

# Methane: TAPPING THE UNTAPPED POTENTIAL

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Clean Air Task Force is a nonprofit organization dedicated to reducing atmospheric pollution through research, advocacy, and private sector collaboration.

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## Introduction

Over the past few years, the reality of global warming has become unequivocal. Steady reports of rising Arctic temperatures, disappearing glaciers, rising sea levels, and dislocated wildlife have silenced most climate change skeptics and lent a new level of urgency to the search for solutions. Much of the world's attention has focused on cutting emissions of carbon dioxide (CO<sub>2</sub>), the greenhouse gas with the most profound and lasting effect on the planet's heat exchange system. Yet the science is clear: even under the most optimistic reduction scenarios, CO<sub>2</sub> concentrations already in the atmosphere will continue to warm the earth for decades, pushing the climate toward potentially irreversible changes. Containing this warming trend over the next century to levels in the range of past human experience will likely require additional non-CO<sub>2</sub> mitigation strategies.

Methane (CH<sub>4</sub>), a powerful greenhouse gas with a much shorter lifespan than CO<sub>2</sub>, offers a clear, though under-utilized, opportunity to achieve near-term climate gains. While less abundant in the atmosphere than CO<sub>2</sub>, ton-for-ton, methane traps 25 times more heat than CO<sub>2</sub> over a 100-year period. Measured over 20 years, methane's warming impact is 72 times greater than an equivalent weight of CO<sub>2</sub>.<sup>1</sup> Because methane survives in the atmosphere for only 8-12 years (compared to more than a century for CO<sub>2</sub>), substantial emissions cuts today will diminish concentration levels within one to two decades—a critical time frame for slowing warming especially in the earth's most vulnerable regions, such as the poles.

More than half of the earth's methane output comes from human-related sources—primarily in the areas of agriculture (livestock and rice cultivation), waste management (landfills, sewage treatment, and manure), and energy (coal and oil/gas production)—and many of these allow for cost-effective reduction. Emissions collected from municipal landfills, manure storage sites or coal mines can be harnessed to generate local electricity or upgraded to produce pipeline quality natural gas. When substituted for more carbon-intensive fossil fuels, methane-based energy contributes to further greenhouse gas

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<sup>1</sup> [United Nations](#) Intergovernmental Panel on Climate Change (IPCC). Climate Change 2007: the Fourth Assessment Report (AR4).

reductions. At the same time, because CH<sub>4</sub> (as it breaks down in the atmosphere) adds to the background level of ground-level ozone pollution (a major component of smog), emissions cuts will yield significant health benefits and reduce damage to crops. Recent modeling suggests that methane reductions of 65 Mt/yr beginning in 2010 would prevent 370,000 premature deaths over the next 20 years.<sup>2</sup>

Given these advantages, methane abatement clearly belongs—alongside aggressive CO<sub>2</sub> reductions—at the center of a global climate change response. Yet efforts to reduce methane have faced barriers, and many recent opportunities to capture methane’s energy potential have been stymied. A number of obstacles have contributed to this lag, including inadequate regulation, constrained markets, a lack of public awareness of the role of non-CO<sub>2</sub> pollutants in global warming, limited technical capacity in many nations, and uncertainty about future carbon markets; the recent global credit crisis has further slowed the pace of progress.

The following pages offer an up-to-date account of methane’s potential—its contribution to climate change and the most promising targets and technologies for achieving swift, energy-wise reductions. There are critical steps that governments and the international community can take quickly, to ensure that the promise of methane is not lost in the coming decades. This discussion seeks to point the way forward, by identifying the primary barriers to global action on this potent greenhouse gas.

## **A powerful short-lived pollutant – and climate forcer**

Climate scientists have recently begun to address an unnerving truth: while drastic cuts in carbon dioxide emissions offer the only hope for long-term stabilization of the earth’s climate, they will do little to change the course of planetary warming over the next century, let alone the next 20 years. The longevity of CO<sub>2</sub> (extending anywhere from several hundred to 2000 years), which is dependent on ocean uptake, means that the hangover effect from past emissions is essentially permanent. With the Arctic heating up at twice the rate of the rest of the globe, there is a risk that melting ice sheets and thawing permafrost will trigger dangerous climate “feedbacks,” permanently altering global sea levels and weather patterns, before CO<sub>2</sub> measures have made an impact.

The potential “good news” is that much of the Arctic’s warming over the next two to three decades will not be driven by carbon dioxide, but rather by the effects of a number of

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<sup>2</sup> West, J. A., et al., Global health benefits of mitigating ozone pollution with methane emission controls. In *PNAS*, 103, 11, 2006: 3988-3993

shorter-lived pollutants—gases and aerosols that only remain in the atmosphere for periods of a few days to several years. Dramatic reductions in these pollutants could work quickly to slow the pace of polar melt, preventing further damage, as CO<sub>2</sub> cuts begin to take hold.

Short-lived pollutants act as “climate forcers” by trapping heat in the atmosphere and troposphere (i.e. the greenhouse effect) and by reducing the reflectivity of snow- and ice-covered surfaces. According to recent modeling results, the major short-lived forcers—black carbon, tropospheric ozone, and methane—have caused roughly 70% as much global warming on an annually averaged basis as CO<sub>2</sub>, since the pre-industrial era. In the Arctic, the climate response to non-CO<sub>2</sub> pollutants accounts for as much as 80% of the warming due to CO<sub>2</sub>—equal to an estimated temperature rise of 1.2 degrees C.<sup>3</sup>

Of all the non-CO<sub>2</sub> forcers, methane has the greatest impact on the planet as whole. Although much shorter-lived than CO<sub>2</sub>, methane’s roughly 8-12 year lifespan (compared to a few days to roughly a month, respectively, for black carbon and ozone) allows for atmospheric concentrations to be “globally well-mixed”: emissions from any locale will have equal impact on the global climate. By contrast, black carbon’s high warming potential stems in part from its effects on the Arctic heat exchange system (and possibly on glaciers worldwide) through deposition of soot particles onto snow and ice. Hence, BC emissions from high northern latitudes have greater climate significance than those from points further south. Regional tropospheric ozone concentrations are similarly determined by geographically and seasonally specific emissions of short-lived ozone precursors (i.e. volatile organic compounds and oxides of nitrogen).

Methane warms the planet through a number of direct and indirect effects. Once released, CH<sub>4</sub> acts as a potent greenhouse gas, absorbing more long-wave radiation, on a molecule-per-molecule basis, than CO<sub>2</sub>. Eventually CH<sub>4</sub> is oxidized in the atmosphere through a chemical reaction with hydroxyl radicals, producing CH<sub>3</sub> and water. When this reaction occurs in the presence of nitrogen oxides and sunlight, it leads to the formation of ozone molecules in the troposphere—another source of radiative forcing, as well as of unhealthy air quality. According to IPCC estimates, methane emissions account for as much as half of the increase in tropospheric ozone since 1750.<sup>4</sup>

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<sup>3</sup> Quinn, P. K., et al. Short-lived pollutants in the Arctic: their climate impact and possible mitigation strategies. In *Atmos. Chem. Phys.*, 8, ,2008: 1723-1735.

