A REVIEW OF THE STATUS OF GLOBAL NON-CO_2 GREENHOUSE GAS EMISSIONS AND THEIR MITIGATION POTENTIAL

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1. Introduction

As part of the IEA Greenhouse R&D Programmes (IEAGHG) strategic review of its activities prior to the commencement of Phase 6 (2012-2017) of its work programme, it was agreed by the members at the 41st Executive Committee to undertake a study looking at the Non-CO_2 greenhouses (GHG's). The IEAGHG actively researched mitigation options for Non-CO_2 GHG's in earlier phases of its work programme, whereas much of IEAGHG's focus in recent years has been on CO_2 mitigation and Carbon Capture and Storage in particular. The mitigation of Non-carbon dioxide (Non-CO_2) greenhouse gas emissions can be a relatively inexpensive supplement to CO_2-only mitigation strategies. The Non-CO_2 gases include methane (CH_4), nitrous oxide (N_2O), and a number of high global warming potential (high-GWP) or fluorinated gases. These gases trap more heat within the atmosphere than CO_2 per unit weight. Approximately 30% of the anthropogenic greenhouse effect since preindustrial times can be attributed to these Non-CO_2 greenhouse gases.

The aim of this study therefore is to update the summary of the work completed by IEAGHG previously (See Section 3). The specific objectives of the study are:

- To review the current sources of Non-CO_2 GHG's and update their emissions data.
- To look at the trends in Non-CO_2 GHG emissions over the years from our study to present date and assess which mitigation options have been successfully deployed.
- To attempt to assess why some measures have not been introduced.

The study will also aim to look at the organisations active in these areas, such as the Methane to Markets Programme in the USA, a body similar to the CSLF. This would enable us to consider if there are any opportunities for further work by IEAGHG on such topics that could assist deployment or address barriers to deployment. The review would therefore also assist in IEAGHG's future strategic planning activities.

The starting point for this study is a review of the historical context of IEAGHG's previous activities in the area of Non-CO_2 GHG's to put in context why it was done, what it hoped to achieve and what resulted in terms of international co-operative actions and further studies.

2. Historical Background

The IEA Greenhouse Gas R&D Programme had an active research programme on the Non-CO_2 GHG's in earlier programme phases. In Phase 2, a series of studies were undertaken to assess the abatement options for methane (CH_4), whilst in Phase 3, the abatement options for nitrous oxide (N_2O) and the so called "engineered chemicals"[1] were assessed. See Table below for list of reports completed.

[1] The term "engineered chemicals", used for the study, referred to a diverse group of volatile halogenated compounds. These compounds include: Hydrofluorocarbons (HFCs), Hydrochlorofluorocarbons (HCFCs), Perfluorocarbons (e.g. CF_4 and C_2F_6), Sulphur Hexaflouride (SF_6) and methyl bromide.

Report Title	Report Number	Date published
Reduction of methane emissions from coalmining	Ph2/5	June 1996
Reduction of methane emissions from oil and gas industry	Ph2/7	January 1997
Reduction of methane emissions from land disposal of solid waste	Ph2/6	October 1996
Reduction of methane emissions from other anthropogenic sources	Ph2/9	July 1997
Reduction of methane emissions from thermal destruction of solid wastes to mitigate methane emissions	Ph2/18	November 1998
Abatement of other greenhouse gases – Nitrous Oxide	Ph3/29	September 2000
Abatement of emissions of other greenhouse gases – Engineered Chemicals	Ph3/35	February 2001

In both the phase 3 studies, marginal abatement cost-curves (MACC's) were developed for the abatement options, although these had not been attempted for some of the Phase 2 methane studies because there was insufficient information available at that time. The MACC approach adopted in these studies was a way of comparing the mitigation options. The MACC's were developed to also allow direct comparison with similar curves for CO_2 abatement options. This was done by developing abatement curves on a CO_2 equivalent (CO_2eq.) basis, which takes account of the different global warming potentials (GWP's) of these gases.

A third and final study by IEAGHG was then undertaken to update the abatement potential and cost data presented in the earlier studies on Non-CO_2 GHG's and to develop cost curves for all the Non-CO_2 GHG's on a common basis. (Note the study was entitled Building the Cost Curves for the Non-CO_2 Greenhouse Gases – Industrial sector, Ph4/25, October 2003). The scope of the study was limited to the industrial sectors only because, it was considered by IEAGHG[2], that at that time there was insufficient data available, on the costs associated with the abatement of the "other anthropogenic sources" that arise from agricultural production, to allow an abatement cost curve to be developed.

At the same time that IEAGHG was developing its Non-CO_2 GHG mitigation and cost data, the Unites States Environmental Protection Agency (USEPA) was also undertaking a similar activity. A report entitled Non-CO_2 Greenhouse Gas Emissions from Developed Countries: 1990-2010 was issued in December 2001. The report was the first attempt by the USEPA to assess the global emissions of Non-CO_2 GHG's, all their previous work had focused on the USA only. The report presented emissions and baseline projections of the Non-CO_2 GHG's from major anthropogenic sources for all developed countries. This report provides a consistent and comprehensive estimate of Non-CO_2 GHG's that was used to understand national contributions to climate change, mitigation opportunities and costs, and progress under the United Nations Framework Convention on Climate Change (UNFCCC). The gases included in this report are the direct greenhouse gases reported by parties to the UNFCCC: methane, nitrous oxide, and the high GWP gases (Note: the term High GWP gases refers to the same set of gases that IEAGHG referred to in its study programme as the "Engineered Chemicals") . Historical estimates were reported for 1990 and 1995, and projections of emissions in the absence of climate measures ("Business as Usual") were provided for 2000, 2005, and 2010.

The Non-CO_2 Greenhouse Gases Network was established by the US EPA, the European Commission Directorate for Environment and the IEAGHG in 2001. The objective of the network was to bring together an international team of leading researchers and policy advisors to compare data, mitigation technology analyses, economic modelling approaches and empirical results on the Non-CO2 greenhouse

[2] This conclusion was based on a review undertaken by IEAGHG from a leading expert at that time on agricultural developments and abatement.

gases. The first meeting of the Non-CO_2 Greenhouse Gas Network was held in June 2001. The meeting was organized as a workshop providing technical presentations and opportunities for discussion. The workshop was entitled "Mitigation technologies and economic analyses". The two-day workshop concentrated on establishing the state of research on mitigation technologies and economic analyses of abatement options for the Non CO_2 GHG's. In particular, the aim was to compare the different methodologies used by various workers to express the economic indicators, e.g. marginal abatement cost curves. In addition, the meeting aimed to consider the best way for these data to be incorporated into economic models for predictive purposes, which in turn complemented both IEAGHG's and USEPA's cost curve analyses (See report Ph4/5, February 2002).

A second meeting of the network was held in January 2002, and was held jointly with a new working group established by the Energy Modelling Forum (EMF) to address multiple greenhouse gas issues. It was agreed at the meeting that the members of the Network would contribute to the EMF working group, known as EMF21. The joint EMF/Network activity to include the Non-CO_2 GHG data in the economic models was launched at a meeting in May 2002. As a first step in the exercise, experts from USEPA, EC and IEA GHG as well as a number of consultants (who have been involved in the development of the marginal abatement cost curves for the 3 organisations above) developed a common data set for use by the economic modellers (See report Ph4/8 March 2002). The results from the different modelling groups taking part in the EMF21 study will then be compared. The EMF21 activity will be carried out between July 2002 and December 2003 and the results published in a Special Issue of the Journal Energy see http://emf.stanford.edu/files/pubs/22519/SpecialIssueEMF21.pdf. The two main conclusions from the numerical simulations work were: CO_2 is the main problem but by including Non-CO_2 GHG's and using GWPs, the costs of climate policy decrease by around 8%.

Two further meetings of the network were organised in 2002 focusing on the agricultural sector. The first meeting of the agricultural group of the Non-CO_2 Greenhouse Gases Network was organized by the in December 2002 (see report Ph4/20, June 2003). The objectives of the meeting were to:

- To improve the understanding of the potential mitigation options that was available to reduce both CH_4 and N_2O emissions from the agricultural sector,
- To determine if the abatement potential for the identified mitigation options could be quantified as well as the mitigation costs.

