



Australian Government

Department of Climate Change

**INDUSTRIAL PROCESSES SECTOR
GREENHOUSE GAS EMISSIONS
PROJECTIONS
2007**

Published by the Department of Climate Change.

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ISBN: 978-1-921297-81-6

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February 2008.

Executive summary

Key results — Industrial Processes sector

In 2005, industrial process emissions represented 5 per cent of Australia's total greenhouse gas emissions, and at 30.2 Mt CO₂-e were 19 per cent higher than 1990 emissions of 25.3 Mt CO₂-e.

Taking into account existing measures, emissions from the industrial processes sector are projected to be:

- 37.9 Mt CO₂-e per annum over the Kyoto period, up 49 per cent over 1990 levels.
- 49.4 Mt CO₂-e in 2020, up 95 per cent over 1990 levels.

Projected emissions are made up of:

- 'Business as Usual' emissions, which in the absence of measures are projected to increase to:
 - 45.2 Mt CO₂-e per annum over the Kyoto period, up 79 per cent over 1990 levels.
 - 58.5 Mt CO₂-e in 2020, up 131 per cent over 1990 levels.
- The impact of measures to reduce emissions is estimated to be 7.4 Mt CO₂-e per annum over the Kyoto period and 9.1 Mt CO₂-e in 2020.

Average annual projected 'With Measures' emissions over the Kyoto period are 0.4 Mt CO₂-e lower than in the previous projection. This is due to:

- An update of the leakage rates used in HFC emissions from mobile air conditioning, which reduces projected Kyoto period emissions by 0.4 Mt CO₂-e per annum.
- A reduction of 0.07 Mt CO₂-e per annum in projected Kyoto period emissions from the production of iron and steel as emissions from coke ovens are now included in the stationary energy sector.
- A revision of the carbon dioxide emission factor from clinker manufacturing, which increases average annual Kyoto period emissions by 0.1 Mt CO₂-e per annum.
- An update of carbon dioxide emission factor of rutile (titanium dioxide) in the chemicals subsector, which reduces projected Kyoto period emissions by 0.03 Mt CO₂-e per annum.

i 'With Measures' results

Emissions from the industrial processes sector over the Kyoto period are projected to be 37.9 Mt CO₂-e per annum (with a low-high range of 34.1 to 41.5 Mt CO₂-e per annum). This represents a 49 per cent increase over the 1990 level of 25.3 Mt CO₂-e (with a low-high range of 34.4 per cent to 63.7 per cent increase).

Table ES1: **Greenhouse gas emissions from the industrial processes sector**

	1990	2005 ^a	Kyoto Period (2008-2012) Average	2020
	Mt CO ₂ -e	Mt CO ₂ -e	Mt CO ₂ -e	Mt CO ₂ -e
With measures	25.3	30.2	37.9	49.4
Measures	0.0	3.6	7.4	9.1
Business as usual	25.3	33.8	45.2	58.5

^a The 2005 'with measures' estimates presented here differ slightly from those published in the 2005 NGGI due to updated leakage rates used in estimating HFC emissions from commercial refrigeration.

Note: Columns may not add due to rounding errors.

Source: 2005 NGGI; Burnbank Consulting (2006); DCC Analysis 2008.

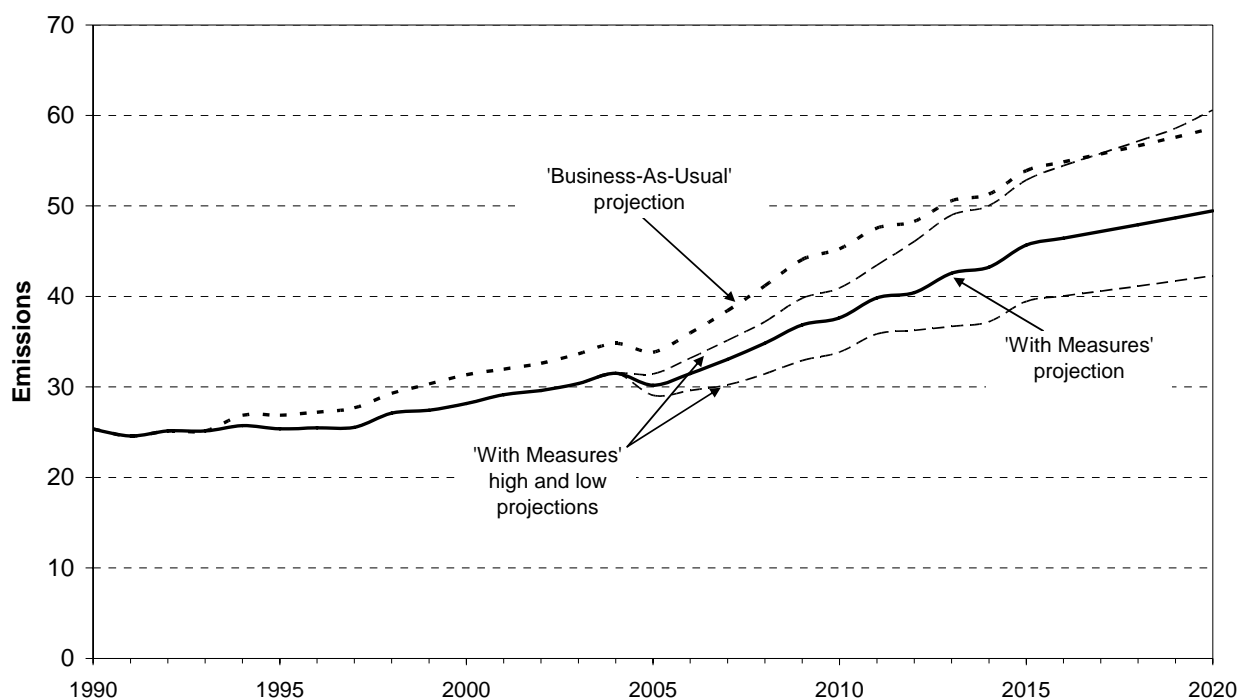
Emissions from the industrial processes sector in 2020 are projected to be 49.4 Mt CO₂-e (with a low-high range of 42.3 to 60.6 Mt CO₂-e). This represents a 95 per cent increase over the 1990 level (with a low-high range of 66.9 per cent to 139 per cent increase). 'With Measures' projections for 2020 should be considered indicative only. The projections time series are shown in Figure ES1.

Emissions from the industrial process sector increased 19 per cent over the period 1990-2005. This reflects strong growth in both the consumption of HFC in Montreal Protocol Industries and the chemical industry. However, this strong emissions growth has been partially offset by a substantial decline in emissions from metal production, due to the contraction in the iron and steel industry and reductions of PFC emissions from aluminium smelting.

Strong emissions growth is projected in the near term to the Kyoto period, and medium term to 2020. Projected growth in emissions is driven by:

- increased production in chemical industries, resulting in a 61 per cent increase in emissions between 2005 and the Kyoto period driven by strong annual growth in synthetic rutile, ammonia and nitric acid production;
- continued expansion of synthetic gas usage in Montreal Protocol Industries as these industries make the transition away from Ozone Depleting Substances. Emissions from these gases grow 22 per cent between 2005 and the Kyoto period; and
- expected increases in metals production, driven by strong demand for iron and steel products resulting in a 20 per cent growth in emissions from metals between 2005 and the Kyoto period.

Figure ES1: Greenhouse gas emissions from the industrial processes sector, 1990 to 2020 (Mt CO₂-e)



Source: 2005 NGGI; Burnbank Consulting (2006); DCC Analysis 2008.

ii Impact of measures

The impact of measures is estimated to be 7.4 Mt CO₂-e per annum over the Kyoto period.

- Abatement in the mineral products, chemical industry and metal production subsectors of 3.8 Mt CO₂-e per annum over the Kyoto period is attributed to Greenhouse Challenge Program and comprises:
 - 3.5 Mt CO₂-e of abatement due to reduction of PFC emissions from aluminium production.
 - 0.3 Mt CO₂-e due to initiatives in the cement production industry, such as the accelerated use of cement extenders.
- Abatement from the implementation of the *Ozone Protection and Synthetic Greenhouse Gas Management Act 1989* (Cth) is estimated at 3.5 Mt CO₂-e per annum over the Kyoto period. The actions covered by the act include better management and reduced usage of HFC.
 - Three GGAP projects - the National Refrigeration and Air-conditioning Council, Refrigerant Reclaim Australia and Natural Refrigerants Transition Board projects - are estimated to provide 0.7 Mt CO₂-e per annum of abatement over the Kyoto period. However, these projects encourage actions that now overlap with those deemed mandatory under the new synthetic gas legislation, and hence are included in the above total.

The impact of measures is projected to increase to 9.1 Mt CO₂-e in 2020. This growth in abatement is due to the growth in emissions from the sector and does not assume new measures between the Kyoto period and 2020.

- By 2020 abatement from the mineral products, chemical industry and metal production subsectors is projected to rise to 4.2 Mt CO₂-e.
- Abatement from the synthetic greenhouse gas legislation is projected to reach 4.9 Mt CO₂-e by 2020.

iii 'Business as Usual' (BAU) results

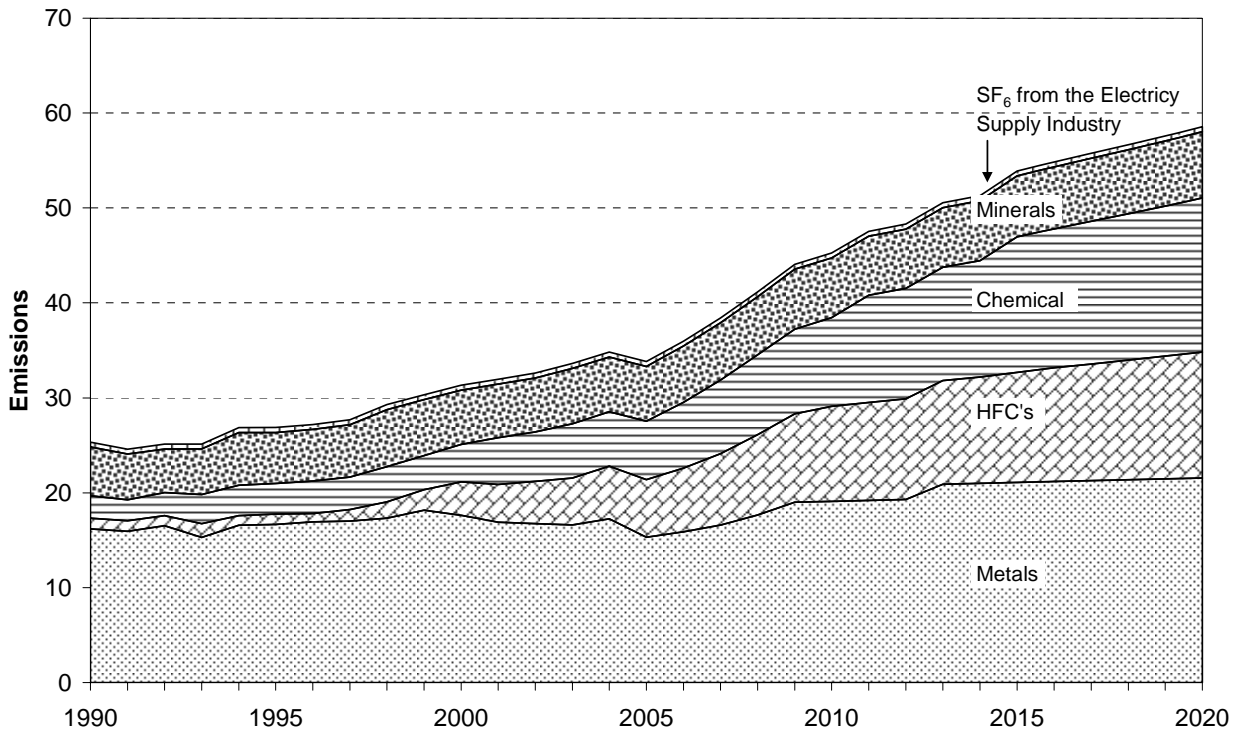
'Business-As-Usual' emissions from the industrial processes sector over the Kyoto period are projected to be 45.2 Mt CO₂-e per annum. This represents a 79 per cent increase over the 1990 level and is due to the following factors.

- The metals subsector is the largest source of emissions in the industrial processes sector. As a result of domestic economic expansion and strong export demand, BAU emissions from this subsector are projected to grow by 16 per cent between 1990 and the Kyoto period, while the share of emissions from the subsector is expected to decrease from 64 per cent in 1990 down to an average of 42 per cent over the Kyoto period.
- Estimates of HFCs used as replacements for ozone depleting substances by Montreal Protocol industries (refrigeration and air conditioning, foam blowing, fire extinguishers, aerosols and solvents) show emissions growing rapidly from a base of 1.1 Mt CO₂-e in 1990, reaching 9.7 Mt CO₂-e per annum over the Kyoto period.
- The emissions from the chemicals subsector are 2.3 Mt CO₂-e in 1990. This rises to 9.9 Mt CO₂-e per annum over the Kyoto period, an increase of 331 per cent. This large growth is due to high annual growth rates in the manufacturing of synthetic rutile, ammonia and nitric acid.

In 2020, BAU emissions are projected to be 58.5 Mt CO₂-e. This is an increase of 131 per cent over the 1990 level.

Figure ES2 shows the historic and projected BAU emissions time series for the industrial processes subsectors.

Figure ES2: **BAU emissions projection by subsector for industrial processes, 1990 to 2020 (Mt CO₂-e)**



Source: 2005 NGGI; Burnbank Consulting (2006); DCC Analysis 2008.

iv **Uncertainty and sensitivity**

Uncertainty associated with industrial processes emissions is estimated between 10.1 per cent below to 9.6 per cent above the 'With Measures' projection for the Kyoto period. This interval reflects uncertainty associated with production data, emission factors, the impact of the *Ozone Protection and Synthetic Greenhouse Gas Management Act 1989* (Cth), the timing and extent of substitution away from ozone depleting substances to HFC, and the development of new chemicals and technologies.

v Changes from the previous projections

- The 2007 projection makes only a minor revision to the 2006 projection. The major change relates to the leakage rate used in the HFC emissions from mobile air conditioning. This reduces the Kyoto period ‘with measures’ HFC emissions from 6.6 Mt CO₂-e per annum in the previous projection to 6.2 Mt CO₂-e per annum in this projection. Measures aimed at reducing the emissions of HFCs are projected to provide an annual average abatement of 3.5 Mt CO₂-e over the Kyoto period, a decrease of 0.3 Mt CO₂-e compared to the previous projection.
- Minor changes have also been made to emission factors and activity levels in the minerals, metal and chemical subsectors with negligible net impact on Kyoto period emissions.
- The carbon dioxide emissions factor from clinker manufacture has been revised consistent with changes in the NGGI methodology. This has resulted in an increase of 0.1 Mt CO₂-e on the average annual ‘with measures’ emissions over the Kyoto period.
- The quantity of in-house produced limestone and limestone used by the glass production industry and the iron and steel industry have been revised to ensure consistency between the NGGI and the projections. This has resulted in a 0.1 Mt CO₂-e per annum increase in Kyoto period ‘with measures’ emissions from the minerals subsector. This is offset by a removal of emissions from ‘Other Limestone’ (estimated to be 0.1 Mt CO₂-e per annum over the Kyoto period in the 2006 projections), which is now accounted for in the emissions from limestone used by glass production and iron and steel industry.
- Emissions from coke ovens, previously estimated to be 0.07 Mt CO₂-e per annum over the Kyoto period, was removed to ensure consistency with the NGGI methodology, which includes emissions from coke ovens in the SE sector.
- Carbon dioxide emission factors for rutile (titanium dioxide) in the chemicals subsector were also revised resulting in a decrease of 0.03 Mt CO₂-e per annum in the ‘with measures’ emissions over the Kyoto period.

