EUROPEAN COMMITTEE FOR STANDARDIZATION
COMITÉ EUROPÉEN DE NORMALISATION
EUROPÄISCHES KOMITEE FÜR NORMUNG

CEN/TC 264/WG 33 "Greenhouse gas emissions in energy-intensive industries"

2nd Interim Report

including the Final Report on the Field Verification Tests

May 2014

Contract SA/CEN/ENTR/478/2011-12

Contents

1 Introduction

EC and EFTA have given a mandate (M/478) to CEN for the standardization of the determination of the greenhouse gas emissions from energy-intensive industries. According to the mandate the new standard shall provide harmonized methods for

- measuring, testing and quantifying greenhouse gas (GHG) emissions from sector specific sources
- assessing the level of GHG emissions performance of production processes over time, at production site and
- establishing and providing reliable, accurate and quality information for reporting and verification purposes.

The new standard will consist of six sector-specific standards, covering GHG emissions from sector specific sources of the iron and steel, the cement, the aluminium, the lime and the ferro-alloys industry. The complete list of standards to be worked out reads as follows:

prEN xxxxx, Stationary source emissions – Determination of greenhouse gas (GHG) emissions in energy-intensive industries – Part 1: General Aspects

prEN xxxxx, Stationary source emissions – Determination of greenhouse gas (GHG) emissions in energy-intensive industries – Part 2: Iron and steel industry

prEN xxxxx, Stationary source emissions – Determination of greenhouse gas (GHG) emissions in energy-intensive industries – Part 3: Cement industry

prEN xxxxx, Stationary source emissions – Determination of greenhouse gas (GHG) emissions in energy-intensive industries – Part 4: Aluminium industry

prEN xxxxx, Stationary source emissions – Determination of greenhouse gas (GHG) emissions in energy-intensive industries – Part 5: Lime industry

prEN xxxxx, Stationary source emissions – Determination of greenhouse gas (GHG) emissions in energy-intensive industries – Part 6: Ferro-alloy industry

Working Group CEN/TC264/WG33 is responsible for the development of the sector-specific standards, the supervision and monitoring of the work being done in the respective six sub-groups as well as the planning, performing and evaluation of verification tests in the five covered industry sectors.

This interim report gives an overview of the work being carried out in the six sub-groups and describes the current status of the standardization process. Sub-group 1 “General Aspects” has developed a draft standard describing the systematics of the standard itself as well as those applied methodologies which are the same for all industry sectors.

The five sector specific sub-groups have together with SG1

- developed a draft of the sector specific standard for the respective industry sector
- have delivered the draft standards through the secretariat of WG33 to CEN before end of April 2014.
- have organized the conducting and evaluation of the verification tests and
- have discussed the field test results.

2 Related documents

This summary report is based on the interim reports of the different sector specific sub-groups. Furthermore this report relates to the draft standards which have been provided by Sub-group 1 "General Aspects" as well as the 5 sector sub-groups:

Document N2196 (general aspects), N2197 (iron and steel industry), N2198 (cement industry), N2199 (aluminium industry), N2200 (lime industry) and N2201 (ferroalloys and silicon industry).

3 Background

Climate change is a topic with a very high priority in European policies. Therefore in 2008 the European Commission had formulated the general objective to create a European standard, "that will support policies and measures set up from moving towards a global low emissions economy. Standardization work will build upon international protocols and guidelines for reporting and verification aspects, and cover technical measurement aspects of production processes in energy-intensive industries, in coherence with EU-legislation and relevant provisions of international agreements."

Within a programming mandate (M/431), given to CEN in October 2008, a so called gap-analysis of EN and ISO standards as well as other international protocols or guidelines has been performed in order to investigate the necessity of developing an additional standard for greenhouse gas emissions reporting and assessment for energy-intensive industry. Six individual gap analyses have been worked out for the iron and steel, cement, lime, aluminium, ferroalloys and chlorine industries. The report was published in February 2010. The work performed based on this mandate has confirmed the presumed standardization needs. The recommendation was to set up a coherent set of standards as required and to realize this by the development of a new EN and ISO generic standard and a set of sector specific standards.

In December 2010 the EU-Commission gave the new mandate (M/478) to CEN in order to develop such standards. For this work the cooperation and involvement of industry experts were deemed to be essential, as the detailed knowledge of the industrial processes and industry plant structure is needed. According to the mandate the new standard to be developed shall cover the three major aspects mentioned in chapter 1. The new standard should build upon existing European and international guidelines and standards and should not overlap with or duplicate them.

After having invited several industry sectors to participate in the standardization procedure, the European iron and steel, cement, aluminium, lime as well as ferroalloys and silicon industry sectors agreed to contribute to this work. Industry´s contribution mainly consists of providing the required know-how by industry experts as well as by organizing the verification tests and providing the test plants or facilities.

4 Development of draft standards and planning of verification tests

The work of Working Group 33 has been divided into six topics: Sub-group 1 deals with all general aspects which are relevant for all sector specific standards. As the technical conditions of each industry sector and production technologies differ significantly from each other, Working Group 33 has delegated the work for the covered industry sectors to five sub-groups (Figure 4.1). The secretariat of WG33 is supported by DIN/VDI as well as the secretariat for Sub-Group 1 "General Aspects". Sub-group 2 (iron and steel industry) is supported by NEN, Sub-group 3 (cement industry) is supported by DIN/VDI, Sub-group 4 (aluminium industry) by SN, Sub-group 5 (lime industry) by NEN and Sub-group 6 (ferro-alloys industry) by AENOR), see Figure 4.1.

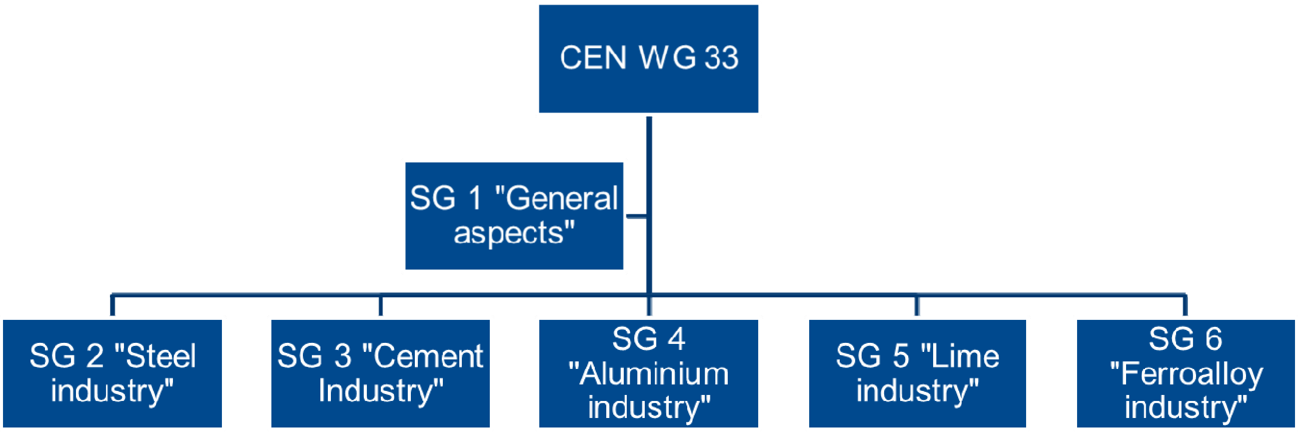

Figure 4.1: Structure of WG33 including sub-groups

For some of the involved industry sectors there is a significant importance to extend later the validity of this standard from European to global level. Therefore ISO has been involved from the beginning by an observer from Japan, who has participated in several meetings of WG33, SG1 and SG3. The draft standards have been sent to CEN/CCMC in April 2014. The objective was to initiate the parallel processing of the standards on CEN and ISO level. From WG33 point of view the result of the ISO voting was surprising: The ISO members voted for creating a new work item for this topic. On the other hand they denied to accept the CEN lead in this standardization process. This was based on the revised Vienna agreement which gives ISO the lead in all global standardization procedures in the future (with the exception if the ISO members specifically vote for a CEN lead). Furthermore a number of comments came regarding the contents, mainly of the general aspect standard. For WG33 and CEN this could create a problem with meeting the targets mentioned in the mandate. During the plenary meeting of CEN/TC 264 in May 2014 a compromise was agreed, which foresees that WG33 will continue its work under ISO lead, the same convenor and, if need be, the inclusion of additional members from ISO level. Based on this compromise it should be possible to conduct the parallel voting as planned and to finalize the standard according to the EC/EFTA mandate.

WG33 has held one meeting in Dusseldorf (9 May 2014). With respect to the timeline, all relevant milestones have been met. The draft standards have been delivered according to the planned target date (30 April 2014).

The convenor of WG33 together with the secretariat visited the European Commission, DG Enterprise in order to discuss the progress of the work of WG33. In this context DG Enterprise proposed to organize a conference in November 2014 in order to publish the results of this standardization project to the interested stakeholders. A conference will be organized in Brussels on 24 November 2014. Besides interested people from the Commission, the respective industry sectors, members of other energy intensive industry sectors shall be invited as well as ISO. Currently the agenda of the conference is being discussed and finalized.

5 SG1 General aspects

5.1 Organizational aspects

As Sub-group 1 is working on general aspects which are relevant for all industry sectors, the membership of Sub-group 1 covers experts from the iron and steel, cement, aluminium, lime and ferro-alloys industries. Furthermore experts for measurements and standardization are covered.

Sub-group 1 has met twice:

- on 19.11.2013 in Dusseldorf
- on 05.02.2014 in Dusseldorf

5.2 Progress summary

SG1 has achieved the following major outcomes:

- discussion and final decision on the elements covered by the general aspects standard
- discussion of and decision on general principles for GHG emissions determination and performance assessment according to the standard
- harmonization of major aspects with respect to methodology of the industry sector specific standards
- development of the draft standard on “general aspects” (Document N2196)
- coordination of planning, evaluation and results of verification tests
- discussion of general organizational aspects of all sub-groups

5.3 Drafting of the standard on general aspects

This draft standard deals with general aspects and is understood as a generic “umbrella standard” which defines common methodological issues and overall requirements which are applicable to all covered sectors. Figure 5.1 gives an overview of the final contents and structure of the developed draft standard.

This draft standard has been revised in the last year mainly regarding requirements to measurements, calibration as well as uncertainty assessment. As uncertainty has to be calculated / assessed according to the sector-specific methodologies, the detailed description has been shifted to the sector-specific standards.

The draft standard on general aspects has been finalized end of 2013, so that it could be used for the conducting and evaluation of the field tests.

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Figure 5.1: Final structure of draft standard on general aspects

6 SG2 Iron & steel industry

6.1 Summary

The Iron & Steel industry participates to a project of standardization of the assessment of GHG emission performance in energy intensive sectors. For verification of this standard, the European Commission's mandate requested verification tests of the carbon balance methodology used for calculation of direct emissions; these tests aim at comparing the calculated carbon flows derived from the material balance with the measured flows in stack fumes.

Such verification is impossible for an integrated production facility where 20-40 chimneys should have to be monitored - excluding the flares for which fume analysis and flow measurements are impossible - also because of the losses due to combustion of coke during its transfer from ovens and quenching operation. For these reasons, the best way to determine the total direct emissions of a steelmaking facility is to calculate the global carbon balance at site level.

Following the requirement of the Commission's mandate, the Iron & Steel sector proposed a limited verification on "simple" operations where it could be possible to check the agreement of carbon balance between inputs and outputs through products and stack fumes.

Two test campaigns have been realized TÜV Süd in a steel production facility in Germany and measurements have taken place on one particular sinter strand and the stoves of one particular blast furnace, each time for a duration of 48 hours. The first tests were performed in 2013 during the period Sept. 17th to Sept. 19th 2013 (Test 1) and were not really successful. The second test campaign realized during the period Feb. 11th to Feb. 14th (Test 2) gave good results with an excellent fit of both determinations.

6.2 Activities since first interim report

At time of first interim report only the sub-contractors were determined after the tender examination. Contracts were not yet signed and all the technical work occurred between September 2013 and April 2014.

Some delay occurred for starting the project due to confidentiality issues with the facility selected for performing the field tests. As a consequence, only TÜV people were authorized to be on site during the tests.

6.3 Verification tests

6.3.1 Selection and characterization of plants

During the call for tender examination, only one proposal appeared complete including the participation of a German steel production company and this tender was selected. Following the specifications of the call for tender, two specific plants were selected:

- A sinter strand which prepares the burden of blast furnace. The selection of the unit took into account the possibility of access to the stack and sampling of solid flows. This unit has a grid area of 250 m² and a production capacity close to 4 Mt/year.
- A battery of hot blast stoves (4 stoves) with a capacity of heating 200,000 Nm³/h of hot blast at a temperature of 1125°C and feeding a blast furnace with a capacity of 2 Mt/year.

6.3.2 Selected subcontractors

The subcontractors selected for these field tests are:

- Work Package 1 – Supervision: Yann de Lassat de Pressigny – Independent consultant member of WG 33/SG1 and formerly CO_2 manager at ArcelorMittal. Yann de Lassat de Pressigny has developed the methodological basis of the standard proposed by the Iron & Steel Industry.
- Work Packages 2 to 5 – Sampling, stack measurements, analysis and site organization: TÜV Süd in cooperation with TKSE Duisburg.

6.3.3 Measuring program

6.3.3.1 Sinter plant tests

After analysis of the production flow sheet, TÜV and the plant agreed on a procedure for the tests. Process inputs consist in two flows:

- Sinter mix ready for use, including coke breeze, ores, limestone, flue dust and recycling.
- Coke oven gas used for ignition of the mix on the travelling grate.

Outputs also consist of two flows:

- Merchant sinter delivered to the blast furnace plant,
- Sintering fumes extracted by a stack.

A sampling procedure was applied, giving a one sample per two hours sampling rate for the solid materials and the coke oven gas. The plant flow measurements were used for inputs and sinter delivery.

Stack monitoring included flow measurement by pitot probe and continuous fume analysis for oxygen (para-magnetism), CO, CO_2 (NDIR) and CH_4 (FTIR). Measurement data have been averaged on 2 hours periods. Plant flow measurements by venturi implemented at fan inlet have also be recorded and compared to stack measurements.

6.3.3.2 Hot blast stoves

Stove batteries work in a cyclic way with periods of blast heating and periods of checkers heating. In the case of the selected battery, two stoves are "on blast" and two "on gas" at any time except during inversion of flows when fuel gas inlet is stopped.

This battery uses a mix gas of BF and BOF gas prepared by a mixing station prior to the stoves and a small amount of coke oven gas, sent directly to the stove burners, for control of flame temperature. For safety and operation reasons, it was impossible to implement specific flow measurement devices on the gas ducts and the plant measurements have been used. Samples of gas have been taken and analysed for their total carbon content.

One single chimney collects the fumes of the stove battery. Measurements were made in the stack by means of pitot probe and compared with plant measurements. Flue gas was continuously analyzed for O_2 (para-magnetism), CO and CO_2 (NDIR) and all collected data have been aggregated to give 2 hour averages.

6.3.4 Measurement results

6.3.4.1 Sinter plant

6.3.4.1.1 Comparison of carbon flows

The test results show a major problem of discrepancy between inputs and outputs for Test 1 as presented in Figure 6.1. The calculated average carbon flow, based on the average of venturi and pitot flow measurements, shows an excess of 23% in output as compared to input and the trend line of comparison has a slope of only 0.24 with a correlation coefficient (R2) of only 0.11 indicating that output does not reflect the variations of input proportionally.

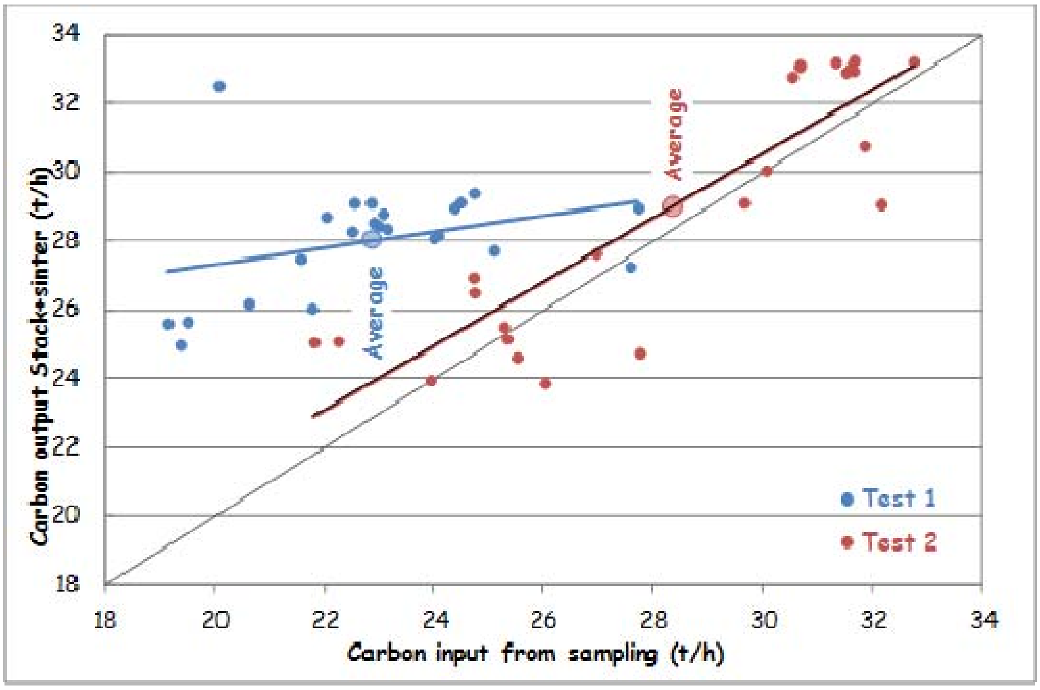

Figure 6.1: Comparison of input and output carbon flows

An analysis of the results led to modification of the test procedure during the second field test with enlarged number of sampling of sinter mix to compose the two hour samples and more frequent calibration of the gas analysers. As a consequence the result of the second field test can be considered as excellent with a difference of only 2.2% between carbon input and carbon output. During this test, the measured output reflects better the variation of input; the slope of the trend line is 0.93 and the correlation coefficient 0.77.

6.3.4.1.2 Analysis of results

Looking at the summary results given in Table 6.1, it appears that sinter mix and fumes are predominant in the carbon balance since they represent respectively more than 98% and 99% of the carbon flows. These two flows will be examined with more details.

	Sinter mix			CO gas			Input	
	Flow	C content	C flow	Flow	C content	C flow	Total C	Sinter mix share
	t/h dry	% dry	t/h	Nm³/h	kg/Nm³	t/h	t/h	
Test 1	465.9	4.83	22.48	2 465	0.1522	0.38	22.86	98.4%
Test 2	579.2	4.81	27.85	2 614	0.1898	0.50	28.34	98.2%

	Fume flow			Fume analysis				
	Venturi	Pitot	Average	O2	CO	CO2	CH4	Total C
	Nm³/h dry	Nm³/h dry	Nm³/h dry	Vol % dry	Vol % dry	Vol % dry	mg/Nm³ dry	kg/Nm³ dry
Test 1	772 448	775 743	774 096	15.70	0.80	5.91	15.91	0.0360
Test 2	786 087	783 150	784 619	15.29	0.95	5.89	14.18	0.0366

	Sinter			Fumes	Output	
	Flow	C content	C flow	C flow	C flow	Fume share
	t/h dry	% dry	t/h	t/h	t/h	
Test 1	379.8	0.053	0.20	27.85	28.05	99.3%
Test 2	466.2	0.050	0.23	28.75	28.99	99.2%

Table 6.1: Summary results of field tests at sinter plant

Although its share in carbon input is not really material, it can be noticed that the measured C content of coke oven gas is 25% higher for Test 2 as compared with Test 1. This is a consequence of care given to gas sampling and fast analysis to avoid contamination of samples. Carbon analysis of sinter mix samples

6.3.4.1.3 Stack flow measurements

Stack flow measurements by pitot tubes have been compared to plant measurements by venturi devices installed before the suction fans.

During the first test, there was no correlation between these two measurements (Figure 6.3). The alignment between the two measurements is much better for the second test with less scattered measured and a difference of averages also equal to 0.4%.

The average fume flows measured during the two test periods differ only by 1.4%, a value which is consistent with common practice of sinter plants where the fans are usually operated at constant conditions the speed of the travelling grate being adjusted depending on the characteristics of the burden.

Figure 6.2 shows that the improved sampling procedure during Test 2 had a noticeable effect on the spread of measured carbon contents. If the averages are almost equal at 4.8% C, the standard deviation has been more than halved from 0.37 to 0.16.

In the absence of information on the composition of the sinter mix considered as confidential, it is impossible to give any idea on the validity of the average C content.

6.3.4.1.4 Stack flow measurements

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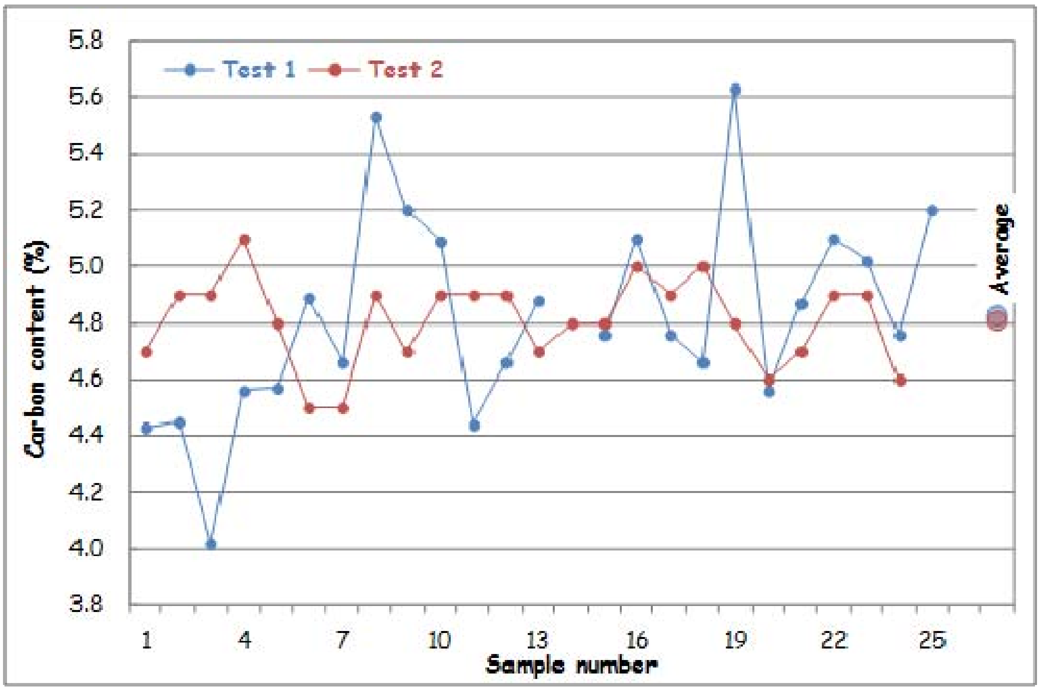


Figure 6.2: Carbon content of sinter mix samples

6.3.4.1.5 Solid flows

Between the measurement points of sinter mix and sinter flow, the solids pass through a number of tools and bins which allow for some disconnection of these flows, keeping a steady operation of the sinter strand while feeding and sinter extraction can vary. Therefore, the calculated sinter mix ratio (kg/t sinter) varies at the level of two hour data but these variations are smoothed on the test duration and both tests give the same average sinter mix ratio at a level close to 1235 kg/t sinter with a difference of only 1.3% between the two tests (Figure 6.4).