The key areas of focus in the agricultural sector were: soil management (in particular inorganic and organic nitrogen addition), manure management, enteric fermentation in livestock and rice cultivation.

The second meeting of the agricultural group was held in conjunction with the 3rd International Conference on Methane and Nitrous Oxide held in China in November 2003. At this meeting the USEPA presented a preliminary analysis on agricultural sector emissions, abatement options and cost curves. The results of their preliminary assessment were discussed and critiqued by the members of the network.

Non-CO_2 Greenhouse Gases Network disbanded in 2004 as its agreed function had been achieved and no further work was identified for it to undertake.

Whilst IEAGHG did not then complete any further work on this topic. The USEPA went on to produce its own report entitled Global Mitigation of Non-CO_2 Greenhouse Gases (EPA Report 430-R-06-005) in June 2006[3]. This report covered the same sectoral areas as IEAGHG's report but also included the agricultural sector data building upon the work developed through the Non-CO_2 greenhouse gases network. It has subsequently updated this report in 2012.

[3] The full report can be found at :
http://www.epa.gov/climatechange/EPAactivities/economics/nonco2mitigation.html

3. IEAGHG Non CO_2 GHG report summary

The industrial emission sectors, emission sources, and greenhouse gases (GHGs) covered by the study are summarised in Table 1 below.

Emission Sector	Emission Sources	Greenhouse Gases
Coal Mining	Underground mines	CH_4
Oil Systems	Oil production	CH_4
Natural Gas Systems	Natural gas production, transmission, processing, storage, and distribution	CH_4
Solid Waste Management	Landfills	CH_4
Wastewater Management	Anaerobic wastewater management	CH_4
Nitric Acid Production	Nitric acid production	N_2O
Adipic Acid Production	Adipic acid production	N_2O
Industrial Sector High-GWP Gases (Engineered chemicals)	HCFC-22 Production	HFC-23
	Aluminium Production	CF_4 and C_2F_6
	Magnesium Production	SF_6
	Electricity Transmission and Distribution	SF_6
	Electrical GIS[4] Manufacturing	SF_6
	Semiconductor Manufacturing	PFCs, HFCs, and SF_6
Use of Ozone Depleting Substance (ODS) Substitutes	Refrigeration and Air Conditioning (AC)	HFC-134a and others
	Foams	HFC-134a, HFC-152a, HFC-245fa, HFC-365mfc
	Non-MDI Aerosols	HFC-134a, HFC-152a
	MDI Aerosols	HFC-134a, HFC-227ea
	Solvents	HFC-4310mee
	Fire Extinguishing	HFC-227ea and others

Table 1: Emission sectors, emission sources and greenhouse gases covered by this study

A total of 119 different abatement options were analysed in the study and their technical and cost characteristics assessed to allow them to be integrated into the abatement cost curves. Within each sector, major emission sources were determined (e.g. methane emissions from natural gas transmission), which were then further subdivided into emissions from individual sources (e.g. compressors, pipeline leaks, etc.). The results have been collated for 12 different regions (Asia, Australia, China, Eastern Europe, FSU[5], Japan, Latin America, Middle East, North America, OECD-Europe, Rest of Asia and South Asia.

To develop the abatement cost curves, a baseline emission level was determined for each emission source and each region. The purpose of these baselines[6] was to determine potential emission reductions that could be achieved by a specific option by a given year. After establishment of the baseline, the technical and cost characteristics for each abatement option were then derived on a consistent basis to allow an abatement cost curve for each sector to be developed. The individual abatement cost curves from each sector (for 2000, 2010 and 2020) were then compiled into a combined abatement cost curve

[4] Gas Insulated Switchgear
[5] Former Soviet Union.
[6] Baselines in this report describe emissions that are expected to occur if no additional measures (projects) to reduce emissions are implemented with respect to the current situation. Additional measures can include international actions to reduce greenhouse gas emissions (such as the Montreal and Kyoto protocols) and national regulatory requirements (e.g., the "landfill rule" in the U.S).

for each gas (methane, nitrous oxide and engineered chemicals). Finally, a composite abatement cost curve for all the Non-CO_2 GHG's was developed. The detailed methodology for the construction of the abatement cost curves is outlined in the main report.

In addition, the main report discusses in detail the identified mitigation options and the combined abatement cost curves for each gas and group of gases.

Global emissions of Non-CO_2 GHG's (2000-2020)

The emissions for all the Non-CO_2 GHG's on a regional basis for the period 2000 to 2020 are given in Figure 1.

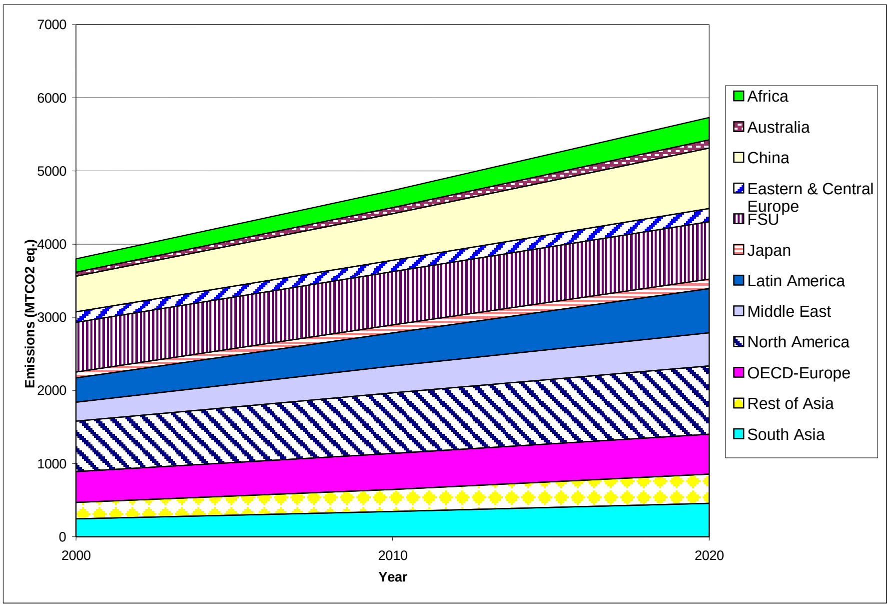


Figure 1: Global emissions of all Non-CO_2 Greenhouse Gases

Annual emissions of Non-CO_2 GHG's were projected to increase from 3 800 Mt CO_2eq. in 2000 to 6 700 Mt CO_2eq. by 2020. The regions showing the largest emissions growth are expected to be: China, North America Latin America and the Rest of Asia. The projected emissions growth for each gas is shown in Table 2.

Greenhouse Gas	**Greenhouse Gas Emissions, Mt CO_2eq.**		
	2000	**2010**	**2020**
Methane	3156	3786	4435
N_2O	230	271	298
Engineered Chemicals	411	683	995
Total	**3797**	**4740**	**5728**

Table 2: All GHG Baseline Emissions by Gas (Mt CO_2eq.)

The biggest growth in (weighted) emissions will come from methane (1279 Mt CO_2eq.) and the engineered chemicals (584 Mt CO_2eq.) Methane, therefore, will remain the most important Non-CO_2 greenhouse gas. Nitrous oxide emissions from industrial sources are not projected to rise significantly between 2000 and 2020.

The main increases in methane emissions are predicted to come from the natural gas sector (560 Mt CO_2eq.) and the solid waste management (320 Mt CO_2eq.) sectors. On a regional basis, methane emissions growth between 2000 and 2020 in the natural gas sector is expected to be significant in: Latin America, Middle East, Asia, FSU and North America (46 Mt CO_2eq.). Whilst in the solid waste management sector, the most significant increases in methane emissions were projected for China and Africa. For the engineered chemicals or High GWP gases the main increases in emissions were predicted to come from the foam manufacturing (224 Mt CO_2eq.) and refrigeration/air conditioning sectors (142 Mt CO_2eq.) which between them contribute 62% of the predicted emissions increase. The biggest regional increases are projected for: North America, OECD Europe, China and Japan.

