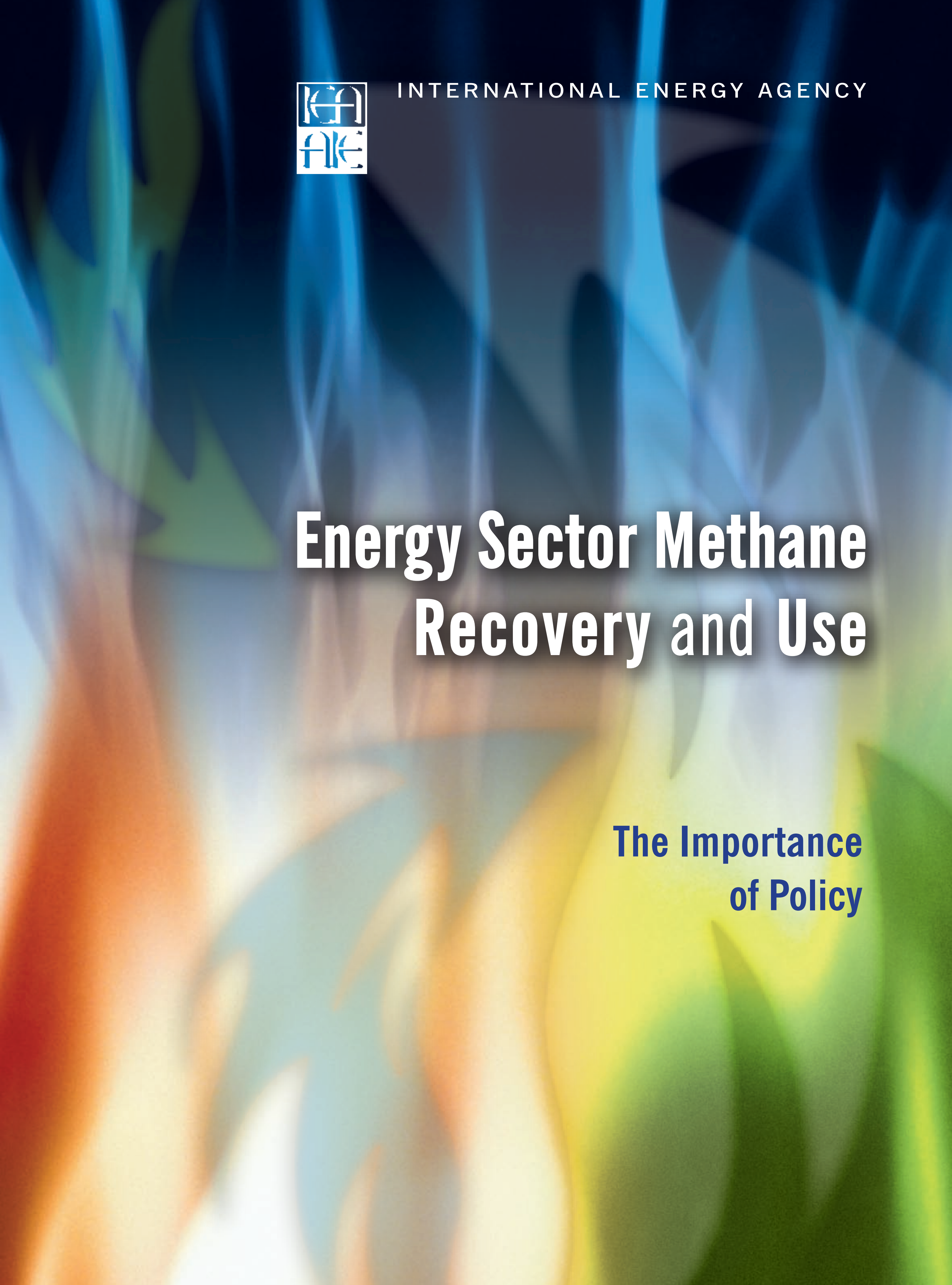
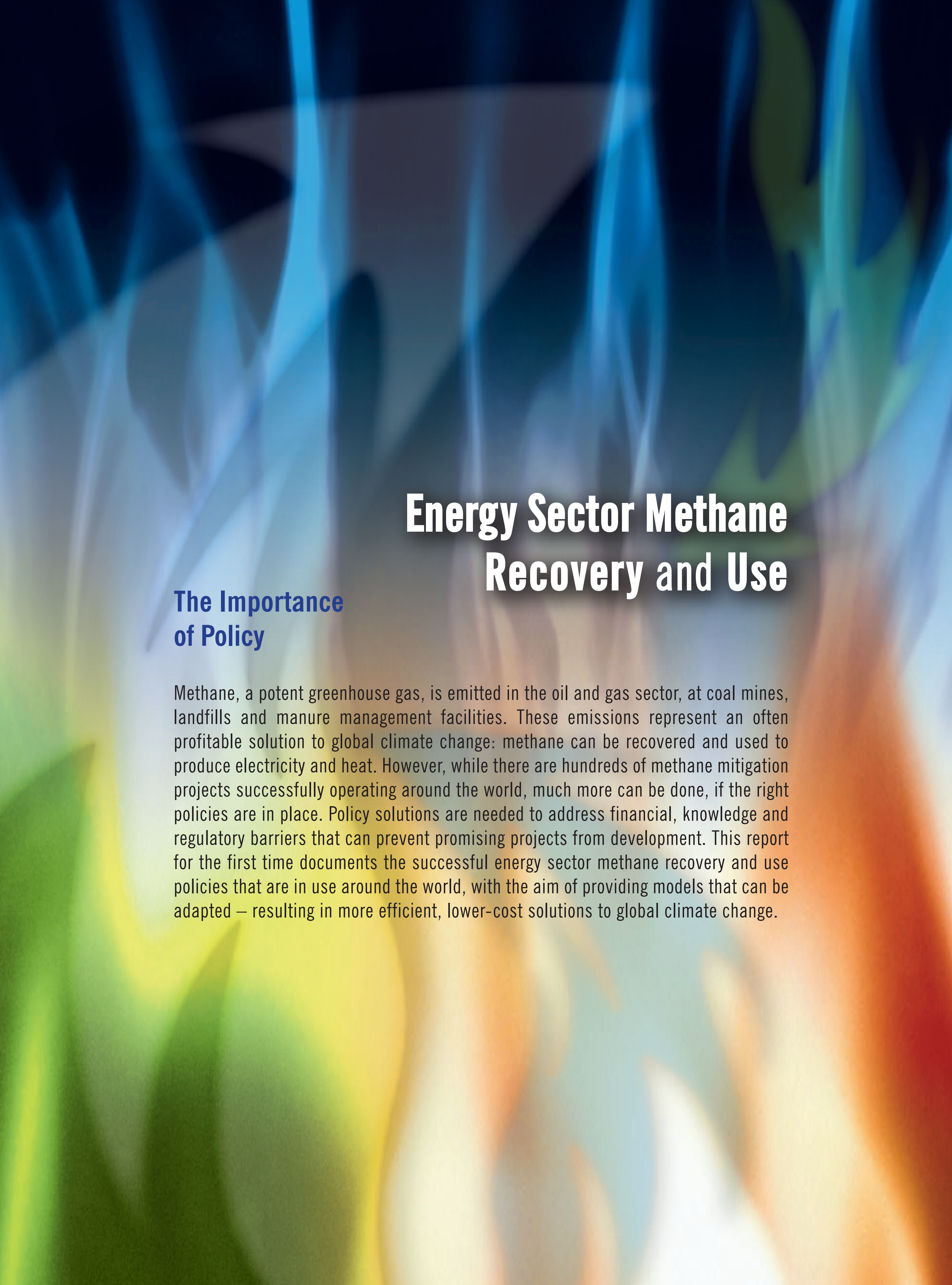


INTERNATIONAL ENERGY AGENCY

Energy Sector Methane Recovery and Use

The Importance of Policy



Energy Sector Methane Recovery and Use

The Importance of Policy

Methane, a potent greenhouse gas, is emitted in the oil and gas sector, at coal mines, landfills and manure management facilities. These emissions represent an often profitable solution to global climate change: methane can be recovered and used to produce electricity and heat. However, while there are hundreds of methane mitigation projects successfully operating around the world, much more can be done, if the right policies are in place. Policy solutions are needed to address financial, knowledge and regulatory barriers that can prevent promising projects from development. This report for the first time documents the successful energy sector methane recovery and use policies that are in use around the world, with the aim of providing models that can be adapted – resulting in more efficient, lower-cost solutions to global climate change.

INTERNATIONAL ENERGY AGENCY

Energy Sector Methane Recovery and Use

The Importance of Policy

INTERNATIONAL ENERGY AGENCY

The International Energy Agency (IEA) is an autonomous body which was established in November 1974 within the framework of the Organisation for Economic Co-operation and Development (OECD) to implement an international energy programme.

It carries out a comprehensive programme of energy co-operation among twenty-eight of the thirty OECD member countries. The basic aims of the IEA are:

- To maintain and improve systems for coping with oil supply disruptions.
- To promote rational energy policies in a global context through co-operative relations with non-member countries, industry and international organisations.
- To operate a permanent information system on international oil markets.
- To provide data on other aspects of international energy markets.
- To improve the world's energy supply and demand structure by developing alternative energy sources and increasing the efficiency of energy use.
- To promote international collaboration on energy technology.
- To assist in the integration of environmental and energy policies, including relating to climate change.

IEA member countries:

Australia
Austria
Belgium
Canada
Czech Republic
Denmark
Finland
France
Germany
Greece
Hungary
Ireland
Italy
Japan
Korea (Republic of)
Luxembourg
Netherlands
New Zealand
Norway
Poland
Portugal
Slovak Republic
Spain
Sweden
Switzerland
Turkey
United Kingdom
United States

The European Commission also participates in the work of the IEA.

ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

The OECD is a unique forum where the governments of thirty democracies work together to address the economic, social and environmental challenges of globalisation. The OECD is also at the forefront of efforts to understand and to help governments respond to new developments and concerns, such as corporate governance, the information economy and the challenges of an ageing population. The Organisation provides a setting where governments can compare policy experiences, seek answers to common problems, identify good practice and work to co-ordinate domestic and international policies.

International Energy Agency (IEA)
9 rue de la Fédération, 75739 Paris Cedex 15, France

Foreword

In the analysis of climate change, most of the attention has focused on emissions of carbon dioxide (CO_2) from the energy sector, which contribute over 61% of total manmade greenhouse gas (GHG) emissions. However, while CO_2 is the biggest concern for the energy sector, as the world crafts an effective and efficient solution to climate change, energy sector methane emissions merit a closer look. Methane is a potent greenhouse gas – 25 times more powerful than CO_2 over a 100-year time period – but has a short atmospheric lifetime. As a result, reductions realised today can help to stabilise the climate in the near term, buying time for longer-term energy technology solutions to be implemented. In addition, methane, which is the main component of natural gas, is a valuable commodity and can increase efficiency in the oil and gas sector, or be used as an opportunity fuel arising from the waste, coal or agricultural sectors. Recovering and using methane offers a host of local co-benefits, including reduced local air and water pollution, improved safety conditions, and a local source of revenue. This is important particularly in emerging economies, where energy sector methane emissions are expected to increase the most.

Methane recovery and use technologies are widely available and ready today. However, in many cases, market barriers prevent their widespread adoption. Developing countries lack awareness, policy frameworks and know-how to evaluate methane recovery and use opportunities. Projects can face difficulties gaining access to gas or electricity networks to sell their energy; or, as in the case of coal mine methane, regulatory frameworks are unclear as to property rights. These barriers have been addressed in individual countries, but successful policies need to be shared and applied more widely. Additionally, in the international climate policy arena, while the multilateral Methane to Markets Partnership combines government and industry expertise to successfully address some barriers, policy makers need to do more to ensure the success of methane mitigation projects in the carbon market. One important step is to address some of the issues that methane projects have faced in the Clean Development Mechanism.

