Non-Energy Emissions
Industrial Processes

An input into the **Long Term Mitigation Scenarios**
process

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A   Long Term Mitigation Scenarios for South Africa

B   Technical Summary

C   Technical Report

C.1   Technical Appendix

D   Process Report

The study was supported by the following inputs:

LTMS Input Report 1: Energy emissions

LTMS Input Report 2: Non-energy emissions: Agriculture, Forestry and Waste

LTMS Input Report 3: Non-energy emissions: Industrial Processes

LTMS Input Report 4: Economy-wide modeling

LTMS Input Report 5: Impacts, vulnerability and adaptation in key South African sectors

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1.   Introduction

As part of the Long Term Management Scenarios exercise carried out by the Energy Research Centre at the University of Cape Town for the Department of Environmental Affairs and Tourism, options for the mitigation of greenhouse gas emissions from the non-energy sector are to be investigated. This report lists such options prioritised according to the contribution of each source to the national inventory.

1.1 General assumptions

The non-energy sector consists of a number of diverse activities. To ensure meaningful results from a model, the input data needs to be reliable and consistent across sectors. The output from the model has to be structured in the same format as the outputs from the energy sector model to allow for comparison across all sectors.

1.2 Methodology

The 1990 GHG emission inventory for the industrial sector was used as a basis. A projection to 2003 or 2005 was made based on growth rates, and data that was not considered for the 1990 inventory is included. Emissions from the mining sector, mitigation of which is to be included in this study, are also summarised. This provides the basis for prioritisation of the sectors or sources for which mitigation should be considered in the context of the total South African inventory. Finally, mitigation options under the different scenarios are summarised, together with mitigation costs estimates based on literature data.

1.3 Selection of mitigation options

To select mitigation options available local and international literature was assessed. The most relevant studies are described for each sector. The most critical general studies used were;

- the previous South African GHG inventories and the associated country studies
- IPCC assessments and Working Group documents
- Industry estimates for the mining and synfuels sectors.

In addition, the representatives of sectors that form a part of the LTMS stakeholder group, as well as other sector representatives, were consulted and where possible more recent data was incorporated into the models.

The selection of the areas in which additional research and the acquisition of new data is required was based on the relative importance of the sector and relative importance of the error resulting from the uncertainty associated with the existing calculations.

Some models and calculations were updated in cases when new information became available to allow for more accurate modelling. Modelling methodology, emission factors and assumptions are described for each sector.

2. Emission estimates

2.1.1 Sector emissions for 1990

The GHG Inventory provided the assessment of emissions for 1990 summarised in the table 1 below (Scholes and van der Merwe 1993). The GHG Inventory showed zero GHG emissions for solvents, food and drink and pulp and papers sectors. Similarly, The SA First National Communication shows no emissions from the pulp and paper sector (South Africa 2000). The 2000 SA Country study (Borland et al 2000) does provide an estimate for the pulp and paper industry, but this is linked to the energy use in that sector and therefore dealt with elsewhere in the LTMS process.

Table 1: 1990 Emissions from the industrial sector (Scholes and van der Merwe 1993)

