerinox (2012) Annual report
Columbus	Emissions intensity	0.39	tonnes CO_2/ tonne steel	2012	Acerinox (2012) Annual report
Evraz Highveld Steel and Vanadium	Emissions intensity	8.32	tonnes CO_2e/ tonne steel	2010	Evraz Highveld (2011) CDP Disclosure
Evraz Highveld Steel and Vanadium	Emissions intensity	5.94	tonnes CO_2e/ tonne steel	2011	Evraz Highveld (2012) CDP Disclosure

A.2.2 Ferroalloys

Table 68: Publically available company data on production, fuel and electricity use (including own generation), emissions and emissions intensity for the ferroalloys sector

Company/ plant/ region	Ferroalloy	Description	Value	Units	Year	Reference
Production						
South Africa	Ferroalloys total	Ferroalloys production	4,547,000	tonnes per annum	2010	DMR (2012) SA Ferroalloys Handbook
South Africa	Ferrochromium	Ferrochromium production	3,364,780	tonnes per annum	2010	DMR (2012) SA Ferroalloys Handbook
South Africa	Ferromanganese	Ferromanganese production	1,000,340	tonnes per annum	2010	DMR (2012) SA Ferroalloys Handbook
South Africa	Ferrosilicon	Ferrosilicon production	136,410	tonnes per annum	2010	DMR (2012) SA Ferroalloys Handbook
South Africa	Ferrovanadium	Ferrovanadium production	45,470	tonnes per annum	2010	DMR (2012) SA Ferroalloys Handbook
South Africa	Ferroalloys	Ferroalloys production	4,049,000	tonnes per annum	2012	DMR (2013) SA Ferroalloys Handbook
South Africa	Ferrochromium	Ferrochromium production	3,061,044	tonnes per annum	2012	DMR (2013) SA Ferroalloys Handbook
South Africa	Ferromanganese	Ferromanganese production	842,192	tonnes per annum	2012	DMR (2013) SA Ferroalloys Handbook
South Africa	Ferrosilicon	Ferrosilicon production	125,519	tonnes per annum	2012	DMR (2013) SA Ferroalloys Handbook
South Africa	Ferrovanadium	Ferrovanadium production	20,245	tonnes per annum	2012	DMR (2013) SA Ferroalloys Handbook
Assmang Machadodorp Works	ChCr	Production	189,000	tonnes per annum	FY 2010	Assmang (2012) Annual Report
Assmang Machadodorp Works	ChCr	Production	238,000	tonnes per annum	FY 2011	Assmang (2012) Annual Report
Assmang Machadodorp Works	ChCr	Production	174,000	tonnes per annum	FY 2012	Assmang (2012) Annual Report
International Ferro Metals (IFM)	ChCr	Production	200,440	tonnes per annum	FY 2010	IFM (2011) Annual Report
International Ferro Metals (IFM)	ChCr	Production	194,869	tonnes per annum	FY 2011	IFM (2012) Annual Report
International Ferro Metals (IFM)	ChCr	Production	153,046	tonnes per annum	FY 2012	IFM (2013) Annual Report
Tata Steel KZN Pty Ltd	HCFeCr	Production	118,000	tonnes per annum	FY 2010	Tata Steel (2011) Annual Report
Tata Steel KZN Pty Ltd	HCFeCr	Production	107,000	tonnes per annum	FY 2011	Tata Steel (2012) Annual Report
Tata Steel KZN Pty Ltd	HCFeCr	Production	94,000	tonnes per annum	FY 2012	Tata Steel (2012) Annual Report
Merafe Group and Xstrata-Merafe Chrome Venture	FeCr	Production	1,284,690	tonnes per annum	2010	Merafe Resources (2011) Integrated Annual Report

Company/ plant/ region	Ferroalloy	Description	Value	Units	Year	Reference
Merafe Group and Xstrata-Merafe Chrome Venture	FeCr	Production	1,274,400	tonnes per annum	2011	Merafe Resources (2012) Integrated Annual Report
Merafe Group and Xstrata-Merafe Chrome Venture	FeCr	Production	1,180,000	tonnes per annum	2012	Merafe Resources (2012) Integrated Annual Report
Assmang Manganese Cato Ridge	Manganese alloys, total	Production	252,000	tonnes per annum	FY 2010	ARM (2013) Integrated Annual Report
Assmang Manganese Cato Ridge	Manganese alloys, total	Production	291,000	tonnes per annum	FY 2011	ARM (2013) Integrated Annual Report
Assmang Manganese Cato Ridge	Manganese alloys, total	Production	372,000	tonnes per annum	FY 2012	ARM (2013) Integrated Annual Report
Samancor, Metalloys	Manganese alloys, total	Production	364,000	tonnes per annum	FY 2010	BHP Billiton (2012) Annual Report
Samancor, Metalloys	Manganese alloys, total	Production	486,000	tonnes per annum	FY 2011	BHP Billiton (2013) Annual Report
Samancor, Metalloys	Manganese alloys, total	Production	404,000	tonnes per annum	FY 2012	BHP Billiton (2013) Annual Report
Evraz Highveld Steel and Vanadium	FeV	Production	5,392	tonnes per annum	2010	Evraz Highveld (2012) Integrated Annual Report
Evraz Highveld Steel and Vanadium	FeV	Production	6,059	tonnes per annum	2011	Evraz Highveld (2012) Integrated Annual Report
Evraz Highveld Steel and Vanadium	FeV	Production	4,724	tonnes per annum	2012	Evraz Highveld (2012) Integrated Annual Report
Vanchem Vanadium Products	FeV	Production	4,150	tonnes per annum	FY 2011	Duferco (2011) Annual Report
Vanchem Vanadium Products	FeV	Production	4,516	tonnes per annum	FY 2012	Duferco (2012) Annual Report
						Fuel and electricity consumption
Assmang Machadodorp Works	ChCr	Diesel	417	'000 litres	FY 2010	Assore (2011) Integrated Annual Report
Assmang Machadodorp Works	ChCr	Diesel	1,501	'000 litres	FY 2011	Assore (2011) Integrated Annual Report
Assmang Machadodorp Works	ChCr	Diesel	1,273	'000 litres	FY 2012	Assore (2013) Integrated Annual Report
Assmang Machadodorp Works	ChCr	Electricity	645,107	kWh	FY 2010	Assore (2011) Integrated Annual Report
Assmang Machadodorp Works	ChCr	Electricity	1,007,538	kWh	FY 2011	Assore (2011) Integrated Annual Report
Assmang Machadodorp Works	ChCr	Electricity	825,131	kWh	FY 2012	Assore (2013) Integrated Annual Report

Company/ plant/ region	Ferroalloy	Description	Value	Units	Year	Reference
Assmang Manganese Cato Ridge	HCFeMn and MCFeMn	Diesel	642	'000 litres	FY 2010	Assore (2011) Integrated Annual Report
Assmang Manganese Cato Ridge	HCFeMn and MCFeMn	Diesel	524	'000 litres	FY 2011	Assore (2011) Integrated Annual Report
Assmang Manganese Cato Ridge	HCFeMn and MCFeMn	Diesel	492	'000 litres	FY 2012	Assore (2013) Integrated Annual Report
Assmang Manganese Cato Ridge	HCFeMn and MCFeMn	Electricity	533,183	kWh	FY 2010	Assore (2011) Integrated Annual Report
Assmang Manganese Cato Ridge	HCFeMn and MCFeMn	Electricity	588,410	kWh	FY 2011	Assore (2011) Integrated Annual Report
Assmang Manganese Cato Ridge	HCFeMn and MCFeMn	Electricity	747,392	kWh	FY 2012	Assore (2013) Integrated Annual Report
International Ferro Metals (IFM)	ChCr	Electricity consumption	850.20	kWh	FY 2010	IFM (2011) Annual Report
International Ferro Metals (IFM)	ChCr	Electricity consumption	833	kWh	FY 2011	IFM (2011) Annual Report
International Ferro Metals (IFM)	ChCr	Electricity consumption	600,595,268	kWh	FY 2012	IFM (2013) Annual Report
Merafe Group and Xstrata-Merafe Chrome Venture	FeCr	Direct energy use	1,501,832	GJ	2010	Merafe Resources (2012) Integrated Annual Report
Merafe Group and Xstrata-Merafe Chrome Venture	FeCr	Direct energy use	2,327,798	GJ	2011	Merafe Resources (2012) Integrated Annual Report
Merafe Group and Xstrata-Merafe Chrome Venture	FeCr	Direct energy use	1,590,049	GJ	2012	Merafe Resources (2012) Integrated Annual Report
Merafe Group and Xstrata-Merafe Chrome Venture	FeCr	Indirect energy use	19,033,755	GJ	2010	Merafe Resources (2012) Integrated Annual Report
Merafe Group and Xstrata-Merafe Chrome Venture	FeCr	Indirect energy use	17,204,622	GJ	2011	Merafe Resources (2012) Integrated Annual Report
Merafe Group and Xstrata-Merafe Chrome Venture	FeCr	Indirect energy use	15,300,925	GJ	2012	Merafe Resources (2012) Integrated Annual Report
Merafe Group and Xstrata-Merafe Chrome Venture	FeCr	Total energy use	20,535,587	GJ	2010	Merafe Resources (2012) Integrated Annual Report
Merafe Group and Xstrata-Merafe Chrome Venture	FeCr	Total energy use	19,532,420	GJ	2011	Merafe Resources (2012) Integrated Annual Report

Company/ plant/ region	Ferroalloy	Description	Value	Units	Year	Reference
Merafe Group and Xstrata-Merafe Chrome Venture	FeCr	Total energy use	16,890,974	GJ	2012	Merafe Resources (2012) Integrated Annual Report
						Energy intensity
Merafe Group and Xstrata-Merafe Chrome Venture	FeCr	Energy intensity per tonne FeCr	68.43	GJ/ tonne	2010	Merafe Resources (2010) Integrated Annual Report
Merafe Group and Xstrata-Merafe Chrome Venture	FeCr	Energy intensity per tonne FeCr	15.23	GJ/ tonne	2011	Merafe Resources (2012) Integrated Annual Report
Merafe Group and Xstrata-Merafe Chrome Venture	FeCr	Energy intensity per tonne FeCr	14.31	GJ/ tonne	2012	Merafe Resources (2012) Integrated Annual Report
						Electricity generated an/or exported
International Ferro Metals (IFM)	ChCr	Co-generation plant electricity generation	not reported	GWh	FY 2010	IFM (2011) Annual Report
International Ferro Metals (IFM)	ChCr	Co-generation plant electricity generation	not reported	GWh	FY 2011	IFM (2012) Annual Report
International Ferro Metals (IFM)	ChCr	Co-generation plant electricity generation	28	GWh	FY 2012	IFM (2013) Annual Report
International Ferro Metals (IFM)	ChCr	% of company electricity requirements met by co-gen	not reported		FY 2010	IFM (2011) Annual Report
International Ferro Metals (IFM)	ChCr	% of company electricity requirements met by co-gen	not reported		FY 2011	IFM (2012) Annual Report
International Ferro Metals (IFM)	ChCr	% of company electricity requirements met by co-gen	4.5%		FY 2012	IFM (2013) Annual Report
						Annual emissions
Assmang operation	All products	Scope 1 emissions	584,717	tonnes CO_2e	FY 2010	Assore (2011) Integrated Annual Report
Assmang operation	All products	Scope 1 emissions	573,055	tonnes CO_2e	FY 2011	Assore (2011) Integrated Annual Report
Assmang operation	All products	Scope 1 emissions	858,431	tonnes CO_2e	FY 2012	Assore (2013) Integrated Annual Report
Assmang operation	All products	Scope 2 emissions	1,277,003	tonnes CO_2e	FY 2010	Assore (2011) Integrated Annual Report
Assmang operation	All products	Scope 2 emissions	1,426,879	tonnes CO_2e	FY 2011	Assore (2011) Integrated Annual Report
Assmang operation	All products	Scope 2 emissions	1,808,549	tonnes CO_2e	FY 2012	Assore (2013) Integrated Annual Report

Company/ plant/ region	Ferroalloy	Description	Value	Units	Year	Reference
Assmang operation	All products	Scope 1 and 2 emissions	1,861,720	tonnes CO_2e	FY 2010	Assore (2011) Integrated Annual Report
Assmang operation	All products	Scope 1 and 2 emissions	1,999,934	tonnes CO_2e	FY 2011	Assore (2011) Integrated Annual Report
Assmang operation	All products	Scope 1 and 2 emissions	2,666,980	tonnes CO_2e	FY 2012	Assore (2013) Integrated Annual Report
Assmang Machadodorp Works	ChCr	Scope 1 and 2 emissions	781,922	tonnes CO_2e	FY 2010	Assore (2011) Integrated Annual Report
Assmang Machadodorp Works	ChCr	Scope 1 and 2 emissions	799,974	tonnes CO_2e	FY 2011	Assore (2011) Integrated Annual Report
Assmang Machadodorp Works	ChCr	Scope 1 and 2 emissions	1,066,792	tonnes CO_2e	FY 2012	Assore (2013) Integrated Annual Report
Assmang Manganese Cato Ridge	HCFeMn and MCFeMn	Scope 1 and 2 emissions	670,219	tonnes CO_2e	FY 2010	Assore (2011) Integrated Annual Report
Assmang Manganese Cato Ridge	HCFeMn and MCFeMn	Scope 1 and 2 emissions	679,978	tonnes CO_2e	FY 2011	Assore (2011) Integrated Annual Report
Assmang Manganese Cato Ridge	HCFeMn and MCFeMn	Scope 1 and 2 emissions	1,120,132	tonnes CO_2e	FY 2012	Assore (2013) Integrated Annual Report
International Ferro Metals (IFM)	ChCr	Company total CO_2 emissions	736,240	tonnes CO_2e	FY 2010	IFM (2011) Annual Report
International Ferro Metals (IFM)	ChCr	Company total CO_2 emissions	721,363	tonnes CO_2e	FY 2011	IFM (2011) Annual Report
International Ferro Metals (IFM)	ChCr	Company total CO_2 emissions	520,170	tonnes CO_2e	FY 2012	IFM (2013) Annual Report
Merafe Group and Xstrata-Merafe Chrome Venture	FeCr	Scope 1	2,993,579	tonnes CO_2e	2010	Merafe Resources (2012) Integrated Annual Report
Merafe Group and Xstrata-Merafe Chrome Venture	FeCr	Scope 1	2,697,533	tonnes CO_2e	2011	Merafe Resources (2012) Integrated Annual Report
Merafe Group and Xstrata-Merafe Chrome Venture	FeCr	Scope 1	2,454,056	tonnes CO_2e	2012	Merafe Resources (2012) Integrated Annual Report
Merafe Group and Xstrata-Merafe Chrome Venture	FeCr	Scope 2	4,418,030	tonnes CO_2e	2010	Merafe Resources (2012) Integrated Annual Report
Merafe Group and Xstrata-Merafe Chrome Venture	FeCr	Scope 2	3,993,461	tonnes CO_2e	2011	Merafe Resources (2012) Integrated Annual Report

Company/ plant/ region	Ferroalloy	Description	Value	Units	Year	Reference
Merafe Group and Xstrata-Merafe Chrome Venture	FeCr	Scope 2	3,551,583	tonnes CO_2e	2012	Merafe Resources (2012) Integrated Annual Report
Merafe Group and Xstrata-Merafe Chrome Venture	FeCr	Company total	7,411,607	tonnes CO_2e	2010	Merafe Resources (2012) Integrated Annual Report
Merafe Group and Xstrata-Merafe Chrome Venture	FeCr	Company total	6,690,994	tonnes CO_2e	2011	Merafe Resources (2012) Integrated Annual Report
Merafe Group and Xstrata-Merafe Chrome Venture	FeCr	Company total	6,005,637	tonnes CO_2e	2012	Merafe Resources (2012) Integrated Annual Report
						Emissions intensity
Merafe Group and Xstrata-Merafe Chrome Venture	FeCr	Emissions intensity per tonne of FeCr	5.06	tonnes CO_2e/ tonne FeCr	2010	Merafe Resources (2012) Integrated Annual Report
Merafe Group and Xstrata-Merafe Chrome Venture	FeCr	Emissions intensity per tonne of FeCr	5.22	tonnes CO_2e/ tonne FeCr	2011	Merafe Resources (2012) Integrated Annual Report
Merafe Group and Xstrata-Merafe Chrome Venture	FeCr	Emissions intensity per tonne of FeCr	5.09	tonnes CO_2e/ tonne FeCr	2012	Merafe Resources (2012) Integrated Annual Report

A.2.3 Cement

Table 69: Publically available company data on production, fuel and electricity use (including own generation), emissions and emissions intensity for the cement sector

Company/ plant/ region	Description	Value	Units	Year	Reference
Production					
South Africa	Cementitious materials sales	10.870	million tonnes	2010	ACMP (2011) Sustainability Report
La Farge, Lichtenburg	Cement production	2,400,000	tonnes cement	2010	Lafarge (2010) Corporate Brochure; Cemnet (undated) SA Cement Review
La Farge, Richards Bay grinding station	Cement production	200,000	tonnes cement	2010	Lafarge (2010) Corporate Brochure
La Farge, Randfontein grinding station	Cement production	1,000,000	tonnes cement	2010	Lafarge (2010) Corporate Brochure
NPC-Cimpor, Simuna	Clinker production	1,500,000	tonnes clinker	2011	SRK (2011) NPC-Cimpor Draft EIA Report
NPC-Cimpor, Simuna grinding station	Cement production	450,000	tonnes cement	2011	SRK (2011) NPC-Cimpor Draft EIA Report
NPC-Cimpor, Durban grinding station	Cement production	1,200,000	tonnes cement	2011	SRK (2011) NPC-Cimpor Draft EIA Report
NPC-Cimpor, Newcastle grinding station	Slagment production	450,000	tonnes slagment	2011	SRK (2011) NPC-Cimpor Draft EIA Report
					Fuel and electricity consumption

Company/ plant/ region	Description	Value	Units	Year	Reference
South Africa	Total electricity purchased	852,230	MWh	2010	ACMP (2011) Sustainability Report
South Africa	Average energy consumption	1,511,703	GJ	2010	ACMP (2011) Sustainability Report
NPC-Cimpor	Coal	130,000	tonnes per annum	2011	SRK (2011) NPC-Cimpor Draft EIA Report
NPC-Cimpor	Paraffin	16,000	litres per start-up	2011	SRK (2011) NPC-Cimpor Draft EIA Report
PPC South Africa	Electricity	586,071	MWh	FY 2010	PPC (2011) CDP disclosure
PPC South Africa	Electricity	588,728	MWh	FY 2011	PPC (2012) CDP disclosure
PPC South Africa	Electricity	615,555	MWh	FY 2012	PPC (2013) CDP disclosure
PPC South Africa	Sub bituminous coal	6,110,016	MWh	FY 2010	PPC (2011) CDP disclosure
PPC South Africa	Sub bituminous coal	6,091,944	MWh	FY 2011	PPC (2012) CDP disclosure
PPC South Africa	Sub bituminous coal	5,548,419	MWh	FY 2012	PPC (2013) CDP disclosure
PPC South Africa	Diesel/Gas oil	113,522	MWh	FY 2010	PPC (2011) CDP disclosure
PPC South Africa	Diesel/Gas oil	109,166	MWh	FY 2011	PPC (2012) CDP disclosure
PPC South Africa	Diesel/Gas oil	115,905	MWh	FY 2012	PPC (2013) CDP disclosure
PPC South Africa	Motor gasoline	-	MWh	FY 2010	PPC (2011) CDP disclosure
PPC South Africa	Motor gasoline	-	MWh	FY 2011	PPC (2012) CDP disclosure
PPC South Africa	Motor gasoline	1,874	MWh	FY 2012	PPC (2013) CDP disclosure
PPC South Africa	Liquefied petroleum gas (LPG)	-	MWh	FY 2010	PPC (2011) CDP disclosure
PPC South Africa	Liquefied petroleum gas (LPG)	-	MWh	FY 2011	PPC (2012) CDP disclosure
PPC South Africa	Liquefied petroleum gas (LPG)	424	MWh	FY 2012	PPC (2013) CDP disclosure
PPC South Africa	Waste oils	7,259	MWh	FY 2010	PPC (2011) CDP disclosure
PPC South Africa	Waste oils	15,000	MWh	FY 2011	PPC (2012) CDP disclosure
PPC South Africa	Waste oils	14,291	MWh	FY 2012	PPC (2013) CDP disclosure
PPC South Africa	Fuel: Other	32,126	MWh	FY 2010	PPC (2011) CDP disclosure
PPC South Africa	Fuel: Other	26,944	MWh	FY 2011	PPC (2012) CDP disclosure
PPC South Africa	Fuel: Other	27,233	MWh	FY 2012	PPC (2013) CDP disclosure
					Annual emissions

Company/ plant/ region	Description	Value	Units	Year	Reference
South Africa	Clinker production contribution to emissions	50%	n/a		ACMP (2011) Sustainability Report
South Africa emissions breakdown	Burning fuel contribution to emissions	40%	n/a		ACMP (2011) Sustainability Report
South Africa emissions breakdown	Electricity use and transportation contribution to emissions	10%	n/a		ACMP (2011) Sustainability Report
Lafarge Sub-Saharan Africa	Scope 1 emissions	5,393,985	tonnes CO_2e	2010	Lafarge (2011) CDP Disclosure
Lafarge Sub-Saharan Africa	Scope 1 emissions	5,800,422	tonnes CO_2e	2011	Lafarge (2012) CDP Disclosure
Lafarge Africa	Scope 1 emissions	17,322,147	tonnes CO_2e	2012	Lafarge (2013) CDP Disclosure
Lafarge Sub-Saharan Africa	Scope 2 emissions	481,267	tonnes CO_2e	2010	Lafarge (2011) CDP Disclosure
Lafarge Sub-Saharan Africa	Scope 2 emissions	495,562	tonnes CO_2e	2011	Lafarge (2012) CDP Disclosure
Lafarge Africa	Scope 2 emissions	1,698,293	tonnes CO_2e	2012	Lafarge (2013) CDP Disclosure
PPC South Africa: Cement division	Scope 1 emissions	3,646,024	tonnes CO_2e	FY 2010	PPC (2011) CDP Disclosure
PPC South Africa: Cement division	Scope 1 emissions	3,582,478	tonnes CO_2e	FY 2011	PPC (2012) CDP Disclosure
PPC South Africa: Lime and dolomite division	Scope 1 emissions	1,119,256	tonnes CO_2e	FY 2010	PPC (2011) CDP Disclosure
PPC South Africa: Lime and dolomite division	Scope 1 emissions	1,145,793	tonnes CO_2e	FY 2011	PPC (2012) CDP Disclosure
PPC South Africa	Scope 1 emissions	4,765,280	tonnes CO_2e	FY 2010	PPC (2011) CDP Disclosure
PPC South Africa	Scope 1 emissions	4,728,271	tonnes CO_2e	FY 2011	PPC (2012) CDP Disclosure
PPC South Africa	Scope 1 emissions	4,437,330	tonnes CO_2e	FY 2012	PPC (2013) CDP Disclosure
PPC South Africa: Cement division	Scope 2 emissions	491,457	tonnes CO_2e	FY 2010	PPC (2011) CDP Disclosure
PPC South Africa: Cement division	Scope 2 emissions	498,968	tonnes CO_2e	FY 2011	PPC (2012) CDP Disclosure
PPC South Africa: Cement division	Scope 2 emissions	513,036	tonnes CO_2e	FY 2012	PPC (2013) CDP Disclosure
PPC South Africa: Lime and dolomite division	Scope 2 emissions	82,912	tonnes CO_2e	FY 2010	PPC (2011) CDP Disclosure
PPC South Africa: Lime and dolomite division	Scope 2 emissions	83,873	tonnes CO_2e	FY 2011	PPC (2012) CDP Disclosure
PPC South Africa: Lime and dolomite division	Scope 2 emissions	81,074	tonnes CO_2e	FY 2012	PPC (2013) CDP Disclosure
PPC South Africa	Scope 2 emissions	574,369	tonnes CO_2e	FY 2010	PPC (2011) CDP Disclosure
PPC South Africa	Scope 2 emissions	582,841	tonnes CO_2e	FY 2011	PPC (2012) CDP Disclosure
PPC South Africa	Scope 2 emissions	594,110	tonnes CO_2e	FY 2012	PPC (2013) CDP Disclosure
PPC SA, Hercules	Scope 1 emissions	296,324	tonnes CO_2e	FY 2010	PPC (2012) CDP Disclosure
PPC SA, Dwaalboom	Scope 1 emissions	1,164,323	tonnes CO_2e	FY 2010	PPC (2012) CDP Disclosure
PPC SA, De Hoek	Scope 1 emissions	469,464	tonnes CO_2e	FY 2010	PPC (2012) CDP Disclosure

