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SMED
Swedish Environmental Emissions Data

Improved statistics for SSAB, refineries and lime producers

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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

In the beginning of 2003, two projects carried out by SMED resulted in suggestions on how to improve the quality of reported emissions for three different sectors (Iron and steel production, refineries and lime production) to the UNFCCC, the European Union's Greenhouse Gas Monitoring Mechanism and to CLRTAP.

In one of the projects[1] it was analysed whether to use activity data from the national energy statistics or information on emissions from the companies' legal Environmental Reports when reporting energy emissions from combustion. It was concluded that the energy statistics should be used in the future as well. However, some improvements of the methodology and activity data should be made for the iron and steel producing company SSAB and for the refineries. These improvements were to result in consistent time series in line with the IPCC Good Practice Guidance (GPG)[2] and subsequently improved quality of reported emissions.

In the other project[3] CO_2 emissions from about 300 companies in some 7 sectors were estimated. The emissions were to be used as a basis for allocation of CO_2 emission rights within the system of green house gas emission trading. In the study it was found that the time series of the lime-producing industry were inconsistent. This was due to the fact that the activity data used did not include all lime-producing companies in Sweden for all years between 1990 and 2001.

1.1 Aim of study

As a result of the projects described above the aim of this study is to assemble consistent activity data and recalculate emissions for SSAB, the refineries and the lime-producing companies for the years 1990-2002. Further, the methodology applied for the emission calculations shall be in line with the IPCC Guidelines[4] and GPG for emissions reported to the UNFCCC, the European Union's Greenhouse Gas Monitoring Mechanism and to CLRTAP.

2. SSAB

The SSAB plants in Oxelösund and Luleå are the only two Swedish iron and steel plants that base their production of iron on iron sinter reduction in a blast furnace process. Coke and coal are injected to the blast furnace along with iron sinter in order to reduce the iron (lower the oxygen content). One of the outputs of the process is the so-called blast furnace gas, which is collected and reused as fuel in the coke ovens and blast furnaces et c. The fact that SSAB uses blast furnace gas, coke oven gas and steel converter gas (LD gas) as fuels makes the calculations of emissions from SSAB more complicated than for other iron and steel producing companies.

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[1] Ivarsson & Skårman, 030505: Energy Statistics versus Environmental Reports. SMED report.
[2] IPCC NGGIP. Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories, 15 June 2001.
[3] Iverfeldt, Å., 030407: Förbättring av dataunderlag för tilldelning av utsläppsrättigheter-FlexMex2. SMED report.
[4] IPCC Guidelines for National Greenhouse Gas inventories, revised 1996.

2.1 Former method

Energy emissions from stationary combustion have earlier been calculated by use of the following equation:

$$\text{Emissions from fuel combustion}_{fuels}\text{ (unit)} = \sum \text{Fuel consumption (unit)} * TV_{fuel} * EF_{fuel}$$

TV = Thermal value EF = Emission factor

The emissions from stationary combustion were based on the fuel consumption of coke oven gas, blast furnace gas, LD gas, coal, oil, propane and butane. Transformation losses in the coke oven were added to this category.

Fugitive emissions are defined as transmission losses and these included losses of coke oven gas, blast furnace gas and LD gas during transport and storage.

Process emissions of CO_2 from pig iron production in the blast furnace were calculated by use of the following equation:

$$\text{Emissions}_{pig\ iron} = [\text{Amount of coke oven coke}_{total} - \text{Amount of coke oven coke}_{blast\ furnace\ gas}] * TV_{coke\ oven\ coke} * EF_{coke\ oven\ coke}$$

All non-CO_2 process emissions were collected from SSAB's Environmental Reports.

2.1.1 Problems with the former method

- Emissions from fuel combustion were overestimated as they were, amongst others, based on the consumption of coal, which is used to produce coke and coke oven gas.
- Emissions in the form of transformation losses do not occur in the coke oven from stationary combustion since the carbon that is not included in the coke oven gas or coke is bound in tar and benzene.
- Emissions from combustion in coke ovens were included in CRF *1A2a – Iron and steel production,* but should be included in CRF *1A1ci – Manufacture of solid fuels*.
- Transmission losses are gases that are flared. Emissions from flaring of coke oven gas, blast furnace gas and LD gas should be reported in CRF *1B1c - Other fugitive emissions* and not in CRF *1A2a – Iron and steel production* or *1B1b – Fugitive emissions in petroleum refining* as was the case before.
- The process emissions of CO_2 are not correctly calculated when using the equation above. Apart from coke, coal and other carbon containing materials are also used as reducing agents and should therefore be included in the equation. Also, the blast furnace gases produced in the blast furnace are collected and no extra process emissions occur.