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1. Introduction

This paper presents projections of greenhouse gas emissions from the industrial processes sector. The 2007 industrial process projection is a minor update of the 2006 projection and incorporates a number of changes to emissions factors. Projections have been compiled previously in 1997, 2001, 2002, 2003, 2004 and 2006. On each occasion, consistent with the continuous improvement of the projections process, emission factors have been revised, activity levels have been updated and/or the coverage of sources accounted for in the projections has been extended.

This paper provides:

- background information regarding the industrial processes inventory emissions in this chapter;
- a summary of the industrial processes emissions projection in chapter 2; and
- detailed projections analysis for the mineral products, chemical industries, metal production, and HFCs and SF₆ subsectors in chapters 3, 4, 5 and 6 respectively.

1.1 Coverage of the Industrial Processes Sector

Greenhouse gas emissions from industrial processes are primarily by-products of production, and they vary with the process technology used and the level of industrial output. These emissions arise from non-energy related sources. For example, high temperature processing of calcium carbonate to produce quicklime releases carbon dioxide emissions. Technological changes in production processes can affect the energy and greenhouse intensity of industrial processes but rarely reduce process emissions, which are dictated by the process chemistry. However, product substitution may result in substantial changes in process emissions by changing the underlying chemistry.

Subsectors

The sources of emissions from industrial processes include:

- *Mineral Products*: carbon dioxide from cement clinker and lime production; the use of limestone and dolomite in industrial smelting processes; soda ash use; and magnesia production.
- *Chemical Industry*: Nitrous oxide emissions from the production of nitric acid; carbon dioxide emissions from ammonia production; and methane emissions from the production of organic polymers and other chemicals.

-
- *Metal Production*: carbon dioxide and perfluorocarbon emissions from aluminium smelting; and carbon dioxide, methane and nitrous oxide emissions from iron and steel production.
 - *Consumption of halocarbons*: emissions of hydrofluorocarbons, perfluorocarbons and sulfur hexafluoride from refrigeration and air conditioning equipment; foam blowing; metered dose inhalers; fire extinguishers; solvent use; and electrical equipment.

Table 1.1 disaggregates the sources of emissions from industrial processes by gas species.

Gas Species

The gas emissions from industrial processes cover all groupings of greenhouse gases. These are:

- *Carbon Dioxide (CO₂)*: The main source of CO₂ in the sector is from the release of CO₂ through the processing of carbonate materials (e.g. to produce cement or lime) and in the use of a reductant in metal manufacturing (e.g. the use of coke in steel production).
- *Methane (CH₄)*: Methane is produced as a by-product from coke production used in steel manufacturing. A small amount of methane is also produced in the reduction process of steel.
- *Nitrous Oxide (N₂O)*: A small amount of nitrous oxide is produced through the use of reductant in steel production. The majority of nitrous oxide is produced in the chemical subsector. However, emissions from this subsector are aggregated into a single CO₂-e to reflect the confidential nature of the data received from companies in the chemical manufacturing sector.
- *Perfluorocarbons (PFC)*: Tetrafluoromethane and hexafluoroethane are generated and emitted during process disturbances (anode effect) in the production of aluminium. Perfluorocarbons are used as an insulating cover gas in the smelting pots.
- *Hydrofluorocarbons (HFC)*: A range of hydrofluorocarbons are used in refrigeration, air conditioning, aerosol and other industrial applications. These gases are emitted either through leakage from faulty equipment or during maintenance of this equipment or as a by-product of a process (e.g., foam blowing, fire extinguishers).
- *Sulfur Hexafluoride (SF₆)*: sulfur hexafluoride is used as an electrical insulator in high voltage applications. Emissions of this gas are mainly due to leakage from faulty equipment and poor handling when servicing this high voltage equipment.

Table 1.1 Disaggregation of the industrial processes sector

ID	Category	Industry subsector	Greenhouse gases					
			CO ₂	CH ₄	N ₂ O	PFC	SF ₆	HFC
A	Mineral Products							
1		Cement production	♦					
2		Lime production	♦					
3		Limestone/dolomite use	♦					
4		Soda ash production and use ^a	♦					
5		Magnesia production ^a	♦					
B	Chemical Industries							
1		Ammonia production ^a	♦					
2		Nitric acid production ^a			♦			
3		Nitrous oxide use ^a			♦			
4		Acetylene use ^a	♦					
5		Synthetic rutile and titanium dioxide	♦					
		Polymers and other organic chemicals	♦					
		Methanol production	♦					
C	Metal Production							
1		Iron and steel production	♦	♦	♦			
3		Aluminium production	♦			♦		
4		SF ₆ used in aluminium and magnesium foundries					♦	
F	HFC and SF ₆							
1		Montreal Protocol Industries						♦
2		SF ₆ emissions from switchgear and circuit breakers					♦	

^a Emissions reported under this subsector include the aggregated emissions from individual subsectors that report their emissions on a confidential bases. These industries include ammonia and nitric acid production.

1.2 Projections methodology

The 2007 emissions projection for the industrial processes sector is a minor update of the 2006 projection. A number of changes have been made to emission factors based on new information relating to the industrial processes sector. These changes include:

- A revision to the leakage rates used in HFC emissions from mobile air conditioning.
- A revision to the carbon dioxide emission factor from clinker manufacture.

- Revision of the quantities of cement kiln dust, in-house produced limestone and limestone used by the glass production industry and the iron and steel industry.
- Exclusion of emissions from coke ovens as these emissions are now included in the stationary energy sector.
- Revision of the carbon dioxide emission factor relating to the production of synthetic rutile and titanium dioxide in the chemicals subsector.

The impact of measures are evaluated and deducted from the 'BAU' estimate based on production levels and emission factors for each subsector. Total greenhouse gas emissions from industrial processes are the sum of the emissions from each subsector.

1.3 Historical trends

Emissions from the industrial processes sector contributed 5.4 per cent of total net national emissions in 2005 (Table 1.2).

Table 1.2 Industrial processes sector CO₂-e emissions^a, 2005

	CO ₂ -e emissions (Mt)					% Total net national emissions
	CO ₂	CH ₄	N ₂ O	HFC/ PFC/ SF ₆	Total	
Total net national emissions	415.5	112.9	24.3	6.4	559.1	100.0
INDUSTRIAL PROCESSES	23.0	0.07	0.02	6.4	30.2	5.4
Mineral products	5.6	NA	NA	NA	5.6	1.0
Chemical industries ^b	NE	NE	NE	NE	6.2	1.1
Metal production	11.2	0.002	0.02	1.6	12.8	2.3
HFC and SF ₆ ^c	NA	NA	NA	4.8	5.6	1.0

^a NE – Not estimated; NA – Not applicable.

^b Emissions reported under this subsector include the aggregated emissions from individual subsectors that report their emissions on a confidential bases. These industries include ammonia and nitric acid production.

^c The 2005 'with measures' estimates presented here differ slightly from those published in the 2005 NGGI due to updated leakage rates used in estimating HFC emissions from commercial refrigeration.

Source: 2005 NGGI; Burnbank Consulting (2006); DCC Analysis 2008.

Trends in industrial process emissions by subsector for the years 1990 to 2005 are shown in Table 1.3.

Table 1.3 Industrial Processes emission trends, 1990 to 2005 (Mt CO₂-e)

	1990		2005		% Change on 1990 emissions
	CO ₂ -e emissions (Mt)	% of Sector	CO ₂ -e emissions (Mt)	% of Sector	
INDUSTRIAL PROCESSES	25.3	100	30.2	100	+19
Mineral products	5.1	20.2	5.6	18.5	+10
Chemical industries ^a	2.3	9.1	6.2	20.5	+170
Metal production	16.2	64.0	12.8	42.4	-21
HFC and SF ₆ ^b	1.6	6.3	5.6	18.5	+250

^a Emissions reported under this subsector include the aggregated emissions from individual subsectors that report their emissions on a confidential bases. These industries include ammonia and nitric acid production.

^b The 2005 'with measures' estimates presented here differ slightly from those published in the 2005 NGGI due to updated leakage rates used in estimating HFC emissions from commercial refrigeration.

Source: 2005 NGGI; DCC Analysis 2008.

Table 1.3 shows that emissions from the industrial processes sector increased by 19 per cent between 1990 and 2005. This reflects strong growth in the consumption of halocarbons in Montreal Protocol Industries, and significant growth in emissions from the chemical industry (primarily ammonia and nitric acid production). The increase in emissions from mineral products of 10 per cent reflects consistently solid growth in economic activity over the period under consideration. The substantial decline in emissions from metal production of 21 per cent is due to contraction in the iron and steel industry with the closure of the plant in Newcastle along with actions taken by BHP to reduce greenhouse emissions from steel production, and significant reductions in PFC emissions from aluminium smelting despite strong growth in production of primary aluminium metal. PFC emission reductions have resulted from improved process monitoring and control leading to a decline in the frequency and duration of anode effects.

1.3 Key Drivers

Greenhouse gas emissions from industrial processes are the by-products of materials and reactions used in the production process.

In the mineral, chemical and metal subsectors, production levels of the relevant product largely influence annual fluctuations in resulting emissions. Over time, technological change in production processes can have a significant impact on process emissions. For example, improved process monitoring and control has resulted in a substantial reduction in PFC emissions from aluminium smelting. Nonetheless, in these subsectors the process chemistry places a physical limit on emissions reductions. Once minimum greenhouse emissions intensity is achieved, further reductions in emission factors can occur only through technological changes that fundamentally alter the chemistry of the production processes. Major changes of this type are infrequent and difficult to predict.

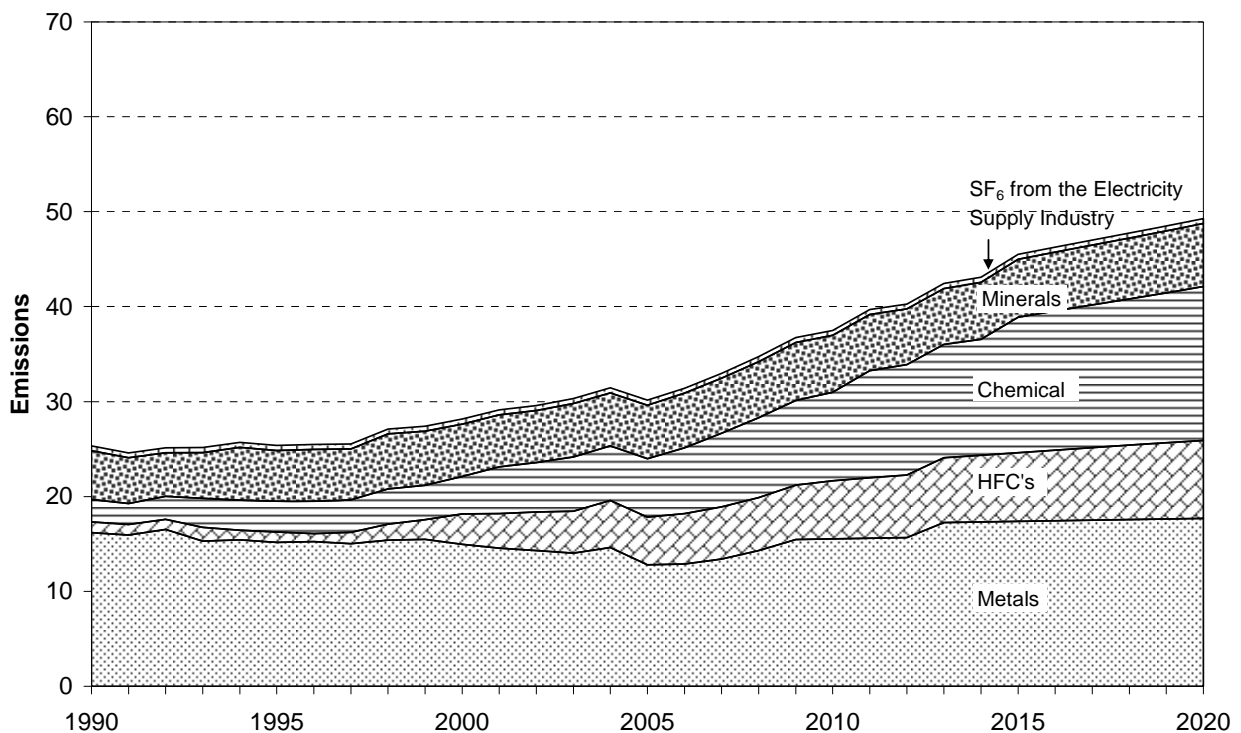
In the Montreal Protocol and electricity supply industries emissions are associated with leakages from equipments charged with synthetic greenhouse gases. Emissions in these subsectors are increasing rapidly from a low base as HFCs replace ozone-depleting substances, whose use is controlled by the Montreal Protocol. The key drivers of emissions in these subsectors include growth in demand for products and equipments that require synthetic gases in operation (such as air conditioning units and electrical switchgear) and the amount of gas leakage occurring from those products. Emissions from these industries can be reduced through improved sealing, handling and maintenance of equipment.

It should be noted that many of the industries contributing to industrial process emissions are successfully reducing both combustion (stationary energy) and non-combustion (fugitive and transport) emissions accounted for in other NNGI sectors.

2. Emissions projections from industrial processes

Greenhouse gas emissions from industrial processes are projected to rise steadily to 2020, driven by expected strong growth in the production of chemicals and through the expansion of synthetic gas usage. Projected emissions from the industrial processes sector for 1990 to 2020 are shown in Figure 2.1.

Figure 2.1 'With Measures' greenhouse gas emissions from the industrial processes sector, 1990 to 2020 (Mt CO₂-e)



Source: 2005 NGGI; Burnbank Consulting (2006); DCC Analysis 2008.

Figure 2.1 shows that, taking into account existing measures, emissions from the industrial processes sector are projected to grow to 37.9 Mt CO₂-e per annum over the Kyoto period, a 49 per cent over 1990 emissions of 25.3 Mt CO₂-e. This can be compared with the BAU scenario where emissions are projected to have increased by 79 per cent from 25.3 Mt CO₂-e in 1990 to 45.2 Mt CO₂-e per annum over the Kyoto period.

Measures are projected to reduce emissions by 7.4 Mt CO₂-e per annum over the Kyoto period. Measures abatement is comprised of 3.5 Mt CO₂-e due to abatement under the synthetic gases regulatory scheme, 3.5

Mt CO₂-e attributable to reductions of PFC emissions from aluminium smelting and a further 0.3 Mt CO₂-e due to increased use of supplementary cementitious materials in the cement industry.

The continued growth in the chemicals industry is the most significant driver of increasing emissions over the projections period. Emissions from this subsector are projected to increase by 7.6 Mt CO₂-e between 1990 and the Kyoto period, an increase of 331 per cent.