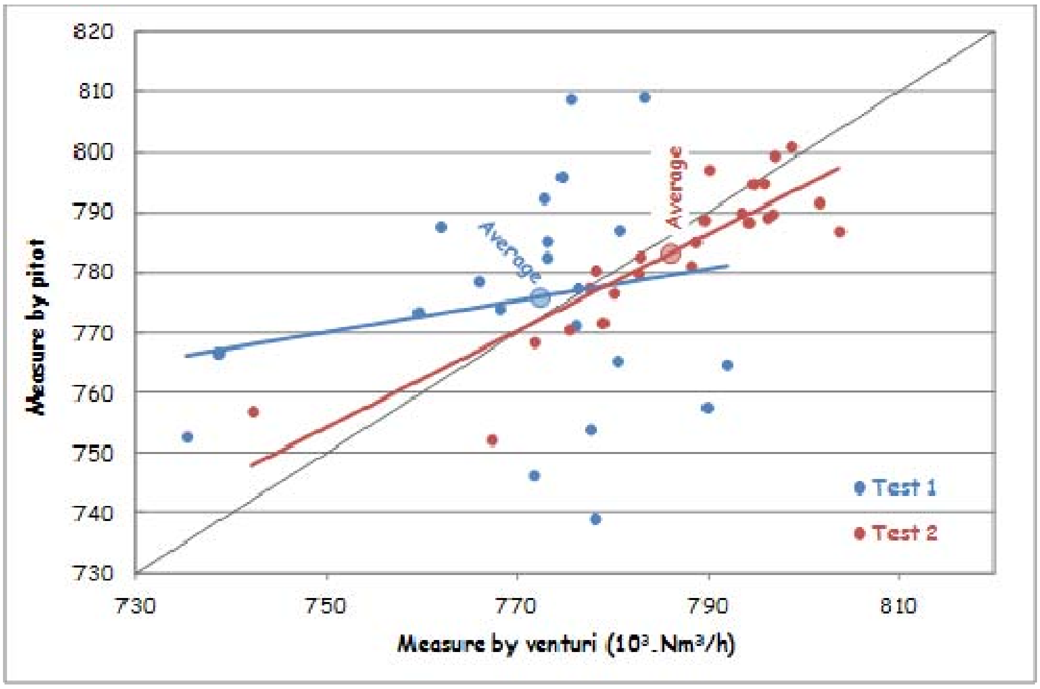


Figure 6.3: Comparison of stack flow measurements

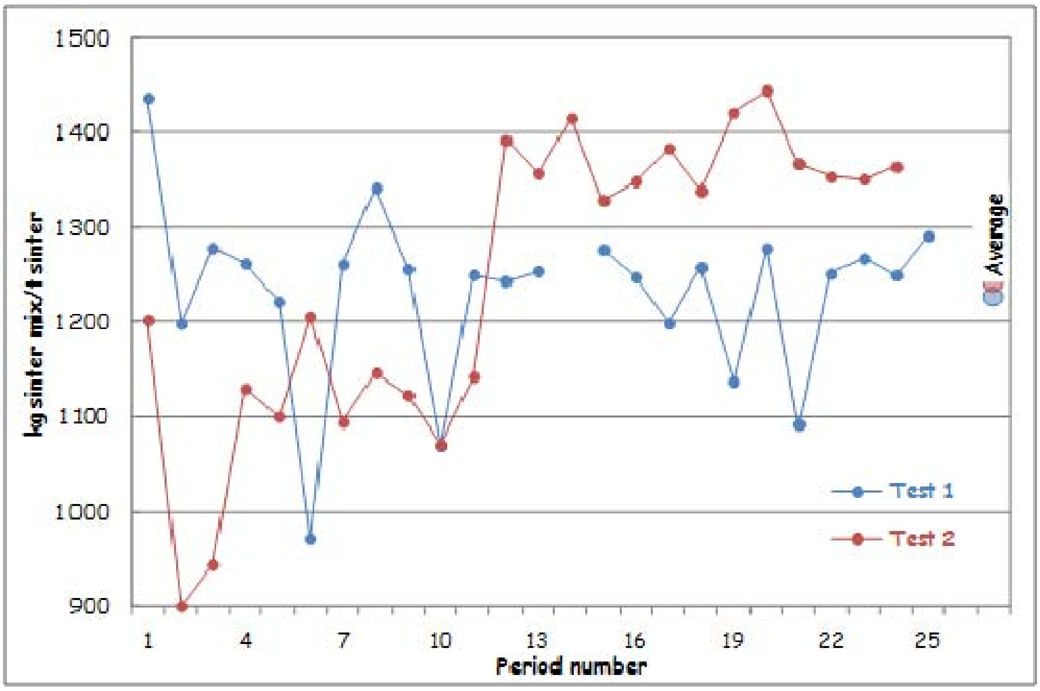


Figure 6.4: Variation of sinter mix ratio

6.3.4.1.6 Specific fume flows

The specific fume flow (Nm^3/t sinter) is not at the same level during the two field tests as shown in Figure 6.5. The average values differ by 17.4% and even if a lower O_2 content of the fumes during

Test 2 can explain part of the decrease further information would be necessary to ascertain the values trying to link the fume flow to the process conditions and evaluation of secondary air inlets which govern the oxygen content. However, the fume ratio during the second test is more stable than during the first one except for two measurement periods and could indicate better measurements.

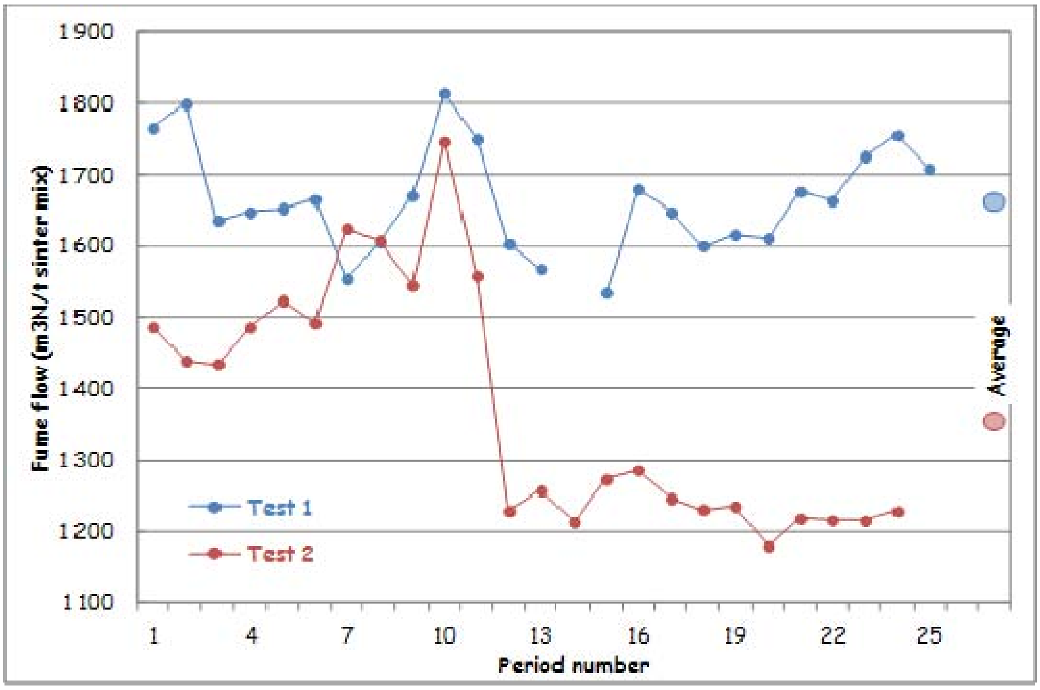


Figure 6.5: Variation of fume volume ratio

6.3.4.1.7 Flue gas analysis

During the test, CO, CO_2 and CH_4 were analysed in the flue gas. A first conclusion is the very low impact of CH_4 as well as carbon output or as GHG equivalent due to its GWP (21 kg CO_2 equivalent/kg CH_4). This is shown in Table 6.2 for the repartition of C in flue gas and for their participation to total GHG equivalent assimilating CO to CO_2 due to its oxidation in atmosphere.

		CO_2	CO	CH_4
C content	Test 1	88.06%	11.91%	0.033%
	Test 2	86.06%	13.91%	0.031%
GWP	Test 1	87.86%	11.88%	0.253%
	Test 2	85.88%	13.88%	0.239%

Table 6.2: Beak-down of carbon in flue gas

These results show that methane is a negligible part of carbon output and equivalent CO_2 emissions for this plant which consumes only coke breeze. Higher methane contents are found for sinter plants consuming a mix of coke breeze and anthracite.

In sinter plants, the oxygen content of flue gas varies in large proportions in relation with the tightness of the equipments resulting in false air inlet. In Figure 6.6, the O_2 and CO_2 contents measured during the field test are compared to measurements on three other stacks. The results of the first field test show globally higher CO_2 content at similar O_2 content and the average CO_2 is 6% higher than indicated by the trend line. During Test 2, excepting two measurements giving only 12% O_2 in the flue gas and depicting a problem of measurement, the average point in much closer to the trend line with only 2% deviation.

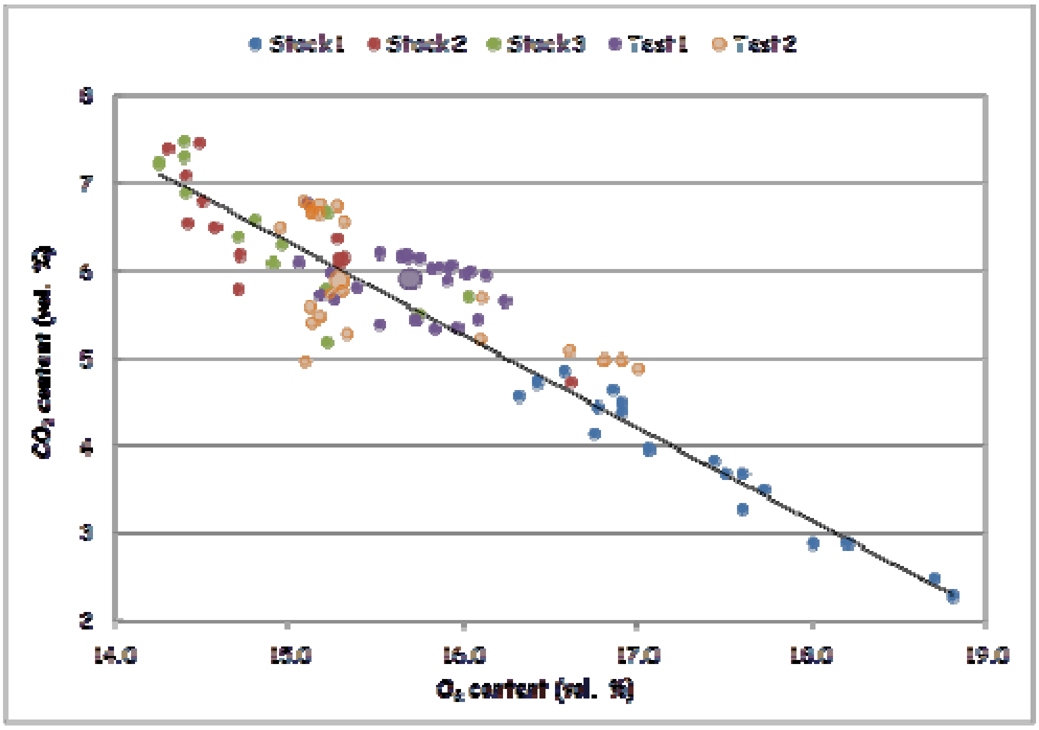


Figure 6.6: Comparison of flue gas analysis

6.3.4.1.8 Conclusion on sinter plant tests

If the first field test did not give the expected result, it allowed to improve the procedure for measurement and the second field test gave an excellent alignment between calculated carbon input coming from sinter mix (and for a very minor part from coke oven gas used for mix ignition) and measured output in flue gas (and here also a minor part for sinter). The two values differ by 2.2% only. Further analysis needs to be done on the basis of the TÜV report indications on the uncertainties of samplings and measurements. However the difference observed during the second test limits the interest of an uncertainty analysis which has no significance due to the short duration of the test.

6.3.4.2 Hot blast stoves test

6.3.4.2.1 Comparison of carbon flows

During Test 1 and like for sinter plant the measured carbon flow in the fumes is higher than the calculated input from fuel gas. In this case, the measured C output was 15.8% higher than the C input and the distribution of the results (Figure 6.7) shows a poor correlation between input and output.

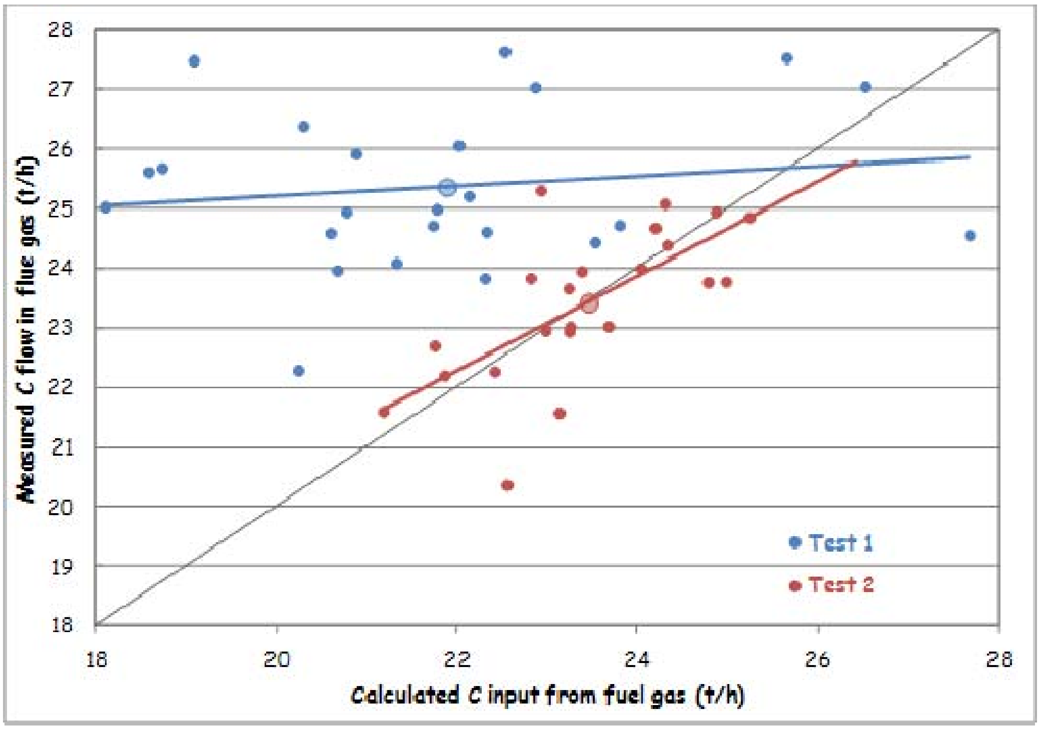


Figure 6.7: Comparison of carbon flows at hot blast stoves

During Test 2, the correlation is much better between input and output and the global averages over test duration differ by 0.3% only.

	Mix gas			CO gas			Input	
	Flow	C content	C flow	Flow	C content	C flow	Total C	Mix gas share
	Nm /h dry	kg/Nm dry	t/h	Nm /h dry	kg/Nm dry	t/h	t/h	
Test 1	87 644	0.2446	21.45	2 733	0.1678	0.45	21.90	97.9%
Test 2	83 746	0.2737	22.92	2 972	0.1862	0.55	23.47	97.6%

	Fume flow			Fume analysis				Fumes
	Plant	Pitot	Average	O2	CO	CO2	Total C	C flow
	Nm /h dry	Nm /h dry	Nm /h dry	Vol % dry	Vol % dry	Vol % dry	kg/Nm dry	t/h
Test 1	171 927	175 650	173 788	2.28	0.54	26.95	0.1457	25.35
Test 2	166 538	167 033	166 786	2.68	0.38	26.16	0.1404	23.41

Table 6.3: Summary results of stove tests

6.3.4.2.2 Analysis of the results

6.3.4.2.2.1 Comparison of flows

The results presented in Figure 6.8 show the poor correlation between the two flow measuring devices during Test 1. The spread for plant measurements was much smaller than the pitot tube but the average values on the test period differ by 2.2 %.

During Test 2, the correlation between both measurements is almost perfect with a difference in test average of 0.3%.

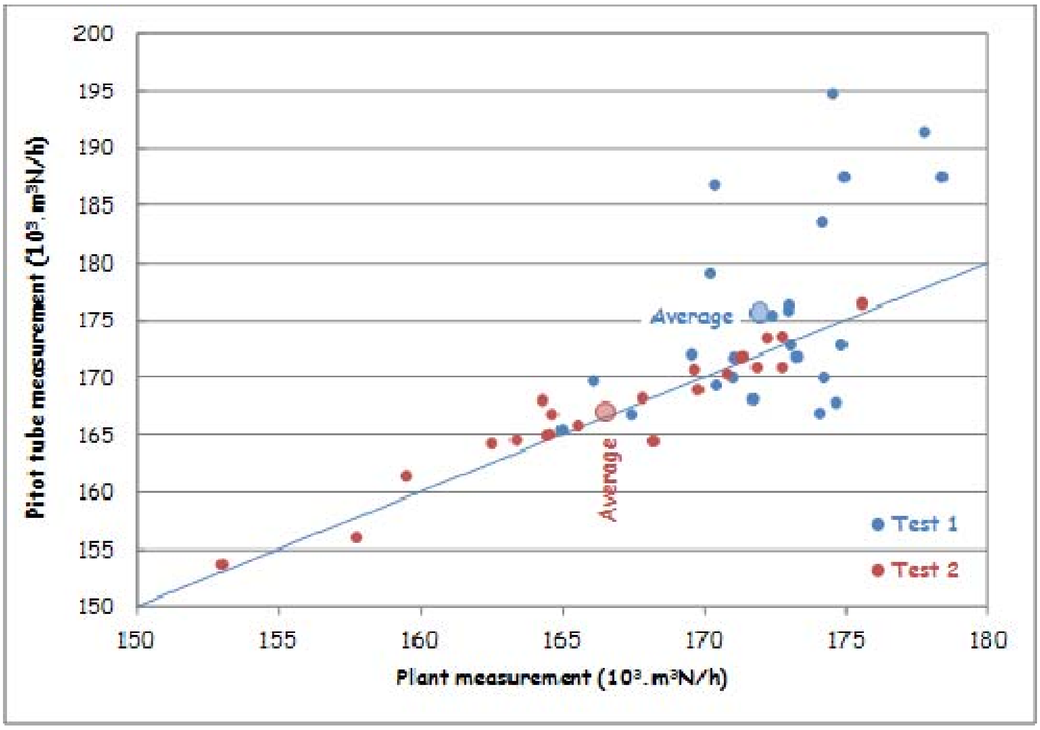


Figure 6.8: Comparison of fume flow measurements

Looking at the ratio between flows of fuel gas and fumes given in Figure 6.9, Test 2 gives less variation of this parameter. This also indicates better reliability of the measures.

6.3.4.2.2.2 Flue gas analysis

The results of flue gas analysis show that CO_2 represents more than 99% of carbon output and that the CO concentration is only 0.3 to 0.6% in volume. The total carbon content in flue gas show similar variations during the two tests (Figure 6.10).

6.3.4.2.3 Conclusions on stove tests

The field tests at hot blast stoves gave similar results as at sinter plant. The first test did not give good fit between calculated and measured CO_2 emissions due to measurement problems which has been solved. The second test gives a perfect fit between calculation and measurement.

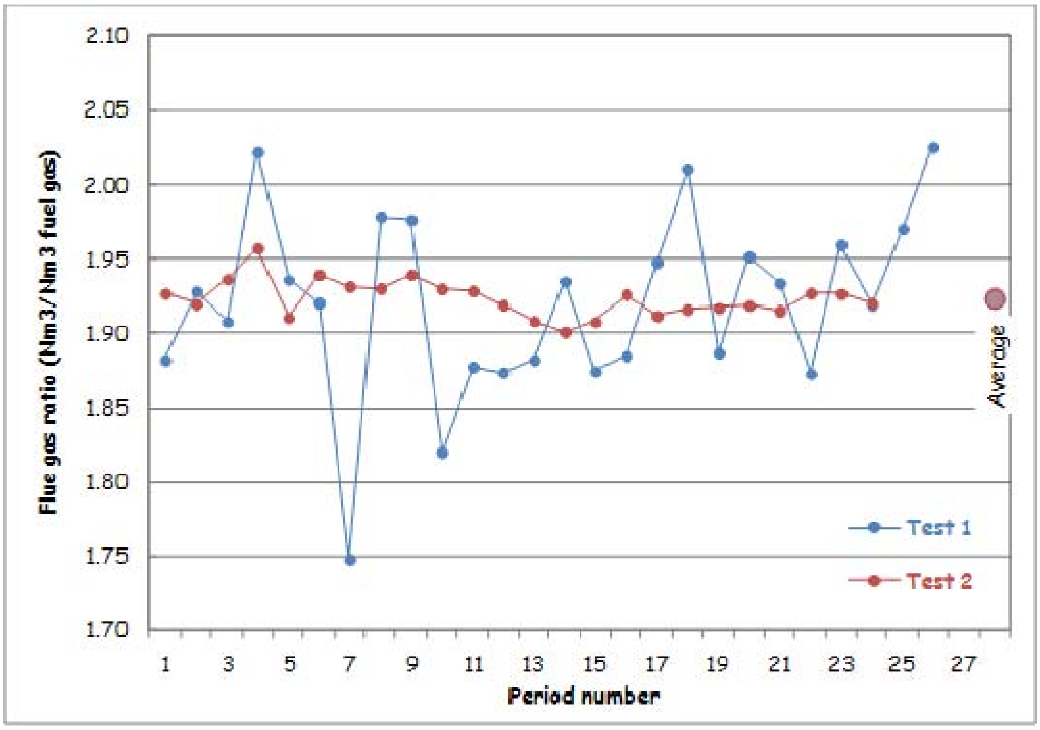


Figure 6.9: Flue gas ratio

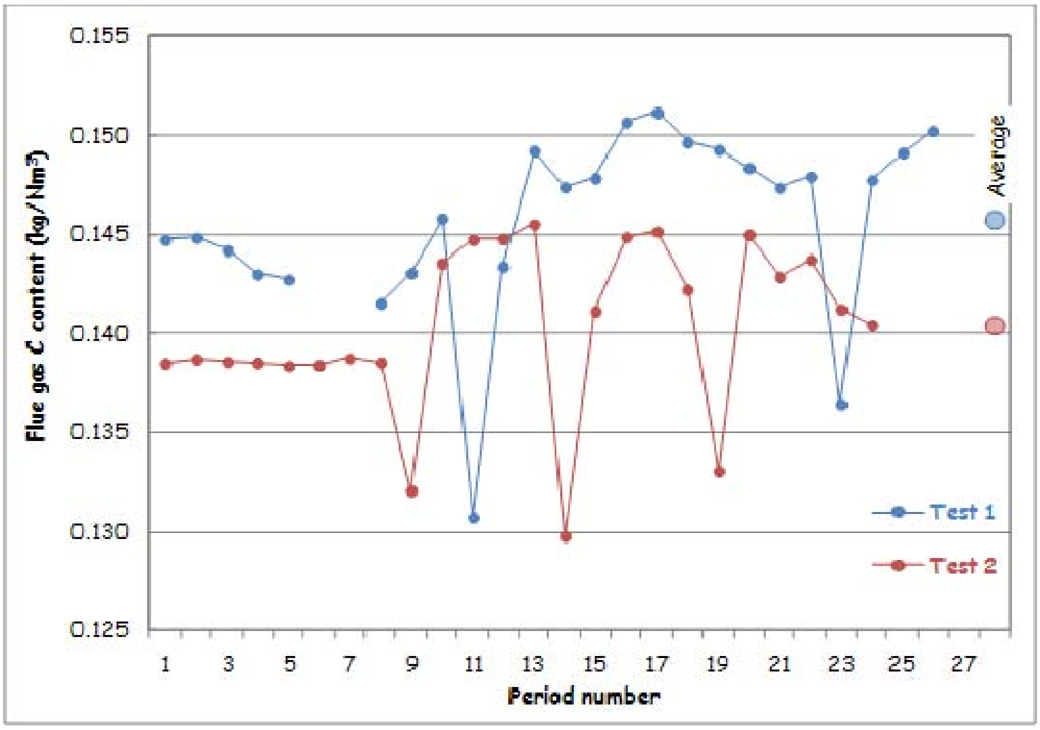


Figure 6.10: Carbon content of flue gas

6.3.5 General conclusion of field tests

Finally the field tests have shown that the principle of Lavoisier allows calculating the emission from inputs. However, the conclusion remains that measuring emissions of all stacks of an integrated steel production would not be possible due to the large number of stacks to monitor and the existence of non measurable sources like flares or coke combustion during transfer to quenching systems.

The short duration of the tests also shows the difficulty of getting representative samples at process level where access to the solid flows is difficult due to continuous operation and risks of segregation in material mixes.

In operations, materials are sampled and analysed separately upon reception before storage. During use, the material flows are monitored to produce the desired mix and their analysis is used for calculation of CO_2 emissions at facility level.

6.4 Sub-sector standard for the Iron & Steel Industry

6.4.1 Status of work

A draft standard has been transmitted to VDI (secretariat of WG33) in the second half of April. This draft standard covers two important aspects of GHG assessment:

- Determination of GHG impact at facility level on the basis of external exchanges and stock variations including direct and indirect emissions directly linked to plant operation. This determination takes into account the important problem of by-product gas exports and proposes a rough assessment of direct emission performance in account of the capacity structure of the facility.
- Determination of GHG performance at process level allowing for a comparison of CO_2 intensity with a reference operation. Roll-up rules allow assessing the performance of the production route. The methodology allows identifying gaps of performance and gives a management tool for measurement of performance improvement.

6.4.2 Impact of field tests on draft standard

Due to the impossibility of measuring all direct emissions of a steel production facility, the field tests do not directly impact the draft standard. The problems encountered during the first tests show the importance of implementing a performing quality control on all the measurement chain to achieve the best possible reliability of results.

This includes:

- Adequate sampling procedures for materials, number of samples, analysis.
- Frequent verification of calibration of weight and flow measuring devices.
- Frequent calibration of gas analysers.
- Implementation of data check procedures to limit the risk of non reliable data.

Due to their predominant part in direct emissions, sampling and analysis of solid fuels (coke, coals) must be carefully managed.