CATEGORIES	Production	CO_2 emission factor	CO2	CH_4 emission factor	CH4	N2O	CO2 eq
	(t)	(t emitted/t produced)	(Gg)	(t emitted/t produced)	(Gg)	(Gg)	(Gg)
Total Industrial Processes			**23441.29**		**3.81**		**23 528.9**
A Mineral Products	**12 261 342**		**7649.29**				**7 649.3**
Cement Production	7 751 520	0.575	4457.12				4 457.1
Lime Production	1 862 000	0.8	1489.60				1 489.6
Dolomite Use	2 340 000	0.673	1574.82				1 574.8
Soda Ash Production and Use	307 822	0.415	127.75				127.7
B Chemical Industry	**1 621 648**		**2981.74**		**3.81**		**3 069.3**
Ammonia Production	450 173	1.5	675.26	0.0047	2.12		683.3
Ammonia Production	287 816	6.995	2013.27	0.0047	1.35		2 018.4
Nitric Acid Production	274 659	0.009	2.47				2.47
Carbide Production	269 000	1.09	293.21				293.2
Emissions from ethylene	285 000			0.0010	0.29		1.1
Emissions from propylene	55 000			0.0010	0.06		0.2
C Metal Production			**12810.26**				**12 810.3**
Iron and Steel Production	6 256 961	1.6	10011.14				10 011.1
Ferroalloys Production	1 796 725		2698.17				2 698.2
FeSi (75% Si)	60 000	3.9	234.00				234.0
FeCr	1 076 000	1.3	1398.80				1 398.8
Si Metal	37 725	1.2	45.27				45.3
FeMn	390 000	1.6	624.00				624.0
SiMn	233 000	1.7	396.10				396.1
Aluminium Production			100.95				101.0
Sóderberg	86 500	0.56	48.44				48.4
Prebaked Anode Process	89 000	0.59	52.51				52.5

The selection of the areas where additional research and the acquisition of new data is critical was based on the relative importance of the sector and relative importance of the error

resulting from the uncertainty associated with the existing calculations. Table 2 below provides some estimates for non-energy sources, based on the industrial data in table 1 only:

Table 2: Uncertainty associated with sector emissions and accuracy of existing models (based on the total national emissions for 1990 of 347346 Gg $CO_{2 eq}$.) (South Africa 2000)

Sectors	1990 emissions	% of total	Mitigation potential	Uncer-tainty	Error	Error(% of national emission)
	Gg CO2 eq	%	Gg CO2 eq	%	Gg CO2 eq	%
Mineral products	7 649	2.2				
Cement	4 457	1.3	30	50	15	0.00
Chemical sector	3 836	1.1				
Nitric Acid production	766	0.2	80	50	40	0.01
Metal Production	15 572	4.5				
Iron and Steel Production	10 074	2.9	30	50	15	0.00

2.1.2   Update of emission inventory for purposes of this study

Sources requiring updating, or not included in table 1, are the following:

- Nitrous oxide (N_2O) from the nitric acid production plants; this was severely underestimated at the time and as the reduction potential is estimated to be 1 436 Gg CO_2-e/a. (SA DNA 2007), the 2003 emission rate is estimated to be 1 595 Gg.

- Perfluorocarbons (PFCs) from the aluminium sector, which were not included at all, and will add approximately 0.073 Gg/a of PFC or 472 Gg CO_2-e to the 1990 figure, based on 1990 Australian default emission factors (Australia 2004) .

- The emission factors provided by the SA aluminium sector in 1990 may be in tons C (rather than CO_2) per ton of aluminium produced, as the ratio between the factor provided and the IPCC default factor is close to the ratio 44/12. Correcting this error would add 100 Gg/a to the 1990 figures.

- Methane emissions from the synfuels process, then estimated at approximately 47 000 ton per annum, with a carbon dioxide equivalence of close to a million ton or 1000 Gg CO_2-e are not included in the table. Subsequent estimates indicate this to be considerably higher at approximately 170 000 ton per annum or 3 570 Gg/a CO_2-e (Sasol 2003, Marais 2007).

- The synfuels industry releases approximately 23 million ton carbon dioxide in a concentrated form from gas processing (Goede 2007), mitigation of which will be considered in this report.

- Also to be considered in this report are the methane emissions from mining. For the coal mining sector, an estimate of 0.3 kg methane (6.9 kg CO2-e) per ton of coal has been made, based on sampling at six mines (de Wit 2006). When non-methane emissions are included, the intensity is 29.1 kg CO2-e per ton of coal, resulting in an estimated total release of 6.55 million ton CO_2-e at 2003 production levels. For gold mining, initial measurements on one shaft have been carried out; the data obtained is of too preliminary a nature to extrapolate to the entire gold/platinum group metals sector, but indicates that the concentration is too low, by some orders of magnitude, to utilise or oxidise cost-effectively (Human 2007). Methane emissions from sectors other than coal mining are therefore not addressed in this study.