Further, the continued expansion of synthetic gas usage in Montreal Protocol industries is projected to increase emissions by 5.1 Mt CO₂-e between 1990 and the Kyoto period, an increase of 452 per cent.

A projected increase in emissions from mineral production is offset by a reduction in emissions from metal production. In total, the growth in industrial process sector emissions between 1990 and the Kyoto period is projected to be 12.5 Mt CO₂-e.

2.1 Comparison to the previous projection

Average annual projected 'With Measures' emissions over the Kyoto period are 0.4 Mt CO₂-e lower than they were estimated in the previous projection. This is due to:

- An update of the leakage rates used in the HFC emissions from mobile air conditioning, which reduces projected Kyoto period emissions by 0.4 Mt CO₂-e per annum.
- A reduction of 0.07 Mt CO₂-e per annum in projected Kyoto period emissions from the production of iron and steel as emissions from coke ovens are now included in the stationary energy sector.
- A revision of the carbon dioxide emission factor from clinker manufacturing, which increases average annual Kyoto period emissions by 0.1 Mt CO₂-e per annum.
- An update of carbon dioxide emission factor of rutile (titanium dioxide) in the chemicals subsector, which reduces projected Kyoto period emissions by 0.03 Mt CO₂-e per annum.

Table 2.1 provides a detailed comparison of the 2006 and 2007 projections for each subsector.

Table 2.1 **Comparison between 2007 and 2006 projections of Kyoto period emissions**

	Business as Usual			With Measures			Measures		
	2007	2006	Change	2007	2006	Change	2007	2006	Change
INDUSTRIAL PROCESSES TOTAL	45.2	45.9	-0.6	37.9	38.3	-0.4	7.4	7.6	-0.3
Minerals Production	6.2	6.1	+0.1	5.9	5.8	+0.1	0.3	0.3	0.0
Cement production	3.8	3.7	+0.1	3.5	3.4	+0.1	0.3	0.3	0.0
Lime	1.3	1.3	0.0	1.3	1.3	0.0	na	na	na
Limestone/dolomite	1.1	1.1	0.0	1.1	1.1	0.0	na	na	na
Chemical industries^a	9.9	9.9	0.0	9.9	9.9	0.0	na	na	na
Metal Production	18.8	18.9	-0.1	15.3	15.4	-0.1	3.5	3.5	0.0
Iron and Steel	11.3	11.4	-0.1	11.3	11.4	-0.1	na	na	na
Aluminium	7.5	7.5	0.0	4.0	4.0	0.0	3.5	3.5	0.0
Montreal Protocol Industries	9.7	10.4	-0.7	6.2	6.6	-0.4	3.5	3.8	-0.3
SF₆ Electrical Industry	0.5	0.5	0.0	0.5	0.5	0.0	0.0	0.0	0.0

^a Emissions reported under this subsector include the aggregated emissions from individual subsectors that report their emissions on a confidential bases. These industries include ammonia and nitric acid production.

Note: Figures may not add due to rounding errors.

Source: Burnbank Consulting (2006); DCC Analysis 2008.

2.2 Uncertainty and sensitivity

Uncertainty associated with industrial processes emissions is estimated between 10.1 per cent below to 9.6 per cent above the 'With Measures' projection over the Kyoto period. Hence, projected emissions for the Kyoto period are 37.9 Mt CO₂-e per annum with a high scenario of 41.5 Mt CO₂-e per annum and a low scenario of 34.1 Mt CO₂-e per annum, increases of 63.7 per cent and 34.4 per cent from the 1990 levels, respectively.

This interval reflects uncertainty associated with production data, emission factors, the impact of the *Ozone Protection and Synthetic Greenhouse Gas Management Act 1989* (Cth), the timing and extent of substitution away from ozone depleting substances to HFC, and the development of new chemicals and technologies.

Emission factor uncertainties range from ± 2.5 per cent for CO₂ emissions from dolomite to ± 16 per cent for N₂O emissions from natural gas reductant use in HBI production. The emission factor uncertainties applied to the projections are shown in Table 2.2. The lower factors are used to calculate the 'low' emissions estimate while the higher factors are used for the 'high' estimate.

Table 2.2 Emissions Factors and Uncertainties by industry and gas

Industry	CO ₂	CH ₄	N ₂ O	PFC	HFC/SF ₆
Cement clinker production	0.534 t per t (±5%)	NA	NA	NA	NA
Lime production	0.785 t per t (±5%)	NA	NA	NA	NA
Limestone use	0.396 t per t (±2.5%)	NA	NA	NA	NA
Dolomite use	0.453 t per t (±2.5%)	NA	NA	NA	NA
Iron and steel coke reductant	119.5 Gg per PJ (±6%)	1.07 t per PJ (±6%)	0.8 t per PJ (±15%)	NA	NA
Iron and steel natural gas reductant	(±4%)	(±4%)	(±16%)	NA	NA
Aluminium	1.611 t per t (±5%)	NA	NA	Varies each year (±5%)	NA
Ammonia	C (±5%)	NA	NA	NA	NA
Nitric acid	NA	NA	C (±5%)	NA	NA
Magnesia	C (±5%)	NA	NA	NA	NA
Stationary Refrigeration and Air Conditioning	NA	NA	NA	NA	See Appendix A
Mobile Air Conditioning	NA	NA	NA	NA	See Appendix A
Sulfur Hexafluoride	NA	NA	NA	NA	0.5 % annual leakage (0%)

C – Confidential; NA – Not Applicable.

Source: Burnbank Consulting (2006).

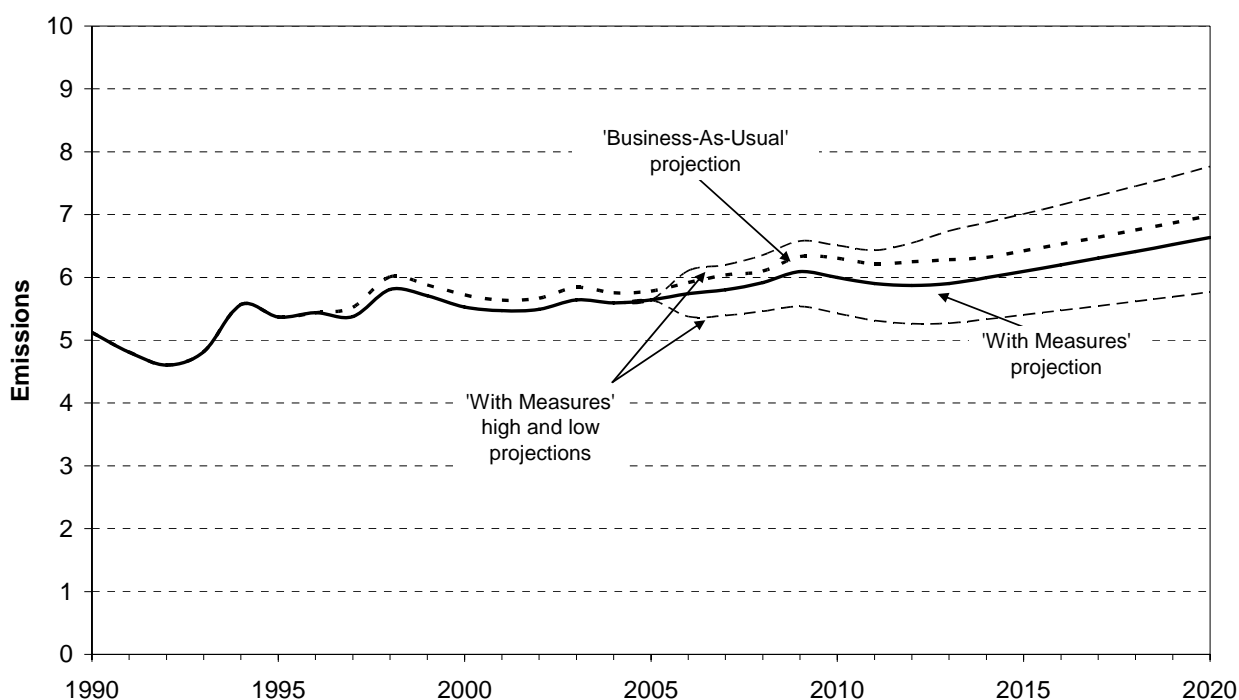
Production sensitivity is generally taken as two standard errors from the growth rate. For new developments and expansions to existing capacity, sensitivity is determined by lowering the rate at which design capacity is expected to be reached, and the high estimate is determined by assuming that full design capacity will be achieved in the minimum time and consistent with industry advice on the most optimistic production schedule.

3. Mineral Products

This chapter reports projections of emissions from mineral products industries. The mineral products subsector covers emissions from cement production, lime production, and limestone and dolomite use. Soda ash production and magnesia production are reported under the chemical subsector as the emissions data from these activities are provided on a commercial in confidence basis. Projected greenhouse gas emissions from mineral products are broadly unchanged compared to the previous estimate.

Figure 3.1 shows the emissions from the subsector from 1990 to 2020. There is a 15 per cent growth in the 'with measures' emissions between 1990 and the Kyoto period. This mainly reflects growth from lime production while the variations are mainly due to fluctuations in cement production and limestone and dolomite use. Table 3.1 summarises the 'with measures' projection for the subsector.

Figure 3.1 Minerals Products subsector emissions, 1990 to 2020 (Mt CO₂-e)



Source: 2005 NGGI; Burnbank Consulting (2006); DCC Analysis 2008.

Table 3.1 Minerals Products Subsector Emissions (Mt CO₂-e)

Industry	1990	Kyoto period (2008-2012) average	Growth from 1990 to Kyoto period	2020	Growth from 1990 to 2020
Cement	3.46	3.53	+2.1%	3.59	+3.6%
Lime	0.71	1.33	+88.4%	1.89	+168.2
Limestone/ Dolomite	0.96	1.04	+9.1%	1.11	+15.8%
TOTAL WM	5.12	5.91	+15.3%	6.59	+28.5%
Measures	0.0	0.3		0.3	

Note: Figures may not add due to rounding errors.

Source: 2005 NGGI; Burnbank Consulting (2006); DCC Analysis 2008.

3.1 Cement Production

Clinker production plants are located across Australia with two plants in NSW and one plant in each of the other States - WA, SA, Victoria, Tasmania and Queensland. All the primary capacity is based on efficient dry process technology with some reserve plants relying on the more energy intensive wet process technology. This reserve capacity is brought into service to meet unexpected increases in demand and in the event of problems with the main process.

The overall greenhouse gas emissions from cement production in Australia are shown in Table 3.2. ‘With measures’ emissions from cement production is projected to be 3.5 Mt CO₂-e per annum over the Kyoto period, which is 2.1 per cent above the 1990 level and similar to the previous estimate.

Table 3.2 Cement Production Emissions (Mt CO₂-e)

	1990	Kyoto period (2008-2012) average	Growth from 1990 to Kyoto period	2020	Growth from 1990 to 2020
WM	3.46	3.53	+2.1%	3.59	+3.6%
Measures	0.0	0.28	na	0.35	na
BAU	3.46	3.81	+10.3%	3.94	+13.7%

Source: 2005 NGGI; Burnbank Consulting (2006); DCC Analysis 2008.

Portland cement clinker in ground form is the principal component in cement and is produced through high temperature firing of ‘raw meal’, which mainly consists of limestone (calcium carbonate – CaCO₃). The chemical reaction to produce clinker emits carbon dioxide. Based on the World Business Council’s methodology, an emission factor of 534 kg of CO₂ per tonne of clinker produced is used (NGGI 2005). Prior to the compilation of the 2004 inventory, cement kiln dust (CKD) and total organic content (TOC) of the raw meal, were not accounted for separately. The 2007 projections, as the previous two projections, adopts a revised methodology which takes a separate account of cement kiln dust (CKD) and total organic content of the raw meal. It is assumed that CKD represents 1.2 per cent of the clinker production in any year and that 10 kg CO₂-e per tonne of clinker are produced to account for TOC.

Cement demand drives cement production, which in turn determines clinker production. However, clinker production does not grow at the same rate as cement production due to increased penetration of supplementary cementitious materials¹ (SCM). The rate of growth in clinker production will continue to be slower than the rate of growth of cement production due to the continued displacement of Portland cement with SCM. This will continue until SCM substitution reaches a technical or market defined threshold. At this time, the growth rate of clinker production will be matched by the growth rate in overall cement production. This threshold is estimated at 25 per cent based on industry advice and overseas experience.

The approach used to develop the current projection is similar to that used in the previous projection.

Analysis of the most recent dataset indicates that in recent years there has been strong growth in total cementitious materials (TCM) consumption reflecting very strong growth in net imports and the use of cement extenders and mineral additions. This TCM consumption data was disaggregated into its different sources since process emissions only arise from domestic production of clinker², and not from the use of imports or other cement extenders. The resulting growth rate in domestic clinker production is estimated to be 1.24 per cent per annum.

The ‘with measures’ projection is calculated using the following assumptions:

- The proportions of net imports are the actual shares up to 2005 and are assumed to increase to 15 per cent by 2011. The share of net imports is held constant at 15 per cent for all subsequent years;
- The share of cement extenders increases from 14 per cent in 2006 to 25 per cent of the market by 2013 and is held constant to 2020; and
- Mineral addition to cement reduces from 22 per cent in 2000 to 10 per cent in 2010 and remains constant for future years.

The resulting ratio of clinker produced domestically to TCM follows the scheme in Table 3.3.

¹ SCM are mineral additives such as ground granulated blast furnace slag and fly ash, and cement imports.

² Cement is produced through grinding clinker, which is then mixed with imports and cement extenders.

Table 3.3 Assumptions for the Cement Production Projection

Year	Production (Mt t clinker)		Emissions Factor (t CO ₂ -e/t clinker)	Proportion of Clinker to TCM	
	BAU	WM		BAU	With Measures
1990	6.21	6.21	0.534	0.80	0.80
2000	6.92	6.56	0.534	0.70	0.66
2005	6.92	6.66	0.534	0.64	0.62
2010	7.01	6.44	0.534	0.61	0.56
2020	7.15	6.50	0.534	0.55	0.50

Source: Burnbank Consulting (2006); DCC Analysis 2008.

The BAU projection is constructed from adding the impact of greenhouse response measures to the ‘with measures’ projection. The greenhouse measures for cement production reflect the reduction in emissions due to the increased use of cement extenders. Under BAU it is assumed that the cement extenders share of the market reaches 20 per cent by 2014 and is held constant to 2020. All other assumptions outlined above for ‘with measures’ also apply to BAU.

The effect of measures is to increase the ratio of cement extenders to TCM and results in less ‘raw meal’ being processed, which reduces the amount of CO₂-e produced. Over the Kyoto period, this measure produces an average abatement of 0.3 Mt CO₂-e per annum and this remains constant out to 2020. All of this abatement is attributed to Greenhouse Challenge Plus since the cement industry voluntarily reports to that program.

3.2 Lime Production

Lime is a common mineral used in many industries including mineral processing and agriculture. Production of lime is undertaken both for commercial sale and for in-house use. Emissions from lime production over the Kyoto period are projected to be 1.3 Mt CO₂-e per annum, broadly unchanged from the previous projection. This is an increase of 88 per cent over the 1990 base. There are no measures that apply to emissions from lime production. Production of lime gives rise to emissions of CO₂ due to the same chemistry involved in cement clinker production.