7 SG3 Cement industry

7.1 Summary

1. The subgroup 3 has concluded its work with a draft standard for the emissions of relevant greenhouse gases (GHG) from the cement industry.
2. In total four 48 hour field tests in two cement plants (with simple and complicated setting) have been performed for practical verification of the methods described in the cement specific part of the standard.
3. The field test with simple setting first has indicated higher uncertainties than expected, which are partly the results of calibration errors. Reduction of these errors during the second set of field tests results in reasonable uncertainties for the input and output mass balances, and higher uncertainties for stack measurements.
4. During the first round of field tests also non-CO_2 GHG were measured at stack. Those GHG turned out to be not relevant for the cement sector.
5. Due to several delays (especially of the last field test with complicated setting) the work has not yet been finally concluded. Significant results are available and are reported in this cement specific section. Final work will be done and may lead to minor amendments in the enquiry phase especially on the uncertainty assessment.

7.2 Introduction

CEN Technical Committee 264 Working Group 33 has received the mandate 478 to develop standards for the determination of greenhouse gas emissions of energy intensive industries (cement, steel, aluminium, lime, and ferroalloys). Subgroup 3 has been formed to develop such a standard for the cement industry.

Different methodologies can be used to determine the amount of relevant GHG emissions. A guideline for the cement sector has been developed by the Cement Sustainability Initiative (CSI) of the World Business Council for Sustainable Development (WBCSD), namely “The Cement CO_2 and Energy Protocol” (CSI Protocol), which comprises a mass balance method based on the determination of mass stream amounts and laboratory analyses of their corresponding calculation factors. The production of cement is an energy intensive process, which causes GHG emissions not only from the combustion of fuels, but also process related CO_2 from the calcination of calcium (Ca) and magnesium (Mg) carbonates from raw materials, mainly limestone and clay.

The objective of the field test and verification project is the comparison and assessment of the input methods, the output methods (both according to the CSI Protocol) and the stack emission measurements for determining CO_2 emissions as well as key performance indicators (KPIs) in cement plants. This has been performed by four on-site field tests, which concentrate on the most important emission sources - the clinker burning process - and a practical test period of 48 h. The field tests took place in two different plants:

- Simple test setting: Combustion of fossil fuels and use of conventional raw materials.
- Complicated test setting: Additionally consumption of alternative fuels and raw materials.

The results of the verification tests form the basis for standardising the GHG and KPI reporting methods for the cement industry in the developed draft standard of subgroup 3.

The European Standard for the cement industry will contain harmonized methods for

- Measuring, testing and quantifying emissions from relevant GHGs caused by sector-specific sources;
- Assessing the level of GHG emissions performance of production processes over time, at production sites (formulation of key performance indicators, KPIs);
- Establishing and providing reliable, accurate and qualitative information for reporting and verification purposes.

7.3 Activities since 1st Interim report

The first interim report was published in May 2013. Since then Subgroup 3 has focused on:

- The organization, conduction and evaluation of all four field tests
- The drafting of the standard.

The subgroup has met eight times

- First meeting: 23rd April 2012
- Second meeting: 29th May 2012
- Third meeting: 9th October 2012
- Fourth meeting: 10th December 2012
- Fifth meeting: 14th January 2013
- Sixth meeting: 29th April 2013

  In this meeting the subgroup continued to work on the draft standard and the field tests. The subgroup discussed possible other methodologies than coming from the CSI Protocol to be included in the draft standard on basis of a hybrid proposal combining the input and output methodology. Furthermore, the set-up of the field tests has been presented by the supervisor.
- Seventh meeting: 4th February 2014

  The results of the first set of field tests have been discussed extensively. The conclusion is that the field tests are well on track, but that the uncertainty assessment will be the key element. Uncertainties found during the first two tests have to be studied in more details during the second series of field tests.

  Uncertainties are furthermore relatively high due to the analysis method used for one of the field tests. The subgroup recommended the use of X-ray fluorescence (XRF) analysis for the determination of calcium oxide (CaO) and magnesium oxide (MgO) in raw materials to have better input values for the mass balance methods.
- Eighth meeting: 20th March 2014

  The eighth meeting was concluded by the finalization of the draft standard. The subgroup approved the version for the enquiry phase.

Due to the fact that a kiln stop has delayed one of the second field tests, the subgroup was not able to discuss in detail the results of the field tests in total. But the conclusion of the work was that the earlier reported high uncertainties have mainly been caused by incorrect calibration of the kiln feed scale.

The composition of Subgroup 3 covers the required different competences:

- Experts from the European cement industry are representing nine countries and six major cement companies.
- An expert on emissions measurements is part of the subgroup.
- Three European cement associations are represented.
- ISO has sent an observer from Japan to the subgroup.

7.4 Verification tests

Integral part of the development of the cement specific part of the standard is the performance of four field tests in two European cement plants. The call for tender for the following five work packages (WPs) has been issued early July 2012:

- WP 1 - Supervisor
- WP 2 - Continuous stack measurements
- WP 3 - Sampling and analyzing by plant laboratories
- WP 4 - Sampling and analyzing by external laboratories
- WP 5 - Indicative measurements of other GHG emissions

Finally, the call for tender was completed in March 2013 by the European Commission with the approval of the contracts for the five work packages.

During the evaluation of the first field test in the complicated setting the need for XRF analyses instead of titration on CaO and MgO in raw materials turned out. Furthermore, additional tasks regarding the field test evaluation and uncertainty assessment arose. These requirements led to two auxiliary contracts within WP 1 (supervisor) and WP 4 (external laboratories).

7.5 Methodology

The boundaries of the field tests are indicated below (Table 7.1 and Figure 7.1), which are focused on the major emission source of the cement production - the clinker burning process. The system boundaries of the drafted cement specific part of the standard and the CSI Protocol also include the quarry (e.g. crushers) and cement production (blending, grinding). The reason for these differences is not only the time coverage of 48 hours each field test versus one year in the standard and the CSI Protocol. Furthermore, the comparison of the different input and output methods for determining CO_2 emissions stemming from the calcination of carbonates is one of the main tasks of the verification program. Thus, the verification programme covered more than 90 % of the GHG emissions of a cement plant.

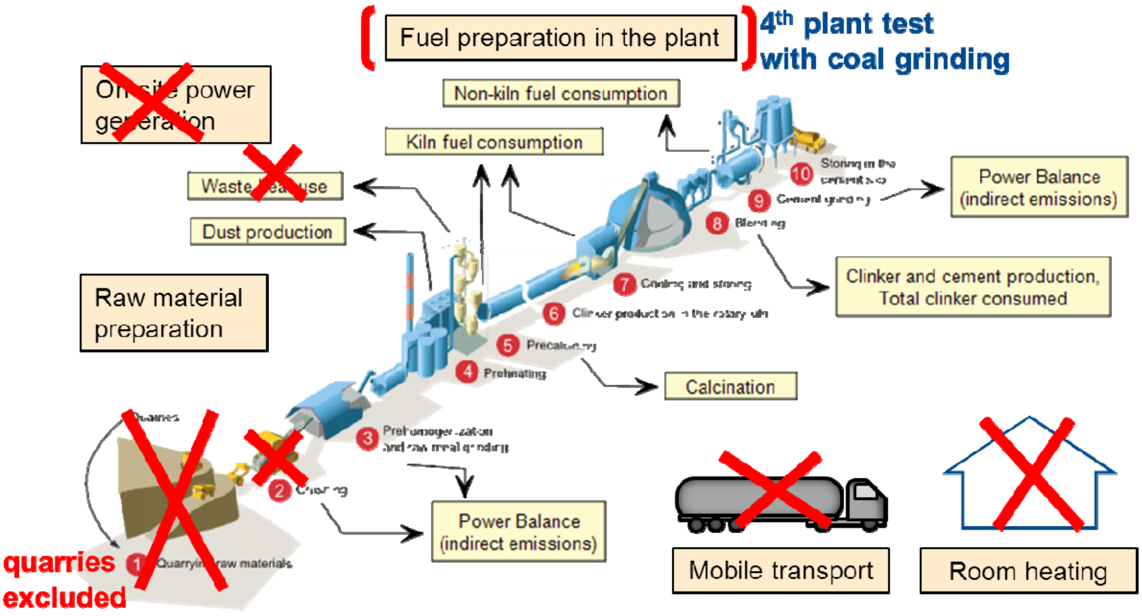
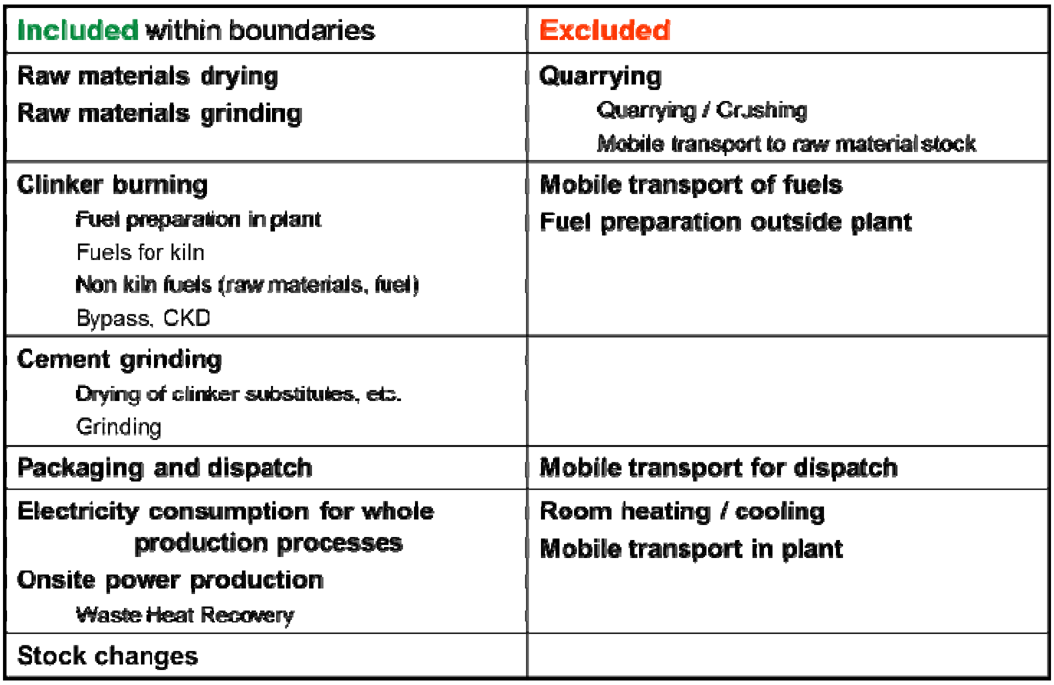


Figure 7.1: Boundaries of field tests for the verification project. Crossed sections are out of the scope of the verification project.



Included within boundaries	**Excluded**
Raw materials drying **Raw materials grinding**	**Quarrying** Quarrying / Crushing Mobile transport to raw material stock
Clinker burning Fuel preparation in plant Fuels for kiln Non kiln fuels (raw materials, fuel) Bypass, CKD	**Mobile transport of fuels** **Fuel preparation outside plant**
Cement grinding Drying of clinker substitutes, etc. Grinding	
Packaging and dispatch	**Mobile transport for dispatch**
Electricity consumption for whole production processes **Onsite power production** Waste Heat Recovery	**Room heating / cooling** **Mobile transport in plant**
Stock changes	

Table 7.1: System boundaries field tests

The field tests deliver a comprehensive set of data of the GHG emissions of a cement plant. These data include a comparison of the results from the common mass balance methods as defined in the CSI Protocol (method A based on inputs, method B based on outputs plus fuel emissions) and the measurements at stack (Figure 7.2).

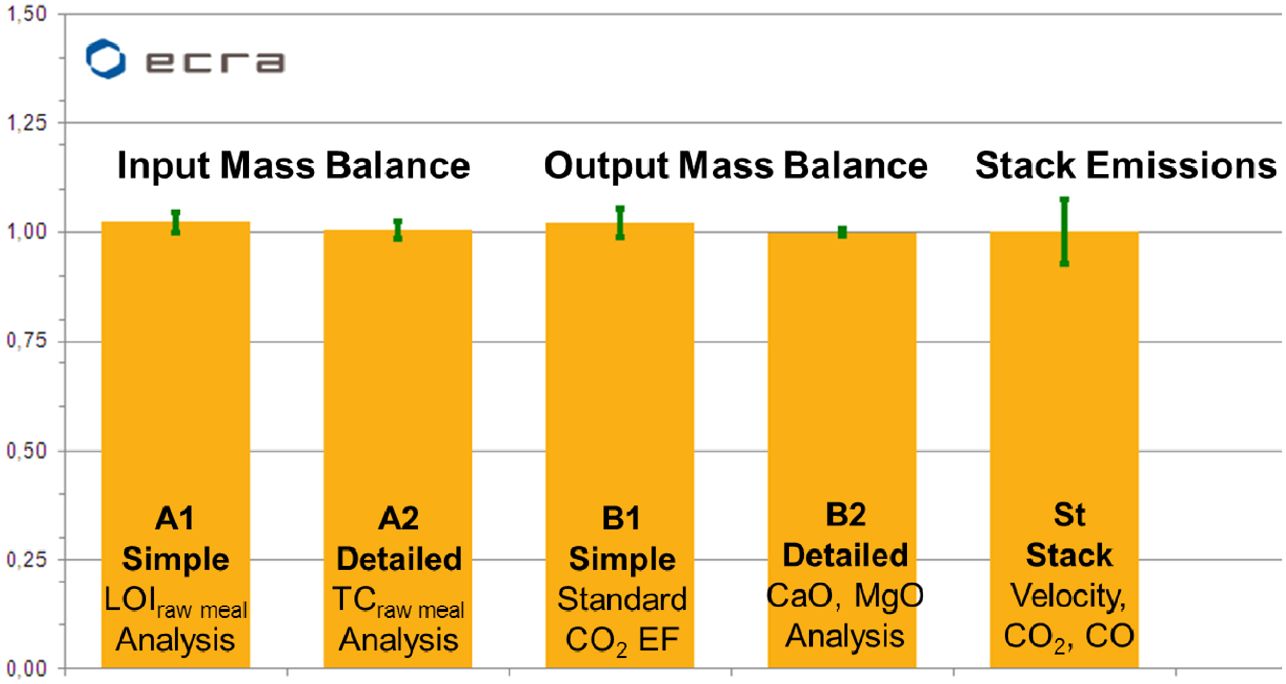


Figure 7.2: The comparison of in total five different methods for determining GHG emissions from the clinker production process is the aim of the verification tests.

Based on the field tests data the uncertainties of the different methods are assessed and compared.

7.6 Selection and characterization of plants

The call for tender resulted finally in two plants for the field tests. For the simple plant without using alternative fuels only one plant applied: Gubbio Plant of Colacem in Italy. Subgroup 3 concluded that this plant met the requirements for the field tests very well.

For the second, more complex plant, three plants applied. The decision of Subgroup 3 was to select finally Lixhe Plant of CBR in Belgium as most suitable plant mainly because of the kiln feed weighing facility of that plant. For the field tests the clinker produced can be directly transported to a barge and in that way measured with very low uncertainty.

Details on the two plants can be found in Table 7.2 below.

Cement Plant	Plant A	Plant B
Verification test setting	simple	complicated
1st and 2nd plant tests	20-24 May 2013	10-14 June 2013
3rd and 4th plant tests	11-15 Nov 2013	25-29 Nov 2013 (cancelled) 10-14 February 2014 (caught up)
Number of kilns	1 grey clinker kiln line in test	1 grey clinker kiln
Type of kiln	Dry + preheater (5) + pre-calciner	Dry + preheater (4) + pre-calciner, dryer for raw materials
Raw materials	alternative raw material use in small amounts	alternative raw material preparation and use
Fuels	standard fuel use only	standard and alternative fuel use
Number of stacks	1 main stack for kiln and raw mill 2 coal mill stack with cooler air for 2: limited application of sampling standard conditions, 2 spot measurements for CO, in order to check for any relevance	1 main stack for kiln and dryer 2 cooler including bypass 3 coal mill stack (sampling during 2nd test) for 2 and 3: limited application of sampling standard conditions (volume flow, CO_2 and CO,)
Clinker weighing unit installed	No	No
Clinker output measurement possible	Yes, via small silo and trucks, even for 48 hours, truck scale for 48 h and 4 h interval resolution	Via separate small (center) silo and then via a ship (barge) the mass can be measured by 48 h ship draft survey, 4 h calculated from kiln inputs, will be corrected by ship draft survey
Clinker sampling	Every 1 h at cooler outlet	Every 1 h at cooler outlet
Bypass dust and CKD leaving the kiln system (filter dust) measurement	No bypass. All filter dust returned to the kiln, will be collected before kiln test, to be measured via truck scale.	Bypass and clinker dust from cooler is transported in a separate silo, to be measured via truck scale. Filter dust over a silo, measured via truck scale.
Kiln feed	Pressure differential calibrated to silo weight drop, Uncertainty determined from test in the week before and after test (total of at least 4 scale tests).	Weigh feeder scale, Uncertainty determined from scale test in the week before and after test (total of at least 4 scale tests).

Cement Plant	Plant A	Plant B
Dust return rate	Determined in the week/day before test from complete collection of all filter dust in direct mode plus uncertainty assessment needed.	Determined in the week before test from complete collection of all filter dust in direct mode (without dryer), weighing with truck scale, plus uncertainty assessment needed, will be checked by kiln mass balance based on raw material and ash analysis.
Raw material sampling	2 samples per material before test for raw material used during the test	2 samples per material before test for raw material used during the test 2nd test alternatively raw mix sampling before raw meal silo before test in order to account for the time delay in raw meal silo.
Raw meal sampling (without recycled filter dust)	Raw meal samples from output of raw meal silo every, 1 h	No direct raw meal sampling possible. Alternatively the raw meal composition without dust return is calculated from raw mix recipe, raw material analysis and compared to the kiln feed analysis.
Kiln feed sampling (raw meal including recycled filter dust as fed to the kiln)	every 4 h	every 1 h
Number of alternative fuels	No, only petroleum coke	Above 10 including mixed alternative fuels to calciner, no use of tyres during 1st test
Sampling of fuels	Yes	Yes, sampling of tyres during 2nd test limited to water and mud content
Scope, System boundaries	2nd kiln line completely separated and pozzolana processing out of scope of the tests	Coal fuel preparation (for external consumers) and tyres out of scope during 1st test, inclusion of tyres in 2nd test. contaminated soil input to kiln inlet (=additional raw material, AddRM) out of scope
	No on-site power generation, No clinker import, Room heating out of scope regarding fuels. Crushers in the quarries and transport to clinker plant out of scope regarding electrical power consumption. Crushers at clinker plant included in scope (< 5% electrical power consumption)	No on-site power generation, No clinker import, Room heating out of scope regarding fuels. Crushers in the quarries and transport to clinker plant out of scope regarding electrical power consumption.
Power demand	Meters reading once at start and end of plant test. This means one value for the whole duration of the 48 h field test.	Meters reading once at start and end of plant test. This means one value for the whole duration of the 48 h field test.
Cement production, stock levels, dispatch	Determination of the values for the year 2013 (<u>not</u> every 4 hours). Special focus on uncertainty assessment for process scales	Determination of the values for the year 2013 (<u>not</u> every 4 hours). Special focus on uncertainty assessment for process scales

Table 7.2: Verification test setting

7.6.1 Selected subcontractors

The involved contractors in the verification project are

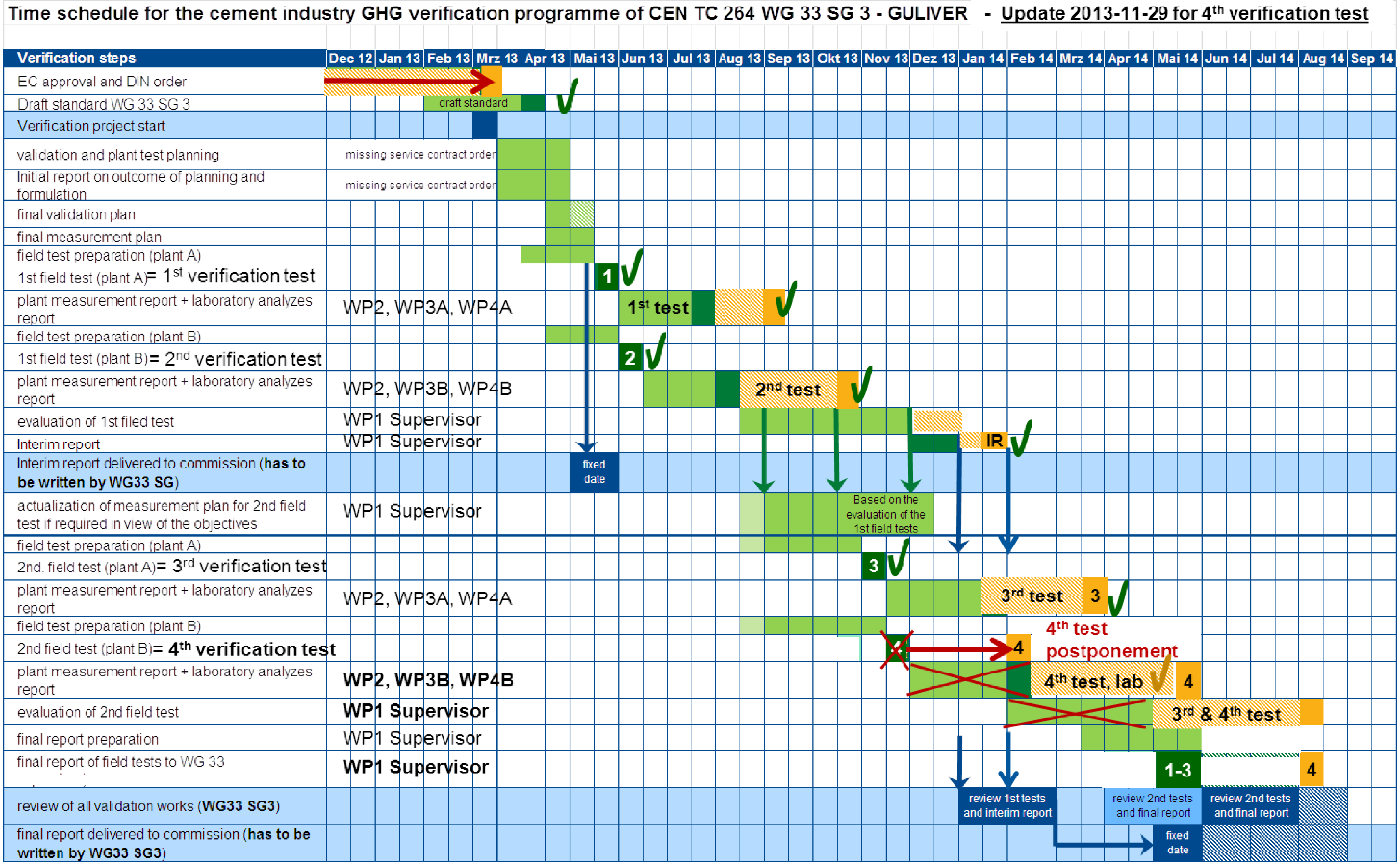
- WP 1 – Supervisor
  European Cement Research Academy GmbH (ECRA)
- WP 2 - Continuous stack measurements
  Forschungsinstitut der Zementindustrie GmbH - Environmental measuring
- WP 3 - Sampling and analyzing by plant laboratories
  - COLACEM S.p.A.
  - S.A. Cimenteries CBR
- WP 4 - Sampling and analyzing by external laboratories
  - Eurofins Umwelt West GmbH
  - Forschungsinstitut der Zementindustrie GmbH
- WP 5 - Indicative measurements of other GHG emissions
  Müller-BBM GmbH - Niederlassung Dresden

7.6.2 Measuring program

The verification steps from EC approval until submitting the final report to EC are shown in Table 7.3.

It was not always possible to keep the strict and short time schedule in place during this project of developing a standard. The first delay happened during the tendering phase of the work packages as for two of them we have not received directly offers. Secondly, the approval process by the EU Commission resulted again in a further delay.

Moreover, SG 3 has been confronted with an unexpected kiln stop for several weeks in one of the plants just before the start of the second series of measurements. For this reason the field tests had to be rescheduled with the consequence that not all final evaluation results are available at the moment of drafting this report. It also means that in the draft standard especially the uncertainty assessment could not be concluded completely, which will be updated during the enquiry phase.



Time schedule for the cement industry GHG verification programme of CEN TC 264 WG 33 SG 3 - GULIVER - Update 2013-11-29 for 4th verification test

Verification steps		
EC approval and DIN order		
Draft standard WG 33 SG 3		draft standard ✓
Verification project start		
validation and plant test planning		missing service contract order
Initial report on outcome of planning and formulation		missing service contract order
final validation plan		
final measurement plan		
field test preparation (plant A)		
1st field test (plant A)= 1st verification test		1 ✓
plant measurement report + laboratory analyzes report	WP2, WP3A, WP4A	1st test ✓
field test preparation (plant B)		
1st field test (plant B)= 2nd verification test		2 ✓
plant measurement report + laboratory analyzes report	WP2, WP3B, WP4B	2nd test ✓
evaluation of 1st filed test	WP1 Supervisor	
Interim report	WP1 Supervisor	IR ✓
Interim report delivered to commission (**has to be written by WG33 SG**)		fixed date
actualization of measurement plan for 2nd field test if required in view of the objectives	WP1 Supervisor	Based on the evaluation of the 1st field tests
field test preparation (plant A)		
2nd. field test (plant A)= 3rd verification test		3 ✓
plant measurement report + laboratory analyzes report	WP2, WP3A, WP4A	3rd test 3 ✓
field test preparation (plant B)		
2nd field test (plant B)= **4th verification test**		4 4th test postponement
plant measurement report + laboratory analyzes report	**WP2, WP3B, WP4B**	4th test, lab ✓ 4
evaluation of 2nd field test	**WP1 Supervisor**	3rd & 4th test
final report preparation	WP1 Supervisor	
final report of field tests to WG 33	**WP1 Supervisor**	1-3 4
review of all validation works (**WG33 SG3**)		review 1st tests and interim report review 2nd tests and final report review 2nd tests and final report
final report delivered to commission (**has to be written by WG33 SG3**)		fixed date

Table 7.3: Time schedule for the cement industry GHG verification program.