3. Estimates for 2003 emissions

The production quantities and emission factors of the major non-energy sources listed in section 2 were updated to 2003/4 (the latest year for which figures are available) for most of the sources in order to (i) provide a basis for prioritisation in that year and (ii) act as the baseline for emission time series for the sources

3.1 Mineral products

3.1.1 Cement production

Cement production and emissions figures were provided by the Association of Cementitious Material Producers (ACMP) as given in table 3.2 below. It was noted that the CO_2 emissions from the cement production process have two main sources: calcination and fuel firing. Calcination is the process whereby $CaCO_3$ dissociates into CaO and CO_2 through the application of energy. The IPPC default factor for calcination is 575 kg CO_2 per ton of clinker produced from limestone. In addition to CO_2 generated through calcination, CO_2 from fuel firing also needs to be considered. When CO_2 generated from fuel consumption is included, the total CO_2 generated per ton of cementitious material produced, was 930 kg per ton. The increased use of alternative sources of pozzolanic materials (slags from the metallurgical industry, fly ash from pulverised coal firing) has lead to a lower clinker content of finished cement and a concomitant reduction of GHG emissions per ton of final product as indicated in table 3.2 below.

Table 3.2:   ACMP production and emission values (combustion and dissociation).

Year	Total Clinker produced (ton)	Total Cementitious material produced	Total CO_2 produced (ton)	Specific emissions kg/ton cementitious material
1990	7 770 000	8 450 000	7 858 500	930
2003	7 346 239	9 511 469	6 798 178	715

The ACMP indicates that they believe that cement production should follow the GDP trend; however, the same growth rate has been used in this case as in the MARKAL energy model for this sector – resulting in an output of around 20% lower by 2050 than if the sector had grown at the assumed GDP growth rate.

3.1.2 Lime production and dolomite use

Statistics are provided by DME (2003). The report indicates that production and sales are variable, depending somewhat on exports to adjacent territories and on agricultural conditions.

Table 3.3:   Change in lime production and emissions

Year	Production (ton)	Total CO_2 emitted	Specific emissions kg CO_2/ton lime
1990	1 862 000	1 489 600	800
2002	1 700 000	1 360 000	800

Table 3.4   Change in limestone and dolomite use

Year	Use (ton)	Total CO_2 emitted	Specific emissions kg CO_2/ton
1990	2 340 000 dolomite only	1 060 200	453
2002	3 393 000	1 425 060	Approx 420

In the absence of alternative data, these emissions are assumed to follow the same trend as those for cement production.

3.2 Chemicals

3.2.1   Ammonia production

Implied production in 1994 was 762 000 ton (South Africa, 2000) at an emission factor (for production in the synthetic fuels process) of 2.45 ton CO_2 per ton ammonia produced. Production increased somewhat (12% in Sasolburg, Sasol 2003) due to the switch to natural gas at Sasolburg. Estimated production in 2003 was therefore approximately 775 000 ton, and emissions at a constant factor 1 892 Gg. CO_2

3.2.2   Nitric acid production

As given under section 2.1.3, emissions from the four operating plants are estimated to be 1 595 Gg.

3.2.3   Carbide production

Production has decreased from the 1990 figure to 70 000 ton per annum in 2006. At a constant default emission factor, this represents emissions of 76.3 Gg/a.

3.2.4   Balance of the chemical sector

As the emissions are minor compared to the ammonia/nitric acid streams, these will not be considered further.

3.3 Metals

3.3.1   Iron and steel industry

Production data for the iron and steel industry is available for 2003 (www.saisi.co.za.) Available on this site are the production figures and predictions for 2003 to 2007.