<sup>4</sup> Prather, M., et al., Atmospheric chemistry and greenhouse gases, In: *Climate Change 2001: The Scientific Basis, Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change*, Cambridge Univ. Press, Cambridge and New York, 2001.

A further way in which methane contributes to warming is by using up the atmospheric supply of hydroxyl radicals, which might otherwise provide a sink for additional compounds that affect climate. Because hydroxyls are also necessary for the oxidation of sulfur dioxides (SO<sub>2</sub>) to produce sulfates—reflective aerosols that exert a net cooling effect—CH<sub>4</sub> reduces sulfate concentrations, thus resulting in more warming. A recent climate model calculation suggests that methane’s depletion of atmospheric hydroxyls may substantially increase its 100-year climate forcing contribution relative to CO<sub>2</sub>, well above the IPCC’s most recent estimate of 25.<sup>5</sup>

## Anthropogenic Methane on the Rise

Methane forms when organic matter decomposes in the absence of oxygen, such as in wetlands, rice fields or the digestive systems of certain animals; it also results from the combustion of carbon-based fuels. Methane was present in high concentrations when life first appeared on earth, some 3.5 billion years ago. Volcanic activity released the earliest methane into earth’s atmosphere, and ancient bacteria subsequently added to methane concentrations by converting hydrogen and carbon dioxide into methane and water. With no oxygen, methane levels were 1,000 times greater than they are today.

But for most of the planet’s history methane concentrations have remained much lower than they are now. Analysis of air bubbles trapped in glaciers indicates that CH<sub>4</sub> is more abundant in the earth’s atmosphere today than at any time over the last 400,000 years.<sup>6</sup> During glacial periods, CH<sub>4</sub> levels in the atmosphere hovered at around 350 parts per billion (ppb), while inter-glacial levels reached roughly 700 ppb due to increases in natural emissions from northern latitude wetlands (as well as from oceans, termites, wildfires and wild ruminant animals).<sup>7</sup> Atmospheric concentrations of methane are currently at 1745 parts per billion—an increase of 150% since the start of the industrial era (1750). Anthropogenic sources have caused most of this steep rise.

While wetlands continue to provide the largest single source of atmospheric methane, human-related activities now account for well over half of global CH<sub>4</sub> emissions. Livestock contribute the largest anthropogenic portion, roughly 29%, according to USEPA

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<sup>5</sup> Shindell, D. T., et al., Improved attribution of climate forcing to emissions. In *Science* 326, 2009.

<sup>6</sup> National Research Council (NRC), *Climate Change Science: An Analysis of Some Key Questions*. National Academy Press, Washington D.C., 2001.

<sup>7</sup> Saphni, R. et al., Atmospheric methane and nitrous oxide of the late Pleistocene from Antarctic ice cores. *Science* 310, 2005: 1317-1321; Also, Dallenbach, A. et al. Changes in the atmospheric CH<sub>4</sub> gradient between Greenland and Antarctica during the last glacial and the transition to the Holocene. *Geophys. Res. Lett.* 27, 2000: 1005-1005.

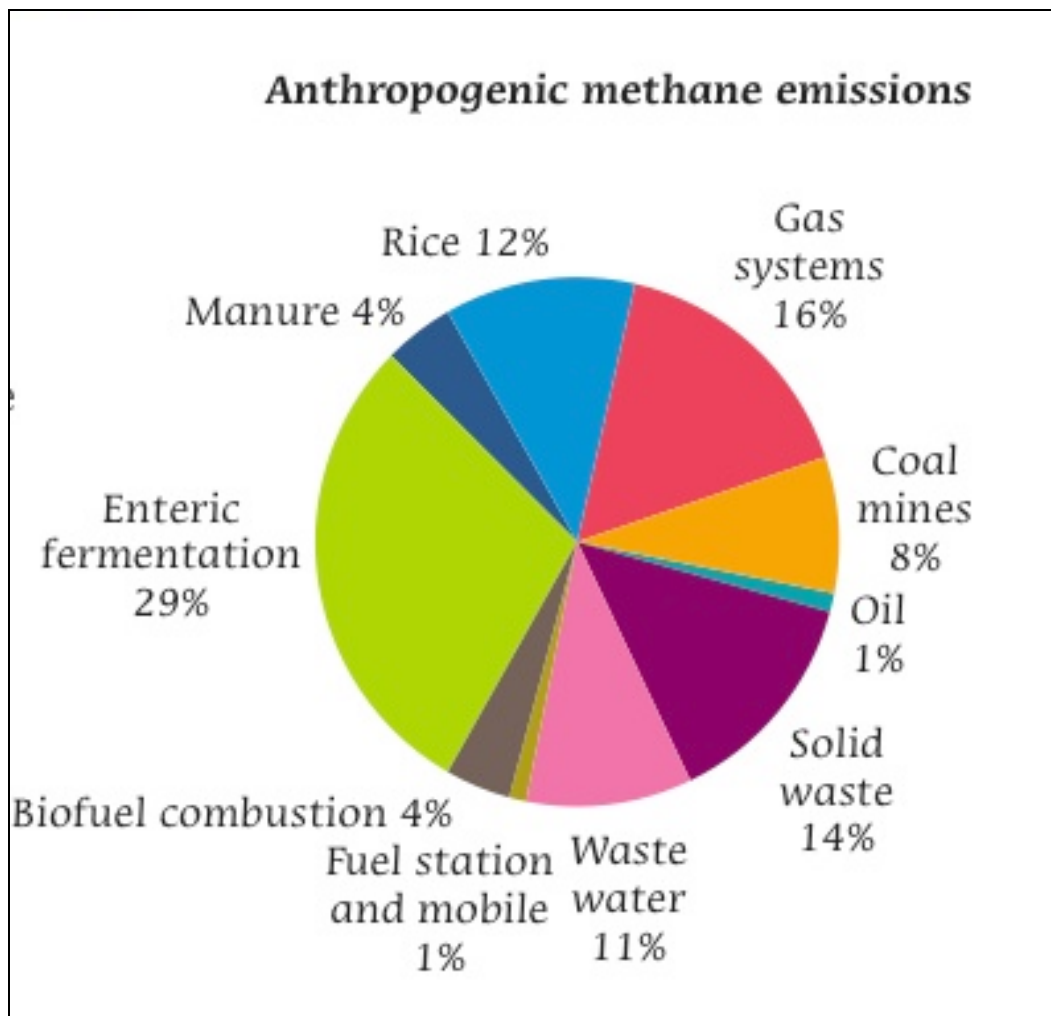
estimates.<sup>8</sup> Microbes in the stomachs of cows (as well as other ruminants such as sheep, goats, buffalo and camels) produce methane by fermenting food during digestion—a process known as enteric fermentation; emissions exit when the animals exhale or belch. Other agricultural sources include rice cultivation and cattle manure, which correspondingly produce 12% and 4% of global anthropogenic emissions.