7.6.3 Measuring results

7.6.3.1 Simple setting

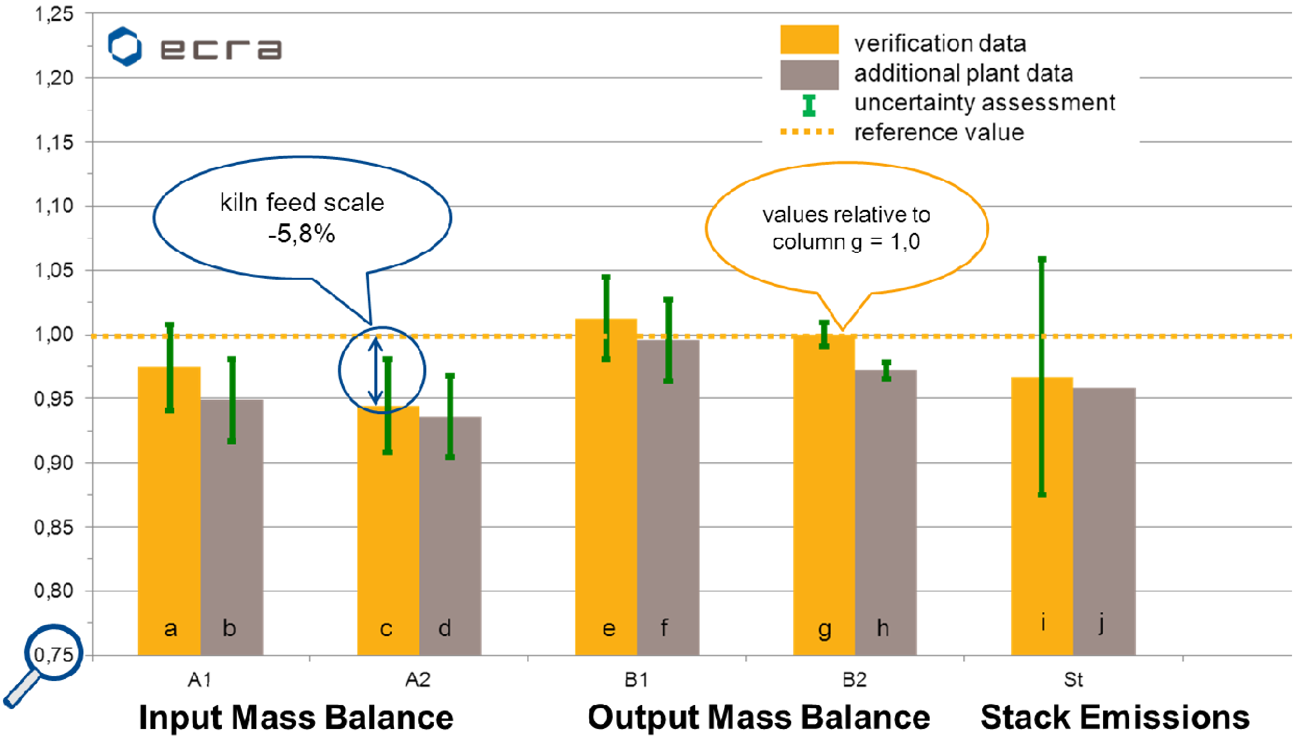


Figure 7.3: Results of the first 48 hour field test with simple setting. Direct fossil and biogenic CO_2 emissions, Values are reported relative to column g (g = 1,00).

The results of the field tests of the simple plant indicate a good correlation between the input and output mass balances and somehow a higher uncertainty for the stack measurements. The uncertainties found during the first test was mainly attributed to the improper calibration of the kiln feed scale (Figure 7.2). In the following field test this uncertainty was reduced significantly by careful calibration of the kiln feed scale resulting in comparable values for the input and output mass balances (Figure 7.4).

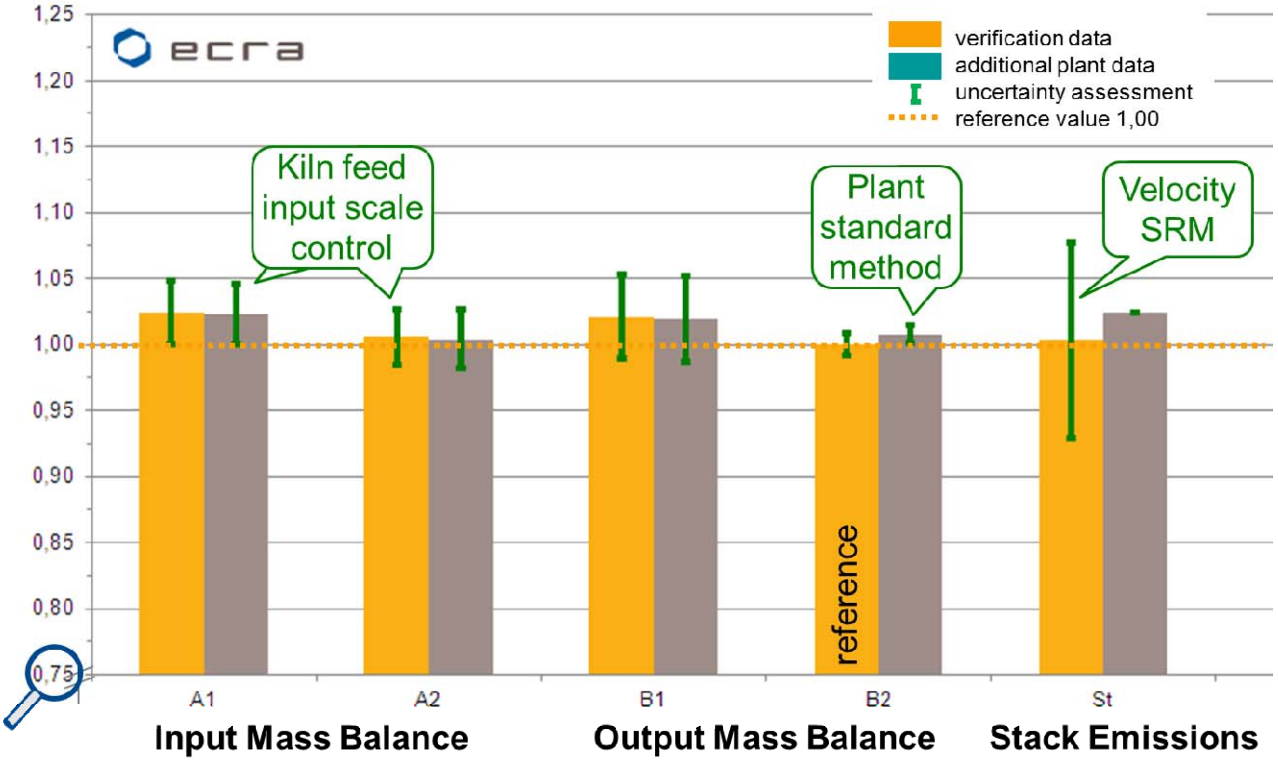


Figure 7.4: Results of the second 48 hour field test with simple setting. Direct fossil and biogenic CO_2 emissions, Values are reported relative to column g (g = 1,00). SRM: Standard reference method.

The results of the second 48 hour field test in Figure 7.4 show that all five methods proposed for cement plants by SG 3 are well suitable for determining CO_2 emissions in simple plants. All results show a close agreement of all results with differences < 2.5 % within expanded uncertainties.

7.6.3.2 Complicated setting

The calibration of the kiln feed scale at the second and more complex plant has caused higher uncertainties than expected Figure 7.5. Also important is that the uncertainty in the analysis of the input materials can be significantly reduced by using XRF analysis, which was not part of the contract for the work package. For that reason the subgroup had strongly recommended to extend the tender with these XRF analyses.

Figure 7.5 shows the results of the first field test with complicated setting. It gives the impression that the simple input and output methods A1 and B1 (unfilled column) are not appropriate for GHG reporting in this plant with complicated setting due to the use of alternative fuels and raw materials. In other complicated plants this may not be valid. About half of the uncertainties of columns g and h are due to relative high uncertainty of emission factors of alternative fuels.

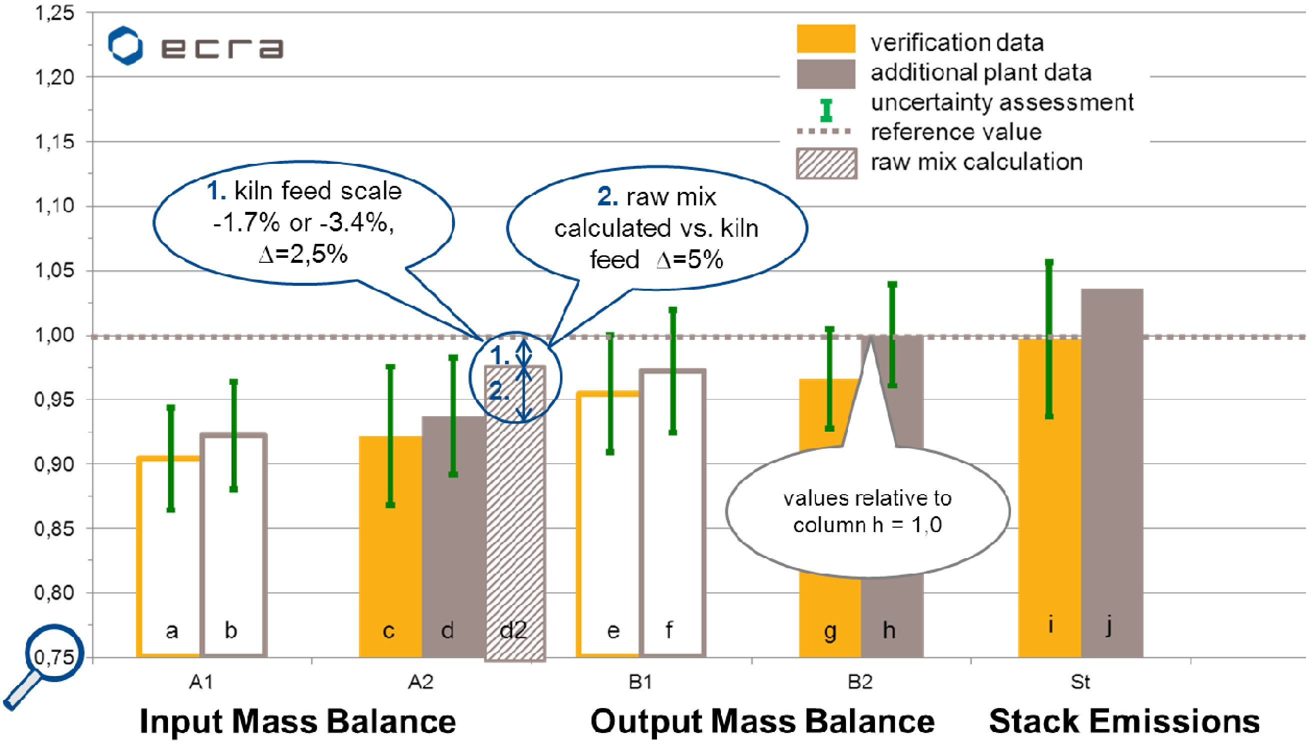


Figure 7.5: Results of the first 48 hour field test with complicated setting. Direct fossil and biogenic CO_2 emissions, values are reported relative to column h (h = 1,00).

For the CO_2 emissions from the combustion of fuels a systematic difference of 3 % between the verification data and the additional plant data has been identified (Figure 7.6). It results from higher CO_2 emission factors determined for alternative fuels in the plant laboratory and makes up for about 1.8 % difference in the direct CO_2 emissions. This systematic error is the same for all four mass balance methods as the method for determining CO_2 stemming from fuels is always the same. Relatively high uncertainty is given for emission factors and biogenic carbon content of alternative fuels.

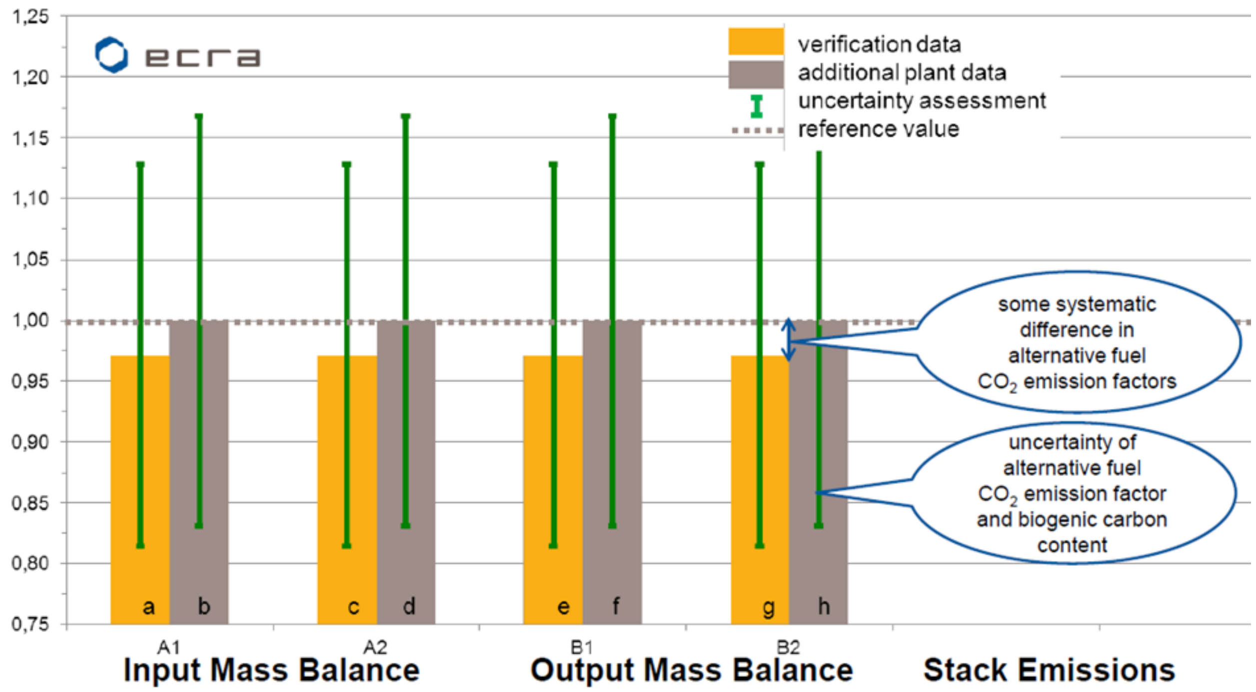


Figure 7.6: CO_2 emissions from the combustion of fuels during the first field test with complicated setting. Values are reported relative to column h (h = 1,00).

As for the simple setting in the second field test with complicated settings the difference between input and output methods are reduced through careful calibration and maintenance of the kiln feed weighing system (Figure 7.7).

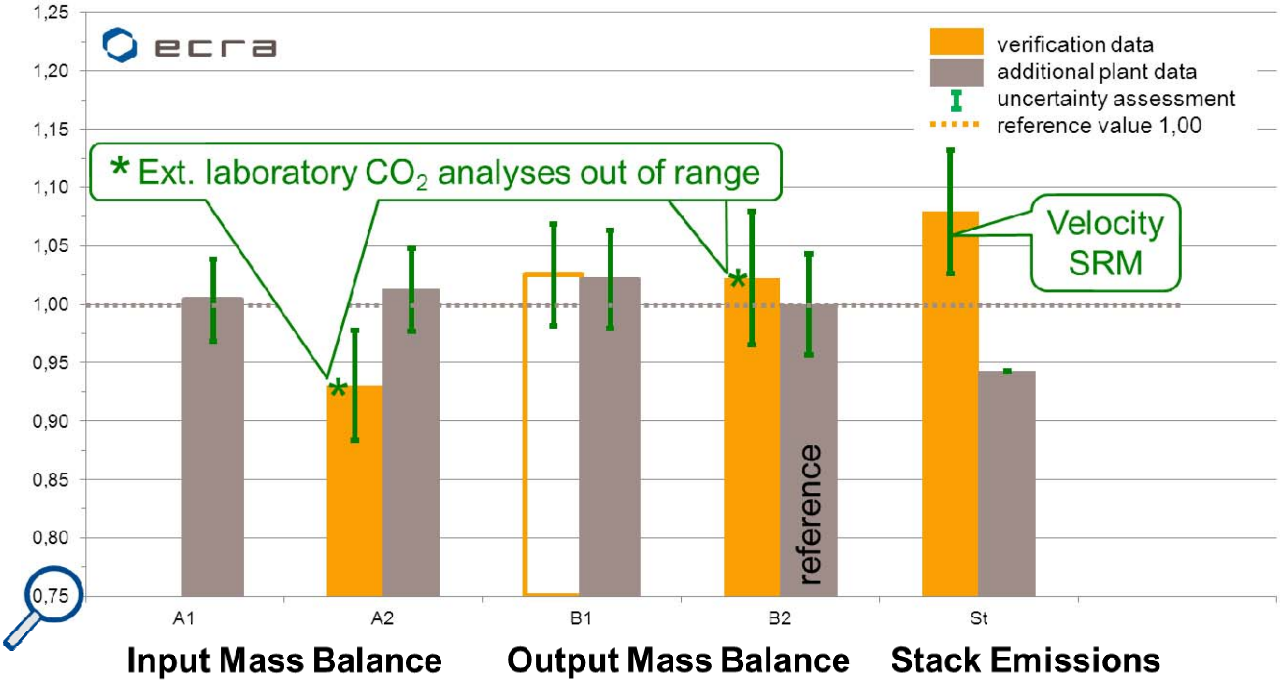


Figure 7.7: Preliminary results of the second 48 hour field test with complicated setting (status: 23 May 2014). Direct fossil and biogenic CO_2 emissions, values are reported relative to column h (h = 1,00). SRM: Standard reference method.

Also the results of the verification tests in the “complex plant” (Figure 7.7) show that the methods proposed for cement plants by SG 3 are well applicable in complicated plant setting with significant share of alternative raw materials and fuels. Experience with raw meal and clinker matrix is required. The status “preliminary” refers only to the final uncertainty assessment, which will be finalised soon and introduced during the enquiry process.

7.6.3.3 Non-CO_2 greenhouse gas emissions

A further scope of the verification programme was to demonstrate which GHG are relevant for the cement sector. Therefore, direct measurements at stack were performed in both plants. The results show that CO_2 (incl. CO) is the only relevant GHG for cement plants (Table 7.4).

Component mass flow		Result	GWP [CO_2eq] IPCC AR5	CO_2 equivalent emissions [CO_2eq]	Relative uncertainty incl. uncertainty of velocity SRM (pitot tube)
CO_2		**measured**	1	99.4%...99.8% ≥ 99.5%	6.4% … 9.5%*
CO		**measured**	1	0.08%...0.15%	12% … 48%**
non-CO_2 GHGs	**CH_4**	**at LOD**	28	< 0.01% **at LOD < 0.5 %**	≥ 50%
	N_2O	**at LOD**	265	≤ 0.02%… ≤ 0.4%	≥ 50%
	SF_6	**not detected**	23500	not detected	not detected
	HFC	**not detected**	≥ 140	not detected	not detected
	PFC	**not detected**	≥ 6500	not detected	not detected

Table 7.4: Results of non-CO_2 GHG measurements in flue gas. LOD: Limit of detection. * Close to LOD of stack gas velocity. ** Close to LOD of CO measurements.

7.7 Uncertainty assessments

During the field tests it has been concluded that several factors influence significantly the results of the measurements and mass balances:

- Characterization of raw materials, fuels and alternative raw materials.
- Feeding of the materials to the installations. Proper calibration of scales is important.
- Output measurements of materials. The two plants have been selected on the possibility to measure adequately the mass flow of clinker produced, which is in general not the case for all cement plants.
- Measurements in the stack, as especially uncertainties in the volume measurement will have a multiplier effect on the final results.
- The simple setting showed a difference < 2. 5 % between all five applied methods that are within expanded uncertainty.
- The time span covered. The uncertainty of the short 48 hours field tests are higher than on a yearly basis.

7.8 Sector-specific standard for the cement industry

7.8.1 Status of work

During its eighth meeting the subgroup concluded the work on the draft standard. Compared to the basis of the standard, the CSI Protocol, the standard is different in wording, some definitions and contributes significantly added value in the uncertainty assessments. The draft standard has been drafted in such a way that it corresponds to other CEN and ISO standards valid for the cement industry.

7.8.2 Impact of verification tests on draft standard

Due to the fact that the final evaluation and uncertainty assessment of the measurement results from the delayed last field test are not yet available, the subgroup had to be careful to use exact values in the draft standard. For that reason the draft standard includes ranges for especially the uncertainty assessments, which are currently worked out further to exact values which will be implemented in the standard during the enquiry phase.

8 SG4 Aluminium industry

8.1 Summary

SG4 has achieved the following major outcomes:

- A field test program for verification of methods for CO_2 emission and PFC emissions of the draft sub-standard has been conducted and completed by the appointed contractors, with the related reports submitted on time to the secretariat
- A draft of the aluminium standard has been finalized for CEN enquiry, and the document has been circulated to the Secretariat of Working Group 33 and published on Livelink as document CEN/TC264/WG33/N0137.

8.2 Activities since 1st Interim Report

Since the first interim report, the role of convenor within the SG 4 passed in April 2013 to Sandro Starita, Director for Environment, Health and Safety of the European Aluminium Association (EAA), who succeeded Eirik Nordheim.

The members of the SG4 therefore were:

Sandro Starita (Convenor), European Aluminium Association
Martin Angelo, Denmark
Michael Robert, Germany
Nancy Jorunn Holt, Norway
Eirik Nordheim, Norway
Rolf Duus, Standards Norway (Secretariat)

In the past months SG 4 continued drafting the aluminium sub-standard, which is based on the Aluminium sector Greenhouse gas protocol (International Aluminium Institute) and the Protocol for Measurement of Tetrafluoromethane (CF_4) and Hexafluoroethane (C_2F_6) - Emissions from Primary Aluminium Production (International Aluminium Institute). The protocol is also an addendum to the WRI/WBCSD Greenhouse Gas Protocol.

In this context, the group coordinated the activities of the consultants contracted to validate the calculation models:

- ANECO for the field measures of the CO_2 emissions at installations
- Jerry Marks for the review of the extensive field data available for PFC emissions measures

One meeting of SG 4 and mail exchanges have taken place in since the 1st interim report.

8.3 Verification Tests

8.3.1 Selected subcontractors

The subcontractors selected for performing the verification activities were already mentioned in the first interim report:

- Jerry Marks, on behalf of IAI (International Aluminium Institute), for the verification of the PFC emissions calculation method based on the available measurement data
- ANECO for the verification of the CO_2 emissions calculation method based on field measurements at European aluminium smelters

8.3.2 Verification of a method for determination of PFC-emissions from European aluminium smelters

The measurement of PFC emissions from aluminium smelters is specified in the Protocol for Measurement of Tetrafluoromethane (CF_4) and Hexafluoroethane (C_2F_6) Emissions from Primary Aluminium Production from the US EPA and the IAI.

In fact, the measurement of PFC is complicated and normally requires specialist assistance and measuring equipment and would not normally be done by the smelters' own personnel. For this reason, a calculation method has been developed, using process parameters regularly recorded by the plants and a slope factor calculated from the measurements already done, and which is specific for each technology.

Considering the large amount of measurement data of CF_4 and C_2F_6 collected at aluminium smelters over the past 15 years, the verification methodology used in this context was to compare available PFC measurement data made following the publication of the 2006 IPCC Guidelines with emission factor values that would be calculated using IPCC Tier 2 equation coefficients. A statistical analysis was then used to determine if the new measurements are outside the range that would have been expected from the variance of the original data sets used to calculate the 2006 Tier 2 coefficients.

The verification report of PFC was delivered by Jerry Marks, on behalf of IAI, in June 2013.

8.3.2.1 Evaluation of results

An analysis of the data from PFC measurements at thirty-eight primary aluminum production facilities made after publication of the 2006 updated Tier 2 equation coefficients confirms and validates the IPCC Tier 2 methodology for calculation of anode effect related CF_4 and C_2F_6 emissions from primary aluminum production based on plant anode effect process data. The data analyzed covered all the major primary aluminum technology types including point feed prebake, side work prebake, vertical stud Søderberg and horizontal stud Søderberg cell types. The analysis of the measurement data also confirmed that the IPCC Tier 2 equation slope and overvoltage parameters for calculation of PFC emission factors from plant anode effect process data conforms to statistical expectations. For the most widely used PFPB technology the expanded measurement data set confirms the accuracy of the 2006 IPCC Tier 2 equation parameter is better than +/-6%. Similarly the post 2006 measurement data confirm the documented Tier 2 factors for the other technology types used to produce primary aluminum.