Emissions arising from SSAB and problems connected to the former method are described in detail in the SMED report "Energy Statistics versus Environmental Reports".[5]

[5] Ivarsson & Skårman, 030505: Energy Statistics versus Environmental Reports. SMED report.

2.2 New method

In the following chapter the new methods to calculate emissions from stationary combustion, flaring and processes for SSAB are described. The changes involve activity data, thermal values and emission factors.

2.2.1 Emissions from stationary combustion

All emissions from stationary combustion are calculated by use of the following equation:

$$\text{Emissions from fuel combustion}_{\text{fuels}}\ (\text{unit}) = \sum \text{Fuel consumption (unit)} * TV_{\text{fuel}} * EF_{\text{fuel}}$$

According to the IPCC Guidelines, emissions from fuels such as coke oven gas and blast furnace gas used in the *coke oven* to produce coke should be reported in CRF *1A1ci – Manufacture of solid fuels*. Emissions from all combustion of coke oven gas, oil, propane and butane to produce heat in the *steel converter and rolling mill* should be reported in CRF *1A2a – Iron and steel production*.

At both SSAB in Oxelösund and Luleå coke oven gas and blast furnace gas are used in energy plants to *produce electricity and heat*. According to the IPCC Guidelines all public (i.e. sold) electricity and heat production should be reported in CRF *1A1a – Public electricity and heat production*. In Luleå the gases are sold to Luleå Energi that in turn reports the fuel consumption. These emissions are not recalculated within this project. Oxelösund, however, has integrated energy plants (OK2/OK3) and emissions arising from combustion of oil and gases in these plants have been recalculated within this project.

2.2.2 Fugitive emissions

Flaring of gases should be reported separately as fugitive emissions and since the coke oven gas, blast furnace gas and LD gas are produced from solid fuels (coal and coke), emissions from flaring should be reported in CRF *1B1c – Other fugitive emissions from solid fuels*.

2.2.3 Process emissions

Since the primary purpose of coal and coke in the blast furnace is to secure oxidation and act as reducing agents, the emissions from combustion of blast furnace gas to produce pig iron in the blast furnace are to be reported in CRF *2C1 – Iron and steel*.

The recommended Tier 2 method in the IPCC guidelines is to base the calculations on the amount of reducing agents– injection coal, coke oven coke and petroleum coke– used in blast furnaces for the production of iron. Other information that is needed for the Tier 2 method is the amount of pig iron and sludge produced, as well as the amount of pig iron used for steel production and the amount of produced steel, and the carbon contents in all those parts. This information is not provided by the energy statistics or by the Environmental Reports. The only way to achieve this information is to contact SSAB directly. A more convenient way, and not less accurate, is to calculate emissions from the blast furnace based on consumed blast furnace gas.

The blast furnace gas mainly comes from the coke and the injection coal, but also from limestone. According to the IPCC guidelines, emissions of CO_2 from the use of limestone should be reported separately in CRF *2A3 – Limestone and dolomite use*. However, since the proportions of carbon from limestone released as CO_2 and the carbon bound in sludge are not known, [6] all emissions from blast furnace gas are reported in CRF *2C1 – Iron and steel production*.

2.3 Activity data

Activity data on fuel consumption are based on data collected directly from SSAB by the Energy Statistics Programme.[7] New data were collected for this project to make sure that the emissions from the use of different fuels were reported in the correct CRFs. The reported emissions and their origin are summarised in Table 2.1.

Table 2.1. Distribution of emissions from SSAB in different CRF sectors.

Emission source	Fuel	CRF	Sector
Stationary combustion			
Coke oven	Coke oven gas Blast furnace gas	1A1ci	Manufacture of solid fuels
Steel converter and rolling mill	Coke oven gas Propane/butane Oil	1A2a	Iron and steel production
Energy plants (OK2/OK3 + Luleå energi)	Coke oven gas Blast furnace gas Oil	1A1a	Public electricity and heat production
Fugitive emissions			
Flaring	Coke oven gas Blast furnace gas LD gas	1B1c	Other fugitive emissions from solid fuels
Processes			
Blast furnace	Blast furnace gas	2C1	Iron and steel production

2.4 Thermal values

The thermal values of the gases change due to different composition of coal and coke et c. The thermal values of coke oven gas and blast furnace gas are measured at SSAB every third minute. Mean values are reported from both SSAB plants to Statistics Sweden four times a year together with activity data. The thermal values used in earlier submissions were mean values from both plants, see Table 2.2. This is the reason why the thermal values have changed over the years at least for blast furnace gas and LD gas.