This report offers an overview of four types of methane mitigation projects that have the strongest links to the energy sector: oil and gas methane recovery and reduction of leaks and losses; coal mine methane; landfill methane; and manure methane recovery and use. It identifies successful policies that have been used to advance these important projects. This information is intended to guide policy makers as they search for low-cost, near-term solutions to climate change.

Nobuo Tanaka
Executive Director

Purpose of report

To raise awareness about appropriate policy options to advance methane recovery and use in the energy sector, the IEA has conducted a series of analyses and studies over the past few years. This report continues IEA efforts by providing policy makers with examples and best practices in methane mitigation policy design and implementation.

Acknowledgements

The authors of this paper were Tom Kerr and Michelle Hershman, who was seconded to the IEA from the US Federal Transit Administration during the production of this report. The authors wish to thank all of their reviewers, including Rebecca Gaghen, Anne-Sophie Corbeau and Barbara Buchner of the IEA and the U.S. Environmental Protection Agency's Carey Bylin, Henry Ferland, Roger Fernandez, Pamela Franklin, Rachel Goldstein, Paul Gunning, Ashley King, Kurt Roos and Jayne Somers. Muriel Custodio, Bertrand Sadin, and Annette Hardcastle also provided much-needed editorial, layout and graphics support.

Table of contents

Foreword 3

Acknowledgements 5

Executive summary 9

Methane emissions: context 13

Energy sector methane mitigation: a closer look 15

Methane in the international climate change and energy arena 31

Conclusions 35

Abbreviations/acronyms and units 37

Appendix: Relevant UNFCCC Clean Development Mechanism Methodologies 39

References 41

List of figures

Figure 1 Methane is the second most important greenhouse gas 9

Figure 2 There are important methane mitigation opportunities in the near term 10

Figure 3 Impact of a 50% reduction in BAU in 2050, maintained to 2100 11

Figure 4 Methane emissions contribution and breakdown of anthropogenic sources 13

Figure 5 Methane emissions from oil and gas systems are estimated to grow substantially in developing regions 15

Figure 6 Alberta has realised major emissions reductions associated with a drop in gas flaring volumes 19

Figure 7 China and other coal producers continue to see rising CMM emissions 20

Figure 8 Methane emissions from solid waste management are expected to grow, particularly in developing regions 25

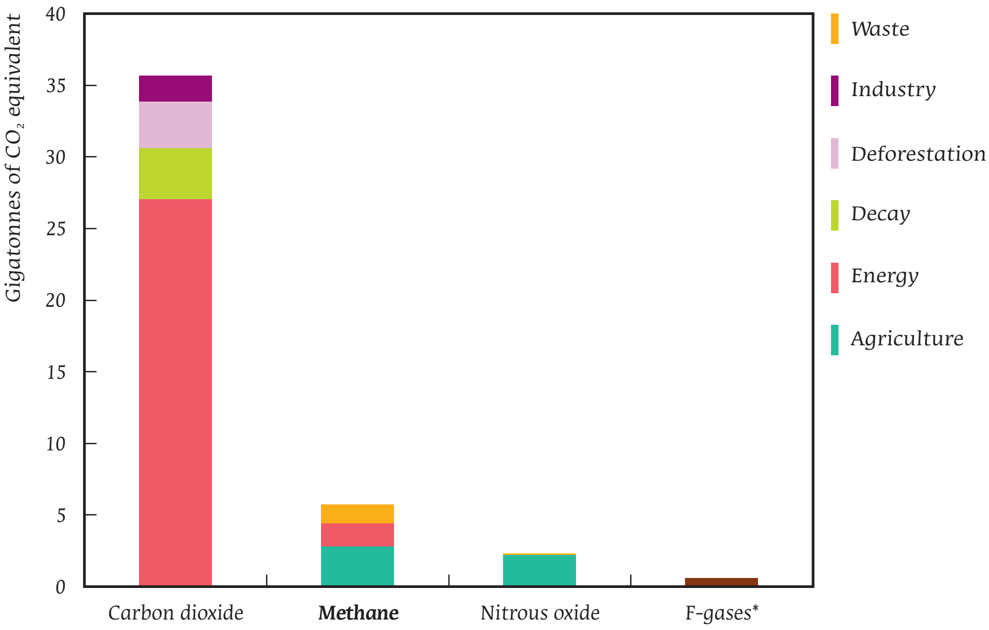
Figure 9 Manure management methane emissions are rising globally 28

Figure 10 Methane recovery has been a popular project category in the CDM, but numbers are declining 32

Executive summary

Secure, reliable and affordable energy supplies are needed for sustainable economic growth, but increases in associated GHG emissions and their implications for climate change are a cause of major concern. The energy sector accounts for 82% of GHG emissions in OECD countries, and 59% in non-OECD countries (U.S. EPA, 2006a, 2006b). Energy-related emissions have been rising rapidly since 1990, driven by the economic growth of emerging economies and the availability of fossil fuel resources. While carbon dioxide (CO_2) is the biggest concern for the energy sector, emissions of methane are expected to increase 23% to nearly 8 million metric tonnes (Mt) of carbon dioxide equivalent (CO_2-eq) by 2020, driven by growth in emerging economies, particularly in the natural gas and coal sectors (IEA, 2008a).

Figure 1 Methane is the second most important greenhouse gas



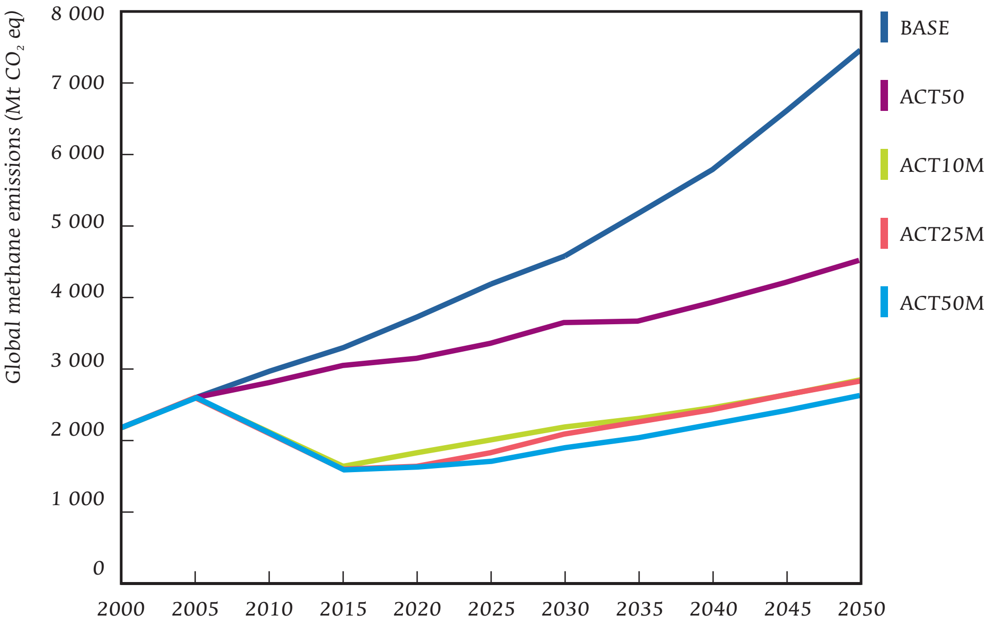
*F-gases include Hydroflurocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6) from several sectors, mainly industry.

Note: Industry CO_2 includes non-energy uses of fossil fuels, gas flaring, and process emissions. Energy sector methane includes coal mines, gas leakages, and fugitive emissions.

Source: IEA, *World Energy Outlook 2008*.

Due to its high potency and short atmospheric lifetime, addressing methane emissions is a particularly effective tactic for mitigating the near term impacts of climate change. A number of analyses show that there are important methane mitigation opportunities, particularly in the near term (U.S. EPA, 2006; IEA, 2008a). Figure 2 shows that under the *Energy Technology Perspectives* scenario ACT 10M, which has USD 10/t CO_2-eq incentives, significant methane reductions occur before 2015: a 37% reduction (925 Mt CO_2-eq) compared to the baseline scenario. These early reductions are realised primarily in the gas (496 Mt CO_2-eq), coal (214 Mt CO_2-eq) and waste sectors (365 Mt CO_2-eq).

Figure 2 There are important methane mitigation opportunities in the near term



Source: IEA, *Energy Technology Perspectives* (2008).

Also, substantial reductions in radiative forcing can be achieved by reducing methane emissions in the short term. It has been estimated that such reductions could contribute as much as one-half the abatement levels needed to limit future increases in radiative forcing consistent with international GHG stabilisation goals (US Climate Change Science Program (CCSP), 2007). Figure 3 shows that feasible reductions in methane (and other non-CO_2 GHGs)[1] could make a contribution to slowing global warming that is as large as similar reductions in CO_2 over the next 50 years (Pew Center on Global Climate Change, 2003).

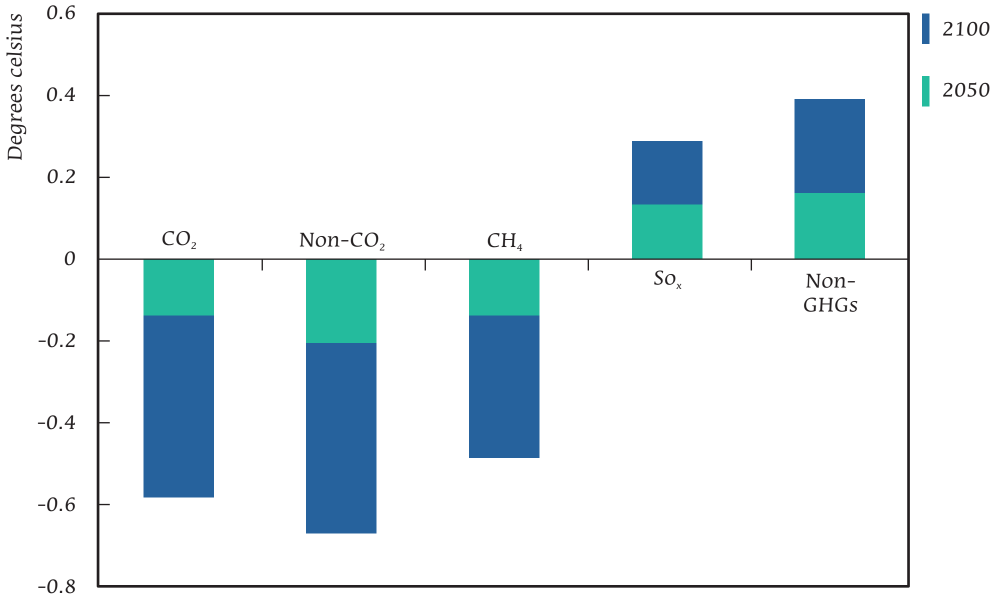
In addition to its environmental benefits, recovering and using methane is one of the most cost-competitive GHG mitigation options for the energy sector. There are a number of efficiency measures that can be implemented in the oil and gas industry to reduce leaks and losses of methane and contribute to profitability. Methane can also be recovered for energy production from the coal mining, landfill and agricultural manure management systems, offering a new source of revenue for these operations. Methane's climate characteristics, coupled with the economic benefits of recovering and using it as fuel, mean that methane mitigation in the energy sector merits a closer look.

