

SMED Report No 58 2003



Swedish Environmental Emissions Data

Energy Statistics versus Environmental Reports

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SMED is short for Swedish Environmental Emissions Data, which is a collaboration between IVL Swedish Environmental Research Institute, SCB Statistics Sweden, SLU Swedish University of Agricultural Sciences, and SMHI Swedish Meteorological and Hydrological Institute. The work co-operation within SMED commenced during 2001 with the long-term aim of acquiring and developing expertise within emission statistics. Through a long-term contract for the Swedish Environmental Protection Agency extending until 2014, SMED is heavily involved in all work related to Sweden's international reporting obligations on emissions to air and water, waste and hazardous substances. A central objective of the SMED collaboration is to develop and operate national emission databases and offer related services to clients such as national, regional and local governmental authorities, air and water quality management districts, as well as industry. For more information visit SMED's website www.smed.se.

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1. Introduction

On a yearly basis Sweden is obligated to submit reporting on emissions to air of several substances to EU (Monitoring Mechanisms), UNFCCC and CLRTAP. The Swedish Environmental Protection Agency (Swedish EPA) is responsible for the submissions. Swedish Environmental Emissions Data (SMED) is performing the calculations for the Swedish EPA.

Emissions from fuel combustion at industries and emissions of carbon dioxide from industrial processes are based on fuel consumption reported to Statistics Sweden, Energy Statistics, from now on called the Energy Statistics. Other industry process emissions are based on information in the companies legal annual Environmental Reports. During the time SMED has been working with the submissions it has been obvious that emissions based on the Energy statistics sometimes differ from emissions reported in the Environmental Reports.

The main purpose of collecting the Energy Statistics is not to estimate emissions and some adjustments have to be made before using the statistics for estimating emission. Therefore it has been suggested, instead of the Energy Statistics, to use Environmental Reports, which include reported emissions directly from the operators for emissions from industrial processes, emissions from fuel combustion and fugitive emissions. Before making a decision it is important to investigate if an exchange of data source is in line with the IPCC Guidelines and if it will result in comparable time series for all emissions.

1.1 Aim of study

The aim of this study is to ensure that emission data reported by Sweden are in line with IPCC Guidelines revised 1996¹ and Good Practice Guidance². For two sectors; iron and steel industries and refineries, the fuel consumption and emissions have been compared for 2000 and 2001 between the two possible approaches, i.e. based on Energy Statistics or on Environmental reports. Also the definitions of emissions from fuel combustion and processes and the methods for calculating emissions have been compared and evaluated based on the guidelines. Contact has been made with iron and steel industries (SSAB in Oxelösund and Luleå) and refineries (Scanraff, Preem, Shell, and Nynäs Petroleum in Nynäshamn and Gothenburg) to receive their definitions of different emission sources and information about calculation methods for time series between 1990-2001. Finally, an evaluation has been made, where the possibilities to improve the statistics based on Energy Statistics or to exchange the method from using Energy Statistics, to use Environmental Reports also for emissions from stationary combustion, has been described. The processes occurring at iron and steel industries and refineries are described in Appendix 1 and 2.

¹ IPCC Guidelines for National Greenhouse Gas inventories, revised 1996

² IPCC NGGIP. Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories, 15 June 2001

2. Definitions of emission sources

The definitions in IPCC guidelines and Good Practice Guidance of emissions from fuel combustion, fugitive emissions and emissions from industrial processes are presented in this chapter together with CFR-code for reporting to the UNFCCC for emissions from iron and steel production and refineries.

2.1 Combustion, CRF 1A1-2

This sector includes emissions of all greenhouse gases from stationary combustion of all fossil carbon for combustion purposes. Carbon dioxide (CO₂) emissions from combustion results from the release of carbon from fuels during combustion. CO₂ emissions depend on the carbon content of the fuel. During the combustion process, most of the carbon is emitted as CO₂ immediately. However due to incomplete combustion, some carbon is emitted as carbon monoxide (CO), methane (CH₄) or non-methane volatile organic compounds (NMVOCs), all of which oxidise to CO₂ in the atmosphere within a few days to about twelve years.

Iron and steel

1A1ci, manufacture of solid fuels includes emissions arising from fuel combustion in the coke oven for the production of coke.

1A2a, iron and steel should include all emissions from fuel combustion in the blast furnace steel converter and rolling mill in the iron and steel production, except for emissions from the coke oven (1A1ci).

Refineries

1A1b, include all combustion activities supporting the refining of petroleum products, but does not include evaporative emissions from vehicles (1A3bv) or fugitive emissions (1B2a).

2.2 Fugitive emissions, CRF 1B

During all of the stages from the extraction of fossil fuels through to their final use the escape or release of gaseous fuels or volatile components or absorbed gases may occur. These fugitive emissions are intentional or unintentional escapes and releases of gases from extraction point through to final oxidation. In particular, they may arise from the production, processing, transmission, storage and use of fuels, and include emission from combustion only where it does not support a productive activity (e.g. flaring).

Iron and steel

1B1b include fugitive emissions from the iron and steel production and **1B1c** could include flaring of gases.

Refineries

From oil activities at refineries, transmission and distribution are the most important fugitive emission sources. **1B2aiv** include fugitive emissions from the refining of oil and from storage in tanks. **1B2c** include emissions from venting and flaring from the release and/or combustion of excess gas at facilities for the production of oil or gas and for the processing of gas.

2.3 Industrial processes, CRF 2

Emissions within this sector comprise by-product or fugitive emissions of greenhouse gases from industrial processes other than combustion. The main emissions sources are industrial production processes, which chemically or physically transform materials. During these processes, many different greenhouse gases, including CO₂, CH₄, N₂O, PFCs, SO₂, NO_x etc., can be released.

Iron and steel

Process emissions from iron and steel production are reported under **2C1**. Crude iron is typically produced by the reduction of iron oxides ores in a blast furnace, using the carbon in coke as both fuel and reducing agent. Since the primary purpose of coke oxidation is to produce pig iron, the emissions should be considered as coming from an industrial process if a detailed calculation of industrial emissions is being undertaken as in Sweden. It is good practice to clearly state whether or not the emissions from the coke use in the blast furnace have been allocated to Energy or to Industrial Processes, to indicate that no double counting has occurred.

Refineries

The Guidelines do not state any emissions from refining as process emissions.

3. Data sources for international reporting

In this chapter a brief description of the Energy Statistics and the Environmental Reports are made. The possibility to use Environmental reports for calculating emissions from stationary combustion will be discussed in chapter 6.

3.1 Energy Statistics

For years between 1990-1996 activity data is received from Industry Statistics, Statistics Sweden and includes information on fuel consumption, reported by industry plant level. But the statistics only included fuels that were externally bought and hence not fuels produced within the industry plant. From 1997 activity data is received from Energy Statistics, Statistics Sweden. During 1997-1999 all fuels are included, but data then includes information on economic activity plant level, which means that several plants can be grouped together or that plants can be divided in sub-plants. From 2000 information on fuel consumption is again reported by plant level. This change has caused better quality on the Statistics.

3.2 Environmental reports

According to the Swedish environmental laws operators that perform environmentally hazardous activities that require a permit by law have to compile an annual Environmental Report and send to their supervisory authority. The Environmental report includes information about the facility, environmental-story for the actual year, production data, fuel consumption, emission data and in some cases information about how emission data have been accounted for. These data often originate from measurements or surveys and refer to real emissions, known e.g. by measurements or mass balances. The use of default emission factors is limited. Today, Sweden uses the Environmental Reports as data source when accounting for non-CO₂ emissions from industrial processes.

4. Calculating emissions from iron and steel production

In this chapter the methods currently used by Sweden for reporting emissions from the iron and steel sector is presented as well as with the recommended methods according to the IPCC Guidelines and Good Practice Guidance. The iron and steel companies own definitions of emissions from stationary combustion, fugitive emissions and emissions from industrial processes are described and compared with the definitions described in the guidelines and presented in chapter 4.2.1. Recommendations for how to improve the calculations if using Energy Statistics are also made.