Combined global cost abatement curves

Three global abatement cost curves for 2000, 2010 and 2020 were developed. The global abatement cost curve for all the Non-CO2 greenhouse gases for 2020 is given in Figure 2 (abatement options with costs above US$200/t CO_2eq. were excluded).

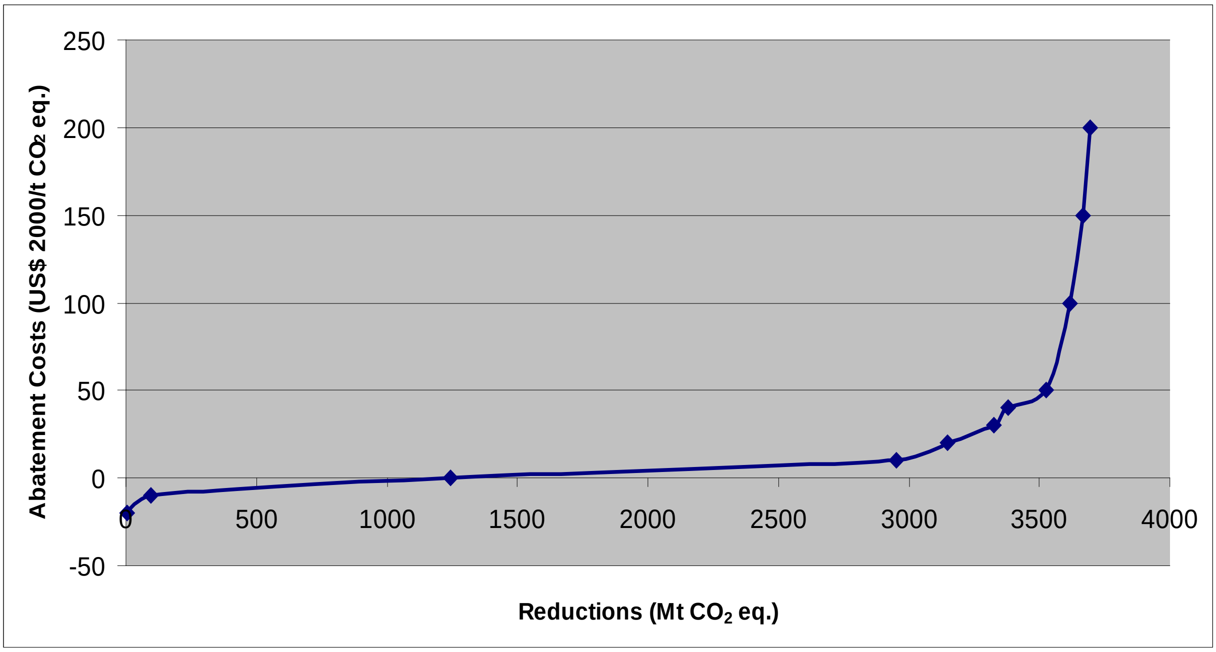


Figure 2: Cost Abatement Curve for All Non-CO_2 GHG's for 2020

The results indicated that up to 1 050 Mt CO_2eq. could be abated at costs of typically -$10 to $0/t CO_2 eq. A further 1 200 Mt CO_2eq could be abated at costs of up to $10/t CO_2 eq. and 1 000 Mt CO_2eq. at cost of up to $50/t CO_2eq. On a regional basis, the most significant regions with potential for cost-effective abatement of Non CO_2 GHG emissions in 2000 are: North America, China, South Asia, Latin America, Rest of Asia and OECD Europe.

On an individual gas basis, the largest cost-effective reductions (costs up to $0/t CO_2eq. abated) in emissions could be achieved through the abatement of methane emission sources (900 Mt CO_2eq.), followed by abatement of the engineered chemicals/high GWP gases (150 Mt CO_2eq.). The cost-effective abatement measures identified are summarised in Table 3 overleaf. For methane the cost-effective abatement options come from the natural gas, waste water management and solid waste management sectors. The abatement measures for the natural gas sector have been summarised into 5 categories in the overview, full details of all the abatement options identified are given in the main report. For the engineered chemicals, cost-effective abatement measures were identified in the semi-conductor and aluminium production industries as well in sub-sectors like foam blowing, refrigeration/air conditioning, and aerosols and for fire extinguishers.

Greenhouse Gas Sector	Sub Sector	Abatement Option
Methane		
Coal mining		Methane drainage combined with injection into a natural gas pipeline
Natural Gas Production, Transmission and Distribution		a) Revised maintenance procedures for gas compressors b) Equipment surveying to identify leaks and direct maintenance/repairs c) Installation of dry seals on compressors d) Reduced glycol circulation rates in dehydrators e) Installation of low-bleed pneumatic devices on compressors
Solid waste management		a) Anaerobic digestion with compost production b) Use of landfill gas in existing boilers for heat production
Waste water management		Electricity generation from recovered methane
Engineered Chemicals		
ODS Substitutes from multiple sources	Refrigeration and air conditioning	Replacement of direct expansion systems with distributed systems in Retail food and cold storage
	Aerosols	Replacement of high GWP HFC based propellants with Hydrocarbons or lower GWP HFC's[7] in Non Metered Dose Inhalers.
	Foams	Replacement of HFC blowing agents in spray foams with CO_2/water blowing agents
	Fire extinguishing	Use of water mists for Class B fire hazards
PFC emissions from semiconductors	Semiconductors	Drop in C_3F_8 replacement in Chemical Vapour Deposition Cleaning Equipment
CF_4 and C_2F_4 from Aluminium production		Retrofits for side worked pre-bake technologies and centre-worked pre-bake technologies

Table 3: Summary of Cost-effective Abatement Options for the Methane and the Engineered Chemicals

Sensitivity studies

In the development of the abatement cost curves IEAGHG's standard assessment criteria were used (10% discount rate, natural gas price of $2/GJ, etc.)[8]. The sensitivity was determined of the emission reductions to discount rate (2 to 20%) and natural gas price (-50% to 200% of base price). The sensitivity analyses indicated that the potential emissions reductions for all of the Non-CO_2 GHG's were generally insensitive to discount rate at costs above $0/t. Some sensitivity to methane emissions was observed at low discount rates (2 and 5%) for methane emission reductions. Sensitivity to lower discount rates would be expected for projects where there is a larger capital cost component compared to labour cost - the abatement options identified in the methane sector all have a higher fixed capital/labour cost ratio.

Sensitivity to energy price was found for the methane abatement options, where increasing the natural gas price, resulted in more of the methane emission reduction measures showing negative costs as might be expected.

[7] HFC-152a has a GWP of 120 which can be used to replace higher GWP HFC's as a propellant in applications where hydrocarbons and dimethyl ether are too flammable.

[8] Since the study commenced the natural gas price in IEA GHGs standard assessment criteria has been increased to $3/GJ.

In conclusion, the study showed that the emissions of the Non-CO_2 GHG's were projected to rise significantly (from 3800 Mt CO_2eq. in 2000 to 5700 Mt CO_2eq. by 2020). Whilst the increase in Non-CO_2 GHG emissions (1900 Mt CO_2eq.) was lower than that predicted for CO_2 emissions at that time (10090 Mt CO_2 between 2000 and 2020[9]), the contribution to climate change of these gases would continue to be significant. The trend in emissions growth indicates that Asia will see the largest growth followed by North America and OECD Europe. This trend was consistent with projections for increased CO_2 emissions which indicate that Asian emissions would grow substantially.

About 70% of the predicted increase in Non-CO_2 GHG emissions (1280 Mt CO_2eq.) was due to methane and the rest due to the engineered chemicals (550 Mt CO_2eq.) By comparison, increases in emissions of nitrous oxide from industrial operations were projected to be much less significant (68 Mt CO_2eq.).