Table 3.4 Overall Lime Production Projections (Mt CO₂-e)

	1990 emissions	Kyoto period (2008-2012) average emissions	Growth from 1990 to Kyoto period	2020 emissions	Growth from 1990 to 2020
With Measures	0.71	1.33	+88.4%	1.89	+168.2%

Source: 2005 NGGI; Burnbank Consulting (2006); DCC Analysis 2008.

For the 2007 projection it is assumed that:

- Commercial lime production will grow by 3.7 per cent per annum until 2020; and
- In-house lime production will grow by 91 per cent from 2006 to 2009 concomitant with an expansion of alumina capacity of 850 kt. From 2010, growth is projected to be around 1.2 per cent per year reflecting minor incremental improvements in production.

Historical and projected rates of commercial and in-house lime production rates are shown in Table 3.5.

Table 3.5 Assumptions for the Lime Production Projection

	Commercial Lime Production (kt)	In-house Lime Production (kt)	Total Lime Production (kt)	Emission Factor (t CO₂-e/ kt)
1990	927	109	1035	0.785
2000	1157	120	1277	0.785
2005	1575	42	1617	0.785
2010	1895	68	1962	0.785
2020	2719	76	2794	0.785

Source: Burnbank Consulting (2006); DCC Analysis 2008.

The assumed growth rates are consistent with ABARE's listing of major projects along with the existing strong commodity markets. These indicate that large lime consumers such as alumina production are likely to grow at more than 3.0 per cent per year.

3.3 Limestone and Dolomite Use

Limestone and dolomite are used in integrated iron and steel production, glass production, iron and steel foundries, lead production, and copper and ferro-alloys production. The main driver for the use of these materials is annual crude steel production. Emissions from limestone and dolomite use are projected to be 1.1 Mt CO₂-e per annum over the Kyoto period, an 11.6 per cent rise from the 1990 base of 1.0 Mt CO₂-e. This is broadly unchanged from the previous projection.

Table 3.6 Overall Limestone and Dolomite Projection (Mt CO₂-e)

	1990 emissions	Kyoto period (2008-2012) average emissions	Growth from 1990 to Kyoto period	2020 emissions	Growth from 1990 to 2020
With Measures	0.96	1.04	+9.1%	1.11	+15.8%

Source: 2005 NGGI; Burnbank Consulting (2006); DCC Analysis 2008.

The previous projection distinguishes between emissions from limestone used in the iron and steel production and those from use in other industries (mainly cement and lead production). To ensure consistency with the NGGI and to make use of updated data, this projection combines all emissions from the use of limestone in one category. A weighted average of the growth rates of limestone use in iron and steel production and limestone use in the ‘other’ category used in the previous projection is used to forecast limestone use to 2020.

Emissions from limestone and dolomite use are estimated using estimates of crude steel production and advice from the industry. The estimates envisage some expansion in iron and steel production over the projections period. The assumptions in relation to iron and steel production which drive the estimates are discussed under iron and steel in chapter 5. The annual usage rates of limestone and dolomite are shown in Table 3.7

Table 3.7 Assumptions for the Limestone and Dolomite Use Projection

Year	Annual Usage		Emission Factor	
	(kt)		(t CO₂-e/kt)	
	Limestone	Dolomite	Limestone	Dolomite
1990	1587	721	440	477
2000	1863	660	440	477
2005	1565	625	440	477
2010	1895	696	440	477
2020	1971	718	440	477

Source: Burnbank Consulting (2006); DCC Analysis 2008.

The following assumptions are made in the emissions projection of limestone use in iron and steel production:

- There are 3.23 tonne of steel produced per tonne of limestone and dolomite use, held constant for the projections period; and

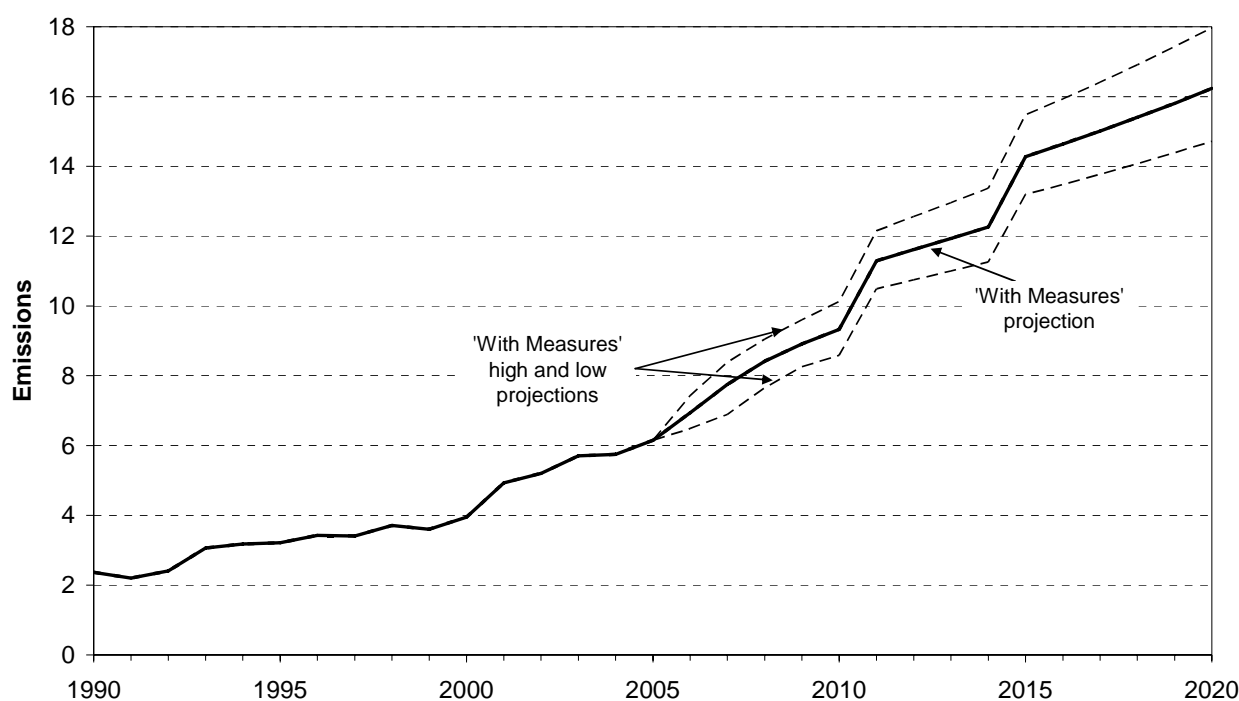
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- The proportion of limestone and dolomite use is 70 per cent and 30 per cent respectively. This is the average proportion over the previous 16 years and is held constant for the projections period.

4. Chemical Industry

The chemical industry comprises rutile and synthetic rutile production, polymers and organic chemicals production and other chemical production processes (such as ammonia and nitric acid production) that report their emissions on a confidential basis.

Greenhouse gas emissions from the chemical industry subsector are projected to increase by 331 percent between 1990 and the Kyoto period. This growth is mainly driven by strong projected growth in the production of ammonia and nitric acid. Figure 4.1 shows emissions trend for the chemical industry.

Figure 4.1 **Chemical Industry subsector emissions, 1990 to 2020 (Mt CO₂-e)**



Source: 2005 NGGI; Burnbank Consulting (2006); DCC Analysis 2008.

The average annual Kyoto period 'with measures' emissions from the chemicals subsector is projected to be 9.9 Mt CO₂-e. The largest contributor to these emissions is emissions reported by industry on a confidential basis. Rutile, which encompasses synthetic rutile and titanium dioxide, accounts for 13 per cent of the emissions from the subsector. Emissions from the production of polymers and other organic chemicals are negligible in the Kyoto period but increases stepwise between the Kyoto period and 2020. This is due to a

proposed two stage methanol project. Projected emissions from the chemicals subsector are unchanged from the previous projection. Table 4.1 shows emission levels and growth rates for the industries in the chemical industry subsector.

Table 4.1 Summary of Emissions from the Chemical Industry, 1990 to 2020 (Mt CO₂-e)

Industry	1990	Kyoto period (2008-2012) average	Growth from 1990 to Kyoto period	2020	Growth from 1990 to 2020
Confidential Chemical Industries	1.9	7.9	+320%	10.6	+460%
Rutile	0.4	1.3	+179%	2.3	+392%
Polymers and organic chemicals	0.0	0.7	na	3.3	Na
TOTAL WM	2.3	9.9	+331%	16.2	+586%
Measures	None				

Source: 2005 NGGI; Burnbank Consulting (2006); DCC Analysis 2008.

4.1 Confidentially Reported Chemical Industries

Several emission sources reported in the NGGI depend on data collected from industry on a confidential basis. The number of these sources has been expanded since the 2004 projections and comprises soda ash production and use, magnesia production, ammonia production, nitric acid production, nitrous oxide production and use, and acetylene use. Production data and in some cases emission factors are provided by companies. Emissions from these sources are reported as an aggregated CO₂-e total for the chemical industries.

For the 2007 projections, it is assumed that:

- There is strong growth in production of ammonia and nitric acid from existing plants in the short to medium term.
 - Ammonia production is assumed to grow at 3.5 per cent per year. This provides sufficient allowance for new plants³ and expansions by existing producers. In addition, the large export scale ammonia plant at the Burrup Peninsula in WA commissioned in early 2006 is included as a separate source of ammonia production. This plant is assumed to reach full planned capacity by 2009 in the 'with measures' scenario.

³ For example, the Deepak Fertilisers plant that is under consideration (DoIR, 2006; p.37)

-
- Nitric acid production grows by around 7 per cent up to 2010, and by 3.5 per cent from 2011 to 2020. This allows for growth in production by existing producers and reflects new projects under consideration such as the one proposed by Deepak Fertilisers in Western Australia.
 - Magnesia production grows in accordance with estimates supplied by industry. These estimates indicate relatively slow growth over the projections period.
 - Nitrous oxide production and use, and acetylene use grow at the same rate as population (ABS, 2004).
 - Soda ash production and use is a minor component of the confidential emissions and is held constant at 2004 levels.

Emissions from the confidential chemical industries are projected to be 7.9 Mt CO₂-e per annum over the Kyoto period. This is a 320 per cent increase over its 1990 level of 1.9 Mt CO₂-e.

4.2 Rutile

This projection accounts for synthetic rutile and titanium dioxide (TiO₂) production. Synthetic rutile production uses coal as a reductant to reduce the ilmenite ore to synthetic rutile. TiO₂ production via the chloride route uses metallurgical coke as an integral part of the reaction.

The projections for synthetic rutile are based on a comprehensive dataset published by the WA Department of Industry and Resources. It is assumed that:

- Synthetic rutile production grows at 6.1 per cent per year for the projections period, similar to the average annual growth rate since 1990. While this is a very high growth rate to apply in the longer term, over the projection period it is considered that the industry will grow strongly. Based on a production rate of 650 kt in 2005, this rate implies that production will increase to 1.6 million tonnes by 2020.

TiO₂ production is based on an estimate of production rates using public information on Australian capacity. No input was received from industry.

- It is assumed that TiO₂ production remains constant at the estimated production level of 80 kt TiO₂ per year. This is considered a weak assumption and likely to be an underestimate. However, since TiO₂ and synthetic rutile are competing materials, a high assumed growth rate in synthetic rutile balances the 'no growth' assumption made for TiO₂ production.

There are no measures that apply to the rutile industry.

4.3 Polymers and organic chemicals

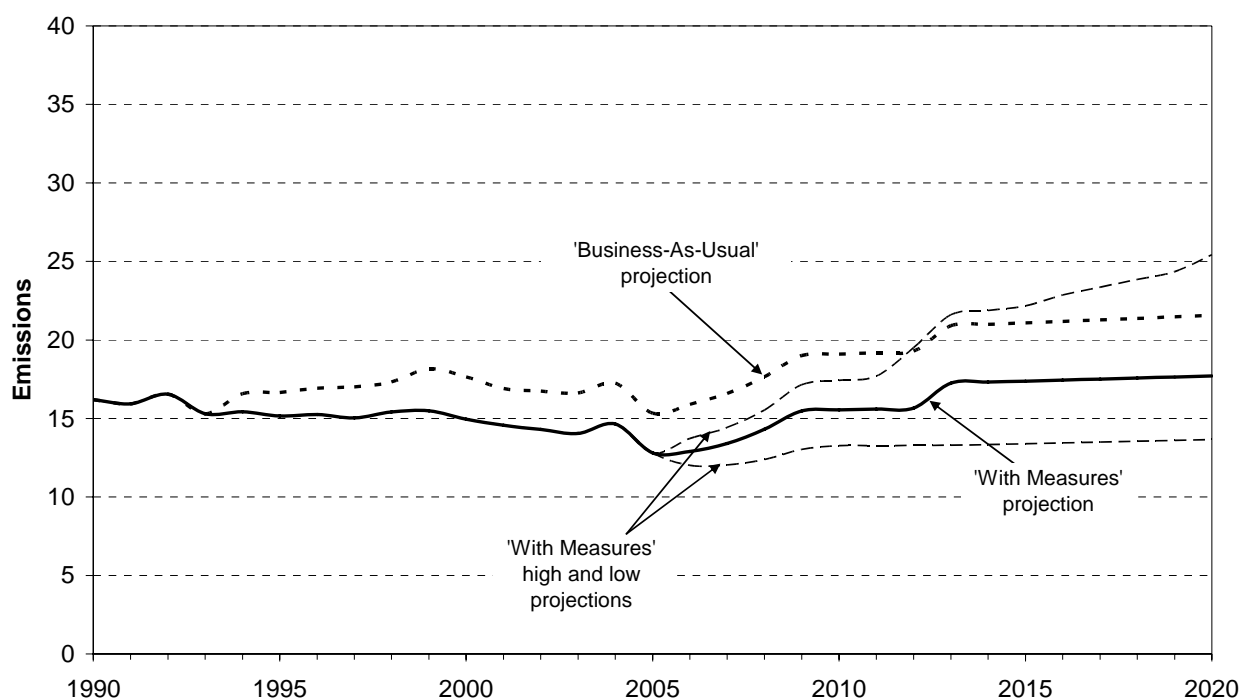
Polymers and other chemicals comprises emissions from butadiene, carbon black, ethyl benzene, ethylene, ethylene oxide, formaldehyde, high density polyethylene, low density and linear low density polyethylene, methanol, propylene, polypropylene, polystyrene, styrene, styrene butadiene latex, styrene butadiene rubber, and polyvinyl chloride. Emissions from these sources are small at around 8.8 Gg CO₂-e in 2004. These emissions have been projected to grow at the same rate as GDP used in 2006 stationary energy projection.

A proposed methanol plant in the Northern Territory aims to produce 1.7 million tonnes of methanol annually in its first stage and double this in the second stage. Energy Strategies (2005) assumed that the first stage would reach full capacity in 2011 while the second stage would reach full capacity four years later. Methanol production is an energy intensive process and uses a raw gas with a high CO₂ content. Hence the emissions from this process are projected at 1.7 Mt CO₂-e in 2011, rising to 3.3 Mt CO₂-e in 2015. Emissions from polymers and organic chemical production over the Kyoto period are projected to be 0.7 Mt CO₂-e per annum.