Within the project the thermal values used in Submission 2003 were compared with those used in the Flexmex2 project and those reported for this project by SSAB, see Table 2.2.

[6] Klas Lundbergh, SSAB Oxelösund 020823: klas.lundbergh@ssabox.com.
[7] Data collected by Michel Schöllin, Energy Statistics, SCB: 019- 176899

The results show that the thermal values for coke oven gas and blast furnace gas are quite similar. Since there is more knowledge on how the thermal values reported by SSAB have been calculated, it has been decided to use these in Submission 2004. The thermal values are specific for each year and plant. For LD gas, however, the knowledge of thermal values is insufficient. SSAB in Luleå has reported thermal values for 8 years out of 13. For the years without reported thermal values, a mean value of the eight years with reported values has been used (7.12 MJ/m^3 LD gas). SSAB in Oxelösund has not reported any thermal values. In the Environmental Report of 2001 the total energy content of the LD gas was reported. When calculating the thermal value on the basis of this energy content the resulting value was unreasonably low (4.6 MJ/ m^3 LD gas). Therefore the mean value for LD gas from SSAB in Luleå has been used for all years in Oxelösund. In future submissions new thermal values will be collected from SSAB to assure the correctness of the calculations. If no thermal values are measured and reported by SSAB, adequate values/mean values from earlier years will be used.

2.5 Emission factors

Except for the emission factor of CO_2, all emission factors for coke oven gas, blast furnace gas and LD gas will be the same in Submission 2004 as they were in Submission 2003. The Swedish EPA has earlier calculated the emission factors for CO_2 for the gases. Again, the emission factors from Submission 2003 have been compared to those used in the FlexMex2 project, those reported by SSAB (through carbon balances for the entire plants) for this project and the IPCC default values, see Table 2.2).

Table 2.2. Comparison of thermal values and emission factors from different sources: Swedish reporting to UNFCCC submission 2003, values from SSAB, IPCC default values, values used in the Flexmex2 project and values agreed on for Submission 2004, based on this comparison.

	Coke oven gas	Blast furnace gas	LD gas
Thermal value (MJ/Nm3)			
SMED (Subm 2003)	16.75	2.9	7.2
SSAB 2001 (mean value Luleå)	18.48	2.78	7.12
Flexmex 2 (Jernkontoret)[8]	18.36	2.88	8.10
Submission 2004 (all years)	Ind. Values for each plant and year, ca 17-18	Ind.values for each plant and year, ca 2.6-3.0	Ind. values and mean value (7.12)
Emission factor CO_2 (g/MJ)			
SMED (Subm 2003)	60.0	103	200
Flexmex 2 (Jernkontoret)[8]	37.6	299	185
SSAB 2001 (Oxelösund)	46.4	314	187
IPCC default	47.7	242	-
Submission 2004 (all years)	46.4	299	187

[8] Birgitta Lindblad, Jernkontoret: 08-679 17 00

The results of the comparison show that the emission factors vary quite a lot. The IPCC Guidelines recommend the use of country specific factors, when available. There is no knowledge of how the emissions factors provided by the Swedish EPA were calculated. The emission factor for blast furnace gas seems particularly low.

SSAB creates a carbon balance for each plant to control the flow of carbon through the processes, based on the carbon content in incoming and outgoing material:[9]

<u>Coke oven</u>:
coal + blast furnace gas → *coke oven gas* + coke + slag + tar + benzene

<u>Blast furnace</u>:
coal + coke + iron pellets + limestone + briquettes → *blast furnace gas* + pig iron + slag + soth

<u>Steel converter</u>:
crude iron + carbide → *LD gas* + crude steel + slag

The emission factors for coke oven gas and blast furnace gas were calculated by using data on the amount of used gases and CO_2 emissions reported in the carbon balances of Oxelösund in the years 2001 and 2002, as well as the specific thermal values reported to the Energy Statistics. The emission factor for coke oven gas is a little bit lower in 2002 than in 2001 (43.94 and 46.35 g CO_2/MJ) and is closer to the IPCC default value in 2001. The emission factor for blast furnace gas is a bit higher in 2002 than in 2001 (323.10 in 2002 and 313.87 g CO_2/MJ in 2001).

The emission factor for LD gas is the same for both 2001 and 2002 (187.22 g CO_2/MJ). The calculations are based on the carbon balance of SSAB in Oxelösund and the values for amount of used gas, emissions and thermal values are the same for both years. Unfortunately there was no carbon balance available from SSAB in Luleå. Due to lack of information on the thermal value for the Oxelösund plant, the mean thermal value from the Luleå plant, as described above, is used.