Company/ plant/ region	Description	Value	Units	Year	Reference
PPC SA, Jupiter	Scope 1 emissions	251	tonnes CO_2e	FY 2010	PPC (2012) CDP Disclosure
PPC SA, Riebeeck	Scope 1 emissions	390,310	tonnes CO_2e	FY 2010	PPC (2012) CDP Disclosure
PPC SA, PE	Scope 1 emissions	218,164	tonnes CO_2e	FY 2010	PPC (2012) CDP Disclosure
PPC SA, Slurry	Scope 1 emissions	1,102,331	tonnes CO_2e	FY 2010	PPC (2012) CDP Disclosure
PPC SA, Saldanha	Scope 1 emissions	4,352	tonnes CO_2e	FY 2010	PPC (2012) CDP Disclosure
PPC SA, Lime Acres	Scope 1 emissions	1,119,256	tonnes CO_2e	FY 2010	PPC (2012) CDP Disclosure
PPC SA, Distribution Depots	Scope 1 emissions	505	tonnes CO_2e	FY 2010	PPC (2012) CDP Disclosure
PPC SA, Hercules	Scope 2 emissions	54,538	tonnes CO_2e	FY 2010	PPC (2012) CDP Disclosure
PPC SA, Dwaalboom	Scope 2 emissions	120,324	tonnes CO_2e	FY 2010	PPC (2012) CDP Disclosure
PPC SA, De Hoek	Scope 2 emissions	63,827	tonnes CO_2e	FY 2010	PPC (2012) CDP Disclosure
PPC SA, Jupiter	Scope 2 emissions	38,831	tonnes CO_2e	FY 2010	PPC (2012) CDP Disclosure
PPC SA, Riebeeck	Scope 2 emissions	40,785	tonnes CO_2e	FY 2010	PPC (2012) CDP Disclosure
PPC SA, PE	Scope 2 emissions	26,546	tonnes CO_2e	FY 2010	PPC (2012) CDP Disclosure
PPC SA, Slurry	Scope 2 emissions	128,890	tonnes CO_2e	FY 2010	PPC (2012) CDP Disclosure
PPC SA, Saldanha	Scope 2 emissions	17,697	tonnes CO_2e	FY 2010	PPC (2012) CDP Disclosure
PPC SA, Lime Acres	Scope 2 emissions	82,912	tonnes CO_2e	FY 2010	PPC (2012) CDP Disclosure
PPC SA, Distribution Depots	Scope 2 emissions	1,019	tonnes CO_2e	FY 2010	PPC (2012) CDP Disclosure
					Emissions intensity
Lafarge Global	Emissions intensity	0.603	tonnes CO_2e/ tonnes equivalent cement	2010	Lafarge (2011) CDP Disclosure
Lafarge Global	Emissions intensity	0.593	tonnes CO_2e/ tonnes equivalent cement	2011	Lafarge (2012) CDP Disclosure
Lafarge Global	Emissions intensity	0.585	tonnes CO_2e/ tonnes equivalent cement	2012	Lafarge (2013) CDP Disclosure
PPC South Africa	Cement emissions intensity	869	kg CO_2e/ tonne cement	FY 2010	PPC annual report (2013)
PPC South Africa	Cement emissions intensity	892	kg CO_2e/ tonne cement	FY 2011	PPC annual report (2013)
PPC South Africa	Cement emissions intensity	886	kg CO_2e/ tonne cement	FY 2012	PPC annual report (2013)

Company/ plant/ region	Description	Value	Units	Year	Reference
PPC South Africa	Clinker emissions intensity	1,077	kg CO_2e/ tonne clinker	FY 2010	PPC annual report (2013)
PPC South Africa	Clinker emissions intensity	1,083	kg CO_2e/ tonne clinker	FY 2011	PPC annual report (2013)
PPC South Africa	Clinker emissions intensity	1,068	kg CO_2e/ tonne clinker	FY 2012	PPC annual report (2013)

A.2.4 Petroleum (crude oil refineries)

Table 70: Publically available company data on production, fuel and electricity use, emissions and emissions intensity for crude oil refineries

Company/ plant/ region	Description	Value	Units	Year	Reference
Production					
South Africa	Petrol refining capacity, total	10,550	million litres/ year	2012	SAPIA (2012) Annual Report
South Africa	Diesel refining capacity, total	9,657	million litres/ year	2012	SAPIA (2012) Annual Report
South Africa	Kerosene refining capacity, total	2,979	million litres/ year	2012	SAPIA (2012) Annual Report
Sapref	petrol production	2.7	billion litres per year	undated	Sapref (2014) Company website
Sapref	marine fuel oil and specialties component	28%	n/a	2010 and 2011	Sapref (2011) Sustainability Report.
Sapref	petrol component	25%	n/a	2010 and 2011	Sapref (2011) Sustainability Report.
Sapref	diesel and jet fuel component	40%	n/a	2010 and 2011	Sapref (2011) Sustainability Report.
Sasol Oil	Total production	8.7	million tonnes/ year	2010	Sasol (2012) Integrated annual reports
Sasol Oil	Total production	8.6	million tonnes/ year	2011	Sasol (2012) Integrated annual reports
Sasol Oil	Total production	8.1	Mm^3/ year	2012	Sasol (2013) Integrated annual reports
					Fuel and electricity consumption
SA crude refineries, total	Electricity consumption	925	GWh	2010	SAPIA (2012) Annual Report
SA crude refineries, total	Electricity consumption	1,207	GWh	2011	SAPIA (2012) Annual Report
Enref	Refinery energy usage	8.6	10^9 MJ/ year	2010	Engen (2011) Corporate and Sustainability Report
Enref	Refinery energy usage	9.5	10^9 MJ/ year	2011	Engen (2011) Corporate and Sustainability Report
Sapref	Total energy consumption	-	MW/ year	2010	Sapref (2010) Sustainability Report
Sapref	Total energy consumption	189,002	MW/ year	2011	Sapref (2011) Sustainability Report
Sapref	Daily average consumption on energy	711	MW/ day	2010	Sapref (2010) Sustainability Report
Sapref	Daily average consumption on energy	522	MW/ day	2011	Sapref (2011) Sustainability Report

Company/ plant/ region	Description	Value	Units	Year	Reference
Sapref	Energy from Eskom Merewent substation	40	MW/ day	2010	Sapref (2010) Sustainability Report
Sapref	Energy from Eskom Merewent substation	34	MW/ day	2011	Sapref (2011) Sustainability Report
Sapref	Own steam-driven generator	2	MW/ day	2010	Sapref (2010) Sustainability Report
Sapref	Own steam-driven generator	2	MW/ day	2011	Sapref (2011) Sustainability Report
Sapref	Furnace fuel	balance	MW/ day	2010	Sapref (2010) Sustainability Report
Sapref	Furnace fuel	balance	MW/ day	2011	Sapref (2011) Sustainability Report
					Annual emissions
SA crude refineries, total	CO_2 emissions	3,183,018	tonnes CO_2e	2010	SAPIA (2012) Annual Report
SA crude refineries, total	CO_2 emissions	2,734,124	tonnes CO_2e	2011	SAPIA (2012) Annual Report
Sapref	Scope 1 emissions	983,000	tonnes CO_2e	2010	Sapref (2011) Sustainability Report
Sapref	Scope 1 emissions	866,000	tonnes CO_2e	2011	Sapref (2011) Sustainability Report
Enref	Refinery GHG emissions	570,000	tonnes CO_2e	2010	Engen (2011) Corporate and Sustainability Report
Enref	Refinery GHG emissions	610,000	tonnes CO_2e	2011	Engen (2011) Corporate and Sustainability Report
Sasol Oil	Scope 1 emissions	0.5	million tonnes CO_2e	2010	Sasol (2011) Integrated Annual Report
Sasol Oil	Scope 1 emissions	0.2	million tonnes CO_2e	2011	Sasol (2011) Integrated Annual Report
Sasol Oil	Scope 1 emissions	0.9	million tonnes CO_2e	2012	Sasol (2013) Integrated Annual Report
Natref	Scope 1 emissions	0.79	million tonnes CO_2e	2010	calculated
Natref	Scope 1 emissions	0.31	million tonnes CO_2e	2011	calculated
Natref	Scope 1 emissions	1.42	million tonnes CO_2e	2012	calculated
					Emissions intensity
Sapref	Scope 1 emissions intensity	130	kg CO_2e/ tonne crude	2010	Sapref (2011) Sustainability Report
Sapref	Scope 1 emissions intensity	120	kg CO_2e/ tonne crude	2011	Sapref (2011) Sustainability Report

A.2.5 Petroleum (GTL)

Table 71: Publically available company data on production, fuel and electricity use, emissions and emissions intensity for GTL refineries

Company/ plant/ region	Description	Value	Units	Year	Reference
Production					
PetroSA	Total Indigenous GTL refinery production	not reported	-	FY 2011	Petro SA (2011) Annual Report
PetroSA	Total Indigenous GTL refinery production	5.491	Million barrels	FY 2012	Petro SA (2012) Annual Report

Company/ plant/ region	Description	Value	Units	Year	Reference
PetroSA	GTL production	5.300	Million barrels of oil equivalent	2010 FY	Petro SA (2011) Annual Report
PetroSA	GTL production	7.150	Million barrels of oil equivalent	2011 FY	Petro SA (2011) Annual Report
PetroSA	GTL production	7.525	Million barrels of oil equivalent	2012 FY	Petro SA (2012) Annual Report
PetroSA	Petrol (unleaded)	53%	-	2012 FY	Petro SA (2012) Annual Report
PetroSA	Diesel (50 ppm)	6%	-	2012 FY	Petro SA (2012) Annual Report
PetroSA	Kerosene	11%	-	2012 FY	Petro SA (2012) Annual Report
PetroSA	Fuel oil	4%	-	2012 FY	Petro SA (2012) Annual Report
PetroSA	Propane and LPG	8%	-	2012 FY	Petro SA (2012) Annual Report
PetroSA	Distillates	12%	-	2012 FY	Petro SA (2012) Annual Report
PetroSA	Alcohols	6%	-	2012 FY	Petro SA (2012) Annual Report
					Electricity generated and/or exported
PetroSA	BioTherm Biogas Project at PetroSA Mossgas site	4.2	MW	2007 - current	http://www.biothermenergy.com/methcapspv1
					Annual emissions
PetroSA	GHG emissions	2.11	million tonnes CO_2e	2010 FY	Petro SA (2013) Annual Report.
PetroSA	GHG emissions	2.21	million tonnes CO_2e	2011 FY	Petro SA (2013) Annual Report.

A.2.6 Petroleum (CTL)

Table 72: Publically available company data on production, fuel and electricity use, emissions and emissions intensity for CTL refining

Company/ plant/ region	Description	Value	Units	Year	Reference
Production					
Sasol synfuels	Refined products	3,912	ktonnes	2010	Sasol (2012) Analyst Book
	Refined products	3,657	ktonnes	2011	Sasol (2012) Analyst Book
	Refined products	3,574	ktonnes	2012	Sasol (2012) Analyst Book
	Heating fuels	620	ktonnes	2010	Sasol (2012) Analyst Book
	Heating fuels	607	ktonnes	2011	Sasol (2012) Analyst Book
	Heating fuels	680	ktonnes	2012	Sasol (2012) Analyst Book
	alcohols and ketones - feedstock	628	ktonnes	2010	Sasol (2012) Analyst Book
	alcohols and ketones - feedstock	577	ktonnes	2011	Sasol (2012) Analyst Book
	alcohols and ketones - feedstock	554	ktonnes	2012	Sasol (2012) Analyst Book
	Other chemical feedstocks	1,562	ktonnes	2010	Sasol (2012) Analyst Book

Company/ plant/ region	Description	Value	Units	Year	Reference
	Other chemical feedstocks	1,576	ktonnes	2011	Sasol (2012) Analyst Book
	Other chemical feedstocks	1,647	ktonnes	2012	Sasol (2012) Analyst Book
	Gasification products	517	ktonnes	2010	Sasol (2012) Analyst Book
	Gasification products	530	ktonnes	2011	Sasol (2012) Analyst Book
	Gasification products	558	ktonnes	2012	Sasol (2012) Analyst Book
	Other products	141	ktonnes	2010	Sasol (2012) Analyst Book
	Other products	141	ktonnes	2011	Sasol (2012) Analyst Book
	Other products	155	ktonnes	2012	Sasol (2012) Analyst Book
	Total synfuels production	7,380	ktonnes	2010	Sasol (2012) Analyst Book
	Total synfuels production	7,088	ktonnes	2011	Sasol (2012) Analyst Book
	Total synfuels production	7,168	ktonnes	2012	Sasol (2012) Analyst Book
					Fuel and electricity consumption
Sasol South Africa	Purchased and consumed electricity, heat, steam or cooling	7,581,066	MWh	FY 2012	Sasol (2013) CDP Disclosure
Electricity generation and/or export					
Sasol Synfuels	Electricity from two 100 MW gas turbines on open-cycle mode	200	MW	2010 - current	Sasol (2010) Annual Integrated Report
Sasol Synfuels	Electricity from two 100 MW gas turbines in combined cycle mode with heat recovery steam generators (HRSG)	325,455	MWh	FY 2012	Sasol (2013) CDP Disclosure
					Annual emissions
Sasol South Africa	Scope 1 emissions	61,173,000	tonnes CO_2e	FY 2010	Sasol (2011) CDP Disclosure
Sasol South Africa	Scope 1 emissions	61,396,000	tonnes CO_2e	FY 2011	Sasol (2012) CDP Disclosure
Sasol South Africa	Scope 1 emissions	59,880,000	tonnes CO_2e	FY 2012	Sasol (2013) CDP Disclosure.
Sasol South Africa	Scope 2 emissions	9,690,000	tonnes CO_2e	FY 2010	Sasol (2011) CDP Disclosure
Sasol South Africa	Scope 2 emissions	8,813,000	tonnes CO_2e	FY 2011	Sasol (2012) CDP Disclosure
Sasol South Africa	Scope 2 emissions	7,504,000	tonnes CO_2e	FY 2012	Sasol (2013) CDP Disclosure
Sasol Synfuels	Direct GHG emissions (carbon dioxide)	47.2	million tonnes	2010	Sasol (2011) Integrated annual report
Sasol Synfuels	Direct GHG emissions (carbon dioxide)	46.7	million tonnes	2011	Sasol (2011) Integrated annual report

Company/ plant/ region	Description	Value	Units	Year	Reference
Sasol Synfuels	Direct GHG emissions (carbon dioxide)	45.0	million tonnes	2012	Sasol (2013) Integrated annual report

A.2.7 Chemicals

Table 73: Publically available company data on production, fuel and electricity use, emissions and emissions intensity for chemicals

Company/ plant/ region	Description	Value	Units	Year	Reference
Production					
Delta EMD (Pty) Ltd, Black Rock plant	Reduced manganese ore capacity	36,000	tonnes per annum	2011	Delta EMD (2012) Annual Report
Delta EMD (Pty) Ltd, Nelspruit	EMD Production capacity	30,000	tonnes per annum	2011	Delta EMD (2012) Annual Report
EvonikPeroxide Africa (Pty) Ltd	Hydrogen preoxide capacity	300,000	tonnes per annum	2013	Evonik (2013) Portrait of Sub-Saharan Africa; http://corporate.evonik.com/en/company/locations/africa/Pages/sub-saharan-africa.aspx
Karbochem, Newcastle Rubber plant	Rubber nominal capacity	30,000	tonnes	2011	Bus-Ex article (2011) Karbochem: Dedicated to Development, http://www.bus-ex.com/article/karbochem
Karbochem, Newcastle Rubber plant	Rubber production	25,000	tonnes	2011	Bus-Ex article (2011) Karbochem: Dedicated to Development, http://www.bus-ex.com/article/karbochem
Karbochem, Newcastle Neodymium plant	Production	35,000	tonnes	2011	Bus-Ex article (2011) Karbochem: Dedicated to Development, http://www.bus-ex.com/article/karbochem
Karbochem, Sasolburg plant	Production capacity of styrene, pure acrylics and carboxylated styrene butadiene latices	35,000	tonnes	2011	Bus-Ex article (2011) Karbochem: Dedicated to Development, http://www.bus-ex.com/article/karbochem
Orion Engineered Carbon	Carbon black capacity	65,000	tonnes per year	2010	SA Plastics (2010) Algorax celebrates 50 years in production, http://www.saplastics.co.za/readmore.php?highlight=29
Safripol (Pty) Ltd	Polyproplene (PP)	115,000	tonnes per year		Safripol (undated) Company website,http://www.safripol.com/Products/products.asp
Safripol (Pty) Ltd	High-density polyethylene (HDPE)	160,000	tonnes per year		Safripol (undated) Company website,http://www.safripol.com/Products/products.asp
Sasol polymers	Global sales	1,551	thousand tonnes per annum	2010	Sasol (2013) Analyst Book

Company/ plant/ region	Description	Value	Units	Year	Reference
Sasol polymers	Global sales	1,784	thousand tonnes per annum	2011	Sasol (2013) Analyst Book
Sasol polymers	Global sales	1,801	thousand tonnes per annum	2012	Sasol (2013) Analyst Book
Sasol polymers	Global sales	1,551	thousand tonnes per annum	2010	Sasol (2013) Analyst Book
Sasol polymers	Global sales	1,784	thousand tonnes per annum	2011	Sasol (2013) Analyst Book
Sasol polymers	Global sales	1,801	thousand tonnes per annum	2012	Sasol (2013) Analyst Book
Sasol polymers	Ethylene	618	thousand tonnes per annum	2010 - 2012	Sasol (2013) Analyst Book
Sasol polymers	Propylene	950	thousand tonnes per annum	2010 - 2012	Sasol (2013) Analyst Book
Sasol polymers	LDPE	220	thousand tonnes per annum	2010 - 2012	Sasol (2013) Analyst Book
Sasol polymers	LLDPE	150	thousand tonnes per annum	2010 - 2012	Sasol (2013) Analyst Book
Sasol polymers	M/HDPE	-	thousand tonnes per annum	2010 - 2012	Sasol (2013) Analyst Book
Sasol polymers	Polypropylene	520	thousand tonnes per annum	2010 - 2012	Sasol (2013) Analyst Book
Sasol polymers	Ethylene dichloride	160	thousand tonnes per annum	2010 - 2012	Sasol (2013) Analyst Book
Sasol polymers	Vinyl chloride	205	thousand tonnes per annum	2010 - 2012	Sasol (2013) Analyst Book
Sasol polymers	PVC	200	thousand tonnes per annum	2010 - 2012	Sasol (2013) Analyst Book
Sasol polymers	Chlorine	145	thousand tonnes per annum	2010 - 2012	Sasol (2013) Analyst Book
Sasol polymers	Caustic soda	160	thousand tonnes per annum	2010 - 2012	Sasol (2013) Analyst Book
Sasol polymers	Cyanide	40	thousand tonnes per annum	2010 - 2012	Sasol (2013) Analyst Book
Sasol polymers	Hydrochloric acid	90	thousand tonnes per annum	2010 - 2012	Sasol (2013) Analyst Book
Sasol polymers	Calcium chloride	10	thousand tonnes per annum	2010 - 2012	Sasol (2013) Analyst Book
Sasol solvents	Global sales	1,706	thousand tonnes per annum	2010	Sasol (2013) Analyst Book
Sasol solvents	Global sales	1,611	thousand tonnes per annum	2011	Sasol (2013) Analyst Book
Sasol solvents	Global sales	1,563	thousand tonnes per annum	2012	Sasol (2013) Analyst Book
Sasol solvents	Global production	1.7	million tonnes per annum	2010	Sasol (2011) Annual report
Sasol solvents	Global production	1.6	million tonnes per annum	2011	Sasol (2011) Annual report
Sasol solvents	Global production	1.6	million tonnes per annum	2012	Sasol (2013) Annual report

Company/ plant/ region	Description	Value	Units	Year	Reference
Sasol solvents	Ketones (Acetone), capacity	175	thousand tonnes per annum	2010 - 2012	Sasol (2013) Analyst Book
Sasol solvents	Ketones (MEK), capacity	125	thousand tonnes per annum	2010 - 2012	Sasol (2013) Analyst Book
Sasol solvents	Ketones (MiBK), capacity	58	thousand tonnes per annum	2010 - 2012	Sasol (2013) Analyst Book
Sasol solvents	Acetates (ethyl acetate), capacity	54	thousand tonnes per annum	2010 - 2012	Sasol (2013) Analyst Book
Sasol solvents	Mixed alcohols, capacity	215	thousand tonnes per annum	2010 - 2012	Sasol (2013) Analyst Book
Sasol solvents	Pure alcohols (Methanol), capacity	140	thousand tonnes per annum	2010 - 2012	Sasol (2013) Analyst Book
Sasol solvents	Pure alcohols (Ethanol), capacity	254	thousand tonnes per annum	2010 - 2012	Sasol (2013) Analyst Book
Sasol solvents	Pure alcohols (n-Propanol), capacity	54	thousand tonnes per annum	2010 - 2012	Sasol (2013) Analyst Book
Sasol solvents	Pure alcohols (n-Butanol), capacity	150	thousand tonnes per annum	2010 - 2012	Sasol (2013) Analyst Book
Sasol solvents	Pure alcohols (iso-Butanol), capacity	15	thousand tonnes per annum	2010 - 2012	Sasol (2013) Analyst Book
Sasol solvents	Acrylates (Ethyl acrylate), capacity	35	thousand tonnes per annum	2010 - 2012	Sasol (2013) Analyst Book
Sasol solvents	Acrylates (Butyl acrylate), capacity	80	thousand tonnes per annum	2010 - 2012	Sasol (2013) Analyst Book
Sasol solvents	Acrylates (Glacial acrylic acid), capacity	10	thousand tonnes per annum	2010 - 2012	Sasol (2013) Analyst Book
Sasol solvents	C5-C8 alpha olefins, capacity	356	thousand tonnes per annum	2010 - 2012	Sasol (2013) Analyst Book
Sasol solvents	Other, capacity	39	thousand tonnes per annum	2010 - 2012	Sasol (2013) Analyst Book
Sasol Olefins & Surfactants (O&S)	Global sales	1,925	thousand tonnes per annum	2010	Sasol (2013) Analyst Book
Sasol Olefins & Surfactants (O&S)	Global sales	2,042	thousand tonnes per annum	2011	Sasol (2013) Analyst Book
Sasol Olefins & Surfactants (O&S)	Global sales	1,951	thousand tonnes per annum	2012	Sasol (2013) Analyst Book
Sasol Olefins & Surfactants (O&S)	Global production	1.900	million tonnes per annum	2010	Sasol (2011) Annual report
Sasol Olefins & Surfactants (O&S)	Global production	2.100	million tonnes per annum	2011	Sasol (2011) Annual report
Sasol Olefins & Surfactants (O&S)	Global production	2.000	million tonnes per annum	2012	Sasol (2013) Annual report
Sasol Olefins & Surfactants (O&S)	Ethylene, capacity	455	thousand tonnes per annum	2010 - 2012	Sasol (2013) Analyst Book
Sasol Olefins & Surfactants (O&S)	C6+ alcohol, capacity	630	thousand tonnes per annum	2010 - 2012	Sasol (2013) Analyst Book
Sasol Olefins & Surfactants (O&S)	Inorganics, capacity	70	thousand tonnes per annum	2010 - 2012	Sasol (2013) Analyst Book
Sasol Olefins & Surfactants (O&S)	Paraffins and olefins, capacity	750	thousand tonnes per annum	2010 - 2012	Sasol (2013) Analyst Book

Company/ plant/ region	Description	Value	Units	Year	Reference
Sasol Olefins & Surfactants (O&S)	LAB, capacity	435	thousand tonnes per annum	2010 - 2012	Sasol (2013) Analyst Book
Sasol Olefins & Surfactants (O&S)	Surfactants, capacity	1,000	thousand tonnes per annum	2010 - 2012	Sasol (2013) Analyst Book
Sasol Wax	Global production	0.61	million tonnes per annum	2010	Sasol (2011) Annual report
Sasol Wax	Global production	0.62	million tonnes per annum	2011	Sasol (2011) Annual report
Sasol Nitro	Global production	1,333	million tonnes per annum	2010	Sasol (2011) Annual report
Sasol Nitro	Global production	1,278	million tonnes per annum	2011	Sasol (2011) Annual report
Sasol, other chemicals	Nitro and ammonia sales	1,318	thousand tonnes per annum	2010	Sasol (2013) Analyst Book
Sasol, other chemicals	Nitro and ammonia sales	1,079	thousand tonnes per annum	2011	Sasol (2013) Analyst Book
Sasol, other chemicals	Nitro and ammonia sales	1,347	thousand tonnes per annum	2012	Sasol (2013) Analyst Book
Sasol, other chemicals	Wax sales	626	thousand tonnes per annum	2010	Sasol (2013) Analyst Book
Sasol, other chemicals	Wax sales	636	thousand tonnes per annum	2011	Sasol (2013) Analyst Book
Sasol, other chemicals	Wax sales	574	thousand tonnes per annum	2012	Sasol (2013) Analyst Book
Sasol, other chemicals	Infrachem (reformed gas) sales	37.2	thousand tonnes per annum	2010	Sasol (2013) Analyst Book
Sasol, other chemicals	Infrachem (reformed gas) sales	37.8	thousand tonnes per annum	2011	Sasol (2013) Analyst Book
Sasol, other chemicals	Infrachem (reformed gas) sales	33.0	thousand tonnes per annum	2012	Sasol (2013) Analyst Book
Sasol, other chemicals	Merisol sales	52.0	thousand tonnes per annum	2010	Sasol (2013) Analyst Book
Sasol, other chemicals	Merisol sales	50.0	thousand tonnes per annum	2011	Sasol (2013) Analyst Book
Sasol, other chemicals	Merisol sales	48.0	thousand tonnes per annum	2012	Sasol (2013) Analyst Book
Sasol, Nitro / Infrachem	Ammonia	660	thousand tonnes per annum	2010 - 2012	Sasol (2013) Analyst Book
Sasol, Nitro	Sulphur	205	thousand tonnes per annum	2010 - 2012	Sasol (2013) Analyst Book
Sasol, Nitro	Granular and liquid fertilisers	700	thousand tonnes per annum	2010 - 2012	Sasol (2013) Analyst Book
Sasol, Nitro	Fertilisers bulk blending	300	thousand tonnes per annum	2010 - 2012	Sasol (2013) Analyst Book
Sasol, Nitro	Phosphates	-	thousand tonnes per annum	2010 - 2012	Sasol (2013) Analyst Book
Sasol, Nitro	Phosphoric acid	225	thousand tonnes per annum	2010	Sasol (2013) Analyst Book
Sasol, Nitro	Ammonium sulphate	100	thousand tonnes per annum	2010 - 2012	Sasol (2013) Analyst Book