4.1 Current calculation methods and methods according to the guidelines

Total emissions from SSAB, are further described below and are currently calculated as:

Emissions from stationary combustion + fugitive emissions + process emissions

4.1.1 Emissions from stationary combustion, 1A2a and 1A1c

Current method for reporting to EU, UNFCCC and CLRTAP

The Tier 2/Tier 3 methods are used to calculate emissions arising from stationary combustion at SSAB. The calculations are based on fuel consumption of coke oven gas, blast furnace gas, steel converter gas, coal, oil, propane and butane. Coal and coke are used as reducing agents. Emissions arising from use of coal and coke should hence be reported as process emissions according to IPCC Guidelines. The fuel consumption is reported by SSAB to Statistics Sweden, Energy Statistics and the emissions are calculated by using the following equation:

Emissions from fuel combustion_{fuels} (unit) = \sum Fuel consumption (unit) * thermal value_{fuels} * EF_{fuels}

Thermal values are used to convert fuel consumption data from mass or volume unit to energy units. Emission factors (EF) are used to calculate the emissions when the energy content in the fuel is known.

So-called transformation losses (adjustment made by Statistics Sweden) in coke ovens have been reported as emissions from manufacture of solid fuels (CRF 1A1c). The transformation losses are calculated by using the following equation:

Transformation losses (TJ) =
Coal (TJ) + Petroleum coke (TJ) – Produced coke (TJ) - coke oven gas (TJ)

Emissions from transformation losses are calculated by multiplying with a specific emission factor:

Emissions from stationary combustion_{transformation losses} = Transformation losses (TJ) * EF

Total emissions from stationary combustion at SSAB:

Emissions_{fuels} + Emissions_{transformation losses}

Recommended method according to the IPCC Guidelines

Emissions from stationary combustion should if possible be calculated by using data on a plant level and use the bottom-up approach, Tier 2/Tier 3, when energy consumption data are reasonably complete. It is good practice to obtain the carbon content of the fuel and the thermal values from the fuel suppliers. Hence, the calculations of emissions from fuel combustion obtained today are in line with the recommended methods by the IPCC Guidelines except for one aspect: transformation losses should not be included as emissions from stationary combustion, since the coal is not used as a fuel, according to the Guidelines.

*Suggested future improvements*Exclude emissions from stationary combustion

According to the IPCC Guidelines emissions from the use of coal and coke in for instance the coke oven should be reported as process emissions. Hence transformation losses connected to these fuels should be excluded from 1A1c and rather be added to the process emissions in 2C1- coke production for emissions of CO₂, since the lost energy will never be used for energy purposes. For all other greenhouse gases, except CO₂, information about process emissions is collected from the companies' annual Environmental Reports.

Flaring of gas should not be included as emissions from fuel combustion but as fugitive emissions, (see next chapter).

Separate emissions from coke ovens

Fuels such as oil and gas used in the coke oven to produce coke should be excluded from CRF 1A2a, iron and steel production and be added in CRF 1A1ci, manufacture of solid fuels according to the IPCC Guidelines.

4.1.2 Fugitive emissions, 1B1b-c*Current method for reporting to EU, UNFCCC and CLRTAP*

Besides direct emissions arising from combustion, there are fugitive emissions caused by transmission losses. Transmission losses include losses of coke oven gas, blast furnace gas and steel converter gas from storing and transporting, and for SSAB in Luleå also from flaring. Transmission losses are reported directly by SSAB to the Energy Statistics and no further calculations are needed. Gas is flared also at SSAB in Oxelösund but it is not reported as transmission losses, but as emissions from stationary combustion.

Recommended method according to the Guidelines

Flaring of gases should be reported separately as fugitive emission.

*Suggested future improvements*Separate flaring of gas

The part of the gas from SSAB in Oxelösund that is flared should be excluded from 1A2a and be reported as fugitive emissions in 1B1c-Other.

Part of gas flared at SSAB in Oxelösund (mean values for 1999-2001)³:

Coke oven gas: 3,4 %

Blast furnace gas: 6,9 %

Steel converter gas (LD-gas): 100 %

The part of the gas from SSAB in Luleå that is flared should be excluded from 1b1b and be reported in 1B1c-Other.

Part of gas flared at SSAB in Luleå: (mean values for 2000-2002)⁴:

Coke oven gas: 13,3 %

Blast furnace gas: 2,0 %

Steel converter gas (LD-gas): 28,3 %

4.1.3 Emissions from industrial processes, 2C1

Current method for emissions of CO₂ from processes for reporting to EU, UNFCCC and CLRTAP

Process emissions of CO₂ from pig iron production in the blast furnace in ton=

$$\text{Emissions}_{\text{pig iron}} = [\text{Coke oven coke}_{\text{total}} (\text{ton}) - \text{Coke oven coke}_{\text{blast furnace gas}} (\text{ton})] * \text{Thermal value}_{\text{coke oven coke}} * \text{EF}_{\text{coke oven coke}}$$

All non-CO₂ process emissions are collected from SSAB's Environmental Reports.

Recommended method according to the guidelines, Tier 2 method

Plants can differ substantially in their technology. To achieve the highest accuracy, it is therefore *Good Practice* to develop emission estimates at the plant level. This will avoid double counting or omissions. The Tier 2 method is based on tracking the carbon through the production process. The activity data needed are the amount of reducing agents i.e. injection coal, coke oven coke and petroleum coke used for iron production. The amount of pig iron produced as well as the amount used for steel production and produced steel, and their carbon contents are also needed. The amount of carbon in ore is normally almost zero, crude iron contains about 4% coal and the produced steel less than 1% carbon.

Since the primary purpose of the use of coal and coke in the blast furnace is to secure oxidation and act as reducing agent, the emissions are to be reported as Industrial processes according to IPCC Guidelines and Good Practice Guidance.

With the Tier 2 method emissions from the iron production and steel production are calculated separately.

The recommended method for calculating total process emissions from pig iron production and steel production according to Good Practice Guidance is:

Emissions_{pig iron} + Emissions_{crude steel}

³ Information from Klas Lundbergh, Head of Environment at SSAB Oxelösund, 0155-25 40, 2002-08-16

⁴ Information from Leif Wahlberg, SSAB Luleå, 0920- 92 000, 2003-03-04

Emissions_{pig iron}=

$$EF_{\text{injection coal}} * \text{Mass Carbon}_{\text{injection coal}} + EF_{\text{coke oven coke}} * \text{Mass C}_{\text{coke oven coke}} + EF_{\text{petroleum coke}} * \text{Mass C}_{\text{petroleum coke}} + (\text{Mass C}_{\text{core (iron pellets)}} - \text{Mass C}_{\text{pig iron}}) * 44/12$$

Emissions from crude steel production are based on the difference between the carbon contents in iron (3-5%) and steel (0.5-2%).

$$\text{Emissions}_{\text{crude steel}} = (\text{Mass Carbon}_{\text{crude iron}} - \text{Mass C}_{\text{crude steel}}) * 44/12$$

There is a difference in energy content between coke oven coke produced from coal and petroleum coke produced in a refinery from crude oil and hence they have different emission factors. Country specific emission factors for CO₂ from these different reducing agents can be used if better data are available for the carbon content in the fuels, otherwise default values could be used.

According to the IPCC guidelines, CO₂ emissions from lime stone should be reported as emissions from limestone and dolomite use. The limestone emits CO₂ during reduction of pig iron in the blast furnace and when the limestone is heated CO₂ is generated. Care should be taken not to double count these emissions. In Sweden CO₂ emissions from the use of limestone are reported separately.

*Suggested future improvements*Process emissions from coke ovens

How to calculate process emissions from the coke oven are not described in the guidelines, but could possibly be calculated as transformation losses as described in chapter 4.1.1 above, and be reported under 2C1- coke production. If transformation losses are to be reported as process emissions, it is important to make sure that the coke oven gas subtracted in the equation in chapter 4.1.1 above includes all produced coke oven gas, before purification. This since the purification will result in by-products such as tar and benzene, which both include carbon. The equation will also have to be revised for SSAB in Oxelösund since they do not add any coke to the coke oven. According to the carbon balance (described in chapter 4.2.2) the remaining emissions of CO₂ is for instance less than 1% of the total CO₂ emissions, and it is hence likely to believe that the equation for transformation losses is not completely correct. A simplified method would instead be to calculate all emissions from the coke oven based *only* on the produced amount of coke oven gas.