Fossil fuel production accounts for the second greatest share of human-related methane—25%. Natural gas and oil systems contribute the bulk of these emissions (17%). Because CH<sub>4</sub> makes up 87% of natural gas, leaks in natural gas pipelines or compressor stations (where the gas gets pumped through the pipeline) regularly allow “fugitive methane” to escape into the atmosphere. Methane emissions are also released during routine pipeline venting for maintenance reasons. Since oil and gas often exist in conjunction, oil field operations may emit methane during the ventilation of oil wells, storage tanks, and other production-related equipment, as well as during refinement and transportation of crude oil. Meanwhile, coal mining produces an additional 8% of anthropogenic methane worldwide. CH<sub>4</sub> is a byproduct of “coalification”—the transformation of plant material into coal. In underground mines, the presence of methane creates an explosive hazard to miners, and thus must be removed through ventilation systems, which, in turn, release the CH<sub>4</sub> emissions into the atmosphere. Methane also escapes through natural fissures in abandoned and surface mines.

Waste treatment—the decaying of organic matter under anaerobic conditions—contributes another large quantity of anthropogenic methane (25%). Landfills, mostly in developed countries, account for the bulk of solid waste emissions—14%. A landfill’s size and age, combined with the quantity of deposited waste, determine the level of methane output. (Because deeply buried waste takes many years to decompose fully, past landfill disposal practices affect present-day emissions.) Wastewater treatment produces an additional 11% of human-related CH<sub>4</sub>; latrines, open sewers and lagoons emit a substantial share of emissions in developing countries, while industrial wastewater from facilities such

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<sup>8</sup> US EPA, Global Anthropogenic Non-CO<sub>2</sub> Greenhouse Gas Emissions: 1990-2020. Report from the Office of Atmospheric Programs, Washington, DC, 2006.



**Source:** USEPA 2006, IEA 2009<sup>9</sup>

as food processing and pulp and paper plants may also emit significant amounts of methane in parts of the developed world.

According to data compiled by the US Environmental Protection Agency, methane emissions from human-related sources could rise 23% from 2005 to 2020—totaling 7,904 million metric tons of equivalent CO<sub>2</sub>.<sup>10</sup>

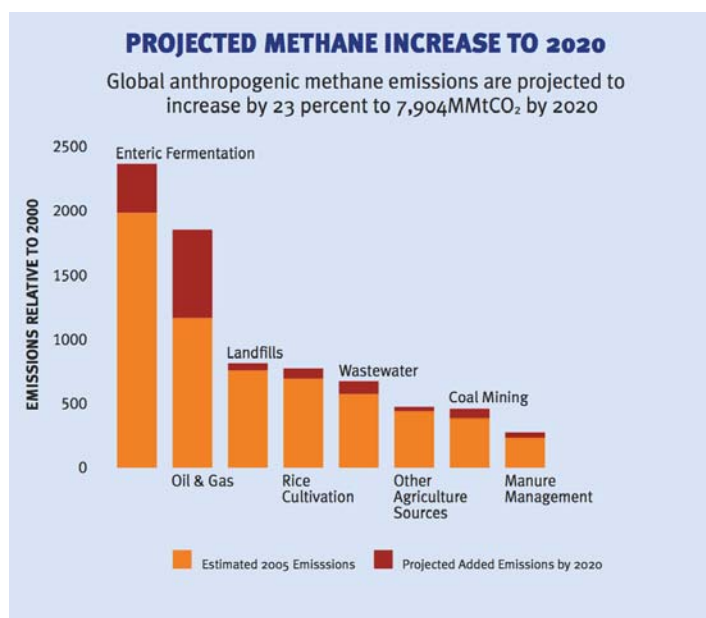
While projection scenarios for methane vary—due to different measurement methodologies, timeframes, and assumptions about baseline and future emissions—all studies predict a moderate to steep rise in emissions over the coming decades. A projected

<sup>9</sup> US EPA. Global Mitigation of Non-CO<sub>2</sub> Greenhouse Gases. Report from the Office of Atmospheric Programs (6207J), Washington, DC, June, 2006; International Energy Agency (IEA). Energy Sector Methane Recovery and Use: The Importance of Policy. Paris, 2009.

<sup>10</sup> Gunning, Paul. Methane to Markets: Accomplishments and Future Directions. Power Point Presentation. US EPA, Climate Change Division, Washington, DC, February 4, 2009.



35% rise in anthropogenic methane between 2000 and 2030,<sup>11</sup> correlates with a radiative forcing effect of between .125-.167 Watts/m<sup>2</sup> and a consequent temperature rise from 0.09 to 0.12 degrees C<sup>12</sup> (given an assumed climate sensitivity of 0.75 degrees (+/- 0.25) C per W/m<sup>2</sup><sup>13</sup>) Curbing these emissions could remove a measurable portion of anticipated near-term warming.



Source: US EPA<sup>14</sup>

The possibility for reductions differs widely across sectors and between countries. While enteric fermentation in livestock continues to comprise the greatest source of anthropogenic methane, it does not—thus far—present an easy target for mitigation. By contrast, natural gas operations—which contribute a large and growing share of global CH<sub>4</sub> emissions—appear to offer ready opportunities for cost-effective reductions in the US, Europe, Russia and elsewhere. Coal, with only 6% of the global total, has increasing promise for abatement, especially in China, Australia and the US, while agricultural waste

<sup>11</sup> Hoglund\_Isaksson, L. and Mechler, R. Interim Report IR-05-54: The Gains Model for Greenhouse Gases - Version 1.0: Methane (CH<sub>4</sub>). International Institute for Applied Systems Analysis (IIASA), Laxenburg, Austria, 2005.

<sup>12</sup> Dentener, F., et al. The impact of air pollutant and methane emission controls on tropospheric ozone and radiative forcing: CTM calculations for the period 1990-2030. *Atmos. Chem. Phys.*, 5, 2005: 1731-1755.

<sup>13</sup> Hansen, J. Climate Threat to the Planet: Implications for Energy Policy and Inter Generational Justice. Bjerknes Lecture, American Geophysical Union, San Francisco, CA, December 17, 2008.