Company/ plant/ region	Description	Value	Units	Year	Reference
Sasol, Nitro	Explosives	300	thousand tonnes per annum	2010 - 2012	Sasol (2013) Analyst Book
Sasol, Wax	Paraffin wax and wax emulsions	430	thousand tonnes per annum	2010 - 2012	Sasol (2013) Analyst Book
Sasol, Wax	FT-based wax and related products	240	thousand tonnes per annum	2010 - 2012	Sasol (2013) Analyst Book
Sasol, Wax	Paraffin wax	30	thousand tonnes per annum	2010 - 2012	Sasol (2013) Analyst Book
Sasol, Wax	Paraffin wax	100	thousand tonnes per annum	2010 - 2012	Sasol (2013) Analyst Book
					Fuel and electricity consumption
AECI South Africa	Electricity consumption	194,873	MWh	2012	AECI (2013) CDP Disclosure
Afrox, total	Consumption of purchased electricity	470,496	MWh	2010	Afrox (2012) Annual Report
Afrox, total	Consumption of purchased electricity	445,744	MWh	2011	Afrox (2012) Annual Report
Afrox, total	Consumption of purchased electricity	448,841	MWh	2012	Afrox (2012) Annual Report
Delta EMD (Pty) Ltd, manufacturing process	Petrol and diesel consumption	68.87	thousand litres	2010	Delta EMD (2012) Integrated Annual Report
Delta EMD (Pty) Ltd, manufacturing process	Petrol and diesel consumption	90.42	thousand litres	2011	Delta EMD (2012) Integrated Annual Report
Delta EMD (Pty) Ltd, manufacturing process	Petrol and diesel consumption	74.60	thousand litres	2012	Delta EMD (2012) Integrated Annual Report
Delta EMD (Pty) Ltd, Black Rock manufacturing site	Electricity consumption	11,927	MWh	2010	Delta EMD (2012) Integrated Annual Report
Delta EMD (Pty) Ltd, Black Rock manufacturing site	Electricity consumption	14,148	MWh	2011	Delta EMD (2012) Integrated Annual Report
Delta EMD (Pty) Ltd, Black Rock manufacturing site	Electricity consumption	15,799	MWh	2012	Delta EMD (2012) Integrated Annual Report
Delta EMD (Pty) Ltd, Nelspruit manufacturing site	Electricity consumption	66,882	MWh	2010	Delta EMD (2012) Integrated Annual Report
Delta EMD (Pty) Ltd, Nelspruit manufacturing site	Electricity consumption	69,517	MWh	2011	Delta EMD (2012) Integrated Annual Report
Delta EMD (Pty) Ltd, Nelspruit manufacturing site	Electricity consumption	65,924	MWh	2012	Delta EMD (2012) Integrated Annual Report
Delta EMD (Pty) Ltd, Black Rock manufacturing site	Coal and charcoal consumption	1,346	tonnes	2010	Delta EMD (2012) Integrated Annual Report
Delta EMD (Pty) Ltd, Black Rock manufacturing site	Coal and charcoal consumption	1,331	tonnes	2011	Delta EMD (2012) Integrated Annual Report
Delta EMD (Pty) Ltd, Black Rock manufacturing site	Coal and charcoal consumption	1,611	tonnes	2012	Delta EMD (2012) Integrated Annual Report
Delta EMD (Pty) Ltd, Nelspruit manufacturing site	Coal and charcoal consumption	19,381	tonnes	2010	Delta EMD (2012) Integrated Annual Report
Delta EMD (Pty) Ltd, Nelspruit manufacturing site	Coal and charcoal consumption	24,493	tonnes	2011	Delta EMD (2012) Integrated Annual Report
Delta EMD (Pty) Ltd, Nelspruit manufacturing site	Coal and charcoal consumption	21,521	tonnes	2012	Delta EMD (2012) Integrated Annual Report
Merck & Co., Inc., South Africa	Purchased and consumed electricity, heat, steam or cooling	not reported	MWh	2010	Merck & Co. (2011) CDP Disclosure

Company/ plant/ region	Description	Value	Units	Year	Reference
Merck & Co., Inc., South Africa	Purchased and consumed electricity, heat, steam or cooling	not reported	MWh	2011	Merck & Co. (2012) CDP Disclosure
Merck & Co., Inc., South Africa	Purchased and consumed electricity, heat, steam or cooling	6,100	MWh	2012	Merck & Co. (2013) CDP Disclosure
Omnia Group	Energy consumption	1,379,176	GJ	FY 2010	Omnia (2011) Annual Report
Omnia Group	Energy consumption	626,452	GJ	FY 2011	Omnia (2012) Annual Report
Omnia Group	Energy consumption	593,905	GJ	FY 2012	Omnia (2013) Annual Report
Omnia Group	Energy intensity	0.530	GJ/ tonne product	FY 2010	Omnia (2011) Annual Report
Omnia Group	Energy intensity	0.215	GJ/ tonne product	FY 2011	Omnia (2012) Annual Report
Omnia Group	Energy intensity	0.227	GJ/ tonne product	FY 2012	Omnia (2013) Annual Report
Sasol South Africa	Purchased and consumed electricity, heat, steam or cooling	7,581,066	MWh	FY 2012	Sasol (2013) CDP Disclosure
					Annual emissions
AECI South Africa	Scope 1 emissions	309,916	tonnes CO_2e	2010	AECI (2011) CDP Disclosure
AECI South Africa	Scope 1 emissions	296,582	tonnes CO_2e	2011	AECI (2012) CDP Disclosure
AECI South Africa	Scope 1 emissions	276,809	tonnes CO_2e	2012	AECI (2013) CDP Disclosure
AECI South Africa	Scope 2 emissions	191,264	tonnes CO_2e	2010	AECI (2011) CDP Disclosure
AECI South Africa	Scope 2 emissions	197,313	tonnes CO_2e	2011	AECI (2012) CDP Disclosure
AECI South Africa	Scope 2 emissions	194,873	tonnes CO_2e	2012	AECI (2013) CDP Disclosure
AECI South Africa	Total emissions	501,180	tonnes CO_2e	2010	AECI (2011) CDP Disclosure
AECI South Africa	Total emissions	493,895	tonnes CO_2e	2011	AECI (2012) CDP Disclosure
AECI South Africa	Total emissions	471,682	tonnes CO_2e	2012	AECI (2013) CDP Disclosure
AECI Global, Explosives	Scope 1 emissions	219,310	tonnes CO_2e	2010	AECI (2012) Annual Report
AECI Global, Explosives	Scope 1 emissions	201,499	tonnes CO_2e	2011	AECI (2012) CDP Disclosure
AECI Global, Explosives	Scope 1 emissions	188,610	tonnes CO_2e	2012	AECI (2013) CDP Disclosure
AECI Global, Specialty chemicals	Scope 1 emissions	24,665	tonnes CO_2e	2010	AECI (2012) Annual Report
AECI Global, Specialty chemicals	Scope 1 emissions	59,801	tonnes CO_2e	2011	AECI (2012) CDP Disclosure
AECI Global, Specialty chemicals	Scope 1 emissions	30,252	tonnes CO_2e	2012	AECI (2013) CDP Disclosure
AECI Global, Property	Scope 1 emissions	65,941	tonnes CO_2e	2010	AECI (2012) Annual Report
AECI Global, Property	Scope 1 emissions	68,075	tonnes CO_2e	2011	AECI (2012) CDP Disclosure
AECI Global, Property	Scope 1 emissions	62,685	tonnes CO_2e	2012	AECI (2013) CDP Disclosure
AECI Global, Explosives	Scope 2 emissions	77,768	tonnes CO_2e	2010	AECI (2012) Annual Report
AECI Global, Explosives	Scope 2 emissions	76,622	tonnes CO_2e	2011	AECI (2012) CDP Disclosure
AECI Global, Explosives	Scope 2 emissions	76,277	tonnes CO_2e	2012	AECI (2013) CDP Disclosure
AECI Global, Specialty chemicals	Scope 2 emissions	103,446	tonnes CO_2e	2010	AECI (2012) Annual Report
AECI Global, Specialty chemicals	Scope 2 emissions	135,297	tonnes CO_2e	2011	AECI (2012) CDP Disclosure
AECI Global, Specialty chemicals	Scope 2 emissions	115,553	tonnes CO_2e	2012	AECI (2013) CDP Disclosure
AECI Global, Property	Scope 2 emissions	10,050	tonnes CO_2e	2010	AECI (2012) Annual Report
AECI Global, Property	Scope 2 emissions	8,315	tonnes CO_2e	2011	AECI (2012) CDP Disclosure
AECI Global, Property	Scope 2 emissions	6,863	tonnes CO_2e	2012	AECI (2013) CDP Disclosure
AECI, Chemserve	Scope 1 emissions	24,665	tonnes CO_2e	2010	AECI (2011) CDP Disclosure

Company/ plant/ region	Description	Value	Units	Year	Reference
AECI, Heartlands	Scope 1 emissions	65,941	tonnes CO_2e	2010	AECI (2011) CDP Disclosure
AECI, AEL	Scope 1 emissions	219,310	tonnes CO_2e	2010	AECI (2011) CDP Disclosure
AECI, Chemserve	Scope 2 emissions	103,446	tonnes CO_2e	2010	AECI (2011) CDP Disclosure
AECI, Heartlands	Scope 2 emissions	10,050	tonnes CO_2e	2010	AECI (2011) CDP Disclosure
AECI, AEL	Scope 2 emissions	77,768	tonnes CO_2e	2010	AECI (2011) CDP Disclosure
AECI, Chemserve	Total emissions	128,111	tonnes CO_2e	2010	AECI (2011) CDP Disclosure
AECI, Heartlands	Total emissions	75,991	tonnes CO_2e	2010	AECI (2011) CDP Disclosure
AECI, AEL	Total emissions	297,078	tonnes CO_2e	2010	AECI (2011) CDP Disclosure
Afrox, Total	Total direct CO_2 emissions from multiple sites	6,908	tonnes CO_2e	2010	Afrox (2012) Annual Report
Afrox, Total	Total direct CO_2 emissions from multiple sites	48,106	tonnes CO_2e	2011	Afrox (2012) Annual Report
Afrox, Total	Total direct CO_2 emissions from multiple sites	49,732	tonnes CO_2e	2012	Afrox (2012) Annual Report
Afrox, Total	Total indirect CO_2 emissions from multiple sites	438,868	tonnes CO_2e	2010	Afrox (2012) Annual Report
Afrox, Total	Total indirect CO_2 emissions from multiple sites	375,331	tonnes CO_2e	2011	Afrox (2012) Annual Report
Afrox, Total	Total indirect CO_2 emissions from multiple sites	480,373	tonnes CO_2e	2012	Afrox (2012) Annual Report
Afrox, Total	Total CO_2 emissions from multiple sites	445,776	tonnes CO_2e	2010	Afrox (2012) Annual Report
Afrox, Total	Total CO_2 emissions from multiple sites	383,436	tonnes CO_2e	2011	Afrox (2012) Annual Report
Afrox, Total	Total CO_2 emissions from multiple sites	490,105	tonnes CO_2e	2012	Afrox (2012) Annual Report
Air Products, Europe, Middle East and Africa (EMEA)	Scope 1 emissions	1,172,092	tonnes CO_2e	2012	Air Products (2013) CDP Disclosure
Air Products, Europe, Middle East and Africa (EMEA)	Scope 2 emissions	1,789,736	tonnes CO_2e	2012	Air Products (2013) CDP Disclosure
Merck & Co. Inc., South Africa	Scope 1 emissions	39	tonnes CO_2e	2010	Merck & Co. (2011) CDP Disclosure
Merck & Co. Inc., South Africa	Scope 1 emissions	237	tonnes CO_2e	2011	Merck & Co. (2012) CDP Disclosure
Merck & Co. Inc., South Africa	Scope 1 emissions	1,200	tonnes CO_2e	2012	Merck & Co. (2013) CDP Disclosure
Merck & Co. Inc., South Africa	Scope 2 emissions	4,564	tonnes CO_2e	2010	Merck & Co. (2011) CDP Disclosure
Merck & Co. Inc., South Africa	Scope 2 emissions	7,800	tonnes CO_2e	2011	Merck & Co. (2012) CDP Disclosure
Merck & Co. Inc., South Africa	Scope 2 emissions	5,700	tonnes CO_2e	2012	Merck & Co. (2013) CDP Disclosure
Sasol polymers	Direct GHG emissions (carbon dioxide)	0.1	million tonnes CO_2e	2010	Sasol (2011) Annual report
Sasol polymers	Direct GHG emissions (carbon dioxide)	0.1	million tonnes CO_2e	2011	Sasol (2011) Annual report
Sasol polymers	Direct GHG emissions (carbon dioxide)	0.1	million tonnes CO_2e	2012	Sasol (2013) Annual report
Sasol solvents	Direct GHG emissions (carbon dioxide)	0.5	million tonnes CO_2e	2010	Sasol (2011) Annual report
Sasol solvents	Direct GHG emissions (carbon dioxide)	0.5	million tonnes CO_2e	2011	Sasol (2011) Annual report
Sasol solvents	Direct GHG emissions (carbon dioxide)	0.5	million tonnes CO_2e	2012	Sasol (2013) Annual report

Company/ plant/ region	Description	Value	Units	Year	Reference
Sasol Olefins & Surfactants (O&S)	Direct GHG emissions (carbon dioxide)	1.1	million tonnes CO_2e	2010	Sasol (2011) Annual report
Sasol Olefins & Surfactants (O&S)	Direct GHG emissions (carbon dioxide)	1.5	million tonnes CO_2e	2011	Sasol (2011) Annual report
Sasol Olefins & Surfactants (O&S)	Direct GHG emissions (carbon dioxide)	1.4	million tonnes CO_2e	2012	Sasol (2013) Annual report
Sasol Wax	Direct GHG emissions (carbon dioxide)	0.06	million tonnes CO_2e	2010	Sasol (2011) Annual report
Sasol Wax	Direct GHG emissions (carbon dioxide)	0.07	million tonnes CO_2e	2011	Sasol (2011) Annual report
Sasol Nitro	Direct GHG emissions (carbon dioxide)	0.30	million tonnes CO_2e	2010	Sasol (2011) Annual report
Sasol Nitro	Direct GHG emissions (carbon dioxide)	0.20	million tonnes CO_2e	2011	Sasol (2011) Annual report
sasol nitro, sasol wax, sasol infrachem and merisol	Direct GHG emissions (carbon dioxide)	4.80	million tonnes CO_2e	2010	Sasol (2010) Annual report
Sasol South Africa	Scope 1 emissions	9,690,000	tonnes CO_2e	FY 2010	Sasol (2011) CDP Disclosure
Sasol South Africa	Scope 1 emissions	61,396,000	tonnes CO_2e	FY 2011	Sasol (2012) CDP Disclosure
Sasol South Africa	Scope 2 emissions	9,690,000	tonnes CO_2e	FY 2010	Sasol (2011) CDP Disclosure
Sasol South Africa	Scope 2 emissions	61,396,000	tonnes CO_2e	FY 2011	Sasol (2012) CDP Disclosure
					Certified emission reductions
Omnia	Certified emissions reductions (CER)	462,150	CER credits per annum	FY 2013	Omnia (2013) Annual Report

A.2.8 Pulp and paper

Table 74: Publically available company data on production, fuel and electricity use, emissions and emissions intensity for pulp and paper

Company/ plant/ region	Description	Value	Units	Year	Reference
Production					
South Africa	Pulp capacity	2.69	million tonnes per annum	historical	Department of Labour (2008) A sectoral analysis of wood, paper and pulp industries in South Africa
South Africa	Paper milling capacity	2.94	million tonnes per annum	historical	Department of Labour (2008) A sectoral analysis of wood, paper and pulp industries in South Africa
South Africa	Printing and writing paper	939	thousand tonnes	2010	PAMSA (2013) Summary production, import and export statistics
South Africa	Printing and writing paper	790	thousand tonnes	2011	PAMSA (2013) Summary production, import and export statistics
South Africa	Printing and writing paper	796	thousand tonnes	2012	PAMSA (2013) Summary production, import and export statistics

Company/ plant/ region	Description	Value	Units	Year	Reference
South Africa	Packaging papers	1,341	thousand tonnes	2010	PAMSA (2013) Summary production, import and export statistics
South Africa	Packaging papers	1,251	thousand tonnes	2011	PAMSA (2013) Summary production, import and export statistics
South Africa	Packaging papers	1,419	thousand tonnes	2012	PAMSA (2013) Summary production, import and export statistics
South Africa	Tissue paper	217	thousand tonnes	2010	PAMSA (2013) Summary production, import and export statistics
South Africa	Tissue paper	219	thousand tonnes	2011	PAMSA (2013) Summary production, import and export statistics
South Africa	Tissue paper	216	thousand tonnes	2012	PAMSA (2013) Summary production, import and export statistics
South Africa	Total paper	2,497	thousand tonnes	2010	PAMSA (2013) Summary production, import and export statistics
South Africa	Total paper	2,261	thousand tonnes	2011	PAMSA (2013) Summary production, import and export statistics
South Africa	Total paper	2,431	thousand tonnes	2012	PAMSA (2013) Summary production, import and export statistics
South Africa	Total pulp	2,307	thousand tonnes	2010	PAMSA (2013) Summary production, import and export statistics
South Africa	Total pulp	2,321	thousand tonnes	2011	PAMSA (2013) Summary production, import and export statistics
South Africa	Total pulp	2,277	thousand tonnes	2012	PAMSA (2013) Summary production, import and export statistics
Mondi, South Africa Division	Containerboard	260,000	tonnes	2010	Mondi (2012) Integrated Annual Report
Mondi, South Africa Division	Containerboard	257,680	tonnes	2011	Mondi (2013) Integrated Annual Report
Mondi, South Africa Division	Containerboard	263,468	tonnes	2012	Mondi (2013) Integrated Annual Report
Mondi, South Africa Division	Uncoated fine paper	278,000	tonnes	2010	Mondi (2012) Integrated Annual Report
Mondi, South Africa Division	Uncoated fine paper	233,837	tonnes	2011	Mondi (2013) Integrated Annual Report
Mondi, South Africa Division	Uncoated fine paper	257,747	tonnes	2012	Mondi (2013) Integrated Annual Report
Mondi, South Africa Division	Hardwood pulp, internal consumption	not reported	tonnes	2010	

Company/ plant/ region	Description	Value	Units	Year	Reference
Mondi, South Africa Division	Hardwood pulp, internal consumption	316,388	tonnes	2011	Mondi (2013) Integrated Annual Report
Mondi, South Africa Division	Hardwood pulp, internal consumption	320,722	tonnes	2012	Mondi (2013) Integrated Annual Report
Mondi, South Africa Division	Hardwood pulp, external	not reported	tonnes	2010	
Mondi, South Africa Division	Hardwood pulp, external	320,817	tonnes	2011	Mondi (2013) Integrated Annual Report
Mondi, South Africa Division	Hardwood pulp, external	337,596	tonnes	2012	Mondi (2013) Integrated Annual Report
Mondi, South Africa Division	Softwood pulp, internal consumption only	not reported	tonnes	2010	
Mondi, South Africa Division	Softwood pulp, internal consumption only	182,651	tonnes	2011	Mondi (2013) Integrated Annual Report
Mondi, South Africa Division	Softwood pulp, internal consumption only	169,724	tonnes	2012	Mondi (2013) Integrated Annual Report
Mondi, South Africa Division	Total pulp production	702,000	tonnes	2010	Mondi (2012) Integrated Annual Report
Mondi, South Africa Division	Total pulp production	819,856	tonnes	2011	calculated from above
Mondi, South Africa Division	Total pulp production	828,042	tonnes	2012	calculated from above
Mondi, South Africa Division	Newsprint	not reported	tonnes	2010	
Mondi, South Africa Division	Newsprint	124,914	tonnes	2011	Mondi (2013) Integrated Annual Report
Mondi, South Africa Division	Newsprint	114,854	tonnes	2012	Mondi (2013) Integrated Annual Report
Mpact, Paper Manufacturing Division	Containerboard production	266	thousand tonnes per year	2010	Mpact (2011) Business Overview
Mpact, Paper Manufacturing Division	Cartonboard production	133	thousand tonnes per year	2010	Mpact (2011) Business Overview
Sappi SA, Stanger Pulp and Paper Mill	Bleached bagasse pulp for own consumption capacity	60	thousand tonnes per year	2012	Sappi (2013) Integrated Annual Report
Sappi SA, Ngodwana Pulp and Paper Mill	Dissolving pulp capacity	210	thousand tonnes per year	2012	Sappi (2013) Integrated Annual Report
Sappi SA, Ngodwana Pulp and Paper Mill	Unbleached chemical pulp for own consumption, bleached chemical pulp for own consumption and market pulp capacity	200	thousand tonnes per year	2012	Sappi (2013) Integrated Annual Report
Sappi SA, Ngodwana Pulp and Paper Mill	Mechanical pulp for own consumption capacity	110	thousand tonnes per year	2012	Sappi (2013) Integrated Annual Report
Sappi SA, Tugela Pulp and Paper Mill	Neutral Sulfite semi-chemical pulp for own consumption capacity	130	thousand tonnes per year	2012	Sappi (2013) Integrated Annual Report
Sappi SA, Saiccor Pulp Mill	Dissolving wood pulp capacity	800	thousand tonnes per year	2012	Sappi (2013) Integrated Annual Report
Sappi ReFibre	Waste paper collection and recycling for own consumption capacity	250	thousand tonnes per year	2012	Sappi (2013) Integrated Annual Report

Company/ plant/ region	Description	Value	Units	Year	Reference
Sappi SA, Cape Kraft Paper Mill	Waste based linerboard and corrugating medium capacity	60	thousand tonnes per year	2012	Sappi (2013) Integrated Annual Report
Sappi SA, Enstrata Paper Mill	Uncoated woodfree and business paper capacity	200	thousand tonnes per year	2012	Sappi (2013) Integrated Annual Report
Sappi SA, Stanger Pulp and Paper Mill	Coated woodfree paper and tissue paper capacity	110	thousand tonnes per year	2012	Sappi (2013) Integrated Annual Report
Sappi SA, Ngodwana Pulp and Paper Mill	Kraft and white top linerboard capacity	230	thousand tonnes per year	2012	Sappi (2013) Integrated Annual Report
Sappi SA, Ngodwana Pulp and Paper Mill	Newsprint capacity	140	thousand tonnes per year	2012	Sappi (2013) Integrated Annual Report
Sappi SA, Tugela Pulp and Paper Mill	Corrugating medium capacity	210	thousand tonnes per year	2012	Sappi (2013) Integrated Annual Report
					Fuel and electricity consumption
Mondi, South Africa Division	Total energy use	29.479	million GJ	2010	Mondi (2012) Integrated Annual Report.
Mondi, South Africa Division	Total energy use	29.480	million GJ	2011	Mondi (2013) Integrated Annual Report.
Mondi, South Africa Division	Total energy use	29.720	million GJ	2012	Mondi (2013) Integrated Annual Report.
Mondi, Pulp and Paper Division	% electricity requirements generated by own power plants	93%	%	2012	Mondi (2012) Energy and Climate Change
Mondi, Pulp and Paper Division	Fossil fuel consumption for electricity generation	63.30	million GJ	2012	Mondi (2012) Energy and Climate Change
Mondi, Pulp and Paper Division	Biomass fuel consumption for electricity generation	79.80	million GJ	2012	Mondi (2012) Energy and Climate Change
Mondi, Pulp and Paper Division	Electricity consumption	5.40	million MWh	2011	Mondi (2012) Energy and Climate Change
Mondi, Pulp and Paper Division	Electricity consumption	5.50	million MWh	2012	Mondi (2012) Energy and Climate Change
Nampak SA, paper and flexibles	Electricity consumption	157,952,601	kWh	FY 2012	Nampak (2012) Integrated Annual Report
Nampak SA, tissue	Electricity consumption	96,482,281	kWh	FY 2012	Nampak (2013) Integrated Annual Report
Sappi SA	Electricity, heat, steam or cooling	not reported	MWh	FY 2010	Sappi Ltd (2011) CDP Disclosure
Sappi SA	Electricity, heat, steam or cooling	not reported	MWh	FY 2011	Sappi Ltd (2012) CDP Disclosure
Sappi SA	Electricity, heat, steam or cooling	1,313,223	MWh	FY 2012	Sappi Ltd (2013) CDP Disclosure
Sappi SA	Low carbon electricity, heat, steam or cooling	not reported	MWh	FY 2010	Sappi Ltd (2011) CDP Disclosure
Sappi SA	Low carbon electricity, heat, steam or cooling	not reported	MWh	FY 2011	Sappi Ltd (2012) CDP Disclosure
Sappi SA	Low carbon electricity, heat, steam or cooling	140,014	MWh	FY 2012	Sappi Ltd (2013) CDP Disclosure
					Electricity generated and/or exported
Sappi SA, Ngodwana Pulp and Paper Mill	Power sold to Eskom, from Ngodwana Mill	not reported	MWh	FY 2010	Sappi (2011) CDP Disclosure
Sappi SA, Ngodwana Pulp and Paper Mill	Power sold to Eskom, from Ngodwana Mill	37,500	MWh	FY 2011	Sappi (2012) CDP Disclosure