The emission factors (Submission 2004) for coke oven gas (in 2001) and LD gas seem to be of good quality when compared to e. g. the IPCC default values. Since carbon balances are only available for the years 2001 and 2002, the emission factors are more uncertain for remaining years. The uncertainty is estimated to +/- 5 % for years around 2000 and +/-10 % for years in the beginning of the 1990.[10]

SSAB's emission factor for blast furnace gas, however, seems to be very high compared to the IPCC default value, and default values are in most cases over- rather than under-estimated. Therefore it has been decided to use the emission factor calculated by Jernkontoret (the Swedish Steel Producers' Association) for all years.[11] This emission factor is a mean value calculated on the basis of yearly values for a long period of time.

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[9] Rolf Didriksson, SSAB Oxelösund 030814: rolf.didriksson@ssabox.com.
[10] Estimated by Curt-Åke Boström, IVL: 031-7256212.
[11] Approved by Curt-Åke Boström, Tina Skårman, Anna-Sofia Kumlin: IVL and Maria Lidén and Anna-Karin Ivarsson: SCB.

2.6 Non-CO_2 process emissions

Non-CO_2 process emissions that are calculated on the basis of fuel consumption have been recalculated to match the system boundaries used for CO_2 emissions. The used emission factors for these emissions are the same as those used in earlier submissions.

2.7 Results

For confidential reasons the resulting emissions from SSAB will not be presented here.

Recalculations have been made for all emissions. A comparison was made with data in the company's Environmental Reports for 2000 and 2001 for emissions of CO_2, NO_X and SO_2, which correlate very well with the emissions that have been reported by SSAB in the company's Environmental Report. The small differences in the values are most probably a result of the differing emission factors used. The CO_2 emissions have landed on a more reasonable level than was the case before, the main reason for this being the excluded emissions from the consumption of coal and new emission factors.

2.8 Quality control

Activity data and thermal values have been collected directly from SSAB and are considered to be of good quality and high accuracy. The emission factors for CO_2 have been reviewed and changed for Submission 2004. The other emission factors are the same as in earlier submissions.

3. Refineries

The Swedish refineries have about 0.5 % of the worlds and 2.5 % of the European refinery capacity.[12] They are considered to be very energy efficient in an international perspective and increased emissions the last couple of years are mainly due to increased production of more refined and purified products and subsequently increased energy demand within the refinery.

3.1 Former method

Energy emissions from stationary combustion (CRF *1A1b*) have been calculated by use of the following equation:

$$\text{Energy emissions}_{\text{fuels}} = \sum \text{Fuel consumption (unit)} * TV_{\text{fuel}} * EF_{\text{fuel}}$$

Activity data have earlier been collected from Energy Statistics surveys. The fuels used by refineries are oil, petroleum coke, diesel, natural gas, propane and butane and different refinery gases produced within the refineries.

Fugitive emissions (CRF *1B2a*), consist of emissions from catalytic cracking (NO_x), desulphurisation (SO_2) and from storage and handling of oil (NMVOC). Data on emissions have been and will continuously be collected from the companies' legal Environmental Reports.

3.1.1 Problem

For the years 1990-1999 the in-house generated fuels – different so called refinery gases – were not completely included in the surveys by the Energy Statistics Programme. To include emissions from the combustion of these gases, transformation losses and/or extra oil consumption were added to the total combustion of fuels. This resulted in inconsistent and incomparable time series due to very high fuel consumption and hence too high emissions, especially in the beginning of the 1990's.

Emissions arising from refineries and problems connected with the former method are described in detail in the SMED report "Energy Statistics versus Environmental Reports".

All activity data are available for the years 2000 and 2001, and the time series are consistent for all refineries except for one. Calculated emissions for this refinery were too low in the years 2000 and 2001 compared to earlier years and 2002 and compared to reported data in Environmental Reports in 2000 and 2001. The calculated emissions from the other refineries seemed to be comparable with reported emissions in the Environmental Reports for 2000 and 2001.[13] During the course of this project it has come to our attention that wrong units have been reported from two refineries, and that the use of LPG has been double-counted by one of the refineries.

[12] SOU 2003:60, Handla för bättre klimat
[13] Ivarsson & Skårman, 030505: Energy Statistics versus Environmental Reports. SMED report.

3.2 New method for emissions from stationary combustion 1990-1999

In this chapter the recalculations made for 1990-1999 and 2000-2002 are explained.