5. Metal production

The metal production subsector consists of iron and steel production and aluminium production. Emissions from the subsector arise from the conversion of metal ores to pure metal and through perfluorocarbons emissions from aluminium smelting. Metal production is the largest and most stable contributor to emissions from industrial processes. Emissions from this subsector account for 64 per cent of the 1990 industrial processes emissions and 40 per cent of the Kyoto period average annual emissions.

Figure 5.1 **Metal Production subsector emissions, 1990 to 2020 (Mt CO₂-e)**



Source: 2005 NGGI; Burnbank Consulting (2006); DCC Analysis 2008.

Greenhouse gas emissions from metal production are projected to reach 15.3 Mt CO₂-e per annum over the Kyoto period, a decrease of 5.4 per cent from the 1990 level, of 16.3 Mt CO₂-e. Table 5.1 summarises the emissions projection for the metal production subsector.

Table 5.1 **Summary of Emissions from Metal Production, 1990 to 2020 (Mt CO₂-e)**

Industry	1990	Kyoto period (2008-2012) average	Growth from 1990 to Kyoto period	2020	Growth from 1990 to 2020
Iron and Steel	10.3	11.3	+9.7%	13.4	+30.1%
Aluminium	6.0	4.0	-33.0%	4.3	-27.2%
Other Metals	ne				
TOTAL WM	16.3	15.3	-5.4%	17.7	+9.3%
Measures	0	3.5	na	3.9	na

Note: Figures may not add due to rounding error.

Source: 2005 NGGI; Burnbank Consulting (2006); DCC Analysis 2008.

5.1 Iron & steel

The Australian iron and steel industry has been restructured over the last decade. Australia's iconic integrated iron and steel producer, BHP, has been listed as two separate companies, OneSteel and BlueScope Steel. Further, the steel works at Newcastle, NSW, has been closed and a hot briquetted iron (HBI) plant has been established in Western Australia.

Recent changes to the industry include the closure of the HBI plant and the commissioning of a HIs melt plant in WA. While the decommissioning of the HBI plant will reduce emissions from metal production in the future, the commissioning of the HIs melt plant will lead to an increase in emissions. However, the emission intensity of the sector will be lower as the HIs melt plant is less energy intensive compared to the HBI plant.

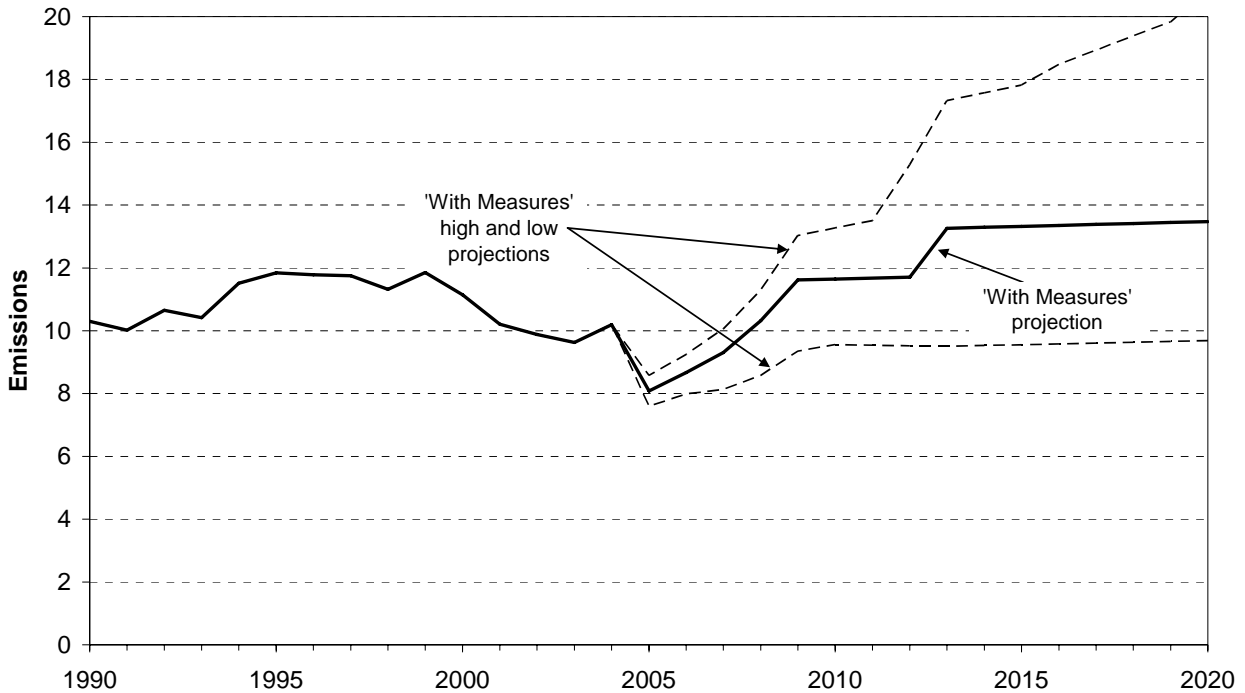
Consistent with the IPCC Guidelines, reductant use was allocated to the industrial processes sector from the 2001 NGGI. Reductant use includes coke used as a reductant in integrated iron and steel plants, and natural gas reductant used in hot briquetted iron production. Emissions of CO₂, CH₄ and N₂O from reductant use are accounted for.

The 2007 projection is based on estimates of production derived from information obtained through extensive discussions with industry in 2006. Some growth in production from integrated iron and steel plants were included in the projection, as well as the establishment of an iron production plant based on HIs melt technology.

The major factors and assumptions that impact projected emissions from iron and steel production are the same as those used in the 2006 projections. These include the closure of the HBI plant and the change in timing for HIs melt. Stage 1 full capacity is assumed to be attained in 2008, while stage 2 capacity is assumed to be reached by 2013. These assumptions are reflected in Figure 5.2. The sharp decrease in emissions

between 2004 and 2005 identifies the closure of the HBI plant, while the growth in emissions between 2005 and 2008 identifies the commissioning of the HIs melt plant.

Figure 5.2 Projected Emissions from Iron and Steel Production, 1990 to 2020 (Mt CO₂-e)



Source: 2005 NNGI; Burnbank Consulting (2006); DCC Analysis 2008.

The best estimate for HIs melt, assuming that 820 kt of iron will be produced by 2008, is conservative given that the technology is new and has not yet been fully implemented on a commercial scale. The high estimate relies on expansions beyond those currently contemplated.

Integrated iron and steel plants are assumed to approach full capacity by around 2009 following which growth will be very small and attributable to minor improvements in the production process. Given the large investment required for a new blast furnace/basic oxygen system (BF/BOS), the best estimate assumes that additional BF/BOS capacity is unlikely. However, it is included in the high estimate as shown by the sharp increase in emissions from 2011 along with HIs melt reaching the second stage capacity by 2013. Once the major changes in capacity have been implemented, increases in production are assumed to be small and result from minor refinements to production processes.

Projected 'with measures' emissions from iron and steel production are expected to reach 11.3 Mt CO₂-e per annum over the Kyoto period. This is an increase of 9.7 per cent over the 1990 emissions and is mainly due to the expansion in the industry. The projected emissions from iron and steel production are slightly different

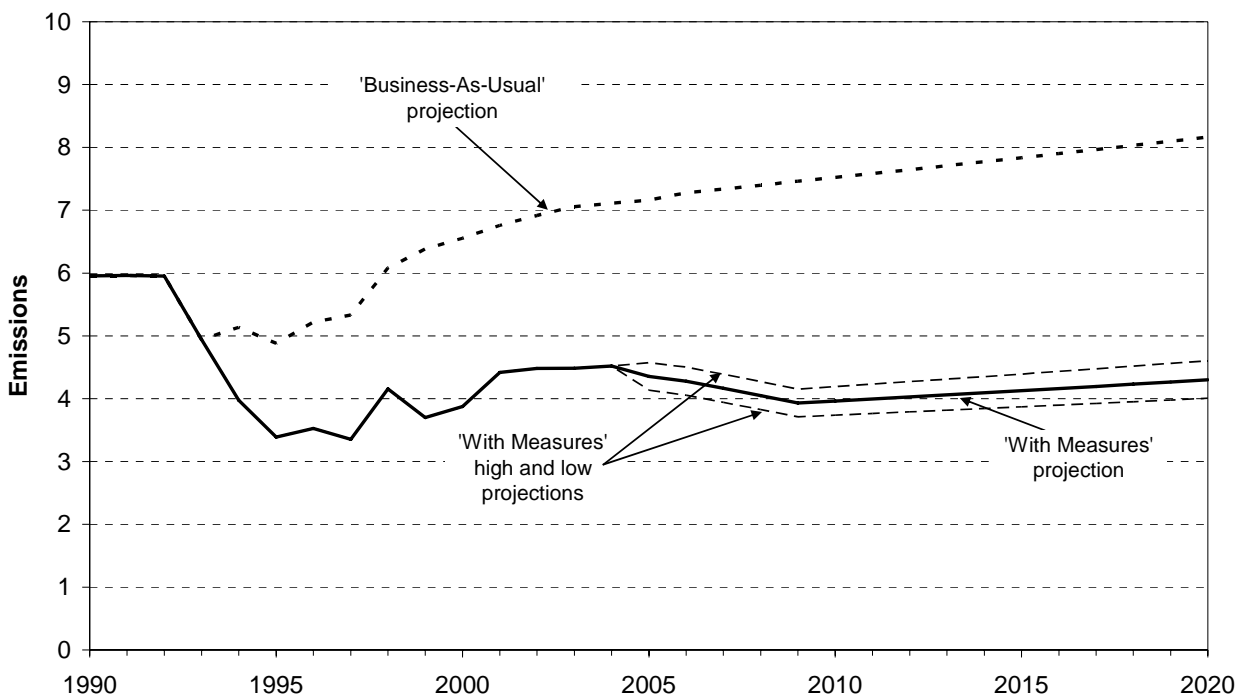
from the previous projection due to the exclusion of emissions from coke ovens, which are now included in the stationary energy sector.

5.2 Aluminium

Aluminium metal production is a very energy intensive process that requires large amounts of electrical energy. The emissions from producing that energy are counted in the Stationary Energy sector while the emissions from the aluminium production process are counted in the Industrial Processes sector. The smelting process gives rise to emissions of CO₂ and SO₂ from anode consumption and emissions of perfluorocarbons (PFC), which are generated through process upsets known as anode effects.

The production of alumina, which acts as a small greenhouse sink, was previously reported under aluminium but has since been removed from the inventory and projections.

Figure 5.3 **Projected Emissions from Aluminium Production, 1990 to 2020 (Mt CO₂-e)**



Source: 2005 NGGI; Burnbank Consulting (2006); DCC Analysis 2008.

Aluminium production is estimated from growth rates using the same approach as for the previous projections and based on industry advice. A growth rate of 0.8 per cent, which is one-quarter of the historical growth rate, was used in the projection. This growth rate projects an increase in aluminium metal production of 265 kt by 2020, which provides reasonable allowance for pot line expansions in existing plants, but tends to discount the possibility of a new greenfield plant.

Both significant expansion in existing plants and a new greenfield plant are considered unlikely in Australia and it appears that most major investments in new smelting capacity are expected to occur in the Middle East (Burnbank, 2006).

Projected emissions from aluminium production are shown in Figure 5.3 and summarised in Table 5.2. Relative to 1990 emissions, the BAU emissions are projected to rise 26 per cent over the Kyoto period to 7.5 Mt CO₂-e per annum.

Table 5.2 Summary of Emissions from Aluminium Production, 1990 to 2020 (Mt CO₂-e)

	1990 emissions	Kyoto period (2008-2012) average emissions	Growth from 1990 to Kyoto period	2020 emissions	Growth from 1990 to 2020
WM	6.0	4.0	-33.0%	4.3	-27.2%
Measures	0.0	3.5	na	3.9	na
BAU	6.0	7.5	+26.3%	8.2	+37.1%

Source: 2005 NGGI; Burnbank Consulting (2006); DCC Analysis 2008.

The only measure identified in the projections is the reduction of PFC emissions from aluminium production. As a result of various agreements with the aluminium industry under the Greenhouse Challenge program, it is estimated that PFC emission rates would decrease by around 85 per cent between 1990 and 2006 compared to a static baseline using constant emission factors from 1990. The Asia Pacific Partnership for Clean Development and Climate has a proposal to improve aluminium production efficiency and reduce PFC emissions through disseminating and deploying the highest standard of work practices appropriate to the smelting operation. Abatement from these projects will be estimated when details of the projects are finalized.

Between 1990 and 2004, the Australian aluminium industry has reduced PFC₄ emissions per tonne of aluminium by around 62 per cent. This has been achieved by improvements in process monitoring and control that has seen a decline in the frequency and duration of anode effects. These improvements are part of the industry's response to concerns about global warming and actions by the industry to reduce emissions of greenhouse gases.

The extent to which the PFC reductions are solely attributable to greenhouse concerns is difficult to determine, and raises issues regarding how the BAU scenario should be defined. The industry prefers to project emissions based on "frozen efficiency" rather than BAU. Frozen efficiency means that emission factors are held constant at 1989-90 levels. However, reducing anode effects improves process efficiency and

⁴ The PFCs generated and emitted are tetrafluoromethane (CF₄ with a GWP of 6500) and hexafluoroethane (C₂F₆ with a GWP of 9200).

it is likely that some improved monitoring and process control would have resulted in actions to reduce anode effects in the absence of greenhouse responses. This implies that part of the PFC reduction would have occurred in the BAU scenario.

The 2007 projection is derived using the same method as the 2006 projection where the BAU emission factors were adopted, based on industry advice. The 2007 projected impact of measures uses the most current values for emission factors and is estimated relative to the BAU baseline as shown in Table 5.3. It is estimated that measures reduce emissions by 47 per cent (3.5 Mt CO₂-e per annum) over the Kyoto period.

Table 5.3 PFC Emission Factors for Aluminium Smelting

PFC	Scenario	Emission factor (kg per tonne of aluminium produced)			
		1990	1995	2000	2006
CF ₄	BAU	0.41	0.28	0.28	0.28
CF ₄	Measure ^a	0.41	0.13	0.083	0.080
C ₂ F ₆	BAU	0.054	0.037	0.037	0.037
C ₂ F ₆	Measure ^a	0.054	0.017	0.011	0.010

^a These emission factor reflects the actual outcome for the years 1990, 1995 and 2000. The very small decline from 2000 to 2006, results from actual outcomes from 2000 to 2004 indicating that reductions over the period to 2006 are likely to be minimal.

Source: Burnbank Consulting (2006).

The 2007 projections are based on information up to and including 2004 along with discussions with industry, and it is considered that the estimate is reasonable rather than conservative. The emission factor for total PFC emissions is projected to be 0.4 tonnes CO₂-e per tonne of aluminium over the Kyoto period.