Methane mitigation offers a number of additional co-benefits. When emissions are reduced, local air quality improves and ozone related-mortalities decrease (West, J. *et al.*, 2006). Methane mitigation also benefits water quality, particularly in the agricultural sector, via improved management of animal waste. Reducing emissions of methane at coal mines and landfills also addresses dangerous explosion hazards while mitigating odour nuisances. These co-benefits are attractive in particular in emerging economies, where carbon finance is not always sufficient to make methane recovery profitable.

---

[1] Other non-CO_2 GHGs include nitrous oxide, PFCs, HFCs and sulphur hexafluoride.

Figure 3 Mean temperature impacts of a 50% emissions reduction in 2050, maintained to 2100



Source: Pew Center on Global Climate Change, 2003.

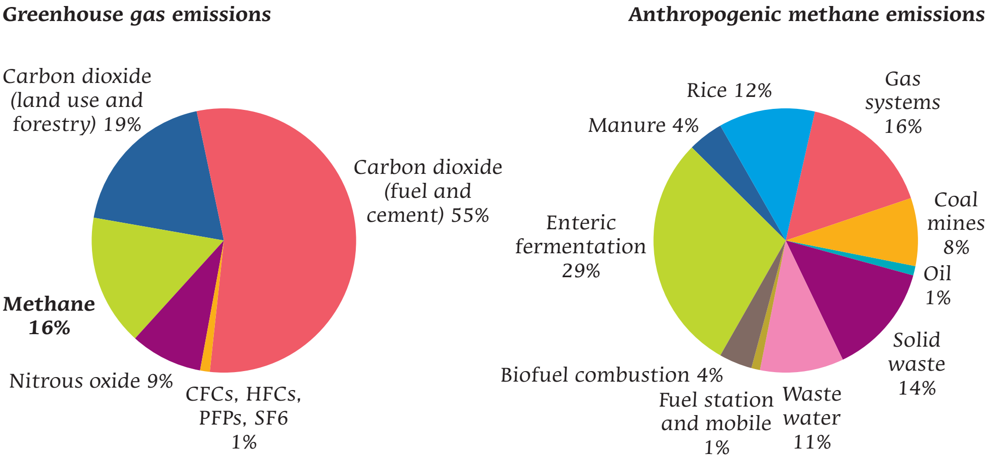
However, a number of barriers exist which prevent the full realisation of the potential of methane mitigation in the energy sector. One of the main challenges for methane recovery and use projects is to increase awareness about the magnitude of methane emissions and the value of the lost fuel, particularly in the oil and gas sector. There are also legal and regulatory barriers to overcome relating to methane ownership at coal mines and landfills and in obtaining access to the electricity grid to sell back power that is generated at landfills, coal mines, or agricultural operations.

While some countries have had success addressing individual barriers for certain sectors, a key finding is that no country has a comprehensive methane recovery and use policy framework in place. It is clear that much more needs to be done to raise global awareness and to share best practice policies. This report is a start – it contains a number of examples of government leadership in setting targets, raising awareness, providing incentives and clarifying methane ownership rights and interconnection rules for power sales. It is hoped that this report can serve as a resource and a call to action to governments worldwide about the importance of energy sector methane mitigation in meeting climate change and energy goals.

Methane emissions: context

Methane is emitted from a variety of both anthropogenic (human-induced) and natural sources and accounts for 16% of global GHG emissions (Figure 4). In 2005, global GHG emissions amounted to over 44 Gt CO_2-equivalent emissions (CO_2-eq), with methane accounting for 7 Gt CO_2-eq. Anthropogenic emission sources include agricultural, coal-mining, landfills, and natural gas and oil activities. Approximately 60% of methane emissions come from these sources and the rest are from natural sources. Over the last two centuries, methane concentrations in the atmosphere have more than doubled. However, in the past decade, while methane concentrations have continued to increase, the overall rate of methane growth has slowed. This is due in part to increased global awareness and action to put in place methane recovery and use practices (U.S. CCSP, 2006).

Figure 4 Methane emissions contribution and breakdown of anthropogenic sources



Note: Enteric fermentation takes place in the digestive processes of ruminant animals (*e.g.*, cows, sheep).

Source: U.S. EPA, 2006a.

Reducing methane emissions provides a number of important energy, safety, economic, and environmental benefits. First, because methane is a potent GHG (25 times more potent than CO_2 on a 100-year basis), and has a short atmospheric lifetime, methane reductions produce important near-term progress toward climate change mitigation. In addition, methane is the primary constituent of natural gas. Thus the collection and use of methane provides a valuable, clean-burning energy source that promotes local economic development and reduces local environmental pollution and odours. Producing energy from methane recovery avoids the use of conventional energy resources, reducing end-user and power plant emissions of CO_2 and air pollutants. Finally, capturing methane from coal mines, landfills, and oil and gas facilities can also improve safety conditions by reducing explosion hazards.

The oil and gas, coal mining, solid waste management and livestock sectors are the focus of this report. The oil and gas sector can view methane emissions reductions as an important energy efficiency opportunity, while coal mine methane, solid waste disposal sites and manure management operations should view methane recovery and use as an important source of energy for their own use or for local gas or electricity networks.

Energy sector methane mitigation: a closer look

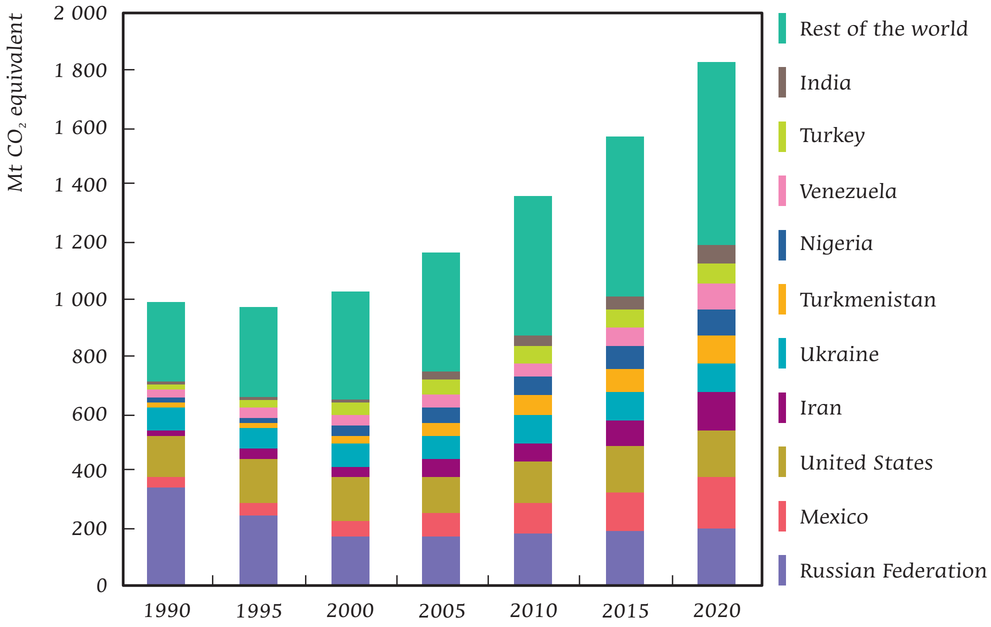
Oil and gas

After enteric fermentation, the oil and gas sector is the second largest anthropogenic methane source worldwide, releasing 85 billion cubic meters (Bcm) (approximately 1 200 Mt CO_2-eq) of methane to the atmosphere annually (M2M, 2008a). Methane is the primary component of natural gas, which is produced on its own or in combination with oil as associated gas. The majority of emissions come from oil and natural gas production and natural gas processing, transmission and distribution. Emissions can be unanticipated leaks or process-related venting and primarily result from normal operations, routine maintenance, and system disruptions. For example, emissions can result from venting the gas from compressors or pipelines when they are taken out of service, or from normal operation of pneumatic devices powered by high-pressure natural gas that is then released into the atmosphere. Emissions vary greatly from facility to facility and are largely a function of the types of equipment and systems, operation and maintenance procedures, and equipment conditions.

Country emissions trends

Currently, natural gas and oil systems account for 17% of total global methane emissions (U.S. EPA, 2006a). As shown in Figure 5, Russia, the United States, Iran, Mexico and Ukraine contribute the most methane emissions. Emissions are projected to increase 57% from 2005 to 2020, with developing countries like Brazil and China having the largest growth, due to their rapidly expanding economies (U.S. EPA, 2006a).

Figure 5 Methane emissions from oil and gas systems are estimated to grow substantially in developing regions



Source: U.S. EPA, 2006a.

Mitigation technologies and practices

As the gas moves through system components under extreme pressure, methane can escape into the atmosphere through, for example, worn valves, pump seals, or joints or connections in pipelines. Methane emissions can also occur from standard oil and gas processes, such as releases from pneumatic controls operated by high-pressure natural gas.

Cost-effective opportunities for reducing methane emissions in the oil and gas sector vary greatly from country to country based on the concentration of emission sources, the condition of the oil and gas infrastructure and the local price of natural gas, among other things. There are, however, a number of proven best management practices that can be applied in any setting.[2] Mitigation options include technology or equipment upgrades, such as conversion to low-bleed pneumatic devices or installation of dry seals on centrifugal compressors; improvement of management practices and operational procedures; and enhanced leak detection and measurement programmes. In addition to these options, the oil and gas sector can directly use the gas or reinject it into oil fields for enhanced oil recovery as methods to avoid releasing methane emissions. Flaring is a mitigation option that addresses the methane emissions, but does not make optimal use of a valuable fuel resource.

Methane leakages are typically difficult to detect. However, improvements in technology in recent years are helping to improve methane emission detection capabilities. For example, infrared (IR) cameras that can be used to see otherwise invisible hydrocarbon emissions have proven to be transformational technologies in raising awareness about methane emission sources and volumes. These cameras operate as normal video cameras, but with an IR component that allows the user to see previously invisible hydrocarbon emissions as black smoke. Used in conjunction with a variety of methane emission quantification technologies, IR cameras are contributing to a rapidly improving body of knowledge about emissions sources and volumes.

An example of these mitigation activities is directed inspection and maintenance (DI&M) programmes, which use a variety of leak detection and measurement technologies to identify and quantify leaks, leading to more accurate, efficient and cost-effective leak repairs. DI&M programmes can be applied to oil and gas production and gas processing, transmission, and distribution operations wherever they take place. In countries with large oil and gas infrastructures, such as Russia and the United States, the wider application of these programmes has the potential to yield both substantial methane emission reductions and gas savings.

Barriers to methane mitigation technologies and practices

Although there are a number of proven mitigation technologies and practices, there are important barriers to their implementation:

- **Financial**. While many oil and gas sector methane reduction technologies and practices can be cost-effective based on the value of the natural gas saved, financial barriers still exist that prevent implementation of these activities. The reasons for this vary and include such factors as competition for capital with other projects; a lower rate of return for methane reduction projects versus traditional operations such as drilling new wells; and a disconnect between the department that would fund the project and the department that would recognise the

---

[2] The U.S. EPA's Natural Gas STAR Program, for example, has identified 80 cost-effective technologies and practices that can reduce methane emissions along the oil and natural gas value chain. According to these documents, assuming a natural gas value of USD 3 per MMBtu, 77% of these 80 mitigation activities will pay back within three years and 47% will pay back within one year. See www.epa.gov/gasstar for more information.

additional natural gas revenue. Additionally, in locations where the natural gas price is well below international values, achieving cost-effectiveness by means of natural gas value alone is challenging or impossible.