Process emissions from blast furnaces and steel converters

For reporting to EU, UNFCCC and CLRTAP current emissions from the blast furnace are calculated in a different way than what is described in the Guidelines. When calculating process emissions from the blast furnace, other reducing materials i.e. petroleum coke and injection coal should be added and the carbon content in the pig iron should be subtracted as shown in the pig iron process description. Besides emissions from the production of pig iron, emissions from the steel converter should be calculated and reported as process emissions according to the guidelines. For process emissions from the steel converter the equation from crude steel could be used. The problem with these equations is that the data needed is provided neither by the Energy Statistics nor by the Environmental Reports. The only way to get this information is to contact SSAB. A more convenient way to calculate

emissions from the processes is to base them on consumed blast furnace-, steel converter- (and coke oven-) gas.

Another question is if these gases are to be reported as either energy or process emissions. These gases are firstly produced due to the processes and some CO₂ will then be produced, but since the gases are collected and later on used as fuels together with oil etc., all carbon will be released during combustion. It is hence not quite easy to decide whether emissions from the combustion of these gases including coke oven gas should be reported as energy or process emissions. Good Practice Guidance recommend that industrial processes should include CO₂ emissions from use of blast furnace gas as a fuel *if* emissions are reported as Industrial processes. By using the word “if” it is not clearly stated how to report the gases. Contact has been taken with the UNFCCC secretariat⁵ to get further information on this issue. Their answer was that both ways are correct and that the important thing is that it is clearly stated how the separation between energy and process emissions is made and that no double counting or omissions occur. In a separate project (FLEX-MEX 2) SMED has provided four proposals on how the separation could be made:

1. Emissions from all gases are reported as emissions from stationary combustion since they are all combusted.
2. Emissions from all gases are reported as process emissions since they are all arising from processes.
3. Only emissions from the blast furnace are reported as process emissions, since it is a compulsory part of an integrated iron and steel work while the coke oven is not because coke can be bought and partly subsidised to coal. The LD-gas is flared and should hence be reported as emissions from stationary combustion.
4. Since some kind of fuels are needed in the different processes, the fourth proposal is to calculate how much oil and emissions from oil that would be needed in the processes if not using the gases. The fuels from the oil would be reported as energy emission and the remaining part of the emissions from the gases should be reported as process emissions.

The method that is chosen for the system of tradable emission permits should also be used for reporting to EU, UNFCCC and CLRTAP.

Other process emissions

It is possible that emissions other than from the gases occur from the processes and will be directly emitted to the air. But according to the carbon balances used by SSAB, these are negligible since big efforts are made to collect the gases that are rich of energy and use for combustion purposes.

4.2 Method used by SSAB to calculate emissions⁶

SSAB only calculate process emissions (according to the IPCC definition) of particles and do not consider any loss of gases in the different processes. In their calculations all incoming material produces gases or other products such as coke, pig iron, steel, slags, tar etc.

⁵ Astrid Olsson, Programme Officer UNFCCC secretariat, aolsson@unfccc.int, 2003-04-01

⁶ Information from Rolf Didriksson, Environmental Engineer at SSAB Oxelösund, 0155- 25 45 72, 2003-03-11 and from Leif Wahlberg, SSAB Oxelösund, 0920- 92 000, 2003-03-04

Environmental Reports are available for the whole period from 1990, but for instance emissions of CO₂ in Oxelösund have only been included for the last couple of years.

4.2.1 Definitions

SSAB in Oxelösund are defining energy emission as emission from fuel combustion in power stations. All other emissions i.e. combustion of gases, oil and liquefied petroleum gas (LPG) in the coke oven, the blast furnaces, the steel converter, the rolling mill and for internal transports are considered to be process emissions. This information was received by contacting SSAB, since the definitions are not stated and the division of energy and process emissions is very unclear, in the Environmental Reports especially for CO₂, NO_x and SO_x. Emissions are mainly separated by source, for instance the blast furnace. No separation for fuel combustion or process is made.

4.2.2 Emissions

CO₂

SSAB in Oxelösund and Luleå are calculating emissions of CO₂ by using a common comprehensive carbon balance including all incoming and outgoing material containing carbon to and from the coke oven, the blast furnace, the steel converter and the rolling mill. The carbon balance also includes internal mobile transports within the production area and emissions from the use of limestone, which is calculated separately for the international reporting. Losses of gas are included as flaring of gas at Luleå.

The carbon balance has only been used since 2000 in Oxelösund and 1995 in Luleå. Earlier, calculations were made by multiplying the amount of incoming products with their carbon content. Emissions of CO₂ have only been reported in the Environmental Reports since year 2000 for Oxelösund. Calculations of CO₂ according to earlier method are available for 1980, 1985 and 1990 for SSAB Luleå.

CO

SSAB does not report emissions of CO in their Environmental Report, since it is not regulated in their permit. CO emissions arise from leakage of gas (fugitive emissions) and from incomplete combustion of fuels (emissions from stationary combustion). At the moment emissions of CO are included in the carbon balance used to calculate CO₂ emissions. This will cause a slight overestimate of the CO₂ emissions.

NM VOC

Emissions of NM VOC are arising in Oxelösund when painting the steel products in the surface treatment/painting plant. There are two painting plants in Oxelösund and the main parts of the emissions are arising from the older one since the abatement equipment installed is not working properly. These emissions have been calculated from measurements once a year.

In Luleå volatile organic carbons are reported as emissions of VOC and the calculations are including fugitive emissions from chemicals.

CH₄

Methane is not reported at all since the only source is leakage of coke oven gas, which cannot be measured.

N₂O

Not reported or measured by SSAB since they do not think that high amount of N₂O is produced and it not is regulated in their permit.

NO_x

NO_x is produced from nitrogen in the air during combustion of fuels if the temperature and the oxygen level is high. These emissions from stationary combustion are measured from the combustion of oil, coke oven gas and blast furnace gas by an external consultant. The last time measurements were made in Oxelösund was in 1999/2000 and the levels have been quite stabile during the years. NO_x emissions originating from the rolling mill is not measured today in Oxelösund and reported emissions are therefore based on old measurements. NO_x emissions from the steel converter are arising from leakage or flaring. This should be considered as process or fugitive emissions according to the Guidelines.

Emissions of NO_x from internal transports and flaring are included for Luleå and for the power plants at Oxelösund. These emissions should be reported separately according to the Guidelines.

The only sites where emissions of NO_x are measured continuously are at the power stations in Oxelösund. In Luleå only a few measurements were made before 1990, but since 1992 calculations have been made on annual and partly continuously measurements.

SO₂

Emissions of SO₂ are reported on basis of fuel combustion of gases and oil at the whole plant (emissions from stationary combustion and fugitive emissions from flaring), measurements once a year made from the sulphur recovery and assumptions for the coke quenching (process emissions). Fugitive sulphur emissions arising from the blast furnace slag and emissions from the power plant are both included in reported "other" SO₂ emissions in Oxelösund. LD-gas does not contain any SO₂ and hence has not been included in the calculations. The same methods for calculating SO₂ emissions have mainly been used for the period 1990-2001.

4.3 Comparison of emissions based on different data sources

Within the study information on fuel consumption and emissions as described above has been collected from the Energy Statistics and the Environmental Reports, and the two sources have been compared. Since the Energy Statistics is confidential on plant level these data are not presented in this report.

4.3.1 Definition of emission sources

SSAB definition of process and emissions from stationary combustion definition differs totally from the definition in the IPCC Guidelines used for reporting to EU, UNFCCC and CLRTAP as described above and hence emissions cannot be compared when separating process emissions from emissions from stationary combustion. It is also difficult to compare total emissions, since emissions originating from internal mobile transports, use

of limestone and emissions from power plants are supposed to be reported separately in reporting to EU, UNFCCC and CLRTAP. Emissions from the power plants in Oxelösund correspond to almost 50 % of SSAB's total emissions of CO₂ in 2001.