<sup>14</sup> Global Mitigation of Non-CO<sub>2</sub> Greenhouse Gases, op. cit.

projects provide a fruitful source of pollution reduction in Southeast Asia and other parts of developing world. The relative promise of a particular reduction approach reflects the availability of technology, prospects for cost-effective emissions recovery, and the likelihood of adoption by relevant industries, nations and communities.

## Measuring Mitigation Potentials

Researchers have applied the concept of marginal abatement costs (MACs) in order to assess a given strategy's economic reduction potential. They first determine the baseline reduction level for a given methane source assuming no price signals exist from greenhouse gas credits to motivate emissions cuts—hence a CO<sub>2</sub> equivalent (CO<sub>2</sub>e) price of \$0 (per ton). Reductions achieved at this point on the graph would be due to a combination of available markets, increased energy efficiencies, conservation of production materials, or all three factors. As the CO<sub>2</sub>e price rises, more reductions are expected, with the cheapest options being adopted first. The points on the curve below \$0 represent mitigation options that are already cost-effective (i.e. “no-regret” options) but have not yet been implemented because of non-monetary barriers. The calculations make no assumptions about how existing policies might encourage implementation of reduction options in a given country or sector.

The MAC data included in this discussion are not meant as definitive assessments of different options, but rather offer general estimates of reduction potentials. Moreover, as technology improves and implementation experience grows over time, the costs of abatement can be expected to decline.

## Agriculture

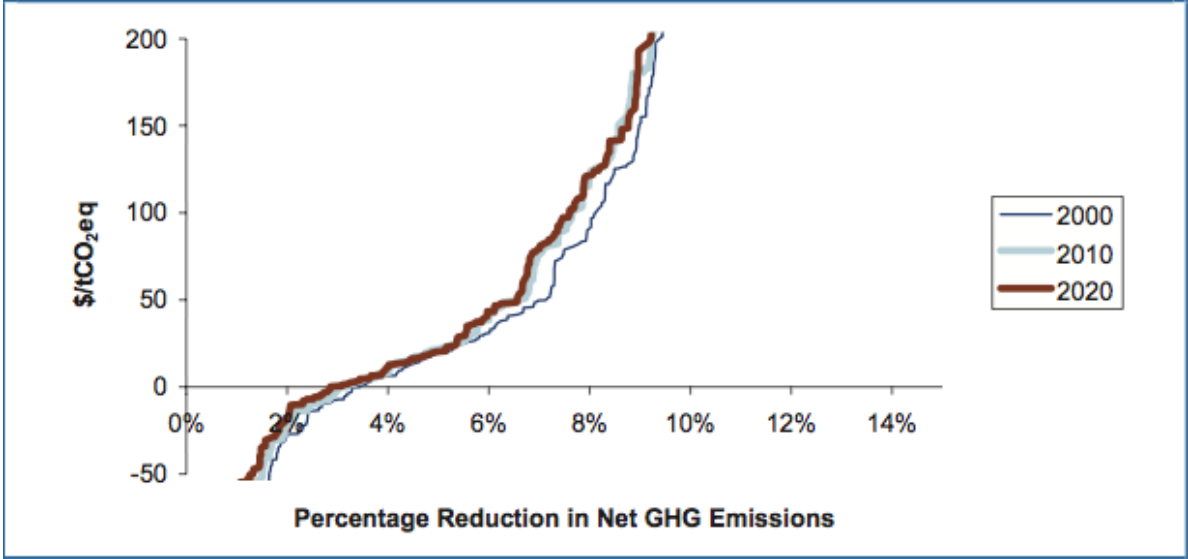
Any increases in agriculture-based methane will come primarily from ruminant livestock in the coming decades. Because food that is producing methane in a cow's fore-stomach (or *rumen*) is not contributing to the animal's growth or milk production, enteric CH<sub>4</sub> emissions represent an economic loss to farmers. Changing the quality or quantity of animal feed or altering the animal's metabolism or growth rate can serve to reduce methane output relative to overall livestock production.

The primary strategies for mitigating enteric methane currently include: 1. Increasing the energy content and digestibility of feed in order to improve food conversion efficiency. 2. Using natural or synthetic compounds (such as antibiotics or bovine growth hormone, BST) to enhance animal growth or lactation and thus increase animal productivity. 3. Supplementing feed in order to combat nutrient deficiencies that prevent

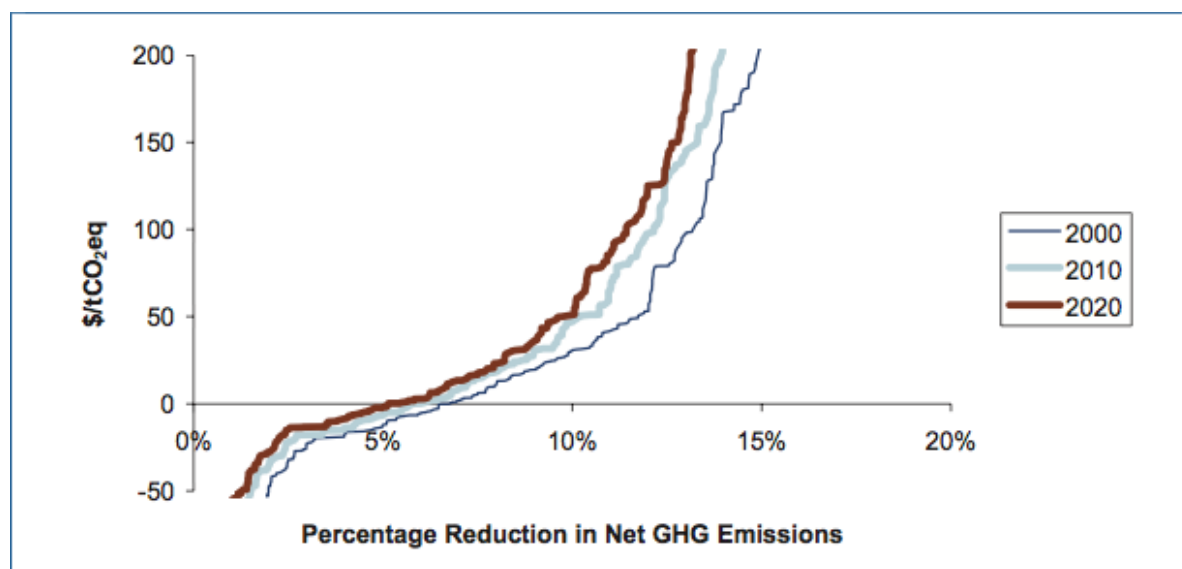
animals from fully utilizing the energy potential in their feed. 4. Changing herd management (e.g., using intensive grazing). While these approaches may reduce CH<sub>4</sub> emissions per unit of beef or milk, since they actually increase average animal size, many in turn increase CH<sub>4</sub> output per animal. Thus, achieving methane reductions at the national or regional level requires a sufficient decrease in the number of animals to more than offset the increase in emissions per head of cattle.