Company/ plant/ region	Description	Value	Units	Year	Reference
Sappi, SA	Power sold to Eskom, from Ngodwana Mill	32,200	MWh	FY 2012	Sappi (2012) Integrated Report
					Annual emissions
Mondi, South Africa Division	CO2e emissions	1.331	million tonnes CO_2e	2010	Mondi (2012) Integrated Annual Report.
Mondi, South Africa Division	Total scope 1 and 2 GHG emissions	1.33	million tonnes CO_2e	2011	Mondi (2013) Integrated Annual Report.
Mondi, South Africa Division	Total scope 1 and 2 GHG emissions	1.43	million tonnes CO_2e	2012	Mondi (2013) Integrated Annual Report.
Mondi, South Africa Division includes Mpact	Scope 1 emissions	1,047,983	tonnes CO_2e	2010	Mondi (2011) CDP Disclosure
Mondi, South Africa Division includes Mpact	Scope 1 emissions	879,388	tonnes CO_2e	2011	Mondi (2012) CDP Disclosure
Mondi, South Africa Division includes Mpact	Scope 1 emissions	733,832	tonnes CO_2e	2012	Mondi (2013) CDP Disclosure
Mondi, South Africa Division includes Mpact	Scope 2 emissions	929,758	tonnes CO_2e	2010	Mondi (2011) CDP Disclosure
Mondi, South Africa Division includes Mpact	Scope 2 emissions	723,557	tonnes CO_2e	2011	Mondi (2012) CDP Disclosure
Mondi, South Africa Division includes Mpact	Scope 2 emissions	693,211	tonnes CO_2e	2012	Mondi (2013) CDP Disclosure
Mondi, Merebank	Scope 1 emissions	357,107	tonnes CO_2e	2010	Mondi (2011) CDP Disclosure
Mondi, Merebank	Scope 1 emissions	348,572	tonnes CO_2e	2011	Mondi (2012) CDP Disclosure
Mondi, Merebank	Scope 1 emissions	333,683	tonnes CO_2e	2012	Mondi (2013) CDP Disclosure
Mondi, Richards Bay	Scope 1 emissions	353,046	tonnes CO_2e	2010	Mondi (2011) CDP Disclosure
Mondi, Richards Bay	Scope 1 emissions	367,321	tonnes CO_2e	2011	Mondi (2012) CDP Disclosure
Mondi, Richards Bay	Scope 1 emissions	400,149	tonnes CO_2e	2012	Mondi (2013) CDP Disclosure
Mondi, Piet Retief	Scope 1 emissions	103,424	tonnes CO_2e	2010	Mondi (2011) CDP Disclosure
Mondi, Piet Retief	Scope 1 emissions	52,991	tonnes CO_2e	2011	Mondi (2012) CDP Disclosure
Mondi, Piet Retief	Scope 1 emissions	not reported	tonnes CO_2e	2012	Mondi (2013) CDP Disclosure
Mondi, Springs	Scope 1 emissions	114,509	tonnes CO_2e	2010	Mondi (2011) CDP Disclosure
Mondi, Springs	Scope 1 emissions	51,986	tonnes CO_2e	2011	Mondi (2012) CDP Disclosure
Mondi, Springs	Scope 1 emissions	not reported	tonnes CO_2e	2012	Mondi (2013) CDP Disclosure
Mondi, Felixton	Scope 1 emissions	119,897	tonnes CO_2e	2010	Mondi (2011) CDP Disclosure
Mondi, Felixton	Scope 1 emissions	58,518	tonnes CO_2e	2011	Mondi (2012) CDP Disclosure
Mondi, Felixton	Scope 1 emissions	not reported	tonnes CO_2e	2012	Mondi (2013) CDP Disclosure
Mondi, Merebank	Scope 2 emissions	573,516	tonnes CO_2e	2010	Mondi (2011) CDP Disclosure
Mondi, Merebank	Scope 2 emissions	489,578	tonnes CO_2e	2011	Mondi (2012) CDP Disclosure
Mondi, Merebank	Scope 2 emissions	570,801	tonnes CO_2e	2012	Mondi (2013) CDP Disclosure
Mondi, Richards Bay	Scope 2 emissions	121,347	tonnes CO_2e	2010	Mondi (2011) CDP Disclosure
Mondi, Richards Bay	Scope 2 emissions	125,794	tonnes CO_2e	2011	Mondi (2012) CDP Disclosure

Company/ plant/ region	Description	Value	Units	Year	Reference
Mondi, Richards Bay	Scope 2 emissions	122,410	tonnes CO_2e	2012	Mondi (2013) CDP Disclosure
Mondi, Piet Retief	Scope 2 emissions	77,572	tonnes CO_2e	2010	Mondi (2011) CDP Disclosure
Mondi, Piet Retief	Scope 2 emissions	not reported	tonnes CO_2e	2011	Mondi (2012) CDP Disclosure
Mondi, Piet Retief	Scope 2 emissions	not reported	tonnes CO_2e	2012	Mondi (2013) CDP Disclosure
Mondi, Springs	Scope 2 emissions	92,845	tonnes CO_2e	2010	Mondi (2011) CDP Disclosure
Mondi, Springs	Scope 2 emissions	not reported	tonnes CO_2e	2011	Mondi (2012) CDP Disclosure
Mondi, Springs	Scope 2 emissions	not reported	tonnes CO_2e	2012	Mondi (2013) CDP Disclosure
Mondi, Felixton	Scope 2 emissions	64,478	tonnes CO_2e	2010	Mondi (2011) CDP Disclosure
Mondi, Felixton	Scope 2 emissions	not reported	tonnes CO_2e	2011	Mondi (2012) CDP Disclosure
Mondi, Felixton	Scope 2 emissions	not reported	tonnes CO_2e	2012	Mondi (2013) CDP Disclosure
Nampak, SA	Scope 1 emissions	137,320	tonnes CO_2e	FY 2010	Nampak Ltd (2011) CDP Disclosure
Nampak, SA	Scope 1 emissions	160,738	tonnes CO_2e	FY 2011	Nampak Ltd (2012) CDP Disclosure
Nampak SA	Scope 1 emissions	128,568	tonnes CO_2e	FY 2012	Nampak Ltd (2013) CDP Disclosure
Nampak, SA	Scope 2 emissions	570,855	tonnes CO_2e	FY 2010	Nampak Ltd (2011) CDP Disclosure
Nampak, SA	Scope 2 emissions	589,439	tonnes CO_2e	FY 2011	Nampak Ltd (2012) CDP Disclosure
Nampak, SA	Scope 2 emissions	577,785	tonnes CO_2e	FY 2012	Nampak Ltd (2013) CDP Disclosure
Nampak SA, Paper and flexibles	Carbon emissions	236,745	tonnes CO_2e	FY 2010	Nampak (2011) Integrated Annual Report
Nampak SA, Paper and flexibles	Carbon emissions	226 533	tonnes CO_2e	FY 2011	Nampak (2013) Integrated Annual Report
Nampak SA, Paper and flexibles	Carbon emissions	215 354	tonnes CO_2e	FY 2012	Nampak (2013) Integrated Annual Report
Nampak SA, Tissue	Carbon emissions	79,784	tonnes CO_2e	FY 2010	Nampak (2011) Integrated Annual Report
Nampak SA, Tissue	Carbon emissions	78 373	tonnes CO_2e	FY 2011	Nampak (2013) Integrated Annual Report
Nampak SA, Tissue	Carbon emissions	125 500	tonnes CO_2e	FY 2012	Nampak (2013) Integrated Annual Report
Sappi SA, total	Scope 1 emissions	2,655,085	tonnes CO_2e	FY 2010	Sappi Ltd (2011) CDP Disclosure
Sappi SA, total	Scope 1 emissions	2,829,691	tonnes CO_2e	FY 2011	Sappi Ltd (2012) CDP Disclosure
Sappi SA, total	Scope 1 emissions	2,620,570	tonnes CO_2e	FY 2012	Sappi Ltd (2013) CDP Disclosure
Sappi SA, Cape Kraft Paper Mill	Scope 1 emissions	0	tonnes CO_2e	FY 2010	Sappi Ltd (2011) CDP Disclosure
Sappi SA, Cape Kraft Paper Mill	Scope 1 emissions	130	tonnes CO_2e	FY 2011	Sappi Ltd (2012) CDP Disclosure
Sappi SA, Cape Kraft Paper Mill	Scope 1 emissions	34	tonnes CO_2e	FY 2012	Sappi Ltd (2013) CDP Disclosure

Company/ plant/ region	Description	Value	Units	Year	Reference
Sappi SA, Enstrata Paper Mill	Scope 1 emissions	343,853	tonnes CO_2e	FY 2010	Sappi Ltd (2011) CDP Disclosure
Sappi SA, Enstrata Paper Mill	Scope 1 emissions	403,467	tonnes CO_2e	FY 2011	Sappi Ltd (2012) CDP Disclosure
Sappi SA, Enstrata Paper Mill	Scope 1 emissions	282,517	tonnes CO_2e	FY 2012	Sappi Ltd (2013) CDP Disclosure
Sappi SA, Stanger Pulp and Paper Mill	Scope 1 emissions	206,867	tonnes CO_2e	FY 2010	Sappi Ltd (2011) CDP Disclosure
Sappi SA, Stanger Pulp and Paper Mill	Scope 1 emissions	157,851	tonnes CO_2e	FY 2011	Sappi Ltd (2012) CDP Disclosure
Sappi SA, Stanger Pulp and Paper Mill	Scope 1 emissions	197,473	tonnes CO_2e	FY 2012	Sappi Ltd (2013) CDP Disclosure
Sappi SA, Ngodwana Pulp and Paper Mill	Scope 1 emissions	1,035,039	tonnes CO_2e	FY 2010	Sappi Ltd (2011) CDP Disclosure
Sappi SA, Ngodwana Pulp and Paper Mill	Scope 1 emissions	1,113,205	tonnes CO_2e	FY 2011	Sappi Ltd (2012) CDP Disclosure
Sappi SA, Ngodwana Pulp and Paper Mill	Scope 1 emissions	1,117,321	tonnes CO_2e	FY 2012	Sappi Ltd (2013) CDP Disclosure
Sappi SA, Tugela Pulp and Paper Mill	Scope 1 emissions	473,498	tonnes CO_2e	FY 2010	Sappi Ltd (2011) CDP Disclosure
Sappi SA, Tugela Pulp and Paper Mill	Scope 1 emissions	527,207	tonnes CO_2e	FY 2011	Sappi Ltd (2012) CDP Disclosure
Sappi SA, Tugela Pulp and Paper Mill	Scope 1 emissions	437,145	tonnes CO_2e	FY 2012	Sappi Ltd (2013) CDP Disclosure
Sappi SA, Saiccor Pulp Mill	Scope 1 emissions	578,109	tonnes CO_2e	FY 2010	Sappi Ltd (2011) CDP Disclosure
Sappi SA, Saiccor Pulp Mill	Scope 1 emissions	617,833	tonnes CO_2e	FY 2011	Sappi Ltd (2012) CDP Disclosure
Sappi SA, Saiccor Pulp Mill	Scope 1 emissions	560,007	tonnes CO_2e	FY 2012	Sappi Ltd (2013) CDP Disclosure
Sappi SA, Lomati Sawmill, H.O.	Scope 1 emissions	-	tonnes CO_2e	FY 2010	Sappi Ltd (2011) CDP Disclosure
Sappi SA, Lomati Sawmill, H.O.	Scope 1 emissions	3,333	tonnes CO_2e	FY 2011	Sappi Ltd (2012) CDP Disclosure
Sappi SA, Lomati Sawmill, H.O.	Scope 1 emissions	26,073	tonnes CO_2e	FY 2012	Sappi Ltd (2013) CDP Disclosure
Sappi SA, total	Scope 2 emissions	1,554,210	tonnes CO_2e	FY 2010	Sappi Ltd (2011) CDP Disclosure
Sappi SA, total	Scope 2 emissions	1,393,269	tonnes CO_2e	FY 2011	Sappi Ltd (2012) CDP Disclosure
Sappi SA, total	Scope 2 emissions	1,127,718	tonnes CO_2e	FY 2012	Sappi Ltd (2013) CDP Disclosure
Sappi SA, Cape Kraft Paper Mill	Scope 2 emissions	67,780	tonnes CO_2e	FY 2010	Sappi Ltd (2011) CDP Disclosure
Sappi SA, Cape Kraft Paper Mill	Scope 2 emissions	108,138	tonnes CO_2e	FY 2011	Sappi Ltd (2012) CDP Disclosure
Sappi SA, Cape Kraft Paper Mill	Scope 2 emissions	100,027	tonnes CO_2e	FY 2012	Sappi Ltd (2013) CDP Disclosure
Sappi SA, Enstrata Paper Mill	Scope 2 emissions	307,148	tonnes CO_2e	FY 2010	Sappi Ltd (2011) CDP Disclosure
Sappi SA, Enstrata Paper Mill	Scope 2 emissions	275,575	tonnes CO_2e	FY 2011	Sappi Ltd (2012) CDP Disclosure

Company/ plant/ region	Description	Value	Units	Year	Reference
Sappi SA, Enstrata Paper Mill	Scope 2 emissions	200,067	tonnes CO_2e	FY 2012	Sappi Ltd (2013) CDP Disclosure
Sappi SA, Stanger Pulp and Paper Mill	Scope 2 emissions	146,970	tonnes CO_2e	FY 2010	Sappi Ltd (2011) CDP Disclosure
Sappi SA, Stanger Pulp and Paper Mill	Scope 2 emissions	127,787	tonnes CO_2e	FY 2011	Sappi Ltd (2012) CDP Disclosure
Sappi SA, Stanger Pulp and Paper Mill	Scope 2 emissions	132,180	tonnes CO_2e	FY 2012	Sappi Ltd (2013) CDP Disclosure
Sappi SA, Ngodwana Pulp and Paper Mill	Scope 2 emissions	225,502	tonnes CO_2e	FY 2010	Sappi Ltd (2011) CDP Disclosure
Sappi SA, Ngodwana Pulp and Paper Mill	Scope 2 emissions	112,263	tonnes CO_2e	FY 2011	Sappi Ltd (2012) CDP Disclosure
Sappi SA, Ngodwana Pulp and Paper Mill	Scope 2 emissions	84,774	tonnes CO_2e	FY 2012	Sappi Ltd (2013) CDP Disclosure
Sappi SA, Tugela Pulp and Paper Mill	Scope 2 emissions	368,524	tonnes CO_2e	FY 2010	Sappi Ltd (2011) CDP Disclosure
Sappi SA, Tugela Pulp and Paper Mill	Scope 2 emissions	359,084	tonnes CO_2e	FY 2011	Sappi Ltd (2012) CDP Disclosure
Sappi SA, Tugela Pulp and Paper Mill	Scope 2 emissions	288,859	tonnes CO_2e	FY 2012	Sappi Ltd (2013) CDP Disclosure
Sappi SA, Saiccor Pulp Mill	Scope 2 emissions	380,434	tonnes CO_2e	FY 2010	Sappi Ltd (2011) CDP Disclosure
Sappi SA, Saiccor Pulp Mill	Scope 2 emissions	367,994	tonnes CO_2e	FY 2011	Sappi Ltd (2012) CDP Disclosure
Sappi SA, Saiccor Pulp Mill	Scope 2 emissions	313,562	tonnes CO_2e	FY 2012	Sappi Ltd (2013) CDP Disclosure
Sappi SA, Lomati Sawmill, H.O.	Scope 2 emissions	-	tonnes CO_2e	FY 2010	Sappi Ltd (2011) CDP Disclosure
Sappi SA, Lomati Sawmill, H.O.	Scope 2 emissions	14,430	tonnes CO_2e	FY 2011	Sappi Ltd (2012) CDP Disclosure
Sappi SA, Lomati Sawmill, H.O.	Scope 2 emissions	8,250	tonnes CO_2e	FY 2012	Sappi Ltd (2013) CDP Disclosure
					Emissions intensity
Mondi, Group	Global emissions intensity	0.899	tonnes CO_2e per tonne product	2010	Mondi (2011) CDP Disclosure
Mondi, Group	Global emissions intensity	0.869	tonnes CO_2e per tonne product	2011	Mondi (2012) CDP Disclosure
Mondi, Group	Global emissions intensity	0.799	tonnes CO_2e per tonne product	2012	Mondi (2013) CDP Disclosure
Mondi, Group	Specific Scope 1 emissions intensity	0.67	tonnes CO_2e per tonne saleable product	2010	Mondi (2012)Energy and Climate Change
Mondi, Group	Specific Scope 1 emissions intensity	0.70	tonnes CO_2e per tonne saleable product	2011	Mondi (2012)Energy and Climate Change

Company/ plant/ region	Description	Value	Units	Year	Reference
Mondi, Group	Specific Scope 1 emissions intensity	0.76	tonnes CO_2e per tonne saleable product	2012	Mondi (2012)Energy and Climate Change
Mondi, Group	Specific Scope 2 emissions intensity	0.19	tonnes CO_2e per tonne saleable product	2010	Mondi (2012)Energy and Climate Change
Mondi, Group	Specific Scope 2 emissions intensity	0.16	tonnes CO_2e per tonne saleable product	2011	Mondi (2012)Energy and Climate Change
Mondi, Group	Specific Scope 2 emissions intensity	0.19	tonnes CO_2e per tonne saleable product	2012	Mondi (2012)Energy and Climate Change
Mondi, Group	Specific total emissions intensity	0.86	tonnes CO_2e per tonne saleable product	2010	Mondi (2012)Energy and Climate Change
Mondi, Group	Specific total emissions intensity	0.86	tonnes CO_2e per tonne saleable product	2011	Mondi (2012)Energy and Climate Change
Mondi, Group	Specific total emissions intensity	0.86	tonnes CO_2e per tonne saleable product	2012	Mondi (2012)Energy and Climate Change

A.2.9 Sugar

Table 75: Publically available company data on production, fuel and electricity use, emissions and emissions intensity for sugar

Company/ plant/ region	Description	Value	Units	Year	Reference
Production					
Illovo Sugar Ltd, Noodsberg	Refined sugar production	167,561	tonnes	2009 - 2010	SMRI (2010) Milling Review.
Illovo Sugar Ltd, Noodsberg	Refined sugar production	158,774	tonnes	2010 - 2011	SMRI (2011) Milling Review
Illovo Sugar Ltd, Noodsberg	Refined sugar production	113,138	tonnes	2011 - 2012	SMRI (2012) Milling Review.
Illovo Sugar Ltd, Eston	Raw sugar production	144,520	tonnes	2009 - 2010	SMRI (2010) Milling Review.
Illovo Sugar Ltd, Eston	Raw sugar production	133,582	tonnes	2010 - 2011	SMRI (2011) Milling Review
Illovo Sugar Ltd, Eston	Raw sugar production	122,165	tonnes	2011 - 2012	SMRI (2012) Milling Review.
Illovo Sugar Ltd, Sezela	Raw sugar production	227,917	tonnes	2009 - 2010	SMRI (2010) Milling Review.
Illovo Sugar Ltd, Sezela	Raw sugar production	187,920	tonnes	2010 - 2011	SMRI (2011) Milling Review
Illovo Sugar Ltd, Sezela	Raw sugar production	198,899	tonnes	2011 - 2012	SMRI (2012) Milling Review.
Illovo Sugar Ltd, Umzimkulu	Raw sugar production	128,693	tonnes	2009 - 2010	SMRI (2010) Milling Review.
Illovo Sugar Ltd, Umzimkulu	Raw sugar production	92,264	tonnes	2010 - 2011	SMRI (2011) Milling Review
Illovo Sugar Ltd, Umzimkulu	Raw sugar production	-	tonnes	2011 - 2012	SMRI (2012) Milling Review.
Tongaat Hulett Sugar Ltd, Felixton	Raw sugar production	186,999	tonnes	2009 - 2010	SMRI (2010) Milling Review.

Company/ plant/ region	Description	Value	Units	Year	Reference
Tongaat Hulett Sugar Ltd, Felixton	Raw sugar production	174,426	tonnes	2010 - 2011	SMRI (2011) Milling Review
Tongaat Hulett Sugar Ltd, Felixton	Raw sugar production	193,440	tonnes	2011 - 2012	SMRI (2012) Milling Review.
Tongaat Hulett Sugar Ltd, Amatikulu	Raw sugar production	151,411	tonnes	2009 - 2010	SMRI (2010) Milling Review.
Tongaat Hulett Sugar Ltd, Amatikulu	Raw sugar production	121,348	tonnes	2010 - 2011	SMRI (2011) Milling Review
Tongaat Hulett Sugar Ltd, Amatikulu	Raw sugar production	124,732	tonnes	2011 - 2012	SMRI (2012) Milling Review.
Tongaat Hulett Sugar Ltd, Darnall	Raw sugar production	131,218	tonnes	2009 - 2010	SMRI (2010) Milling Review.
Tongaat Hulett Sugar Ltd, Darnall	Raw sugar production	77,839	tonnes	2010 - 2011	SMRI (2011) Milling Review
Tongaat Hulett Sugar Ltd, Darnall	Raw sugar production	89,408	tonnes	2011 - 2012	SMRI (2012) Milling Review.
Tongaat Hulett Sugar Ltd, Maidstone	Raw sugar production	104,266	tonnes	2009 - 2010	SMRI (2010) Milling Review.
Tongaat Hulett Sugar Ltd, Maidstone	Raw sugar production	81,656	tonnes	2010 - 2011	SMRI (2011) Milling Review
Tongaat Hulett Sugar Ltd, Maidstone	Raw sugar production	79,048	tonnes	2011 - 2012	SMRI (2012) Milling Review.
TSB Sugar Holdings (Pty) Ltd, Malelane	Refined sugar production	103,188	tonnes	2009 - 2010	SMRI (2010) Milling Review.
TSB Sugar Holdings (Pty) Ltd, Malelane	Refined sugar production	104,203	tonnes	2010 - 2011	SMRI (2011) Milling Review
TSB Sugar Holdings (Pty) Ltd, Malelane	Refined sugar production	103,812	tonnes	2011 - 2012	SMRI (2012) Milling Review.
TSB Sugar Holdings (Pty) Ltd, Malelane	Raw sugar production	99,141	tonnes	2009 - 2010	SMRI (2010) Milling Review.
TSB Sugar Holdings (Pty) Ltd, Malelane	Raw sugar production	88,765	tonnes	2010 - 2011	SMRI (2011) Milling Review
TSB Sugar Holdings (Pty) Ltd, Malelane	Raw sugar production	95,826	tonnes	2011 - 2012	SMRI (2012) Milling Review.
TSB Sugar Holdings (Pty) Ltd, Komati	Raw sugar production	286,338	tonnes	2009 - 2010	SMRI (2010) Milling Review.
TSB Sugar Holdings (Pty) Ltd, Komati	Raw sugar production	275,266	tonnes	2010 - 2011	SMRI (2011) Milling Review
TSB Sugar Holdings (Pty) Ltd, Komati	Raw sugar production	290,812	tonnes	2011 - 2012	SMRI (2012) Milling Review.
TSB Sugar Holdings (Pty) Ltd, Pongola	Refined sugar production	117,197	tonnes	2009 - 2010	SMRI (2010) Milling Review.
TSB Sugar Holdings (Pty) Ltd, Pongola	Refined sugar production	102,334	tonnes	2010 - 2011	SMRI (2011) Milling Review
TSB Sugar Holdings (Pty) Ltd, Pongola	Refined sugar production	109,162	tonnes	2011 - 2012	SMRI (2012) Milling Review.
TSB Sugar Holdings (Pty) Ltd, Pongola	Raw sugar production	7,481	tonnes	2009 - 2010	SMRI (2010) Milling Review.
TSB Sugar Holdings (Pty) Ltd, Pongola	Raw sugar production	19,492	tonnes	2010 - 2011	SMRI (2011) Milling Review
TSB Sugar Holdings (Pty) Ltd, Pongola	Raw sugar production	19,264	tonnes	2011 - 2012	SMRI (2012) Milling Review.
Gledhow Sugar Company (Pty) Ltd, Gledhow	Refined sugar production	129,408	tonnes	2009 - 2010	SMRI (2010) Milling Review.
Gledhow Sugar Company (Pty) Ltd, Gledhow	Refined sugar production	96,909	tonnes	2010 - 2011	SMRI (2011) Milling Review
Gledhow Sugar Company (Pty) Ltd, Gledhow	Refined sugar production	107,791	tonnes	2011 - 2012	SMRI (2012) Milling Review.
UCL Company Ltd, Union (Dalton)	Raw sugar production	89,293	tonnes	2009 - 2010	SMRI (2010) Milling Review.
UCL Company Ltd, Union (Dalton)	Raw sugar production	89,577	tonnes	2010 - 2011	SMRI (2011) Milling Review
UCL Company Ltd, Union (Dalton)	Raw sugar production	67,506	tonnes	2011 - 2012	SMRI (2012) Milling Review.
Umfolozi Sugar Mill (Pty) Ltd, Umfolozi	Raw sugar production	119,644	tonnes	2009 - 2010	SMRI (2010) Milling Review.
Umfolozi Sugar Mill (Pty) Ltd, Umfolozi	Raw sugar production	124,524	tonnes	2010 - 2011	SMRI (2011) Milling Review
Umfolozi Sugar Mill (Pty) Ltd, Umfolozi	Raw sugar production	127,139	tonnes	2011 - 2012	SMRI (2012) Milling Review.
Additional fuels and electricity (apart from bagasse)					
Illovo Sugar Ltd, Noodsberg	Total coal use	24,352	tonnes	2009 - 2010	SMRI (2010) Milling Review.
Illovo Sugar Ltd, Noodsberg	Total coal use	22,258	tonnes	2010 - 2011	SMRI (2011) Milling Review
Illovo Sugar Ltd, Noodsberg	Total coal use	29,036	tonnes	2011 - 2012	SMRI (2012) Milling Review.
Illovo Sugar Ltd, Eston	Total coal use	1,027	tonnes	2009 - 2010	SMRI (2010) Milling Review.
Illovo Sugar Ltd, Eston	Total coal use	10	tonnes	2010 - 2011	SMRI (2011) Milling Review
Illovo Sugar Ltd, Eston	Total coal use	388	tonnes	2011 - 2012	SMRI (2012) Milling Review.
Illovo Sugar Ltd, Sezela	Total coal use	21,256	tonnes	2009 - 2010	SMRI (2010) Milling Review.
Illovo Sugar Ltd, Sezela	Total coal use	22,170	tonnes	2010 - 2011	SMRI (2011) Milling Review
Illovo Sugar Ltd, Sezela	Total coal use	25,428	tonnes	2011 - 2012	SMRI (2012) Milling Review.
Illovo Sugar Ltd, Umzimkulu	Total coal use	876	tonnes	2009 - 2010	SMRI (2010) Milling Review.
Illovo Sugar Ltd, Umzimkulu	Total coal use	71	tonnes	2010 - 2011	SMRI (2011) Milling Review

