

# Global Abatement Potential of Methane and Nitrous Oxide Emissions from Energy, Industry, and Waste Management

Gale, J.,  
IEA Greenhouse Gas R&D Programme, Cheltenham, Glos. UK GL52 7RZ  
Tel. +44 1242 680753, fax. +44 1242 680758, email:  
[johng@ieagreen.demon.co.uk](mailto:johng@ieagreen.demon.co.uk)

Sankovski, A. and Pape, D.

ICF Consulting,  
1725 Eye Street, NW, Suite 1000  
Washington, DC; Tel: 202-862-1200; fax: 202-862-1144,  
email: [asankovski@icfconsulting.com](mailto:asankovski@icfconsulting.com); [dpape@icfconsulting.com](mailto:dpape@icfconsulting.com)  
[http: www.icfconsulting.com](http://www.icfconsulting.com)

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## Abstract

The current study summarized and standardized currently available information on the global methane and nitrous oxide abatement potential and produced marginal abatement cost curves (MACCs) for twelve regions, 7 separate emission sectors (methane – coal mining, natural gas production/transmission/distribution, oil production, solid waste and wastewater management; nitrous oxide – adipic and nitric acid production), and various combination of discount rates and energy prices. The total of 66 individual abatement options were analyzed with respect to their technical and cost characteristics and integrated into custom-built methane/nitrous oxide and industrial gas MACC models.

The largest 2000-2020 baseline emissions of methane and N<sub>2</sub>O from the reviewed sources are projected for FSU, closely followed by China and North America. The natural gas sector is estimated to remain the major source of emissions, followed by the solid waste management.

The analysis revealed a large potential for the worldwide cost-effective abatement of non-CO<sub>2</sub> emissions. For example, the 2010 annual cost-effective emission reductions (with 10 percent discount rate) from all the methane sources covered by this study exceed 920 MTCO<sub>2</sub>Eq (24 percent of baseline), while the reductions under \$50/tCO<sub>2</sub>Eq (in fixed 2000 U.S. dollars) exceed 2200 MTCO<sub>2</sub>Eq (60% of baseline). Regionally, the largest methane and N<sub>2</sub>O reductions from all the sources can be attained in North America followed by China and FSU. On the gas-source basis, the largest total reductions can be achieved in the waste management and natural gas sectors.

## 1. Introduction

The abatement of methane (CH<sub>4</sub>) and nitrous oxide (N<sub>2</sub>O) emissions can substantially reduce the overall costs of climate change mitigation and achieve a greater flexibility of meeting specific emission reduction targets. A major complication in working with CH<sub>4</sub> and N<sub>2</sub>O emissions is associated with a wide range of processes and activities that lead to these emissions and a significant uncertainty in the availability and costs of corresponding abatement options.

This paper presents key methodologies and results of a recently completed study by the IEA Greenhouse Gas Programme to combine and standardize previous analyses of CH<sub>4</sub> and N<sub>2</sub>O abatement potential. The main objective of the IEA GHG study discussed in this paper was to develop an internally consistent and comprehensive assessment of non-CO<sub>2</sub> abatement potential and costs for different gases, sectors, and regions. The study was based on results of previous non-CO<sub>2</sub> mitigation studies and also included original research on selected sectors and abatement options (e.g., wastewater management sector). The core study results were summarized in a form of marginal abatement cost curves (MACCs), which show the magnitude of cumulative emission reductions that can be achieved at or below a given net specific cost (expressed in 2000 US dollars per tonne of CO<sub>2</sub> equivalent).

## 2. Data and Methods

The methodology used in the report to develop MACCs for different sets of input assumptions is a synthesis of methods used in the IEA GHG Programme, U.S. EPA, and EC analyses (IEA GHG, 1999; EC, 2001; U.S. EPA, 2003). This methodology combines different approaches to economic analysis of non-CO<sub>2</sub> mitigation, which facilitates the comparison of abatement potentials and costs of various options across different regions and years.

