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Methane—a neglected greenhouse gas

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Methane is a greenhouse gas that gets far less public attention than carbon dioxide. This is entirely unwarranted. Being 25 times more potent than carbon dioxide in trapping heat in the atmosphere, methane accounts for about one-sixth of all anthropogenic (i.e. human-induced) greenhouse gas emissions. Methane is also overlooked when it comes to taking concrete measures for climate protection, despite the fact that reducing methane emissions is potentially cheap. Major sources of methane emissions are livestock farming, the natural gas sector, landfills, wetland rice cultivation and coal mining. In many cases, it is possible to mitigate substantial amounts of methane in a cost-effective way. Moreover, captured methane can be used for generating heat and power. In other words, abating one ton of methane emissions is sometimes cheaper than abating an equivalent amount of carbon dioxide. The challenge is to effectively incorporate cutbacks of methane gas emissions into climate policy strategies.

The European Union and the G8 states, as well as most recently the Major Economies Forum on Energy and Climate, have agreed[1] that the average global temperature should be prevented from rising by more than two degrees Celsius in comparison to pre-industrial times.[2] With current emission trends, however, this goal will be extremely difficult to achieve. The average global surface temperature has risen by roughly 0.8°C since pre-industrial times, and has gained speed in the last 50 years. In order to achieve the „two-degree goal", global greenhouse gas emissions must (depending on the climate change scenario) peak between 2015 and 2020 and decline afterwards.[3] By the year 2050, a 50-85 percent reduction of global greenhouse gas emissions compared to 2000 is necessary. Accordingly, an ambitious and binding follow-up protocol must be agreed upon at the UN Climate Conference held in Copenhagen in December 2009 to replace the Kyoto Protocol when it expires in 2012 (see box).

1 Declaration of the Leaders—the Major Economies Forum on Energy and Climate, L'Aquila, Italy, July 9, 2009. Forum members include the G8 states, Australia, Brazil, China, the European Union, India, Indonesia, South Korea, Mexico and South Africa.

2 Many experts make references to the „two-degree goal", among them the German Advisory Council on Global Change: Solving the Climate Dilemma—the budget approach. Special report, Berlin, September 2009.

3 According to IPCC reports, atmospheric concentrations of greenhouse gases must be stabilized at between 445—490 ppm (parts per million) CO_2 equivalents. This includes both CO_2 and other greenhouse gases that have been converted into CO_2 equivalents. IPCC: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report. Geneva, 2007.

JEL Classification:
Q52, Q53, Q54

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Climate policy-milestone Copenhagen

The upcoming UN Climate Change Conference in Copenhagen in December 2009 will determine the course of future climate policy. Achieving a follow-up agreement for the Kyoto Protocol is of utmost necessity. Despite the global acknowledgement of the „two-degree goal," the outcome of the discussions cannot be predicted. The US has never ratified the Kyoto Protocol, and it is unclear today if the US will agree to adopt binding emissions limitations. Europe's approach to climate protection is different from that of the US. Europe would like to see at least industrial nations setting concrete emission reduction goals for different target years. Japan is basically in favor of more climate protection and has suggested binding emissions limits. China has sent a clear signal that it is willing to consider climate protection goals, despite the fact that its emissions will continue to grow until 2030. India, too, has signaled that it is willing to consider more climate protection. Developing countries, however, demand that industrial nations take on a special responsibility by both drastically reducing their own emissions and by providing financial support for adaptation to climate change. The positions held by Australia, Canada and Russia are currently entirely unclear. The Russian government still perceives that climate change has positive impacts on the country. The OPEC states will oppose binding climate legislation, as they believe that lower oil exports will lead to economic losses. It has to be seen which goals and mechanisms will end up being agreed upon in Copenhagen. It is likely that additional nations will come to accept the „two-degree goal." However, there is a risk that no according agreement on ambitious emission reduction goals and on ways to implement them will be reached.