Company/ plant/ region	Description	Value	Units	Year	Reference
Illovo Sugar Ltd, Umzimkulu	Total coal use	-	tonnes	2011 - 2012	SMRI (2012) Milling Review.
Tongaat Hulett Sugar Ltd, Felixton	Total coal use	26,699	tonnes	2009 - 2010	SMRI (2010) Milling Review.
Tongaat Hulett Sugar Ltd, Felixton	Total coal use	25,368	tonnes	2010 - 2011	SMRI (2011) Milling Review
Tongaat Hulett Sugar Ltd, Felixton	Total coal use	31,672	tonnes	2011 - 2012	SMRI (2012) Milling Review.
Tongaat Hulett Sugar Ltd, Amatikulu	Total coal use	6,043	tonnes	2009 - 2010	SMRI (2010) Milling Review.
Tongaat Hulett Sugar Ltd, Amatikulu	Total coal use	5,740	tonnes	2010 - 2011	SMRI (2011) Milling Review
Tongaat Hulett Sugar Ltd, Amatikulu	Total coal use	13,198	tonnes	2011 - 2012	SMRI (2012) Milling Review.
Tongaat Hulett Sugar Ltd, Darnall	Total coal use	1,076	tonnes	2009 - 2010	SMRI (2010) Milling Review.
Tongaat Hulett Sugar Ltd, Darnall	Total coal use	713	tonnes	2010 - 2011	SMRI (2011) Milling Review
Tongaat Hulett Sugar Ltd, Darnall	Total coal use	1,061	tonnes	2011 - 2012	SMRI (2012) Milling Review.
Tongaat Hulett Sugar Ltd, Maidstone	Total coal use	24,191	tonnes	2009 - 2010	SMRI (2010) Milling Review.
Tongaat Hulett Sugar Ltd, Maidstone	Total coal use	6,110	tonnes	2010 - 2011	SMRI (2011) Milling Review
Tongaat Hulett Sugar Ltd, Maidstone	Total coal use	27,144	tonnes	2011 - 2012	SMRI (2012) Milling Review.
TSB Sugar Holdings (Pty) Ltd, Malelane	Total coal use	20,943	tonnes	2009 - 2010	SMRI (2010) Milling Review.
TSB Sugar Holdings (Pty) Ltd, Malelane	Total coal use	34,605	tonnes	2010 - 2011	SMRI (2011) Milling Review
TSB Sugar Holdings (Pty) Ltd, Malelane	Total coal use	29,861	tonnes	2011 - 2012	SMRI (2012) Milling Review.
TSB Sugar Holdings (Pty) Ltd, Komati	Total coal use	1,049	tonnes	2009 - 2010	SMRI (2010) Milling Review.
TSB Sugar Holdings (Pty) Ltd, Komati	Total coal use	2,058	tonnes	2010 - 2011	SMRI (2011) Milling Review
TSB Sugar Holdings (Pty) Ltd, Komati	Total coal use	3,279	tonnes	2011 - 2012	SMRI (2012) Milling Review.
TSB Sugar Holdings (Pty) Ltd, Pongola	Total coal use	23,484	tonnes	2009 - 2010	SMRI (2010) Milling Review.
TSB Sugar Holdings (Pty) Ltd, Pongola	Total coal use	21,847	tonnes	2010 - 2011	SMRI (2011) Milling Review
TSB Sugar Holdings (Pty) Ltd, Pongola	Total coal use	23,053	tonnes	2011 - 2012	SMRI (2012) Milling Review.
Gledhow Sugar Company (Pty) Ltd	Total coal use	11,352	tonnes	2009 - 2010	SMRI (2010) Milling Review.
Gledhow Sugar Company (Pty) Ltd	Total coal use	12,498	tonnes	2010 - 2011	SMRI (2011) Milling Review
Gledhow Sugar Company (Pty) Ltd	Total coal use	10,390	tonnes	2011 - 2012	SMRI (2012) Milling Review.
UCL Company Ltd	Total coal use	4,367	tonnes	2009 - 2010	SMRI (2010) Milling Review.
UCL Company Ltd	Total coal use	3,090	tonnes	2010 - 2011	SMRI (2011) Milling Review
UCL Company Ltd	Total coal use	4,453	tonnes	2011 - 2012	SMRI (2012) Milling Review.
Umfolozi Sugar Mill (Pty) Ltd	Total coal use	6,569	tonnes	2009 - 2010	SMRI (2010) Milling Review.
Umfolozi Sugar Mill (Pty) Ltd	Total coal use	6,804	tonnes	2010 - 2011	SMRI (2011) Milling Review
Umfolozi Sugar Mill (Pty) Ltd	Total coal use	8,001	tonnes	2011 - 2012	SMRI (2012) Milling Review.
Illovo Sugar Ltd, Noodsberg	Total wood use	-	tonnes	2009 - 2010	SMRI (2010) Milling Review.
Illovo Sugar Ltd, Noodsberg	Total wood use	-	tonnes	2010 - 2011	SMRI (2011) Milling Review
Illovo Sugar Ltd, Noodsberg	Total wood use	-	tonnes	2011 - 2012	SMRI (2012) Milling Review.
Illovo Sugar Ltd, Eston	Total wood use	688	tonnes	2009 - 2010	SMRI (2010) Milling Review.
Illovo Sugar Ltd, Eston	Total wood use	343	tonnes	2010 - 2011	SMRI (2011) Milling Review
Illovo Sugar Ltd, Eston	Total wood use	662	tonnes	2011 - 2012	SMRI (2012) Milling Review.
Illovo Sugar Ltd, Sezela	Total wood use	-	tonnes	2009 - 2010	SMRI (2010) Milling Review.
Illovo Sugar Ltd, Sezela	Total wood use	-	tonnes	2010 - 2011	SMRI (2011) Milling Review
Illovo Sugar Ltd, Sezela	Total wood use	-	tonnes	2011 - 2012	SMRI (2012) Milling Review.
Illovo Sugar Ltd, Umzimkulu	Total wood use	-	tonnes	2009 - 2010	SMRI (2010) Milling Review.
Illovo Sugar Ltd, Umzimkulu	Total wood use	-	tonnes	2010 - 2011	SMRI (2011) Milling Review
Illovo Sugar Ltd, Umzimkulu	Total wood use	-	tonnes	2011 - 2012	SMRI (2012) Milling Review.
Tongaat Hulett Sugar Ltd, Felixton	Total wood use	-	tonnes	2009 - 2010	SMRI (2010) Milling Review.
Tongaat Hulett Sugar Ltd, Felixton	Total wood use	-	tonnes	2010 - 2011	SMRI (2011) Milling Review
Tongaat Hulett Sugar Ltd, Felixton	Total wood use	-	tonnes	2011 - 2012	SMRI (2012) Milling Review.
Tongaat Hulett Sugar Ltd, Amatikulu	Total wood use	-	tonnes	2009 - 2010	SMRI (2010) Milling Review.

Company/ plant/ region	Description	Value	Units	Year	Reference
Tongaat Hulett Sugar Ltd, Amatikulu	Total wood use	-	tonnes	2010 - 2011	SMRI (2011) Milling Review
Tongaat Hulett Sugar Ltd, Amatikulu	Total wood use	-	tonnes	2011 - 2012	SMRI (2012) Milling Review.
Tongaat Hulett Sugar Ltd, Darnall	Total wood use	298	tonnes	2009 - 2010	SMRI (2010) Milling Review.
Tongaat Hulett Sugar Ltd, Darnall	Total wood use	202	tonnes	2010 - 2011	SMRI (2011) Milling Review
Tongaat Hulett Sugar Ltd, Darnall	Total wood use	219	tonnes	2011 - 2012	SMRI (2012) Milling Review.
Tongaat Hulett Sugar Ltd, Maidstone	Total wood use	36	tonnes	2009 - 2010	SMRI (2010) Milling Review.
Tongaat Hulett Sugar Ltd, Maidstone	Total wood use	41	tonnes	2010 - 2011	SMRI (2011) Milling Review
Tongaat Hulett Sugar Ltd, Maidstone	Total wood use	40	tonnes	2011 - 2012	SMRI (2012) Milling Review.
TSB Sugar Holdings (Pty) Ltd, Malelane	Total wood use	398	tonnes	2009 - 2010	SMRI (2010) Milling Review.
TSB Sugar Holdings (Pty) Ltd, Malelane	Total wood use	6,669	tonnes	2010 - 2011	SMRI (2011) Milling Review
TSB Sugar Holdings (Pty) Ltd, Malelane	Total wood use	-	tonnes	2011 - 2012	SMRI (2012) Milling Review.
TSB Sugar Holdings (Pty) Ltd, Komati	Total wood use	46	tonnes	2009 - 2010	SMRI (2010) Milling Review.
TSB Sugar Holdings (Pty) Ltd, Komati	Total wood use	67	tonnes	2010 - 2011	SMRI (2011) Milling Review
TSB Sugar Holdings (Pty) Ltd, Komati	Total wood use	47	tonnes	2011 - 2012	SMRI (2012) Milling Review.
TSB Sugar Holdings (Pty) Ltd, Pongola	Total wood use	-	tonnes	2009 - 2010	SMRI (2010) Milling Review.
TSB Sugar Holdings (Pty) Ltd, Pongola	Total wood use	-	tonnes	2010 - 2011	SMRI (2011) Milling Review
TSB Sugar Holdings (Pty) Ltd, Pongola	Total wood use	35	tonnes	2011 - 2012	SMRI (2012) Milling Review.
Gledhow Sugar Company (Pty) Ltd	Total wood use	-	tonnes	2009 - 2010	SMRI (2010) Milling Review.
Gledhow Sugar Company (Pty) Ltd	Total wood use	-	tonnes	2010 - 2011	SMRI (2011) Milling Review
Gledhow Sugar Company (Pty) Ltd	Total wood use	-	tonnes	2011 - 2012	SMRI (2012) Milling Review.
UCL Company Ltd	Total wood use	143	tonnes	2009 - 2010	SMRI (2010) Milling Review.
UCL Company Ltd	Total wood use	103	tonnes	2010 - 2011	SMRI (2011) Milling Review
UCL Company Ltd	Total wood use	142	tonnes	2011 - 2012	SMRI (2012) Milling Review.
Umfolozi Sugar Mill (Pty) Ltd	Total wood use	-	tonnes	2009 - 2010	SMRI (2010) Milling Review.
Umfolozi Sugar Mill (Pty) Ltd	Total wood use	-	tonnes	2010 - 2011	SMRI (2011) Milling Review
Umfolozi Sugar Mill (Pty) Ltd	Total wood use	-	tonnes	2011 - 2012	SMRI (2012) Milling Review.
					Electricity generated and/or exported
Illovo Sugar Ltd	Renewable electricity generation	9,124	GWh	2012	Illovo (2013) Integrated Annual Report
Tongaat Hulett Sugar Ltd	Electricity generated from bagasse	not reported	MWh	FY 2011	THS Ltd (2011) CDP Disclosure reports
Tongaat Hulett Sugar Ltd	Electricity generated from bagasse	392,202	MWh	FY 2012	THS Ltd (2012) CDP Disclosure reports
Tongaat Hulett Sugar Ltd	Electricity generated from bagasse	427,376	MWh	FY 2013	THS Ltd (2013) CDP Disclosure reports
TSB Sugar Holdings (Pty) Ltd	Electricity from bagasse exported to the grid	190,255	MWh	FY 2012	Remgro Ltd (2013) CDP Disclosure
					Annual emissions
Illovo Sugar Ltd, SA	Total emissions	277	thousand tonnes CO_2e	FY 2011	Illovo (2012) Integrated Annual Report
Illovo Sugar Ltd, SA	Total emissions	387	thousand tonnes CO_2e	FY 2012	Illovo (2013) Integrated Annual Report
Illovo Sugar Ltd, SA	Total emissions	365	thousand tonnes CO_2e	FY 2013	Illovo (2013) Integrated Annual Report

Company/ plant/ region	Description	Value	Units	Year	Reference
Illovo Sugar Ltd, SA	Scope 1 emissions	138	thousand tonnes CO_2e	FY 2011	Illovo (2012) Integrated Annual Report
Illovo Sugar Ltd, SA	Scope 1 emissions	192	thousand tonnes CO_2e	FY 2012	Illovo (2013) Integrated Annual Report
Illovo Sugar Ltd, SA	Scope 1 emissions	170	thousand tonnes CO_2e	FY 2013	Illovo (2013) Integrated Annual Report
Illovo Sugar Ltd, SA	Scope 2 emissions	139	thousand tonnes CO_2e	FY 2011	Illovo (2012) Integrated Annual Report
Illovo Sugar Ltd, SA	Scope 2 emissions	195	thousand tonnes CO_2e	FY 2012	Illovo (2013) Integrated Annual Report
Illovo Sugar Ltd, SA	Scope 2 emissions	195	thousand tonnes CO_2e	FY 2013	Illovo (2013) Integrated Annual Report
Illovo Sugar Ltd	Total scope 1 emissions	180,086	tonnes CO_2e	FY 2012	Illovo (2012) CDP Disclosure
Illovo Sugar Ltd	Total scope 1 emissions	169,817	tonnes CO_2e	FY 2013	Illovo (2013) CDP Disclosure
Illovo Sugar Ltd	Scope 1 Noodsberg Mill	88,669	tonnes CO_2e	FY 2012	Illovo (2012) CDP Disclosure
Illovo Sugar Ltd	Scope 1 Noodsberg Mill	44,101	tonnes CO_2e	FY 2013	Illovo (2013) CDP Disclosure
Illovo Sugar Ltd	Scope 1 Sezela Mill	69,279	tonnes CO_2e	FY 2012	Illovo (2012) CDP Disclosure
Illovo Sugar Ltd	Scope 1 Sezela Mill	81,871	tonnes CO_2e	FY 2013	Illovo (2013) CDP Disclosure
Illovo Sugar Ltd	Scope 1 Eston Mill	6,862	tonnes CO_2e	FY 2012	Illovo (2012) CDP Disclosure
Illovo Sugar Ltd	Scope 1 Eston Mill	15,191	tonnes CO_2e	FY 2013	Illovo (2013) CDP Disclosure
Illovo Sugar Ltd	Scope 1 Umzimkulu Mill	681	tonnes CO_2e	FY 2012	Illovo (2012) CDP Disclosure
Illovo Sugar Ltd	Scope 1 Umzimkulu Mill	6,089	tonnes CO_2e	FY 2013	Illovo (2013) CDP Disclosure
Illovo Sugar Ltd	Scope 1 Merebank Distillery	12	tonnes CO_2e	FY 2012	Illovo (2012) CDP Disclosure
Illovo Sugar Ltd	Scope 1 Merebank Distillery	5,368	tonnes CO_2e	FY 2013	Illovo (2013) CDP Disclosure
Illovo Sugar Ltd	Scope 1 Glendale Distillery	14,583	tonnes CO_2e	FY 2012	Illovo (2012) CDP Disclosure
Illovo Sugar Ltd	Scope 1 Glendale Distillery	17,197	tonnes CO_2e	FY 2013	Illovo (2013) CDP Disclosure
Illovo Sugar Ltd	Total scope 1 emissions	105,185.00	tonnes CO_2e	FY 2012	Illovo (2012) CDP Disclosure
Illovo Sugar Ltd	Total scope 1 emissions	194,881.00	tonnes CO_2e	FY 2013	Illovo (2013) CDP Disclosure

Company/ plant/ region	Description	Value	Units	Year	Reference
Illovo Sugar Ltd	Scope 2 Noodsberg Mill	2,275	tonnes CO_2e	FY 2012	Illovo (2012) CDP Disclosure
Illovo Sugar Ltd	Scope 2 Noodsberg Mill	2,412	tonnes CO_2e	FY 2013	Illovo (2013) CDP Disclosure
Illovo Sugar Ltd	Scope 2 Sezela Mill	10,127	tonnes CO_2e	FY 2012	Illovo (2012) CDP Disclosure
Illovo Sugar Ltd	Scope 2 Sezela Mill	38,796	tonnes CO_2e	FY 2013	Illovo (2013) CDP Disclosure
Illovo Sugar Ltd	Scope 2 Eston Mill	2,620	tonnes CO_2e	FY 2012	Illovo (2012) CDP Disclosure
Illovo Sugar Ltd	Scope 2 Eston Mill	3,462	tonnes CO_2e	FY 2013	Illovo (2013) CDP Disclosure
Illovo Sugar Ltd	Scope 2 Umzimkulu Mill	1,171	tonnes CO_2e	FY 2012	Illovo (2012) CDP Disclosure
Illovo Sugar Ltd	Scope 2 Umzimkulu Mill	3,356	tonnes CO_2e	FY 2013	Illovo (2013) CDP Disclosure
Illovo Sugar Ltd	Scope 2 Merebank Distillery	62,967	tonnes CO_2e	FY 2012	Illovo (2012) CDP Disclosure
Illovo Sugar Ltd	Scope 2 Merebank Distillery	143,556	tonnes CO_2e	FY 2013	Illovo (2013) CDP Disclosure
Illovo Sugar Ltd	Scope 2 Glendale Distillery	26,025	tonnes CO_2e	FY 2012	Illovo (2012) CDP Disclosure
Illovo Sugar Ltd	Scope 2 Glendale Distillery	3,299	tonnes CO_2e	FY 2013	Illovo (2013) CDP Disclosure
Tongaat Hulett Sugar Ltd	Total Scope 1 emissions	371,590	tonnes CO_2e	FY 2011	THS Ltd (2011) CDP Disclosure
Tongaat Hulett Sugar Ltd	Total Scope 1 emissions	182,153	tonnes CO_2e	FY 2012	THS Ltd (2012) CDP Disclosure
Tongaat Hulett Sugar Ltd	Total Scope 1 emissions	422,842	tonnes CO_2e	FY 2013	THS Ltd (2013) CDP Disclosure
Tongaat Hulett Sugar Ltd	Scope 1 Felixton	42,541	tonnes CO_2e	FY 2011	THS Ltd (2011) CDP Disclosure
Tongaat Hulett Sugar Ltd	Scope 1 Felixton	75,758	tonnes CO_2e	FY 2012	THS Ltd (2012) CDP Disclosure
Tongaat Hulett Sugar Ltd	Scope 1 Felixton	62,587	tonnes CO_2e	FY 2013	THS Ltd (2013) CDP Disclosure
Tongaat Hulett Sugar Ltd	Scope 1 Amatikulu	11,171	tonnes CO_2e	FY 2011	THS Ltd (2011) CDP Disclosure
Tongaat Hulett Sugar Ltd	Scope 1 Amatikulu	23,703	tonnes CO_2e	FY 2012	THS Ltd (2012) CDP Disclosure
Tongaat Hulett Sugar Ltd	Scope 1 Amatikulu	17,077	tonnes CO_2e	FY 2013	THS Ltd (2013) CDP Disclosure
Tongaat Hulett Sugar Ltd	Scope 1 Darnall	2,381	tonnes CO_2e	FY 2011	THS Ltd (2011) CDP Disclosure
Tongaat Hulett Sugar Ltd	Scope 1 Darnall	2,779	tonnes CO_2e	FY 2012	THS Ltd (2012) CDP Disclosure
Tongaat Hulett Sugar Ltd	Scope 1 Darnall	4,650	tonnes CO_2e	FY 2013	THS Ltd (2013) CDP Disclosure
Tongaat Hulett Sugar Ltd	Scope 1 Maidstone	57,538	tonnes CO_2e	FY 2011	THS Ltd (2011) CDP Disclosure

Company/ plant/ region	Description	Value	Units	Year	Reference
Tongaat Hulett Sugar Ltd	Scope 1 Maidstone	63,511	tonnes CO_2e	FY 2012	THS Ltd (2012) CDP Disclosure
Tongaat Hulett Sugar Ltd	Scope 1 Maidstone	90,578	tonnes CO_2e	FY 2013	THS Ltd (2013) CDP Disclosure
Tongaat Hulett Sugar Ltd	Scope 1 refinery	241,907	tonnes CO_2e	FY 2011	THS Ltd (2011) CDP Disclosure
Tongaat Hulett Sugar Ltd	Scope 1 refinery	not reported	tonnes CO_2e	FY 2012	THS Ltd (2012) CDP Disclosure
Tongaat Hulett Sugar Ltd	Scope 1 refinery	228,688	tonnes CO_2e	FY 2013	THS Ltd (2013) CDP Disclosure
Tongaat Hulett Sugar Ltd	Scope 1 Voermol	16,052	tonnes CO_2e	FY 2011	THS Ltd (2011) CDP Disclosure
Tongaat Hulett Sugar Ltd	Scope 1 Voermol	16,402	tonnes CO_2e	FY 2012	THS Ltd (2012) CDP Disclosure
Tongaat Hulett Sugar Ltd	Scope 1 Voermol	19,262	tonnes CO_2e	FY 2013	THS Ltd (2013) CDP Disclosure
Tongaat Hulett Sugar Ltd	Total Scope 2 emissions	54,264	tonnes CO_2e	FY 2011	THS Ltd (2011) CDP Disclosure
Tongaat Hulett Sugar Ltd	Total Scope 2 emissions	57,742	tonnes CO_2e	FY 2012	THS Ltd (2012) CDP Disclosure
Tongaat Hulett Sugar Ltd	Total Scope 2 emissions	73,026	tonnes CO_2e	FY 2013	THS Ltd (2013) CDP Disclosure
Tongaat Hulett Sugar Ltd	Scope 2 Felixton	0	tonnes CO_2e	FY 2011	THS Ltd (2011) CDP Disclosure
Tongaat Hulett Sugar Ltd	Scope 2 Felixton	5,346	tonnes CO_2e	FY 2012	THS Ltd (2012) CDP Disclosure
Tongaat Hulett Sugar Ltd	Scope 2 Felixton	6,159	tonnes CO_2e	FY 2013	THS Ltd (2013) CDP Disclosure
Tongaat Hulett Sugar Ltd	Scope 2 Amatikulu	2,007	tonnes CO_2e	FY 2011	THS Ltd (2011) CDP Disclosure
Tongaat Hulett Sugar Ltd	Scope 2 Amatikulu	5,616	tonnes CO_2e	FY 2012	THS Ltd (2012) CDP Disclosure
Tongaat Hulett Sugar Ltd	Scope 2 Amatikulu	5,275	tonnes CO_2e	FY 2013	THS Ltd (2013) CDP Disclosure
Tongaat Hulett Sugar Ltd	Scope 2 Darnall	25,456	tonnes CO_2e	FY 2011	THS Ltd (2011) CDP Disclosure
Tongaat Hulett Sugar Ltd	Scope 2 Darnall	5,777	tonnes CO_2e	FY 2012	THS Ltd (2012) CDP Disclosure
Tongaat Hulett Sugar Ltd	Scope 2 Darnall	5,975	tonnes CO_2e	FY 2013	THS Ltd (2013) CDP Disclosure
Tongaat Hulett Sugar Ltd	Scope 2 Maidstone	1,401	tonnes CO_2e	FY 2011	THS Ltd (2011) CDP Disclosure
Tongaat Hulett Sugar Ltd	Scope 2 Maidstone	17,020	tonnes CO_2e	FY 2012	THS Ltd (2012) CDP Disclosure
Tongaat Hulett Sugar Ltd	Scope 2 Maidstone	20,666	tonnes CO_2e	FY 2013	THS Ltd (2013) CDP Disclosure
Tongaat Hulett Sugar Ltd	Scope 2 refinery	12,236	tonnes CO_2e	FY 2011	THS Ltd (2011) CDP Disclosure
Tongaat Hulett Sugar Ltd	Scope 2 refinery	13,033	tonnes CO_2e	FY 2012	THS Ltd (2012) CDP Disclosure

Company/ plant/ region	Description	Value	Units	Year	Reference
Tongaat Hulett Sugar Ltd	Scope 2 refinery	22,521	tonnes CO_2e	FY 2013	THS Ltd (2013) CDP Disclosure
Tongaat Hulett Sugar Ltd	Scope 2 Voermol	13,164	tonnes CO_2e	FY 2011	THS Ltd (2011) CDP Disclosure
Tongaat Hulett Sugar Ltd	Scope 2 Voermol	10,950	tonnes CO_2e	FY 2012	THS Ltd (2012) CDP Disclosure
Tongaat Hulett Sugar Ltd	Scope 2 Voermol	12,430	tonnes CO_2e	FY 2013	THS Ltd (2013) CDP Disclosure
TSB Sugar Holdings (Pty) Ltd	Scope 1 emissions	250,415	tonnes CO_2e	FY 2011	Remgro Ltd (2012) CDP Disclosure
TSB Sugar Holdings (Pty) Ltd	Scope 1 emissions	202,367	tonnes CO_2e	FY 2012	Remgro Ltd (2013) CDP Disclosure
TSB Sugar Holdings (Pty) Ltd	Scope 2 emissions	102,854	tonnes CO_2e	FY 2011	Remgro Ltd (2012) CDP Disclosure
TSB Sugar Holdings (Pty) Ltd	Scope 2 emissions	97,683	tonnes CO_2e	FY 2012	Remgro Ltd (2013) CDP Disclosure
TSB Sugar Holdings (Pty) Ltd	Total GHG emissions	357,332	tonnes CO_2e	FY 2011	TSB Sugar Holdings (Pty) Ltd
TSB Sugar Holdings (Pty) Ltd	Total GHG emissions	304,425	tonnes CO_2e	FY 2012	TSB Sugar Holdings (Pty) Ltd
					Emissions intensity
Tongaat Hulett Sugar Ltd	CO_2e savings from electricity export, electricity generated from cane fibre (bagasse)	300,100	tonnes CO_2e	FY 2012	THS Ltd (2012) CDP Disclosure reports
Illovo Sugar Ltd	Emission intensity	not reported	tonnes CO_2e/ tonne sugar	FY 2011	
Illovo Sugar Ltd	Emission intensity	0.3234	tonnes CO_2e/ tonne sugar	FY 2012	Illovo (2012) CDP Disclosure reports
Illovo Sugar Ltd	Emission intensity	0.3153	tonnes CO_2e/ tonne sugar	FY 2013	Illovo (2013) CDP Disclosure reports
Tongaat Hulett Sugar Ltd	Emission intensity	0.62	tonnes CO_2e/ tonne sugar	FY 2011	THS Ltd (2011) CDP Disclosure reports
Tongaat Hulett Sugar Ltd	Emission intensity	0.31	tonnes CO_2e/ tonne sugar	FY 2012	THS Ltd (2012) CDP Disclosure reports
Tongaat Hulett Sugar Ltd	Emission intensity	0.59	tonnes CO_2e/ tonne sugar	FY 2013	THS Ltd (2013) CDP Disclosure reports

III Annex 3: Overview of international benchmarks

A.3.1. Iron and steel

A.3.1.1. EU ETS Benchmarks

For the iron and steel industry, the sector report describes the underlying methodology and data used to set preliminary benchmarks (Ecofys, 2009d). The final reported benchmark values are taken from the Benchmarking Decision.