- **Access**. While cost-effective technologies and practices exist, there may be access limitations in some regions. A lack of local service and technology providers for methane identification, quantification, and mitigation activities can significantly hinder oil and gas operators' ability to implement methane reductions.
- **Awareness**. Oil and gas companies and governments often are not aware of the actual volumes of methane emissions from oil and natural gas operations. This can be the result of a lack of focus on quantifying these emissions or lack of access to methane emission detection and quantification equipment. Additionally, a historical focus on oil as the dominant value-producing hydrocarbon and natural gas as a "by-product" has resulted in the development of inefficient infrastructure as well as a mentality in the oil and gas industry that natural gas losses are insignificant in the context of their overall operations.
- **Lack of strategic policy framework**. Most countries do not currently have a comprehensive policy framework to encourage and enforce the implementation of technologies to reduce methane emissions in the oil and gas sector. Without strong, well-developed policies that promote execution of programmes to reduce methane emissions there is often little incentive to invest in the necessary mitigation technologies.

Country methane reduction efforts

To address these barriers, some governments have initiated successful outreach programmes and/or targeted policies. However, there are only a few examples of governmental policies designed to encourage methane mitigation in the oil and gas sector. The most important examples include:

- **Voluntary public-private partnerships**. To improve awareness about methane emissions and best management practices, and to create a framework for knowledge transfer, some countries have implemented voluntary partnerships with the oil and gas sector.
- **Strategic targets and flexible mechanisms**. A strategic approach for addressing oil and gas sector emissions is to develop a national methane reduction target for the sector, supported by flexible mechanisms to let industry determine the best approach reinforced with penalties for failure to achieve targets.

Voluntary public-private partnerships: the United States

The United States has used a voluntary partnership policy to encourage methane emissions reductions in the oil and gas sector and has achieved significant results. The US Environmental Protection Agency's (U.S. EPA) Natural Gas STAR Program is a voluntary partnership that encourages oil and gas companies to adopt proven, cost-effective technologies and practices that improve operational efficiency and reduce methane emissions. As a result of this partnership, EPA has compiled comprehensive technical information on methane mitigation technologies and practices that have been successfully implemented by partner companies. Participants in the Natural Gas STAR Program benefit from information sharing and technology transfer; programme support and technical assistance; peer networking; voluntary record of reductions where companies create a permanent record of their voluntary accomplishments in reducing methane emissions; and public recognition.[3]

---

[3] Note that Natural Gas STAR is a domestic US programme; there is also a companion Gas STAR International programme that follows a similar model. See http://www.epa.gov/gasstar/international/index.html.

Since 1993, Natural Gas STAR partner companies have reported nearly 677 billion cubic feet (Bcf) of methane emissions reductions in the United States. Specifically, in 2007, domestic partners reduced methane emissions by 92.5 Bcf, which added nearly USD 650 million to natural gas sales (based upon an average gas price of USD 7.00 per thousand cubic feet).[4]

In 2006, in support of the Methane to Markets Partnership (M2M), EPA expanded Natural Gas STAR to include international operations, significantly increasing opportunities to reduce methane emissions from the oil and netural gas sector worldwide. Natural Gas STAR International partners reported 6.7 Bcf in emissions reductions for 2007 and a total of 14.4 Bcf since the inception of the Natural Gas STAR International Program.[5]

Strategic targets and flexible mechanisms: Alberta, Canada

The province of Alberta, Canada has a strategically designed policy for reducing methane emissions in the oil and gas sector. Alberta produces 77% of Canada's natural gas and 38% of the nation's oil (CAPP, 2009). The environmental management of this energy production and utilisation has long been recognised as an important element in the province's economic development. The oil and gas industry in Alberta has achieved a conservation rate of 95.8% of total solution gas production;[6] however the remaining amount represents significant gas volumes (Johnson, 2009). Flaring is among one of the methods used to handle the waste gases. Currently, there are more than 5 500 active flares in Alberta that burn an estimated 1.1 bcm per year produced by the upstream oil and gas industry annually; of this total, flaring and venting was 0.720 bcm (0.35 flaring and 0.37 venting) (Johnson, 2009).[7] Because flaring largely destroys methane, it reduces GHG emissions and is preferable to venting. However, flaring is still problematic in that flared gas wastes a non-renewable hydrocarbon resource that could be put to beneficial use.

To create a comprehensive, flexible approach to regulate these active flares while achieving significant reductions, in the 1990s, Alberta's Energy and Utilities Board (EUB) implemented flaring and venting requirements for the upstream petroleum industry via Directive 60, with the following features:

- A province-wide short-term **voluntary reduction target of 15%-25%**; with long-term reduction targets of up to 70%, along with a **regulatory backstop** requiring more prescriptive requirements if the voluntary targets did not result in satisfactory reductions.
- A **methodology for testing the economic feasibility** of conserving/utilising the solution gas and **clustering requirements** whereby multiple facilities in close proximity must consider the economics of gas conservation on a combined basis.
- A **decision tree support tool** that allows operators to demonstrate that they have considered all of the options to eliminate or reduce flaring.

- Regular and transparent assessment via a **public annual report** showing all flaring and venting data for Alberta, including volumes of gas flared and vented for each operating company.
- The **trigger of enforcement** if a company fails to comply with Directive 60 (or related Directive 19),[8] leading to suspension of operations or removal of an operator's right to produce from non-compliant facilities.

---

[4] Accomplishments of the Natural Gas STAR Program can be accessed at http://www.epa.gov/gasstar/accomplishments/index.html.

[5] For more information, see http://www.epa.gov/gasstar/international/index.html.

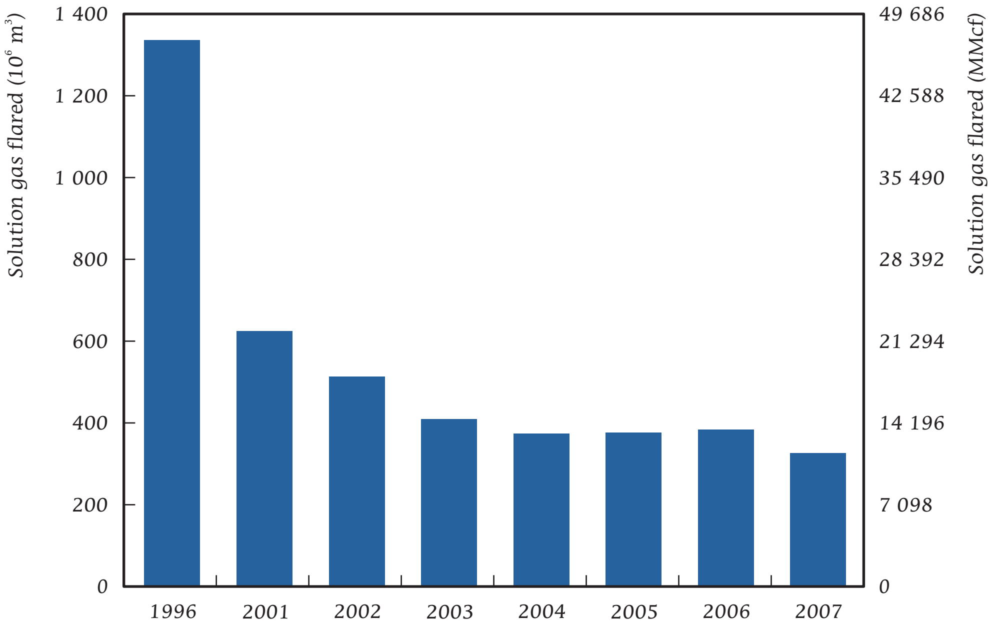
[6] Solution gas, also referred to as associated gas, is gas produced in association with oil production.

[7] This does not include additional facility-level and test well flaring.

[8] The Alberta Directives can be accessed at: http://www.ercb.ca/docs/documents/directives/Directive019.pdf.

The result of this comprehensive, flexible approach was a significant reduction in flaring, in fact, industry outperformed the targets in the most cost-effective manner. Figure 6 shows that solution gas flaring in Alberta has been reduced by 76% since the baseline year of 1996. As a result, 96% of all solution gas produced in Alberta is conserved and is either sent to market or used as fuel.

Figure 6 Alberta has realised major emissions reductions associated with a drop in gas flaring volumes



Source: Alberta Energy and Utilities Board.

These models demonstrate the importance of government leadership in creating the framework for data collection on methane emissions and emissions reduction opportunities, and in forming a partnership with industry to achieve a common goal of cost-effective methane emissions reductions in the oil and gas sector.

Coal mine methane

Coal mine methane (CMM) refers to methane released from the coal and surrounding rock strata due to mining activities.[9] In underground mines, it can create an explosive hazard to coal miners, so it is removed through ventilation systems. Some underground mines are sufficiently "gassy" that they must augment their ventilation systems with degasification (also called "drainage") systems. In abandoned mines and surface mines, methane might also escape to the atmosphere through natural fissures or other diffuse sources.

---

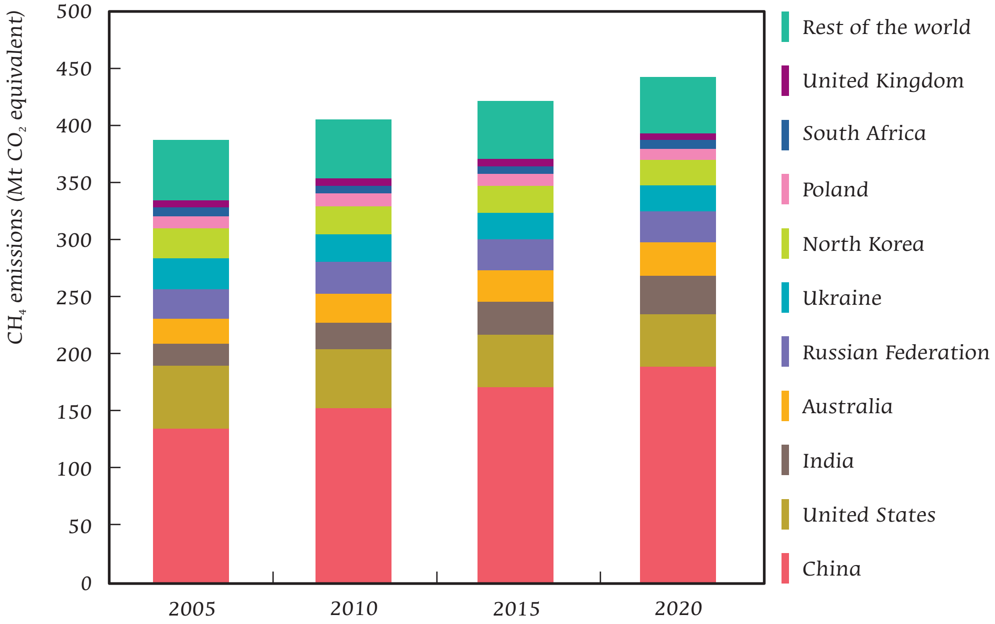
[9] Coal mine methane should be distinguished from coal bed methane: coal mine methane is the gas that is released immediately prior to or during coal mining activities, and thus has climate change impacts; coal bed methane is harvested as a natural gas resource.

Country emissions trends

Coal mining contributes 8% of total global anthropogenic methane emissions (U.S. EPA, 2006a). Worldwide coal production has increased at roughly 6% annually in the past several years, driven by developing country growth. As a result of this growth, combined with technology improvements that enable coal extraction from increasingly greater depths, CMM emissions are projected to grow 20% from 2000 to 2020 (IEA, 2008a). China, the United States, India and Australia are the largest producers, together accounting for about 75% of global production (IEA, 2008a).

China and other coal producers continue to see rising CMM emissions

Figure 7



Source: U.S. EPA, 2006a.

Many factors affect the quantity of methane released during coal mining, including the gas content of the coal, the permeability and porosity of the coal seams, the method of mining, the depth of coal seam being mined, and the production capacity of the mining operation. Abandoned (closed) underground coal mines also emit methane, depending on the extent to which the mine has been sealed or the extent to which it has flooded.