Emission sectors, emission sources, and greenhouse gases (GHGs) covered by this study are specified in Table 1.

Table 1: Emission Sectors, Emission Sources, and Greenhouse Gases

<b>Emission Sector</b>	<b>Emission Sources</b>	<b>Greenhouse Gases</b>
Coal Mining	Underground mines	CH <sub>4</sub>
Oil Systems	Oil production	CH <sub>4</sub>
Natural Gas Systems	Natural gas production, transmission, processing, storage, and distribution	CH <sub>4</sub>
Solid Waste Management	Landfills	CH <sub>4</sub>
Wastewater Management	Anaerobic wastewater management	CH <sub>4</sub>
Nitric Acid Production	Nitric acid production	N <sub>2</sub> O
Adipic Acid Production	Adipic acid production	N <sub>2</sub> O

Within each sector, this study analyses major emission sources (e.g., methane emissions natural gas transmission, which are further subdivided into emissions from compressors; pipeline leaks, etc.) and specifically focuses on emissions that can be abated using widely available or emerging technologies.

The MACCs in this study were developed using the following major steps:

1. Compile 2000-2020 baseline emissions for all sources, gases, and regions;
2. Calculate technical and economic parameters of abatement options applicable to specific emission sectors (net specific costs of each option were calculated using the methodology described in IEA GHG, 1999 and EPA, 2003);
3. Develop a source-specific schedule of applying options to sources, which avoids the double counting of emission reductions
4. Calculate region-specific emission reductions achievable by each option in a given year; and
5. Assemble the region- and sector-specific marginal abatement cost curves (MACCs).

The baseline emissions and MACCs were developed for the following regions: Africa; Australia; Central and Eastern Europe; China; Former Soviet Union (FSU); Japan; Latin America; Middle East; North America; OECD-Europe; Rest of Asia; and South Asia. The initial sources of most of baseline emissions were a number of IEA GHG and U.S. EPA reports (e.g., IEA GHG, 2000; U.S. EPA, 2001, 2002). The reported baselines were further adjusted to remove the effects of additional application of abatement technologies with respect to the pre-2000 level.

The total of 66 abatement options have been quantified to be included in the MACCs. The following technical and economic parameters were quantified:

- applicability (equal to the percentage of baseline emissions to which an option can be applied based on its engineering characteristics, costs and the potential overlap with other options);
- reduction efficiency (equal to the percentage of emissions that can be abated by an option once it is applied to a specific point-source of emissions).
- one-time (fixed) cost.
- recurring (annual) cost. and
- cost offset (e.g., revenue from energy sales).

The schedule of applying each option to a given emission source was determined by either the options' technological characteristics (e.g., one option always precedes another one) or by their relative costs (the most cost-effective option is applied to a greater share of emissions).

It should be noted that the MACCs developed using the described methodology reflect a *complete spectrum of new emission-reductions*

*opportunities*, whether they are regulatory- or commercially-driven. The baselines and MACCs adopted here *do not represent the most probable or most likely GHG emission scenarios*, but instead delineate a potential “playing field” for different national and international mitigation initiatives.

### 3.Results and Discussion

Table 2 presents regional sums of baseline methane emissions from coal mining, natural gas and oil systems, solid waste, and wastewater management. The largest baseline emissions in 1990 occurred in the FSU region, followed by North America and China. By 2020, FSU is estimated to still have the largest emissions, with China in the second and North America in the third place.

From 2000 to 2020, baseline emissions are expected to grow in non-Annex I countries and remain relatively flat in Annex I countries. While in 1990 Annex I emissions exceeded emissions in non-Annex I countries by about 400 MTCO<sub>2</sub>Eq, by 2020 emissions in non-Annex I countries are estimated to exceed Annex I emissions by about 1000 MTCO<sub>2</sub>Eq (Table 2).