The production of pig iron and direct reduced iron for 2003 is 7.8 million ton/a, which means that the growth in this industry was approximately 1.5%/a since 1990.

It is suggested that a constant emission factor (as provided by the 1990 GHG Inventory) should be used for the year 2003, as no material process upgrades occurred between 1990 and 2003.

3.3.2   Ferro-alloy production

Comparative production figures are given in table 3.5 below.

Table 3.5: Ferro-alloy production 1990 and 2004 (1990 inventory and DME 2006)

	1990		2004	
Commodity	Production tpa	CO2 emission Gg	Production tpa	CO2 emission Gg
FeCr	1 076 000	1 399	2 900 000	3 770
FeMn	390 000	624	575 000	865
FeSi	60 000	234	106 000	413
FeSiMn	233 000	396	300 000	510
Si	37 700	45	50 000	60
	Totals	2 698		5 618

This represents a compound growth rate in emissions of 5.4% annually over the 14 years. IFM has commissioned portions of a ferrochrome smelter with a final capacity of 267 400 ton per annum in 2006 (Engineering News 23 Feb 2007), while Xstrata's Lion project added 250 000 ton in 2007 from a plant that is planned for an eventual 1 000 000 ton per annum. The growth rate has therefore continued at approximately 5.5% per annum between 2004 and 2007.

3.3.3   Aluminium

As indicated earlier, in the original 1990 emission inventory, the 1990 CO_2 emission were probably underestimated and the figure given in the 2000 First National Communication (249 Gg CO_2 only) is probably more correct. The PFC emissions were not calculated for 1990 but probably were of the order of 472 Gg CO_2-e. Since then, South African aluminium production has increased considerably, but aluminium cell technology has reduced PFC emissions approximately fourfold (International Aluminium Institute 2006). A comparison of emissions is given in table 3.6 below.

Table 3.6: Aluminium production and emissions.

1990		2004	
Production ton	CO$_2$-e emission Gg (CO$_2$ + PFC)	Production ton	CO$_2$-e emission Gg (CO$_2$ + PFC)
175 500	761	865 000	2 010

Thus, although production increased almost fivefold, estimated CO2-e emissions increased at only half the rate.

A further 720 000 ton per annum capacity is being planned for Coega, presently expected to start producing in 2010. (Engineering News 23 February 2007). As this will use the latest Alcan technology, specific emissions can be expected to be low.

3.4 Mine emissions

3.4.1 Coal mining

As indicated earlier, baseline emissions for coal mining for 2003 are estimated at 29 kg/ton CO_2-e coal produced in total or 6 550 Gg /a. Of this 6.9 kg/ton CO_2-e/ton, or 1 558 Gg/a is in the form of methane.

3.5 Synfuels-specific emissions

3.5.1 Methane emissions

The Rectisol process used for cleaning the syngas stream of carbon dioxide and sulphur compounds after gasification also captures methane and other light hydrocarbons. The carbon dioxide containing 2-3 mole% of total hydrocarbons is released to the atmosphere after removal of the hydrogen sulphide and contains approximately 178 000 ton per annum of methane, equivalent to 3 738 Gg CO_2-e/a(Sasol 2007, Marais 2007)

3.5.2 Concentrated carbon dioxide streams

The Rectisol process produces a number of gas streams from its different expansion stages, most of which contain in excess of 95% carbon dioxide and 2-3 mole % total hydrocarbons (see previous section) after removal of the sulphur compounds. The Benfield process, situated in the Synthol gas loop, similarly produces a concentrated carbon dioxide stream. At the Secunda operations, these two streams together release approximately 23 000 Gg carbon dioxide.