More attention must be paid to methane gas emissions

Methane (CH_4) is an important, but often neglected, greenhouse gas. In comparison to carbon dioxide (CO_2), it has a relatively short atmospheric lifetime of roughly twelve years. According to the latest IPCC Assessment Report, it has a high global warming potential (GWP)—nearly 25 times higher than the one of CO_2.[4] Figure 1 shows the contributions of different greenhouses gases to global anthropogenic emissions in the year 2005. Accounting for roughly one-sixth of all emissions, methane is the second largest contributor.[5]

Methane is generally produced through the degradation of organic materials under anaerobic (i.e. oxygen-deficient) conditions.[6] Natural sources of methane emissions include wetlands, but also termites, oceans, and other sources.[7] The most important anthropogenic sources include livestock farming, especially that of cattle (ruminant animals), but also the extraction, transportation and distribution of natural gas, as well as landfills, wetland rice cultivation, waste water and coal mining. Figure 2 shows how these sources contributed to global anthropogenic methane emissions in the year 2005. Agricultural sources, such as ruminant animals, manure and rice cultivation are currently responsible for nearly half of all greenhouse gas emissions.

However, the percentage of these sources varies greatly from country to country. China, Brazil, India and many OECD countries are the major emitters of livestock-related methane. Emissions from the natural gas industry mainly come from Russia, the US and various countries in the Middle East and Latin America. Emissions from landfills are produced to a large extent in the US and other OECD countries, but also in African, Asian and Latin American countries. Wetland rice cultivation is practiced predominantly in China and South-East Asia. Methane emissions resulting from waste mainly come from developing countries that lack controlled wastewater systems. Coal mine methane is predominantly produced in China, followed by the US.[8] Figure 3 shows the development of methane emissions in selected countries and regions between 1970 and 2005.

4 This GWP value, which has been used to convert methane emissions into CO_2 equivalents, has been calculated based on a time interval of 100 years. Hereafter, an older GWP of 21, which is cited in most literature, will be used in its place. This value stems from the IPCC's Second Assessment Report and was used for the Kyoto Protocol. IPCC: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report. Cambridge and New York, 2007.

5 The atmospheric concentration of methane has more than doubled since pre-industrial times.

6 In contrast, in aerobic conditions (rich in oxygen), CO_2 is produced. Methane can be oxidized to CO_2.

7 When termites digest wood, they emit great deals of methane. Bousquet et al.: Contribution of Anthropogenic and Natural Sources to Atmospheric Methane Variability. In: Nature 443, 2006.

8 United States Environmental Protection Agency 2006: Global Anthropogenic Non-CO_2 Greenhouse Gas Emissions: 1990-2020. Washington, June 2006.

Reducing methane emissions in all sectors

Measures for reducing methane gas emissions either set out to avoid methane production altogether, or to capture produced methane in order to oxidize it, e.g. by burning it, which diminishes its global warming potential by the factor 25. In principle, the energy released can be utilized. It should replace fossil fuels, where this is possible, which decreases greenhouse gas emissions even further. Accordingly, methane should be captured and thermally utilized wherever possible, especially in decentralized combined heat and power plants.[9]

Livestock farming

Livestock farming invariably leads to the production of methane gas: it is a waste product of ruminant animals' digestion. However, certain measures can be taken to lower the amount of methane produced by following specific feeding and keeping methods, nutritional supplements that suppress methane production, making breed changes, or by increasing animal productivity, such that they produce more meat or milk with the same methane emissions. These measures nonetheless require strict adherence to species-appropriate animal husbandry criteria. Livestock farming also generates methane through the degradation of animal manure under oxygen-deficient conditions. These emissions can be lowered by improving both manure storage and its dispersion, as well as utilizing digesters for producing biogas from the animal waste products, which can then be used for generating combined heat and power.[10] Furthermore, an extremely effective (albeit unpopular) way of avoiding livestock-related methane is to reduce the consumption of animal products, especially beef and dairy products.