The results indicated that emissions of up to 1050 Mt CO_2eq. could be avoided cost-effectively (i.e. at costs of -$10 to $0/t CO_2 eq.) by 2020. A further 2200 Mt CO_2eq. could be abated at costs of up to $50/t CO_2eq. by 2020. The cost-effective measures, in particular, indicated that there are a significant number of early opportunities for greenhouse gas abatement in the Non-CO_2 greenhouse gas area. Such early abatement options were thought to be attractive to many countries to meet their Kyoto commitments in the period up to 2012.

4. Recent USEPA Updates on Non-CO_2 GHG's

Global Non-CO_2 GHG Emission Projections

The USEPA has recently updated its earlier report of its global Non-CO_2 GHG emission projections, last published in 2006[10]. The draft report provides estimated projections to 2030 for emissions from more than twenty emissions sources. The gases included in this report are methane, nitrous oxide, and fluorinated greenhouse gases or F-Gases i.e. hydrofluorocarbons, perfluorocarbons, and sulphur hexafluoride).

Some of the main findings of the report are as follows:

- Between 1990 and 2005, global Non-CO_2 GHG emissions grew by 10 % from about 9,800 to 10,800 MtCO_2eq and are expected to grow approximately 43 % from 2005 to 2030.
- Historical emissions of CH_4 have increased 9 % (from about 6,300 to 6,800 MtCO_2eq), N_2O emissions increased 4 % (from about 3,200 to 3,400 MtCO_2eq), and F-GHG emissions increased 128 % (from about 250 to 600 MtCO_2eq) from 1990 to 2005.
- Emissions of High GWP gases, now termed F-Gases are projected to increase 336 % from 2005 to 2030, much faster than CH_4 (26%) and N_2O (26%). The large increase in F-GHG emissions stems predominately from the increase in use of HFCs as substitutes for ozone depleting substances.

Table 4 overleaf provides emissions by gas for 1990, 2005 and 2030 for each sector and source. The F-GHGs are provided by their constituent gases for each sector and source.

[9] Source: IEA World Energy Outlook, 2002.
[10] The draft summary can be found in full at:
http://www.epa.gov/climatechange/Downloads/EPAactivities/Summary_Global_NonCO2_Projections_Dec2012.pdf

Table 4: Global Non-CO_2 GHG Emissions by Sector, by Gas ($MtCO_2eq$)

Source Category	Sector	Gas	1990	2005	2030
Energy	Natural Gas and Oil Systems	CH_4	1,278.3	1,542.7	2,112.9
	Coal Mining Activities	CH_4	529.8	521.6	784.3
	Stationary and Mobile Combustion	CH_4	221.3	224.3	362.9
		N_2O	201.3	256.1	402.5
	Biomass Combustion	CH_4	176.3	198.0	230.4
		N_2O	40.6	47.6	59.4
	Other Energy Sources	CH_4	0.5	0.5	0.5
		N_2O	2.6	3.5	3.4
	Total		**2,450.8**	**2,794.3**	**3,956.3**
Industrial	Adipic Acid and Nitric Acid	N_2O	199.8	126.5	147.2
	Use of Substitutes for Ozone Depleting Substances	HFCs	-	307.7	1,902.7
	HCFC-22 Production	HFCs	104.2	179.0	286.4
	Operation of Electric Power Systems	SF_6	49.3	41.2	63.8
	Primary Aluminum Production	PFCs	83.9	30.6	37.4
	Magnesium Manufacturing	SF_6	12.0	9.8	5.2
		HFCs	0.8	0.7	1.1
		PFCs	9.0	14.0	12.2
		SF_6	2.8	5.4	3.3
		NF_3	0.1	5.5	5.0
		PFCs	0.0	0.1	5.2
	Flat Panel Display Manufacturing	SF_6	0.1	3.3	133.2
		NF_3	0.0	0.5	23.9
	Photovoltaic Manufacturing	PFCs	-	0.5	112.1
		NF_3	-	0.0	16.3
	Other Industrial Processes Sources	CH_4	7.7	7.5	6.3
		N_2O	80.8	77.0	76.3
	Total		**550.4**	**809.2**	**2,837.6**
Agriculture	Agricultural Soils	N_2O	1,658.1	1,840.0	2,482.8
	Enteric Fermentation	CH_4	1,763.9	1,894.3	2,320.5
	Rice Cultivation	CH_4	480.0	500.9	510.4
	Manure Management	CH_4	232.7	219.2	252.7
		N_2O	203.8	179.0	213.6
	Other Agricultural Sources	CH_4	506.6	421.0	421.0
		N_2O	776.7	744.1	744.1
	Total		**5,621.8**	**5,798.5**	**6,945.0**
Waste	Landfilling of Solid Waste	CH_4	706.1	794.0	959.4
	Wastewater	CH4	351.9	476.7	608.8
	Human Sewage – Domestic	N_2O	68.0	81.7	99.8
	Other Waste Sources	CH_4	13.4	15.2	15.5
		N_2O	8.9	11.2	11.4
	Total		**1,148.3**	**1,378.8**	**1,694.9**
Total			**9,771.2**	**10,780.7**	**15,433.8**

The historical emission trends for CH_4 and N_2O are considered to be the cumulative effect of a number of factors. Although basic activities (waste generation and landfilling, energy production and consumption, etc.) have predominantly increased, several factors have helped constrain emission growth, which include:

- The recovery and use of CH_4 has reduced these emissions in many countries.
- Sectoral level restructuring has decreased emissions.
- Economic restructuring in several countries, such as Russia and Germany, caused a decrease in emissions in the 1990s.

However since 2000, emissions have also increased due to economic and sectoral growth in recently restructured countries and sectors. The two effects to a degree counterbalancing each other.

Based on the USEPA's latest data F-GHG emissions were relatively small in 1990, but have increased substantially as HFC's have been deployed as substitutes for the ozone-depleting substances (ODS) that are being phased out globally under the Montreal Protocol[11]. This historical deployment of HFCs has taken place primarily in developed countries, where hydrofluorocarbon (HCFC) phase out regulations have been promulgated, although emissions are also now present in developing countries where HFCs are being used as direct replacements for the globally-phased out chlorofluorocarbons (CFCs) in some technologies (e.g., air conditioning for passenger cars).

Projections of future growth in emissions of Non-CO_2 GHG's are driven by several factors. Countries with fast-growing economies and populations are expected to contribute more to the global CH_4 and N_2O totals as their economies grow, energy consumption increases, and waste generation rates increase. Countries with more steady-state economies, and small or even declining population growth rates, are likely to experience minimal growth in CH_4 and N_2O emissions. The large increase in F-GHG emissions stems predominately from the increase in use of HFCs as substitutes for ozone depleting substances. While this trend has largely been observed only for OECD countries to 2005, throughout the projection period all regions are projected to have increases in HFC emissions, as more countries transition away from ODS's amidst strong global growth in demand expected for refrigeration and air conditioning and other technologies that utilize HFCs in lieu of ODS's. While emissions of HFCs used as substitutes for ODS's increasing, the ODS's that HFC's replace are also greenhouse gases, in many cases more potent than the substitutes. Thus, although emissions of HFC's used as substitutes of ODS's increasing, the radiative forcing from the CFC's and HCFC's they replace would have been much higher had the phase out of ODS's not taken place.

Between 1990 and 2005, emissions grew from Africa, Central and South America, the Middle East, and non-OECD Asia, while falling from the OECD and Non-OECD Europe and Eurasia regions. By 2030, BAU emissions of Non-CO_2 GHGs are projected to increase in every region compared to 2005 emissions. Emissions are projected to grow the fastest in Non-OECD Asia, the Middle East, and the OECD. Table 5 shows the decadal growth rates by region from 1990 to 2030.

[11] The Montreal Protocol on Substances that Deplete the Ozone Layer (a protocol to the Vienna Convention for the Protection of the Ozone Layer) is an international treaty designed to protect the ozone layer by phasing out the production of numerous substances believed to be responsible for ozone depletion. The treaty was opened for signature on September 16, 1987, and entered into force on January 1, 1989, followed by a first meeting in Helsinki, May 1989. Since then, it has undergone seven revisions, in 1990 (London), 1991 (Nairobi), 1992 (Copenhagen), 1993 (Bangkok), 1995 (Vienna), 1997 (Montreal), and 1999 (Beijing). It is believed that if the international agreement is adhered to, the ozone layer is expected to recover by 2050.[1] Due to its widespread adoption and implementation it has been hailed as an example of exceptional international co-operation. The two ozone treaties have been ratified by 197 states and the European Union making them the most widely ratified treaties in United Nations history.