3.5.3 Expansion of Synfuels production using natural gas.

The use of natural gas in the synthetic fuel production process was initially intended to increase production at the Secunda facility by approximately 15% but at a much lower specific CO_2 emission rate. The possibility exists of using gas that is available (i e not taken up by the industrial fuels market) for further expansion of liquid fuel production (GTL or gas-to liquids). This would replace imported liquid fuels presumably derived from crude oil. It has been shown that the use of GTL fuels, from a life-cycle approach, leads to approximately the same lifecycle carbon emission than crude-derived fuels. (IEA 2004). From a GHG emission point of view, this use of natural gas in GTL would have a neutral effect on GHG emissions and is not considered further here.

3.5.4 Expanded coal to liquids production.

Sasol is at present carrying out a pre-feasibility study into building a CTL facility on the Waterberg coal field with a capacity of approximately 80 000 barrels per day (Engineering News 23 February 2007). If the same technology as the Secunda plants is used, this would produce approx. 11 000 Gg/a CO_2 as concentrated stream. Carbon capture and storage (CCS) forms part of the investigations. Improvements in the Rectisol process would probably result in much improved capture of the light hydrocarbons, so that methane emissions would be minimal. Sasol have also indicated (van der Walt, 2007) that a further five plants of similar capacity could be built without coal and water supply constraints being exceeded.

3.6 Summary of baseline (2003) non-energy emissions

Table 3.7: Baseline (2003) GHG emissions, industrial (non-energy) sector.

	Gg CO_2-e /a	Growth rate of commodity production
Cement production	6 798 (incl. fuel)	Markal elasticity
Lime production	1 360	Markal elasticity
Limestone/Dolomite use	1 425	Markal elasticity
Ammonia production	1 892	Markal elasticity
Nitric acid production	1 595	Markal elasticity Zero?
Carbide production	76	4.5% pa 2004-2007; thereafter Markal
Iron and Steel production	12 494	Markal elasticity
Ferro-alloy production	5 618	5.4% pa 2004-2007; thereafter Markal
Aluminium production	2 010	83% between 2006 and 2011; thereafter Markal
Coal mine methane	6 550	Coal production growth rate
Synfuels concentrated carbon dioxide	23 000.	See text 3.5.4.
Synfuels point-source methane	3 738	0

From this table, the main emission sources to be considered for mitigation are those from synfuels production, coal mining, iron and steel, ferro-alloy production, aluminium and cement.

4. Emissions for baseline and mitigation scenarios, including cost estimates for reduction

4.1 Synfuels point-source emissions

The Rectisol concentrated carbon dioxide stream also containing light hydrocarbons presents a number of GHG mitigation possibilities as follows:

- The entire stream could be used for carbon storage or sequestration, the "capture" step of carbon capture and storage (CCS) already having been carried out. The possibilities for carbon or sequestration in South Africa were summarised by Engelbrecht *et al*. (2004). The possibilities for capture in geological formation are considered to be unfavourable due to the poor porosity and permeability of even the more promising formations. Lately, the possibility of sequestration in coal seams in Botswana, in conjunction with methane recovery from the formations is being investigated by Sasol (Liebenberg 2007). Should favourable geology be encountered, transportation cost for 5-40 million ton of CO2/a is estimated to cost $1 to $ 8 per ton (distance up to 250 km), with the storage itself, including monitoring and verification $ 0.6 to $ 8.3 per ton (IPPC 2006).

Should this possibility be used for Secunda Rectisol and Benfield off-gas, the cost for transport would be $3 to $24 per ton of CO_2 (if transport cost is taken to be linear with distance), with storage/sequestration cost probably at the higher side of the scale due to unfavourable geology, thus a total of approximately $33 per ton.

Sasol has made some preliminary cost estimates for partial CCS, subject to their estimate of capacity, at R62.65 (assuming R7/$ exchange rate, real terms, year uncertain) per ton of CO_2, and max storage capacity starting at 1 Mt per year in 2007, and increasing to 20Mt per year in 2030 remaining constant after that (Goede 2006). This estimate probably does not include transport cost.

A more detailed estimate can be made using methodology developed by the Institute of Transportation Studies at the University of California at Davis. (McCollum and Ogden 2006, Freund and Davison n.d.)