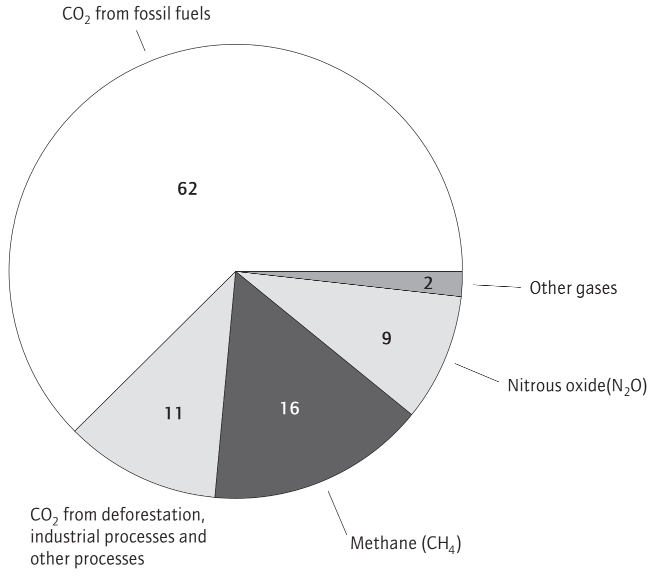
Natural gas sector

Along the supply chain of the natural gas industry, methane may be released to the atmosphere during extraction, transportation and distribution. Typical sources include leaky pipelines or compressors and maintenance work. Such emissions can be avoided by optimizing maintenance and by replacing leaky components, especially old compressors. The natural gas industry should have an economic interest in avoiding unnecessary methane losses.

Figure 1

Global anthropogenic greenhouse gas emissions in 2005

% share

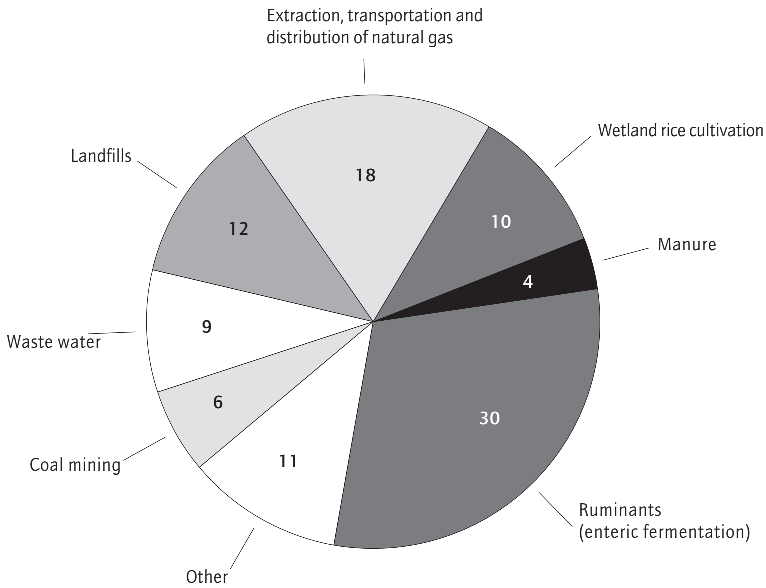


Source: International Energy Agency 2008. **DIW** Berlin 2009

Figure 2

Source of global anthropogenic methane gas emissions in 2005

% share



Source: United States Environmental Protection Agency 2006. **DIW** Berlin 2009

9 Unless indicated otherwise, the reference for the following sections is from the United States Environmental Protection Agency 2006: Global Mitigation of Non-CO_2 Gases, June 2006.

10 Smith, P. et al.: Greenhouse Gas Mitigation in Agriculture. In: Philosophical Transactions of the Royal Society B, 363, 2008, 789-813. When producing biogas, it has to be ensured that methane emissions from digesters and from remaining digestate are avoided.