Activity data along with the corresponding energy content for all fuels consumed in 1990-1999 have been collected directly from the five Swedish refineries: Shell, Preem, Scanraff, Nynäshamn Petroleum in Nynäshamn and in Gothenburg.[14] Specific thermal values have been calculated for each producer and fuel. The thermal values differ due to the fact that used fuels mainly consist of by-products, with varying energy content, generated in the in-house production. The emissions have then been calculated by use of the same equation as for other combustion emissions:

$$\text{Energy emissions}_{fuels} = \sum \text{Fuel consumption (unit)} * TV_{fuel} * EF_{fuel}$$

Thermal values differ for all producers and may not be published for confidential reasons. Refinary gases have in earlier submissions been included in the fuel category *Other petroleum.* In order to be able to calculate more accurately the emissions from refinery gases, these will from now on be reported separately as *Refinery gas*.

The IPCC default value has been used for refinery gases. The IPCC default emission factor for CO_2 is:[15]

Refinery gas: 18.2 t C/TJ * 44/12 = 66.73 g CO_2 / MJ gas

3.3 Recalculations for emissions from stationary combustion for 2000-2002

For the two refineries with incorrect units on refinery gases, the units were changed and emissions recalculated.

For the one refinery with double-counted LPG, the LPG was excluded for the years 2000-2002, in order to establish consistent time series.

For the refinery with insufficient data in 2000 and 2001 data on fuel consumption was collected directly from the refinery for 2000 and from the Environmental Report in 2001, to create consistent time series.

The Quarterly Statistics survey used for the reporting to the Monitoring Mechanism do not fully include in-house fuels, such as refinery gases. Since three of the refineries mainly use in-house produced fuels it is preferable to include them both for the reporting to the Monitoring Mechanism and for the reporting to the UNFCCC. Data for two of these refineries were already available in the Industry Statistics survey that will be used for UNFCCC, and these data have therefore been used. For the third refinery though, data was not yet available but will be included to the UNFCCC submission 2004.

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[14] Shell- Ivan Mares: 031-744 60 00, Preem- Thomas Wennerberg: 031-64 60 00, Scanraff- Marie Colldén: 0523-669000, Nynäshamn in Nynäshamn- Jan Olsson: 08-52065111 and Nynäshamn in Gothenburg- Karin Max: 031-7551200.

[15] IPCC Guidelines for National Greenhouse Gas inventories, revised 1996. Workbook 1.6.

3.4 Results

Emissions calculated on the basis of activity data from the five refineries have resulted in a more consistent time series, since the same sources and fuels have been reported for all years. In Table 3.1 the emissions of CO_2 reported in Submission 2003 together with emission data reported in the legal Environmental Reports and recalculated emissions that will be reported in Submission 2004 are presented. Note that the time series for Submission 2003 are even more consistent than what has been reported in the Environmental Reports. It should be noticed that one of the refineries is not included in the data from Environmental Reports for the year 1990, which explains the low emissions for that year. Emission data for the year 2002 are not included in the table since they have not yet been available for all refineries.

Table 3.1. Emissions of CO_2 reported in Submission 2003, 2004 and in Environmental Reports.

Gg CO_2	2001	2000	1999	1998	1997	1996	1995	1994	1993	1992	1991	1990
Subm. 2003	2476	2350	3710	3376	3347	3296	3237	3869	2304	2675	3178	2964
Subm. 2004	2462	2598	2520	2429	2416	2363	2240	2289	2324	2273	2130	2104
En. Rep.	2311	2304	2280	2136	2304	2162	1856	2002				1271

En.Rep= Data from Environmental Reports, submitted by Kemikontoret.

3.5 Quality control

3.5.1 Activity data

The time series of activity data for 1990-1999 from the refineries have been controlled and they are now complete and accurate, without any abnormal dips or jumps in fuel consumption between individual years. All activity data and thermal values used are collected directly from the refineries and have hence been reviewed by the refineries themselves. Activity data have been checked against data in the Environmental Reports for 2000 and 2001 with satisfactory results.

3.5.2 Emissions

Emissions vary with activity data and the time series of the calculated emissions of CO_2 are thus very regular. Calculated emissions have been compared with reported data in the Environmental Reports for 1990 and 1994-2001. Generally, the emission reported in the legal Environmental Reports are lower than SMED's new calculations. Concerning the time series variation between the two data sources, it seems quite good for three refineries, but not for the remaining two. For these two refineries the variation in reported emissions between individual years were much higher in data from the Environmental Report than in new data for Submission 2004.

Also, newly calculated emissions of NO_x and SO_2 were compared with data in the Environmental Reports in 2000 and 2001. It was noticed that for the two refineries that mainly use conventional residual oils for combustion, the emissions were quite similar. However for the other three refineries, the emissions calculated within this project were much higher.