A.3.1.1.1. Scope

Emission data for iron and steel facilities in the EU from 2005 to 2009 were used to set the set the benchmarks. Emission data gaps were approximated with production volumes and direct specific emissions to ensure 100% of the sector's direct emissions were covered. The number of iron and steel related production installations in the EU 27 that were assessed, as well as their share of overall direct emissions were (Ecofys, 2009d):

Table 76 EU ETS Benchmarks: Iron and Steel number of installations

Activity	Number of installations	Share in total sector emissions (%)
Coke production	42	9.1
Sinter production	32	12.7
Hot metal production	41	69.3
Electric arc furnaces (EAF)	200	3.3
Hot rolled steel	500	2.3
Processed steel	600	1.8
Foundries	40	1.4

A.3.1.1.2. Methodology and explanation

A detailed description of how the benchmarks were determined can be found in the sector report for the iron and steel industry (Ecofys, 2009d). In this report it was estimated that in European facilities approximately 88% of the CO_2 emissions arise from the production of coke, sinter, BOF crude steel and EAF crude steel. The remaining 12% of emissions are from downstream processes that include foundry casting, hot rolling, cold rolling and surface treatment. The following table outlines the benchmarks developed for the iron and steel sector, detailing the definition and explanation of the products, processes and emissions covered. More detail can be found in the Guidance Document 9 (GD9) report.

In determining the benchmarks for processes where waste fuels are produced (most notably the hot metal benchmark), the reference fuel approach as briefly touched upon in Section 2.3 was used. The surplus emissions from the waste fuels (as compared to a reference fuel) has been allocated to the hot metal production processes with the remaining emissions (i.e. those of the reference fuel) have been allocated to the production processes consuming the waste fuels.

Table 77 EU ETS Benchmarks: Iron and Steel products, processes and emissions covered

Product Benchmark	Products Covered	Processes and emissions covered
Coke	Coke-oven coke (obtained from the carbonization of coking coal, at high temperature) or gas-works coke (by-product of gas-works plants) expressed as tonnes of dry coke. Lignite coke is not covered by this benchmark.	All processes directly or indirectly linked to the following process units are included: - coke ovens - H_2S/NH_3 incineration - coal preheating (defreezing) - coke gas extractor - desulphurization unit - distillation unit - steam generation plant - pressure control in batteries - biological water treatment - miscellaneous heating of by-products - hydrogen separator Coke oven gas cleaning is included. Emissions related to the production of the consumed electricity are excluded from the system boundaries.
Sintered Ore	Agglomerated iron-bearing product containing iron ore fines, fluxes and iron-containing recycling materials with the chemical and physical properties such as the level of basicity, mechanical strength and permeability required to deliver iron and necessary flux materials into iron ore reduction processes.	All processes directly or indirectly linked to the following process units are included: - sinter strand - ignition - feedstock preparation units - hot screening unit - sinter cooling unit - cold screening unit - steam generation. Emissions related to the production of the consumed electricity are excluded from the system boundaries.
Hot Metal	Liquid iron saturated with carbon for further processing.	All processes directly or indirectly linked to the following process units are included: - Blast furnace; - Hot metal treatment units - Blast furnace blowers - Blast furnace hot stoves - Basic oxygen furnace - Secondary metallurgy units - Vacuum ladles

Product Benchmark	Products Covered	Processes and emissions covered
		- Casting units (including cutting) - Slag treatment unit - Burden preparation - Blast furnace gas treatment unit - Dedusting units - Scrap pre-heating - Coal drying for pulverized coal injection (PCI) - Vessels preheating stands - Casting ingots preheating stands - Compressed air production - Dust treatment unit (briquetting) - Sludge treatment unit (briquetting) - Steam injection in blast furnace unit - Steam generation plant - Converter basic oxygen furnace (BOF) gas cooling - Miscellaneous Emissions related to the production of the consumed electricity are excluded from the system boundaries. The export of measurable heat (steam, hot water, etc.) is not covered by this product benchmark.
EAF: Carbon steel	Steel containing less than 8% metallic alloying elements and tramp elements to such levels limiting the use to those applications where no high surface quality and processability is required.	All processes directly or indirectly linked to the following process units are included: - electric arc furnace - secondary metallurgy - casting and cutting - post-combustion unit - dedusting unit - vessels heating stands - casting ingots preheating stands - scrap drying - scrap preheating For the determination of indirect emissions, the total electricity consumption within the system boundaries shall be considered. These emissions are not eligible for free allocation but are used in the calculation of free allocation (refer to GD9 for more details). The export of measurable heat (steam, hot water, etc.) is not covered by this product benchmark.
EAF: high alloy steel	Steel containing 8% or more metallic alloying elements or where high surface quality and processability is required.	All processes directly or indirectly linked to the following process units are included: - electric arc furnace - secondary metallurgy - casting and cutting - post-combustion unit - dedusting unit - vessels heating stands - casting ingots preheating stands - slow cooling pit - scrap drying - scrap preheating

Product Benchmark	Products Covered	Processes and emissions covered
		For the determination of indirect emissions, the total electricity consumption within the system boundaries shall be considered. These emissions are not eligible for free allocation but are used in the calculation of free allocation (refer to GD9 for more details). The export of measurable heat (steam, hot water, etc.) is not covered by this product benchmark.
Iron Casting	Casted iron as liquid iron ready alloyed, skinned, and ready for casting.	All processes directly or indirectly linked to the following process steps are included: - melting shop - casting shop - core shop - finishing For the determination of indirect emissions, only the electricity consumption of melting processes within the system boundaries shall be considered. These emissions are not eligible for free allocation but are used in the calculation of free allocation (refer to GD9 for more details). The export of measurable heat (steam, hot water, etc.) is not covered by this product benchmark.

Apart from slight changes in the values from the preliminary to the final benchmark values, other changes include:

- Change from one EAF benchmark (covering non-alloy, high alloy and other alloy steel) to two separate benchmarks for EAF: carbon steel and EAF: high alloy steel;
- Inclusion of an Iron Casting benchmark

A.3.1.1.3. Benchmark value

The final benchmark values for the EU ETS iron and steel sector are provided in Table 78.

Table 78: EU ETS Benchmarks: Iron and Steel final benchmark values

Product Benchmark	Value	Units
Coke	0.286	tonne CO_2/tonne product
Sintered Ore	0.171	tonne CO_2/tonne product
Hot Metal	1.328	tonne CO_2/tonne product
EAF: Carbon steel	0.283	tonne CO_2/tonne product
EAF: high alloy steel	0.352	tonne CO_2/tonne product
Iron Casting	0.325	tonne CO_2/tonne product

A.3.1.2. California Cap-and-Trade Benchmarks

The purpose and scope of the California Cap-and-Trade Benchmarks is described in Section 3.2. The underlying methodology and data used in setting the California Cap-and-Trade benchmarks are described in the Air Resource Board's (ARB) "Appendix J: Allowance allocation" (Air Resource Board, 2010), with final reported benchmark values presented in the ARB's "Article 5" (Air Resource Board, 2011).

A.3.1.2.1. Scope

The geographic scope of the California Cap-and-Trade benchmarks is the state of California. In terms of iron and steel production, only one EAF facility operates in California, which gives rise to less than 0.1% of total GHG emissions from industrial facilities covered under the scheme in 2008. Rolling facilities were separated from the primary production process. The two rolling facilities currently in operation produced approximately 0.4% of total GHG emissions from industrial facilities covered by the scheme (Air Resource Board, 2010).

A.3.1.2.2. Methodology and explanation

The output metrics for the benchmark values were established based on the Californian iron and steel sector information. Only direct emissions for the specific production facilities are covered.

A.3.1.2.3. Benchmark value

Final benchmark values provided in the table below were obtained from the latest publicly available "Article 5" (Air Resource Board, 2011).

Table 79: California Cap-And-Trade Benchmarks: Iron and Steel

Product Benchmark	Value	Units
Steel Production Using an Electric Arc Furnace	0.286	tonne CO_2/tonne product
Hot Rolled Steel Sheet Production	0.171	tonne CO_2/tonne product
Picked Steel Sheet Production	1.328	tonne CO_2/tonne product
Cold Rolled and Annealed Steel Sheet Production	0.283	tonne CO_2/tonne product
Galvanized Steel Sheet Production	0.352	tonne CO_2/tonne product
Tin Steel Plate Production	0.325	tonne CO_2/tonne product

A.3.1.3. Australian Carbon Pricing Mechanism Benchmarks

All data relating the underlying methodology and final benchmark values are attained from the paper titled "Establishing the eligibility of activities under the Jobs and Competitiveness Program (Australian Government, 2012a).

A.3.1.3.1. Scope

The geographic scope for the benchmark values are all iron and steel facilities operational in Australia. Historical industry average data for the financial years of 2006-07 and 2007-08 were used for setting the benchmarks in terms of emissions per unit production. The iron and steel sector was separated into two types of activities, each with its own product benchmarks:

- integrated iron and steel manufacturing; and
- manufacture of carbon steel from cold ferrous feed.

The iron and steel sector is relatively small in Australia, with two integrated iron and steel manufacturing facilities owned by two different companies, and one company manufacturing carbon steel from cold ferrous feed at three different facilities.

A.3.1.3.2. Methodology and explanation

The output metrics for the benchmark values were established based on the Australian iron and steel sector information. Benchmarks were set on both direct emissions and electricity consumption for each defined product.

Carbon steel products included under the activity definitions were defined as containing more iron (Fe) by mass than any other single element and having a carbon (C) concentration of less than 2% by mass.

The activity of integrated iron and steel manufacturing was defined as (Australian Government, 2012a):

- "carbonisation of coal (coking coal) into coke oven coke (used as a reducing agent in the iron and steel making process);
- chemical and physical transformation of limestone and/or dolomite into lime, including burnt lime and burnt dolomite (used as a flux in the iron and steel making process);
- agglomeration of iron ore into agglomerated iron ore products such as iron ore sinter or iron ore pellets;
- chemical and physical transformation of iron ore feed, including agglomerated iron ore, which is then melted and reduced into molten iron; and
- chemical and physical transformation of molten iron, which is generally mixed with cold ferrous feed, such as pig iron and ferrous scrap, to produce carbon steel products, including continuously cast products and/or ingots and/or hot-rolled products."

Lime production is considered as a separate activity, unless it is produced as part of an integrated activity in which case it may not be counted towards the basis of issue for a stand-alone lime production activity. Manufacture of carbon steel from cold ferrous feed includes the heating and melting of a cold ferrous feed, such as ferrous scrap and pig iron, into liquid steel, and the casting of solid carbon steel products from the liquid steel.

A.3.1.3.3. Benchmark Value

The final benchmark values for the Australian iron and steel sector are provided in Table 80.

Table 80: Australian Benchmarks: Iron and Steel

	Direct Emissions [tonne CO_2e/tonne]	Electricity usage [MWh/tonne]
Integrated iron and steel manufacturing		
Dry iron ore sinter	0.227	0.0397
Dry iron ore pellets	0.114	0.0742
Dry coke oven coke	0.462	0.0397
Dry lime	0.825	0.0405
Continuously cast carbon steel products and ingots of carbon steel of saleable quality	1.56	0.145
Long products of hot-rolled carbon steel of saleable quality	0.0756	0.133
Flat products of hot-rolled carbon steel of saleable quality	0.0317	0.116
Manufacture of carbon steel from cold ferrous feed		
Continuously cast carbon steel products and ingots of carbon steel of saleable quality	0.0836	0.532
Long products of hot-rolled carbon steel of saleable quality	0.0756	0.133
Flat products of hot-rolled carbon steel of saleable quality	0.0317	0.116

A.3.1.4. World Best Practice Energy Intensity Value Benchmarks

As noted in Section 3.4, the benchmarks developed by Worrel et al. (2008) represent world best practice in 2007/2008 per technology/process route in a number of sectors. For Iron and Steel the four main process routes identified and for which benchmarks were derived were:

- Blast Furnace and Basic Oxygen Furnace (BOF)
- Smelt Reduction and BOF
- Electric Arc Furnace (Direct Reduced Iron)

- Electric Arc Furnace (Scrap)

In addition to these four main process steps, separate energy consumption values are provided for hot rolled bars, thin slab (near net shape) casting, cold rolled and finished steel, and the COREX process. The benchmark values are presented in Table 81.

Table 81: World Best Practice Energy Intensity Values: Iron and Steel

Classification	Process	Value	Units
Material Preparation	Sintering and Pelletizing	2.2	GJ/tonne steel
	Pelletizing	0.8	GJ/tonne steel
	Coking	1.1	GJ/tonne steel
Iron and Steel making	Blast furnace and BOF (blast furnace, basic oxygen furnace (BOF), refining)	12.5	GJ/tonne steel
	Smelt reduction and BOF	18	GJ/tonne steel
	EAF (direct reduced iron)	15.1	GJ/tonne steel
Steel making	EAF (scrap metal)	5.5	GJ/tonne steel
Casting and Rolling	Continuous Casting and Hot Rolling	2.5	GJ/tonne steel
	Casting and Rolling with Thin Slab Casting	0.5	GJ/tonne steel
Cold Rolling and Finishing	Cold Rolling and Finishing	2.3	GJ/tonne steel
COREX	Coal consumption	29.4	GJ/tonne hot metal
	Electricity	75	kWh/tonne hot metal
	Export off-gasses energy value	13.4	GJ/tonne hot metal

A.3.1.5. UNIDO Global Industrial Energy Efficiency Benchmarks

Benchmark surveys were not available for the iron and steel sector at the time when the UNIDO study was conducted (UNIDO, 2010). The report utilised energy indicators from the Worrell, et al. (2008) study, together with production data from the World Steel Association (WSA, 2009), to establish the following energy efficiency indicators (EEI) for the iron and steel sector:

- Best available technology: 1
- Global average: 1.45
- Selected industrialized countries: 1.16-1.4
- Selected developing countries: 1.4-2.2

The broad methodology for this approach is explained in Section 3.4; more detail can be found in the UNIDO report.

A.3.2. Ferroalloys

As indicated in the main body of the report, the only publicly available emissions intensity data for the ferroalloy industry are from an article by Holappa (2010). Emission factors were adopted from Sjardin (2003) and combined with worldwide production figures of common ferroalloys in 2007 (USGS, 2011). The Intergovernmental Panel on Climate Change Report 2007 (IPCC) also used data from this study.

The global average emission intensities for non-energy related emissions as calculated for 2007 were:

- Ferrochromium – 1.63 tonne CO_2/tonne
- Ferromanganese – 1.79 tonne CO_2/tonne
- Ferrosilicon – 2.92 tonne CO_2/tonne
- Siliconmanganese – 1.66 tonne CO_2/tonne

The figures for FeCr and FeMn include different product grades (high, medium, low carbon) with different emission factors. FeSi also comprises different grades with different Si contents. The final values are weighted mean values based on production figures.

A.3.3. Cement

A.3.3.1. EU ETS Benchmarks

The sector specific report for the cement industry describes the underlying methodology and data that was used to set preliminary benchmarks (Ecofys, 2009b). The final reported benchmark values are from the Benchmarking Decision.

A.3.7.1.1. Scope

The benchmark curve used for the cement industry sector report is based on a database developed under the World Business Council for Sustainable Development Cement Sustainability Initiative (Ecofys, 2009b). This Initiative systematically collects data on CO_2 emissions using a uniform protocol, and covers over 94% of the clinker production facilities in the EU27 (226 plants).

A.3.7.1.1. Methodology and explanation

A detailed description of how the preliminary benchmark was determined can be found in the sector report for the cement industry (Ecofys, 2009b). The preliminary benchmark was only for clinker, however final benchmark values (as per the Benchmarking Decision) are for both grey cement clinker and white cement clinker.

The following table describes the final benchmarks developed, detailing the definition and explanation of the products, processes and emissions covered. More detail can be found in the GD9 document.

Table 82 EU ETS Benchmarks: Cement products, processes and emissions covered

Product Benchmark	Products Covered	Processes and emissions covered
Grey Cement Clinker	Grey cement clinker as total clinker produced	All processes directly or indirectly linked to the production of grey cement clinker are included. The emissions related to the production of grey cement clinker include the emissions from the calcination process and fuel-related emissions to provide thermal energy for the production process (including heat losses). Emissions related to the production of the consumed electricity are excluded from the system boundaries.
White Cement Clinker	White cement clinker for use as main binding component in the formulation of materials such as joint filers, ceramic tile adhesives, insulation, and anchorage mortars, industrial floor mortars, ready mixed plaster, repair mortars, and water-tight coatings with maximum average contents of 0.4 mass-% Fe_2O_3, 0.003 mass-% Cr_2O_3 and 0.03 mass-% Mn_2O_3.	All processes directly or indirectly linked to the production of grey cement clinker are included. Emissions related to the production of the consumed electricity are excluded from the system boundaries.

A.3.7.1.1. Benchmark value

The final benchmark values for the EU ETS cement sector are provided in Table 83.

Table 83: EU ETS Benchmarks: Cement final benchmark values

Product Benchmark	Value	Units
Grey Cement Clinker	0.766	tonne CO_2/tonne product
White Cement Clinker	0.987	tonne CO_2/tonne product

A.3.3.2. California Cap-and-Trade Benchmarks

The purpose and scope of the California Cap-and-Trade Benchmarks is described in Section 3.2. The underlying methodology and data used in setting the California Cap-and-Trade benchmarks are described in the Air Resource Board's (ARB) "Appendix J: Allowance allocation" (Air Resource Board, 2010), with final reported benchmark values presented in the ARB's "Article 5" (Air Resource Board, 2011).

A.3.3.2.1 Scope

There were 9 cement plants that produced clinker in California in 2009. These facilities produced about 13.9% of total GHG emissions from the covered industrial sector in 2008. A majority of them used short kilns with preheaters and pre-calciners for clinker production while some used long kilns (Air Resource Board, 2010).

A.3.3.2.2. Methodology and explanation

Tonne cement produced (an adjusted clinker and mineral additives product) was chosen as the output metric based on the Californian cement sector information, which makes this benchmark not directly comparable to other clinker benchmarks. Only direct emissions for the specific production facilities are covered.

To address concerns about the processing of imported clinker or the potential trade of clinker from one facility to another for further processing, the cement metric is based on the level of clinker production at a particular facility and is thus adjusted to exclude traded clinker. The benchmarks are set using verified emissions and output data from 2009, collected through the California Mandatory Greenhouse Gas Reporting Regulation.

An adjustment to the cap decline factor used in the allocation formula for the cement industry was recommended in Article 5 from the California Resource Board (September 2011). This is due to the fact that more than half of the emissions from clinker production result from calcination, with no direct method available for reducing the emissions intensity of this chemical process. For this reason, a separate rate of decline, in effect applying the cap decline factor only to the energy use portion of the industries emissions, was applied. The resulting cap decline is approximately 0.9% per year, rather than the 1.8% per year used for other industries and the electricity sector.

A.3.7.1.1. Benchmark value

The final benchmark value provided in the table below was obtained from the latest publicly available "Article 5" (Air Resource Board, 2011).

Table 84: California Cap-And-Trade Benchmarks: Cement

Product Benchmark	Value	Units
Cement	0.718	tonne CO_2/tonne product

A.3.3.3. Australian Carbon Pricing Mechanism Benchmarks

All data relating the underlying methodology and final benchmark values are obtained from the paper titled "Establishing the eligibility of activities under the Jobs and Competitiveness Program (Australian Government, 2012a).

A.3.3.3.1. Scope

The geographic scope for the benchmark values are for all cement production facilities operational in Australia. Historical industry average data for the financial years of 2006-07 and 2007-08 were used for setting the benchmarks in terms of emissions per unit production. For the cement industry, a benchmark was only set on the activity of clinker production.

During the assessment period, three entities undertook the activity of clinker production at ten facilities in Australia.

A.3.7.1.1. Methodology and explanation

The output metrics for the benchmark values were established based on Australian cement sector information. Benchmarks were set on both direct emissions and electricity consumption for clinker production.

A.3.3.3.3. Benchmark Value

The final benchmark values for the Australian cement sector are provided in Table 85.

Table 85: Australian Benchmarks: Cement

Product Benchmark	Direct Emissions [tonne CO_{2e}/tonne]	Electricity usage [MWh/tonne]
Dry Portland cement clinker of saleable quality	0.886	0.0709

A.3.3.4. World best practice energy intensity benchmarks

Clinker making accounts for about 90% of the energy consumed in the cement making process. The energy used for cement production can thus be reduced by decreasing the ratio of clinker to final cement through mixing clinker with other additives. In line with the European ENV 197-2 standards, for composite Portland cements (CEM II) up to 35% fly ash can be substituted for clinker, whilst for blast furnace slag cements (CEM III/A) up to 65% of the product can be blast furnace slag.

Best practice primary energy use for clinker together with three types of cement (Portland cement, fly ash cement and blast furnace slag cement) is given in Table 86.

Table 86 World Best Practice Energy Intensity Values: Cement sector (Worrell, 2008)

Classification	Processes covered	Value	Units
Clinker	Raw materials and solid fuels preparation, clinker manufacturing	3.34	GJ/tonne clinker
Portland Cement	Raw materials and solid fuels preparation, clinker manufacturing, additives preparation, cement grinding	3.4	GJ/tonne cement
Fly Ash Cement	Raw materials and solid fuels preparation, clinker manufacturing, additives preparation, cement grinding	2.5	GJ/tonne cement
Blast Furnace Slag Cement	Raw materials and solid fuels preparation, clinker manufacturing, additives preparation, cement grinding	2.1	GJ/tonne cement

A.3.3.5. UNIDO Global Industrial Energy Efficiency Benchmarks

The study by UNIDO provides energy intensity values based on production data from the US Geological Survey (U.S. Geological Survey, 2009) and specific energy consumption data from the Cement Sustainability Initiative (CSI, 2009). Specific energy consumption data originates from "Getting the Numbers Right" (GNR) database, a voluntary and independently managed database, that covers approximately 31% of total global cement production. The final energy intensity values are provided in the table below. Electricity consumption is reported separately (expressed per tonne of cement) from the heat used in kilns; a significant share of electricity consumption is for grinding.

Table 87 Global Industrial Energy Efficiency Benchmarks: Cement sector

Average energy range/benchmark	Clinker (GJ/tonne clinker)	Cement (kWh/tonne cement)
Selected industrialized countries	3.3-4.2	109-134
Selected developing countries	3.1-6.2	92-121
Global average	3.5	109
Best available technology	2.9	56
International benchmark	3	88

A.3.4. Petroleum (crude oil refineries)

A.3.4.1. EU ETS and California benchmarks

The sector specific report for the refinery industry (Ecofys, 2009f) describes the underlying methodology and data that was used to set preliminary benchmarks. The final reported benchmark values are from the Benchmarking Decision.

A.3.4.1.1 Scope and Methodology

As noted previously, all crude oil refineries differ in terms of the configuration of processes as well as their throughputs, even though they produce a similar spectrum of products. In both the EU ETS and California benchmark frameworks, the Solomon "CO_2 weighted tonne" (CWT) approach forms the basis of the benchmarking methodology. In this approach, each unit operation in the refinery is identified and assigned a CWT factor. These CWT factors are based on an extensive global database and the current values have been applied in various benchmarking approaches since 2006. The CWT factor represent the average emission intensity of the unit operation as compared to the average emission intensity of the crude distillation unit of the refinery, which by default has a CWT of 1.

To benchmark refineries, the throughput of each unit is multiplied by the corresponding CWT factor and totalled. Each refinery's total CWT will be different, and reflects the particular processes involved. The importance the various units is based on the typical emissions intensity of those units. Units with on average a higher emission intensity get a higher CWT factor, and units with a lower emissions intensity get a lower CWT factor. The units are thus weighted based on their average emissions intensity allowing to compare complex refineries (that will have a higher number of CWT's) and simple refineries (that will have a lower number of CWT's). The CWT method also includes a standard method to account for the small emissions related to non-process related emissions (such as office buildings etc.) and the calculations applied also correct for issues such as imported versus own produced electricity etc.

A benchmark curve can be produced by comparing the resulting emissions per CWT between refineries. A complex and a simple refinery that both operate exactly at the average emissions intensity that formed the basis for the weighing of the units, will have identical emissions per CWT, although their total emissions and emissions per tonne crude will be quite different.

The final benchmark (expressed as t CO2 / CWT) can be set at the average emissions per CWT, the 10% best or any other point on the benchmark curve.

More detail on this methodology, the corrections made, and the overlap with the petrochemical sector are discussed in detail the sector specific report (Ecofys, 2009f).

The following table describes the final benchmarks developed, detailing the definition and explanation of the products, processes and emissions covered. More detail can be found in the GD9 document.

Table 88 EU ETS Benchmarks: Petroleum (oil refinery) products, processes and emissions covered

Product Benchmark	Products Covered	Processes and emissions covered
Refinery products	Mix of refinery products with more than 40% light products (motor spirit (gasoline) including aviation spirit, spirit type (gasoline type) jet fuel, other light petroleum oils/ light preparations, kerosene including kerosene type jet fuel, gas oils) expressed as CO_2 weighted tonne (CWT).	All processes of a refinery matching the definition of one of the CWT process units as well as ancillary non-process facilities operating inside the refinery fence-line such as tankage, blending, effluent treatment, etc. are included. For the determination of indirect emissions, the total electricity consumption within the system boundaries shall be considered. Process units pertaining to other sectors, such as petrochemicals, are sometimes physically integrated with the refinery. Such process units and their emissions are excluded from the CWT approach. Instead, the allocation for these process units should be determined on the basis of other product benchmark (if available) or fall-back approaches (heat benchmark, fuel benchmark or process emissions approach). For the determination of indirect emissions, the total electricity consumption within the system boundaries shall be considered. These emissions are not eligible for free allocation but are used in the calculation of free allocation. The export of measurable heat (steam, hot water, etc.) is not covered by this product benchmark.