Table 5: Percentage Change in Total Global Non-CO_2 Emissions, by Decade and Region

Region	1990-2000	2000-2010	2010-2020	2020-2030	1990-2030
OECD	0.6%	1.6%	14.9%	15.2%	35.3%
Non-OECD Asia	13.0%	24.1%	20.9%	28.7%	118.1%
Non-OECD Europe & Eurasia	-31.6%	9.2%	10.6%	9.1%	-9.7%
Africa	3.5%	23.5%	10.6%	11.3%	57.2%
Central and South America	8.9%	20.3%	10.3%	9.1%	57.7%
Middle East	47.4%	16.0%	20.6%	18.1%	143.4%
Total	**1.3%**	**15.1%**	**15.2%**	**17.6%**	58.0%

Non-CO_2 GHG emissions from the OECD decreased by 2% from 1990 to 2005 (to about 2,800 $MtCO_2eq$), while GDP grew by 44%. Several initiatives took place during this period which had the effect of reducing emissions. Some of the most significant were increasing control of emissions from nitric and adipic acid production, and HCFC-22 manufacturing facilities, tailpipe emissions from vehicles, and capture and combustion of landfill gas. Coal production declined significantly in the EU, which decreased emissions from coal mining. Emissions from OECD countries are projected to increase 37% (from about 2,800 to 3,800 $MtCO_2eq$) from 2005 to 2030. This scenario does not take into account economy-wide programs to control GHG emissions or country emissions reduction pledges. While some emissions reduction activities that have been successful in the OECD in the past will likely continue to be significant, large additional reductions in those areas are less likely since many-cost effective options have already been implemented.

The non-OECD Europe and Eurasia region includes many countries from the former Soviet Union that underwent significant economic changes since 1990. Non-CO_2 GHG emissions from this region dropped 29% between 1990 and 1995, and stayed at approximately this level through 2005. The emissions decline can be attributed to economic contraction, with GDP in 2005 2% lower than 1990, as well as changes in industry structure that accompanied the change to market economies. From 2005 to 2030, emissions from this region are projected to grow 27%, which would result in emission totals returning to nearly 1990 levels.

Non-OECD Asia has grown quickly from 1990 to 2005, both in terms of economy and emissions. Over this period, Non-CO_2 GHG emissions grew 31% (from about 2,400 to 3,200 $MtCO_2eq$), while GDP grew by 178%, nearly tripling the previous level. International offset projects have been concentrated in this region, and especially in the HCFC-22 manufacturing sector, but emissions in this sector have continued to increase. Recent initiatives to close small mines in China may be reducing CH_4 emissions from the coal mining sector. From 2005 to 2030, Non-CO_2 emissions from non-OECD Asia are projected to grow by 67%, with GDP more than quadrupling (increasing by 327%). Two factors are expected to cause ODS substitute emissions to grow significantly: the phase-out of ODS's and the increasing use of air conditioning and refrigeration as the economies grow. Emissions from many industries are expected to grow in parallel with economic expansion.

Non-CO_2 GHG emissions from Africa grew 17% between 1990 and 2005. GDP in Africa grew 57% over the same period. The pattern of emissions is quite different in Africa than other regions. Sources with significant emissions and growth over this period include savanna burning (included in other agricultural sources), biomass burning, natural gas and oil, stationary and mobile combustion, landfills and wastewater. Emissions from Africa are projected to increase 34% from 2005 to 2030, while GDP is expected to triple over this time. As African economies develop, technologies used are likely to change substantially, impacting Non-CO_2 GHG emissions. Technologies used are likely to change substantially, impacting Non-CO_2 GHG emission projections in the future.

Between 1990 and 2005, emissions from Central and South America grew 3%, while GDP grew by 55%. About 82% of Non-CO_2 emissions in Central and South America are attributed to the Agriculture sector in 2005, a much higher proportion than other regions. From 2005 to 2030, emissions from the region are projected to increase 20%, the smallest percentage increase of all regions. GDP is expected to grow 157% over the projection period, slower than any of the other non-OECD regions.

Non-CO_2 GHG emissions from the Middle East region grew 55% from 1990 to 2005. While this rate of growth is the near the highest of any region, emissions from the Middle East comprise only 5% of the world total in 2005. Over half of Non-CO_2 GHG emissions from the Middle East are CH4 emissions from the natural gas and oil sector; thus the emissions trends for the region is highly correlated with trends in oil and gas production. From 2005 to 2030, emissions from the region are projected to grow by 57%.

To examine the trends by gas, by sector and by source category the USEPA grouped emissions into four economic sectors: energy, industrial processes, agriculture and waste. While CO_2 emissions are concentrated in the energy sector, agriculture accounts for the largest share of Non-CO_2 GHG emissions (54% of emissions in 2005). The energy, waste, and industrial processes sectors account respectively for 26%, 8%, and 13% of emissions in 2005. However, emissions from industrial processes are growing at a faster rate than emissions from the other sectors.

The agricultural sector is the largest source of Non-CO_2 GHG emissions. Emissions from agricultural sources accounted for 58% of global Non-CO_2 emissions in 1990, and are expected to remain the largest contributor of emissions in 2030. However, by 2030 the sector's share is expected to decrease to 45% of global emissions. The largest emissions sources within the agricultural sector are N_2O emissions from agricultural soils and CH_4 from enteric fermentation, which account for 32 and 33% respectively of non-CO_2 emissions from agriculture in 2005, respectively. Agricultural soil emissions are projected to increase 35% between 2005 and 2030, representing the largest increase among agricultural sources during this timeframe.

Energy sector emissions are the second largest source of emissions, accounting for approximately 25% of Non-CO_2 GHG emissions in both 1990 and 2005. Emissions from the energy sector increased 14% between 1990 and 2005 (from about 2,500 to 2,800 $MtCO_2eq$), driven by a 21% increase in emissions from natural gas and oil systems. In 2005, fugitive emissions from natural gas and oil systems represented the largest source of Non-CO_2 GHG emissions from the energy sector, accounting for 55% of energy-related emissions. The next largest source in this sector is emissions from coal mining activities, accounting for 19% of energy related emissions in that year. From 2005 to 2030, energy sector emissions are projected to increase 42% (to about 4,000 $MtCO_2eq$), with emissions from stationary and mobile combustion and coal mining activities increasing by 59 and 50%, respectively.

The industrial processes sector was the smallest contributor to global emissions of Non-CO_2 GHG's in 2005, accounting for only 8 % of total emissions. As the fastest growing of all sectors, emissions from industrial processes are projected to increase to 18 % in 2030, surpassing emissions from the waste sector. The industrial processes sector includes all emissions of F-GHGs as well as N_2O emissions from nitric and adipic acid production and other industrial process sources. In 1990, nitric and adipic acid production accounted for 36 % of Non-CO_2 GHG emissions from the sector. Between 1990 and 2005, emissions from nitric and adipic acid declined significantly due to the installation of abatement equipment. However, emissions from production of HCFC-22 and ODS substitutes increased over the same time period. Emissions from the industrial processes sector as a whole have increased 47 % between 1990 and 2005 (from about 550 to 800 $MtCO_2eq$) and are projected to grow even faster, nearly quadrupling between 2005 and 2030 (from about 800 to 2,800 $MtCO_2eq$). This sectoral growth is driven by growth in emissions from ODS substitutes over this period, due to the phase out of ODSs under the Montreal Protocol and strong predicted growth in traditional ODS applications (e.g., refrigeration and air conditioning). As ODS's are phased out, other gases, including HFC's and to a limited extent PFC's, are substituted. The rate of growth is uncertain, however, because the choice of chemicals and potential new technologies or operating procedures could eliminate or diminish the need for these gases. However, without further controls, it is assumed that most users will switch to HFCs.