Table 2: Combined Methane Baseline Emissions by Region (MTCO<sub>2</sub> Equivalent)

<b>Region</b>	<b>1990</b>	<b>2000</b>	<b>2010</b>	<b>2020</b>
Africa	135	165	209	268
Australia	45	50	69	88
China	375	412	529	667
Eastern and Central Europe	150	125	131	147
FSU	825	641	686	729
Japan	12	11	8	6
Latin America	241	304	406	529
Middle East	162	246	343	418
North America	562	532	604	618
OECD-Europe	291	267	266	272
Rest of Asia	158	191	242	303
South Asia	164	211	294	389
Annex I	1788	1555	1657	1731
Non-Annex I	1333	1601	2129	2704
<i>World</i>	<i>3120</i>	<i>3156</i>	<i>3786</i>	<i>4435</i>

On the sectoral basis, the largest methane emissions are produced in the natural gas industry, followed by the solid waste management. Emissions from coal mining that were the third in volume in 1990 are estimated to remain at roughly the same level in 2020, while emissions from waste management are expected to rise proportionally to population growth (Table 3).

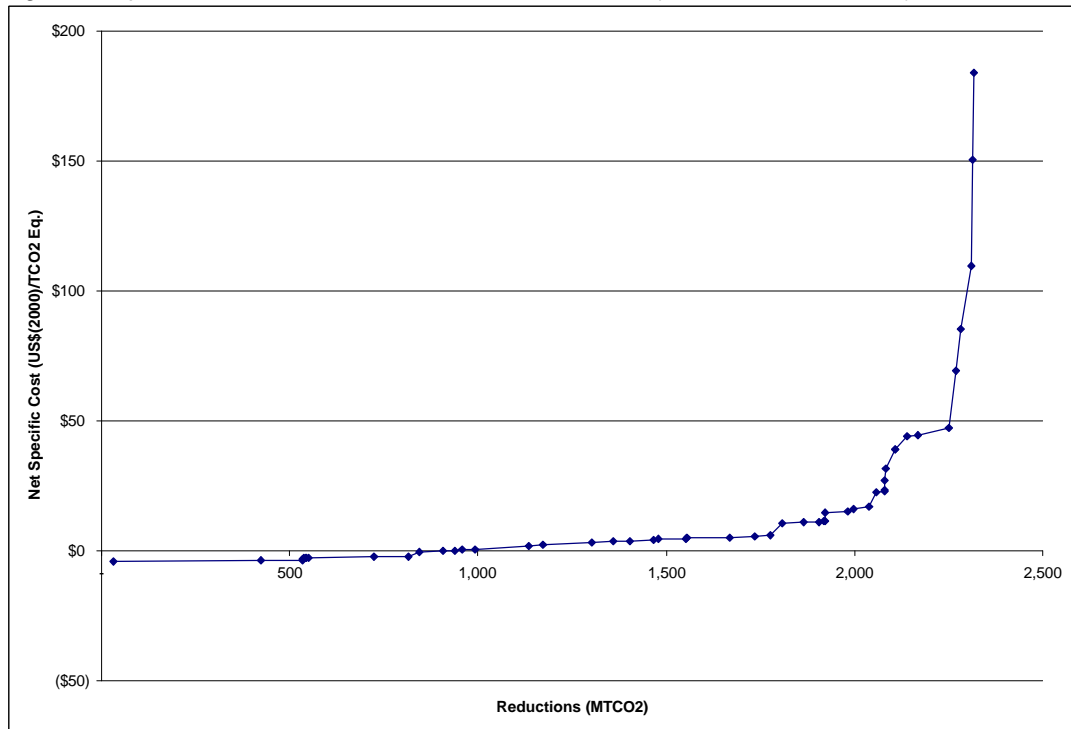
Table 3: Global Methane Baseline Emissions by Sector (MTCO<sub>2</sub> Equivalent)

Sector	1990	2000	2010	2020
Coal Mining	624	478	566	648
Oil Production, Transport, Distribution	215	241	284	342
Natural Gas Production, Transport, Distribution	969	981	1270	1540
Solid Waste Management	822	896	1042	1217
Wastewater Management	490	559	624	688

According to the combined regional MACCs (Table 4), the largest cost-effective methane emissions reductions in 2010 can be achieved in North America, followed by China and South Asia. Substantial reductions at a cost lower than \$10/tCO<sub>2</sub>Eq can be also achieved in the FSU, Latin America, and OECD-Europe regions.