Methane mitigation technologies and practices

A number of technologies are readily available to recover and use methane from active or abandoned coal mines. Methane must be removed from active underground mines for safety reasons using large-scale ventilation systems that move massive quantities of air through the mines. These ventilation systems keep in-mine methane concentrations well below the explosive range. They release large amounts of dilute methane (typically less than 1% methane in air) to the atmosphere, known as ventilation air methane (VAM). Technological development has progressed to the point that very low concentration VAM can be oxidised and the resulting thermal energy can be used to produce heat, electricity, or refrigeration (U.S. EPA, 2003). Several different oxidation technologies for ventilation air methane (both thermal and catalytic) have been demonstrated in Australia, the

US, and China. The West Cliff Ventilation Air Methane Project (WestVAMP) project in Australia is the world's first commercial scale project that converts ventilation air methane to electricity, generating 6 MW of power.[10]

Degasification systems are employed at active underground mines to augment the ventilation systems at especially gassy mines to keep in-mine methane concentrations to safe levels. Degasification systems most commonly employ gob gas[11] wells, to remove methane during and after mining operations. Pre-mining degasification systems, where holes are drilled and methane is captured before mining operations begin, may be used at active or abandoned underground mines, and are currently being used at a number of mines in the United States (IRG, 2004). Advanced drilling techniques such as surface to lateral wells or directional drilling may be used to maximise the gas recovery. Other degasification techniques include in-mine short-hole or long-hole drilling or cross-measure boreholes. Degasification may also be used in advance of mining at surface mines or to remove gas from the void space of abandoned underground coal mines.

It is possible to recover and use the drained gas depending on its quality and on the desired end-use. Technologies are widely available to purify the gas and remove contaminants (U.S. EPA, 2008). Once captured, there are a variety of uses for CMM. Specific uses for recovered CMM depend on the gas quality, especially the concentration of methane and the presence of other contaminants in the drained gas. CMM can be used for power generation, district heating, boiler fuel, or town gas, or sold to natural gas pipeline systems. It can also be used for coal drying; as a heat source for mine ventilation air or supplemental fuel for boilers; for vehicle fuel as compressed natural gas (CNG) or liquefied natural gas (LNG); or as manufacturing feedstock; or as a fuel source for fuel cells and internal combustion engines.[12]

Barriers to methane mitigation

Although there are significant benefits and scope for CMM recovery, projects face several challenges. Some of the barriers include:

- **Financial**. Many CMM projects are not cost-effective at standard market rates for power and natural gas. Further, many coal mines do not have adequate internal investment capital for project funding, and a lack of adequate financing is an important challenge.
- **Lack of clarity on CMM ownership**. In most countries, there is a lack of clarity in regulations on the rights to and priority for CMM development. In some countries, there may be separate owners for the coal, the gas, and the surface land rights. In such cases, multiple ownership issues complicate or delay project development.
- **Technology**. Developing countries often lack access to appropriate technology to assess and develop CMM resources. Other barriers include the ability to tailor technologies to the local situation and gas quality.
- **Grid interconnection**. Coal mine methane projects are relatively small compared to traditional centralised generation plants, and may be located at some distance from regional electricity grids. As such, there can be economic challenges connecting with the electricity system.

---

10. More information on the WestVAMP project can be found at http://www.environment.gov.au/settlements/industry/ggap/bhp.html.

11. The debris which fill the mine after the supports are removed and the roof and walls collapse is referred to as the "gob". Methane existing within the debris is referred to as "gob gas", and is released into the mine as it collapses. Gob gas is initially of high-quality, usually 30%-80% methane; however, over time its quality declines as the methane mixes with air.

12. For more information on CMM mitigation technologies and practices, visit http://www.methanetomarkets.org/coalmines/index.htm; there are also a number of utilisation technologies described in the technical option series at www.epa.gov/cmop/resources/technical_options.html.

- **Lack of comprehensive policy frameworks**. Many countries lack a strategic policy framework for CMM development and use, and fail to address (and coordinate) needs like project approval for property leases, regulation of CMM safety, and beneficial use.

Country CMM reduction efforts

There are some good examples of countries that have addressed these barriers through targeted policy development and implementation. The most important policies include:

- **Creation of appropriate financial incentives**. A variety of economic incentives have been successfully used to support CMM use, including feed-in tariffs, grants and tax incentives.
- **Clarification of property and gas ownership**. To address confusion about CMM ownership and priority of use, some countries have clarified ownership rights and priorities.
- **Capacity building to address technology barriers**. Many potential CMM projects are located in developing economies that lack the training and technological capacity to implement them. To address this gap, governments are providing aid via know-how and technology transfer efforts.
- **Development of comprehensive CMM policy frameworks**. To improve efficiency, clarify ownership, and signal the government's priorities, some countries are developing comprehensive policy frameworks. While these are promising developments, there is still no country that has a comprehensive framework in place.

Financial incentives and interconnection: Australia, Germany and the United Kingdom

To bridge the financial gap facing some CMM use projects, governments are adopting a variety of market-based or financial mechanisms. Feed-in tariffs promote renewable energy and methane recovery by mandating the utility to pay higher-than-market rates for produced power. Australia is a leading government actor, having directly funded and provided grants to a number of coal mine methane projects, including the innovative West Cliff Colliery VAM power generation project.[13]

In Germany, the Renewable Energy Sources Act (2004) (Erneuerbare-Energien-Gesetz or EEG) provides fixed tariffs that grid operators must pay for the feed-in of electricity generated from a number of sources, including CMM and landfill gas. It provides a guaranteed price for 20 years (IEA, 2008b). Other countries are using tax exemptions to support CMM. The United Kingdom, for example, has implemented the Climate Change Levy (CCL) to encourage clean, renewable energy. Clause 123 exempts electricity generated from CMM from paying the CCL (HM Treasury, 2002). CMM energy operators also face challenges in accessing electricity markets on a level playing field; these UK and German policies also provide project developers with grid access and thus address the challenges of grid interconnection that prevent some CMM power projects from going forward.

Clarification of property and gas ownership: Germany

In Germany, the Federal Mining Authority is responsible for CMM-related activities, including exploration, extraction and processing. CMM ownership rights are transferred to a mining company for the duration of a coal mining licence, after which CMM use requires a renewed licence (U.S. EPA, 2009). This legal framework has resolved disputes over ownership of CMM, and has led Germany to be a leader in terms of CMM utilisation per available mine site.

---

[13] For a summary, see the Australia chapter of the M2M Global Overview of CMM Opportunities: www.methanetomarkets.org/resources/coalmines/docs/overview_ch2.pdf.

Capacity building to address technology barriers: international financial institutions and the United States

Given that many developing countries lack basic understanding and expertise in CMM recovery and utilisation, international financial institutions are providing valuable capacity building efforts in CMM technologies, mine operation, economic analysis of projects and training of skilled workers who can manage the technology and equipment. The World Bank and Asian Development Bank, as well as bilateral donors, are providing resources and expertise through targeted training workshops on CMM recovery and utilisation technologies and practices, loan delivery, and technology transfer (IEA, 2009).[14]

The United States has also done a tremendous amount of work in capacity building, both within the US via the Coalbed Methane Outreach Program and around the world. The U.S. EPA has helped to establish CMM clearinghouses in several countries, beginning in 1994 with the China Coalbed Methane Clearinghouse, and continuing with the recent establishment of a clearinghouse in India.[15]

Development of comprehensive CMM policy frameworks: Mongolia and China

Mongolia has recognised the challenges in clarifying CMM rights, providing incentives and leasing CMM. In 2006, the Parliament revised the 1997 Minerals Law, which covers exploration and mining of all mineral resources, including coal. This amendment provides a scheme for issuing licences for CMM development, whereby the exploration license holder has the exclusive right to obtain a mining license for a given area. The government is now developing additional policies to clarify overlapping areas which may include coal mines and natural gas/CMM resources; these policies will address several issues, including: technical safety standards and degasification requirements, gas ownership issues, and tax incentives, including import tax exemptions on CMM equipment (B. Mendbayar, 2009).

Another example is China. As the world's leading emitter of CMM, and host of the largest number of projects, the Chinese government has enacted a number of policies to govern CMM recovery and use. To address coal mine safety, in June 2006, the State Council issued *Opinions on Speeding up CBM/CMM Extraction and Utilisation*, which requires that local land and planning authorities ensure that coal mines implement a safety first approach, focusing on prevention, safety standards and oversight by the government, and the use of technology when extracting gas prior to coal mining.

To increase CMM output and address market barriers, in April 2007, the National Development and Reform Commission (NDRC) issued a *Notice on CBM/CMM Price Management*, while the price of gas distributed via city pipeline networks depends on ex-plant price (based on production costs), transportation tariffs – both determined by the government – and end-user price determined by the local government. In the same month, NDRC issued a *Notice on Executing Opinions on Generating Electricity with CBM/CMM* which requires that electricity generated by CBM/CMM power plants be given priority by grid operators who should purchase surplus electricity at a subsidised price. CBM/CMM power plant owners were also exempted from market price competition and do not undertake any responsibilities for grid stability. Also in April 2007, the Ministry of Finance issued

---

[14] The United Nations Economic Commission for Europe (UNECE) has been active in this area and is working on facilitating CMM finance. Fore more information on CMM financing, visit http://www.unece.org/energy/se/pdfs/cmm/sessfebdec06/Topic6/Vitchev_RFI2.pdf.

[15] The China Coal Information Institute now manages the Clearinghouse; for more information visit www.coalinfo.net.cn/coalbed/coalbed.htm; the India CMM Clearinghouse can be accessed at www.cmmclearinghouse.cmpdi.co.in/

Executing Opinions on Subsidising CBM/CMM Development and Utilisation Enterprises whereby any enterprise engaged in CBM/CMM extraction within China is entitled to financial subsidies, if it is used on site or marketed for residential use or as a chemical feedstock.[16]

Finally, in April 2008, the Ministry of Environmental Protection issued an *Emission Standard of CBM/CMM*, which dictates the following:

- CBM drainage systems are prohibited from emitting CBM;
- Coal mine drainage systems with a gas concentration of 30% methane or higher are prohibited from emitting the methane (*e.g.*, they must either use or flare the gas); and
- If the methane concentration is less than 30%, the methane is allowed to be released.

This comprehensive set of policies provides a basis to move forward on CMM development in China; the next challenge for the national government will be to ensure that the full set of measures is effectively monitored and implemented.

Landfill gas recovery and use

Landfill gas (LFG) is approximately 50% methane, and is produced through the natural process of the bacterial decomposition of organic waste under anaerobic conditions in sanitary landfills and open dumps. The amount of LFG generated depends on a number of factors, including the type of waste disposal site, the organic content of the waste, and the climate.