The waste sector was the third largest contributor to global emissions in 2005, accounting for 13 % of total emissions. In the waste sector, the two largest sources of Non-CO_2 GHG emissions are landfilling of solid waste and wastewater, together contributing 92 to 93% of emissions throughout the 1990 to 2030 period. CH_4 from landfills accounts for an average of 58% of waste emissions across the same timeframe. Increases in waste generation and population drive global waste emissions upward but increases in waste-related regulations and gas recovery and use are expected to offset this increase. Emissions from wastewater are projected to grow more quickly than those from landfills, and are projected to account for 36% of waste emissions by 2030. Projected wastewater emissions are driven by population growth and the underlying assumption that growing populations in the developing world are largely served by latrines and open sewers, rather than advanced wastewater treatment systems.

4.2 Global Mitigation of Non-CO_2 Greenhouse Gases

The USEPA has recently updated its earlier report of its Global Mitigation of Non-CO_2 Greenhouse Gases again last published in 2006[12]. This updated report provides a comprehensive global analysis and resulting data set of marginal abatement cost curves (MACCs) that illustrate the abatement potential of Non-CO_2 greenhouse gases by sector and by region. This assessment of mitigation potential is unique because it is comprehensive across all Non-CO_2 gases, across all emitting sectors of the economy, and across all regions of the world. The analysis does not make any explicit assumptions about policy options to mitigate these gases. Therefore, this report provides estimates of technical mitigation potential. The result of these efforts is a new set of MACCs that allow for improved understanding of the mitigation potential for Non-CO_2 GHG sources, as well as inclusion of non-CO_2 GHG mitigation in economic modelling.

The analysis shows clearly that the mitigation of Non-CO_2 GHG's can play an important role in climate strategies. Worldwide, the study shows that there is significant potential for low cost Non-CO_2 GHG abatement.

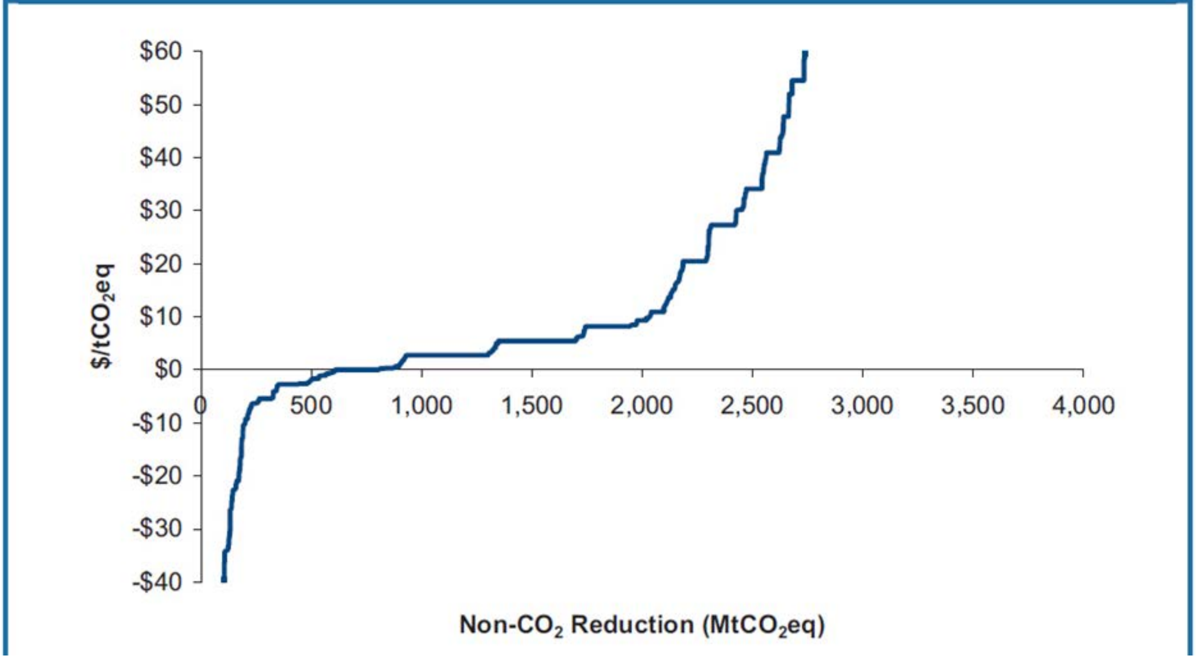
Figure 3 shows the global total aggregate MACC for the year 2020. Without a price signal (i.e., at \$0/tCO_2eq), the global mitigation potential is greater than 600 $MtCO_2eq$, or 5% of the Baseline emissions. The global mitigation potential at a price of \$10/tCO_2eq is greater than 2,000 $MtCO_2eq$,

[12] The Executive Summary of this report can be found at:
http://www.epa.gov/climatechange/Downloads/EPAactivities/GM_ES.pdf

or 15% of the baseline emissions, and greater than 2,185 $MtCO_2eq$ or 17% of the baseline emissions at $20/$tCO_2eq$.

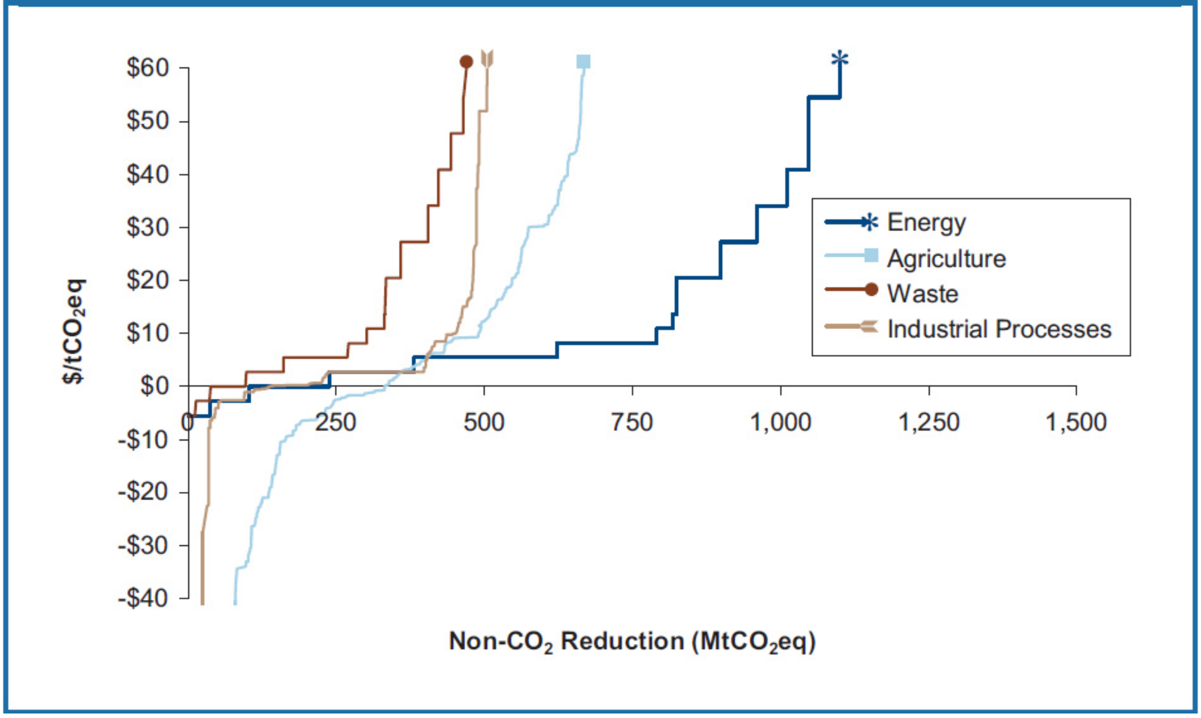
Figure 3 (ES-1): Global total aggregate MACC for the year 2020

Figure ES-1: Global Total Aggregate MAC for Non-CO_2 Greenhouse Gases in 2020



Globally, the Sectors with the greatest mitigation potential are the Energy and Agriculture Sectors. Figure 4 (ES-2) shows the global MACC's by economic sector in 2020.