The cost of sequestration of the entire Secunda concentrated GHG stream of approximately 23 million tons CO_2e per year into suitable (presently economically unminable) coal seams at 500 m below surface at 400 km from Secunda is as follows (in 2006 USD):

Capital cost compressors/pumps $220 million
Capital cost pipeline $416 million
Capital cost at the well field (for the most pessimistic case about 4000 wells would be required) for drilling $634 million and other equipment $50 million

Running cost side (in 2006 USD per year)
Compressor/pumping power 250 to 300 MW. Other on-site costs at the well field 181 million.

If however 2 million tons per annum is taken to be the realistic maximum for CCS, as this is the maximum that has in practice been achieved in a single field, the economy of scale on the pipeline, which dominates the capital cost, is lost. For 2 million tons per year, the pipeline cost is approximately $160 million and the cost of pumps and compressors approximately $50 million, both in 2006 values. Running cost would be approximately linear with tonnage.

- The light hydrocarbons in the Rectisol off-gas stream including the methane could be combusted, either as is or with pre-concentration of the hydrocarbons. For combustion of the stream as is, oxygen and possibly supplemental fuel would need to be supplied; alternatively the stream needs to be fed to an existing combustion installation such as a boiler. If pre-concentration proves to be feasible, the hydrocarbon stream could be used to as additional feedstock to the Synthol operation. A suitable technology is however not available for the latter separation.

A preliminary estimate of the cost of regeneratively oxidising the light hydrocarbons in this stream, using technology developed for coal mine ventilation air, is US$19 million in 2002 values. Annual operating cost is given as 10% of this cost. (US EPA 2002) Due to the present uncertainties, the possible credit for steam raised is not included in this number.

Conclusion:

Scenario 1 (maximum development). Future CTL plants will probably include the Selective Rectisol process, which will virtually eliminate the methane emissions. However, each Sasol

2/Sasol 3 size installation (approximately equal to 80 000 barrels per day) will emit approximately 11 million ton per annum CO_2-e.

Intermediate scenarios: Capture and storage from the existing Secunda installation would probably not be feasible under these scenarios. New installations expressly designed for CCS and possibly situated near favourable geological formations could have a somewhat reduced cost.

Reduction of the present methane emissions could however be feasible under these scenarios.

Scenario 4 (reduction required by science) would probably require sequestration of all CO_2 from existing and new plant at the cost given above.

4.2 Iron and steel industry

The production growth factors for the period after 2003 (from 7.8 million ton pig iron per annum) should be based on the indexed growth rates calculated from the elasticities used for this sector in the MARKAL model. A constant emission factor (as provided by the 1990 GHG Inventory) of 1.6 ton CO_2/ton of pig iron should be applied for the baseline scenario between 1990 and 2003.

Modernised processes could increase the energy use efficiency while simultaneously reducing the emission of pollutants. Examples of these processes are: continuous casting technology, recovery and utilization of gas from steel converters (this possibility should be included in the energy sector) and the use of waste heat for preheating. All of these are typically applied to new plant rather than retrofitted to existing plant.

Conclusion

For Scenario 1 and the intermediate scenarios, no material reduction in the emission factor is to be expected; the increased production rate should be multiplied by the constant emission factor. The possibility for using biomass-based reductants is limited by the SA production potential of such material.

For scenario 4, the IPCC estimates (IPCC 2006) that a reduction specific in emissions of between 20 and 33% could be achieved at $20-$50 per ton reduction; this could be phased in from 2020 onwards. The reductions would mainly be in the form of energy efficiency measures and should be allowed for in the energy sector report.

4.3 Ferroalloy industry

Similar to iron and steel.
(The SA DNA has listed an off-gas utilisation project on its website with a potential savings of 600 Gg/a. This represents a significant reduction in terms of energy efficiency; further details are not given).