Country emission trends

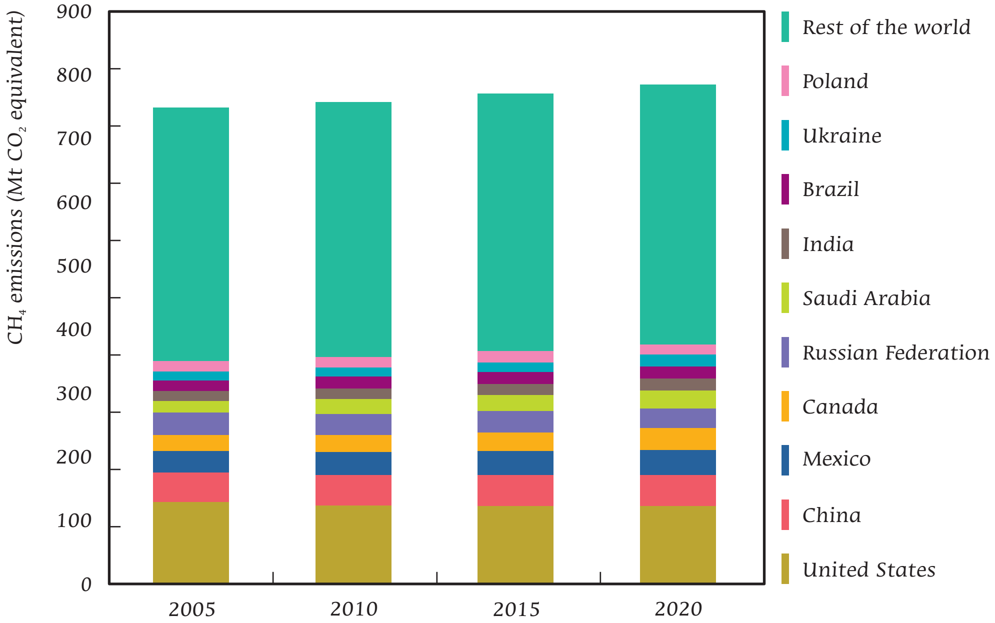
Municipal solid waste (MSW) management contributes 14% of total global methane emissions. Global methane emissions from landfills are expected to grow by 9% between 2005 and 2020. Currently, the United States, China, Russia, Canada and Southeast Asia are the main contributors of methane emissions from MSW (Figure 8).

Most developed countries have policies that will constrain and potentially reduce future growth in methane emissions from landfills, such as expanded recycling and composting programmes, increased regulatory requirements to capture and combust LFG and improved LFG recovery technologies (U.S. EPA, 2006a). However, developing regions in Asia and Eastern Europe are projected to experience steady growth in landfill methane emissions because of expanding populations, combined with a trend away from unmanaged open dumps to sanitary landfills with increased anaerobic conditions conducive to methane production.

---

[16] The IEA's 2009 report *Coal Mine Methane in China: A Budding Asset with the Potential to Bloom* made a number of recommendations to address key barriers to Chinese CMM capture and use, including (1) continued government reform and elevated attention to CMM; (2) involving all stakeholders – particularly electric utilities – in CMM recovery and use policy/subsidy development; (3)increased capacity building for medium and small coal mines; and (4) continuing to adapt international CMM technologies to Chinese circumstances. The report can be downloaded at http://www.iea.org/Textbase/publications/free_new_Desc.asp?PUBS_ID=2085.

Figure 8 Methane emissions from solid waste management are expected to grow, particularly in developing regions



Source: U.S. EPA, 2006.

Methane mitigation technologies and practices

LFG can be extracted using a proven system involving a series of wells and a vacuum that directs the collected gas to a point to be processed. Once the gas is collected, it may be flared, used for electricity production, used directly, or upgraded to pipeline-quality natural gas or alternative vehicle fuel. Historically, flaring has been the most common manner of mitigating LFG emissions; however, while flaring has proven effective in reducing methane emissions, it misses an opportunity to use a clean energy resource.

Barriers to LFG use

LFG collection and use technologies are mature and there are many options for landfill gas use. However, barriers prevent the wider use of these technologies, including:

- **Financial**. Investors are unlikely to put forth the capital needed for an LFG capture and utilisation scheme unless it will be sufficiently profitable. Furthermore, there is higher risk and uncertainty relating to predicting the LFG flow from waste disposal sites in developing countries, where the climatic or disposal site conditions are quite different from those at landfills with existing LFG recovery and use projects.
- **Interconnection to the electricity grid**. As with other methane recovery electricity generation projects, there are often economic and technical barriers in connecting LFG power projects to the grid to sell their power output.
- **Solid waste management practices**. Developing countries are more likely to dispose of municipal solid waste in open or minimally managed dumpsites. Before these countries can consider LFG use, they will first need to improve solid waste management practices, which requires additional capital and human resource investments.

- **Awareness**. There is the need to increase awareness of the existence of LFG emissions and the value of the lost fuel, especially in developing countries with rapidly growing waste sectors. Policy makers often fail to understand the full impact of LFG emissions on local air quality and climate change risk. Waste disposal sites also lack clear, unbiased information about costs and performance of various LFG use options.

Country landfill gas reduction efforts

Many of the barriers listed above have been addressed by countries using targeted policies. Governments have used mechanisms such as:

- **Creation of financial incentives**. Countries are creating financial incentives through inclusion of LFG in renewable portfolio standards or feed-in tariff schemes, or via directed tax credits toward methane recovery and use.
- **Streamlined interconnection policies**. Standardised interconnection requirements help level the playing field for smaller-scale projects like LFG energy recovery. They can be tailored to project size, and help to streamline the application process for projects seeking to access the grid to market their power.
- **Improved waste management regulations that include LFG collection and flaring**. Implementing these requirements, driven by air pollution and/or climate measures, is another policy mechanism that has been used to change the economics of LFG use.
- **Education and awareness campaigns**. These campaigns collect landfill methane emission data at specific sites, as well as provide objective information on technology options and costs.

Creation of financial incentives: Germany

As discussed in the CMM section above, the feed-in tariff (FIT) mechanism is a proven mechanism for incentivising electricity from LFG. FITs are typically set for a certain number of years to allow for investor certainty. As projects are built and become cost-competitive, FIT rates can be lowered or phased out. The German EEG FIT scheme is credited with encouraging landfill gas development as part of a large and growing domestic biogas market in the country (IEA, 2008b).

Streamlined interconnection policies: Massachusetts

A number of states in the United States, including Massachusetts, have designed standardised interconnection requirements to address the uncertainty and economic challenges that smaller-scale generators, including methane recovery from landfills, often face. In 2002, the state initiated a Distributed Generation (DG) Collaborative to develop a model generation tariff. The application process for interconnection uses consistent criteria to determine the fees and timelines for DG systems of various sizes. For larger systems, including most LFG energy systems, the process has been shortened to 150 days or less and includes a USD 2 500 application fee. This transparency in the timing and the costs for interconnection applications directly addresses the uncertainty that LFG developers typically face when attempting to negotiate a grid connection with the incumbent utility.[17]

---

[17] For more information, see www.mass.gov/dte/restruct/competition/distributed_generation.htm; as well as www.masstech.org/policy/dgcollab.

Improved waste management regulations that include LFG collection and flaring: China and India

China is one of a growing number of countries that have recently enacted regulations requiring LFG capture and flaring. In April 2008, China's Ministry of Environmental Protection released the *Standard for Pollution Control on the Landfill Site of Municipal Solid Waste* which requires LFG capture and flaring as part of landfill management (Ministry of Environmental Protection of the PRC, 2008). These regulations are designed to remove air pollution and safety hazards caused by uncontrolled LFG venting. These regulations also change the economic viability of LFG use by making the cost of the LFG collection system a part of doing business in the solid waste industry.[18]

In 2000, recognising the environmental problems associated with MSW, India's Ministry of Environment and Forests required that all organic waste be organised and processed separately and not be dumped into landfills. The ban immediately faced difficulties in enforcement, as a number of municipalities failed to implement the new rules. As a result, organic wastes continued to be dumped at waste sites, leading to significant methane emissions. While the ban was in place, however, LFG recovery and use was not seen as economically viable. Recognising this problem, the Ministry has begun the process to repeal the organics ban. In this way, LFG use can provide a new revenue source to help fund the upgrade and improvement of the dump sites toward cleaner, safer sanitary landfills (IEA, 2008c).

Education and awareness campaigns: the United States.

Educating stakeholders about the value of LFG is an important strategy that can help support all of the other policy approaches by ensuring that the policies achieve their goals. An example from the United States is the U.S. EPA Landfill Methane Outreach Program (LMOP), a voluntary assistance programme that helps to reduce methane emissions from landfills by encouraging LFG recovery and use. LMOP forms partnerships with stakeholders to overcome barriers to project development by helping them assess project feasibility, find financing and market the benefits of project development to the community.[19] Also, the M2M Landfill Subcommittee Action Plan recognised the LFG sector's need to collect data and build capacity for improved LFG extraction system operations and maintenance, and the Subcommittee was reorganised to focus on two barriers: limited information and insufficient in-country knowledge (M2M, 2009a).

Manure methane recovery

Methane is produced and emitted during the anaerobic decomposition of organic material in livestock manure (mainly from swine, cattle and some poultry operations). The quantity of methane emitted from manure management operations is a function of the type of treatment or storage facility, climate and the composition of the manure (U.S. EPA, 2006b).

Country emissions trends

Manure management contributes roughly 4% of total anthropogenic methane emissions. Global methane emissions from manure management are projected to increase by 21% between 1990 and 2020, with increasing emissions in all regions except the non-EU FSU countries (U.S. EPA,

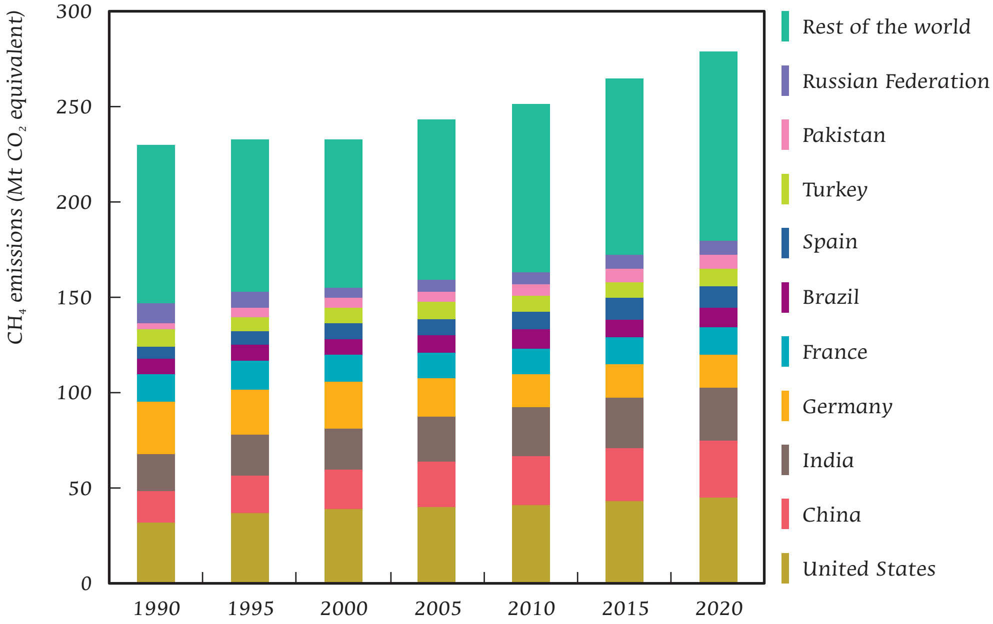
---

[18] Note, however, that in order to qualify for GHG credits, *e.g.*, under the Clean Development Mechanism, projects must be able to prove that there is no legal or regulatory requirement to control LFG emissions.

[19] More information on LMOP can be found at http://www.epa.gov/lmop/.

2006b). The expected growth rate for developing regions is large; this is due to the expected growth in livestock populations and the trend towards larger, more concentrated commercial livestock management operations in these countries (Figure 9).