8.3.3 Verification of a method for determination of CO_2 emissions from European aluminium smelters

At aluminium smelters two main sources for carbon dioxide can be identified. First the exhaust fumes of the potrooms (with high volume flows and low CO_2 concentrations) and second the anode baking process (with lower volume flows and higher CO_2 concentrations).

In both cases, a calculation of the CO_2 emissions based on the inputs and outputs is possible. Contrary to the PFC, the measurement of carbon dioxide is not complicated and normally only requires well known measuring equipment.

The mass flow of carbon dioxide is important for any further calculations. Therefore it is necessary to measure the stack flow exactly in order to be able to calculate the overall uncertainty.

For the verification of the method for the CO_2 emissions, the measurements were performed in the second half of 2013 at two German smelters by ANECO, with two measurement sites at each plant (potroom and anode baking).

The CO_2 emissions measured were then reported and compared with the amounts of carbon dioxide resulting from the calculation method, based on a mass balance.

The verification report of CO_2 was delivered by Michael Robert, on behalf of ANECO, in March 2014.

8.3.3.1 Selection and characterization of plants

The measurements took place at two German smelters, both working with prebaked anodes. Both smelters have their own anode baking plants. Both plants are typical mid-sized manufacturers (approximately 200-300 pots, point feeder technology) and therefore they are representative (concerning their emission behaviour) for the technology used by the majority of aluminium smelters.

Besides other sources of carbon dioxide (heating facilities etc.) there are two main sources of carbon dioxide:

- Electrolysis: most of the CO_2 emissions result from the electrolytic reaction of the carbon anode with alumina which reduces the alumina to elemental aluminium and the carbon of the anodes to carbon dioxide.
- Anode baking: another source of CO_2 emissions, specific to prebake technologies, is the baking of green anodes, wherein CO_2 is emitted from the combustion of volatile components from the pitch binder and, for baking furnaces fired with carbon based fuels, from the combustion of the fuel source. Some of the packing coke used to cover the anodes is also oxidized, releasing CO_2 during anode baking.

8.3.3.2 Measuring programme

Measurements took place for a time of 30 days at each sampling site within the following periods of time:

Anode baking plant A: 10.05. – 09.06.2013

Anode baking plant B: 30.06. – 01.08.2013

Electrolysis plant A: 20.08. – 20.09.2013

Electrolysis plant B: 01.10. – 05.11.2013

Below a description of the methodology used to measure each relevant parameter is reported (Table 8.1):

Carbon dioxide (CO_2):	Continuous measurement over a period of one month at each sampling location with a mobile FTIR-system
Carbon monoxide (as CO_2 equivalent):	Continuous measurement over a period of one month at each sampling location with a mobile FTIR-system
Volume flow:	Continuous measurement over a period of one month at each sampling location with a pitot tube according to EN 16911-1 [1]
Water vapour:	Continuous measurement over a period of one month at each sampling location with a mobile FTIR-system
Oxygen:	Continuous measurement over a period of one month at each sampling location with a paramagnetic analyzer according to EN 14789 [2]
Temperature:	Continuous measurement over a period of one month at each sampling location with a thermocouple Type K (NiCr-Ni)

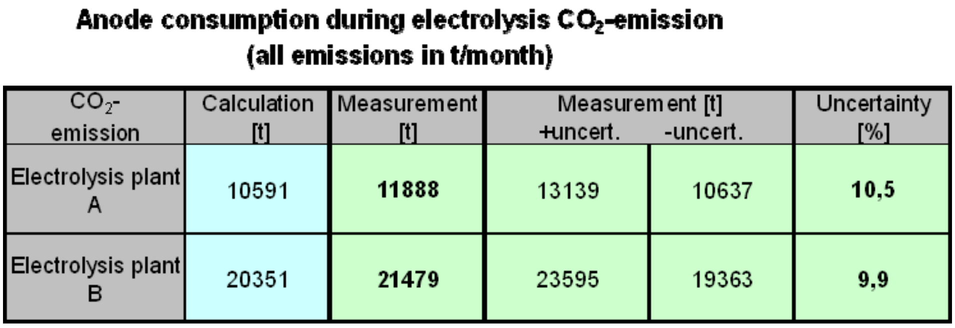
Table 8.1: Applied measurement methods

8.3.3.3 Measuring results

The results of the measuring campaigns are reported below.

For clarification, these results represent the total amount of CO_2 measured in one month, expressed in tonnes. Furthermore, the carbon monoxide was calculated as CO_2-equivalent and no other GHG (e.g. CH_4 or N_2O) could be detected with the FTIR system, further than PFCs.

In the table below the results of the measurement performed at the electrolysis stage for the two plants considered are reported, with the related measurement uncertainty, and compared with the values calculated with the calculation method (Table 8.2). The results are also plotted in the following graph (Figure 8.1).



Anode consumption during electrolysis CO_2-emission
(all emissions in t/month)

CO_2-emission	Calculation [t]	Measurement [t]	Measurement [t] +uncert.	Measurement [t] -uncert.	Uncertainty [%]
Electrolysis plant A	10591	**11888**	13139	10637	**10,5**
Electrolysis plant B	20351	**21479**	23595	19363	**9,9**

Table 8.2: Comparison of calculated and measured CO_2 emissions (electrolysis)

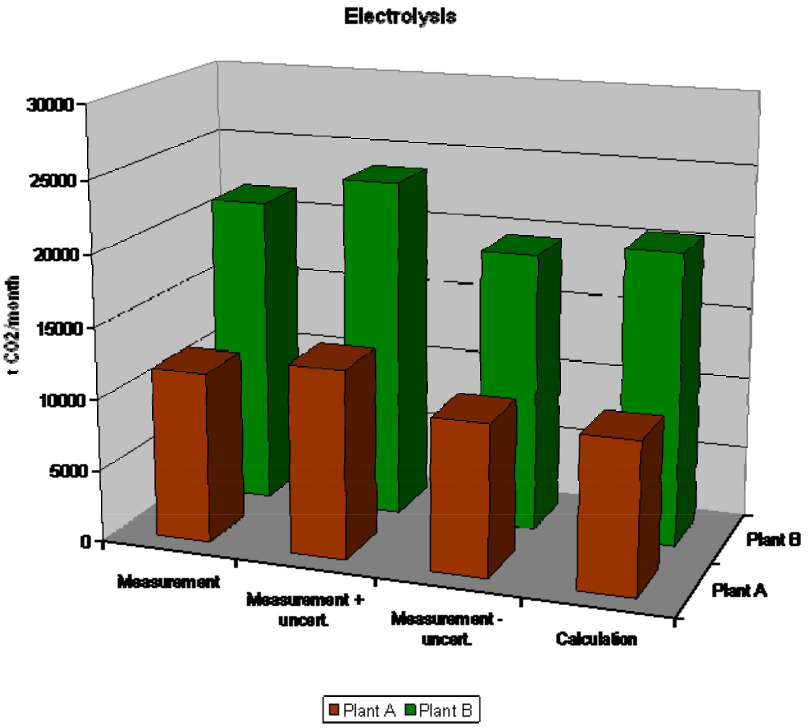


Figure 8.1: Comparison of calculated and measured CO_2 emissions (electrolysis)

Similarly, the following table (Table 8.3) and graph (Figure 8.2) report the result of the measuring campaigns in the anode baking furnaces for the two plants considered.

Also in this case, results of the field measurements are compared with the calculation method, which is based on a mass balance considering three main sources of carbon: pitch, packing coke and fuel.

Anode baking process CO_2-emission (all emissions in t/month)

CO_2-emission	Calculations (subtotal)							
	Pitch Coking [t]	Packing Coke [t]	Fuel [t]	Calculation [t]	Measurement [t]	Measurement [t] +uncert.	Measurement [t] -uncert.	Uncertainty [%]
Anode baking furnace plant A	1052	301	**1583**	2937	**2893**	3187	2599	**10,2**
Anode baking furnace plant B	740	76	**742**	1557	**1408**	1543	1273	**9,6**

Table 8.3: Comparison of calculated and measured CO_2 emissions (anode baking)

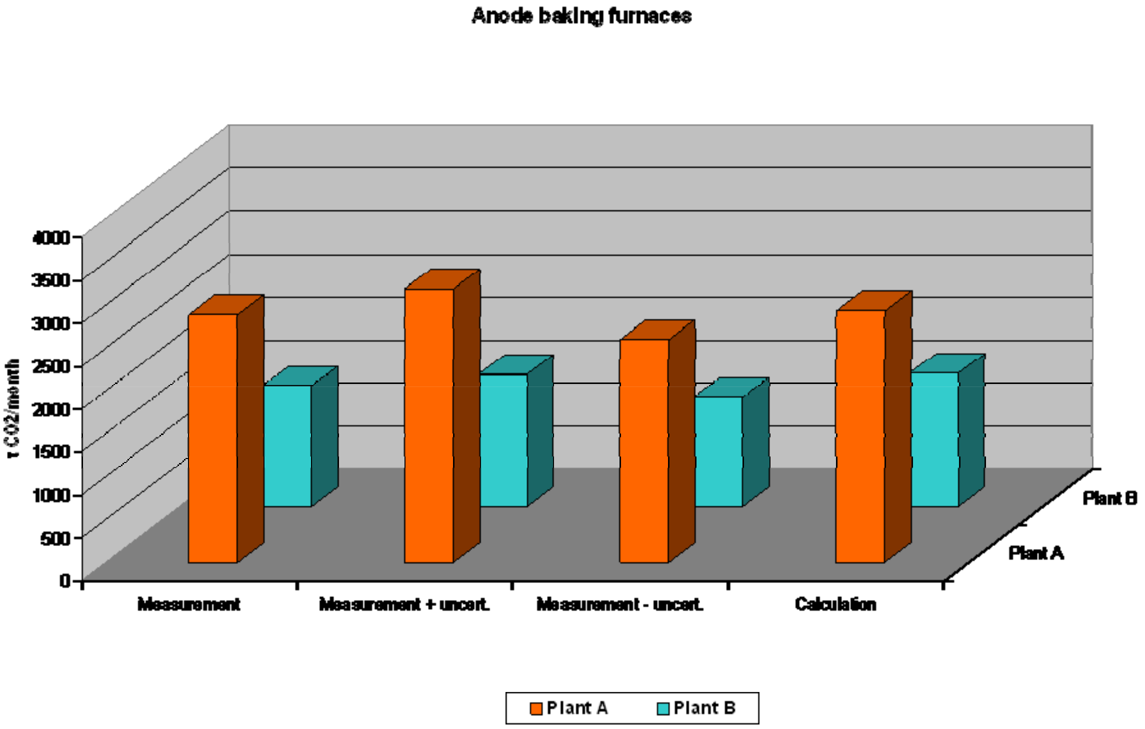


Figure 8.2: Comparison of calculated and measured CO_2 emissions (anode baking)

8.3.3.4 Assessment of results and uncertainties

- Uncertainty of the determination of mass concentrations: for the measured concentration range (0 - 5 Vol.% of CO_2), the resulting measurement uncertainty is +/- 3.9% of the value, based on the calculation of the uncertainty of the measurement of CO_2 with FTIR according to EN ISO 14956 [6] (Implementation of all relevant uncertainty sources into an uncertainty budget).
- Uncertainty of the volume flow: the values are reported in the following Table 8.4

Stack	Range (appr.) [m^3/s]	Uncertainty +/- [%]
Anode baking furnace plant A	**14**	**3.28**
Anode baking furnace plant B	**13**	**2.81**
Electrolysis plant A	**280**	**3.55**
Electrolysis plant B	**520**	**3.03**

at standard conditions (1013 hPa, 273 K, dry gas)

Table 8.4: Determined uncertainties

- Uncertainty of the mass flow (U flow): calculation made by combining the measurement uncertainties (pressure, velocity moisture, flue gas density etc.) of the volume flow at each measurement site according to EN 16911-1 [1] (including all relevant influences like velocity, pressure, moisture, diameter etc.) with the uncertainty of the mass concentration measurement.

8.3.3.5 Evaluation of the results

Considering the uncertainty of the measurements the result of the measurements and the results of the calculations are in good accord.

8.4 Sector-specific standard for the aluminium industry

8.4.1 Status of work

The final draft of the sub-standard for the aluminium industry was submitted to the Secretariat of WG 33 in March 2014.

8.4.2 Impact of verification tests on draft standard

The verification tests supported the calculation method described in the standard, both for the PFC and CO_2 emissions.

9 SG 5 Lime industry

This second interim report presents the progress made since the first interim report published in April 2013 regarding the development and verification of a GHG performance standard for the lime industry. This report was requested by the European Commission, and is the 3rd milestone for releasing part of the compensation.

The report presents the structure put in place to work on the standard, the progress made on developing the standard itself, and gives the current status of the verification tests.

9.1 Summary

Subgroup 5 (SG5) has been created under CEN/TC264/WG33 on “Greenhouse gas (GHG) emissions in energy-intensive industries" to prepare the standard ‘ISO/DIS 19694-5 Stationary source emissions — Determination of Greenhouse gas (GHG) emissions in energy-intensive industries — Part 5: Lime industry’.

SG5 is chaired by Dr. Martyn Kenny – and the Secretariat is managed by Mr. Bert Dijkstra of the Dutch Standardization Body (NEN).

The following persons participate in the activities of SG5 (Table 9.1):

UK	Dr. Martyn Kenny	Convener
Belgium	Ms. Mira Tayah	Member
Germany	Mr. Werner Fuchs	Member
Germany	Mr. Ferdinand Hencks	Member
Belgium	Mr. Julien Coubronne	Observer
Secretariat	Mr. Bert Dijkstra	NEN

Table 9.1: SG5 members

SG5 has completed both the first and second rounds of verification tests required for the verification of the methodology given in the draft standard, and has incorporated the findings of the tests in the draft standard.

The draft standard ‘ISO/DIS 19694-5 Stationary source emissions — Determination of Greenhouse gas (GHG) emissions in energy-intensive industries — Part 5: Lime industry’ has been submitted for CEN enquiry on 1 April 2014.

9.2 Activities since First Interim Report

Since the first interim report published in April 2013, a number of formal SG5 meetings have taken place, with much of the drafting work, comments and information exchange undertaken by e-mail in between the formal meetings. The two rounds of verification tests at two plants have also been completed.

The third SG5 meeting took place on 7 October 2013, with the main objectives:

- Debriefing results of the first verification test and recommendations for improving the standard
- Preparation of the second verification test
- The latest draft of the GHG standard for lime was presented and comments reviewed

The fourth SG5 meeting took place on 20 March 2014, with the following objectives:

- Debriefing of the second round of verification tests
- Finalization of the draft of the lime standard for CEN enquiry

The minutes of this meeting on 20 March 2014 have been finalized and will be shortly published by NEN.

In addition to its formal meetings, SG5 maintains strong links with the European Lime Association (EuLA) which represents about 95% of European lime production. Mr. Julien Coubronne, who joined EuLA in February 2014, replaced Bert D'Hoogue as advisor at EuLA. He continued to animate the EuLA “GHG Monitoring and Reporting Ad Hoc Group” that was created to monitor and contribute on behalf of the EU lime sector to the work of SG5 on the lime GHG standard. Dr. Martyn Kenny is also chair of the EuLA GHG Monitoring and Reporting Ad Hoc Group. The EuLA group held six meetings in 2012, four in 2013, and 3 in 2014. Around 30 national trade bodies and members are included on the group’s mailing list. All EuLA members have been invited to join the SG5 meetings. Through the link with EuLA, EU lime producers are closely involved and able to contribute to the development of the lime GHG standard.

The draft standard was edited into CEN format and ‘ISO/DIS 19694-5 Stationary source emissions — Determination of Greenhouse gas (GHG) emissions in energy-intensive industries — Part 5: Lime industry’ has been submitted for CEN enquiry on 1 April 2014.

9.3 Verification Tests

The lime GHG standard has been validated on the basis of a two rounds of verification tests carried out on two different production sites, giving a total of four verification tests. The design of the verification tests was set out in detail in the tender specification. The results of these verification tests have been assessed; and the draft lime GHG standard has been updated according to the findings and recommendations made.

In the second round of verification tests, practical issues highlighted in the first round were taken into account by making minor amendments to the approach to data collection and measurement. The second round of tests were undertaken on the same two production sites used in the first round to allow direct comparison of results.

A final verification test report has been completed. All findings from the second verification test have been accommodated within the draft standard submitted for CEN enquiry.

9.3.1 Selection and characterization of plants

Two plants (A and B) were selected as host sites for the verification tests. The selection was based on the need to be generally representative of the lime kilns types operated by lime manufacturers. Selection was also made on the basis of the fuel types used. The general characteristics of the plants were as follows (Table 9.2):

Plant A	• Parallel flow regenerative kiln (PFRK) • Single fuel fired (natural gas) • Limestone purchased from neighbouring quarry • Quicklime and hydrated lime product
Plant B	• Rotary kiln • Multiple fuel fired (coal, solvent waste, biomass) • Limestone purchased from neighbouring quarry • Dololime product

Table 9.2: Characteristics of selected kiln types

9.3.2 Selected subcontractors for the second verification test

The field verification test consists of:

- An assessment of the methodology proposed in the draft lime GHG standard for quantifying relevant non-kiln GHG emissions and indirect kiln GHG emissions, on the basis of annual data for the test site. This assessment of relevant non-kiln GHG emissions will be carried out for each of the sites where a field verification test is undertaken.
- An assessment of the methodology proposed in the draft lime GHG standard for quantifying relevant direct GHG emissions generated by the kiln. Direct emissions from the kiln make up the majority of the GHG emissions from the lime manufacturing process. A comparison will be made between the results of a two "mass balance" approaches, one using inputs and the other outputs. Comparison of the two mass balance approaches will be made with a third approach using stack measurements. These approaches will be assessed in terms of the practicality and uncertainty of the measurements.

The results of the field verification tests have been used to determine to which extent the methods in the draft lime GHG standard are fit for purpose. The results of the field verification test have been incorporated in the preparation of the lime GHG standard.

NEN managed the appointment of a project team to undertake the verification testing. The project team comprised of four work packages with both lime producers and analytical/test laboratories being appointed to undertake the work following a formal selection process.

The four work packages (WP) are (Table 9.3):

- WP1 Supervisor to manage and coordinate all aspects of the verification test program in compliance with the draft standard, to undertake uncertainty analysis and prepare reports
- WP2 Stack measurements
- WP3 In-house sampling, sample preparation and analysis – and assistance in preparing ' the reports
- WP4 External analysis

WP1 Project supervisor	Dr N Ford Environmental Scientifics Group	Preparation, coordination and supervision of verification testing. Assessment of draft standard methodologies based on verification testing. Reporting of results.
WP2 Stack measurements	Environmental Scientifics Group	Undertaking of measurements for GHGs at each verification test.
WP3 Sampling and analysing at plant	EuLA coordinator Plant A Plant B	Hosting of verification tests. Measurement of relevant plant operating parameters during verification tests. Sampling of input and output stream during verification tests.
WP4 External analysis	IKM	Undertaking chemical analysis on site samples

Table 9.3: SG5 Work packages

9.3.3 Measurement programme

The first round of the verification tests was somewhat delayed due to contractual issues and was undertaken during June and July 2013. It was originally intended that the interim report on the verification tests would be presented to SG5 on the 20 April 2013, but the delay meant that the results were presented to SG5 on 7 October 2013. The second round of verification tests were undertaken in December 2013 and January 2014 and presented to SG5 on 20 March 2014.

The measurement programme was undertaken according to the specification set out in the tender document, with potential improvements identified in the first round being incorporated into the approach used in the second round.

The field verification test covers the emissions from the sources indicated in the diagram below (Figure 9.1). The main focus of the field verification test program is on the emissions associated with the kiln process.

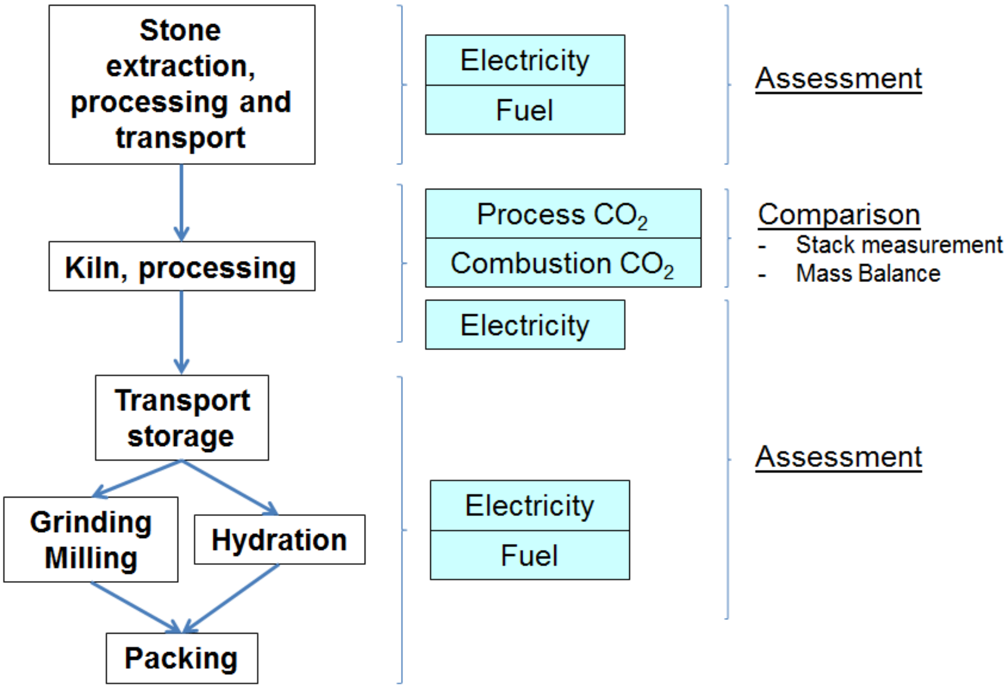
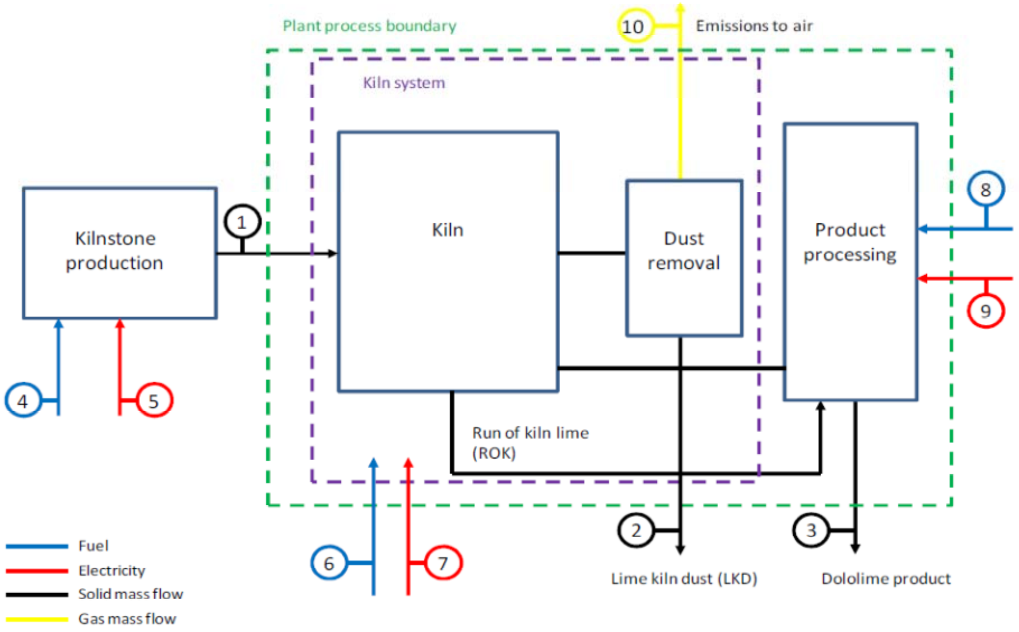


Figure 9.1: Occurrence of GHG sources in lime production processes



No.	Scope	Emission	Description	Standard ref.
1	1	Kiln - direct	Limestone processed (LS)	8.1.1.1
2	1	Kiln - direct	Lime kiln dust (LKD) produced from the process	8.1.1.2
3	1	Kiln - direct	The product produced from the process either as run of kiln (ROK) lime or as processed product.	8.1.1.3
4	3	Non kiln - indirect	Electricity used in the production of the kiln stone and transport to plant	9.1.1
5	3	Non kiln - indirect	Fuel used in the production of the kiln stone and transport to plant	8.3.1
6	2	Kiln - indirect	Electricity used in the kiln operation including any requirements for transport of kiln stone or fuel from plant delivery point to the kiln.	9.1.1
7	1	Kiln - direct	Fuel used in kiln operations (gas, coal, biomass etc.)	8.2.1
8	2	Non kiln - indirect	Electricity used in post kiln processing of product	8.1
9	1	Non kiln - direct	Fuel used in post kiln processing of product	8.3.1
10	1	Kiln - direct	GHG emissions from kiln system released to atmosphere via plant exhaust stack	-

Figure 9.2: Lime kiln mass balance

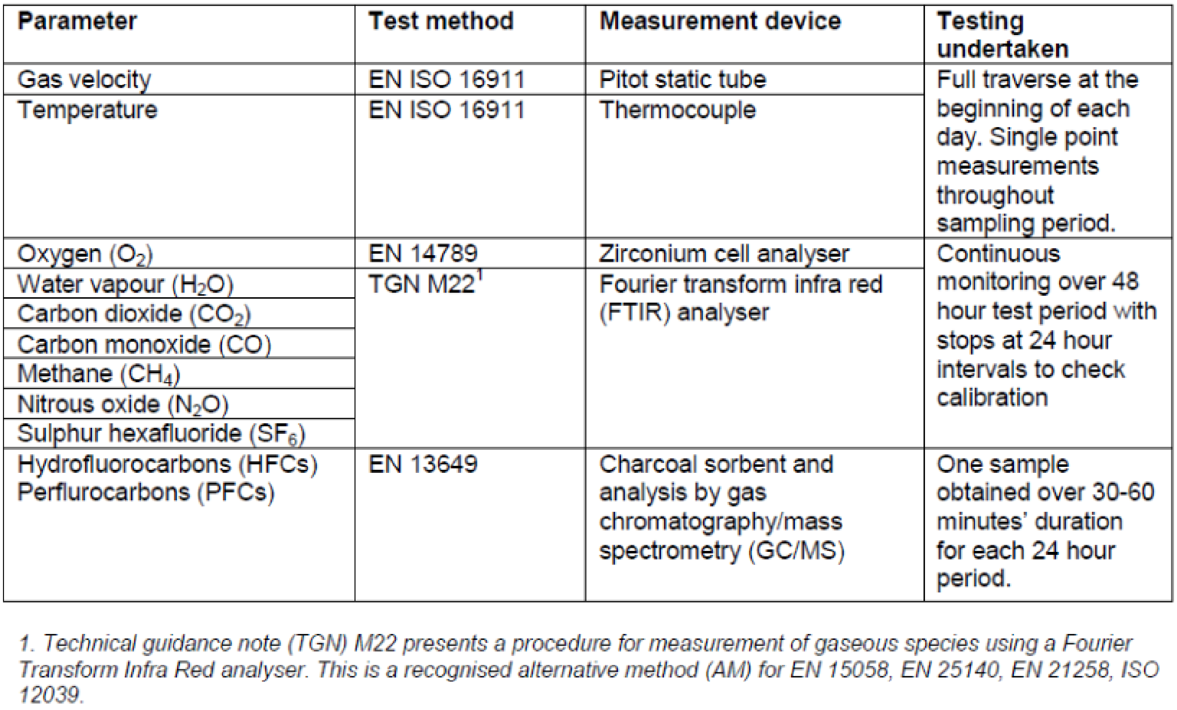
The typical workflow for each verification test was the following:

- Advance planning of the field verification tests
- Preparation for the field verification tests
- Measurement and quantification of kiln GHG emissions: stack emissions during a 48 hours period and a mass balance assessment:
- Post-processing and data preparation
- Assessment of non-kiln GHG emissions
- Laboratory analysis
- Data analysis and evaluation interim report (after each Round)
- Final report on all field tests (after the 2nd Round)

Measurements at the kiln exhaust stack

During Round 1 site measurements at the nominated kiln exhaust stack at each plant were undertaken over the designated 48 hour test period using the equipment and methods described in Table 9.4.