The following graphs show the percentage of global enteric emissions reductions achievable at different costs (in \$/tCO<sub>2</sub>e), when holding the number of animals constant and when holding production constant.

**Global Marginal Abatement Curve for Greenhouse Gas Emissions from Livestock Management, Number of Animals Held Constant**



## Global Marginal Abatement Curve for Greenhouse Gas Emissions from Livestock Management, With Reduction in Number of Animals



Source: US EPA, 2006<sup>15</sup>

A 7% reduction can occur at zero cost by 2020, given a necessary decline in the total number of animals—compared to 3.5% when livestock numbers remain the same. The bulk of reductions are achieved in the low cost range, with higher CO<sub>2</sub>e prices yielding only modest gains. (A peak price of \$200/tCO<sub>2</sub>e achieves only a 15% cut in emissions.) While opportunities are limited, so far options for mitigating CH<sub>4</sub> from ruminants show greater promise in industrialized nations (particularly the United States and the EU-15) than in the developing world. The wide dispersion of livestock and the entrenchment of local feeding practices in large-emitter countries, such as China, India and Brazil, pose challenges to the implementation of enteric CH<sub>4</sub> solutions.<sup>16</sup>

By contrast, livestock manure offers a more attainable, though smaller-scale, mitigation target in developing countries. Anaerobic digestion technology allows for the reduction, capture and clean-energy use of manure-based CH<sub>4</sub>, which in 2005 totaled more 230 MMT CO<sub>2</sub>e. Anaerobic digesters work best in warm humid climates and hence are highly applicable in Southeast Asian countries. Farms that install the digesters can benefit from a cost-effective source of gas to generate electricity or to provide cooking fuel to households, eliminating the harmful health effects of wood burning stoves. Another

<sup>15</sup> “Global Mitigation of Non-CO<sub>2</sub> Greenhouse Gases,” op. cit.

<sup>16</sup> Kempfert, C. and W-P Schill. An analysis of Methane Mitigation as a Response to Climate Change. Copenhagen Consensus on Climate. Copenhagen Consensus Center, 2009. [www.copenhagenconsensus.com](http://www.copenhagenconsensus.com).

method of capturing manure-CH<sub>4</sub> is through the use of covered lagoons: the cover captures the biogas produced by anaerobic bacteria in the water. Moreover, by improving management of animal waste, methane mitigation practices can reduce contamination of local water supplies. The US EPA and the World Bank are conducting feasibility assessments and technology demonstration projects in 11 countries in Southeast Asia, Latin America and Eastern Europe.<sup>17</sup>

Finally, rice cultivation presents a sizeable emissions source with mitigation challenges similar to those facing enteric fermentation. While research into rice field mitigation is still evolving, preliminary findings suggest that social and cultural barriers—including traditional cultivation practices that rely on monsoons or reliable rainy seasons, as well as problems of enforcement and monitoring—will likely hinder reductions at this methane source.<sup>18</sup>

Like wetlands, rice fields produce methane through the decomposition of biomass in the absence of oxygen. When fields are flooded, decaying plant matter depletes the O<sub>2</sub> present in the soil and floodwater, causing anaerobic conditions to develop in the soil—the perfect conditions for methane production. The most effective means of reducing rice field emissions involve changes in water management, such as: implementing full mid-season drainage of fields (China currently drains 80% of rice fields, but other Asian countries drain 0%); keeping surface water levels low at 5-10 cm (“shallow flooding”); and applying off-season straw (which reduces the availability of dissolved organic carbon, required for methane production)<sup>19</sup> Estimates of reduction potentials for rice show the highest returns in the low-cost range, with potentials hardly increasing at higher prices.<sup>20</sup>

Overall, the combined reduction potentials for global agricultural methane in 2020, based on baseline emissions in 2000, range from around 7% at zero cost to 14% at \$60/tCO<sub>2</sub>e<sup>21</sup>—suggesting that mitigation strategies in this area, while still developing, could provide a significant low-cost component to a global climate change response.

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<sup>17</sup> See: [http://www.epa.gov/methanetomarkets/pdf/2009-accomplish-report/agriculture\\_highlights.pdf](http://www.epa.gov/methanetomarkets/pdf/2009-accomplish-report/agriculture_highlights.pdf)

<sup>18</sup> Kemfert and Schill, op. cit.

<sup>19</sup> US EPA Global Mitigation of Non-CO<sub>2</sub> Greenhouse Gases, op. cit.

<sup>20</sup> DeAngelo, B.J. et al., 2006: Methane and nitrous oxide mitigation in agriculture, *The Energy Journal*, Multi-Greenhouse Gas Mitigation and Climate Policy, Special Issue 3, 89-108, an, Smith, P. et al. 2009: Greenhouse gas mitigation in agriculture, *Philosophical Transactions of the Royal Society B*, **363**, 789–813; and US EPA. Global Mitigation of Non-CO<sub>2</sub> Greenhouse Gases, op. cit.

<sup>21</sup> US EPA. Global Mitigation of Non-CO<sub>2</sub> Greenhouse Gases, op. cit.

## Landfills

Solid waste treatment comprises a far smaller fraction of global anthropogenic CH<sub>4</sub> than agriculture, but offers relatively higher mitigation potential. Because landfills present a confined source point of methane emissions, they allow for straightforward capture techniques. Moreover, landfill gas (LFG), which contains approximately 50% CH<sub>4</sub> and 50% CO<sub>2</sub>, provides a valuable renewable energy source.

The most common method of collecting landfill gas involves drilling vertical wells into the waste and then connecting the wellheads to lateral pipes that—through the use of a blower or vacuum system—transport the gas to a collection point. The area of gas extraction is “capped,” closing it off to additional waste disposal. (Another approach, primarily used in deep landfills and areas of active filling, relies on horizontal pipes installed in trenches within the waste.) Once captured, LFG can either be flared or used in an energy recovery system to generate heat or electricity. In the US, many municipal landfills provide LFG to the local electricity grid or to adjacent production facilities; some manufacturing plants choose to locate near a landfill for the express purpose of using LFG as a cost-effective renewable fuel. LFG can also be cleaned and purified to produce high quality (or high Btu) gas that can be injected into a natural gas pipeline.