Figure 9 *Manure management methane emissions are rising globally*



Source: U.S. EPA, 2006b

Methane mitigation technologies and practices

Methane from manure can be recovered using anaerobic digesters, including covered anaerobic lagoons, plug flow digesters, complete mix digesters, and small scale digesters (M2M, 2008b). The waste handled is in the form of liquid, slurry, or semi-solid, depending on the system design requirements. The following are brief descriptions of conventional anaerobic digestion technologies, any of which may be used at smaller farms in regions with technical, capital, and material resource constraints.[20]

- **Covered anaerobic lagoons** are constant volume reactors that can be operated at ambient temperatures. Manure is treated under anaerobic conditions producing methane, which is collected using impermeable lagoon covers.
- **Plug flow digesters** are heated systems that operate at a constant temperature year round, producing stable gas flows that support gas-to-energy applications in all climates.
- **Complete mix digesters** are heated digesters constructed of concrete or steel designed to enhance anaerobic decomposition and maximise methane recovery.

Anaerobic digestion can be cost-competitive when compared to conventional waste management practices; current technology offers a range of opportunities to abate livestock manure methane emissions while generating an alternative income source. Methane released from liquid manure

---

[20] For more information about technology options, see http://www.methanetomarkets.org/ag/index.htm#outreach.

management systems can be captured and used as a clean energy source to produce heat, electricity, or combined heat and power; or in fuel gas-fired equipment such as engines, boilers, or chillers to meet a portion of a farm's energy requirements.

Barriers to methane mitigation

Barriers to implementing manure methane mitigation are similar to other methane recovery technologies and include:

- **Financial**. Capital costs for manure methane projects can be high, and available energy tariffs are insufficient to make projects economic.
- **Lack of awareness about suitable technologies**. There is a lack of understanding in most countries about the potential for methane recovery from manure management, as well as low awareness of appropriate technologies and practices.
- **Lack of a comprehensive approach**. While some regions are investing in manure methane recovery for water quality or GHG mitigation, there are very few examples of strategic frameworks for development of this resource.

Country methane reduction efforts

To achieve widespread implementation of projects that aid methane emissions reductions, governments can take the lead in developing more comprehensive and programmatic approaches to manure methane recovery, including mechanisms such as:

- **Creation of financial incentives**. Countries can create financial incentives to encourage manure methane recovery and address high capital costs.
- **Education and outreach**. Raising awareness of the benefits, economics, and technology options can make farmers more willing to adopt the technologies. Demonstration projects are also often beneficial.
- **Comprehensive deployment strategies**. Countries can develop comprehensive policy frameworks to encourage the deployment of anaerobic digesters. This involves assessing the potential manure methane resource, identifying barriers to realising this potential, and designing targeted policies and measures to address each of the barriers in a systematic manner.

Creation of financial incentives: the United States.

The US Farm Bill uses loan guarantees to incentivise manure methane recovery (see section 3702(a) The Farm Bill [S.3036]). Section 29 of the Internal Revenue Code, established in the Windfall Profit Tax of 1980, provides tax credits for produce fuel from nonconventional sources, such as coal seams, steam from agricultural products, and gas from biomass (Energy Information Administration, 2004). The tax credit is equal to the product of USD 3.00 and the appropriate inflation adjustment factor (IAF) per barrel-of-oil equivalent (OBE). In 2004, the IAF was 2.1853; therefore, the credit was USD 6.56 per OBE of qualified fuels (USD 3.00 x 2.1853).[21]

Education and outreach: the United States

The AgSTAR Program is an effort sponsored by the U.S. EPA, the US Department of Agriculture, and the U.S. Department of Energy to encourage the use of methane recovery technologies on livestock operations. This programme provides information and tools designed to assist farmers in the evaluation and implementation of methane recovery systems. AgSTAR conducts outreach

---

[21] These Section 29 credits were set to gradually phase out if the average annual price of US wellhead crude oil per barrel in calendar year 2005 exceeded USD 52.38.

events and conferences, provides project development and industry listings, performs performance characterisations for systems, and collaborates with federal and state renewable energy, agricultural, and environmental programmes. Construction and implementation of anaerobic digestion systems in the US has increased substantially since the establishment of the programme in 1994. In 2008, farm digester systems produced an estimated 290 000 MWh equivalents of energy generation.[22]

Comprehensive deployment strategies: the United Kingdom and Mexico

The United Kingdom (UK) has been a leader in promoting approaches for anaerobic digestion internationally. This is due in part to the UK's active domestic programme, most recently communicated in its Shared Goals strategic document of February 2009 (DEFRA, 2009). The Shared Goals identify the potential for anaerobic digestion in key sectors, including waste management, water, and agriculture. The process also involved engagement of the stakeholders in each sector in "roadmap" efforts to develop targets and milestones, and strategies for achieving these targets. For example, in the Milk Roadmap, there is a vision for the UK dairy industry towards 2020, which sets targets for 30 farms piloting on-farm digestion by 2010 and 3 centralised digesters at processing sites by 2015. The long-term target is for 40% of energy used on dairy farms to be from renewable sources (DEFRA, 2009). The Shared Goals also outlines roles and responsibilities for other important stakeholders, including government, regional authorities, and the research and development community. Finally, there is an important linkage to feed-in tariffs, bio-energy grants schemes and rural development programme support to address the financial barrier faced by farms wishing to invest in manure methane recovery.

Mexico has utilised the Methane to Markets Partnership to apply the scientific and technical knowledge developed in other countries to design a comprehensive approach to manure methane recovery. Mexico has designed its own anaerobic digestion systems and lagoon sizing protocols, adapting the standards to Mexican temperatures and farm-specific loading rates. As a result of this strategic approach, the country has put into operation five demonstration projects in two high-density swine regions. With the help of M2M and its participating countries, Mexico is looking to provide further clarification on methane mitigation technologies and continue capacity building on manure management (M2M, 2008c).

---

[22] For more information, visit the website at www.epa.gov/agstar.

Methane in the international climate change and energy arena

The previous discussion focuses on domestic policy choices that countries can make to identify and address specific barriers to energy sector methane recovery and use. In addition, because methane is one of the gases covered by the United Nations Framework Convention on Climate Change (UNFCCC) Kyoto Protocol, there are also international structures designed to support national efforts to reduce methane emissions. The most significant of these are the UNFCCC flexibility mechanisms and the Methane to Markets Partnership.

As the previous sections have discussed, financial barriers can significantly impede actions to reduce methane emissions. For projects located in developing countries and in emerging economies, the GHG reductions can be marketed to provide an additional revenue stream to help address these barriers. The primary international mechanisms for this are the Clean Development Mechanism (CDM) and Joint Implementation (JI) flexibility mechanisms of the UNFCCC.

The UNFCCC is an international treaty that sets an overall framework for intergovernmental efforts to tackle the challenge posed by climate change. It recognises that the climate system is a shared resource whose stability can be affected by GHG emissions. In 1997, the UNFCCC agreed to the Kyoto Protocol, setting for the first time binding GHG emissions reduction targets for industrialised countries (UNFCCC, 2009). The Kyoto Protocol entered into force in 2005, with a number of legally binding measures (UN, 1998). The central feature of the Protocol is its requirement that signatory countries limit or reduce their GHG emissions (UN, 1998). By setting targets, GHG emission reductions have economic value. To help countries meet their emission targets in the most cost-effective way, and to encourage the private sector and developing countries to contribute to emission reduction efforts while helping the latter to get on a sustainable development path, negotiators of the Protocol included three market-based flexibility mechanisms – Emissions Trading, the CDM and JI (UN, 1998).

The CDM allows emission reduction/removal projects in developing countries to earn certified emission reduction (CER) credits, each equivalent to one tonne of CO_2. These CERs can be traded and used by industrialised countries to meet a part of their emission reduction targets under the Protocol. Joint Implementation allows a country with an emission reduction or limitation commitment under the Protocol (Annex B Party) to earn emission reduction units (ERUs) from an emission-reduction or emission removal project in another Annex B Party, each equivalent to one tonne of CO_2, which can be counted towards meeting its Kyoto target.

Methane recovery and use has been one of the leading types of projects developed under the CDM. Energy sector methane projects comprise almost 8% of the over 4 700[23] projects currently in the CDM pipeline (UNEP Risoe, 2009). These projects provided nearly 69 million metric tons (Mt) CO_2-equivalent per year in their first period, which is approximately 11%[24] of the total amount of emission reduction credits expected to be generated by all CDM projects.[25] Countries are also showing an interest in JI projects to reduce methane emissions. Currently, there are almost 70 JI methane projects, which is 34% of the over 200 JI projects in the pipeline (UNEP Risoe, 2009).

---

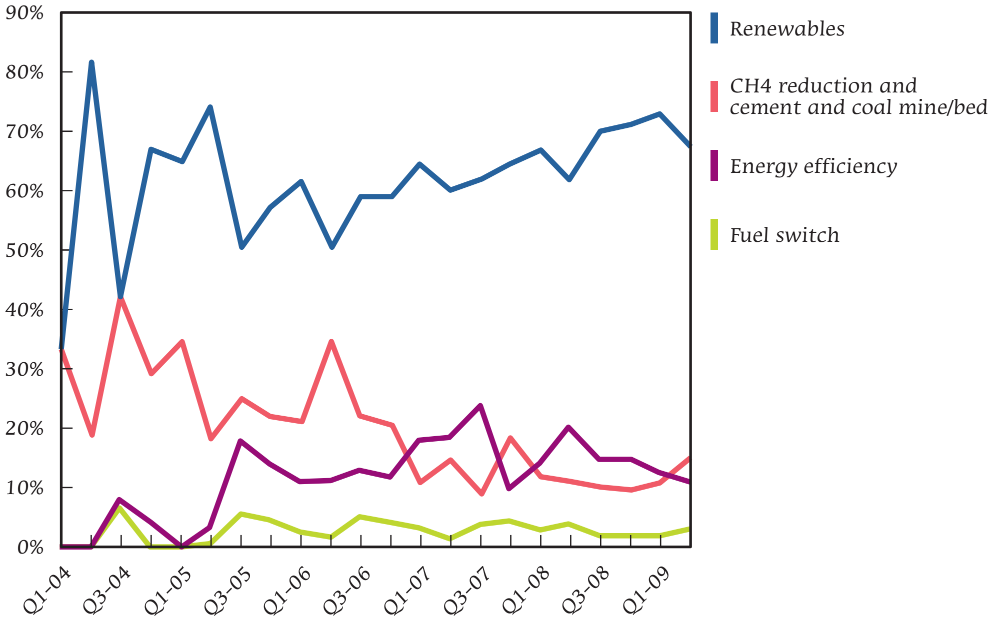
[23] This number excludes the 136 projects that have been withdrawn/rejected.

[24] This analysis was based on an analysis of CDM project methodologies; and some projects use more than one methodology so the percentage is not exact but a very close approximation. See the appendix for more information on the methodologies used.

[25] This is again excluding the 136 projects that have been withdrawn/rejected.

This section looks at the progress to date in these mechanisms for the different types of energy sector methane projects, and identifies lessons learned to inform future climate change policy discussions.

Figure 10 **Methane recovery has been a popular project category in the CDM, but numbers are declining**[26]



Source: UNEP RISO Centre

While energy sector methane projects have been a major CDM/JI project category (see Figure 10), their prominence appears to be diminishing. This is due to a number of possible factors. There have not been any comprehensive assessments of the success or failure of methane projects in the CDM/JI frameworks. However, project experience to date shows that there have been some common challenges relating to methane projects. These include a tendency to overestimate emissions reductions during the project feasibility stage; challenges with monitoring and verification of actual emissions reductions; and slow progression through the CDM pipeline due to the technical complexities of some projects. This may have contributed to the reduction in the number of projects that is seen above. The four sectors have unique issues that have arisen; these are discussed in more detail below.