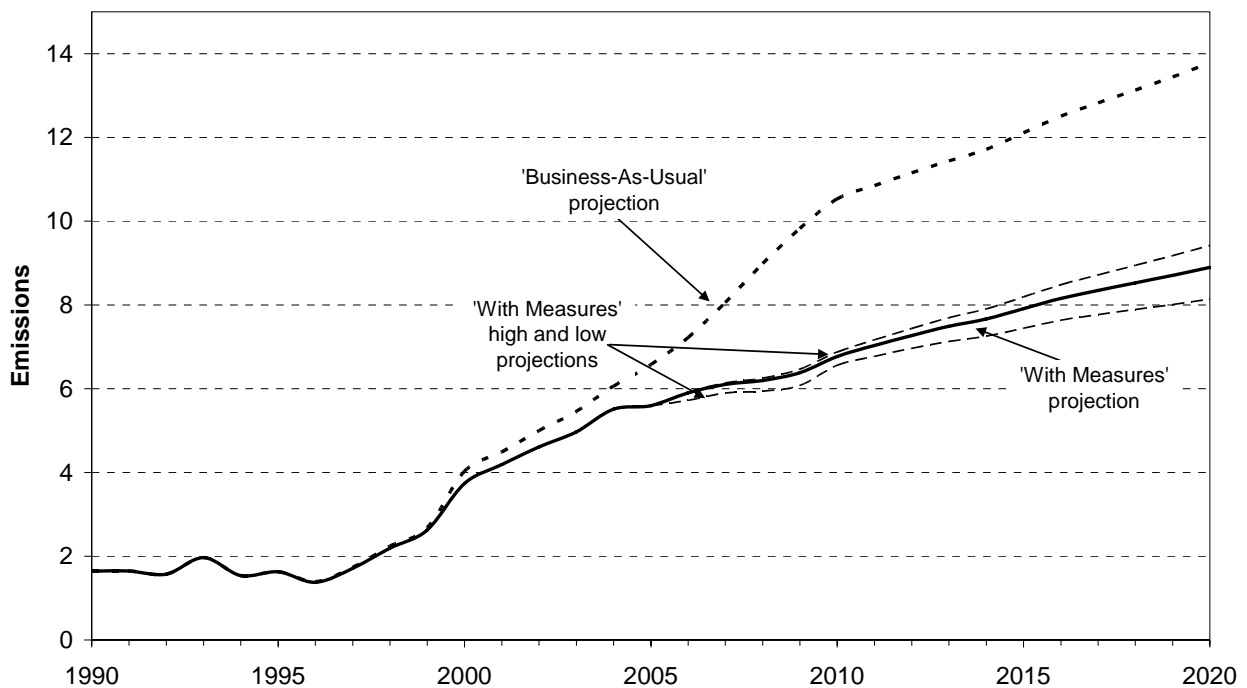
This leads to a 'with measures' projection of 4.0 Mt CO₂-e per annum over the Kyoto period, which is 33 per cent lower than the 1990 base.

6. Hydrofluorocarbons and SF₆

The production and consumption of HFCs and the consumption of SF₆ are covered together in this section. HFCs are chemicals that are replacing Ozone Depleting Substances (ODS) in refrigeration, air conditioning, foam blowing, fire protection, solvents and aerosols. SF₆ is used as an insulating agent in the electricity supply industry.

Total emissions from the sector are projected to grow by 309 per cent between 1990 and the Kyoto period. Some HFCs were produced in Australia in the 1990s but this company ceased production in 1995. Hence the projected emissions only cover the consumption of HFC together with the usage of SF₆ in the electricity supply industry. The projected emissions time series are shown in Figure 6.1 with a breakdown of results in Table 6.1.

Figure 6.1 HFC and SF₆ subsector emissions, 1990 to 2020 (Mt CO₂-e)



Source: 2005 NNGI; Burnbank Consulting (2006); DCC Analysis 2008.

The Kyoto period ‘with measures’ emissions from this subsector are estimated at 6.2 Mt CO₂-e per annum, a reduction of 0.4 Mt CO₂-e compared to the previous projection, reflecting a lower leakage rate used in estimating emissions from mobile air conditioning.

Table 6.1 Summary of HFC and SF₆ Emissions, 1990 to 2020 (Mt CO₂-e)

	1990 emissions	Kyoto period (2008-2012) average emissions	Growth from 1990 to Kyoto period	2020 emissions	Growth from 1990 to 2020
HFC Production & Consumption	1.1	6.2	+452%	8.4	+644%
SF ₆ Consumption	0.5	0.5	0%	0.5	0%
TOTAL WM	1.6	6.7	+309%	8.9	+440%
Measures	0	3.5	na	4.9	na

Source: 2005 NGGI; Burnbank Consulting (2006); DCC Analysis 2008.

6.1 Hydrofluorocarbons (HFC)

The Montreal Protocol industries (air conditioning, refrigeration, foams, fire protection, aerosols and solvents) are increasing their use of synthetic greenhouse gases, including hydrofluorocarbons (HFC) and to a lesser extent perfluorocarbons (PFC). This increase is due to the requirement under the Montreal Protocol to reduce consumption of ozone depleting substances (ODS), such as chlorofluorocarbons, hydrochlorofluorocarbons, and halons.

While HFCs are not ODS and are not restricted by the Montreal Protocol, they are included in the United Nations Framework Convention on Climate Change and form part of Australia’s Kyoto Protocol emissions target. This section deals only with the emissions of HFCs since PFCs are covered in the aluminium production industry within the metal production subsector described in Chapter 5.

Emissions of HFCs in 2005 represented less than one per cent of Australia’s total net national emissions, but are expected to increase significantly as a result of replacement of ODS and continuing economic growth. The uptake of synthetic greenhouse gases is dependent largely on the timing and nature of the transition from ODS. However, emissions of these gases are important from a greenhouse accounting perspective since they have very high global warming potentials.

Due to the substantial uncertainties relating to the size of the HFC market and the rate of leaked emissions both in Australia and overseas, projected emissions from this subsector should be considered as indicative ‘best estimates’ based on current information. Mandatory reporting established under the *Ozone Protection*

and *Synthetic Greenhouse Gas Act 1989* and research being undertaken to develop improved methodologies are expected to lead to more robust inventory and projections estimates.

HFC emissions projection methodology

The methodologies for calculating HFC emissions in this projection are the same as those used in the 2006 projections. This projection has been compiled using the same bottom-up approach for refrigeration and stationary and mobile air conditioning as that used by Burnbank (2004). First, BAU emission projections are estimated. The estimated abatement expected under the *Ozone Protection and Synthetic Greenhouse Gas Act 1989*, and some Greenhouse Gas Abatement Programmes is then calculated to provide a ‘with measures’ projection. The estimates are based on data supplied by Burnbank (2006). Burnbank extrapolates the historic leakage rates of HFC from air conditioning and refrigeration to those projected during the Kyoto period and beyond under the legislation.

The refrigeration and air conditioning industry is not directly emissive. HFCs are typically stored in equipment and products for many years. Emissions of HFCs occur when:

- an equipment is originally charged with gas,
- during the life of the equipment as a result of leakage and servicing, and
- at the time of disposal.

The 2007 BAU emissions projections are only a minor update of the 2006 BAU emissions projections which were prepared by Burnbank on an industry-by-industry basis. For stationary refrigeration and air conditioning, emission trends were projected assuming synthetic greenhouse gases replace ODS and then grow in proportion to GDP or population or industry expectations of growth for particular applications. The projections for foams, aerosols (including metered dose inhalers (MDI)), fire extinguisher use and solvents use are based on data reported in the 2004 NGGI (AGO, 2006). These aerosols and solvents emissions are projected using the AGO’s composite GDP growth rate used in the 2006 Greenhouse Gas Emissions Projections for Stationary Energy. The different gases used in the Montreal Protocol industries and a detailed description of the methodologies used by Burnbank Consulting to develop these projections is contained in Appendix A and Burnbank (2002). A summary description of the analysis for the 2007 projections is given below.

Overall assumptions of the 2007 update of HFC emissions projections

Estimates of emissions from stationary refrigeration and air conditioning are derived from the bottom-up method described in detail in Burnbank (2002). Most of the data sets used in this projection are the same as those used in the previous projection except the average leakage rates from mobile air conditioning. The key assumptions include:

- growth rates for domestic air conditioning are the same as those used in the 2006 projections;
- the rate at which HFC displaces HCFC from domestic air conditioners is the same as the rate used in the 2006 projection;

-
- growth rates for motor vehicles are the same as the rates used in the 2006 projection;
 - the extent of recovery and recycling/destruction in motor vehicle are the same as those used in the 2006 projection; and
 - average leakage rates from mobile air conditioning have been altered to better reflect the observed rates in the 2005 NGGI.

The CO₂-e emissions are based on HFC emissions estimates by species multiplied by their global warming potential.

Measures

In December 2003, the *Ozone Protection and Synthetic Greenhouse Gas Legislation Amendment Bill 2003*, amending the *Ozone Protection Act 1989*, was passed to improve monitoring, management and control of these substances. The provisions established a licensing and reporting regime for imports of bulk HFC and equipment containing HFC. The licensing scheme took effect on 1 April 2004 and specifies that:

- Any manufacture, import and export of HFC, PFC and BCM will be prohibited without a licence.
- Any import of air conditioning or refrigeration equipment containing HFC or HCFC will be prohibited without a licence.
- Applications for these licenses need to be addressed to the Minister for the Environment and Water Resources.

Three Greenhouse Gas Abatement Programme projects funded prior to the announcement of the act also reduce the HFC emissions through recycling and better management. The abatement from these GGAP projects is now covered by the act.

In the Kyoto period, the legislation is expected to lead to abatement of 38 per cent of BAU emissions per year, and within this the GGAP projects are expected to contribute 17 per cent of this reduction.

Synthetic Greenhouse Gas Legislation (2003)

The Act provides a comprehensive regime of controls over the use of synthetic greenhouse gases in Montreal Protocol industries across the entire spectrum of uses in Australia. Prior to the Act, there were no restrictions on how the gases were used.

The Act prohibits the venting of synthetic greenhouse gases except where this is consistent with and integral to the effectiveness of the product, such as with asthma puffers. Where there is a reasonable likelihood of preventable emissions, end-use regulations require individuals handling synthetic gases to be both appropriately trained and licensed by the Australian Government. Similarly, companies and individuals will not be able to buy or sell synthetic greenhouse gases unless they are registered with the Australian Government. Registration will require that any individual who handles the gas be appropriately trained and licensed and that the company has the necessary equipment to safely use the gas.

Additionally, end-use regulations under the Act will cover the entire lifecycle of synthetic greenhouse gas use in Australia, from import or manufacture through to disposal. These provisions will include requirements on how synthetic greenhouse gases are:

- imported or manufactured;
- stored, transported and decanted;
- used to maintain equipment; and
- disposed of at the end of life.

The legislative scheme has not been in place for a sufficient period of time to allow a detailed and robust projection on the impact of the Act on synthetic greenhouse gas emissions in Australia.

The Australian Government continues to collect and improve the data on Australian emissions to enable robust inventory and projections estimates and, where possible, emission projections are based on data published in the NGGI. This facilitates better estimates of ‘with measures’ emissions for future projections.

Burnbank (2002) considered the impact of improved environmental management practices and the type of legislative scheme that has been implemented by the Act on average emission factors for stationary refrigeration and air conditioning and mobile air conditioning. The reduction in emissions is taken as a discounted figure taken from a 1999 United Nations Environment Programme report (UNEP 1999b, p.116). The UNEP experts looked at the potential effectiveness of management strategies for managing ozone depleting substances and concluded that:

“HFC refrigerant [and use in other industry sectors] can be reduced by at least 50 per cent . . . by recycling . . . and better handling procedures”.

The UNEP report also observed that further abatement was possible if additional steps were taken. Even though the UNEP suggests emissions can be reduced by one-half using international data, on a conservative basis for the projections it is assumed that emissions from these sources will fall by one-third by 2010. These assumptions are shown in Table 6.2 for the different industries in the subsector.

The total abatement achieved under the act is projected to be 3.5 Mt CO₂-e per annum over the Kyoto period, rising to 4.9 Mt CO₂-e in 2020. This is a reduction of 0.6 Mt CO₂-e per annum over the Kyoto period compared to the 2006 projection due to the lower leakage rates used in mobile air conditioning and consideration of the Kyoto period average compared to the year 2010 in the 2006 projection.

Greenhouse Gas Abatement Programme

In addition to the abatement measures under the Act, there are three GGAP projects designed to facilitate better technician handling and recovery of HFC refrigerants on a voluntary basis. These are the National Refrigeration and Air-conditioning Council, the Refrigerant Reclaim Australia and the Natural Refrigerants Transition Board projects.

The estimated abatement as a result of these projects is 0.7 Mt CO₂-e in 2010, with 0.4 Mt CO₂-e in the stationary refrigeration and air conditioning subsector and 0.3 Mt CO₂-e in mobile air conditioning. The

abatement from these projects is expected to be a sub-set of the total abatement achieved under the new legislation of 3.5 Mt CO₂-e.

Emission factors used for BAU and ‘with measures’ emissions projections from Montreal Protocol Industries is presented in Table 6.2.

Table 6.2 Emission Factors of Montreal Protocol Industries

Emissions Source	Business-as-usual (BAU)	With measures (WM)
Domestic refrigeration	AEF as for NGGI (0.3%); no recovery which differs from NGGI.	Same assumptions as for BAU – quantities of substances are so small per unit that recovery is unlikely to be viable and “accidental” venting is more probable than not.
Domestic air conditioning	AEF = 20%.	AEF = 15%.
Commercial refrigeration	AEF declines from 25% in 1990 to 15% by 2014.	AEF declines from 25% in 1990 to 7.5% in 2011.
Commercial air conditioning	AEF chillers = 20% AEF non-chillers = 15%	AEF chillers = 15% AEF non-chillers = 10%
Dairies, hotels, pubs and clubs	Same assumptions as for Burnbank (2002).	Same assumptions as for Burnbank (2002).
Motor vehicle air conditioning ^a	AEF ranges from 8.9% to 29.2% dependent on vintage of the vehicle and proportion of vehicle population where there is recovery. To better reflect the observed leakage rates in the 2005 NGGI, the rates used in this projection are 20 percent lower compared to the rates used in the previous projection.	For measures AEF ranges from 8.9% to 29.2% dependent on vintage of the vehicle and proportion of vehicle population where there is recovery, and it is assumed that there is increased recovery for destruction or recycling relative to BAU. The rates used for the ‘with measures’ projection decline at the same rate as those used in the previous projection.
Directly emissive uses	Emissions = use	Measures reduce emissions by 1/3 based on conservative application of UNEP assertion that these emissions can be reduced by 50%.

^a Different factors are assumed for different vintages based on improved sealing of units and maintenance regimes.

Source: Burnbank (2006); DCC Analysis 2008.

Montreal Protocol Industries Analysis

The projected BAU emissions from these industries are 9.7 Mt CO₂-e per annum over the Kyoto period, rising to 13.3 Mt CO₂-e in 2020. The overall Projected HFC emissions are shown in Table 6.3. The 2007 projection is down 0.4 Mt CO₂-e per annum over the Kyoto period compared to the previous projection. This decrease is mainly attributable to a fall in projected emissions from mobile air conditioning resulting from the use of updated leakage rates.

Table 6.3 Summary from HFC Consumption Emissions, 1990 to 2020 (Mt CO₂-e)

	1990	Kyoto period (2008-2012) average	Growth from 1990 to Kyoto period	2020	Growth from 1990 to 2020
WM	1.1	6.2	+452%	8.4	+644%
Measures	0	3.5	na	4.9	na
BAU	1.1	9.7	+766%	13.3	+1078%

Source: 2005 NGGI; Burnbank Consulting (2006); DCC Analysis 2008.