4.3.2 Methodology

According to the IPCC Guidelines emissions should be calculated using the same method for every year in the time series. This is achieved by using the Energy Statistics but not by using the Environmental Reports for emissions of CO₂.

The same method has not been used by SSAB for all years from 1990 and forwards to calculate CO₂. SSAB's definition of process emissions and energy emission is also totally different from the definitions in the IPCC Guidelines.

Process emissions are not accounted for as requested by the IPCC Guidelines since SSAB does only calculate process emissions (with the IPCC definition) of particles and do not consider any losses of gas from the processes. Besides, SSAB define process emissions and energy emission totally different from the definitions in the IPCC Guidelines.

4.3.3 Fuel consumption

SSAB correctly calculates emissions from stationary combustion based on fuel consumption at the whole plant including the coke oven, blast furnace, steel converter and the rolling mill. Fuels included are oil, propane and butane, coke oven gas, blast furnace gas, steel converter gas and finally also fuels for internal transports, which should be reported separately according to the Guidelines.

By comparing the two data sources it has then been clear that the fuel consumption of blast furnace gas according to the Energy Statistics is much lower. On the other hand is transmission losses of coke oven gas and blast furnace gas reported as fugitive emissions very high for both gases. According to SSAB's carbon balance the loss is very small and the transmission losses are probably overestimated.

To make correct calculations of the emissions, the methods discussed in chapter 4.1.3 should be used. Within a separate project (FLEX-MEX 2) the Energy Statistic program at Statistics Sweden delivered other data on gas consumption and flaring for the whole nineties that might be used to revise the calculated emissions for the whole period 1990-2001.

4.3.4 Emissions

Since SSAB does not separately report emissions of CO, N₂O, NH₃ and CH₄ in Environmental Reports, no comparison with data from the Energy Statistics could be made for these emissions. Emission of CO₂, SO_x, NO_x, and NMVOC could be compared.

SSAB includes CO₂ emissions from internal transports, power plants and use of limestone. This is not in line with the IPCC Guidelines, which recommend that these emissions should be reported separately. Therefore, collecting emission data from Environmental Reports for reporting to EU, UNFCCC and CLRTAP seems not to be a proper choice. It is now hard to compare data from Environmental Reports with emission data in reporting to EU, UNFCCC and CLRTAP, since the Guidelines are currently followed in this respect.

Remaining emissions of CO₂ and emissions of SO_x and NO_x for both Oxelösund and Luleå are much higher when based on the Energy Statistics, despite that emissions from for instance the power plant are included in emissions reported in the Environmental Report. This is probably due to several errors in the current calculation methods, i.e. double counting of carbon, very high transmission losses and old emission factors. Emissions of NMVOC are also much higher when based on the Energy Statistics, this is a result of that SSAB don't report NMVOC emission from fuel combustion. NMVOC, CO and CH₄ are produced during incomplete combustion and should therefore be calculated from fuel combustion.

4.3.5 Conclusions

When summarising how emissions of CO₂, CH₄, N₂O, NO_x, CO, NMVOC and SO₂ are estimated for reporting to EU, UNFCCC and CLRTAP versus reported by SSAB compared to what is recommended in the IPCC Guidelines, we make the conclusion that all energy and fugitive emissions should be based on Energy Statistics also in the future.

The main disadvantages with the Environmental Reports are following:

- SSAB separates emissions in subcategories energy, fugitive and process not at all or not in line with definitions in IPCC Guidelines
- SSAB has changed method for calculating some emissions since 1990
- SSAB does not report emissions of CO, N₂O and CH₄
- SSAB does not explain how several emissions are calculated
- SSAB does not clearly separate emissions from the power plant.

5. Calculating emissions from refineries

5.1 Current calculation methods and methods according to the guidelines

In this chapter methods used for reporting emissions from refineries are presented as well as the recommended methods according to the IPCC Guidelines and Good Practice Guidance. The refineries own definitions of emissions from stationary combustion, fugitive emissions and emissions from industrial processes are described and compared with definitions presented in chapter 2. Recommendations on how to improve calculations if using Energy Statistics are also made.

In a basic refinery crude oil is converted into a variety of sub-products. Principal products of a refinery may include liquid fuels, coke, feedstocks and primary petrochemicals (like ethylene).

Total emissions from refineries are further described below and are calculated as:

Emissions from stationary combustion + fugitive emissions

Emissions from industrial processes are not reported, which is further discussed below.

5.1.1 Emissions from stationary combustion, 1A1b

Current method for international reporting, tier 2

Emissions at refineries arising from stationary combustion are estimated on basis of fuel consumption of oil, refinery gas, petroleum coke, diesel, natural gas, propane and butane reported to the Energy Statistics survey for the years 1990-2001, and the emissions are calculated by using the following equation:

Total emissions for stationary combustion for 2000-2001:

$$\text{Emissions from stationary combustion}_{\text{fuels}} \text{ (unit)} = \sum \text{Fuel consumption (unit)} * \text{thermal value}_{\text{fuels}} * \text{EF}_{\text{fuels}}$$

By using this equation for refineries for the years 2000-2001 all emissions from stationary combustion have been covered. For the years 1990-1997 the Energy Statistic survey only covered purchased fuels and not fuels produced within the refineries. Since some refineries mainly use their own products, i.e. refinery gases, and these fuels were not reported in the energy surveys for 1990-1997 so called transformation losses have been added to compensate the lack of fuel data. Since 1997 the survey has also included fuels produced by companies themselves, but for 1997-1998 only small amounts of refinery gases were reported and in 1999 again, no internally produced fuels were reported. Hence in total, transformation losses have been added for 1990-1999. For 2000 and 2001 all fuels used in the refineries are reported and hence no transformations losses have been added.

Transformation losses are expressed as a fuel measured by energy content (TJ) with a special emission factor.

Total emissions for stationary combustion for 1990-1999:

$$\text{Emissions from stationary combustion}_{\text{fuels}} + \text{transformation losses}$$

Only aggregated data has been available for the refinery sectors use of residual oils during 1990-1999. It seems that this amount of residual oils has been overestimated. This has caused that emissions for the years before 2000 are generally to high and can not be separated at plant level.

Recommended method according to the guidelines

All fuels used for combustion and flaring should be included. Some feedstocks delivered to petrochemical plants may be used for energy purposes and not for manufacture of other products and should hence also be reported as emissions from stationary combustion_{fuels}.

Suggested future improvements

Separate refinery gas from the fuel category “other petroleum”

Refinery gas includes a mixture of non-condensable gases mainly consisting of hydrogen, methane, ethane and olefins obtained during distillation of crude oil or treatment of oil products (e.g. cracking) in refineries. The refinery gas is used as a fuel for heating distillation columns at three of the refineries in Sweden, and is the main fuel used at these

three plants. Refinery gas is now included in the fuel category “other petroleum”, but it should be separated reported as a single fuel. The IPCC default values for refinery gas could be used to calculate emissions when no local values are available.

The IPCC default values are⁷:

Emission factor for CO₂: 18,2 t Carbon/TJ * 44/12= 66,73 t CO₂ / TJ
 Thermal value: 48,15 TJ/ kt
 1 ton refinery gas = 48,15 * 66,73 = 3,213 t CO₂

The corresponding values used now in the international reporting is:

Emission factor for CO₂: 60,0 g/MJ
 Thermal value: 41,87 GJ/ toe
 1 toe gas of “other petroleum”= 41,87 * 60 = 2,512 t CO₂

Exclude transformation losses and/or residual oils for 1990-1999

Data on fuel consumption 1990-2001 has been collected from Scanraff, which is the refinery with highest emissions from fuel combustion. These data could be used to calculate emissions from stationary combustion for the period 1990-1999, and at the same time be able to exclude transformation losses and/or reported use of residual fuels. This could probably also be made by collecting data direct from the remaining four refineries as well or by extrapolating data for “other petroleum” from 2000-2001 to earlier years. Extrapolation of data is an accepted method according to the Good Practice Guidance and according to data from the refineries Environmental Reports collected by the trade organisation Plast- & Kemiföretagen⁸. From 1990 and 1994-2001 the time series has been quite consistent for at least CO₂, which makes the extrapolation easier. But extrapolation of ten years can despite of that be hard and plant specific data is preferable.