Waste management sector

Through the degradation of organic waste materials under anaerobic conditions, landfills produce landfill gas, which is mainly comprised of methane. One way of preventing these emissions is pre-treating organic waste such that hardly any methane is produced in landfills. This can be achieved through either bio-mechanical or thermal treatment. On the other hand, methane produced in landfills can be captured by installing surface caps and gas extraction systems. Afterwards, it may be used to generate heat and power. Another possibility, which, however, requires higher logistical efforts, is collecting organic waste separately and transporting it directly to composting plants, where it is turned into compost under aerobic conditions without producing methane. In Germany, these practices are not only state-of-the-art, but also required by law. Since June 2005, only pre-treated municipal waste may be landfilled.[11] This is not the case for the rest of the world: especially in many developing countries, untreated organic waste is often dumped in uncontrolled landfills.

Wetland rice cultivation

Methane is produced in flooded rice paddies. These emissions can be decreased by improved water management with lower water levels, periodical draining, or specific rice cultivars, to name a few examples. In some instances, switching to upland rice cultivation may also be an option.

Wastewater

Methane emissions from wastewater mainly come from anaerobic decomposition processes in uncontrolled wastewater disposal of many developing and newly industrializing countries. These emissions can be reduced by building wastewater collection systems and treatment plants. However, the main reason for taking such costly infrastructure measures is not lowering methane emissions, but rather improving both the health and the sanitary conditions of people in these countries.[12]

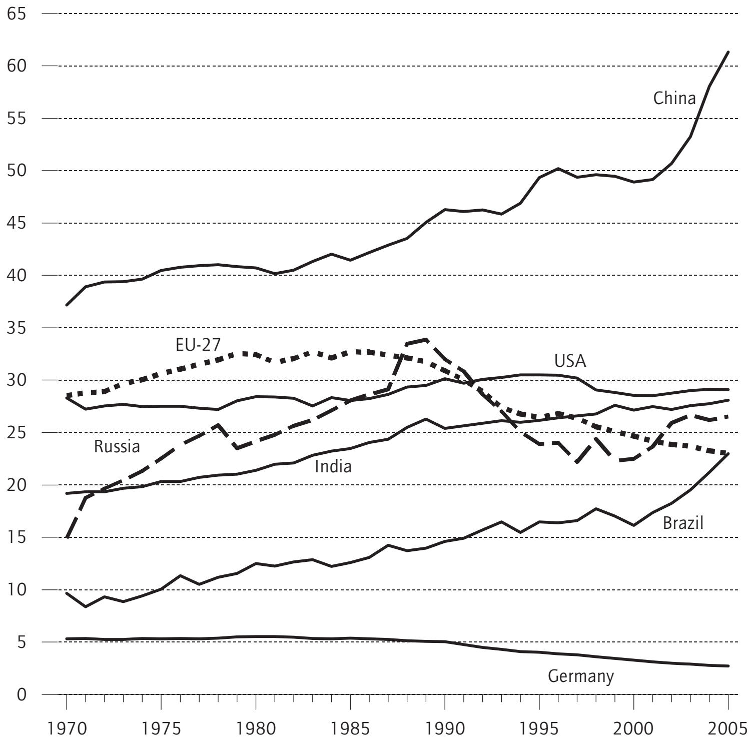
Coal mining

Coal seams usually contain large amounts of methane, which is released to the atmosphere prior to or during mining processes. For safety reasons, coal mine methane is ventilated from mines (degasifica-