On a sector-by-sector basis, the largest cost-effective reductions can be achieved in the wastewater management sector, followed by the solid waste management, natural gas and coal sectors. This result is partially explained by the assumed link between growth in wastewater-related emissions and population and also by relatively low estimated costs of collecting and utilizing methane at wastewater management facilities.

Figure 1: Option-Based 2010 MACC for Methane Sources (at 10% Discount Rate)<sup>a</sup>



<sup>a</sup> Based on regional net specific costs weighted by emission reductions attained by an option in each region. Each point represents a single option. Options with NSC > \$200/tCO<sub>2</sub>Eq. are excluded.

Table 4: Combined Methane MACCs by Region.

Regional MACCs for Year 2010, Global MACCs for 2000, 2010, 2020; Discount Rate – 10% (MTCO<sub>2</sub> Equivalent/year)

Region	Value of CO <sub>2</sub> Eq. (US \$ (2000)/TCO <sub>2</sub> Eq.)											
	(20)	(10)	0	10	20	30	40	50	100	150	200	>200
MACCs for 2010												
Africa	0	0	62	109	116	116	120	128	133	137	137	140
Australia	0	0	12	39	41	42	42	45	46	47	47	48
China	0	0	159	333	342	342	342	367	373	375	375	375
Eastern and Central Europe	0	0	45	70	74	74	76	80	82	82	82	85
FSU	0	0	59	251	272	294	295	319	326	331	331	380
Japan	0.84	3	5	6	6	6	6	6	6	6	6	6
Latin America	0	0	93	179	204	211	215	224	233	239	239	259
Middle East	0	0	64	122	144	153	161	166	170	176	176	203
North America	0	75	175	315	321	368	374	391	396	402	402	423
OECD-Europe	0	0	51	136	163	163	164	178	187	191	191	198
Rest of Asia	0	0	80	129	138	141	142	146	151	153	153	158
South Asia	0	0	119	157	163	167	169	172	174	175	175	185
Annex I	0.84	77	347	816	877	946	957	1020	1043	1059	1059	1140
Non-Annex I	0	0	577	1028	1107	1131	1148	1203	1234	1254	1255	1320
World	0.84	77	924	1844	1984	2077	2106	2223	2277	2313	2314	2460
<i>World (% of baseline)</i>	<i>0</i>	<i>2</i>	<i>24</i>	<i>49</i>	<i>52</i>	<i>55</i>	<i>56</i>	<i>59</i>	<i>60</i>	<i>61</i>	<i>61</i>	<i>65</i>
MACC for 2000												
World	1	72	791	1563	1673	1749	1770	1869	1914	1946	1946	2058
<i>World (% of baseline)</i>	<i>0</i>	<i>2</i>	<i>25</i>	<i>50</i>	<i>53</i>	<i>55</i>	<i>56</i>	<i>59</i>	<i>61</i>	<i>62</i>	<i>62</i>	<i>65</i>
MACC for 2020												
World	0.51	77	1056	2139	2312	2417	2453	2594	2659	2702	2703	2879
<i>World (% of baseline)</i>	<i>0</i>	<i>2</i>	<i>24</i>	<i>48</i>	<i>52</i>	<i>54</i>	<i>55</i>	<i>58</i>	<i>60</i>	<i>61</i>	<i>61</i>	<i>65</i>

The largest emissions of N<sub>2</sub>O from industrial processes are generated in OECD-Europe and China, followed by North America and South Asia (Table 5).