A.3.4.1.2 Benchmark value

The final benchmark value for the EU ETS petroleum sector is 0.0295 tonne CO_2/CWT.

A.3.4.2. Australian Carbon Pricing Mechanism Benchmarks

All data relating the underlying methodology and final benchmark values are taken from the paper titled "Establishing the eligibility of activities under the Jobs and Competitiveness Program" (Australian Government, 2012a).

A.3.4.2.1. Scope

The geographic scope for the benchmark values are for all facilities operational in Australia. Historical industry average data for the financial years of 2006-07 and 2007-08 were used for setting the benchmarks in terms of emissions per unit production. For the petroleum sector, petroleum refining was defined as one activity with one benchmark on a combined product.

In Australia, four companies comprising seven facilities were benchmarked.

A.3.4.2.2. Methodology and explanation

The output metrics for the benchmark values were established based on the Australian petroleum refining sector information. Benchmarks were set on both the direct emissions and electricity consumption for the defined product.

A.3.4.2.3 Benchmark Value

The final benchmark values for the Australian petroleum refining sector are provided in Table 89.

Table 89: Australian Benchmarks: Petroleum refining

Product Benchmark	Direct Emissions [tonne CO_{2e}/kilolitre]	Electricity usage [MWh/kilolitre]
Combined stabilised crude petroleum oil, condensate, tallow, vegetable oil and eligible petroleum feedstocks (at 15°C and 1 atmosphere)	0.886	0.0709

A.3.4.3. Global Industrial Energy Efficiency Benchmarking

The study by UNIDO only provides energy efficiency indicators (EEI) for the petroleum sector based on 2003 data from several sources[17] (UNIDO, 2010):

- Best available technology: 1
- Global average: 1.25
- Selected industrialized countries: 1.3-3.8
- Selected developing countries: 0.7-0.8

A.3.5. Petroleum (GTL sector)

As indicated in the main body of the report, there are no internationally available benchmarks for GTL.

[17] A benchmark energy use for the 1st decile could not be estimated. The lowest estimated EEI, for OECD Europe, is reported. The average is weighted and is estimated based on the EEI and the crude oil capacity of each region.

A.3.6. Petroleum (CTL sector)

As indicated in the main body of the report, there are no internationally available benchmarks for CTL.

A.3.7. Chemicals

A.3.7.1. EU ETS benchmarks

The sector specific report for the chemicals industry (Ecofys, 2009c) describes the underlying methodology and data that was used to set preliminary benchmarks. As for previous sectors, the final reported benchmark values are taken from the Benchmarking Decision.

A.3.7.1.1. Scope

The chemical industry produces many different products. In 2008 the chemical regulation "European Chemical Agency" received pre-registrations for 150,000 different substances from 65,000 companies. The chemical industry, represented by Cefic (European Chemical Industry Council), provided a ranking of the most emission intensive activities for the industry sector specific report (Ecofys, 2009c). This ranking showed both the absolute figures for the CO_2-equivalent (CO_2 and N_2O emissions) of the activities and the share of those emissions in the total CO_2 and N_2O emissions of the chemical industry in the EU.

A.3.7.1.2. Methodology and explanation

A methodology was followed whereby processes being responsible for 80% of the total emissions of the chemical industry were covered by product benchmarks. For the remaining 20% a fall-back approach was proposed. Emissions released by steam production were counted to the direct emissions, which resulted in benchmarking the overall efficiency of the products concerned. Deriving the number of product benchmarks from the 80/20 principle, there were 8 chemicals whose production accounted for 80% of the N_2O and CO_2 emissions of the chemical industry in the EU:

- Nitric acid
- Cracker products
- Ammonia
- Adipic acid
- Hydrogen / Synthesis gas
- Soda ash
- Aromatics
- Carbon black

A detailed description of how the preliminary benchmarks were determined for each specific product can be found in the sector report for the chemical industry (Ecofys, 2009c).

Apart from slight changes in the values from the preliminary to the final benchmark values, other changes include the addition of the following products:

- Phenol/Acetone
- Ethylene oxide (EO)/Ethylene glycols (EG)
- S-PVC
- Styrene
- Vinyl chloride monomer (VCM)
- Steam Cracking (High value chemicals)

The following table describes the final benchmarks developed, detailing the definition and explanation of the products, processes and emissions covered. More detail can be found in the GD9 document (Directorate, European Commission, 2011).

Table 90 EU ETS Benchmarks: Chemical products, processes and emissions covered

Product Benchmark	Products Covered	Processes and emissions covered
Nitric Acid	Nitric acid (HNO_3), to be recorded in tonnes HNO_3 (100%).	All processes directly or indirectly linked to the production of the benchmarked product, as well as the N_2O destruction process, are included except the production of ammonia. The production of ammonia as well as the production of the consumed electricity is excluded from the system boundaries. No additional allocation must be granted for the export or use of heat stemming from the nitric acid production.
Ammonia	Ammonia (NH_3), to be recorded in tonnes produced.	All processes directly or indirectly linked to the production of the ammonia, and the intermediate product hydrogen, are included. For the determination of indirect emissions, the total electricity consumption within the system boundaries shall be considered. The system boundary of an ammonia installation is defined to be all activities within the plant battery limit as well as processes outside the battery limit associated with steam and electricity import or export to the ammonia installation. The production of the intermediate product hydrogen is also covered. Ammonia production from other intermediate products (such as syngas) is not covered by this product benchmark. The export of measurable heat (steam, hot water, etc.) is not covered by this product benchmark.
Adipic Acid	Adipic acid to be recorded in tonnes of dry purified adipic acid stored in silos or packed in (big)bags.	All processes directly or indirectly linked to the production of the benchmarked product as well as the N2O destruction processes are included. Emissions related to the production and the consumption of electricity are excluded from the system boundaries, irrespective of where and how this electricity is produced. Manufacture of KA-oil and nitric acid are also excluded. The export of measurable heat (steam, hot water, etc.) is not covered by this product benchmark.

Product Benchmark	Products Covered	Processes and emissions covered
Hydrogen	Pure hydrogen and mixtures of hydrogen and carbon monoxide having a hydrogen content >=60% mole fraction of total contained hydrogen plus carbon monoxide based on the aggregation of all hydrogen- and carbon-monoxide-containing product streams exported from the sub-installation concerned expressed as 100% hydrogen.	All relevant process elements directly or indirectly linked to the production of hydrogen and the separation of hydrogen and carbon monoxide are included. These elements lie between: a) The point(s) of entry of hydrocarbon feedstock(s) and, if separate, fuel(s). b) The points of exit of all product streams containing hydrogen and/or carbon monoxide. c) The point(s) of entry or exit of import or export heat. For the determination of indirect emissions from electricity consumption, the total electricity consumption within the system boundaries shall be considered. Indirect emissions from electricity consumption are not eligible for free allocation but are used in the calculation of free allocation. The export of measurable heat (steam, hot water, etc.) is not covered by this product benchmark.
Synthesis Gas	Mixtures of hydrogen and carbon monoxide having a hydrogen content <60% mole fraction of total contained hydrogen plus carbon monoxide based on the aggregation of all hydrogen- and carbon-monoxide-containing product streams exported from the subinstallation concerned referred to 47 volume-percent hydrogen.	All relevant process elements directly or indirectly linked to the production of syngas and the separation of hydrogen and carbon monoxide are included. These elements lie between: a) The point(s) of entry of hydrocarbon feedstock(s) and, if separate, fuel(s). b) The points of exit of all product streams containing hydrogen and/or carbon monoxide. c) The point(s) of entry or exit of import or export heat. For the determination of indirect emissions, the total electricity consumption within the system boundaries shall be considered. Indirect emissions from electricity consumption are not eligible for free allocation but are used in the calculation of free allocation. The export of measurable heat (steam, hot water, etc.) is not covered by this product benchmark.
Soda ash	Disodium carbonate as total gross production except dense soda ash obtained as by-product in a caprolactam production network.	All processes directly or indirectly linked to the following process units are included: - brine purification - limestone calcination and milk of lime production - absorption of ammonia - precipitation of $NaHCO_3$ - filtration or separation of $NaHCO_3$ crystals from mother liquor - decomposition of $NaHCO_3$ to Na_2CO_3 - recovery of ammonia - densification or production of dense soda ash Emissions related to the production of the consumed electricity are excluded from the system boundaries. The export of measurable heat (steam, hot water, etc.) is not covered by this product benchmark.
Aromatics	Mix of aromatics expressed as CO_2 weighted tonne (CWT)	All processes directly or indirectly linked to the following aromatics sub-units are included: - pygas hydrotreater - benzene/toluene/xylene (BTX) extraction - TDP - HDA

Product Benchmark	Products Covered	Processes and emissions covered
		- xylene isomerisation - p-xylene units - cumene production - cyclo-hexane production For the determination of indirect emissions, the total electricity consumption within the system boundaries shall be considered. Indirect emissions from electricity consumption are not eligible for free allocation but are used in the calculation of free allocation. The export of measurable heat (steam, hot water, etc.) is not covered by this product benchmark.
Carbon Black	Furnace carbon black. Gas- and lamp black products are not covered by this benchmark.	All processes directly or indirectly linked to the production of furnace carbon black as well as finishing, packaging and flaring are included. For the determination of indirect emissions, the total electricity consumption within the system boundaries shall be considered. For the determination of indirect emissions from electricity consumption, the total electricity consumption within the system boundaries refers to the total electricity consumption which is exchangeable with heat, considering in particular electricity driven devices like large pumps, compressors, etc. which could be replaced by steam driven units. These emissions are not eligible for free allocation but are used in the calculation of free allocation. The export of measurable heat (steam, hot water, etc.) is not covered by this product benchmark.
Phenol/Aceton e	Sum of phenol, acetone and the byproduct alphamethyl styrene as total production.	All processes directly or indirectly linked to the production of phenol and acetone are included, in particular: - Air compression - Hydroperoxidation - Cumene recovery from spent air - Concentration & cleavage - Production fractionation & purification - Tar cracking - Acetophenone recovery & purification - AMS recovery for export - AMS hydrogenation for ISB recycle - Initial waste water purification (1st waste water stripper) - Cooling water generation (e.g., cooling towers) - Cooling water utilisation (circulation pumps) - Flare & incinerators (even if physically located OSB) - Any support fuel consumption Emissions related to the production of the consumed electricity are excluded from the system boundaries. The export of measurable heat (steam, hot water, etc.) is not covered by this product benchmark.
Ethylene oxide (EO)/Ethylene glycols (EG)	The ethylene oxide/ ethylene glycol benchmark covers the products: - Ethylene oxide (EO, high purity);	All processes directly or indirectly linked to the process units EO production, EO purification and glycol section are included. The total electricity consumption (and the related indirect emissions) within the system boundaries is covered by this product benchmark. For the determination of indirect emissions, the total electricity consumption within the system boundaries shall be considered.

Product Benchmark	Products Covered	Processes and emissions covered
	- Monoethylene glycol (MEG, standard grade + fiber grade (high purity)); - Diethylene glycol (DEG); and, - Triethylene glycol (TEG). The total amount of products is expressed in terms of EO-equivalents (EOE), which are defined as the amount of EO (in mass) that is embedded in one mass unit of the specific glycol.	Indirect emissions from electricity consumption are not eligible for free allocation but are used in the calculation of free allocation. The export of measurable heat (steam, hot water, etc.) is not covered by this product benchmark.
S-PVC	Polyvinyl chloride; not mixed with any other substances consisting of PVC particles with a mean size between 50 and 200 µm.	All processes directly or indirectly linked to the production of S-PVC are included except the production of VCM. Emissions related to the production of the consumed electricity are excluded from the system boundaries. The export of measurable heat (steam, hot water, etc.) is not covered by this product benchmark.
Styrene	Styrene monomer (vinyl benzene, CAS number: 100-42-5).	All processes directly or indirectly linked to the production of styrene, as well as the intermediate product ethylbenzene (with the amount used as feed for the styrene production), are included. For the determination of indirect emissions, the total electricity consumption within the system boundaries shall be considered. Installation boundaries include ethylbenzene and styrene production and all related equipment needed to produce these materials, such as raw material purification, product purification, waste water and waste gas treatment facilities, loading facilities and other directly related areas normally included in the plant production area including cooling water facilities, instrument air supply and nitrogen supply. Energy for these services is taken into account, whether supplied directly by the styrene producer or purchased from an on-site supplier. For the determination of indirect emissions, the total electricity consumption within the system boundaries refers to the total electricity consumption, which is exchangeable with heat, considering heat pumps used in the distillation section. These emissions are not eligible for free allocation but are used in the calculation of free allocation. The export of measurable heat (steam, hot water, etc.) is not covered by this product benchmark.
Vinyl chloride monomer (VCM)	Vinyl chloride (chloroethylene).	All processes directly or indirectly linked to the following production steps are included: - direct chlorination - oxychlorination - EDC cracking to VCM Emissions related to the production of the consumed electricity are excluded from the system boundaries.

Product Benchmark	Products Covered	Processes and emissions covered
		The incineration of chlorinated hydrocarbons contained in the vent gases of EDC/VCM production is included in the benchmark. The production of oxygen and compressed air used as raw materials in VCM manufacture are not excluded in the benchmark. The export of measurable heat (steam, hot water, etc.) is not covered by this product benchmark.
Steam Cracking (High value chemicals)	Mix of high value chemicals (HVC) expressed as total mass of acetylene, ethylene, propylene, butadiene, benzene and hydrogen excluding HVC from supplemental feed (hydrogen, ethylene, other HVC) with an ethylene content in the total product mix of at least 30 mass-percent and a content of HVC, fuel gas, butenes and liquid hydrocarbons of together at least 50 mass-percent of the total product mix.	All processes directly or indirectly linked to the production of high value chemicals (HVC) as purified product or intermediate product with concentrated content of the respective HVC in the lowest tradable form (raw C4, unhydrogenated pygas) are included except C4 extraction (butadiene plant), C4-hydrogenation, hydrotreating of pyrolysis gasoline & aromatics extraction and logistics/storage for daily operation. For the determination of indirect emissions, the total electricity consumption within the system boundaries shall be considered. For the determination of indirect emissions, the total electricity consumption within the system boundaries shall be considered. These emissions are not eligible for free allocation but are used in the calculation of free allocation. The export of measurable heat (steam, hot water, etc.) is not covered by this product benchmark.

A.3.7.1.3. Benchmark value

The final benchmark values for the EU ETS chemical sector are provided in Table 91.

Table 91: EU ETS Benchmarks: Chemical sector final benchmark values

Product Benchmark	Value	Units
Nitric Acid	0.302	tonne CO_2/tonne product
Ammonia	1.619	tonne CO_2/tonne product
Adipic Acid	2.79	tonne CO_2/tonne product
Hydrogen	8.85	tonne CO_2/tonne product
Synthesis Gas	0.242	tonne CO_2/tonne product
Soda ash	0.843	tonne CO_2/tonne product
Aromatics	0.0295	tonne CO_2/CWT (CO_2 weighted tonne[18])
Carbon Black	1.954	tonne CO_2/tonne product
Phenol/Acetone	0.266	tonne CO_2/tonne product

[18] This method is described in sections 5 and 36 of the GD9 report (Directorate, European Commission, 2011).

Product Benchmark	Value	Units
Ethylene oxide (EO)/Ethylene glycols (EG)	0.512	tonne CO_2/tonne product
S-PVC	0.085	tonne CO_2/tonne product
Styrene	0.527	tonne CO_2/tonne product
Vinyl chloride monomer (VCM)	0.204	tonne CO_2/tonne product
Steam Cracking (High value chemicals)	0.702	tonne CO_2/tonne product

A.3.7.2. California Cap-and-Trade benchmarks

The purpose and scope of the California Cap-and-Trade Benchmarks is described in Section 3.2. The underlying methodology and data used in setting the California Cap-and-Trade benchmarks are described in the Air Resource Board's (ARB) "Appendix J: Allowance allocation" (Air Resource Board, 2010), with final reported benchmark values presented in the ARB's "Article 5" (Air Resource Board, 2011).

A.3.7.2.1. Scope

Soda ash is the only chemical product for which a proposed output metric was provided in Appendix J: Allowance allocation. The U.S. soda ash industry consisted of five companies in 2008, with a nameplate capacity of about 15 million tonnes. California has one operator that produced about 10% of the total U.S. production from sodium-carbonate rich brines (Air Resource Board, 2010).

A.3.7.2.2. Methodology and explanation

Short tons of soda ash produced was proposed as the output metric for soda ash manufacturing in Appendix J: Allowance allocation. The final values published in Article 5 contained 4 additional benchmarks for chemical sector activities related to hydrogen production and nitrogenous fertiliser manufacturing. Only direct emissions for the specific production facilities are covered. There is no explanation or methodology publicly available to explain the additional chemical sector benchmarks.

A.3.7.2.3. Benchmark value

Final benchmark values provided in the table below were obtained from the latest publicly available "Article 5" (Air Resource Board, 2011).

Table 92: California Cap-And-Trade Benchmarks: Chemical sector

Product Benchmark	Value	Units
Nitric Acid	0.349	tonne CO_2/short ton product
Calcium Ammonium Nitrate Solution	0.0902	tonne CO_2/short ton product

Product Benchmark	Value	Units
Mining and Manufacturing of Soda Ash and Related Products	0.948	tonne CO_2/short ton of Soda Ash Equivalent (Soda Ash, Biocarb, Borax, V-Bor, DECA, PYROBOR, Boric Acid, and Sulfate
Gaseous Hydrogen Production	8.85	tonne CO_2/short ton product
Liquid Hydrogen Production	8.85	tonne CO_2/short ton product

A.3.7.3. Australian Carbon Pricing Mechanism Benchmarks

All data relating the underlying methodology and final benchmark values are obtained from the paper titled "Establishing the eligibility of activities under the Jobs and Competitiveness Program" (Australian Government, 2012a).

A.3.7.3.1 Scope

The geographic scope for the benchmark values are for all facilities operational in Australia. Historical industry average data for the financial years of 2006-07 and 2007-08 were used for setting the benchmarks in terms of emissions per unit production. For the chemical sector, the following activities were identified for the development of benchmarks (entities and facilities that undertook these activities during the assessment period are indicated in brackets):

- Production of methanol (1 entity with 1 facility);
- Production of carbon black (1 entity with 1 facility);
- Production of ethane (ethylene) (1 entity with 2 facilities);
- Production of sodium carbonate (soda ash) and sodium bicarbonate (1 entity with 1 facility);
- Production of ammonium nitrate (3 entities across 4 facilities);
- Production of ammonia (6 entities across 7 facilities);
- Production of white titanium dioxide pigment (2 entities across 2 facilities); and
- Production of polyethylene (1 entity with 2 facilities).

A.3.7.3.2 Methodology and explanation

The output metrics for the benchmark values were established based on the Australian chemical sector information. Benchmarks were set on both the direct emissions and electricity consumption for the defined products.

Definitions for the different activities are contained in (Australian Government, 2012a).

Table 93: Australian chemical production activity definitions

Activity	Definition
Production of methanol	Chemical transformation of hydrogen, carbon and oxygen feedstocks into methanol. Methanol is most

Activity	Definition
	commonly produced from natural gas or synthesis gas.
Production of carbon black	Chemical transformation of a hydrocarbon through partial combustion and subsequent processing to saleable, dry, pelletised carbon black.
Production of ethane (ethylene)	Steam or catalytic cracking of a hydrocarbon feedstock such as ethane, propane, butane and/or naphtha, to produce ethene (ethylene) and other valuable hydrocarbon products. The ethene (ethylene) produced by this activity must have a concentration of ethene (C_2H_4, ethylene) that is equal to or greater than 99 per cent with respect to mass.
Production of sodium carbonate (soda ash) and sodium bicarbonate	Chemical and physical transformation of calcium carbonate (CaCO3), sodium chloride (NaCl, salt), ammonia (NH3) and carbon bearing materials (e.g. coke) into: a) light sodium carbonate (Na_2CO_3, light soda ash) which has a concentration of light sodium carbonate greater than or equal to 98.0 per cent with respect to mass; and/or b) dense sodium carbonate (Na_2CO_3, dense soda ash) which has a concentration of dense sodium carbonate greater than or equal to 97.5 per cent with respect to mass; and/or c) refined sodium bicarbonate ($NaHCO_3$) which has a concentration of refined sodium bicarbonate greater than or equal to 95.0 per cent with respect to mass.
Production of ammonium nitrate	Chemical transformation of anhydrous ammonia to ammonium nitrate solution where the concentration of ammonium nitrate is greater than 60 per cent with respect to mass. In this process an intermediate product, nitric acid, is produced.
Production of ammonia	Chemical transformation of a source of hydrogen (generally a hydrocarbon), and subsequent reaction of the hydrogen with nitrogen (generally air) to liquefied anhydrous ammonia.
Production of white titanium dioxide pigment	Encompasses several key processes that are generally undertaken to transform rutile, synthetic rutile, ilmenite, leucoxene, or titanium slag into white titanium dioxide pigment. This includes the production of oxygen and nitrogen which is consumed in the activity. In order to meet the activity definition, the output produced from the activity must conform to the standard ASTM classification D476–00 and contain an iron content of less than or equal to 0.5 per cent.
Production of polyethylene	Polymerisation of ethene and other supplemental hydrocarbon feedstocks to produce polyethylene with a standard density of equal to or greater than 0.910 g/cm3. The polyethylene produced may include low

Activity	Definition
	density, linear low density, medium density and high density polyethylene.

A.3.7.3.3. Benchmark Values

The final benchmark values for the Australian chemical sector are provided in Table 94.

Table 94: Australian Benchmarks: Chemicals

Activity	Product Benchmark	Direct Emissions [tonne CO_2e/tonne]	Electricity usage [MWh/tonne]	Natural Gas usage [TJ/tonne]
Production of methanol	100% equivalent methanol	0.389	0.490	0.0268
Production of carbon black	Dry pelletised carbon black of saleable quality	2.66	0.514	n/a
Production of ethane (ethylene)	100% equivalent ethene (ethylene) of saleable quality	1.83	0.275	0.0617
Production of sodium carbonate (soda ash) and sodium bicarbonate	Combined light sodium carbonate, dense sodium carbonate and refined sodium bicarbonate of saleable quality	0.828	0.130	n/a
Production of ammonium nitrate	100% equivalent ammonium nitrate of saleable quality	2.10	0.114	n/a
Production of ammonia	100% equivalent anhydrous ammonia of saleable quality	1.79	0.224	n/a
Production of white titanium dioxide pigment	White titanium dioxide pigment of saleable quality	1.62	0.986	n/a
Production of polyethylene	Pelletised polyethylene of saleable quality	0.129	0.646	n/a

A.3.7.4. World best practice energy intensity benchmarks

Best practice energy intensity values are given for ammonia and for ethylene (together with other high value chemicals) manufacturing.

In the manufacturing of ammonia, synthesis gas is most often utilised as the source of hydrogen. The feedstocks most widely used in the production of synthesis gas are natural gas or coal, with natural gas being the preferred feedstock due to the high hydrogen content. Today, over 80% of the world ammonia capacity is produced from natural gas. Within each of these feedstocks, the most common production processes are steam reforming of natural gas and gasification of coal.

Ethylene is produced from various hydrocarbon feedstocks with the steam cracking process. Along with ethylene, other high value products such as propylene, butadiene and aromatics are co-produced in the process. The dominant feedstock for worldwide ethylene production is naphtha (55%), followed by ethane (30%).

The best practice primary energy use for the production of ammonia from natural gas and coal feedstocks, and for ethylene from naphtha and ethane, are provided below.

Table 95: World Best Practice Energy Intensity Values: Chemical sector

Classification	Processes covered	Value	Units
Ammonia	Haber-Bosch process, natural gas feedstock in steam reforming for synthesis gas production	28	GJ/tonne NH_3
Ammonia	Haber-Bosch process, coal feedstock for synthesis gas production	34.8	GJ/ tonne NH_3
Ethylene (and other high value chemicals)	Ethane cracking	14.5	GJ/tonne high value chemical
Ethylene (and other high value chemicals)	Naphtha cracking	13	GJ/tonne high value chemical

A.3.7.5. UNIDO Global Industrial Energy Efficiency Benchmarking

The study by UNIDO provides energy intensity values for high value chemicals (from steam cracking), ammonia, and methanol based on various data sources (UNIDO, 2010). The final energy intensity values are provided in the table below.

Table 96: Global Industrial Energy Efficiency Benchmarks: Chemical sector

Average energy range/benchmark	High Value Chemicals (GJ/tonne)	Ammonia (GJ/tonne)	Methanol (GJ/tonne)
Selected industrialized countries	12.6-18.3	33.2-36.2	33.7-35.8
Selected developing countries	17.1-18.3	35.9-46.5	33.6-40.2
Global average	16.9	41	35.1
Best available technology	10.6	23.5	28.8
International benchmark	12.5	31.5	30

A.3.8. Applicability of international benchmarks in South Africa and proposed benchmarking approach

There are a large number of chemical products for which benchmarks are potentially required depending on the scale of production and the emissions intensity of production in the South African context. In order to identify these chemicals, the EU relied on industry-wide data from which the products responsible for 80% of the sectors emissions could be identified. Such an industry-wide data set is not available for the South African chemicals sector. Section 11.1 has attempted to highlight which chemicals may require benchmarks, but further industry specific data is required to confirm a final set of chemicals. These include:

- Ammonia
- Aromatics
- Carbon black
- Ethylene oxide
- Ethylene glycol
- Hydrogen
- Methanol
- Nitric acid
- Phenol/acetate
- VCM
- S-PVC
- Steam cracking (high value chemicals)
- Titanium dioxide
- Styrene butadiene rubber
- Polymers
- Others

The EU ETS and Australian Carbon Pricing Mechanism Benchmark frameworks cover some of these chemicals and aspects of the methodologies that may be applicable to the South African context.