Table 6.4 shows the sectoral break down of the projected BAU and 'with measures' emissions from the use of HFCs.

Table 6.4 Montreal Protocol Industries Emissions in Australia, 1990 to the Kyoto period (2008-1012) (Mt CO₂-e)

Emissions Source	1990	Kyoto period (2008-2012) BAU	Kyoto period (2008-2012) abatement	Kyoto period (2008-2012) with measures
Stationary refrigeration and air conditioning	0.0	5.7	1.8	3.9
Mobile air conditioning	0.0	3.1	1.4	1.7
Fugitive HFC-23	1.1	NA	NA	NA
Foam blowing and fire protection, aerosols use and solvents	0.0	1.0	0.3	0.7
<i>Foam blowing & Fire protection</i>	<i>0.0</i>	<i>0.1</i>	<i>0</i>	<i>0.1</i>
<i>Aerosol use</i>	<i>0.0</i>	<i>0.7</i>	<i>0.2</i>	<i>0.5</i>
<i>Solvents</i>	<i>0.0</i>	<i>0.2</i>	<i>0.1</i>	<i>0.1</i>
TOTAL	1.1	9.7	3.5	6.2

Note: Columns may not add due to rounding errors

Source: 2005 NGGI; Burnbank Consulting (2006); DCC Analysis 2008.

In 1990, emissions of synthetic gases from Montreal Protocol industries were around 1.1 Mt CO₂-e. These emissions were fugitive HFC-23 arising from the production of HCFC-22 which ceased in 1995.

Stationary refrigeration and air conditioning (SRAC)

The SRAC industry is the largest source of emission of HFC. It represents 59 per cent of the Kyoto period BAU emissions. Emissions from this industry are disaggregated into five categories: domestic refrigeration, domestic air conditioning, commercial refrigeration, commercial air conditioning and dairies, hotels, pubs and clubs. The assumptions made for the BAU projections of each category are contained in Appendix A.

Based on the assumptions, projected 'with measures' emissions from SRAC industry are 3.9 Mt CO₂-e per annum over the Kyoto period. Projected Kyoto period emissions from the SRAC are the same as the previous projection. 'With measures' emissions from this industry are 6.1 Mt CO₂-e in 2020.

Mobile air conditioning (MAC)

Mobile air conditioning is one of the most significant actual and potential sources of emissions of synthetic greenhouse gases. The majority of emissions occur during the life of the air conditioner as a result of leakage and the requirement for frequent servicing. Emissions from mobile air conditioning covers over 32 per cent of the total projected Kyoto period BAU emissions. BAU emissions from mobile air conditioning are projected to be 3.1 Mt CO₂-e per annum over the Kyoto period, and 3.8 Mt CO₂-e in 2020.

Projections are derived from data and assumptions relating to each vehicle class based on the number of vehicles, proportion of vehicles with air conditioning, conversion rates from ODS, average charges based on vehicle type, average emission factors based on the vintage of the vehicle and assumptions as to whether there is recovery and recycling or destruction on servicing or scrapping. Data used in Burnbank (2002) have been updated for all vehicle types using ABS data, and growth rates have been altered to account for the market reaching saturation based on examination of BTRE projected vehicle population data and reconsideration of the rates used for 2004 projections. Domestic production and import data have also been updated using Department of Industry, Tourism and Resources data. The leakage rates are further updated to reflect the rates observed in the 2005 NGGI.

Projected 'with measures' emissions from MAC are estimated to be 1.7 Mt CO₂-e per annum over the Kyoto period. This is 0.4 Mt CO₂-e lower than the previous projection. 'With measures' emissions from MAC are projected to be 1.5 Mt CO₂-e in 2020.

Fugitive emissions from the production of HCFC-22

Due to its relatively low ozone depleting potential HCFC-22 is widely used by the refrigeration and air conditioning industry as a transitional substance in the phase-out of ODS and the move towards HFC and other non-ODS substances. Until 1995, HCFC-22 was produced in Australia by a single company. HFC-23 was emitted as a by-product from the process.

Emissions are estimated using production data and the IPCC Guidelines default methodology. Estimates from 1990 are published in the NNGI. Fugitive emissions peaked in 1993 at 1.4 Mt CO₂-e and ceased after the closure of the plant in 1995.

Foam blowing and fire protection, other aerosols and solvents

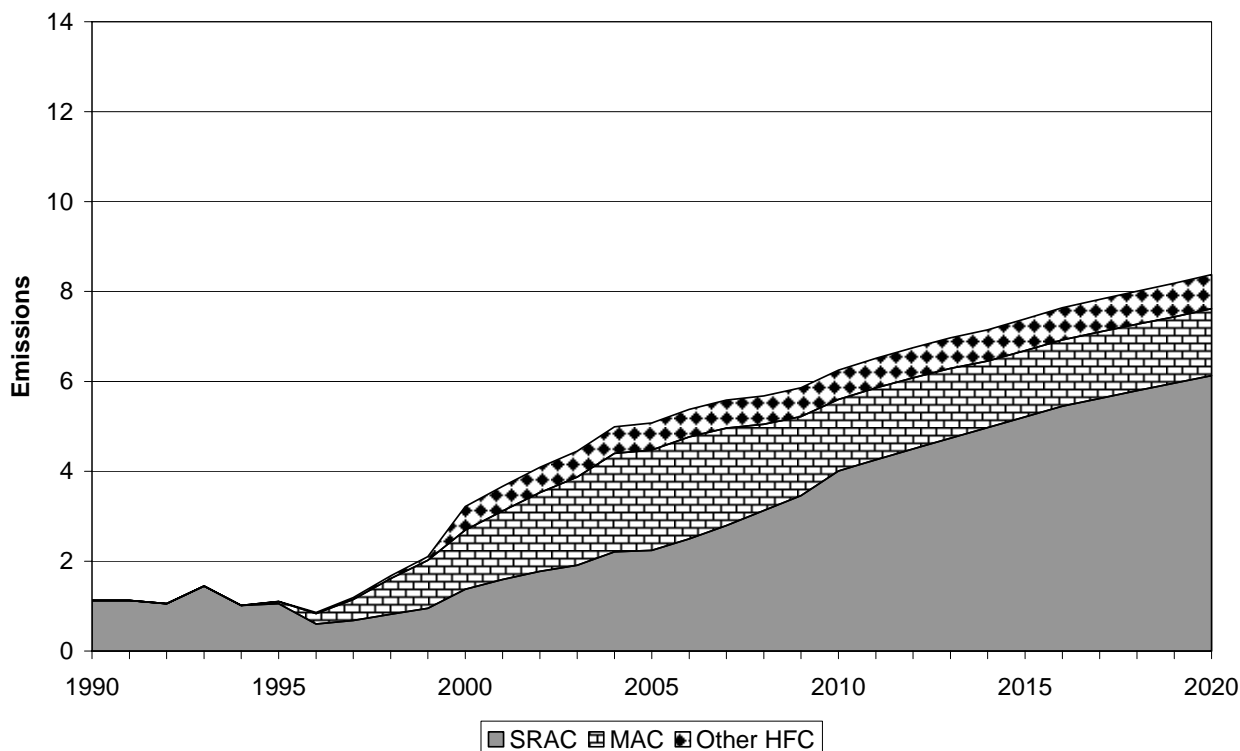
Projected 'with measures' emissions from foam blowing and fire protection, aerosols and solvents use are estimated at 0.7 Mt CO₂-per annum over the Kyoto period, and 0.8 Mt CO₂-e in 2020. Projected emissions from these activities are the same as the previous projection.

Projected 2007 emissions are based on data published in the 2005 NNGI. Currently HCFC are used as foam blowing agents. With the phase-out of ODS, HFC-245fa and HFC-365mfc are expected to replace HCFC. Estimates of HFC are based on the amount of HCFC-141b imported into Australia for use in foam blowing.

The use of aerosols in metered dose inhalants (MDI) are not recorded in the inventory but are included in the projections as it is expected that HFC and alternative products (such as breath activated inhalers) will ultimately displace all CFC products, currently in use. It is noted that timing is affected by the need to ensure that not only is the HFC safe, but also that products containing the HFC meets the therapeutic goods standards for safety. The MDI estimate in the projections assumes that all CFC used in MDI will be replaced by HFCs by 2010. .

Figure 6.2 shows aggregate 'with measures' projection for HFC emissions in Australia. There is a large growth between 1995 and 2005 which reflects the transition from CFCs to HFCs in Montreal Protocol industries. The projected Kyoto period emissions are 6.2 Mt CO₂-e per annum, an increase of 452 per cent of the 1990 base. The emissions in 2020 are projected to grow up to 8.4 Mt CO₂-e.

Figure 6.2 'With Measures' Projection for the Montreal Protocol Industries in Australia, 1990 to 2020 (Mt CO₂-e)



Source: 2005 NGGI; Burnbank Consulting (2006); DCC Analysis 2008.

6.2 Sulfur Hexafluoride (SF₆)

This section presents information on sulphur hexafluoride (SF₆) emissions from the electricity supply industry (ESI). SF₆ is the electric power industry's preferred gas for a range of electrical insulation applications in switchgear and circuit breakers used in the transmission and distribution of electrical energy. The four major types of electrical equipment where SF₆ is used are gas-insulated circuit breakers and current interruption equipment, gas insulated transmission lines, gas-insulated transformers, and gas-insulated substations.

SF₆ use in the ESI is a source of emissions that has posed accounting problems for almost a decade. There are several reasons for the inadequacy of data on emissions of SF₆ from the ESI. There is little data on the amount of SF₆ emitted from high voltage installations; data on the quantity of SF₆ used for recharging equipment is not available; and import data for SF₆ is unavailable. However, the Department of Climate Change is involved in working with the electricity supply industry to improve data collection to assist in inventory compilation and projection estimates.

The largest quantities of SF₆ are contained in high voltage transmission substations which, in the absence of new technology, need to be taken off-line to enable the amount of SF₆ and the extent of losses to be measured. The only readily available information is the quantity used where SF₆ is replaced following major

equipment failures. The problem with ascertaining losses is expected to be solved in the future with the implementation of new technology. A new technology, referred to as image plate x-ray inspection, enables the quantity of SF₆ contained in equipment to be measured without taking the equipment off-line. Preliminary use of this technology implies a total contained amount of 40 tonnes per substation. Discussions with some industry participants suggest that for high voltage transmission substations, around 40 tonnes of SF₆ per substation seems reasonable.

Faced with these uncertainties, the approach adopted by the NGGI in 2005 is used to estimate projected emissions as follows:

- There are 109 high voltage substations (220 kV or above) according to the Electricity Supply Association of Australia map of the Australian electricity network.
- An average charge of 40 tonnes of SF₆ is assumed per substation (based on the observation above) leading to a total contained amount of 4,360 tonnes.
- An annual leakage rate of 0.5% is assumed. The implication of an 0.5% leakage rate, and the fact that the equipment is effective with only 90% of the original charge (Burnbank, 2000; p. 41), is that leakage can continue for 20 years without any deterioration in required performance.
- This implies annual emissions of 21.8 tonnes of SF₆, which equates 0.52 Mt CO₂-e.

Several other methods for estimating emissions were considered. Using publicly available data on emissions for three utilities and estimates of GWh's supplied, average emissions per GWh were derived and applied to total national GWh's supplied. This method implied emissions of around 2.8 tonnes of SF₆.

For the 2004 projection, emissions were estimated by using SF₆ emissions from the US and applying a per capita figure to Australia. Implied emissions from this method are about 74 tonnes of SF₆.

These different approaches are summarised in Table 6.5.

Table 6.5 Sulfur hexafluoride emissions in Kyoto period (2008-2012)

Method	Estimated emissions (tonnes SF₆)	Estimated emissions (Mt CO₂-e)
SF ₆ contained in high voltage substations and emission factor of 0.5%	21.8	0.52
Average SF ₆ per GWh from three utilities applied to total GWh supplied	2.8	0.07
US per capita SF ₆ from ESI applied to Australia	74	1.77

Source: Burnbank Consulting (2006).

Given the current state of knowledge, the base emissions estimate of 21.8 tonnes has been included in the inventory for the period of 1990 to 2005 pending further developments in the ESI. This emissions estimate has been included in the 2007 projections and is held constant for the entire projections period.

Abbreviations and explanations

Abbreviations

ABARE	Australian Bureau of Agricultural and Resource Economics
ABS	Australian Bureau of Statistics
AGO	The Australian Greenhouse Office within the Department of the Environment and Water Resources
BAU	Business as Usual
BF/BOS	Blast Furnace/ Basic Oxygen System
CH ₄	Methane, a greenhouse gas
CIF	Cement Industry Federation
CKD	Cement kiln dust
CO ₂	Carbon dioxide, a greenhouse gas
CO ₂ -e	Carbon dioxide equivalent, used to compare emissions from different greenhouse gases
DCC	Department of Climate Change
ESI	Electricity Supply Industry
HBI	Hot Briquetted Iron, a process for producing iron
HIsmelt	A new process for producing iron
GWh	Gigawatt hour, a unit of electricity
GWP	Global Warming Potential
HFC	Hydrofluorocarbons
IPCC	Intergovernmental Panel on Climate Change
MAC	Mobile Air Conditioning
MDI	Metered Dose Inhalant
MPIs	Montreal Protocol Industries
Mt	A million tonnes
N ₂ O	Nitrous oxide, a greenhouse gas
NGGI	National Greenhouse Gas Inventory
ODS	Ozone Depleting Substance
PFC	Perfluorocarbons
SCM	Supplementary Cementitious Materials
SF ₆	A greenhouse gas
SRAC	Stationary Refrigeration and Air Conditioning
TCM	Total Cementitious Materials
TOC	Total organic content. Used to correct for emissions from cement production
WM	With Measures

Explanations

<i>Abatement</i>	Refers to emissions reductions made beyond that which would have been achieved in the <i>business as usual</i> scenario. Also referred to as <i>beyond BAU abatement</i> .
<i>Best estimate</i>	Same as 'with measures'.
<i>Business as usual</i>	Refers to a projection that incorporates changes in activity levels and greenhouse gas emission factors, but with the exclusion of any effects that are directly attributable to greenhouse policy measures. Also referred to as <i>without measures</i> or <i>Baseline</i> .
<i>Low emissions</i>	A 'low emissions' scenario adopts plausible low emission assumptions.
<i>High emissions</i>	A 'high emissions' scenario adopts plausible high emission assumptions.
<i>Kyoto period average</i>	Refers to the average of emissions over the 5 year Kyoto protocol reporting period, 2008-2012.
<i>Measures</i>	Refers to past, current or committed Australian, State/Territory or local government policy actions that have an impact on greenhouse gas emissions, causing them to deviate from the BAU path after the base year of 1990. Also referred to as <i>measure impacts</i> .
<i>With measures</i>	Refers to the 'reality' or 'best-estimate' of future emission levels. This is also equivalent to the net emissions from reducing the BAU by the greenhouse gas abatement that is directly attributed to the greenhouse policy measures. With measures = BAU – 'measures' abatement.