Levels of N<sub>2</sub>O abatement in different regions are proportional to corresponding baseline emissions. All N<sub>2</sub>O emission reductions can be achieved at moderate costs, under \$10 per tCO<sub>2</sub>Eq. (Table 6).

Table 5: Combined Nitrous Oxide Baseline Emissions by Region (MTCO<sub>2</sub> Equivalent)

Region	1990	2000	2010	2020
Africa	4	5	6	7
Australia	0.5	1	1	1
China	35	48	60	64
Eastern and Central Europe	11	13	15	16
FSU	23	18	16	16
Japan	10	9	10	12
Latin America	4	9	11	12
Middle East	4	8	11	14
North America	42	29	23	39
OECD-Europe	107	48	52	55
Rest of Asia	11	17	19	22
South Asia	15	26	37	42
Annex I	154	85	95	104
Non-Annex I	112	145	177	195
<i>World</i>	266	230	271	298

Table 6: Combined Nitrous Oxide MACCs by Region; Year 2010, Discount Rate – 10% (MTCO<sub>2</sub> Equivalent/year)

Region	Value of CO <sub>2</sub> Eq. (US \$ (2000)/TCO <sub>2</sub> Eq.)											
	(20)	(10)	0	10	20	30	40	50	100	150	200	>200
MACCs for 2010												
Africa	0	0	0	5	5	5	5	5	5	5	5	5
Australia	0	0	0	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53
China	0	0	0	54	54	54	54	54	54	54	54	54
Eastern and Central Europe	0	0	0	14	14	14	14	14	14	14	14	14
FSU	0	0	0	14	14	14	14	14	14	14	14	14
Japan	0	0	0	10	10	10	10	10	10	10	10	10
Latin America	0	0	0	10	10	10	10	10	10	10	10	10
Middle East	0	0	0	10	10	10	10	10	10	10	10	10
North America	0	0	0	30	30	30	30	30	30	30	30	30
OECD-Europe	0	0	0	49	49	49	49	49	49	49	49	49
Rest of Asia	0	0	0	18	18	18	18	18	18	18	18	18
South Asia	0	0	0	33	33	33	33	33	33	33	33	33
Annex I	0	0	0	117	117	117	117	117	117	117	117	117
Non-Annex I	0	0	0	130	130	130	130	130	130	130	130	130
World	0	0	0	247	247	247	247	247	247	247	247	247
<i>World (% of baseline)</i>	0	0	0	91	91	91	91	91	91	91	91	91
MACC for 2000												
World	0	0	0	209	209	209	209	209	209	209	209	209
<i>World (% of baseline)</i>	0	0	0	91	91	91	91	91	91	91	91	91
MACC for 2020												
World	0	0	0	272	272	272	272	272	272	272	272	272
<i>World (% of baseline)</i>	0	0	0	91	91	91	91	91	91	91	91	91

The current study confirms that abatement of non-CO<sub>2</sub> gases can potentially play a significant role in mitigating anthropogenic climate change. For example, the potential CH<sub>4</sub> and N<sub>2</sub>O annual emission reductions under \$10 per tCO<sub>2</sub>Eq. (2121 MTCO<sub>2</sub>Eq - in 2010 at 10% discount rate) are more than double the combined Kyoto Protocol target of all the countries that have initially joined the Protocol (annual average 2008-2012 reduction of 915 MTCO<sub>2</sub>Eq relative to 1990).

Overall, the current analysis reflects the *largest* possible emission reductions that can be obtained based on generic technical and economic characteristics of underlying abatement options. Clearly, the combined reductions that can be realized by specific projects are likely to be lower and carry higher costs due to various inefficiencies, implementation barriers, and transaction expenses. The *timing* of emission reductions can also be different from the one reflected in the current analysis. The period of time when a specific option will be actually implemented in a given region depends of a variety of economic and non-economic factors. Both, temporal changes in option costs and regional penetration could be explored as part of comprehensive region-specific techno-economic scenarios, which can use the current study as a source of starting conditions.

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