Figure 3

Methane emissions of selected countries

In million tons

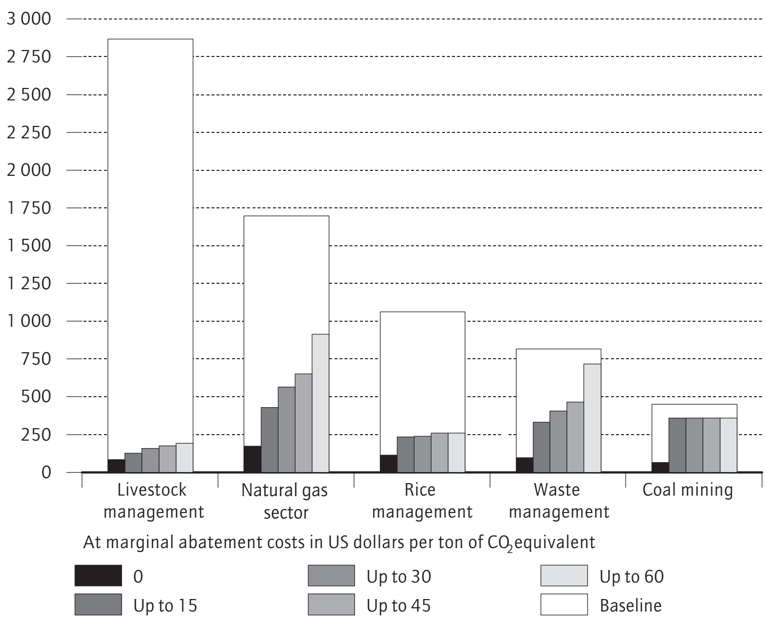


Source: Emission Database for Global Atmospheric Research (EDGAR). **DIW** Berlin 2009

Figure 4

Global methane emissions and mitigation potentials in 2020 at different marginal abatement cost levels

In million tons CO_2 equivalents



Source: United States Environmental Protection Agency 2006.
Calculations by DIW Berlin. **DIW** Berlin 2009

11 German law governing landfills was recently amended with a new ordinance regarding the standards that must be met for both the pre-treatment of waste and for gas capture. Bundesgesetzblatt, Teil I, Nr. 22, Bonn 29. April, 2009, 900-950.

12 Lucas, P.L. et al.: Long-term Reduction Potential of Non-CO_2 Greenhouse Gases. Environmental Science & Policy 10, 2007, 85-103.

tion). However, it should not be simply released into the atmosphere. Depending on the concentration of methane in the degasification air, it can be used to generate heat and/or power by either burning it or by catalytic oxidation. It is also possible to inject coal mine methane into natural gas distribution systems after purification.

Tapping cost-effective methane mitigation potentials

Globally, there are large and sometimes very cost-effective methane mitigation potentials. DIW Berlin recently conducted a study that includes an extensive literature survey on global potentials of methane mitigation measures and on their costs and benefits.[13]

Reducing small amounts of methane emissions is oftentimes very cheap, e.g. by employing low-tech measures, or by making small improvements to operational processes. Due to rising marginal abatement costs, additional methane mitigation gets more and more costly. Figure 4 shows global economic mitigation potentials at different marginal abatement costs for the year 2020 in the aforementioned sectors.[14] Marginal abatement costs are expressed in constant year 2000 US dollars per ton CO_2-equivalent. The baseline development is also indicated, i.e. projected methane emissions in case of no further reduction measures. While calculating the costs of reducing methane emissions, the market value of methane as an energy carrier has been taken into account.

The baseline for 2020 indicates that methane emissions are highest for livestock farming, followed by the natural gas industry and wetland rice cultivation. The largest economic reduction potentials, however, relate to natural gas, waste management and coal mining. There are significant mitigation potentials at low marginal abatement cost of up to 15 US dollars per ton CO_2-equivalents, especially for coal mine methane. Worldwide, emissions of about 1.5 billion tons CO_2-equivalents could be mitigated by the year 2020 at marginal abatement costs of 15 US dollars per ton CO_2-equivalent—nearly a quarter of all methane emissions in the aforementioned sectors, or nearly 4% of total global greenhouse gas emissions in 2005.

Methane mitigation efforts should be spread over all sectors in order to both minimize implementation risks and maximize the impact on the world climate. Economic efficiency nonetheless requires mitigating such amounts in each sector that marginal abatement costs are equal over all sectors.