Appendix A: Projections Methodology for Montreal Protocol Industries

This Appendix summarises the methodologies for the projections developed by Burnbank (2002) which form the basis of the 2007 projections. The gasses included in the Montreal Protocol industries are described in Table A.1

Table A.1 Montreal Protocol Industries in Australia

Industry	Application	Main gases used and global warming potential
Stationary air conditioning and refrigeration	HFC are used as refrigerants in air conditioning and refrigeration systems. These uses are not directly emissive. The HFC are emitted during commissioning, operation, maintenance and decommissioning. SRAC covers domestic and commercial air conditioning, chillers and refrigeration.	HFC-32 – 650 HFC-125 – 2800 HFC-134a – 1300 HFC-143a – 3800 R-407C: blend of HFC-32, HFC-125 and HFC-134a R-410A: blend of HFC-32 and HFC-125 R-507: blend of HFC-125 and HFC-143a
Mobile air conditioning	MAC covers vehicle air conditioning and refrigerated transport.	HFC-134a R-404A: blend of HFC-125, HFC-134a and HFC-143a
Foam blowing	HFC are used as foam blowing agents (mainly in closed cell thermal insulation foams). This use is in part directly emissive with much of the agent being released during the foam blowing. A significant proportion is also released over a number of years as it gradually leaks from the foam cells.	HFC-245fa – 790 HFC-365mfc – 1050
Fire protection	HFC used in fire extinguishants are directly emissive if the fire protection system is activated. HFC are also emitted during commissioning, maintenance and decommissioning.	HFC-23 – 11700 HFC-125 – 2800 HFC-227ea – 2900 HFC-236fa – 6300
Aerosols	HFC are used as the propellant for aerosols (mainly metered dose inhalers such as asthma puffers). This use is directly emissive.	HFC-134a – 1300 HFC-227ea – 2900
Solvents	HFC are used as solvents for precision cleaning. This use is directly emissive, although technologies are being developed to capture the gas vapours.	HFC-43-10mee – 1300

Source: IPCC (1999), UNEP (1999), Burnbank Consulting (2006).

Stationary refrigeration and air conditioning

Stationary refrigeration and air conditioning comprises:

- Domestic refrigeration;
- Domestic air conditioning;
- Commercial refrigeration; and

- Commercial and industrial air conditioning.

HFC emissions from stationary refrigeration and air conditioning are projected using activity data and emission factors. Activity data include:

- production of equipment, which was projected using growth rates estimated from time series of Australian Bureau of Statistics (ABS) production data;
- imports of equipment which was estimated using growth rates estimated from ABS time series data on imports;
- retirement rates of equipment;
- the stock of equipment (change in stock = production + imports – exports – retirements) or alternatively the number of establishments using equipment containing HFCs;
- the equipment charge (the average quantity of gas used in equipment or in establishments), this value and any changes over time were based on industry advice and indications of market changes, such as the increase in refrigerated space in supermarkets as a result of in-store delicatessens and growth in demand for chilled (fresh) and frozen foods; and
- the bank of gas.

Emission factors include:

- the proportion of charge emitted on initial charging of equipment;
- the proportion of charge that is emitted during servicing or leaks during the life of the product; and
- the proportion of charge (residual charge) that is emitted on disposal of the equipment.

The emission factors vary greatly depending on the type of equipment, with some equipment releasing most of the emissions due to leakage and other equipment releasing the majority of emissions on disposal.

The emission factors and any changes over time were determined based on industry advice. The method for deriving emissions can be summarised by the following equation:

$$E_t = e_c C Y_t + e_l C S_t + e_d C R_t$$

where:

E_t = Emissions at time t

e_c = Proportion of charge emitted on charging

C = The charge of gas used in equipment

Y_t = Production at time t

e_l = Charge emitted from leakage (including servicing)

S_t = The stock of equipment or number of establishments at time t

e_d = Charge emitted on disposal

R_t = Retirements at time t

Domestic refrigeration

Emissions from domestic refrigeration were derived based on the assumptions in Table A.2.

Table A.2 Domestic refrigeration - variables and assumptions used in the model

Variable	Assumption
Average charge (C)	HFC-134a: 157.1 grams
Loss on charging (e_c)	0.5 per cent of C
Leakage (e_l)	0.22 per cent per year of C
Disposal emissions	Residual of C after accounting for leakage (92.8 per cent)
Average life	15 years
Age of first units retired in each vintage	5 years (retired in year 6)
Age of last units to be retired in each vintage	25 years

Domestic air conditioning

Emission estimates were derived assuming:

- Average system charge for window/wall units of 0.91kg
- Average system charge for split systems of 1.43kg
- Average leakage rate for window/wall units of 2% per annum
- Average proportion of charge vented on retirement of window/wall units of 81%
- Average leakage rate for split systems of 20% per year (encompasses any residual charge vented on servicing and retirement)
- New units from 2004 comprise 20 per cent R-410A and 80 per cent HCFC-22. This increases to 100 per cent R-410A in 2008. It is possible that some residential systems will use R-407C. This has a GWP of 1526 compared with 1725 for R-410A. There is a possibility that systems with secondary loops could be developed that use propane (HC-290). However, use of R-410A is considered the most likely prospect as noted by UNEP (1998) and units are already commercially available. If R-407C were to be adopted the projected CO₂-e emissions would be lower given the lower GWP of this substance.

Activity data assumptions made are as follows:

- Local production of window/wall units is as stated in GWA (1993; p.200) from 1989 to 1992, and are constant at 30,000 units from 1993 to 1998 with Emailair closing the plant in 1999 when local production falls to zero.
- Domestic sales are equal to imports plus local production with exports assumed to be zero.

- From 2002 the window/wall market falls to zero.
- All market growth in the residential sector is met by split systems (non-ducted and ducted).
- ABS data on reverse cycle imports is taken to include all split systems (both reverse cycle cooling only and split ducted and non-ducted systems).
- The import data for 2002 and 2003, at over 1 million units for each year, are not considered representative of long-term growth in the market. A growth rate for total demand was estimated and yielded a growth rate of over 12 per cent with a standard error of 1.3 per cent. Although the standard error is relatively small, applying a compound growth rate of more than 12 per cent leads to implausibly large estimates of sales and total stocks. It was decided to apply a growth rate of one-half the estimate (6.3 per cent) to a five year moving average of demand (equal to imports) for reverse cycle units. The five year moving average was chosen to smooth the impact of climate-induced volatility in demand, and dampen the influence of the number of units in 2002 and 2003. These assumptions result in total demand in 2003 not being achieved again until 2012.
- Refrigerant per kilowatt of cooling capacity is 0.32kg to 0.34kg for split systems and 0.24kg to 0.26kg for window/wall units (TEAP, 1998). The sales weighted capacity of systems from GWA (1993; p. 201) is 4.2kW for split systems and 3.5kW for window/wall units. This implies averages of 1.34kg to 1.43kg for split systems, and 0.84 to 0.91kg for window/wall units. Window/wall units do not require the same quantity of refrigerant because they are self-contained sealed units without piping compared with split systems.
- The stock for 1990 is assumed to comprise 10% split systems and 90% window/wall units. This composition changes as sales of split systems increase and most retirements are assumed to be window/wall units.
- Average leakage rates for split systems take into account system failures where a unit loses all of its charge, and venting of gas when units are serviced. That is, although the majority of units have low leakage rates, when a unit fails losing all of the charge this increases the average across all units. The average leakage rate assumed is 20%. This implies that the each unit loses the equivalent of two complete charges over the average life.
- Average leakage rates for window/wall units are assumed to be 2% per year. Average loss on disposal is assumed to be around 80% taking into account the age profile of the units scrapped.
- Average system life is assumed to be 8 years with all units surviving for 1/3 of the average life and units scrapped according to a linear retirement schedule each year after 1/3 of the average life. The last units are scrapped after 5/3 of the average life.
- The simplifying assumption is that the retirements each year are equal to 11.2% of the stock for that year. This is derived from an initial simplifying assumption that historical sales increased at 3% per year and retirements are according to the schedule described above in which case once all vintages are represented in the retirements, the ratio of retirements to stocks converges to 11.2%.

Commercial air conditioning

Assumptions, as outlined in Burnbank (2002) for commercial air conditioning are shown in Table A.3.

Table A.3 Data sources and assumptions

Data item	Data source
Number of non-chillers over 18kW	Price Waterhouse (1997)
Number of chillers over 18kW	Price Waterhouse (1997)
Growth rate of non-chillers over 18kW	Assumed to increase at the same rate as real GDP
Growth rate of chillers over 18kW	Advice
Equipment charges (average)	Price Waterhouse (1997)
Substances used	Assumption and advice
Leakage rates (average annual lifetime emission factors)	Assumption and advice – 15% for chillers except HCFC-123 chillers (10%); 15% for non-chillers
Substances used:	
Non-chillers	HCFC-22 switching to HFC-134a, R-407C and R-410A
Chillers	CFC-11 and CFC-12 switching to HCFC-123, HCFC-22 then HFC-134a and R-407C and R-410A

Further assumptions for chillers are:

- In 2000, 40% are CFC-11, 25% are HCFC-22, 30% are HCFC-123 and 5% are HFC-134a. All CFC-12 equipment has been replaced.
- All CFC-11 equipment is scrapped by the end of 2005, HCFC-22 and HCFC-123 equipment is displaced from 2010.
- From 2010, 70% of chillers use HFC-134a and 30% use HFC blends, either R-407C and R-410A. The lower penetration of the blends recognises that product redesign and retooling would be required.

Additional assumptions with regard to non-chillers are:

- In 2000, all non-chillers use HCFC-22.
- HFC-134a, R-407C and R-410A penetrate the market from 2002.
- HCFC-22 is displaced from 2009, when 30% of systems are HFC-134a and 70% are HFC blends, R-407C and R-410A.

Commercial refrigeration

Modelling of emissions uses the data on establishments estimated from data compiled by Price Waterhouse in 1997 along with the following:

- Average quantity of refrigerant per establishment; and
- Average annual leakage per establishment adjusted to reflect the charge emitted on disposal.

The assumptions on the average quantity of refrigerant per establishment are shown in Table A.4.

Table A.4 Average quantity of gas used per establishment

Type of establishment	Average charge per establishment (kg)		
	1990	1996	2000
Supermarkets - Large	713	950	1150
Supermarkets - Medium	192	450	550
Supermarkets - Smaller Independents	95	100	100
Convenience Stores	30	23	23
Other Remaining, Retail Food (Corner Stores, etc.)	15	14	14

Source: Price Waterhouse (1997) except for 2000 which is assumed based on changes such as in-store delicatessens and greater space for chilled and frozen foods.

Mobile air conditioning

The assumptions used to estimate projected emissions from mobile air conditioning are summarised in Table A.5.

Table A.5 Characteristics of the mobile air conditioning industry

Variable	Assumption
Domestic production	Passenger vehicle production: Based on updated data from Department of Industry, Tourism and Resources. Domestic production declines by 0.53 per cent per year
Imports	Imports: Based on updated data from Department of Industry, Tourism and Resources. Annual increase of 4.6% to 2010 and 2.3% from 2011. Percentage of passenger vehicles sales with A/C = 100% from 1998.
Retirement	Not applicable
Average service life	12 years
Population of passenger vehicles (000)	2005 = 10896 2010 = 11623 2020 = 13226
Average charge	0.75 kg –7.5kg depending on the vehicle
Bank of HFCs (tonnes)	1990=0 2000=4007 2010=8992 2020=10644
Charging emissions	5% of charge
Leakage/service emissions(% of charge per year)	13-29% depending on air conditioner seals and recovery/recycling practices adopted by the service agent. To better reflect the observed leakage rates in the 2005 NGGI, the rates used in this projection are 20 percent lower compared to the rates used in the 2006 projections,
Disposal emissions	Nil, included in leakage and service emissions

Fugitive HFC-23

Fugitive HFC-23 is estimated using the IPCC default methodology. Consistent with the Revised IPCC Guidelines (IPCC, 1997, Vol. 3; p. 2.42) recommendations, 4 per cent is used to derive HFC-23 emissions estimates. Closure of the Australian plant means that this source of emissions has been eliminated. Detailed information that could be used to further refine the estimates is not available, but given that the plant was old

it is considered that 4 per cent is appropriate being at the upper limit of the mass ratio analysis from which the IPCC default factor is derived. Emissions were calculated as follows:

$$E_{\text{HFC-23}} = A_{\text{HCFC-22}} \times 0.04$$

where:

- $E_{\text{HFC-23}}$ is emissions of HFC-23 (tonnes)
- $A_{\text{HCFC-22}}$ is the amount of HCFC-22 produced (tonnes)
- 0.04 is the constant mass ratio (or proportion)

Other aerosols and solvents

Projections are based on the assumption that use of HFCs for other aerosols and solvents will grow at the same rate as the AGO's composite GDP growth rate. Emissions are projected using data published in the 2005 NGGI.

Fire protection and foam blowing

Projections are based on the assumption that use of HFCs for fire protection and foam blowing will grow at the same rate as the AGO's composite GDP growth rate. Emissions are projected using data published in the 2005 NGGI.

References

- Australian Bureau of Agricultural and Resource Economics (2005), *Major Developments Projects, October 2005*, Australian Government, Canberra.
- Australian Bureau of Statistics (2005), *ABS 3222.0 Australian Population projection – 2001 to 2100*, Australian Bureau of Statistics – accessed from www.abs.gov.au.
- Australian Greenhouse Office (2004), *Australian Methodology for the Estimation of Greenhouse Gas Emissions and Sinks 2002: Solvents and Other Product Use*, National Greenhouse Gas Inventory Committee, Australian Government.
- Australian Greenhouse Office (2004), *Industrial Processes Sector Greenhouse Gas Emissions Projections*, Australian Government, Canberra.
- Australian Greenhouse Office (2006), *National Greenhouse Gas Inventory (NGGI) 2004*, Australian Government, Canberra.
- Australian Greenhouse Office (2006), *Stationary Energy Sector Greenhouse Gas Projections 2006*, Australian Government, Canberra.
- Australian Greenhouse Office (2006), *Industrial Processes Sector Greenhouse Gas Projections 2006*, Australian Government, Canberra.
- Australian Greenhouse Office (2007), *National Greenhouse Gas Inventory (NGGI) 2005*, Australian Government, Canberra.
- Bureau of Transport and Regional Services (2002), *Report 107: Greenhouse Gas Emissions from Transport: Australian Trends to 2020*, Australian Government, Canberra.
- Burnbank (2002), *Inventories and Projections of Ozone Depleting and Synthetic Greenhouse Gases used in Montreal Protocol Industries*, Commonwealth of Australia, Canberra.
- Burnbank (2004), *2002 Greenhouse Gas Inventory for Industrial Processes and Solvents and Other Product Use*, report prepared for the Australian Greenhouse Office.
- Burnbank (2004), *Emissions Projections for Industrial Processes – 1990 to 2020*, report prepared for the Australian Greenhouse Office.
- Burnbank (2006), *Emissions Projections for Industrial Processes – 1990 to 2020*, report prepared for the Australian Greenhouse Office.
- Department of Industry, Tourism and Resources (2003), *Key Automotive Statistics 2002*, Australian Government, Canberra.

Energy Strategies (2005), *Projection of greenhouse gas emissions from venting at major new gas projects, 2005-20*, report prepared for the Australian Greenhouse Office.

IPCC (1999), *Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories*, Japan.

UNEP (1999), *1998 Report of the Refrigeration, Air Conditioning and Heat Pumps Technical Options Committee*, UNEP Ozone Secretariat, Nairobi, Kenya.