During the project the refineries got the possibility to comment on the emission factors used by SMED, but only three of them answered. One refinery replied that emission factors are used. The other two replied that emissions of for instance CO_2, NO_x, and SO_2 are being directly measured instead of being calculated by means of emission factors. All three refineries considered the SMED emission factors to be too high, especially for refinery gases, but also for residual oil and coke. Refinery gases may include varying amounts of hydrogen gas, which do not cause CO_2 emissions.

The refineries respond that the emission factors used by SMED are too high, which could explain why the emissions for Submission 2004 are higher than in the legal Environmental Reports.

4. Production of lime

In Sweden lime is produced at seven larger plants, owned by two groups: Svenska Mineral AB and Nordkalk AB (4 and 3 plants respectively). There are also a number of smaller plants – conventional producers of quicklime (conventional and produced in lime kilns within the pulp and paper industry) and hydraulic lime.[16]

Quicklime and dolomitic lime are produced by burning limestone or dolomite, the processes are characterised by the following reactions:

$CaCO_3$ (limestone)→ CaO (quicklime) + CO_2

$CaCO_3 \cdot MgCO_3$ (dolomite) → $CaO \cdot MgO$ (dolomitic lime) + CO_2

Quicklime and dolomitic lime are, for instance, used in blast furnaces, in sugar and carbide production and in the pulp and paper industry.
Hydraulic lime is produced by adding water to quick lime and is used in lakes to raise the pH value or as a binding material when making mortar.

As can be seen in the equations above, CO_2 is emitted when producing quick lime and dolomitic lime and these CO_2 emissions should be reported in CRF – *Lime production.*

4.1 Former method

Emissions of CO_2 from the production of lime from conventional ovens were earlier calculated by multiplying an emission factor with the total amount of lime produced in Sweden. Activity data were collected by SCB through a compulsory, yearly mail survey to lime-producing companies in Sweden. The survey included productions of dolomitic lime, quicklime (from both conventional production and the pulp and paper industry) and hydraulic lime[17]. For CO_2 emissions from lime production within the pulp and paper industry a standard value of 31 Gg per year was assumed and reported in CRF *2G – Other* (use of lime) in submissions before 2003. In Submission 2003 these emission data were deleted since these emissions were believed to be included in the emissions calculated on the basis of the survey.

4.1.1 Problems associated with the former method

The time series were inconsistent for the following reasons:

- Only companies that sell lime are included in the survey, which implies that e.g. Danisco Sugars, that produce quicklime to be used when purification process of sugar, is not included.
- Only companies with at least 10 employees are included, which implies that not all smaller companies are included all years.
- The survey only includes companies with own employees. As a result Nordkalk in Luleå that has started to hire employees from SSAB are not included all years.

[16] Quicklime= osläckt kalk baserat på kalksten = bränd kalk, hydraulic lime= släckt kalk som tillverkas från osläckt kalk, dolomoitic lime= osläckt kalk baserat på dolomit.
[17] Terese Kvammen, contact person for the Industrial mail survey at SCB: 019-176806

The production of lime is separated into three categories by SCB: quicklime, hydraulic lime and lime within the pulp and paper industry. For some reason this has not been known when making CO_2 calculations so only the production of quicklime has been included in the calculations of CO_2 from this sector, which means that lime within the pulp and paper industry was not included at all in Submission 2003. Since only a few lime producers within the pulp and paper industry are included in the SCB survey a better source needs to be used for these emissions.

4.2 New method to calculate Process emissions of CO_2

Recalculations affect process-related CO_2 emissions from the production of lime (quicklime, hydraulic lime and dolomitic lime) and these recalculations will be explained in this chapter.

To make a consistent time series covering all production of quicklime, hydraulic lime and lime produced within the sugar and pulp and paper industry, new activity data have been collected for several sources for the years 1990-2002 as described below.

4.2.1 Svenska Kalkföreningen

Svenska kalkföreningen (Swedish lime association) is a trade union for Swedish producers of materials based on lime and dolomite.[18] Kalkföreningen annually collects activity data on the production of quicklime and dolomitic lime from their members. Since hydraulic lime is produced from quicklime there is no need to collect data for this production separately.