Primarily it was required that measurements of exhaust flow rate and the concentration of CO_2 be determined. This enables comparison with the draft standard methodology for estimating Scope 1 direct kiln emissions. In addition, it was also required that the concentrations of other potential GHG emissions from the process be measured to determine significance. Currently draft standard methodologies do not take into account non-CO_2 GHG emissions.

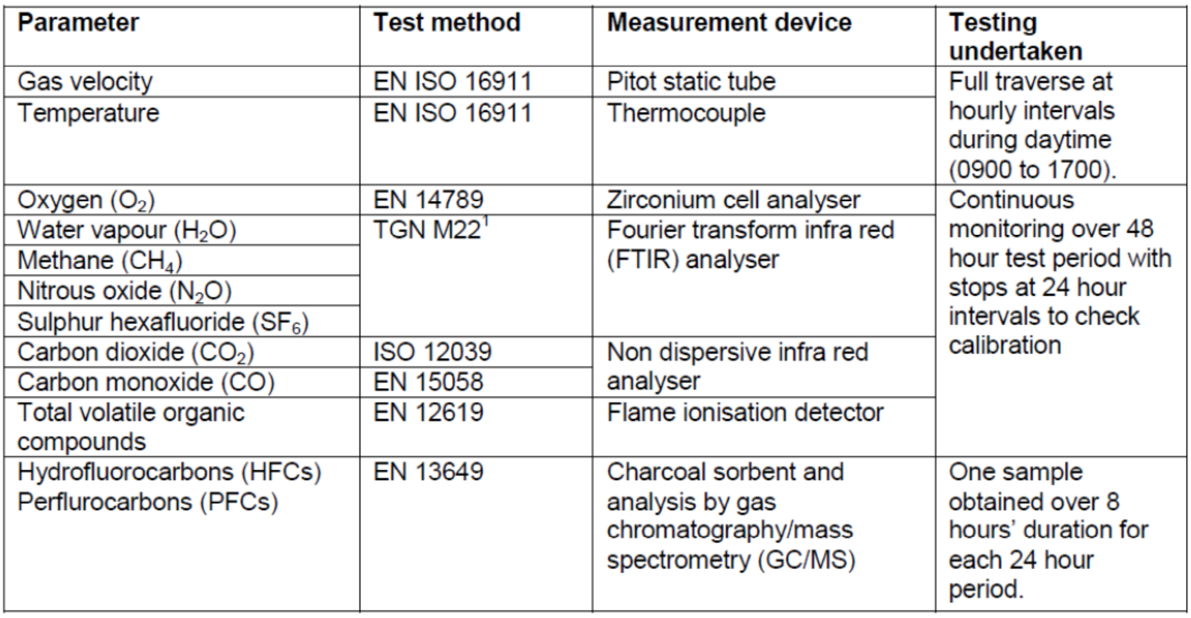


Parameter	Test method	Measurement device	Testing undertaken
Gas velocity	EN ISO 16911	Pitot static tube	Full traverse at the beginning of each day. Single point measurements throughout sampling period.
Temperature	EN ISO 16911	Thermocouple	
Oxygen (O_2)	EN 14789	Zirconium cell analyser	Continuous monitoring over 48 hour test period with stops at 24 hour intervals to check calibration
Water vapour (H_2O)	TGN M22[1]	Fourier transform infra red (FTIR) analyser	
Carbon dioxide (CO_2)			
Carbon monoxide (CO)			
Methane (CH_4)			
Nitrous oxide (N_2O)			
Sulphur hexafluoride (SF_6)			
Hydrofluorocarbons (HFCs) Perflurocarbons (PFCs)	EN 13649	Charcoal sorbent and analysis by gas chromatography/mass spectrometry (GC/MS)	One sample obtained over 30-60 minutes' duration for each 24 hour period.

1. Technical guidance note (TGN) M22 presents a procedure for measurement of gaseous species using a Fourier Transform Infra Red analyser. This is a recognised alternative method (AM) for EN 15058, EN 25140, EN 21258, ISO 12039.

Table 9.4: Kiln exhaust stack measurement methods – Round 1

Following assessment of the Round 1 results the testing methodology for Round 2 was slightly amended as shown in Table 9.5. It was considered necessary to improve the representativeness of the gas velocity measurement in particular. It was also considered that non dispersive infra red measurement provided a more representative measurement for some species in the context of these short term verification tests. In all operational respects the Round 2 testing mirrored that in Round 1.



Parameter	Test method	Measurement device	Testing undertaken
Gas velocity	EN ISO 16911	Pitot static tube	Full traverse at hourly intervals during daytime (0900 to 1700).
Temperature	EN ISO 16911	Thermocouple	
Oxygen (O_2)	EN 14789	Zirconium cell analyser	Continuous monitoring over 48 hour test period with stops at 24 hour intervals to check calibration
Water vapour (H_2O)	TGN M22[1]	Fourier transform infra red (FTIR) analyser	
Methane (CH_4)			
Nitrous oxide (N_2O)			
Sulphur hexafluoride (SF_6)			
Carbon dioxide (CO_2)	ISO 12039	Non dispersive infra red analyser	
Carbon monoxide (CO)	EN 15058		
Total volatile organic compounds	EN 12619	Flame ionisation detector	
Hydrofluorocarbons (HFCs) Perflurocarbons (PFCs)	EN 13649	Charcoal sorbent and analysis by gas chromatography/mass spectrometry (GC/MS)	One sample obtained over 8 hours' duration for each 24 hour period.

Table 9.5: Kiln exhaust stack measurement methods – Round 2

All measurements undertaken during both rounds have a quality accreditation meeting ISO 17025 (accredited by the United Kingdom Accreditation Service as meeting the requirements of the UK Environment Agency MCERTs scheme), with the exception of the measurements for HFCs and PFCs.

Plant operational measurements

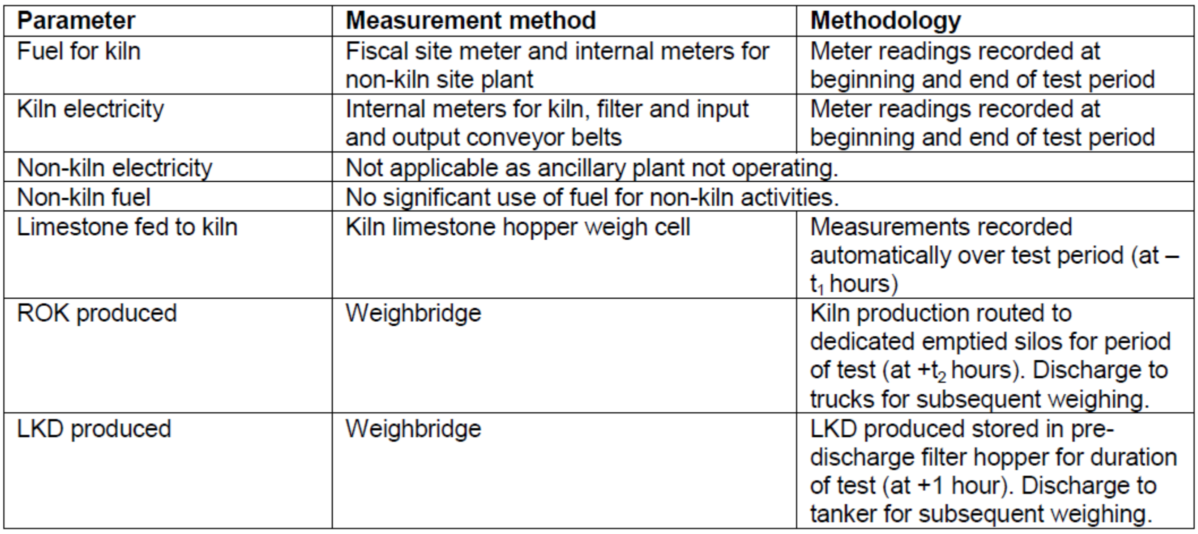
Prior to the commencement of testing the measurement of the required operating parameters at each site was discussed to ensure that suitably calibrated metering devices were available and a measurement programme was in place. At each site measurements of operating parameters necessary to the verification of the draft standard calculation methodology were undertaken. Essentially it was necessary to determine the following parameters over the verification test period:

- Fuel used in the kiln
- Electricity used for kiln operation
- Electricity used for non-kiln activities
- Fuel used in non-kiln activities
- Limestone fed to kiln
- ROK produced
- LKD produced

The specific requirements varied between sites as discussed below.

Plant operational measurements - Plant A

At plant A the main operating parameters were obtained as below (Table 9.6):



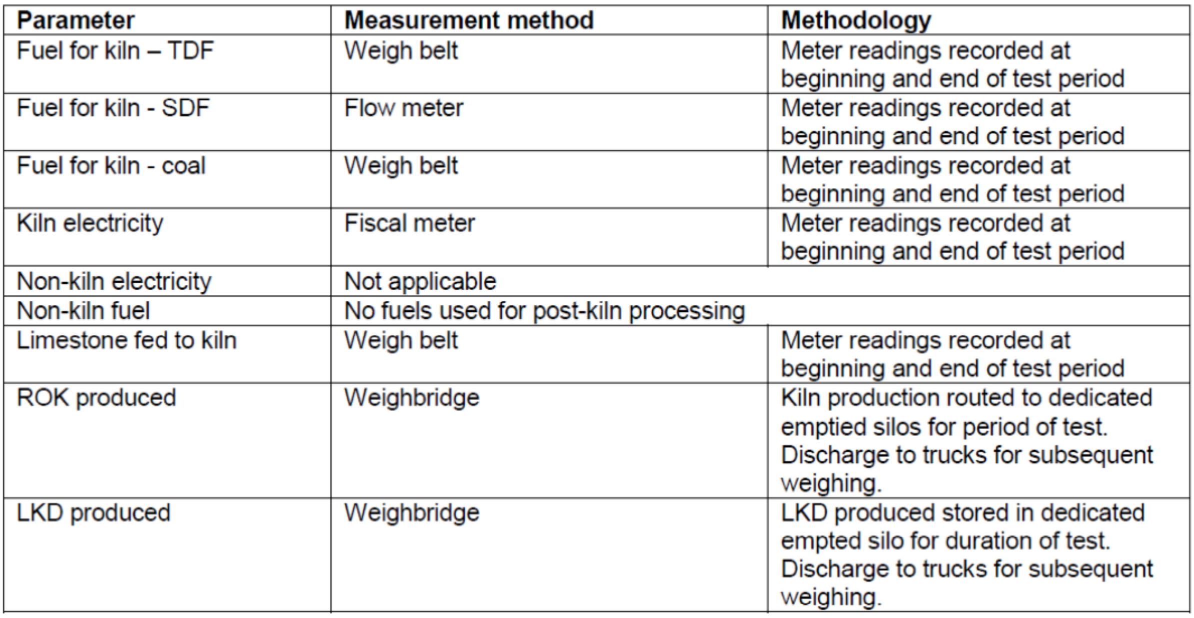
Parameter	Measurement method	Methodology
Fuel for kiln	Fiscal site meter and internal meters for non-kiln site plant	Meter readings recorded at beginning and end of test period
Kiln electricity	Internal meters for kiln, filter and input and output conveyor belts	Meter readings recorded at beginning and end of test period
Non-kiln electricity	Not applicable as ancillary plant not operating.	
Non-kiln fuel	No significant use of fuel for non-kiln activities.	
Limestone fed to kiln	Kiln limestone hopper weigh cell	Measurements recorded automatically over test period (at – t_1 hours)
ROK produced	Weighbridge	Kiln production routed to dedicated emptied silos for period of test (at +t_2 hours). Discharge to trucks for subsequent weighing.
LKD produced	Weighbridge	LKD produced stored in pre-discharge filter hopper for duration of test (at +1 hour). Discharge to tanker for subsequent weighing.

Table 9.6: Determination of main operating parameters at Plant A

The above measurements were provided to the project supervisor following completion of the site test and subsequent product weighing.

Plant operational measurements - Plant B

At plant B the main operating parameters were obtained as below (Table 9.7):



Parameter	Measurement method	Methodology
Fuel for kiln – TDF	Weigh belt	Meter readings recorded at beginning and end of test period
Fuel for kiln - SDF	Flow meter	Meter readings recorded at beginning and end of test period
Fuel for kiln - coal	Weigh belt	Meter readings recorded at beginning and end of test period
Kiln electricity	Fiscal meter	Meter readings recorded at beginning and end of test period
Non-kiln electricity	Not applicable	
Non-kiln fuel	No fuels used for post-kiln processing	
Limestone fed to kiln	Weigh belt	Meter readings recorded at beginning and end of test period
ROK produced	Weighbridge	Kiln production routed to dedicated emptied silos for period of test. Discharge to trucks for subsequent weighing.
LKD produced	Weighbridge	LKD produced stored in dedicated empted silo for duration of test. Discharge to trucks for subsequent weighing.

Table 9.7: Determination of main operating parameters at Plant B

The above measurements were provided to the project supervisor following completion of the site test and subsequent product weighing.

Plant feedstock, product and fuel sampling

The specification for the verification test clearly defines the streams to be sampled and the frequency (Table 9.8):

Stream	No. of samples required	Frequency (h)	Standard
Limestone to kiln	8	6	EN 932-1
LKD	8	6	EN 932-1
ROK	8	6	EN 932-1
Fuel (coal, gas)	8	6	ISO 13909, ISO 10715
Fuel (waste or biomass)	24	2	EN 15440

Table 9.8: Process stream sampling requirements

The specific arrangements at each site are discussed below.

Sampling at Plant A

The streams sampled at Plant A were as follows (Table 9.9):

Stream	Sampling position	Samples obtained	Preparation for analysis
Limestone to kiln	Conveyor belt to kiln stone hopper	8 samples at 6 hour intervals	c. 5 kg per sample of crushed stone
LKD	Chute to filter hopper	8 samples at 6 hour intervals	c. 200 g per sample of raw LKD
ROK	Conveyor belt to storage silo	8 samples at 6 hour intervals	c. 5 kg per sample of crushed product
Natural gas	Sample 5 June 2013 at 1500 for Round 1 Sample 29 November 2013 for Round 2		

Table 9.9: Process stream sampling arrangements at Plant A

Solid samples were collected, prepared where necessary as above, sealed within plastic buckets and dispatched for subsequent analysis. The analysis of natural gas was undertaken by a local laboratory accredited to ISO 17025.

Sampling at Plant B

The streams sampled at Plant B were as follows (Table 9.10):

Stream	Samples obtained	Preparation for analysis
Limestone to kiln	9 samples at 6 hour intervals	c. 5 kg per sample of crushed stone
LKD	9 samples at 6 hour intervals	c. 200 g per sample of raw LKD
ROK	9 samples at 6 hour intervals	c. 5 kg per sample of crushed product
Coal	8 samples at 6 hour intervals	c. 0.5 kg per sample of pulverised coal
Liquid waste	24 samples at 2 hour intervals	c.200ml of raw liquid
Solid waste	24 samples at 2 hour intervals	c. 1 kg per sample of raw waste

Table 9.10: Process stream sampling arrangements at Plant B

Process samples were collected, prepared where necessary as above, sealed within plastic buckets and dispatched for subsequent analysis. Fuel samples were collected from site by Intertek for subsequent analysis.

Analysis of collected test samples

Process samples (limestone, LKD, ROK) collected during the verification tests at each plant were subject to identical analyses. The following primary analyses were undertaken (Table 9.11):

Sample	Property	Method
Limestone	Moisture	EN 12485:2010 EN 459-2:2010
	$CaCO_3$ content	
	$MgCO_3$ content	
LKD	$CaCO_3$ content (by difference)	
	$MgCO_3$ content (by difference)	
	CaO content	
	MgO content	
ROK	$CaCO_3$ content (by difference)	
	$MgCO_3$ content (by difference)	
	CaO content	
	MgO content	

Table 9.11: Primary analytical schedule for process samples

Additional analyses, particularly during Round 2, were undertaken to gain a better understanding of the composition of product. This included analyses, where appropriate, for sulphur trioxide, silicon dioxide and iron oxide.

Fuel samples collected at Plant B were subject to analysis by Intertek. The following analyses were undertaken on each fuel (Table 9.12).

Sample	Property	Method
Coal	Carbon content	ASTM D5291
	Calorific value	ASTM D240
TDF	Carbon content	ASTM D5291
	Calorific value	ASTM D240
SDF	Carbon content	ASTM D5291
	Calorific value	ASTM D240

Table 9.12: Analytical schedule for fuel samples from Plant B

The analysis of natural gas at Plant A was undertaken on a single sample during each round in accordance with EN ISO 6976-05.

All measurements undertaken on collected process and fuel samples were accredited to EN 17025.

9.3.4 Measuring results & evaluation of results

The verification test as based on the draft lime GHG standard consists of:

- An assessment of the methodology proposed in the draft lime GHG standard for quantifying relevant non-kiln GHG emissions and indirect kiln GHG emissions, on the basis of annual data for the test site. This assessment of relevant non-kiln GHG emissions will be carried out for each of the sites where a verification test is undertaken.

- An assessment of the methodology proposed in the draft lime GHG standard for quantifying relevant direct GHG emissions generated by the kiln. Direct emissions from the kiln make up the majority of the GHG emissions from the lime manufacturing process. A comparison will be made between the results of two “mass balance” approaches, one using inputs and the other outputs.

Comparison of the two mass balance approaches will be made with a third approach using stack measurements. These approaches were assessed in terms of the practicality and uncertainty of the measurements (Figure 9.3 and Figure 9.4).

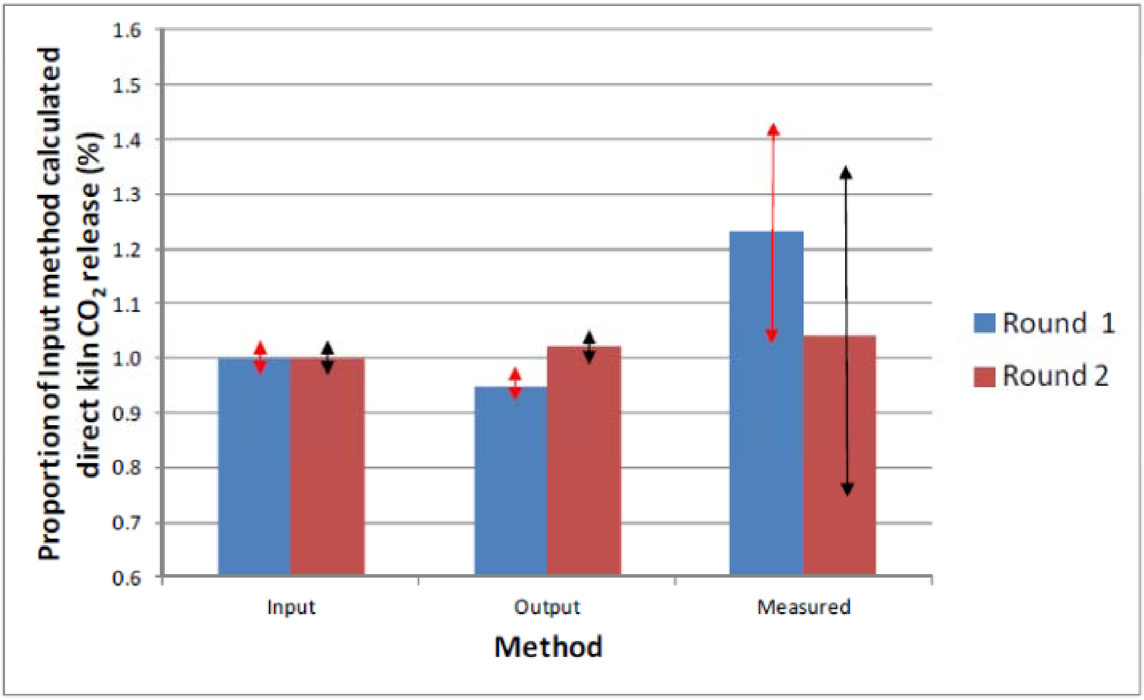


Figure 9.3: Plant A Verification test and uncertainty results summary

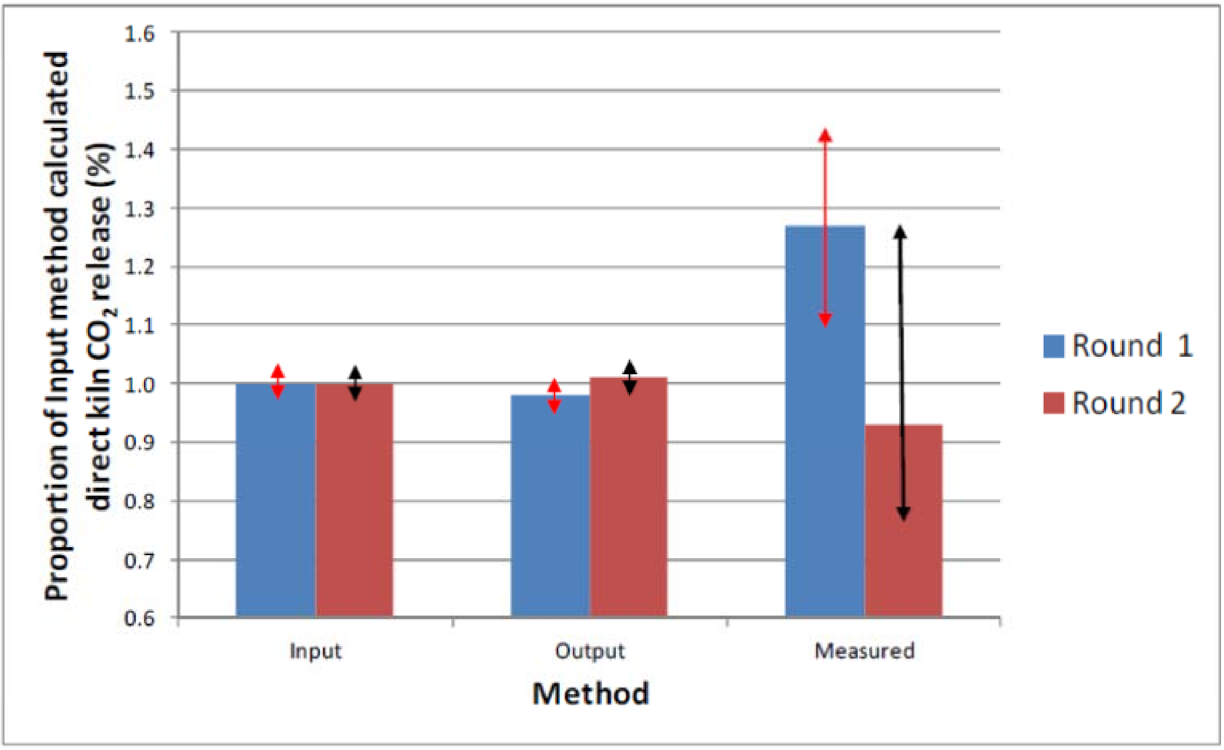


Figure 9.4: Plant B Verification test and uncertainty results summary

In the first round of tests it was concluded that both the input and output calculation methods were workable and produce results which agree closely and which meet uncertainty requirements.