The climate benefits of landfill gas recovery include both the removal of CH<sub>4</sub> emissions that would otherwise enter the atmosphere and the potential replacement of more carbon-intensive fuels. According to the US EPA, which has been involved with LFG recovery over the past 15 years, the annual greenhouse gas emission reduction benefits of a typical 3 megawatt electricity generation project using LFG equals about 16,000 tons of CO<sub>2</sub> a year—offsetting the consumption of almost 15 million gallons of gasoline or the equivalent of powering 1,900 homes.<sup>22</sup>

Emissions levels from solid waste vary significantly between countries and regions. Because CH<sub>4</sub> production requires anaerobic conditions, landfills (which seal organic matter underground) emit higher amounts of methane than do open dumps—the predominant form of waste disposal in poorer societies. As a country’s population increases and its economy grows, governments tend to develop more modern (sanitary) waste management systems to deal with rising amounts of municipal trash. CH<sub>4</sub> emissions from landfills are thus likely to rise before cost-effective abatement and capture technologies have taken hold. The US EPA projects that—after the United States—Africa

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<sup>22</sup> See: <http://www.epa.gov/lmop/benefits.htm>

will have the highest municipal solid waste emissions by 2020, followed by China, Eastern Europe, and the Russian Federation.<sup>23</sup>

Mitigation potentials for landfill methane reflect the total level of emissions and the availability of technology for productive gas recovery. In the US, methods of landfill gas capture and energy conversion are well established, and regulations on hazardous non-CH<sub>4</sub> emissions (under the Clean Air Act's "Landfill Rule" passed in 1996 and 1999), have facilitated methane reduction. The European Union nations also have regulations that serve to constrain landfill CH<sub>4</sub> growth and encourage cost-effective capture. In developing economies, the prospects for landfill CH<sub>4</sub> reductions will depend on rates of access to mitigation technology as well as government policies.

## Wastewater treatment

Opportunities to capture methane emissions from wastewater treatment systems are much more limited in both the industrialized and the developing world. Centralized sewage treatment plants can control anaerobic conditions and thus have the potential to capture and use CH<sub>4</sub>, but those options would require large-scale structural changes are likely to be economically prohibitive. Meanwhile, smaller decentralized sewage systems in developing countries have little control over aerobic versus anaerobic decomposition in wastewater and thus have few feasible means of capturing methane emissions. Moreover, in poorer societies, improving wastewater treatment for the sake of disease prevention will take precedence over the benefits associated with CH<sub>4</sub> reduction.<sup>24</sup>

At the same time, with the use of Clean Development Mechanism (CDM) credits, there are opportunities for wastewater methane abatement in societies that are building their first wastewater plants. Such approaches would bring significant co-benefits in terms of health and development, alongside methane reductions.

## Energy

Methane emissions from oil and gas systems will contribute the greatest increase to anthropogenic methane over the next decade—a rise of 57%—from 2005 to 2020, according to US EPA estimates. Natural gas production and transmission make up the bulk of these emissions, but some are also released from oil production fields. The top emitters currently include Russia, the United States, Iran, Mexico and the Ukraine; but a

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<sup>23</sup> US EPA. Global Mitigation of Non-CO<sub>2</sub> Greenhouse Gases, op. cit.

<sup>24</sup> *ibid.*

number of large developing countries, such as China and Brazil, are expected to experience the highest growth rates in the coming years.<sup>25</sup> Fortunately, methods for controlling “fugitive methane” emissions in the energy sector are increasingly available and cost-effective.

The most promising mitigation options include relatively straightforward steps to prevent and manage leaks. Technology upgrades, such as, conversion to low-bleed pneumatic devices, for instance, or installation of dry seals on centrifugal compressors, can significantly lower the amount of CH<sub>4</sub> that escapes during oil and gas production. In addition, techniques for detecting and measuring gas leakages have advanced significantly in recent years. It is now possible to use infrared cameras to see otherwise invisible hydrocarbon emissions; through the lens, the emissions appear as black smoke. When used in conjunction with emission measurement technologies, these cameras can enormously increase producers’ awareness of emissions sources and volumes. Direct inspection and maintenance programs further ensure that accurate and cost-effective leak repairs take place. In countries with large oil and gas infrastructures, the use of these programs has the potential to yield substantial methane reductions and gas savings.<sup>26</sup>

While most of the efficiency gains from improved leak detection arise from the avoidance of lost gas, the oil and gas industry can also use the fugitive gas directly or re-inject it into oil fields to enhance oil recovery. Flaring is also an option that prevents the CH<sub>4</sub> from entering the atmosphere, but without making use of the economic value of emissions.

The table below shows three sets of estimates of baseline emissions and economic mitigation potentials for natural gas in 2020.<sup>27</sup> While there is marked discrepancy between the studies’ estimates of high-price reduction potentials, the data sets concur in the lower cost range, indicating that substantial reductions in CH<sub>4</sub> emissions could be achieved at \$0-\$30/tCO<sub>2</sub>e.

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<sup>25</sup> *ibid.*, IEA, *op. cit.*

<sup>26</sup> IEA, *op. cit.*

<sup>27</sup> Table compiled by Kemfert and Schill, *op. cit.*, based on data from Delhotal, K.C. et al., Mitigation of methane and nitrous oxide emissions from waste, energy and industry, *The Energy Journal*, Multi-Greenhouse Gas Mitigation and Climate Policy, Special Issue 3, 2006: 45-62, and IEA. Building the Cost Curves for the Industrial Sources on Non-CO<sub>2</sub>-Greenhouse Gases. Report Number PH4/25, October 2003, International Energy Agency Greenhouse Gas R&D Programme, 2003.



**Natural Gas—Projected Baseline Emissions and Economic Mitigation Potentials at Different CO<sub>2</sub> prices<sup>28</sup>**

Source	Year	Baseline in MtCO <sub>2</sub> -eq	Value of CO <sub>2</sub> in US\$/tCO <sub>2</sub> -eq					
			0	15	30	45	60	200
			Economic mitigation potentials in MtCO <sub>2</sub> -eq					
IEA 2003	2020	1,540	182	470	585	623	630	637
Delhotal et al. 2006	2020	379						144
USEPA 2006	2020	1,696	173	428	564	651	913	

Though coal’s global methane contribution is substantially smaller than that of natural gas, it provides another highly promising mitigation target. Coal mine ventilation systems—installed to protect mine workers from underground explosions—release methane and small amounts of associated gases into the atmosphere. CH<sub>4</sub> emissions also seep out of diffuse crevices in abandoned and surface mines. Coal mine methane (CMM) is projected to grow by 20% from 2005 to 2020; China, followed by the United States, India and Australia, will produce the greatest share.<sup>29</sup>

A number of methods are currently available for cost-effective recovery and use of coal mine methane. Ventilation air contains methane at very low concentrations (1%), creating a challenge for emissions collection. Technologies exist to oxidize this dilute methane and, in the process, produce thermal energy for heat, electricity or refrigeration. The first commercial scale project converting ventilation air methane (VAM) to electricity is currently operative in Australia.<sup>30</sup>

Methane capture can also take place during mine degasification. Degasification systems are used to augment ventilation in especially gassy mines. The degassing process can take place in the pre-mining phase: technicians can drill holes and capture methane before operations begin. More recently, advanced coal seam methane recovery drilling techniques have been applied outside of mines to degasify coal seams well ahead of mining operations. After capture, the methane gas can be purified to remove contaminants and—depending on concentrations and quality—used for a variety of purposes (such as power

<sup>28</sup> Table compiled by Kemfert and Schill, *op. cit.*, based on US EPA 2006 data.