Activity data from Kalkföreningen are considered to be of high quality. The association only has a small number of members and the general knowledge of production processes is high. Activity data for the years 1990-1991 are a bit more uncertain since companies were sold and bought and complete information on the amount of produced lime does not exist. For the reason of varying numbers of members through the years, the time series are not completely consistent. The companies represented in activity data are

- Partek Nordkalk in Köping : 1990-2002
- Partek Nordkalk in Luleå: 1998-2002
- Cementa in Limhamn : 1990-1994 (the production continued in Kalproduktion Storugns AB years after that)
- Kalkproduktion Storugns AB: 1990-2002
- SMA Svenska mineral- Sandarne, Boda, Rättvik: 1990-2002
- SMA Oxelö kalkverk; 1997-2002

Due to the better quality activity data from Kalkföreningen have been used in the calculations of CO_2 emissions, for the entire time series, instead of data from the SCB survey. The process emissions of CO_2 are calculated by multiplying the amount of produced quicklime and dolomitic lime with the default emissions factors of IPCC:

[18] http://www.kalkforeningen.se

Emission factor of quicklime: **0.785 ton CO_2 / ton**

Emission factor of dolomitic lime: **0.913 ton CO_2 / ton**

For the IPCC default factors it is assumed that the lime content ($CaCO_3$) in limestone is 100 %. The content of lime in limestone tends to vary, due to the lack of a mean value on the lime content, it has been decided to use the recommended default value.[19]
Emissions from the lime produced at SSAB in Oxelösund and Luleå are only included from 1998 and onward. This is due to the fact that SMA Svenska Mineral and Nordkalk, respectively, bought the plants in 1998. For the years 1990-1997 activity data for SSAB in Luleå has been collected from the Industrial survey, which is described below. Activity data for SSAB in Oxelösund for the same years has been collected directly from the plant within this project.

4.2.2 Sugar production (Danisco)

Danisco produces quicklime, which is used to purify sugar, from limestone. The predominant part of CO_2 emissions from the production of quicklime is however bound when producing calcium carbonate. This lowers the amount of emitted CO_2 in relation to the amount of limestone consumed.[20]

Calculations of CO_2 emissions are based on the consumed amount of limestone in the production of quicklime, as this was the only available information. Danisco assumes the use of limestone to consist of 97 % calcium carbonate ($CaCO_3$) limestone and the average reuse of CO_2 to be 87.5 %

The production of quicklime is described by the following chemical reation:

$CaCO_3 \rightarrow CaO + CO_2$

The molecular weights are:

$CaCO_3$: 100.1 g/moles CO_2: 44.0 g/moles

The emission factor for CO_2 from 1 ton of $CaCO_3$ is:
1 [ton $CaCO_3$] * 44.0 [g CO_2/mole] / 100.1 [g $CaCO_3$/mole] = 0.44 ton CO_2 / ton $CaCO_3$.

CO_2 emissions from limestone in the Danisco case are calculated in the following way:

Emission factor for CO_2 from limestone = 0.44 ton CO_2 / ton $CaCO_3$
$CaCO_3$ content in limestone = 0.97
Amount of bound CO_2 = 0.875

Amount of CO_2 emissions = Amount of limestone [ton] * 0.97 * 0.44 * (1 – 0.875)

[19] Kalkföreningen: Alf Wikander, 08-677 53 26
[20] Danisco: Lennart Rantzow, 040-537168

In the coming year's Industry survey the quicklime produced at Danisco will be included. No further contacts need to be made directly with Danisco as long as the production seems to be in line with earlier years.[21]

4.2.3 Pulp and paper industry

Within the pulp and paper industry lime is produced to recover cooking chemicals in the kraft process. Most of the lime can be reused and only 5 % of the needed amount of lime is new make- up lime. The amount of make-up lime used is about 19.75 kg / ton kraft pulp produced[22] in a modern pulp plant but older plants have somewhat higer need of make up lime.The CO_2 emissions are calculated based on information on produced amount of kraft pulp from 22 Swedish kraft pulp plants[23] and the emission factors used are presented inTable 4.1. The emission factors are calculated based on information from Swedish Forest Industries Federation and from the Swedish Pulp and Paper Research Institute (STFI).

Table 4.1. Emission factors used from lime production within the pulp and paper industry.

Year	2002	2001	2000	1999	1998	1997	1996	1995	1994	1993	1992	1991	1990
Emission factor (ton CO_2/ton pulp)	8,7	8,9	9,3	9,7	10,1	10,5	11,2	11,5	11,8	12	12,3	12,6	12,9

4.2.4 SCB mail survey to lime producers

According to data on produced and sold lime within the Industrial survey there are some companies that produce lime, but are not member of Kalkföreningen. To complement information from Kalkföreningen the intention was to use activity data from the industrial mail survey. However, the lacking companies are, for some years, lacking in the industrial mail survey as well, as some of them have stopped producing lime, some have started production after 1990 and some are too small to be included all years.[24] The time series of emissions from lime production after the exclusion of the companies in Kalkföreningen are hence quite irregular, varying between 900 ton to over 300 000 ton lime per year. Emissions are especially high in 1990 due to the fact that one company with high production was included only that year. The emissions are also higher at the end of the time series due to the fact that a relatively large company was included in the survey from the year 2000 and onward.