Table 97: Applicability of EU ETS and Australian Carbon Pricing Mechanism Benchmark frameworks to the South African context.

Chemical	EU ETS benchmark	Australian Carbon Pricing Mechanism Benchmark
Ammonia	The EU ETS benchmark methodology includes all processes directly or indirectly linked to the production of the ammonia, and the intermediate product hydrogen. Import of heat and import and export of electricity is included, but the export of measurable heat is excluded. Importantly, ammonia production from syngas is not covered by this product benchmark, which makes the methodology less applicable to the South African context.	The Australian benchmark for ammonia includes electricity consumption. Applicability to South Africa depends on differences (or similarities) in process configuration and fuel types used.
Aromatics	The EU ETS benchmark for aromatics considers the total electricity consumption within the system boundaries, but excludes export of measurable heat.	No Australian benchmark available
Carbon black	The EU ETS benchmark for carbon black includes a consideration of electricity (as	The Australian benchmark for carbon black includes electricity.

Chemical	EU ETS benchmark	Australian Carbon Pricing Mechanism Benchmark
	some of energy required by the process can be met by either electricity or steam). Heat export is excluded.	
Ethylene oxide and Ethylene glycol	The EU ETS benchmarks for ethylene oxide and ethylene glycol include a consideration of electricity but exclude exported heat.	The Australian Carbon Pricing Mechanism benchmark includes a product benchmark (including electricity) for ethylene.
Hydrogen	The EU ETS benchmark methodology for hydrogen includes a consideration of electricity, but excludes export heat.	No Australian benchmark available
Methanol	No EU ETS benchmark available for methanol	The Australian Carbon Pricing Mechanism benchmark includes a product benchmark (including electricity) for methanol production from natural gas or synthesis gas.
Nitric acid	No EU ETS or Australian benchmark for nitric acid – needs to be defined if emissions from its production are significant	
Phenol/acetate	The EU ETS benchmark methodology for phenol/acetate includes all associated production processes, but excludes electricity. The export of measurable heat is also not covered.	No Australian benchmark available
VCM	The EU ETS benchmark methodology for VCM excludes electricity and the export of measurable heat.	No Australian benchmark available
S-PVC	The EU ETS benchmark includes all processes for S-PVC production except the production of VCM (covered under a separate benchmark. Electricity and exported measurable heat are excluded.	No Australian benchmark available.
Steam cracking (high value chemicals)	The EU ETS benchmark for high value chemicals includes a consideration of electricity consumption within the system boundaries, but excludes the export of measurable heat.	No Australian benchmark available.
Titanium dioxide	No EU ETS benchmark available.	A benchmark for titanium dioxide production is available based on Australian data. Benchmark includes electricity. Applicability to South Africa depends on differences (or similarities) in process configuration and fuel types used.
Styrene butadiene rubber	No EU ETS or Australian benchmark – needs to be defined if emissions from its production are significant	
Polymers	No EU ETS benchmark is available for polymers.	A single benchmark for polymers (including low density, linear low density, medium density and high density polyethylene) is set under the Australian

Chemical	EU ETS benchmark	Australian Carbon Pricing Mechanism Benchmark
		benchmark framework. Includes separate benchmark for electricity. May be applicable to South African conditions.

A.3.9. Paper and pulp

A.3.9.1. EU ETS benchmarks

The sector specific report for the paper and pulp industry (Ecofys, 2009e) describe the underlying methodology and data that was used to set preliminary benchmarks. The final reported benchmark values are from the Benchmarking Decision.

A.3.9.1.1. Scope

At the time when the sector specific report for the paper and pulp industry was published, the Confederation of European Paper Industries (CEPI) were still in the process of a European industry specific data collection exercise that were to inform the benchmarking. Pending the outcome of data collection, preliminary benchmark values were based on the lowest best available technology heat consumption found in reference documents on best available technologies.

A.3.9.1.2. Methodology and explanation

The product groups as defined by CEPI were adopted as a starting point to distinguish products for the preliminary benchmarks. The main product groupings were virgin pulp, processed recovered pulp, and paper. For some of the paper and most of the pulp benchmarks the final product classification and values in the Benchmarking Decision are different to that of the sector specific report, due to the lack of data at the time of publishing the sector specific report.

One of the issues in the sector specific report that could not be addressed due to a lack of sufficient bottom-up data was dealing with integrated pulp and paper mills. The methodology followed in the sector specific report is therefore not relevant to the Benchmarking Decision's final benchmarks. It is, however not fully clear how the integrated mills are treated in the final benchmark decision. This decision contains a provision on the further processed pulp being excluded from the calculations, but it is not entirely clear how this is done exactly in practice.

The following table describes the final benchmarks developed, detailing the definition and explanation of the products, processes and emissions covered. More detail can be found in the GD9 document.

Table 98: EU ETS Benchmarks: Paper and Pulp products, processes and emissions covered

Product Benchmark	Products Covered	Processes and emissions covered
Short fibre craft pulp	Short fibre kraft pulp is a wood pulp produced by the sulphate chemical process using cooking liquor, characterised by fibre lengths of 1 – 1,5 mm, which is mainly used for products which require specific smoothness and bulk, as tissue and printing paper.	All processes which are part of the pulp production process are included, in particular: - the pulp mill - recovery boiler - pulp drying section - lime kiln - connected energy conversion units (boiler/CHP). Other activities on site that are not part of this process are not included, such as: - sawmilling activities - woodworking activities - production of chemicals for sale - waste treatment (treating waste onsite instead of offsite (drying, pelletizing, incinerating, landfilling)) - PCC (precipitated calcium carbonate) production - treatment of odorous gases - district heating. Emissions related to the production of the consumed electricity are excluded from the system boundaries. The export of measurable heat (steam, hot water, etc.) is not covered by this product benchmark.
Long fibre craft pulp	Long fibre kraft pulp is a wood pulp produced by the sulphate chemical process using cooking liquor, characterised by fibre lengths of 3 – 3,5 mm, which is mainly used for products for which strength is important, as packaging paper expressed as net saleable production in Adt (Air Dried Tonnes)	All processes which are part of the pulp production process are included, in particular: - the pulp mill - recovery boiler - pulp drying section - lime kiln - connected energy conversion units (boiler/CHP). Other activities on site that are not part of this process are not included, such as: - sawmilling activities - woodworking activities - production of chemicals for sale - waste treatment (treating waste onsite instead of offsite (drying, pelletizing, incinerating, landfilling)) - PCC (precipitated calcium carbonate) production - treatment of odorous gases - district heating. Emissions related to the production of the consumed electricity are excluded from the system boundaries. The export of measurable heat (steam, hot water, etc.) is not covered by this product benchmark.
Sulphite pulp, (chemi-) thermo-mechanical and mechanical pulp	Sulphite pulp produced by a specific pulp making process, e.g. pulp produced by cooking wood chips in a pressure vessel in the presence of bisulphite liquor expressed as net saleable production in Adt. Sulphite	All processes which are part of the pulp production process are included, in particular: - the pulp mill - recovery boiler - pulp drying section - lime kiln - connected energy conversion units (boiler/CHP).

Product Benchmark	Products Covered	Processes and emissions covered
	pulp can be either bleached or unbleached. Mechanical pulp grades: TMP (thermomechanical pulp) and groundwood as net saleable production in Adt. Mechanical pulp can be either bleached or unbleached. Not covered by this group are the smaller subgroups of semichemical pulp CTMP – chemithermomechanical pulp and dissolving pulp.”	Other activities on site that are not part of this process are not included, such as: - sawmilling activities - woodworking activities - production of chemicals for sale - waste treatment (treating waste onsite instead of offsite (drying, pelletizing, incinerating, landfilling)) - PCC (precipitated calcium carbonate) production - treatment of odorous gases - district heating. Emissions related to the production of the consumed electricity are excluded from the system boundaries. The export of measurable heat (steam, hot water, etc.) is not covered by this product benchmark.
Recovered Paper Pulp	Pulps of fibres derived from recovered (waste and scrap) paper or paperboard or of other fibrous cellulosic material expressed as net saleable production in Adt.	All processes that are part of the production of pulp from recovered paper and connected energy conversion units (boiler/CHP)) are included. Other activities on site that are not part of this process are not included, such as: - sawmilling activities - woodworking activities - production of chemicals for sale - waste treatment (treating waste onsite instead of offsite (drying, pelletizing, incinerating, landfilling)) - PCC (precipitated calcium carbonate) production - treatment of odorous gases - district heating Emissions related to the production of the consumed electricity are excluded from the system boundaries. The export of measurable heat (steam, hot water, etc.) is not covered by this product benchmark.
Uncoated fine paper	Uncoated fine paper, covering both uncoated mechanical and uncoated woodfree expressed as net saleable production in Adt: 1. Uncoated woodfree papers suitable for printing or other graphic purposes made from a variety of mainly virgin fibre furnishes, with variable levels of mineral filler and a range of finishing processes. This grade includes most office papers, such as business forms, copier, computer, stationery and book papers. 2. Uncoated mechanical papers cover the specific paper grades made from	All processes which are part of the paper production process are included, in particular: - paper or board machine - connected energy conversion units (boiler/CHP) - direct process fuel use Other activities on site that are not part of this process and are not included are: - sawmilling activities - woodworking activities - production of chemicals for sale - waste treatment (treating waste onsite instead of offsite (drying, pelletising, incinerating, landfilling) - PCC (precipitated calcium carbonate) production - treatment of odorous gases - district heating Emissions related to the production of the consumed electricity are excluded from the system boundaries. The export of measurable heat (steam, hot water, etc.) is not covered by this product benchmark.

Product Benchmark	Products Covered	Processes and emissions covered
	mechanical pulp, used for packaging or graphic purposes/magazines.	
Coated fine paper	Coated fine paper covering both: - coated mechanical, and - coated woodfree papers expressed as net saleable production in Adt: 1. Coated woodfree papers made of fibres produced mainly by a chemical pulping process which are coated in process for different applications and are also known as coated freesheet. This group focuses mainly on publication papers. 2. Coated mechanical papers made from mechanical pulp, used for graphic purposes/magazines. The group is also known as coated groundwood.	All processes which are part of the paper production process are included, in particular: - paper or board machine - connected energy conversion units (boiler/CHP) - direct process fuel use Other activities on site that are not part of this process and are not included are: - sawmilling activities - woodworking activities - production of chemicals for sale - waste treatment (treating waste onsite instead of offsite (drying, pelletising, incinerating, landfilling) - PCC (precipitated calcium carbonate) production - treatment of odorous gases - district heating Emissions related to the production of the consumed electricity are excluded from the system boundaries. The export of measurable heat (steam, hot water, etc.) is not covered by this product benchmark.
Newsprint	Specific paper grade (in rolls or sheets) expressed as net saleable production in Adt (air dried tonnes) used for printing newspapers produced from groundwood and/or mechanical pulp or recycled fibres or any percentage of combinations of these two. Weights usually range from 40 to 52 g/m² but can be as high as 65 g/m². Newsprint is machine-finished or slightly calendered, white or slightly coloured and is used in reels for letterpress, offset or flexo-printing.	All processes which are part of the paper production process are included, in particular: - paper or board machine - connected energy conversion units (boiler/CHP) - direct process fuel use Other activities on site that are not part of this process and are not included are: - sawmilling activities - woodworking activities - production of chemicals for sale - waste treatment (treating waste onsite instead of offsite (drying, pelletising, incinerating, landfilling) - PCC (precipitated calcium carbonate) production - treatment of odorous gases - district heating Emissions related to the production of the consumed electricity are excluded from the system boundaries. The export of measurable heat (steam, hot water, etc.) is not covered by this product benchmark.
Tissue	Tissue papers expressed as net saleable production of parent reel cover a wide range of tissue and other hygienic papers for use in households or commercial	All processes which are part of the paper production process are included, in particular: - paper or board machine - connected energy conversion units (boiler/CHP) - direct process fuel use Other activities on site that are not part of this process and are not included are:

Product Benchmark	Products Covered	Processes and emissions covered
	and industrial premises, such as: - toilet paper and facial tissues; - kitchen towels; - hand towels and industrial wipes; - the manufacture of baby nappies; - sanitary towels, etc. TAD - Through Air Dried Tissue is not part of this group.	- sawmilling activities - woodworking activities - production of chemicals for sale - waste treatment (treating waste onsite instead of offsite (drying, pelletising, incinerating, landfilling) - PCC (precipitated calcium carbonate) production - treatment of odorous gases - district heating Emissions related to the production of the consumed electricity are excluded from the system boundaries. The export of measurable heat (steam, hot water, etc.) is not covered by this product benchmark.
Uncoated carton board	This benchmark covers a wide range of uncoated products (expressed as net saleable production in Adt), which may be single or multiply. - Uncoated carton board is mainly used for packaging applications, which the main needed characteristic is strength and stiffness, and for which the commercial aspects as information carrier are of a second order of importance. - Carton board is made from virgin and/or recovered fibres, has good folding properties, stiffness and scoring ability. - It is mainly used in cartons for consumer products such as frozen food, cosmetics and for liquid containers; also known as solid board, folding box board, boxboard or carrier board or core board.	All processes which are part of the paper production process are included, in particular: - paper or board machine - connected energy conversion units (boiler/CHP) - direct process fuel use Other activities on site that are not part of this process and are not included are: - sawmilling activities - woodworking activities - production of chemicals for sale - waste treatment (treating waste onsite instead of offsite (drying, pelletising, incinerating, landfilling) - PCC (precipitated calcium carbonate) production - treatment of odorous gases - district heating Emissions related to the production of the consumed electricity are excluded from the system boundaries. The export of measurable heat (steam, hot water, etc.) is not covered by this product benchmark.
Coated Carton board	This benchmark covers a wide range of coated products (expressed as net saleable production in Adt), which may be single or multiply. Coated carton board is mainly used for commercial applications that need to bring commercial	All processes which are part of the paper production process are included, in particular: - paper or board machine - connected energy conversion units (boiler/CHP) - direct process fuel use Other activities on site that are not part of this process and are not included are: - sawmilling activities - woodworking activities

Product Benchmark	Products Covered	Processes and emissions covered
	information printed on the packaging to the shelf in the store in applications such as food, pharma, cosmetics, and other. Carton board is made from virgin and/or recovered fibres, and has good folding properties, stiffness and scoring ability. It is mainly used in cartons for consumer products such as frozen food, cosmetics and for liquid containers; also known as solid board, folding box board, boxboard or carrier board or core board.	- production of chemicals for sale - waste treatment (treating waste onsite instead of offsite (drying, pelletising, incinerating, landfilling) - PCC (precipitated calcium carbonate) production - treatment of odorous gases - district heating Emissions related to the production of the consumed electricity are excluded from the system boundaries. The export of measurable heat (steam, hot water, etc.) is not covered by this product benchmark.

A.3.9.1.3.Benchmark value

The final benchmark values for the EU ETS paper and pulp sector are provided inTable 99.

Table 99: EU ETS Benchmarks: Paper and Pulp sector final benchmark values

Product Benchmark	Value	Units
Short fibre craft pulp	0.12	tonne CO_2/tonne product
Long fibre craft pulp	0.06	tonne CO_2/tonne product
Sulphite pulp, (chemi-) thermo- mechanical and mechanical pulp	0.02	tonne CO_2/tonne product
Recovered Paper Pulp	0.039	tonne CO_2/tonne product
Uncoated fine paper	0.318	tonne CO_2/tonne product
Coated fine paper	0.318	tonne CO_2/tonne product
Newsprint	0.298	tonne CO_2/tonne product
Tissue	0.334	tonne CO_2/tonne product
Uncoated carton board	0.237	tonne CO_2/tonne product
Coated Carton board	0.273	tonne CO_2/tonne product

A.3.9.2. California Cap-and-Trade benchmarks

The purpose and scope of the California Cap-and-Trade Benchmarks is described in Section 3.2. The underlying methodology and data used in setting the California Cap-and-Trade benchmarks are described in the Air Resource Board's (ARB) "Appendix J: Allowance allocation" (Air Resource Board, 2010), with final reported benchmark values presented in the ARB's "Article 5" (Air Resource Board, 2011).

A.3.9.2.1. Scope

No pulp making is currently conducted in California. Five paper and paperboard mills are engaged in recovered paper processing and/or the paper production process. These facilities produced 1.3% of total GHG emissions from covered industrial facilities in 2008 (Air Resource Board, 2010).

A.3.9.2.2. Methodology and explanation

The following output metrics were proposed for the sector in Appendix J: Allowance allocation:

- Tonne of processed recovered paper
- Tonne of uncoated fine paper
- Tonne of coated fine paper
- Tonne of tissue paper
- Tonne of containerboard
- Tonne of carton board

Paper products were divided into these categories based on the difference in the processes that result in different level of energy requirements. The GHG emission levels per unit product will also be different if the final product was processed from purchased virgin pulp or from secondary fibre from recycled paper. No virgin pulp producer operates in California, but some facilities process recycled paper to make secondary fibre.

The final values published in Article 5 contained only 4 benchmarks (as presented in the table below), however, there is no explanation or methodology publicly available to explain the final chosen benchmarks.

Only direct emissions for the specific production facilities are covered.

A.3.9.2.3. Benchmark value

Final benchmark values provided in the table below were obtained from the latest publicly available "Article 5" (Air Resource Board, 2011).

Table 100: California Cap-And-Trade Benchmarks: Chemical sector

Product Benchmark	Value	Units
Tissue Manufacturing	1.14	tonne CO_2/Air dried short tonne product
Recycled Boxboard Manufacturing	0.499	tonne CO_2/Air dried short tonne product

Recycled Linerboard (Testliner) Manufacturing	0.562	tonne CO_2/Air dried short tonne product
Recycled Medium (Fluting) Manufacturing	0.392	tonne CO_2/Air dried short tonne product

A.3.9.3. Australian Carbon Pricing Mechanism Benchmarks

All data relating the underlying methodology and final benchmark values were taken from the paper titled "Establishing the eligibility of activities under the Jobs and Competitiveness Program" (Australian Government, 2012a).

A.3.9.3.1. Scope

The geographic scope for the benchmark values are for all paper and pulp facilities operational in Australia. Historical industry average data for the financial years of 2006-07 and 2007-08 were used for setting the benchmarks in terms of emissions per unit production. For the paper and pulp sector, the following activities were identified for the development of benchmarks (entities and facilities that undertook these activities during the assessment period are indicated in brackets):

- Newsprint manufacturing (1 entity with 1 facility);
- Packaging and industrial paper manufacturing (3 entities in 9 facilities);
- Cartonboard manufacturing (1 entity with 1 facility);
- Printing and writing paper manufacturing (2 entities in 3 facilities);
- Dry pulp manufacturing (1 entity with 1 facility); and
- Tissue paper manufacturing (4 entities in 4 facilities).

A.3.9.3.2. Methodology and explanation

The output metrics for the benchmark values were established based on detailed Australian paper and pulp sector information. Benchmarks were set on both direct emissions and electricity consumption for the defined products.

It was recognised that the activity of newsprint manufacturing was almost always undertaken in an integrated pulp and paper mill, and therefore this was defined as a stand-alone activity. For all other paper and pulp activities a common sub-activity benchmark for wet pulp manufacturing was defined in addition to the product production benchmark.

Definitions for the different activities are contained in (Australian Government, 2012a).

Table 101: Australian paper and pulp production activity definitions

Activity	Definition
Newsprint manufacturing	Physical transformation of wood products such as woodchips, sawdust and recovered paper into pulp, and the subsequent production from the pulp of rolls of newsprint paper that is used for newspaper products. In order to meet the newsprint activity, the newsprint paper produced from the activity must have a grammage range of 30 g/m^2 to 80 g/m^2, and meet other specifications as detailed in the regulations.
Packaging and industrial paper manufacturing	Physical transformation of woodchips, sawdust, wood pulp and/or recovered paper into rolls of packaging and industrial paper. In order to meet the packaging and industrial paper activity, the packaging and industrial paper produced from the activity must be produced from wholly or partially unbleached input fibre, and meet other specifications as detailed in the regulations.
Cartonboard manufacturing	Physical transformation of woodchips, sawdust, wood pulp and/or recovered paper into rolls of cartonboard. In order to meet the cartonboard activity, the cartonboard produced from the activity must have a grammage range of $150g/m^2$ – $500g/m^2$, and meet other specifications as detailed in the regulations.
Printing and writing paper manufacturing	Physical transformation of woodchips, sawdust, wood pulp and/or recovered paper into rolls of uncoated and coated printing and writing paper. In order to meet the printing and writing paper activity, the printing and writing paper produced from the activity must be produced from 100 per cent bleached or brightened input fibre, and meet other specifications as detailed in the regulations.
Dry pulp manufacturing	Physical transformation of woodchips, sawdust, wood pulp and/or recovered paper into rolls of dry pulp. In order to meet the dry pulp activity, the dry pulp produced from the activity must have moisture content in the range of 4 to 14 per cent by weight, and meet other specifications as detailed in the regulations.
Tissue paper manufacturing	Transformation of woodchips, sawdust, wood pulp and/or recovered paper into rolls of uncoated tissue paper. In order to meet the tissue paper activity, the tissue paper produced from the activity must have a grammage range of $13g/m^2$ $75g/m^2$, and meet other specifications as detailed in the regulations.

A.3.9.3.3 Benchmark Value

The final benchmark values for the Australian paper and pulp sector are provided in Table 102.

Table 102: Australian Benchmarks: Paper and Pulp

Activity	Product Benchmark	Direct Emissions [tonne CO_2e/tonne]	Electricity usage [MWh/tonne]
Newsprint manufacturing	Air dried uncoated newsprint of saleable quality	0.496	0.697
	Bone dried equivalent pulp from either or both of woodchips and sawdust	0.0595	2.48
	Bone dried equivalent pulp from recovered paper	0.0404	0.431
Packaging and industrial paper manufacturing	Packaging and industrial paper of saleable quality	0.338	0.554
	Air dried equivalent pulp from either or both of woodchips and sawdust	0.130	0.448
Cartonboard manufacturing	Cartonboard of saleable quality	0.866	0.774
	Air dried equivalent pulp from either or both of woodchips and sawdust	0.130	0.448
Printing and writing paper manufacturing	Printing and writing paper of saleable quality	0.617	0.88
	Air dried equivalent pulp from either or both of woodchips and sawdust	0.130	0.448
Dry pulp manufacturing	Dry pulp of saleable quality	0.873	0.404
	Air dried equivalent pulp	0.130	0.448
Tissue paper manufacturing	Uncoated tissue paper of saleable quality	0.646	1.67
	Air dried equivalent pulp from either or both of woodchips and sawdust	0.130	0.448

A.3.9.4. World best practice energy intensity benchmarks.

The best practice energy intensities for the main process steps in the paper and pulp industry, as well as the factors affecting energy use and intensity, are provided in the report by Worrell (Worrell, 2008). It has to be noted that due to the large variation of pulp characteristics and paper grades, that the best practice energy intensity values will be affected and that these values have to be interpreted with care.

Values for the pulping and papermaking processes are provided separately, as well as for the integrated process. Integration of the pulp and paper mill will result in energy savings due to the reduced need to dry pulp and opportunities to provide a better heat integration. Only the lime kiln in the Kraft recovery processes uses fuel. All other processes only use steam and electricity. Best practice assumes that the steam and electricity are generated in a cogeneration (combined heat and power) installation.

The best practice primary energy use for the paper and pulp production processes are provided below.

Table 103: World Best Practice Energy Intensity Values: Paper and Pulp sector

Classification	Processes covered	Value	Units
Integrated Paper and Pulp	Bleached Uncoated Fine	27.1	GJ/tonne
Integrated Paper and Pulp	Krafliner (unbleached)/Bag Paper	24.9	GJ/tonne
Integrated Paper and Pulp	Bleached Coated Fine	24.9	GJ/tonne
Integrated Paper and Pulp	Bleached Uncoated Fine	33.4	GJ/tonne
Integrated Paper and Pulp	Newsprint	31.1	GJ/tonne
Integrated Paper and Pulp	Magazine Paper	22.7	GJ/tonne
Integrated Paper and Pulp	Board	22.6	GJ/tonne
Integrated Paper and Pulp	Recovered Paper Board	28.6	GJ/tonne
Integrated Paper and Pulp	Recovered Paper Newsprint	17.8	GJ/tonne
Integrated Paper and Pulp	Recovered Paper Tissue	14.9	GJ/tonne
Pulp	Non-wood Market Pulp	10.7	GJ/tonne
Pulp	Wood Kraft Pulp	11.0	GJ/tonne
Pulp	Wood Sulfite Pulp	23.6	GJ/tonne
Pulp	Wood Thermo-mechanical Pulp	22.6	GJ/tonne
Pulp	Recovered Paper Pulp	3.9	GJ/tonne
Paper	Uncoated Fine Paper	13.7	GJ/tonne
Paper	Coated Fine Paper	16.3	GJ/tonne
Paper	Newsprint	11.3	GJ/tonne
Paper	Board	15.4	GJ/tonne
Paper	Kraftliner	11.7	GJ/tonne
Paper	Tissue	17.8	GJ/tonne

A.3.9.5. Global Industrial Energy Efficiency Benchmarking

The study by UNIDO only provides energy efficiency indicators (EEI) for the paper and pulp sector, based on production data from the United Nations Food and Agriculture Statistics and specific energy consumption data from the International Energy Agency (UNIDO, 2010):

- Best available technology: 1
- Global average: 1.31
- Selected industrialized countries: 0.43-2.29
- Selected developing countries: 0.93-1.73

A.3.10. Sugar

As indicated in the main body of the report, the only publicly available energy or emissions intensity data for the sugar industry is from the UNIDO study. The data utilised is country specific data from Brazil, Thailand, and selected EU countries. The final energy intensity value given for industrialised countries is 5.9 GJ/tonne refined sugar (UNIDO, 2010).

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