<sup>29</sup> US EPA, *Global Mitigation of Non-CO<sub>2</sub> Greenhouse Gases*, *op. cit.*, and IEA, 2009, *op. cit.*

<sup>30</sup> See: <http://www.environment.gov.au/settlements/industry/ggap/bhp.html>

generation, district heating, boiler fuel, and town gas) or sold to natural gas pipeline systems. It can also provide a heat source for mine ventilation or vehicle fuel, in the form of compressed or liquefied natural gas, among other uses.<sup>31</sup>

The table below<sup>32</sup> shows baseline emissions and economic mitigation potentials for coal mining at different CO<sub>2</sub> prices. The maximum reductions are reached at \$15/tCO<sub>2</sub>e: rising prices do not achieve further CH<sub>4</sub> cuts.

**Coal Mining—Projected Baseline Emissions and Economic Mitigation Potentials at Different CO<sub>2</sub> prices<sup>33</sup>**

Source	Year	Baseline in MtCO <sub>2</sub> -eq	Value of CO <sub>2</sub> in US\$/tCO <sub>2</sub> -eq					
			0	15	30	45	60	200
			Economic mitigation potentials in MtCO <sub>2</sub> -eq					
IEA 2003	2020	648	140	418	418	418	418	418
Delhotal et al. 2006	2020	161						129
USEPA 2006	2020	450	65	359	359	359	359	

**Summing it up**

Viewed as a whole, the available approaches to methane mitigation hold clear promise for reducing a sizeable portion of global warming emissions over the next two decades. Recent estimates by the US EPA and IIASA show that methane reductions equivalent to 2.1-2.7 Gigatons of CO<sub>2</sub> annually by 2020 could be achieved for around 2 billion dollars per year over 10-20 years<sup>34</sup>. This is a small fraction of the estimated value of US and EU carbon

<sup>31</sup> IEA, 2009, op. cit.

<sup>32</sup> Kemfert and Schill 2009

<sup>33</sup> Table compiled by Kemfert and Schill, op. cit., based on US EPA 2006 data.

<sup>34</sup> See US EPA, Global Mitigation of non-CO<sub>2</sub> Greenhouse Gases, op. cit., and Amann M, Methane Emissions Reduction Potentials and Costs: A discussion on Near-term Strategies for Slowing Warming in the Arctic: Focus on Methane. IIASA, Washington, DC, February 4, 2009.

markets during this period and roughly equal to all US CO<sub>2</sub> emissions from the power sector in 2008.<sup>35,36</sup>

Some sources clearly offer more fruitful targets than others. While livestock and rice cultivation have high baseline emissions, their reduction potentials are limited by social factors (i.e. by entrenched dietary habits and crop cultivation practices) and by the wide dispersal of emission source points. By contrast, solid waste, natural gas, and coal mining have significantly higher relative low-cost reduction rates, while natural gas (and to a lesser extent landfills) also offers ascending reduction potentials at higher prices.

The table below shows the distribution of mitigation levels in 2020 for the five major anthropogenic source areas at different CO<sub>2</sub>e prices in dollars.

### Summary of Economic Mitigation Potentials At or Below Different CO<sub>2</sub> Prices<sup>37</sup>

Sector	Baseline 2020 in MtCO <sub>2</sub> -eq	Value of CO <sub>2</sub> in US\$/tCO <sub>2</sub> -eq				
		0	15	30	45	60
		Absolute economic mitigation potentials in MtCO <sub>2</sub> -eq				
Livestock management	2,867	83	126	158	175	192
Rice management	1,062	114	235	238	259	259
Solid waste management	817	97	332	405	464	717
Coal mine methane	450	65	359	359	359	359
Natural gas	1,696	173	428	564	651	913
Sum	6,891	531	1,480	1,723	1,908	2,439

### Addressing the Barriers

In 1997, the United Nations Framework Convention on Climate Change included methane in the “basket” of greenhouse gases targeted for reduction under the Kyoto Protocol. Emitters within the signatory nations would be able to receive reduction credits (CERs) for methane cuts, which, under certain conditions, could be substituted for more costly CO<sub>2</sub>

<sup>35</sup> Some carbon market analysts project that, even without US participation, global markets will reach \$550bn annually by 2012 and a little over \$2 trillion by 2020 See <http://carbon.newenergyfinance.com/?p=about&i=pressreleases>.

<sup>36</sup> In 2008, US power sector CO<sub>2</sub> emissions were roughly 2.5 Gigatons. See: <http://www.eia.doe.gov/oiaf/1605/flash/pdf/flash.pdf>

<sup>37</sup> Table compiled by Kemfert and Schill, op. cit., based on US EPA 2006 data.

cuts. Yet, in the ensuing years, international efforts to curb CH<sub>4</sub> emissions have been slow to emerge and limited (in scope) relative to CH<sub>4</sub>'s climate significance.

A number of barriers have kept methane on the margins of global climate change strategy. First, while the Kyoto terms provide flexibility to countries facing emission limits, they restrict which sources of methane will qualify for reduction credits under the Clean Development Mechanism (CDM). (The CDM allows countries with more developed economies to offset their emissions limits by financing emission reduction projects in developing countries.) For instance, the protocol does not include methane projects that capture emissions for fuel—an exclusion that limits the attractiveness of methane mitigation to potential investor countries.

At the same time, there has been little incentive on the part of climate advocates to change the status of methane under the Protocol to more accurately reflect CH<sub>4</sub>'s global warming potential (GWP). The current GWP “credit” for methane of 21 CO<sub>2</sub>e is based on a 100-year time frame and thus does not capture methane's near-term potential to slow warming in sensitive areas such as the Arctic and Amazon—i.e. 72 times CO<sub>2</sub> over 20 years, 100 times CO<sub>2</sub> over 5 years. (Indeed, it does not even reflect growing scientific knowledge of methane's actual 100-year global warming potential, which the 2007 IPCC assessment placed at 25 and more recent research by Shindell, et al. suggests may exceed 30.<sup>38</sup>). Many global warming activists have feared that a greater emphasis on methane, and other short-lived pollutants, will detract attention from the primary goal of CO<sub>2</sub> abatement. In recent years, some of this resistance has begun to give way in the face of accelerated Arctic warming and increased awareness of the role of short-lived climate forcers as a necessary and parallel focus to action on CO<sub>2</sub>. Nevertheless, many practical hurdles remain.