5.1.2 Fugitive emissions, 1B2a

Crude oil is transported by tankers to refineries, where it is stored in tanks for a period of time. Methane is present in varying degrees in crude oil, and leaks or venting of vapours during transport and storage result in methane emissions, particularly from crude oil storage.

Refineries process crude oil into a variety of hydrocarbon products such as gasoline and kerosene. During the refining process, dissolved gases are separated some of which may be leaked or vented during processes. Refinery outputs, referred to as refined products, generally contain negligible amounts of methane and should hence not be estimated according to the Guidelines.

Venting and flaring refers to the disposal of gas that cannot be collected or otherwise handled.

Current method for international reporting

Sweden is calculating fugitive no-CO₂ emissions by using the Tier 2 method. The tier 2 method requires data on plant level and Sweden are using data produced by the refineries

⁷ IPCC Guidelines for National Greenhouse Gas inventories, revised 1996. Workbook chapter 1.2.1, page 1.6

⁸ Birgitta Resvik, Plast- och Kemiföretagen, birgitta.resvik@plastkemiforetagen.se, 2003-04-07

themselves presented in their annual Environmental Reports. Emissions are reported from catalytic cracking (NO_x), desulphurisation (SO₂) and from storage and handling of oil (NMVOC).

Recommended method for fugitive emissions according to the guidelines

Since no- CO₂ emissions already are reported based on the method used by the companies for their Environmental Reports and no fugitive emissions of CO₂ exists the recommended methods will not be further described in this report.

5.1.3 Industrial processes

Emissions from processes in refineries are not described in the Guidelines and not reported in reporting to EU, UNFCCC and CLRTAP or in the Environmental Reports. This is due to that all emissions are arising from combustion of crude oil or other fuels or by leakage of fuels.

5.2 Methods used by refineries to calculate emissions

By reading Environmental Reports from five refineries and by contacting refineries directly⁹, information about definitions of emission types and methods used was received. A visit was also made to Scanraff. In the following chapter the results of this investigation will be described for definitions in general and methods for emissions of CO₂, CO, NMVOC, CH₄, N₂O, NO_x and SO₂.

Environmental Reports have been written for all refineries (except Shell) during the whole nineties and information on reported emissions and reported methodologies for calculating emissions in 2000 are summarised in table 1. The first Environmental Report for Shell is from 1992 but information about emissions for earlier years might be available.

Table 1. Information about emissions from refineries in Environmental Reports for 2000.

	Scanraff	Nynäs Petroleum, Gothenburg	Nynäs Petroleum, Nynäshamn	Shell	Preem
Fuel consumption	Yes	Yes, but described as "External fuels and AD-top gases"	Yes, but described as oil, refinery gas and "HT-fraction"	Yes	Yes
Emissions from stationary combustion ¹⁰	CO ₂ , CO, SO _x , NO _x	CO ₂ , SO _x , NO _x , VOC	NO _x and SO ₂ , also from flaring	CO ₂ , SO ₂ , NO _x , VOC	CO ₂ , SO ₂ and NO _x from flaring
Methodology for emissions from stationary combustion	Not described	Not described	Not described	Only described for NO _x	Only described for CO ₂
Other emissions	VOC, NO _x , SO _x	VOC	SO ₂ , VOC	SO _x , NO _x , HC _x , CH ₄ ,	SO _x ,

⁹ Nynäs Petroleum in Nynäshamn: Jan Olsson, 08-52065111, 2003-03-21
 Nynäs Petroleum in Gothenburg: Karin Max, 031-755 12 00, 2003-03-25
 Scanraff: Marie Colldén, oral information from visit 2003-03-25
 Preem: Thomas Wennerberg, 031-64 60 00, 2003-04-01
 Shell: Ivan Mares, 031-744 60 00, 2003-04-02

¹⁰ As defined in the guidelines.

Methodology for other emissions	VOC- fugitive and flaring. NO _x and SO _x	VOC	VOC	VOC	VOC
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5.2.1 Definitions

All refineries separate emissions from combustion from fugitive emissions (fluid catalytic cracking, flaring and storage and handling) in Environmental Reports.

Emissions from stationary combustion

At all refineries fuel combustion in ovens is considered to be emissions from stationary combustion, in line with the Guidelines.

Fugitive emissions

At all refineries fugitive emissions are defined as emissions leaking from venting, storing tankers and heat exchangers that can not be measured. VOC are considered to be the only fugitive emissions. According to the Guidelines emissions from sulphur recovery and catalytic cracking also should be considered as fugitive emissions. At Shell all fugitive emission are measured every third year with a standard method.

Process emissions

At the Nynäs refineries flaring of gases is defined as process emissions. SO₂ emissions from desulphurising of oil could be called process emission, but is not separated in the Environmental Reports.

Scanraff does not separate any emissions as energy or process. Though CO₂ emissions arising from the cracker is not a result of fuel combustion and could hence reported as process emissions. These emissions corresponded to about 15 % of the total CO₂ emission.

Preem and Shell does not define any emissions to be originating from the processes.

5.2.2 Emissions

At Preem the methods to calculate emissions are assumed to be the same from one year to another, but that the content and extent of the measurements and calculations for different emissions may vary between years.

At Shell emissions have been calculated in mainly the same way during the whole nineties.

CO₂

Emissions of CO₂ are at all refineries calculated on basis of carbon content and the amount of fuels used for combustion. No other sources for CO₂ emissions are considered.

CO

CO emissions have not been measured or reported by any refinery but Nynäs. At Scanraff emissions are continuously measured at the catalytic cracker and at Preem emissions were measured once in 2002 with gas analyst instrument and extrapolated to a yearly value.

NM VOC

All refineries do not separate NMVOC emissions from methane. VOC emissions are estimated by direct measurements. DIAL (Differential Absorption LIDAR) measurements are made at all refineries, which makes it possible to measure the VOC concentration in different positions in the plume from an area at the refinery. This method has been used the two latest years at Nynäs in Nynäshamn, but earlier the emissions were calculated based on measurement at Nynäs in Gothenburg. In Gothenburg DIAL measurements have been made in 1995 and 1999.

At Scanraff the same DIAL method has been used since 1992. They are measuring for one month every fourth year and base estimations on these measurements in the coming years. At the moment they are participating in a research project that is trying to develop a new technique to measure NMVOC emissions.

At Preem and Shell DIAL measurements are performed every third year and estimations for annual values are based on these measurements. The first DIAL measurement at Shell was made in 1996.

CH₄

Only reported from Shell. At all other refineries CH₄ is included in VOC emissions.

N₂O

Not reported at any refinery. At Preem N₂O was measured once in 2002 with a gas analyst and extrapolated to an annual value. The reported emission at Shell is based on an estimated value.

NO_x

At both Nynäs refineries emissions of NO_x are calculated based on measurements once a year. The same method has been used for the whole nineties.

At Scanraff the first measurements of NO_x emissions were made in 1995, by measuring once a year in the chimneys. Earlier there were no restrictions in their permit for NO_x emissions and hence they were not reported. Extrapolations from the measurements have been made to estimate the emissions for the earlier years.

NO_x emissions are measured continuously at Shell.

SO₂

At all refineries emissions of SO₂ are arising from fuel combustion and from losses when desulphuring the oil, and at Scanraff also from flaring. The methods for calculating SO₂ emissions are based on the sulphur content in the fuels and at least at Scanraff the method has been the same since 1990.

5.3 Comparison of emissions based on different data sources

Within the study fuel consumption and estimated emissions described above have been collected from the Energy Statistics and the Environmental Reports, and the two data

sources have been compared. Since the Energy Statistics are confidential on plant level these data are not presented in this report.