The tests were carried out over 48 hours for practical reasons, whereas the standard requires data collected over a 12 month period. The small differences between input and output method results in the first round were considered to be largely due to inaccuracies, such as material held up in silos, which are likely to be significantly minimized over the much longer periods of assessment required by the draft standard.

Determination of CO_2 emissions by direct measurement was found to be subject to far greater levels of uncertainty than the calculation-based methods. The representative measurement of exhaust gas flow is identified as having a major influence on the suitability of this technique.

An assessment of non-CO_2 greenhouse gas emissions indicated that only methane was present in detectable concentrations. However it is considered that measurement at lower detection limits is required before these species can be confidently excluded from consideration within the standard.

The issues highlighted in the first round tests were taken into account in the second round tests by making minor amendments to the test methodology. Modifications included:

- Ensuring all silos are empty before test start and fully cleared following test completion as far as practical
- Improving the velocity measurement position and increasing the frequency of measurement
- Extending sampling periods for some non-CO_2 GHG (PFCs & HFCs) to reduce detection limits

The second round findings reinforced those from the first round.

Both the input and output calculation methods were shown to be practical, workable, in very good agreement and gave low overall uncertainties, below 2% for the direct emissions. The greater attention paid to ensuring silos were empty before and after the 48 hour test reduced the deviation between the input and output methods for Plant A. However, the effect will be significantly minimized when the methodology is applied over the 12 month period called for by the draft standard.

The representative measurement of exhaust gas flow was again identified as having a major influence on the suitability of the measurement technique. Measurements made at the two plants indicated higher releases of CO_2 than determined by calculation in three of the four measurement tests and far higher associated uncertainties in all measurement tests.

The suitability of the measurement technique is largely dependent on the ability to make a representative measurement of the CO_2 content of the exhaust gas and its flow rate. The representativeness of these two measurements, in particular the measurement of flow, was found to be heavily influenced by the homogeneity of the sampling location. Significant efforts to improve flow measurement in the second round reduced the deviation between the calculation and measurement methodologies but despite these efforts the uncertainties of the measurement method remained high as the representative measurement of flow remained an issue. The verification tests show that the measurement method is likely to be subject to much greater uncertainty than the calculation-based methods.

The verification testing indicated that of the non-CO_2 greenhouse gases, only methane is present in any measureable amount. Methane was most significant on the parallel flow regenerative kiln. However, the amount, on a CO_2 equivalent basis was generally less than 0.2% of the GHG emissions. In view of the errors associated with the measurement of methane and the very low levels detected, it is considered that discounting methane, and all other non-CO_2 greenhouse gases, does not have a significant impact on the representativeness or completeness of the GHG measurement.

The tests confirmed that calculations of relevant non-kiln GHG emissions and indirect kiln GHG emissions, on the basis of annual data for the test site were practical, workable and gave low overall uncertainties.

9.3.5 Assessment of results and uncertainties

Based on the analysis undertaken during the verification tests it appears that the measurements which are most crucial to minimising uncertainty are:

- Limestone rate
- Limestone carbonate content
- ROK rate
- ROK oxide content
- LKD rate (in some cases)
- LKD oxide content (in some cases)
- Fuel rate to kiln

Many other measured parameters contribute to the overall mass balance, but their sensitivity is such that they do not have a significant impact on the overall uncertainty of the calculation. The measurement devices, site calibration processes and sampling practices at each site are considered sufficient to ensure the required level of uncertainty when using either the input or output calculation method even for the 48 hour test period.

The verification tests have shown that the uncertainty of the measurement methodology ranged between 15% and 31% for direct emissions. This uncertainty is consistently and significantly higher than the uncertainties derived for the calculation-based input and output methodologies which are at or below 2% for direct emissions. The main reason identified for this difference is the poor quality of the flow measurement due to the nature of stack arrangement and fluctuating process conditions.

9.4 Sector-specific standard for the lime industry

Following the completion of the second verification test, the following chapters of the draft lime GHG standard have been completed:

- Section 8 Determination of GHG emissions: general requirements
- Section 9 Scope 1 emissions and their determination (direct emissions)
- Section 13 Uncertainty of GHG inventories
- The Annexes

The draft GHG standard for lime ‘ISO/DIS 19694-5 Stationary source emissions — Determination of Greenhouse gas (GHG) emissions in energy-intensive industries — Part 5: Lime industry’ has been developed and submitted for CEN enquiry on 1 April 2014. A copy of the draft standard is attached in Annex 1.

9.4.1 Impact of verification tests on draft standard

The following results of the verification tests have been taken into account in the drafting of the standard.

- The measurement method gave a very much higher level of uncertainty compared to the measurement method, despite significant efforts to reduce this during the verification tests.
- Non-CO_2 greenhouse gases do not have a significant impact on the representativeness or completeness of the overall estimate of GHG emissions and so are not required to be assessed in the standard.

9.5 Conclusion

Two rounds of verification tests have been completed for two plants. The results of the verification tests have confirmed the suitability of the input and output calculation methods described in the GHG standard.

The verification tests have shown that the uncertainty of the measurement methodology is consistently and significantly higher than the uncertainties derived for the calculation-based input and output methodologies.

All findings from the verification tests have been taken into account in the draft GHG standard.

10 SG 6 Ferro-alloys industries

10.1 Introduction

This work is part of the standardization mandate M/478 for the development of European Standards in the field of greenhouse gas (GHG) emission in energy intensive industries. CEN TC 264/Working Group 33 is in charge of producing such standards which shall contain harmonized methods for:

- Measuring, testing and quantifying GHG emissions from sector-specific sources;
- Assessing the level of GHG emissions performance of production processes over time at production sites;
- Establishing and providing reliable, accurate and quality information for reporting and verification purposes.

As different industrial sectors have different production processes, a sectorial approach is followed and six Subgroups were created. In this respect, the ferro-alloys sector (CEN/TC 264/WG 33/Subgroup 6) participates in the development of the GHG emissions standards which will address the total CO_2 emissions including direct and indirect emissions in this sector.

10.2 Milestones

The next documents and actions have been performed by the subgroup so far (Table 10.1):

Item	Delivered/Done on
inventory protocol	2012-04-24
Form N	2012-04-24
Consultation procedure for the selection of plants	2012-06-19
Selection report – selection of plants	2012-07-03
Call for tenders	2012-07-06
Call for tenders extension	2012-09-13
Selection report – call for tenders extension	2012-10-09
Subcontracting: Contracts for WP 1, WP 2, WP 3 and WP 4	2013-01-18
Subcontracting: Contracts for the plants	2013-01-18
Kick Off meeting for the field tests	2013-02-07
Delivery of the first progress report to CEN/TC 264/WG 33	2013-04-25
First campaign data collection (covers the data collection for the different plants)	2013-april to 2013-july
Second campaign data collection (covers the data collection for the different plants)	2013-september to 2013-november
Delivery of the draft standard for CEN Enquiry	2014-04-09

Table 10.1: Milestones

Remarks:

- Consultation procedure for the selection of plants

  Objective: to receive offers to host the field tests

  The budget was < EUR 25 000, so according to FPA 2009, at least three candidates were consulted for each type of plant

- Call for tenders

  Objective: to receive offers from laboratories to perform the field tests

  Available in CEN, VDI and Euroalliages websites on 2012-07-10 for 52 days

  This initial call for tenders ended with no valid candidates

- Call for tenders extension

  Available in CEN, VDI and Euroalliages websites on 2012-09-14 for 52 days

  Selection report – selection of plants

  Approved by the European Commission on 2012-08-21

- Selection report – call for tenders extension

  Approved by the European Commission on 2013-01-08

  Selection for an additional test for the Calculation of the biogenic CO_2 fraction for Ferropem

  Approved by the European Commission on 2013-10-21

10.3 Meetings

The meetings related with the work held so far are indicated in Table 10.2:

Date	Meeting	Location
2012-03-09	Subgroup meeting	Brussels
2012-03-22	Secretaries and convenors coordination meeting	Brussels
2012-05-29	Subgroup meeting	Madrid
2013-02-07	Planning of the field test	Dunkirk
2013-10-02	Subgroup meeting	Brussels
2013-12-04	Subgroup meeting	Brussels
2014-03-24	Subgroup meeting	On line

Table 10.2: SG 6 meetings

10.4 Subcontracting

The field tests shall be performed by experienced entities according to standardized sampling methods and analytical procedures. On the other hand, the performance of the tests generates costs in the sites in which they are performed, so subcontracting of suitable and representative sites were needed.

Two processes were launched: a call for tenders for the performance of the tests and a consultation procedure for the selection of plants. Selection criteria were defined and selection panels established for both processes (see clause 2 for details). After the approval of the selection reports by the European Commission the next organizations were subcontracted:

Working packages:

- WP 1, WP 2, WP 3 and WP 4 are allocated to SGS Group

Host Plants:

- Vargön Alloys AB – Sweden: production of FeCr-alloy in semi-closed submerged electric arc furnace
- Ferropem – France: production of Silicon in an open submerged electric arc furnace
- Glencore – France: production of FeMn-alloy in a closed submerged electric arc furnace

10.5 Laboratory and field verification tests

10.5.1 General

The objectives of the field tests are to:

- Verify and to compare the mass balanced method (input and output method) and direct CO_2 emission from stack measurement
- Estimate the uncertainties of both methods
- Validate the methodology that results to be the appropriated

The purpose is to gather, analyse and report field data, by performing sampling and laboratory analysis of total carbon content of input and output materials and by measuring CO_2 emission from stack, at various plants (Host plants) located in Europe producing ferro-alloys or silicon by smelting process (Submerged Electric Arc Furnace - SAF).

The work is split into four working packages:

- Working Package 1, Analysis of the total carbon content of reducing agents and other types of analysis for the mass balance method
- Working Package 2, Analysis of the total Carbon content of alloys, slag, silica fume and sludge and other types of analysis for the mass balance method
- Working Package 3, Measurement of CO_2 emission and other parameters in the duct
- Working Package 4, Evaluation of the data and reporting, general Supervisor/Coordinator
- The field work is divided in two campaigns for the three selected sites.
- In the next paragraphs the four WP's are summarized.

10.5.2 Summary of the working packages

WP 1 – Sampling & analysis Inputs

This WP covers the sampling and analysis of the reducing agents and electrodes. A sampling plan for each campaign according to the number of raw materials to be analyzed and taking into account field's constraints and the need of two measurement campaigns was developed. Each sampling campaign took place for 48 hours. Every four hours samples of the inputs were taken if possible. This leads to a maximum of 12 samples of each mass flow.

Duplicate samples from analyses are being stored for one year after the measurements were performed. These retained samples can be analyzed if any questions will arise.

WP 2 – Sampling & analysis Outputs

This WP covers the sampling and analysis of alloys, slag and dust. A sampling plan for each campaign according to the number of raw materials to be analyzed and taking into account field's constraints and the need of two measurement campaigns was developed. Each sampling campaign took place for 48 hours. Every four hours samples of the inputs were taken if possible. This leads to a maximum of 12 samples of each mass flow.

Duplicate samples from analyses are being stored for one year after the measurements were performed. These retained samples can be analyzed if any questions will arise.

WP 3 – Stack emission measurement

Two measurement campaigns in two plants were performed. At the third location there were no emission measurements due to safety regulations (high CO concentrations).

The measurements were performed with certified equipment and took place for a period of 48 hours. The measurements were undertaken continuously or as spot samples with a minimum of three times at each installation, according to the relevant standard.

The following flue gas parameters were measured in the stack: CO_2, CO, CH_4, N_2O, flue gas velocity, total gaseous organic carbon concentration, dust concentration

WP 4 – Evaluation and reporting

This WP covers the tasks of the general Supervisor / Coordinator and comprises the assessment and drafting of reports on the basis of fields reports delivered by WP 1, 2, 3 after the first and the second measurement campaigns

- Calculation of the CO_2 mass balance based on measured mass flows and results of analyses on contents;
- Statistics (check of the results on plausibility, reproducibility);
- Comparative analysis between coke sampling and analysis according to standard, and the field practice;
- Overall evaluation and conclusion based on the field reports;
- Uncertainty assessment, calculation of uncertainty and mass balance vs. emission measurements at the stack;

10.6 Results of the field verification tests (WP5)

10.6.1 Mass balance calculations

Based on the weighed inputs and outputs (weighings are made by the three locations), the sampled inputs and outputs combined with the analysed C-content, for each campaign the total amount of Carbon input / output is determined. The difference between Carbon input and output is the amount of carbon which will be emitted towards the atmosphere.

For the six campaigns, the results are presented in the next paragraphs. Every paragraph consists of three tables: one table with input results, one table with output results and one summary table.

10.6.1.1 Mass balance results Vargon Alloys AB – first campaign

Carbon Inputs		
Day 1 10 april 8:00 - 11 april 8:00	**kg C**	**% of total input Day 1**
Coke type 1	8092	24.1
Coke type 2	22223	66.2
Ore type 1	34	0.1
Ore type 2	138	0.4
Ore type 3	86	0.3
Quarts	7	0.0
Limestone	777	2.3
Electrode+briquettes	1824	5.4
Middlings	370	1.1
Total Carbon input day 1	**33550**	**100.0**
Day 2 11 april 8:00 - 12 april 8:00	**kg C**	**% of total input Day 2**
Coke type 1	8357	24.4
Coke type 2	22251	64.9
Ore type 1	34	0.1
Ore type 2	120	0.3
Ore type 3	92	0.3
Quarts	10	0.0
Limestone	832	2.4
Electrode+briquettes	2192	6.4
Middlings	393	1.1
Total Carbon input day 2	**34281**	**100.0**

Table 10.3: Input results Vargön Alloys AB

Carbon Outputs		
Day 1 10 april 8:00 - 11 april 8:00	**kg C**	**% of total input Day 1**
Alloy	3941	11.7
Dust	241	0.7
Slag	146	0.4
Middling	370	1.1
Total Carbon Output day 1	**4697**	**14.0**
Day 2 11 april 8:00 - 12 april 8:00	kg C	**% of total input Day 2**
Alloy	4006	11.9
Dust	265	0.8
Slag	114	0.3
Middling	393	1.2
Total Carbon Output day 2	**4779**	**14.2**

Table 10.4: Output results Vargön Alloys AB

Summary	**Kg C**	**% of total carbon input**
Carbon Input day 1	33550	49.5
Carbon Input day 2	34281	50.5
Total carbon input	**67831**	**100.0**
Carbon Output day 1	4697	6.9
Carbon Output day 2	4779	7.0
Total carbon output	**9476**	**14.0**
Expected stack emissions day 1	28853	42.5
Expected stack emissions day 2	29502	43.5
Total exp. Stack emissions	**58355**	**86.0**
Total exp. Stack emissions in kg/h	**1216**	

Table 10.5: Summary results Vargön Alloys AB

10.6.1.2 Mass balance results Vargon Alloys AB B – second campaign

Carbon Inputs		
Day 1 25 September 6:00 – 26 September 6:00	**kg C**	**% of total input Day 1**
Coke type 1	6372	27.6
Coke type 2	15181	65.7
Ore type 1	1	0.0
Ore type 2	7	0.0
Ore type 3	3	0.0
Quarts	1	0.0
Limestone	2	0.0
Electrode+briquettes	1342	5.8
Middlings	212	0.9
Total Carbon input day 1	**23121**	**100.0**
Day 2 26 September 6:00 – 27 September 6:00	**kg C**	**% of total input Day 2**
Coke type 1	9937	28.3
Coke type 2	22701	64.7
Ore type 1	2	0.0
Ore type 2	11	0.0
Ore type 3	4	0.0
Quarts	2	0.0
Limestone	3	0.0
Electrode+briquettes	2138	6.1
Middlings	304	0.9
Total Carbon input day 2	**35101**	**100.0**

Table 10.6: Input results Vargön Alloys AB

Carbon Outputs		
Day 1 25 September 6:00 - 26 September 6:00	**kg C**	**% of total input Day 1**
alloy	2496	10.8
dust	233	1.0
slag	59	0.3
middling	212	0.9
Total Carbon Output day 1	**2999**	**13.0**
Day 2 26 September 6:00 - 27 September 6:00	kg C	**% of total input Day 2**
alloy	3739	16.2
dust	486	2.1
slag	449	1.9
middling	304	1.3
Total Carbon Output day 2	**4978**	**21.5**

Table 10.7: Output results Vargön Alloys AB

Summary	**Kg C**	**% of total carbon input**
Carbon Input day 1	23121	39.7
Carbon Input day 2	35101	60.3
Total carbon input	**58222**	**100.0**
Carbon Output day 1	2999	5.2
Carbon Output day 2	4978	8.5
Total carbon output	**7977**	**13.7**
Expected stack emissions day 1	20122	34.6
Expected stack emissions day 2	30124	51.7
Total exp. Stack emissions	**50245**	**86.3**
Total exp. Stack emissions in kg/h	**1047**	

Table 10.8: Sumarry results Vargön Alloys AB

10.6.1.3 Mass balance results Ferropem – first campaign

Carbon Inputs		
Day 1 12 June 12:00 - 13 June 12:00	**kg C**	**% of total C input Day 1**
Coke type 1	10131	19.1
Coke type 2	25379	48.0
Quartz type 1	13	0.0
Quartz type 2	9	0.0
Limestone	117	0.2
Electrode (graph. core & briquettes	3708	7.0
Woodchips	13568	25.6
Recycle	2	0.0
Total Carbon input day 1	**52927**	**100.0**
Day 2 13 June 12:00 - 14 June 12:00	**kg C**	**% of total C input Day 2**
Coke type 1	11025	16.9
Coke type 2	28238	43.4
Quartz type 1	13	0.0
Quartz type 2	8	0.0
Limestone	118	0.2
Electrode (graph. core & briquettes	3910	6.0
Woodchips	21825	33.5
Recycle	2	0.0
Total Carbon input day 2	**65140**	**100.0**

Table 10.9: Input results Ferropem

Carbon Outputs		
Day 1 12 June 12:00 - 13 June 12:00	**kg C**	**% of total C input Day 1**
Alloy	5	0.01
Slag	66	0.1
Silica fume	159	0.3
Recycle	2	0.004
Total Carbon Output day 1	**232**	**0.44**
Day 2 13 June 12:00 - 14 June 12:00	**kg C**	**% of total C input Day 2**
Alloy	5	0.01
Slag	50	0.08
Silica fume	147	0.22
Recycle	2	0.004
Total Carbon Output day 2	**204**	**0.31**

Table 10.10: Output results Ferropem

Summary	**Kg C**	**% of total carbon input**
Carbon Input day 1	52927	44.8
Carbon Input day 2	65140	55.2
Total carbon input	**118067**	**100.0**
Carbon Output day 1	232	0.2
Carbon Output day 2	204	0.2
Total carbon output	**436**	**0.4**
Expected stack emissions day 1	52695	44.6
Expected stack emissions day 2	64936	55.0
Total exp. Stack emissions	**117631**	**99.6**
Total exp. Stack emissions in kg/h	**2451**	

Table 10.11: Summary results Ferropem

10.6.1.4 Mass balance results Ferropem – second campaign

Carbon Inputs		
Day 1 - 9 October 6:00 - 10 October 6:00	**kg C**	**% of total input Day 1**
Coke type 1	0	0.0
Coke type 2	40971	66.8
Quartz type 1	14	0.0
Quartz type 2	9	0.0
Limestone	129	0.2
Electrode (graph. core & briquettes	2872	4.7
Woodchips	17336	28.3
Recycle	2	0.0
Total Carbon input day 1	**61333**	**100.0**
Day 2 - 10 October 6:00 - 11 October 6:00	**kg C**	**% of total input Day 2**
Coke type 1	0	0.0
Coke type 2	38536	59.9
Quartz type 1	14	0.0
Quartz type 2	8	0.0
Limestone	122	0.2
Electrode (graph. core & briquettes	3317	5.2
Woodchips	22350	34.7
Recycle	1	0.0
Total Carbon input day 2	**64347**	**100.0**

Table 10.12: Input results Ferropem

Carbon Outputs		
Day 1 - 9 October 6:00 - 10 October 6:00	**kg C**	**% of total input Day 1**
Alloy	6	0.01
Slag	77	0.1
Silica fume	159	0.3
Recycle	2	0.003
Total Carbon Output day 1	**244**	**0.40**
Day 2 - 10 October 6:00 - 11 October 6:00	**kg C**	**% of total input Day 2**
Alloy	5	0.01
Slag	50	0.08
Silica fume	147	0.23
Recycle	1	0.002
Total Carbon Output day 2	**203**	**0.32**

Table 10.13: Output results Ferropem

Summary	**Kg C**	**% of total carbon input**
Carbon Input day 1	61333	48.8
Carbon Input day 2	64347	51.2
Total carbon input	**125680**	**100.0**
Carbon Output day 1	244	0.2
Carbon Output day 2	203	0.2
Total carbon output	**447**	**0.4**
Expected stack emissions day 1	61088	48.6
Expected stack emissions day 2	64145	51.0
Total exp. Stack emissions	**125233**	**99.6**
Total exp. Stack emissions in kg/h	**2609**	

Table 10.14: Summary results Ferropem

10.6.1.5 Mass balance results Glencore – first campaign

Carbon Inputs		
Day 1 9 June 6:00 - 10 June 6:00	**kg C**	**% of total C input Day 1**
Sinter	210	0.3
Oxydized ores	33	0.0
Coke type 1	44954	55.1
Coke type 2	33113	40.6
Iron ore	54	0.1
Limestone	1705	2.1
Electrode	1585	1.9
Total Carbon input day 1	**81653**	**100.0**
Day 2 10 June 6:00 - 11 June 6:00	**kg C**	**% of total C input Day 2**
Sinter	163	0.2
Oxydized ores	36	0.0
Coke type 1	40157	44.3
Coke type 2	42495	46.9
Iron ore	24	0.0
Limestone	1867	2.1
Electrode	5844	6.5
Total Carbon input day 2	**90585**	**100.0**

Table 10.15: Input results Vale Manganes

Carbon Outputs		
Day 1 9 June 6:00 - 10 June 6:00	**kg C**	**% of total C input Day 1**
Alloy	16407	20.1
Slag	17	0.02
Sludge	1094	1.3
Total Carbon Output day 1	**17519**	**21.5**
Day 2 10 June 6:00 - 11 June 6:00	**kg C**	**% of total C input Day 2**
Alloy	14005	15.5
Slag	20	0.02
Sludge	1094	1.2
Total Carbon Output day 2	**15119**	**16.7**

Table 10.16: Output results Glencore

Summary	**Kg C**	**% of total carbon input**
Carbon Input day 1	81653	47.4
Carbon Input day 2	90585	52.6
Total carbon input	**172239**	**100.0**
Carbon Output day 1	17519	10.2
Carbon Output day 2	15119	8.8
Total carbon output	**32638**	**18.9**
Expected stack emissions day 1	64134	37.2
Expected stack emissions day 2	75466	43.8
Total exp. Stack emissions	**139601**	**81.1**
Total exp. Stack emissions in kg/h	**2908**	

Table 10.17: Summary results Glencore

10.6.1.6 Mass balance results Glencore – second campaign

Carbon Inputs		
Day 1 12 November 6:00 - 13 November 6:00	**kg C**	**% of total input Day 1**
Sinter	824	0.7
Oxydized ores	43	0.0
Coke type 1	36270	32.3
Coke type 2	70479	62.8
Iron ore	14	0.0
Limestone	1167	1.0
Recycled	0	0.0
Electrode	3390	3.0
Total Carbon input day 1	**112186**	**100.0**
Day 2 13 November 6:00 - 14 November 6:00	**kg C**	**% of total input Day 2**
Sinter	671	0.6
Oxydized ores	27	0.0
Coke type 1	107798	91.1
Coke type 2	4992	4.2
Iron ore	29	0.0
Limestone	1189	1.0
Electrode	3646	3.1
Total Carbon input day 2	**118352**	**100.0**

Table 10.18: Input results Vale Manganes

Carbon Outputs		
Day 1 9 June 6:00 - 10 June 6:00	**kg C**	**% of total input Day 1**
Alloy	21870	19.5
Slag	74	0.07
Sludge	1850	1.6
Total Carbon Output day 1	**23794**	**21.2**
Day 2 10 June 6:00 - 11 June 6:00	**kg C**	**% of total input Day 2**
Alloy	23605	19.9
Slag	59	0.05
Sludge	1850	1.6
Total Carbon Output day 2	**25514**	**21.5**

Table 10.19: Output results Glencore

Summary	**Kg C**	**% of total carbon input**
Carbon Input day 1	112186	48.7
Carbon Input day 2	118352	51.3
Total carbon input	**230539**	**100.0**
Carbon Output day 1	23794	10.3
Carbon Output day 2	25514	11.1
Total carbon output	**49308**	**21.4**
Expected stack emissions day 1	88392	38.3
Expected stack emissions day 2	92838	40.3
Total exp. Stack emissions	**181230**	**78.6**
Total exp. Stack emissions in kg/h	**3776**	

Table 10.20: Summary results Glencore

10.6.2 Uncertainty assessment

The uncertainty assessment for the emission measurements is already given in the WP3 reports. A total uncertainty for the determined carbon emission per hour is calculated for each measuring campaign. The following uncertainties are calculated (Table 10.21):

Location - field test	**Uncertainty of calculated C emission/hour in % (95%BI)**
Vargön Alloys AB – first field test	11.5
Vargön Alloys AB – second field test	10.8
Ferropem – first field test	11.9
Ferropem – second field test	12.6
Glencore – first field test	n.a.
Glencore – second field test	n.a.