Because most methane projects do not pay for themselves in captured energy value alone, they rely on revenues from certified emission reduction credits (CERs). Each ton of avoided CO<sub>2</sub>e emissions earns one CER credit, which can be sold on the carbon trading market as an offset to achieve Kyoto targets. But getting projects off the ground can be costly. The Kyoto mechanisms do not provide front-end funding for projects, and the certification process itself can be expensive and time-consuming. In the US, where no compliance market yet exists, potential investors may be unwilling to commit to methane recovery ventures due to uncertainty about the total amount of recoverable emissions or the future carbon trading price.

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<sup>38</sup> Shindell, D. T., et al. *op. cit.*

There are legal and procedural snags as well. Landfill projects often face difficulties gaining access to the local electricity grid in order to sell back power generated from captured methane. This problem can also afflict gas and coal mine methane ventures. In some regions of the world gas companies restrict oil well produced gas from pipelines, and in other regions, gas pricing structures may offer no incentives to locate and seal leaks. In the case of coal mine methane, ambiguity surrounding the ownership rights to coal mine methane emissions can stall project implementation. Finally, a lack of clarity about forthcoming climate and energy policies—both at the national and global level—has inhibited investment in methane capture enterprises.

So far, one of the most effective approaches to overcoming these obstacles is US EPA’s “Methane to Markets” (M2M) program. Since 2004 M2M has developed partnerships with more than 25 countries, supporting more than 170 of projects in the areas of agriculture, energy, and waste management in 16 countries.<sup>39</sup> With funding primarily from the United States, but also from the Asian Development Bank, the International Finance Corporation and numerous national agencies, the program identifies potential projects, provides support for feasibility studies and offers information on best practices. However, M2M is not set up to provide the equity needed when projects are ready to move forward.

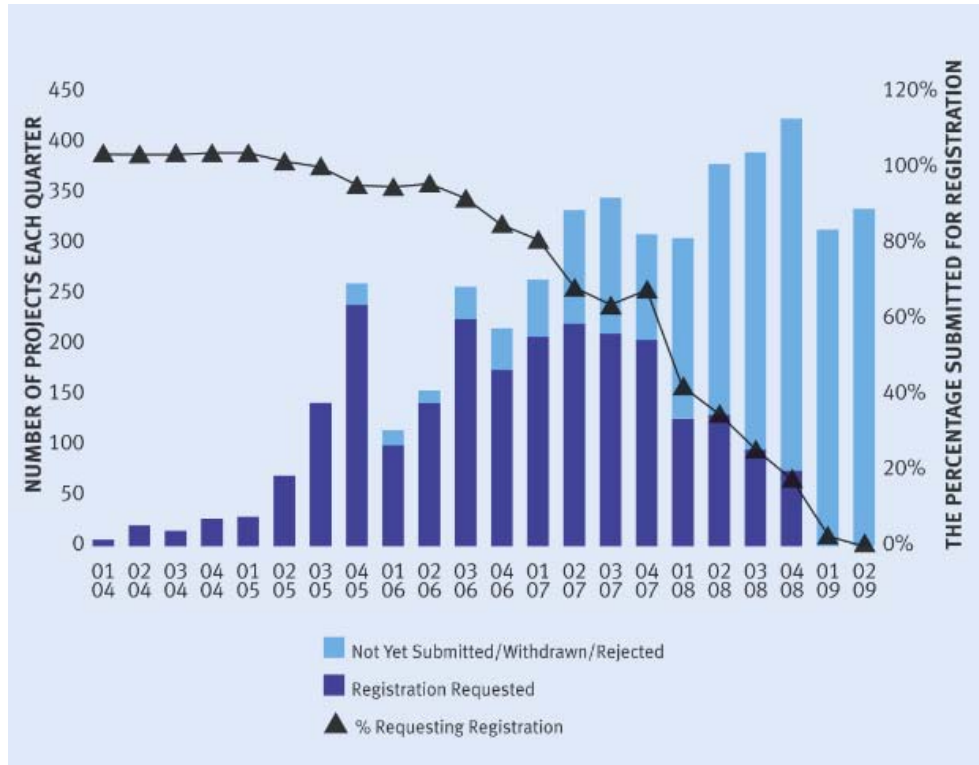
Over the last year, the chronic funding challenges facing methane abatement initiatives have grown acute, as credit markets have dried up. The United Nations Environment Programme (UNEP) tracks the progress of CDM projects from the initial proposal stage through to registration and the issuance of CER credits. New projects entering their database have fallen by half, and all market analysis firms covering the CDM have steadily downgraded their expectation of CER supply in recent months as projects have been cancelled or delayed.

The graph on following page illustrates the dramatic recent decline in the numbers of methane projects seeking approval.

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<sup>39</sup> See: [http://www.epa.gov/methanetomarkets/pdf/2009-accomplish-report/the\\_methane\\_to\\_markets\\_partnership.pdf](http://www.epa.gov/methanetomarkets/pdf/2009-accomplish-report/the_methane_to_markets_partnership.pdf)

## Decline in Methane CDM Applications<sup>40</sup>



## Moving Forward on Methane: A Global Methane Fund

Any hope of achieving global methane reductions in time to protect the Arctic and other sensitive regions of the globe requires a prompt and far-reaching response to these financial hurdles.

In December 2009, a blue-ribbon expert panel consisting of methane, bilateral/multilateral institution, and carbon finance experts will propose the creation of a stand-alone Global Methane Fund dedicated to moving forward global methane projects as rapidly as possible.<sup>41</sup> The Fund would work in concert with the CDM, Methane to Markets, and multilateral institutions, to leverage their funds and expertise. Details of such a fund hopefully will be worked out among interested donors and other parties early in 2010. In addition, Methane to Markets will be “re-chartered” in 2010 and may produce an even more robust organization that will also move methane abatement appreciably forward, even as negotiators finalize the details of any Copenhagen agreement.

<sup>40</sup> UNEP Risoe CDM/ji database. CDM Pipeline Overview, <http://cdmpipeline.org/>, visited November 30, 2009.

<sup>41</sup> Methane Blue Ribbon Panel: “A Rapid Action Plan for Methane Abatement, December 2009 Reference GMF concept paper.

The time to act on methane is now. It is one of the few things we can do to slow Arctic, cryosphere and global warming in the next few decades. In doing so, we will also save lives and improve health by reducing ozone smog and displacing dirtier fuels. Methane abatement projects will also improve other local conditions in the developing world and provide environmentally-friendly jobs.

Methane projects around the world are ready to go. If countries can act to quickly reduce barriers, we can make more rapid progress on climate change and build confidence for other climate-related measures.