Removing barriers and preconceptions

Methane mitigation often faces various obstacles, e.g. information problems of relevant players, institutional barriers, or a lack of both technical and financial resources. Furthermore, some barriers only apply to specific sectors. For example, optimizing livestock feeding or manure management is sometimes difficult due to geographically widespread herds of grazing animals in many parts of the world, and due to specific local customs and traditions. In addition, it is important that methane mitigation measures taken within agricultural sectors do not lead to counterbalancing increases in other greenhouse gases such as nitrous oxide. Regarding coal mine methane, a large obstacle to reducing these emissions—or to utilize them thermally—is the availability of appropriate technologies and capital in China.[15]

In contrast to CO_2 emissions, which often stem from large single industrial or energy-related sources, anthropogenic methane sources are often small, geographically dispersed and not limited to the energy sector. Higher administrative costs can be expected for monitoring and controlling mitigation measures at small and decentralized sources, if according activities are not economically viable for individual operators anyway. Therefore, methane mitigation efforts should focus on larger sources where monitoring and enforcement is easier, such as landfills and coalmines.

It is time for politics to step up

Politicians are responsible for facilitating the realization of cost-effective methane mitigation potentials. Informing relevant players and making pertinent information available is required. Furthermore, both regulatory and financial incentives must be created. Germany, for example, has been very successful in the landfill sector due to both ambitious regulatory measures and financial incentives provided by the Erneuerbare-Energien-Gesetz (Renewable Energy Sources Act) to utilize landfill methane for heat and power generation. Now it is time for increased

13 Kemfert, C., Schill, W.P: Mitigation of Methane Emissions: A Rapid and Cost-effective Response to Climate Change. DIW Discussion Paper No. 918, DIW Berlin, 2009.

14 Waste water has been excluded since no reliable data on the reduction potential or costs was available for the year 2020.

15 Yang, M.: Climate Change and Energy Policies, Coal and Coalmine Methane in China. Energy Policy 37, 2009, 2858-2869.

international efforts to be made in all sectors. In order to create economic incentives for methane mitigation, methane should be included in an international emissions trading scheme and in other flexible mechanisms. Methane mitigation should not be neglected at the UN Climate Change Conference in Copenhagen. But most importantly, according measures must be implemented on national levels.

Considering methane's high global warming potential, new emission sources should categorically be avoided, e.g. in the liquefied natural gas (LNG) supply chain. Both the process of liquefaction, as well as LNG transportation, is prone to methane emissions. Since LNG capacities are currently being developed worldwide, it is important to contain their emissions from the outset by tough regulation and appropriate technical solutions. Future undersea mining of methane hydrate (also called methane clathrate or methane ice) may be yet another potential source of methane emissions. More research is necessary in this area in order to properly assess such risks. Uncontrolled release of methane during future mining activities must be prevented at all costs.

Summary

Methane accounts for approximately one-sixth of total global anthropogenic greenhouse gas emissions. Merely preventing methane emissions will thus not solve the climate problem. However, it is an important element of a cost-efficient climate protection strategy since nearly a quarter of global methane emissions by 2020 can be mitigated at marginal abatement costs of 15 US dollars per ton of CO_2-equivalent. If the global price for greenhouse gas emissions is above 15 US dollars per ton of CO_2-equivalent by the year 2020 (which is not an unlikely scenario), the economically profitable global methane mitigation potential will be even larger. In order to achieve ambitious goals like the „two-degree goal," politicians should not only focus on reducing CO_2, but also on mitigating methane emissions. Of all non-CO_2 greenhouse gases, methane offers the greatest and most cost-effective reduction potentials. Furthermore, methane mitigation can deliver short-term climate impacts due to its short atmospheric lifetime compared to CO_2. All measures taken to reduce methane emissions should be spread over different sectors in a cost-effective way. The natural gas industry, the waste management sector and coal mining are the most promising areas.

Many strategies outlined above involve positive side-effects that should not be ignored. A well-controlled waste management system, for example, will not only result in lower methane emissions, but also have positive impacts with regard to pollution control, recycling rates and the quality of life of citizens. Partially substituting fossil fuels with methane may increase the security of energy supply. And last but not least, worldwide efforts for mitigating methane emissions may create export opportunities for advanced "clean" technologies, for example waste treatment and landfill technologies.

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