5.3.1 Definition of emission sources

The refineries do not always define whether emissions arising from combustion, processes or if they are fugitive, but they clearly report in their Environmental Reports where all emissions arises from. Hence by expert knowledge about the processes it is possible to make the separation of emissions from stationary combustion and fugitive emissions.

5.3.2 Methodology

Refineries partly use the same methods, partly different ones to estimate emissions. It is rarely explained in the Environmental Reports what reported emissions are based on and whether the method changes from one year to another. This makes it difficult to compare data and assure consistent time series.

Fuel consumption is reported in the Environmental Reports but it is not quite easy to identify the fuel types since expressions like HT fraction, AD- top gas, reformer gas etc. are being used. These fuels are mostly some kind of rest products from the refining, mainly refinery gases, and from the Energy Statistics these are aggregated and classified as “other petroleum”. The fuels included in “other petroleum” are reported in the unit toe (ton oil equivalents) in the Energy Statistics, which is an energy unit. These can not be compared with the corresponding fuels in the Environmental Reports since they are reported in ton or m³ and the energy content is not always described.

When comparing other fuels than “other petroleum” it has been noticed that some fuels are lacking in the Energy Statistics, although these fuels, mainly refinery gases, are only used in small amounts and should not contribute much to total emissions.

It seems that sometimes refineries have reported fuels differently in Environmental Reports compared to the Energy Statistics, but that total fuel consumption is comparable. For instance one refinery might have reported one type of refinery gas (sweetgas) as natural gas to the Energy Statistics. Sweetgas and Natural gas is not the same fuel, but if sweetgas is purified from H₂S, they have same properties and then sweetgas should be reported as natural gas according to the guidelines.

5.3.3 Emissions

Energy Statistics is only used to estimate emissions from stationary fuel combustion. All other emissions are collected from Environmental Reports. Hence there is no use comparing other emissions than from fuel combustion. Since emissions of CH₄, NMVOC, CO and N₂O are poorly reported in the Environmental Reports these emissions could not be compared. The only meaningful comparison that could be made is for emissions of CO₂, SO_x and NO_x from fuel combustion.

For CO₂ emissions derived by the two methods agree quite well, although differences in reported fuels result in differences in estimated emissions. As mentioned above fuels and hence emissions are for some refineries reported much higher in the Environmental Reports, which seems to be due to lack of data in the Energy Statistics.

Emissions of SO_x and NO_x are for several refineries much higher in calculations based on Energy Statistics than according to the Environmental Reports. This cannot be due to differences in reported fuel combustion, since emissions of CO₂ agree well. The difference might be due to different emission factors. The sulphur content in the refinery gases might be lower and the desulphurising higher than what is accounted for in the emission factors used for reporting to EU, UNFCCC and CLRTAP. Combustion of fuels might be more efficient than emission factors for NO_x are taking into account.

A suggestion is to make a further investigation to make sure all used fuels are correctly reported from refineries where there seems to be problems and to revise the emission factors for SO_x and NO_x.

5.3.4 Conclusions

When summarising how emissions of CO₂, CH₄, N₂O, NO_x, CO, NMVOC and SO₂ for reporting to EU, UNFCCC and CLRTAP are calculated and reported by refineries compared to what is recommended by IPCC, we make the conclusion that emissions from stationary combustion should preferably be based on Energy Statistics also in the future.

The main disadvantages with Environmental Reports from refineries are the following:

- method for calculating emissions have in some cases been changed since 1990
- emissions of CH₄, NMVOC, CO and N₂O are not completely reported
- calculations of several emissions are not explained

6. Possibilities to use Environmental Reports for calculating emissions from stationary combustion

In this chapter the possibilities for using Environmental Reports to calculate emissions from stationary combustion for industrial companies in general is discussed based on experiences from the investigations on SSAB and refineries.

6.1 Definitions of emissions sources

According to the IPCC Guidelines it is preferable to collect plant specific emission data whether it is based on measurements or not. This is achieved both by using Energy Statistics and Environmental Reports. The difficulty with Environmental Reports is that the definitions of energy- and process emissions are individual and not always clear. In addition, the definitions are not always in line with the guidelines.

The IPCC Guidelines encourages countries to use fuel statistics collected by an officially recognized national body, as made now, while this is usually the most appropriate and accessible data.

6.2 Calculation methods

The IPCC Guidelines ensures that countries may use their own methodologies if they believe this will provide more accurate results given the national circumstances. Further more, it is Good Practice to prepare inventories using the same method for all years in the time series. Where this is difficult due to a change in methods or data over time, estimates for missing data in the time series should be prepared based on backward extrapolation. It

is Good Practice to document estimated emissions, all activity data including reducing agents, carbon stored, and all corresponding emission factors and assumptions used to derive them.

Environmental Reports are used in Austria to report emissions from large companies in the industrial sector (refinery, steel production, cement production) and they say that the key issue is the acceptance by the IPCC Expert review team (ERT). The acceptance is depending on the independent verification of data. In Austria this independent verification is only made for steamboilers over a certain installed capacity. Despite of that Environmental Reports (no legislative demand in Austria except for stemboilers) are used for some other sectors as well when they believe that this give more accurate data than their own calculations on fugitive and process emissions¹¹. Whether this is made for the whole time series and how it is excepted by the ERT has not been clear. In Sweden it has been legalised for a longer time and for more companies to write Environmental Reports, and it is easier to get acceptance to use these data for some process and fugitive emissions as Sweden do. Though all emissions reported to EU, UNFCCC and CLRTAP have not been verified for the whole nineties, i.e. CO₂ and it would probably be harder to get acceptance from the ERT to use Environmental Reports also for Emissions from stationary combustion.

According to the IPCC In-Country Review of the Swedish Greenhouse Gas Inventory in November 2001, transparency and verification are the main issues for improvements in the industry sector. Sweden was encouraged to describe its methodology in general and particularly the methodology used by companies to estimate emissions, especially from key sources. This would improve transparency and make it easier to review methodologies used in the inventory¹². If Sweden is to use Environmental Reports for emissions from stationary combustion it is hence of great importance to collect information on how companies have calculated emissions to make sure the methods are in line with the Guidelines and that time series are comparable. Since methodologies used to calculate emissions seem to be weakly or at least rarely described in Environmental Reports this collection must be made by contacting each company to be able to prove that the methods give accurate calculations of emissions.

6.3 Time series consistency

In order to meet the objectives of the IPCC/OECD/IEA programme, inventories and time series must be readily comparable¹³. This demand is not easy to fulfil either with Energy Statistics nor data from Environmental Reports as described in chapter 3.1 and 3.2. However, by using Energy Statistics it is easier to describe differences between years since the same method is used for all industries. In Environmental Reports on the other hand methodology used can change from one year to another for each company by making calculations instead of estimations, measurements instead of calculations etc. These changes can only be traced by carefully reading Environmental Reports or in most cases by contacting the companies each year: This is very time consuming.

¹¹ Manuela Wieser, Federal Environment Agency – Austria Air Emissions Department, 030409, wieser@ubavie.gv.at

¹² In- country review: Report of the individual review of the greenhouse gas inventory of Sweden submitted in the year 2001, 020430, FCCC/WEB/IRI(2)/SWE

¹³ IPCC NGGIP. Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories, 15 June 2001

7. Suggestions for future improvements

As a result of the discussion on Environmental Reports in chapter 6, we recommend that calculations for emissions from stationary combustion should be based on energy statistics also in the future, when reporting to the UNFCCC, the European Union's Monitoring Mechanism and to CLRTAP. Some improvements should be considered to improve the quality. The improvements we recommend are described as suggested future improvements above and can be summarised as following:

Suggested improvements for reported emissions from SSAB

- Add consumption of fuel gases where there is a lack of data and analyze whether to exclude transmission losses or not.
- Exclude the use of carbon from emissions from stationary combustion.
- Separate fuels used in the coke oven to CRF 1A1ci i.e. manufacture of solid fuels.
- Exclude transformation losses for all years.
- Report flaring of gases in CRF 1B1c instead of 1A2a and 1B1b.
- Decide on how to report emissions from coke oven gas, blast furnace gas and steel converter gas.
- Decide on how to calculate process emissions except those from the gases.
- Revise the time series in line with what has been described above.