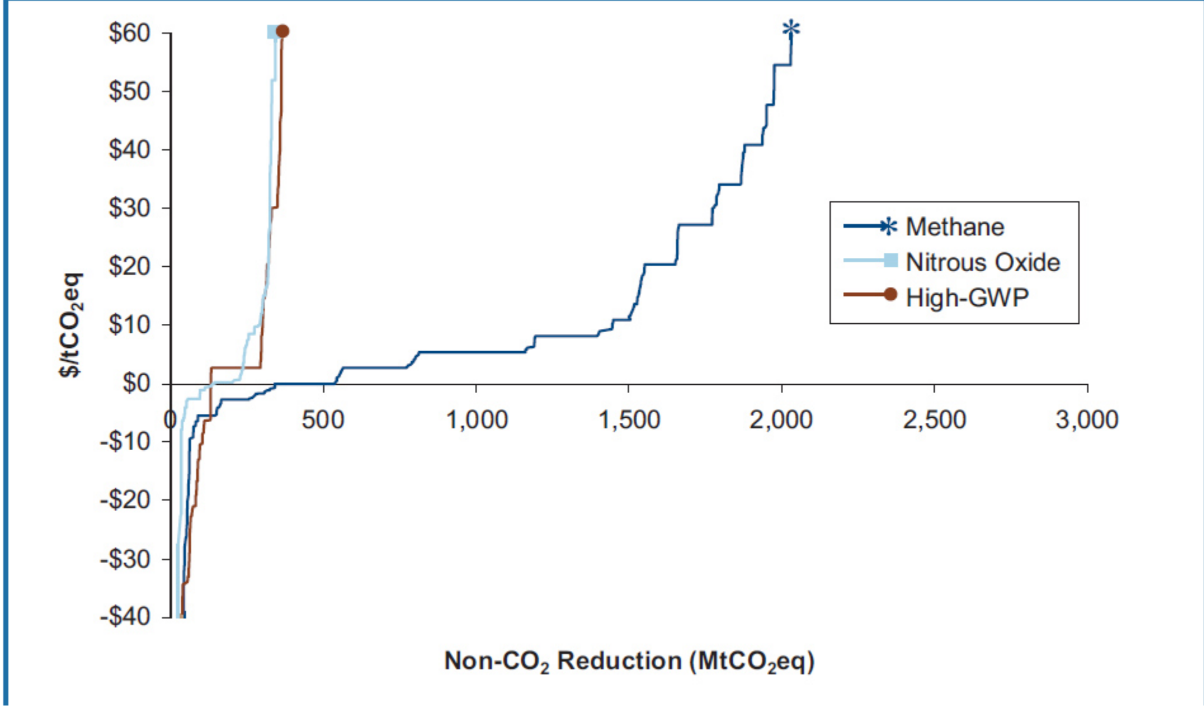
Figure ES-2: Global 2020 MACs for Non-CO_2 Greenhouse Gases by Major Sector



At a price of $30/tCO_2eq, the potential for reduction of Non-CO_2 GHG's is nearly 1,000MtCO_2eq in the energy sector, and approximately 600 MtCO_2eq in the agriculture sector. While less than that of the energy and agriculture sectors, mitigation potential in the waste and industrial processes sectors can play an important role, particularly in the absence of a carbon price incentive.

Methane mitigation has the largest potential of all the Non-CO_2 GHG's. Figure 5 (ES-3) shows the global MACC's by greenhouse gas type for 2020. At or below \$0/tCO_2eq, the potential for CH_4 mitigation is approximately 500 MtCO_2eq. The potential for reducing CH_4 emissions grows to nearly 1,800 MtCO_2eq as the breakeven price rises from \$0 to \$30/tCO2eq. While less than that of CH4, N_2O and high-GWP gases exhibit significant mitigation potential at or below \$0/tCO_2eq.

Figure ES-3: Global 2020 MACs by Non-CO_2 Greenhouse Gas Type



China, the United States, EU, India, and Brazil are the countries or regions that emit the most Non-CO_2 GHG's. As the largest emitters, they also offer important mitigation opportunities. These regions show significant mitigation potential in the lower range of breakeven prices.

5. What Has Changed?

The new global analyses by the USEPA clearly have updated IEAGHG's earlier data sets and also include agricultural emission data whereas IEAGHG's did not. The USEPA data therefore gives a more comprehensive picture of global Non-CO_2 GHG's emissions than IEAGHG's analysis. The USEPA data shows that the agricultural sector is the biggest emitter of Non-CO_2 GHG's notably; N_2O from soils and CH_4 from enteric fermentation. The next most important sectors are energy and industrial processes.

IEAGHG's emission growth forecasts for global Non-CO_2 GHG emissions were predicting an increase of 6,700 Mt CO_2eq from its baseline emission estimate (2000) to 2020. With the biggest increase coming from, CH_4 emissions, then the F-gases and then N_2O. The more recent USEPA analysis predicts a slightly lower increase of 5,662 Mt CO_2e, (and it includes agricultural emissions) but nevertheless the increase is still significant. Also note the time spread is different from the IEAGHG analysis which was 2000 to 2020 whereas the USEPA data is taken from 1990 to 2030.

The USEPA data shows that methane is still the primary gas globally but also a much bigger growth in the F-Gases than IEAGHG predicted from 1990 and 2005 (from about 550 MtCO_2eq) in 1990 to 2,800 MtCO_2eq by 2030. The reason for this is more up to date data on ODS substitutes.

With regard to CH_4 increases from the oil and gas sector this latest USEPA potentially could have underestimated the increase in methane emissions from the recent shale gas boom in the USA which will have occurred whilst this report was being complied, and the further consequences if that boom extends globally..

Both data sets show that there is significant technical potential for mitigation of the Non-CO_2 greenhouse gas emissions globally at low or cost effective prices. The energy sector presents the biggest potential for low cost mitigation potential.

It is not clear from the analyses if there has been a significant take up of Non-CO_2 mitigation actions but decreases in emissions in certain sectors have been noted as a result of mitigation action such as in nitric and adipic acid production and HCFC 23 manufacture. Some reductions will have resulted from indirect actions like the closing of small coal mines in China and the economic down turn in regions.

The latest USEPA report emphasises that the emissions characteristics in regions vary and that there is no one fits all regional mitigation plan. The subtleties of emissions sources in each region need to be considered and how best to mitigate emissions in these regions. This of course may change as new technology take up occurs in developing countries.

The overwhelming messages have remained the same;

1. Non-CO_2 GHG emissions remain a significant component of global greenhouse gas emissions
2. 2. There is significant potential to mitigate the Non-CO_2 GHG emissions at negative and low costs. The options represent a significant “low hanging fruit” option for global GHG emission reduction.
3. Including Non-CO_2 GHG mitigation in a package of greenhouse gas emission reduction must decrease the costs of GHG mitigation compared to a CO_2 only abatement strategy.

It is fair to say that we identified the main mitigation options in IEAGHG’s earlier study (see Table 4) and nothing has radically changed since that time. Some of the technologies may have been adapted or refined since the orginal study but essentially they have remained the same. There is therefore no role in assessing new technology options in the energy sector for instance that is appropriate to IEAGHG’s activities. The main activity that is required is policy actions and financial mechanisms to implement the mitigation options for the Non-CO_2 GHG’s.

6. What is being done globally to implement Non-CO_2 GHG emission reductions?.

The main international body covering the mitigation of all greenhouse gases is the UNFCCC. We are aware that the first phase of the Kyoto accord is now over and discussions are underway to reach a global agreement on extending the Kyoto agreement. Progress however is regarded as slow by many and the recent pledges by Governments to reduce GHG emissions are not sufficient to meet the target of limiting temperature rise to 2^0c. The UNFCCC Clean Development Mechanism provides a route to support financially the implementation of mitigation projects in developing countries. This mechanism has funded a significant number of projects on CH_4 and N_2O mitigation and projects reducing emissions from F-Gas production[13].