A closer look was taken at the companies included in the survey and one of them was contacted. They explained that they don't produce lime themselves, but they buy it from France, and thus emissions from this lime production should not be reported in Sweden.

Kalkföreningen was contacted to ask for some of the other companies that are are included in activity data from the mail survey, but not in the data from Kalkföreningen. These companies where not believed to produce quicklime or hydraulic lime. [25]

Due to the above information and the fact that the production data is very irregular, the companies in question have not been included in CRF *2A2 – Lime production*.

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[21] Terese Kvammen, contact person for the Industrial mail survey at SCB: 019-176806
[22] Per Ulmgren, STFI: 08-6767329 and Ingrid Haglind Skogsindustrierna
[23] Ingrid Haglind Skogsindustrierna: 08-7627211, ingrid.haglind@forestindustries.se
[24] Terese Kvammen, contact person for the Industrial mail survey at SCB: 019-176806
[25] Kalkföreningen: Alf Wikander, 08-677 53 26

The only company, for which data is taken from the Industrial survey, is SSAB in Luleå. Data from the years 1991-1997 have been used. They had no lime production in 1990 and it was quite sparse in 1991. From 1998 data for SSAB in Luleå are included in data from Kalkförening since Nordkalk bought the lime-producing parts. The emission factor used for 1991-1997 is the same as for companies included in Kalkföreningen; 0.785 ton CO_2 / ton quicklime.

4.2.5 SSAB in Oxelösund 1990-1997

Data on lime production at SSAB in Oxelösund are included in data from Kalkföreningen from 1998. For earlier years though data has been collected directly from SSAB for 1990-1997.[26]

4.2.6 Carbide production (Casco)

Casco are producing and using quick lime within the production of carbide. According to the IPCC Guidelines CO_2 emissions arising from the lime production should be included in the calculations of CO_2 emissions from the whole carbide production, reported in CRF *2B4*.[27]

4.3 Results

The time series of CO_2 emissions from production of lime is consistent and all companies are included every year. The trend is that there is a small increase in conventional lime production, and hence the CO_2 emission has increased since 1990. The reported emissions are higher for all years compared to what has been reported in earlier submissions, see Table 4.2, due to that much more companies are included and earlier the activity data was not complete.

Table 4.2. Emissions of CO_2 in kton from the production of lime reported in Submission 2003 and Submission 2004.

		2002	2001	2000	1999	1998	1997	1996	1995	1994	1993	1992	1991	1990
Subm. 2003	Kton		367	367	313	359	385	333	333	367	312	300	346	343
Subm. 2004	Kton	549	525	531	478	527	486	492	504	505	445	416	455	500

4.4 Quality control

All obtained data has been reviewed to make sure that the separate time series are consistent. Thanks to Alf Wikander at Kalkföreningen, all lime-producing companies could be identified and his data could be complemented with data from SSAB, Danisco and producers of lime within the pulp and paper industry.

Activity data has mainly been obtained directly from the companies and the methods to calculate emissions are in line with the IPCC Guidelines for conventional lime producers. For Danisco and pulp and paper industries, with more complex processes, the calculations are based on information from the companies, to be correct.

[26] SSAB, Rolf Didriksson: 0155- 25 45 72.
[27] IPCC Guidelines for National Greenhouse Gas inventories, revised 1996. Reference Manual 2.22.

5. Discussion

Within this project the time series for different emissions from SSAB, refineries and lime producers have been revised to achieve consistency and accuracy.

It should not be a problem to collect activity data from *SSAB* for the coming years, thanks to a good cooperation between the Energy Program at Statistics Sweden and SSAB.
It has come to our attention that the emission factors for SO_2 and NO_x from coke oven gas, blast furnace gas and LD gas probably need to be reviewed. It was not possible to do this within this study. New emission factors for CO_2 from all the gases should be reviewed in a couple of years when more carbon balances are available from SSAB, preferably, in both Luleå and Oxelösund.

Activity data for *refineries* will continuously be collected from the Energy Statistics Program at Statistics Sweden. Data should however always be compared with data from the legal Environmental Reports as well as with earlier years, to make sure that the time series remain consistent. The development of country-specific emission factors for refinery gases and petroleum coke should be considered. The IPCC default values were considered to be too high according to the refineries, as mentioned in chapter 3.5.

To get accurate activity data to calculate CO_2 emissions from *lime producers*, data from Kalkföreningen should be used including SSAB. Data from Danisco might be collected from the SCB survey, but Danisco should be contacted as well at least the first year to make sure that they have reported the right amount of lime. For the amount of make-up lime use by the pulp and paper industries, the Swedish Forest Industries Federation should be contacted to get correct information.