Suggested improvements for reported emissions from refineries:

- Separate refinery gas from "other petroleum" and use the IPCC default emission factor.
- Exclude transformation losses for the years 1990-1999. Emissions should be estimated by using data from Scanraff and by asking other refineries for their fuel consumption in the 90's or alternatively by extrapolations of data.

In addition to these improvements it would be Good Practise to compare the Energy Statistics data with data from the Environmental Reports in the future as a verification method.

Appendix 1

Processes in iron and steel production¹⁴

The Iron and steel industry is a highly material- and energy intensive industry. More than half of the mass input becomes output in the form of off-gases, solid waste or solid by-products. Emissions to air are the most relevant emissions.

A description of the different steps in the processes in integrated iron- and steel production is described in this chapter.

Coke oven (figure 1)

In the coke oven, coke is produced by heating coal with no oxygen present. The coke production gives coke oven gas (COG) as a by-product. The gas could be purified from benzene, tar and sulphur and then used as a fuel in the coke oven, the blast furnace and in electricity production.

The coal is heated to about 1000° C in a combined heating/firing system where mainly purified blast furnace gas and coke oven gas are used as fuels. The heat is lead via a brick wall to the coke oven. The heat in the gases is also used to increase the efficiency in the gaseous fuels. When the coke is pushed out from the oven it spontaneously starts to burn and has to be quenched by adding water. The coke is cooled to 180-200 ° C.

Fugitive emissions are arising from oven doors, in- and out loading of coal and coke, leakage between the heating chamber and the coke oven through cracks in the walls and from purification of gases. The main emissions are NO_x, SO₂ and particles. The sulphur emissions come from the sulphur content in the coke oven gas used and hence depend on how well the gas has been purified. If unpurified coke oven gas is leaking out of the heating chamber and is combusted together with purified gas, emissions of SO₂ and particles will increase heavily. NO_x is also produced during combustion and emissions are depending mainly on temperature and oxygen concentration, but also on the fuels and types of coal used. NO_x emissions increases with higher temperature and the goal is hence to keep the temperature as low as possible.

Blast furnace (figure 2)

The blast furnace is a closed system into which pellets containing iron, additives (limestone, slag formers) and reducing agents (coke) are continuously fed from the top of the furnace shaft through a charging system that prevents escape of blast furnace gas. The additives are added to lower the melting point, improve sulphur uptake by slag, provide the required liquid pig iron quality and allow for further processing of the slag.

A hot air blast, enriched with oxygen and auxiliary reducing agents (coal powder oil, natural gas) is injected near the bottom, providing a counter-current of reducing gases. The hot blast is provided by hot stoves (cowpers) and the blast furnace is the biggest energy consumer in a combined iron- and steel work. The blast is needed to transfer heat to the

¹⁴ IPCC Reference document on Best Available Techniques on the Production of Iron and Steel, December 2001, www.eipccb.jrc.es

solid burden of coke pellet etc. in order to raise temperature for reaction. The blast also helps to provide the oxygen necessary for coke gasification and to transport the gas, which on contact with the burden reduces iron oxides. The stoves are heated by burning gases (usually blast furnace gases enriched with COG.) up to about 1100-1500°C. Then the burning is cut off and cold ambient air is forced through the stoves in reverse direction to be heated and to form the hot blast, which is fed to the blast furnace. Three or four hot stoves are necessary for each blast furnace.

As the blast furnace burden moves down, its temperature increase, thus facilitating oxide reduction reactions and slag formation. The air blast is reacting with reducing agents to produce mainly CO. Oxygen from the iron ore reacts with the coke or the CO to form pig iron, slag and CO or CO₂, which is collected as blast furnace gas (BF-gas) at the top of the furnace. CO is formed due to incomplete oxidation of the reducing carbon. The BF-gas is treated in two steps to remove coarse and fine particulate material, including ammonia, SO₂, Fe, C and cyanide compounds. Treating of BFgas is not always economically favourable. The gas can be used as a fuel for heating purposes or for electricity production.

The liquid pig iron and slag products are collected at the bottom and transported by torpedo vessels to the steel plant. The slag is processed to produce aggregate, granulate pellet for road construction and cement manufacture. The molten slag is treated with water causing steam and fugitive H₂S and SO₂ emissions. When the pig iron leaves the furnace it comes in contact with atmospheric oxygen, resulting in fugitive emissions of Fe₂O₃ (brown fume).

The coke is used both as a reducing agent, to allow proper blast furnace operation, and as a matrix that the gas is transported through in the blast furnace. Without this carrying capacity, blast furnace operations would not be possible. The coke leaves the furnace as CO, CO₂ and as carbon in the pig iron. To decrease costs and emissions, coke is partly replaced by coal, which is injected near the bottom level.

Basic oxygen steel making (figure 3)

The metal is transported from the blast furnace by transfer cars or torpedo ladles. Before the pig iron is put into the LD converter, the metal is being pre-treated with desulphurisation by adding calcium carbide or lime to a sulphur content of less than 0.001 %. The sulphur will be bound in the slag and so will for instance phosphor and metals. The slag does not contain any carbon or nitrogen, since these substances will be bound in the gas. The slag is usually sold and used in road construction or in cement industry.

The objective in oxygen steel making is to burn (oxidise) the undesirable impurities in the pig iron. These impurities are mainly carbon, sulphur, manganese and phosphor. The carbon content is reduced in produced steel and is emitted as CO and CO₂ in the steel converter gas (BOF-gas or LD gas). Oxygen is blown through the LD converter until all impurities are bound in slag or LD-gas. Produced crude steel is then transported to the casting machine.

In the steel converter the pig iron (4 % carbon content) is converted to steel (<1% carbon content) by adding oxygen. Remaining carbon (CO + CO₂) is released as steel converter gas, which could be used as a fuel (as in Luleå) or flared (as in Oxelösund).

The energy required to raise the temperature in the LD converter to melt input materials is supplied by the exothermic oxidation reactions, meaning that no additional heat input is required on the other hand, scrap or ore have to be added to balance the heat. Additional energy is required to preheat and dry the converter after relining and repairing, and preheating the ladle containing liquid steel and electricity is needed to operate the converters and to produce oxygen.

Fugitive emissions are arising from pig iron pre-treatment, converters, ladles (when not tight enough), charging, tapping of liquid steel, handling of additives and oxygen blowing.

After the crude steel production, alloy metals are added and then steel is formed to slabs, before making metal plates in the rolling mill. Finally the metal plates are cut into peaces and painted.