4.4 Nitric acid production

The CDM mechanism plays a major role in the mitigation of N_2O emissions. The mitigation of N_2O emission from nitric acid production is under consideration by all SA manufacturers. AECI, Sasol and Omnia already have registered CDM projects using this technology. Reduction of 80% of N_2O emissions from the figures given in table 3.7 will be achieved within 4 years and 95% of N_2O by 2020 at essentially zero cost due to the income generated from CDM. No further reductions are expected thereafter.

Members of the Fertiliser Society of SA (van der Linde 2007) indicate that they believe nitric acid production to be largely driven by fertiliser demand, which has been static for some time. New nitric acid production capacity is therefore not anticipated, and emissions expected to remain static.

4.5 Balance of chemical industry

Potential for reduction in the emissions over the review period is immaterial.

4.6 Cement production

Modern cement production processes already applied in the local industry include using the dry process with pre-heating for cement production, clinker blending and the use of substitute pozzolanic materials such as blast furnace slag and classified ash from pulverised coal firing in power generation. The cement industry expects to see the clinker content of all cementitious binders used in 2030 to be about 60 %.(Cluett 2006). In South Africa, this approach will reduce the emission factor to 650 CO_2 kg per ton cementitious material (compared to 715 CO_2 kg/t in 2003) by 2010.

The substitution of coal by suitable wastes (e.g. sludges from the petrochemical sector, scrap tyres etc.) is being actively pursued by the local cement sector. A Korean study (Dong-Woon Noh 2006) indicates that a 30% replacement of bituminous coal by scrap tyres could lead to a further 1.2 % reduction in overall emissions at a negative cost. The technology has been tested in South Africa and awaits a regulatory framework for implementation. The possibility of using other alternative fuels in South Africa could increase the reduction to 1.5% at minimal additional cost.

Conclusion: The above reductions apply under Scenarios 1 to 3 – reduction in clinker content is assumed to be 'business as usual', and is thus not considered to be a mitigation option. A 60% as required under scenario 4 could only be achieved a cutback in production, as the CO_2 released by the dissociation of lime cannot be avoided.

4.7 Mining

The possibility of reducing emissions from the gold and platinum sectors is not sufficiently researched for inclusion as a possibility.

In general, the concentration of methane in coal and in the ventilation air in South Africa is too low to warrant profitable recovery or destruction under CDM, which implies a cost in excess of approximately $25 per ton CO_2-e reduced. No reduction is therefore assumed under scenarios 1 and 2. Under scenario 3, some of the higher concentrations could become feasible at the lower end of the estimated costs (say 25% reduction @ $15 per ton) Assuming that an extended programme of identification would be required, start of such an in initiative should not be expected before 2020, with 25% being achieved by 2030. Under scenario 4, 50% reduction could be achieved at the higher end of the cost estimates ($30 per ton CO_2-e), again starting in 2020 and achieving full scale implementation in 2030

4.8 Aluminium production.

It is assumed that new capacity will already be equipped with technology to reduce the PFC emissions to a figure of less than 0.001 Gg CO_2-e per ton of aluminium (IAI 2006). This is

applicable to all scenarios. For existing capacity, a further 45% reduction in emissions is estimated at $15-$30 per ton CO_2-e reduced. (US EPA 2006). Cost estimates for this reduction have been scaled down from a CDM project in Argentina: for a reduction of 0.71 Mt CO_2-eq, capital costs are R1.2 million, and operating costs are R0.15 million per year.

Conclusion

Under Scenarios 1 to 3, future emissions from existing capacity can be calculated by multiplying 2003 production by the emission factor of 0.00232 Gg per ton of production. Additional production above that baseline can be calculated at 0.00128 Gg/ton aluminium produced.

Under scenario 4, a 45% reduction in CO2-e emissions per ton of 2003 production capacity can be achieved at $15 to $30 per ton. New capacity installed after 2003 can be assumed to have minimal reduction potential.

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