The Climate and Clean Air Coalition (CCAC) to Reduce Short Lived Climate Pollutants was formed under a US Initiative in February 2012. The short-lived climate pollutants (SLCP's) included in this initiative include: black carbon, methane and hydrofluorocarbons (HFCs). These are considered to be are responsible for a substantial fraction of current global warming with particularly large impacts in urban areas and sensitive regions of the world like the Arctic, and have harmful health and environmental impacts. It is felt that addressing these short lived climate pollutants can have immediate, multiple benefits. Reducing them will protect human health and the environment now and slow the rate of climate change within the first half of this century. It is noted that by the Partners that action on Short lived climate pollutants must complement and supplement, not replace, global action to reduce carbon dioxide, in particular efforts under the UNFCCC. At the first meeting of the CCAC High Level Assembly, on 24 April 2012 in Stockholm, an initial tranche of five initiatives was agreed upon for rapid implementation, as follows.

- Reducing Black Carbon Emissions from Heavy Duty Diesel Vehicles and Engines
- Mitigating Black Carbon and Other Pollutants From Brick Production
- Mitigating SLCPs from the Municipal Solid Waste Sector
- Promoting HFC Alternative Technology and Standards
- Accelerating Methane and Black Carbon Reductions from Oil and Natural Gas Production

The CCAC comprises 25 country partners, the European Commission and 23 non-state partners. For a full list and for more details on the Coalition please go to: www.unep.org/ccac

The SCLP's are not all currently regulated within the Kyoto protocol or its parent treaty, the 1992 UN Framework Convention on Climate Change. As a result, their levels or actions to reduce them are not formally discussed as part of the annual climate negotiations.

It is too early to gauge the impact the CCAC on global mitigation of the Non-CO_2 GHG's.

THE UNEPs the Emissions Reduction Programme for Non-CO_2 greenhouse gases, was introduced in 1999, however this activity is now fully aligned with that of the CCAC.

Another US led voluntary initiative is the international Global Methane Initiative (formerly Methane to Markets Partnership), launched in November 2004, and committed the United States and 13 other countries to advancing cost-effective, near-term methane recovery and use as a clean energy source. The Initiative focuses on methane recovery and use opportunities in the agriculture (animal waste management), coal mine, landfill, and oil and gas system sectors.

Since its launch, the Initiative has added multiple Partner Governments and private and non-government participants who work collaboratively to implement projects around the globe. Public and private sector organizations around the world are now working together with government agencies to facilitate methane reduction projects in agriculture, coal mines, landfills and oil and gas systems. This collaboration is yielding important benefits, including enhanced economic growth and

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[13] A database of projects implemented under the CDM can be found at: http://cdmpipeline.org/cdm-projects-type.htm#3

energy security, improved air quality and industrial safety, and reduced greenhouse gas (GHG) emissions. See http://www.epa.gov/globalmethane/initiative.htm
The GMI extends the USEPA’s voluntary programmes within the US, namely the AgSTAR Program, the Coalbed Methane Outreach Program, the Landfill Methane Outreach Program and the Natural Gas Star programme. The collective results of EPA’s voluntary methane partnership programs have been substantial according to their web site.. Total U.S. methane emissions in 2005 were more than 11% lower than emissions in 1990, in spite of economic growth over that time period. EPA expects that these programs will maintain emissions below 1990 levels in the future due to expanded industry participation and the continuing commitment of the participating companies to identify and implement cost-effective technologies and practices

The Global Research Alliance on Agricultural Greenhouse Gases was launched in December 2009 and now has more than 30 member countries from all regions of the world. For more information on the membership, see http://www.globalresearchalliance.org/about-us/

The Alliance is focused on research, development and extension of technologies and practices that will help deliver ways to grow more food (and more climate-resilient food systems) without growing greenhouse gas emissions. The Alliance is founded on the voluntary, collaborative efforts of countries.

Members of the Alliance aim to deepen and broaden mitigation research efforts across the agricultural sub-sectors of paddy rice, cropping and livestock, and the cross-cutting themes of soil carbon and nitrogen cycling and inventories and measurement issues. Groups have been set up to address these areas of work. These Groups have developed work plans that bring countries and other partners together in research collaborations, as well as to share knowledge and best practices, build capacity and capability amongst scientists and other practitioners, and move towards breakthrough solutions in addressing agricultural greenhouse gas emissions. The Alliance has three Research Groups: Croplands, Paddy Rice and Livestock. It also has two cross cutting groups on Soil Carbon and Nitrogen Cycling and Inventories and Measurement

Within the EU two Regulations that could have a significant impact on the use of refrigeration in food and drink manufacturing companies are:

1. EU Regulation 2037/2000 on ozone depleting substances
2. EU Regulation 842/2006 on certain fluorinated greenhouse gases (F-Gases)

The Ozone Regulation came into force in 2000 and it has already banned the use of ozone depleting HCFC refrigerants such as R22 in new systems. R22 remains a very common refrigerant in existing systems used by food and drink manufacturers. The Regulation will ban the use of R22 as a “top-up” fluid for maintenance between 2010 (for virgin fluid) and 2015 (for recycled fluid). This is of crucial importance for many companies and means that all users of R22 and other HCFC systems need to consider alternative refrigerants or the purchase of new equipment.

The F-Gas Regulation is more recent, coming into force in July 2006. It relates to the use of HFC refrigerants such as R134a and R404A. It imposes various obligations on the operators of refrigeration plant using HFC refrigerants that apply from July 2007.

Another example of global activities to reduce F-Gas emissions, include the World Semiconductor Council which is collaborating with industry groups in Europe and around the world to reduce PFC emissions from semi-conductor production. There are similar examples in other F-gas industry sectors.

In addition to these actions; there is at least one established conference series; the Seventh International Symposium on Non-CO_2 Greenhouse Gases (NCGG7) will be held in the Netherlands in June 2014. Papers from the conference are published in books by the publisher Kluwer. See http://www.ncgg.info/. Papers on this topic are also published in the International Journal of Greenhouse Gas control.

7. Conclusions

The IEAGHG has not been actively undertaking research in the area of Non-CO_2 greenhouse gases since 2006. The USEPA which started their research activities in this area about the same time as IEAGHG however have been continuing to research this topic and have produced at new set of global Non-CO_2 GHG emissions projection and abatement cost curves that updates the data IEAGHG generated in 2006. IEAGHG would not propose to undertake its own research to update its analyses in this field but merely take the key messages from the research undertaken by the USEPA for its member's reference.

The new global analyses by the USEPA clearly have updated IEAGHG's earlier data sets and also include agricultural emission data whereas IEAGHG's did not. The USEPA data therefore gives a more comprehensive picture of global Non-CO_2 GHG's emissions than IEAGHG's analysis. The USEPA data shows that the agricultural sector is the biggest emitter of Non-CO_2 GHG's notably; N_2O from soils and CH_4 from enteric fermentation. The next most important sectors are energy and industrial processes.

The USEPA analysis predicts a global increase of 5,662 Mt CO_2eq, in Non-CO_2 GHG emissions between 1990 and 2030 which is a significant increase and still represent about 3)5 of global GHG emissions. The USEPA data shows that methane is the primary gas globally but also a much bigger growth in the F-Gases than IEAGHG predicted from 1990 and 2005 (from about 550 MtCO_2eq) in 1990 to 2,800 MtCO_2eq by 2030. The reason for this is more up to date data on ODS substitutes.

Both data sets show that there is significant technical potential for mitigation of the Non-CO_2 greenhouse gas emissions globally at low or cost effective prices. The energy sector presents the biggest potential for low cost mitigation potential.

The key take away messages have remained the same;

1. Non-CO_2 GHG emissions remain a significant component of global greenhouse gas emissions
2. There is significant potential to mitigate the Non-CO_2 GHG emissions at negative and low costs. The options represent a significant "low hanging fruit" option for global GHG emission reduction.
3. Including Non-CO_2 GHG mitigation in a package of greenhouse gas emission reduction must decrease the costs of GHG mitigation compared to a CO_2 only abatement strategy.

The main mitigation options have already been identified what remains are for policy actions and financial mechanisms to implement the mitigation options for the Non-CO_2 GHG's. There are a number of international voluntary programmes aimed at implementing mitigation options for these gases.