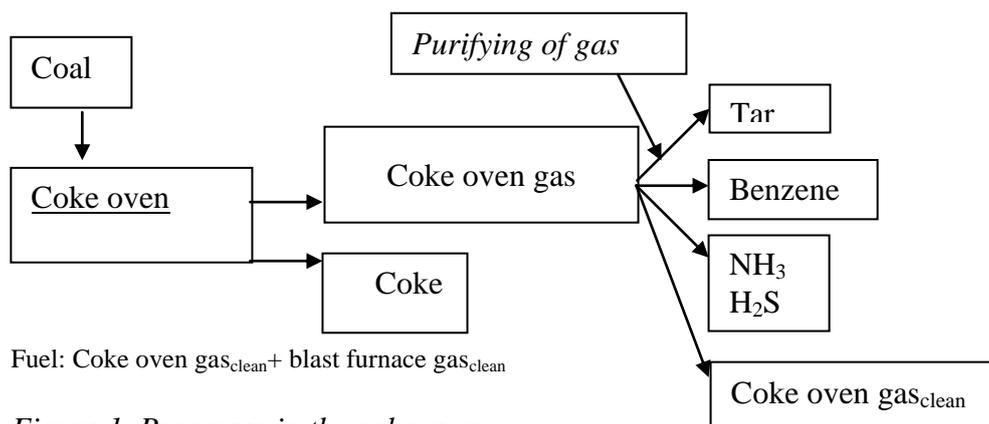


Figure 1. Processes in the coke oven

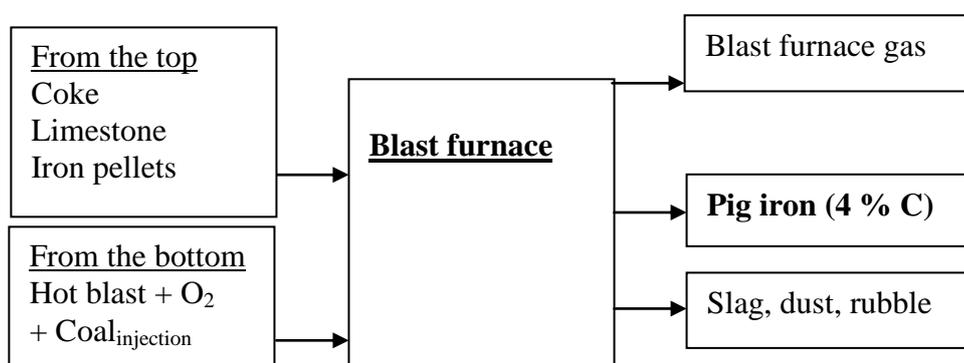
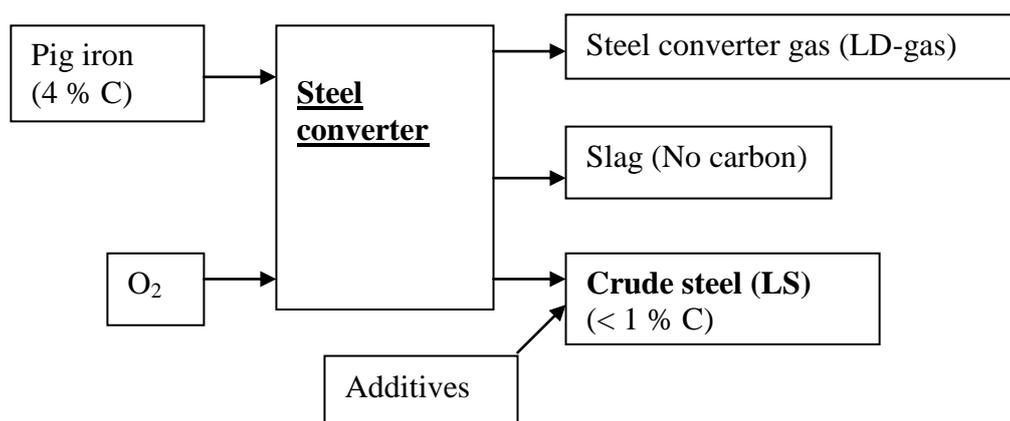


Figure 2. Processes in the blast furnace



Exothermic reaction → no extra energy needed in steel converter, but though to heat the pig iron before pouring it into the converter.

Figure 3. Processes in the steel converter

Appendix 2

Processes in refineries¹⁵

The purpose of refining is to convert natural raw materials such as crude oil into useful marketable products, such as gasoline, oil products, diesel, bitumen, and petroleum coke but also non-fuels such as raw materials for chemical industry etc. Crude oil is naturally occurring hydrocarbons found in many areas of the world in varying quantities and compositions.

Petroleum refineries are complex plants, where the combination of a sequence of processes is usually very specific to the characteristics of the crude oil used and the products produced. The purpose of and emissions sources in different processes are described in table A1.

Table A1. Purposes and emissions from different processes in refineries

Process	Purpose	Emissions
Alkylation	yield high quality motor fuel blending	Fuel combustion
Bas oil production	Evaporate solvents to receive base oil with lubricant and bitumen as by products.	Fuel combustion Fugitive solvent emissions Process vents etc.
Bitumen production	remove waxy distillates from certain crude oils	Fuel combustion, but low energy consumer
Catalytic cracking	using heat to upgrade heavier hydrocarbons into more valuable lighter ones	Major potential for emissions Relative high levels of CO Fuel combustion
Catalytic reformers	upgrade heavy naphtha for use as a gasoline feedstock	
Coking processes	Transform low value residual fuel to transportation fuels such as gasoline and diesel. By-products are refinery fuel gas, LPG and coke etc.	

The *first phase* in the refining process is desalting of crude oil and the subsequent distillation of the lighter components and naphtha is carried out to recover methane and ethane for use as a refinery fuel (refinery gas), LPG (propane and butane), gasoline and petrochemical feedstocks. This light product separation is done in every refinery.

The *second phase* includes breaking hydrocarbon molecules into smaller molecules, joining them to form larger molecules or reshaping them into higher quality molecules. The goal of these processes is to convert some of the distillation fractions into marketable products. The market demand has for many years obliged refineries to convert heavier fractions to lighter

¹⁵ IPCC Reference document on Best Available Techniques for Mineral Oil and Gas Refineries, December 2001, www.eipccb.jrc.es

fractions with a higher economic value. The refineries separates atmospheric residue into vacuum gas oil and vacuum residue fractions by distillation under high vacuum.

Cooling systems is also apart of the refinery, to allow processes to take place at the right temperature and as an energy system as well. Cooling is achieved by heat exchangers and by using water/air.

Energy system

Heat and electricity are needed to run a refinery, for instance in all refineries heat is required to preheat the feed before distillation. The fairly extensive heat required is generally satisfied by fuel combustion. The fuels needed to produce steam and power for heat and electricity production originates either from fuels that are produced by the refinery itself or bought from outside. Refinery gas consisting of methane, ethane and ethylene in combination with excess hydrogen is the most commonly used fuel in the refinery. This gas is produced in different processes and is a quite low-polluting fuel if properly treated.

Emissions

Refineries generates emissions to air from storage and from the refining process, se table A2. The main raw material to the refinery is crude oil, but also huge amounts of chemicals is being used, which leaves the refinery as a part of products or as emissions. Refinery processes requires a lot of energy; typically more than 60 % of the emissions are related to production of energy for the various processes.

Power plants, boilers, heaters and catalytic cracking are the main sources of emissions. The main pollutants are CO₂, CO, NO_x, SO_x, VOC and particles. Table A2 below shows a brief summary of the main pollutants and their main sources. There are several abatement techniques to avoid emissions.

Almost all carbon in the crude oil will be converted to CO₂ sooner or later. About 3-10% will be emitted within the refinery during the processing of crude oil into marketable products. The remainder will be converted to CO₂ once the refined product are sold and consumed. The range of CO₂ emissions within a refinery is normally 0.02-0.82 tonnes of CO₂ per tonne of crude oil processed.

Combustion processes are the main source of **NO_x**. Roughly 60-70 % of the NO_x from a refinery derives from the use of fuels in furnaces, boilers and turbines (emissions from stationary combustion).

Since all crude oil contains sulphur, **SO_x** will be emitted during combustion also within the refinery. About 60-70 % of the SO_x within the refinery comes from fuel combustion. During the last 20 years the crude oils used contain less sulphur, and more sulphur has been recovered within the refinery. Hence the sulphur content in the produced fuels and emissions of SO_x within the refinery has decreased in the same period.

Fugitive emissions of NMVOC occurs form many sources. The most important source is process equipment, which generally accounts for 50 % of total emissions.

Table A2. Main sources of different emission at a refinery.

Emissions	Main sources
CO₂	Process furnaces, boilers, gas turbines Catalytic cracking CO boilers Flare systems Incinerations (burn to ash)
CO	Process furnaces, boilers, gas turbines Catalytic cracking CO boilers Flare systems Incinerations Sulphur recovery units
NO_x, NO₂, N₂O	Process furnaces, boilers, gas turbines Catalytic cracking CO boilers Coke calciners Flare systems Incinerations
SO_x	Process furnaces, boilers, gas turbines Catalytic cracking CO boilers Flare systems Incinerations Coke calciners Sulphur recovery units
NM VOC	Storage and handling facilities Gas separation units Oil/water separation units Fugitive emissions Vents Flare systems
CH₄	Storage and handling facilities Cold vents and leaks