Table 10.21: Uncertainties measured carbon emissions

The uncertainty calculations for the mass balance method (for the 48 hour campaigns) are given in the next table (Table 10.22).

Location - field test	**Uncertainty of calculated C emission/hour in % (95%BI)**
Vargön Alloys AB – first field test	7.0
Vargön Alloys AB – second field test	7.2
Ferropem – first field test	8.9
Ferropem – second field test	9.5
Glencore – first field test	11.1
Glencore – second field test	11.9

Table 10.22: Uncertainties calculated carbon emissions (mass balance method)

The calculated total uncertainties of the mass balance include:

- Uncertainty in sampling inputs and outputs
- Uncertainty in weighing inputs and outputs
- Uncertainty in analysis inputs and outputs
- Uncertainty in electrode paste consumption (by measurement electrode lengths)
- Uncertainty in difference of the present unused material in the furnace (is the possible difference between start and stop of 48 hour campaign)

The calculated uncertainties are based on the JCGM 100:2008 (Evaluation of measurement data – Guide to the expression of uncertainty in measurement).

10.6.3 Comparison mass balance and emission measurements

In the following paragraphs a comparison is made between the 48h mass balance results and the emission measurement results.

10.6.3.1 Comparison results Vargön

In the next two graphs (Figure 10.1 and Figure 10.2) a comparison is made between the mass balance method (set at a reference value of 100, being the most accurate method) and the stack measurements. Also the calculated uncertainty of both methods is given in the graphs.

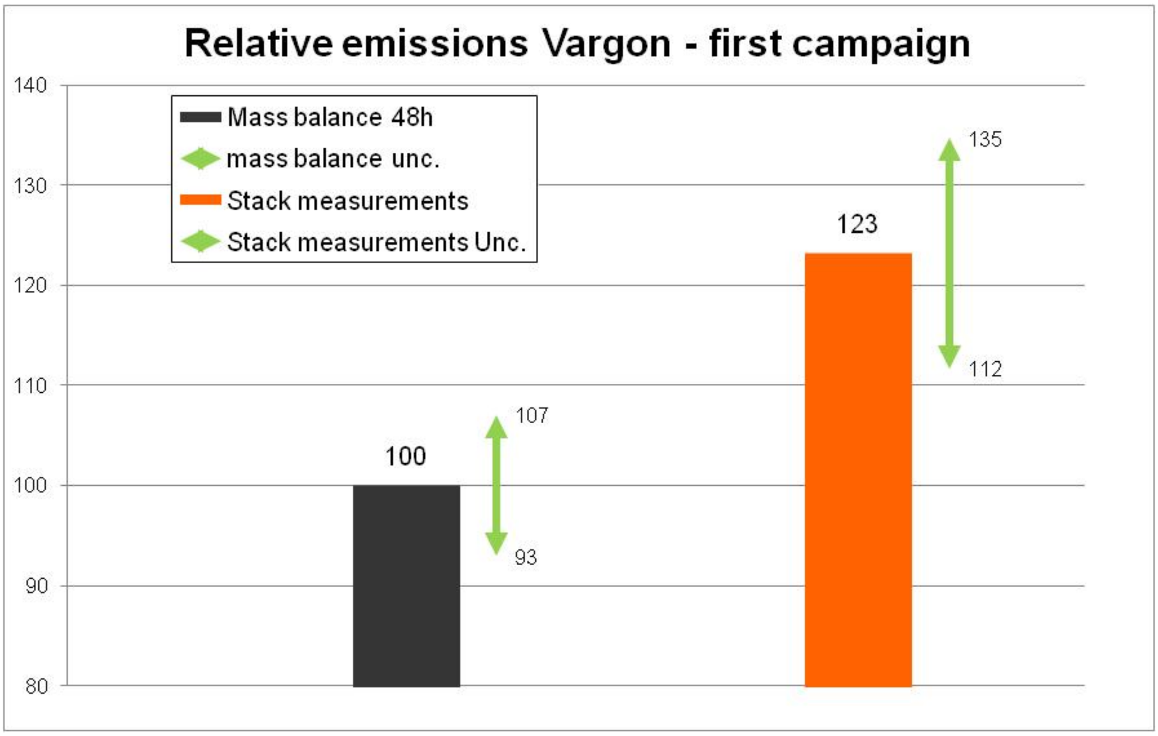


Figure 10.1: Relative emissions Vargön – first campaign

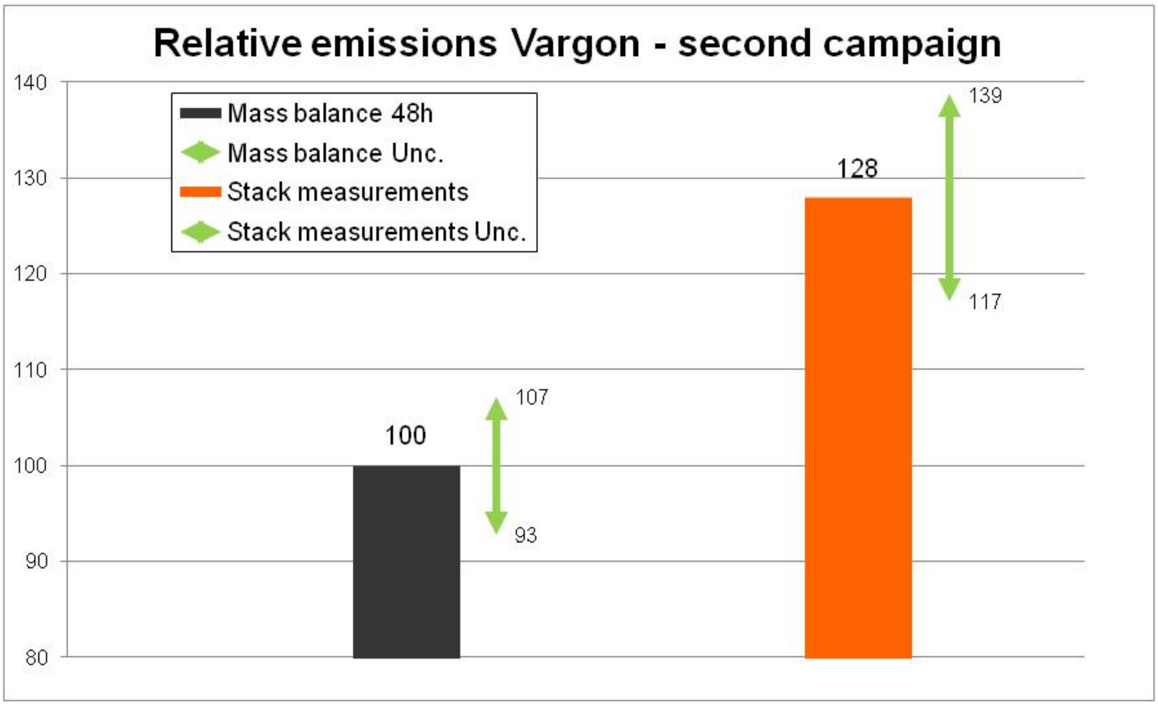


Figure 10.2: Relative emissions Vargön – second campaign

10.6.3.2 Comparison results Ferropem

In the next two graphs (Figure 10.3 and Figure 10.4) a comparison is made between the mass balance method (set at a reference value of 100, being the most accurate method) and the stack measurements. Also the calculated uncertainty of both methods is given in the graphs.

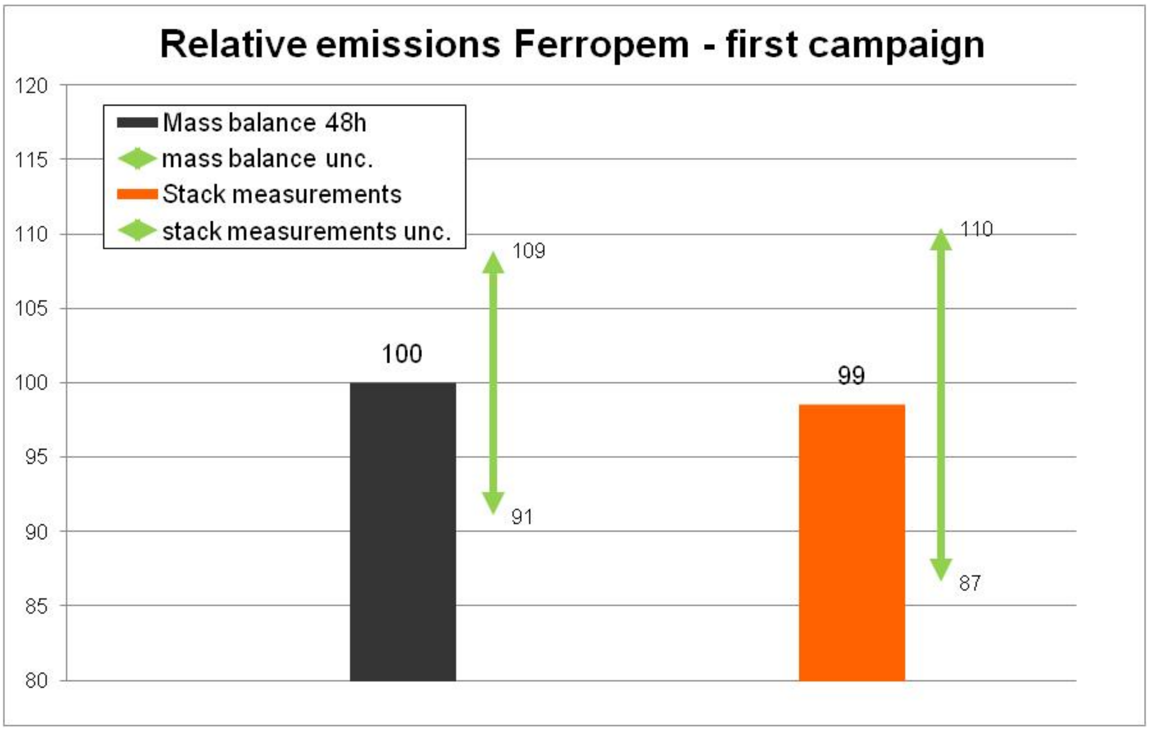


Figure 10.3: Relative emissions Ferropem – first campaign

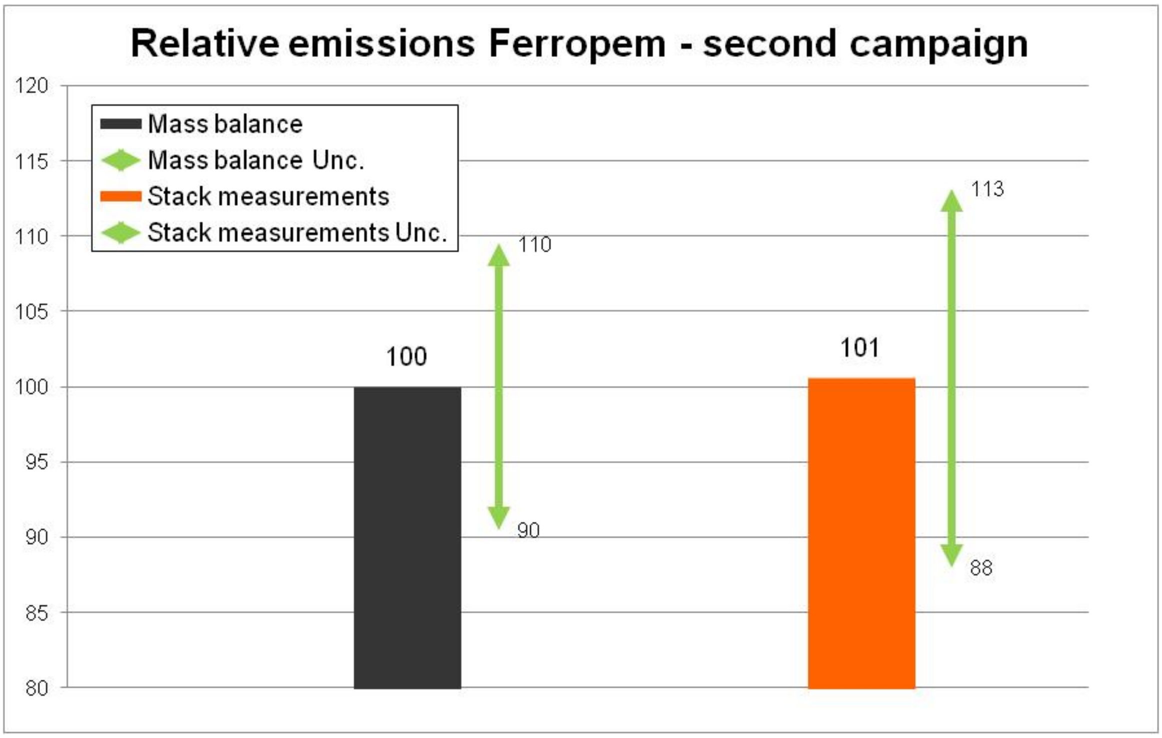


Figure 10.4: Relative emissions Ferropem – second campaign

10.6.3.3 Comparison results Glencore

In the next two graphs (Figure 10.5 and Figure 10.6) a comparison is made between the mass balance method (set at a reference value of 100) and the calculated uncertainty of the method. Since no emission measurements were performed no comparison between mass balance method and stack measurements is possible.

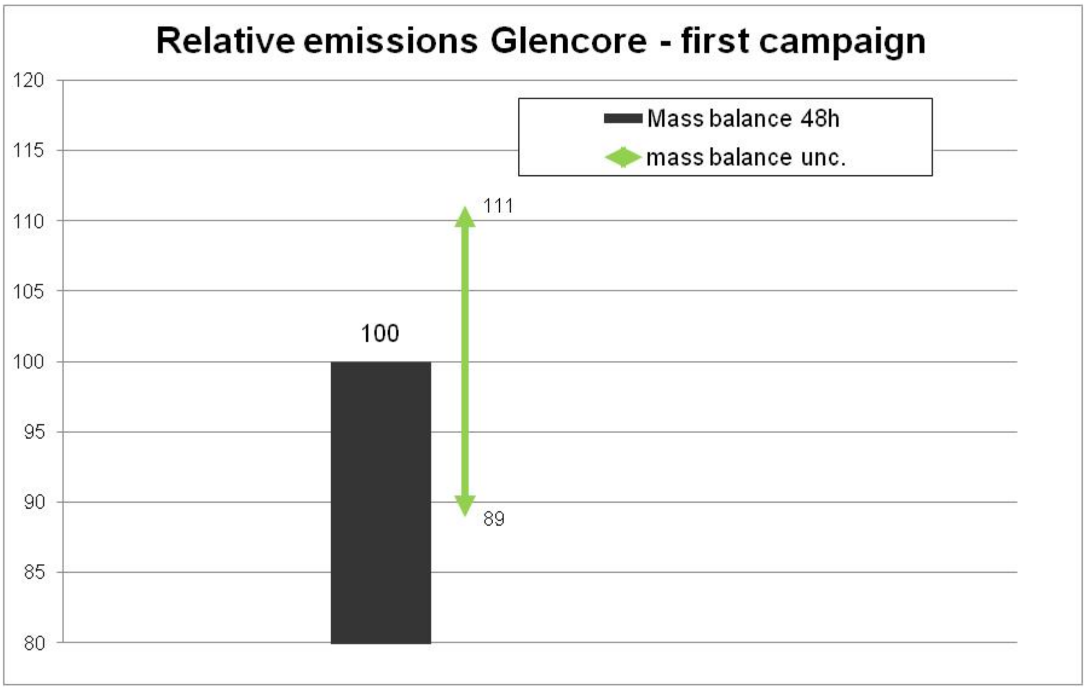


Figure 10.5: Relative emissions Glencore – first campaign

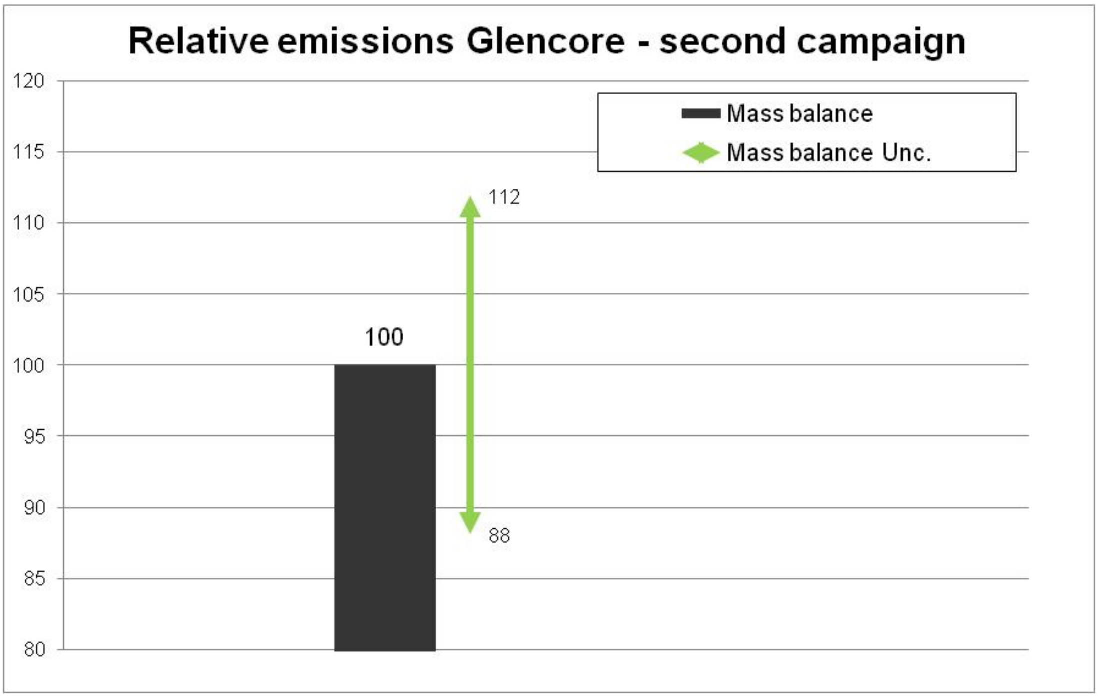


Figure 10.6: Relative emissions Glencore – second campaign

10.6.3.4 Overview differences mass balance vs. stack measurements

In the following Table 10.23 an overview is given from the differences between the determined carbon emissions using the 48h mass balance method and the stack measurement results.

Summarry first campaigns	**Vargön Alloys AB**	**Ferropem**	**Glencore**
Calculated stack emissions in kg C / h	1216	2451	2908
Measured stack emissions in kg C / h	1498	2468	n.a.
difference in % (based on calculated)	23.1	0.7	n.a.
Summarry second campaigns			
Calculated stack emissions in kg C / h	1047	2609	3776
Measured stack emissions in kg C / h	1339	2625	n.a.
difference in % (based on calculated)	27.9	0.6	n.a.

Table 10.23: Overview results mass balance versus stack measurement

10.6.4 Conclusions

10.6.4.1 Conclusions Vargön

For the 2 Vargön campaigns the following conclusions can be drawn:

- For both campaigns there is a significant difference between the calculated amounts of carbon going out of the stack vs. the measured amounts by the emission measurements of WP3 (emission measurements are 23 and 28% higher). The main difference is most likely caused by the volume flow rate measurements in WP3 which seems to overestimate the amount of flue gas flow at the stack. This is most likely caused by the non ideal measuring location and differences of flue gas velocity over the length of the two used measuring axis at the stack.
- When looking at the calculated uncertainties, the uncertainty for the emission measurements is around 11%. For the 48 hour mass balance method the uncertainty is around 7%. Here is to be noted that a 48 period is relatively short for a mass balance evaluation. The accuracy for a mass balance method over a whole year can be expected to be 3-4% vs. an expected uncertainty for an AMS of 5-10%, making the mass balance method the more accurate one.

10.6.4.2 Conclusions Ferropem

For the 2 Ferropem campaigns the following conclusions can be drawn:

- For both campaigns there is no significant difference between the calculated amounts of carbon going out of the stack vs. the measured amounts by the emission measurements of WP3 (emission measurements are only 0.7% and 0.6% higher). Even though the volume flow rate measurements in WP3 were only possible on 1 axis instead of 2, this showes the velocity profile is very stable, justifying the separate location for flow measurements.
- When looking at the calculated uncertainties, the uncertainty for the emission measurements is around 11%. For the 48 hour mass balance method the uncertainty is around 9%. Here is to be noted that a 48 period is relatively short for a mass balance evaluation. The accuracy for a mass balance method over a whole year can be expected to be 3-4% vs. an expected uncertainty for an AMS of 5-10%, making the mass balance method the more accurate one.

10.6.4.3 Conclusions Glencore

For the two Glencore campaigns only the both mass balance results can be compared since no emission measurements were possible due to safety reasons. When comparing both campaigns, the following conclusions can be drawn:

- When looking at the calculated uncertainties, the calculated uncertainty for the first and second 48 hour mass balance method are similar: 11.1% vs 11.9%. The accuracy for a mass balance method over a whole year can be expected to be 3-4%, where continuous emission measurements using AMS are not possible in the current plant set up. So obviously a mass balance method is the only option for calculating Carbon emissions.

10.6.4.4 Overall conlusions

- Comparing the two measuring campaigns at Vargön and Feropem, both with 48 hour mass balance and emission measurements, both campaigns give very similar result. The difference between the mass balance method and the measured carbon emission is larger than expected for Vargön (23 & 28%), while the differences for Ferropem are very small (<1%). Most likely this difference is mainly caused by the non ideal measuring location at the stack of the Vargön furnace.
- For both campaigns at Vargön and Ferropem the calculated uncertainty for the mass balance method is better than the uncertainty achieved with the emission measurements as performed in WP3. Taking into account that the expected uncertainty for a whole year will be around 3-4% for

the mass balance method vs. 5-10% for an AMS, it is clear that the mass balance method is the more accurate method.

- There is a good comparison between the carbon content in the used cokes, as derived from the supplier and by the analysis results from SGS. In general the deviation between the carbon content does not exceed 1% of total carbon. This is well within the expected uncertainty of analysis, which suggests that the used stockpiles are quite homogenous.
- In the calculations the influence of possible diffuse emissions is neglected as being outside the scope of tender. However in reality of course some diffuse emissions will be emitted to the atmosphere. As discussed with the locations the expected amount of diffuse emission is in the range of 1-3% of the total emitted stack emissions.

11 Conclusions

Based on the EU Commission´s mandate M/478, given to CEN in the year 2010, CEN TC264/WG33 is working on a standard for the determination and assessment of greenhouse gas emissions from energy-intensive industries. The involved industry sectors are iron and steel industry, cement industry, aluminium industry, lime industry and ferro-alloys industry. The standardization work has been split in 6 packages, dealed within 6 sub-groups. All general aspects are tackled in Sub-group 1 “General aspects” and the sector-specific work is carried out by 5 sector-specific sub-groups. Each sub-group is supported by a secretariat represented by a national standardization body.

As for this kind of standard the expertise of industry is key, a huge number of experts from all involved industry sectors has been included in the standardization work. Based on these efforts all sub-groups succeeded to elaborate the draft standards in time. They have been submitted to CEN by the secretariat of WG33 before end of April 2014. All verification tests have been performed, some with a more or less significant delay in time. Finally all relevant results were available so that they could be used for the finalization of the draft standards. Remaining findings may be included during the inquiry phase.

The convenor would like to thank all involved experts as well as the secretariat for the huge work they have done within a relatively short time and wishes all sub-groups the best success for the coming year, when the comments from the inquiry have to be processed.