- **Oil and gas**. There are 5 oil and gas methane reduction projects in the CDM pipeline (UNEP Risoe, 2009). Methane reduction projects include fugitive losses from equipment leaks (*e.g.* gas pipeline transmission, valves); production of steam heat or electricity; and production of work by engines and turbines (*e.g.* drive pumps/compressors). One challenge for the oil and gas sector has been a difficulty in attracting company interest in methane reduction projects that are a small part of their operations. Other methodological issues include setting a baseline against which a project can be measured, given the variability of oil and gas production, and establishing additionality for leak reduction practices which may be considered common industry practice.

---

[26] Figure 10 includes all methane projects, including those outside of the energy sector (*e.g.*, enteric fermentation). It also includes cement along with methane projects. However, these additions have a small impact on project trends; there is only one methane avoidance project in the pipeline and cement projects are around 1% of total projects. See http://cdmpipeline.org/cdm-projects-type.htm for this and other data.

- **Coal mining**. There are 72 CMM projects in the CDM pipeline (UNEP Risoe, 2009). However, efforts to capture and use methane emitted from mines to generate power are progressing very slowly through the CDM. Out of the 72 projects in the pipeline, there are only 10 registered. CMM project monitoring requirements are more complex than other sectors, given that meters measuring the level of methane are located thousands of feet underground. In addition, it is often difficult to forecast the quality and quantity of gas flow prior to a project, and methane content can differ widely from one mine to another, which creates uncertainty as to expected CER generation.
- **Landfill methane**. There are 146 LFG projects in the CDM pipeline (UNEP Risoe, 2009). As with CMM projects, progress of implementation of LFG utilisation projects has been slow with only 70 CDM registered projects; some projects are stalled at the agreement stage (UNEP Risoe, 2009). In addition, LFG projects have had a low "CER issuance success rate" (CERs Issued/CERs estimated in PDD for the same period). This under-delivery can be attributed to several possible reasons, including technical and operational issues; delays in the project implementation or equipment installation; and problems with monitoring and verification (ISWA, 2008).

  Also, modelling tools that are suitable to assess sanitary landfill methane emissions have over-predicted expected gas generation (and associated CERs) from unmanaged dump sites. In this situation, project proponents have failed to adequately adjust for local waste and climate conditions (Lee *et al.*, 2007). In some cases, modelling tools have estimated more than double the actual observed LFG generation from a specific site. Operational issues are also important; landfill gas generation may under-perform if cover material is not applied, leachate in unmanaged, or piping becomes blocked with condensate (Lee *et al.*, 2007).
- **Manure management**: There are 64 agriculture projects in the CDM pipeline. The manure methane sector fares better than the other sectors in CDM project registration with 52 projects registered to date (UNEP Risoe, 2009). However, manure management projects have experienced many of the same challenges as LFG projects in the over-prediction of gas generation and quality. In addition, manure management projects tend to be smaller-scale than the other types of methane projects; as a result, these smaller projects have had difficulty attracting interest. One approach to address this issue is to use "community-based" CDM for agricultural CDM projects, which bundles together many smaller farms with 10% of investment going to poor communities for development purposes. The Community Development Carbon Fund (CDCF) can provide the financing (CDCF, 2008) for this type of initiative.

It appears as if there are methodological issues across the energy sector methane projects that require additional effort to address. Most project types have had difficulties in modelling methane (and CER) generation during project preparation. As methane generation is nearly always impacted by site-specific factors and by subsequent operation practices, it is recommended to be conservative in gas generation estimates for planned CDM/JI projects. There may be some benefits to additional information sharing among modellers to develop region-specific models that take into account local factors such as climate, management practices and other issues.

Further, in addition to the sector-specific issues discussed above, there are other common challenges for energy sector methane projects. One such challenge is confusion over methane gas rights (and resulting CERs). As the CDM and JI have become more widely established, oil and gas companies, coal mines, landfill owners and livestock operation managers have begun to realise the value of methane recovery. A key point here is that methane/gas rights and CER ownership need to be established early in the assessment of a proposed CDM/JI project. Ownership needs to be negotiated with all relevant players, including the site owner, nearby land owners, project operators and utilities who are purchasing the gas or power output. There may be a need for standardised contractual forms to clarify and address ownership.

In addition, the CDM Executive Board, which reviews and approves all methodologies that are used to calculate a project's baseline and anticipated emission reductions, has begun to impose additional monitoring requirements on methane projects. For example, a new flaring tool, which is referenced in all of the LFG CDM methodologies, requires enclosed flares to monitor pre- and post-combustion emissions levels (Lee *et al.*, 2007).

A final issue relates to the host country's attitude and regulatory environment. There is a difficulty in some regions with host country reluctance to approve methane projects that involve methane recovery and flaring. The justification has been given that gas utilisation is a more sustainable practice. However, with coal mine, landfill and manure methane recovery projects, there are often important benefits to starting with a flare-only project and subsequently moving to energy recovery after gas flow and quality have been confirmed. This would go a long way toward addressing the gas estimation issues discussed earlier. Related to this, new regulations (*e.g.,* for LFG capture and flaring or CMM recovery and flaring) in some countries have created confusion as to methane projects' qualification under the CDM additionality criteria, whereby in order to qualify as additional, projects must be over and above any regulatory requirements that are in place. Governments are encouraged to issue clarifying regulations or opinions that explain the status of existing and planned methane recovery and use projects under the CDM/JI.

The CDM and JI mechanisms aim to address the financial barriers to methane emissions reductions in countries around the world, but there are information and institutional barriers to be overcome as well. Building on the models used successfully in several developed countries, the Methane to Markets Partnership (M2M) is a public-private partnership of 29 national governments and over 900 private organisations working to advance the methane capture and use projects in the coal, agriculture, landfill, and oil and gas sectors in Partner countries.[27] The M2M model provides a platform to bring all the actors necessary for project success together, and works to reduce the informational and institutional barriers emission reductions in these sectors. To date the Partnership has supported more than 140 methane emissions reductions projects around the world, and has the potential to achieve 180 MMT CO_2 worth of reductions by 2015.

The Partnership has proven to be a good complement to the UNFCCC mechanisms by providing the technical assistance and capacity building necessary for long-term project success. M2M has supported pre-feasibility and feasibility studies that have helped projects enter the CDM/JI pipeline, developed a suite of tools and resources that help governments, project developers, financiers and others to identify potential projects, and has provided capacity building and training for hundreds of people critical to project success. In addition, M2M countries have developed sector specific action plans that identify the opportunities and challenges for methane emissions reductions projects. These activities have been very successful at supporting the UNFCCC mechanisms and facilitating emissions reductions around the world.

---

[27] M2M membership as of June 2009.

Conclusions

Methane recovery and use is a strategic climate change mitigation strategy for the energy sector that merits greater attention. While methane emissions have stabilised in developed countries, global emissions are expected to grow, driven by the expansion in livestock operations, solid waste generation, and energy production in developing economies. Due to methane's short atmospheric lifetime, combined with its economic value as a fuel and the important local environmental, energy security, and industrial safety benefits of methane recovery, policy makers will benefit from giving methane a closer look.

A common finding across sectors is the lack of strategic, comprehensive policy frameworks to guide methane recovery and use. The countries that have seen the most success with methane reduction projects have developed comprehensive approaches that utilise a mix of tools to address financial, technical, and regulatory barriers. On a limited basis, countries have had success enacting targeted policies. For example, there are good examples of regulations to reduce gas flaring and increase associated gas utilisation; clarify coal mine methane ownership rights; and streamline interconnection for coal mine, landfill and manure methane-based electricity generation projects. There are also a number of financial incentives that have been tailored to methane recovery and use. However, countries need to go further; the case studies in this report can serve as a start. The multilateral Methane to Markets Partnership is a strong network which offers interested government and industry stakeholders a wealth of resources, and which should be expanded.

While methane recovery and use projects are one of the four largest categories of CDM/JI project under the UN flexibility mechanisms, there have been challenges that have arisen in gas generation over-estimation, in setting baselines for projects, and establishing additionality. These challenges can be addressed, however, through a more concerted international effort to improve methane project design and to fine-tune methodologies. Developing country hosts will benefit from such an investment via GHG revenues, along with the many co-benefits (improved local air and water quality, reduced explosion hazards, local energy resources) that methane recovery can offer.

The policy examples contained in this report are just the beginning – the next step is widespread outreach and sharing of policy best practices among countries and the private sector. This is of particular significance in developing countries, where a number of methane recovery project opportunities lie. Therefore, it will be important to engage these countries to share best practice policies for methane recovery and use.

Abbreviations/acronyms and units

Abbreviations/acronyms

CBM:	Coalbed methane
CCL:	Climate Change Levy
CDCF:	Community Development Carbon Fund
CDM:	Clean Development Mechanism
CER:	Certified emission reductions
CMM:	Coal mine methane
CNG:	Compressed natural gas
CO_2:	Carbon dioxide
DG:	Distributed generation
DI&M:	Directed inspection and maintenance
EEG:	Erneuerbare-Energien-Gesetz
ERU:	Emission reduction unit
EU:	European Union
FIT:	Feed-in tariff
GHG:	Greenhouse gas
IAF:	Appropriate inflation adjustment factor
JI:	Joint Implementation
LFG:	Landfill gas
LMOP:	Landfill Methane Outreach Program
LNG:	Liquefied natural gas
M2M:	Methane to Markets Partnership
MSW:	Municipal solid waste
NDRC:	National Development and Reform Commission
OBE:	Barrel-of-oil equivalent
SF_6:	Sulphur hexafluoride
UNECE:	United Nations Economic Commission for Europe
UNFCCC:	United Nations Framework Convention on Climate Change
U.S. EPA:	United States Environmental Protection Agency
VAM:	Ventilation air methane

Units

Bcm:	Billion cubic meters
Bcf:	Billion cubic feet
CO_2-eq:	CO_2-equivalent
Gt:	Gigatonnes
kt:	Kiloton
kWh:	Kilowatt-hour
Mt:	Million metric tonnes
MWe:	Megawatt of electricity
MW:	Megawatt
t:	Tonnes

Appendix: Relevant UNFCCC clean development mechanism methodologies

Oil and gas methodologies

AM9 (ver 3.3)	Recovery and utilisation of gas from oil wells that would otherwise be flared or vented
AM37 (ver 2.1)	Flare reduction and gas utilisation at oil and gas processing facilities
AM77	Recovery of gas from oil wells that would otherwise be vented or flared and its delivery to specific end-users (as CNG)
AM23 (ver 2)	Leak reduction from natural gas pipeline compressor or gate stations
AM43 (ver 2)	Leak reduction from a natural gas distribution grid by replacing old cast iron pipes with polyethylene pipes
AM74	Methodology for new grid connected power plants utilizing permeate or associated gas, previously flared and/or vented

Coal mine methane methodologies

ACM8 (ver 5)	Coal bed methane and coal mine methane capture and use for power (electrical or motive) and heat/or destruction by flaring
AM64 (ver 2)	Methodology for mine methane capture and destruction in underground, hard rock, precious and base metal mines

Solid waste methodologies

ACM1 (ver 9.1)	Landfill gas project activities
AM2 (ver 3)	Landfill gas capture and flaring with public concession contract (ex-post baseline correction)
AM3 (ver 4)	Simplified financial analysis for landfill gas capture projects (no CERs from electricity) (ex-ante correction)
AM10	Landfill gas electricity (CERs from electricity)
AM11 (ver 3)	Landfill gas recovery with electricity generation (no CERs from electricity)
AM12	Biodigester power from municipal waste (only India)

Manure management methodologies

AM6	GHG emission reduction from manure management systems
ACM10 (ver 5)	GHG emission reductions from manure management systems
AM16 (ver 3)	Change of animal waste management systems

References

Canadian Association of Petroleum Producers (CAPP) (2009), *Statistical Handbook for Canada's Upstream Petroleum Industry*, accessible at http://www.capp.ca/GetDoc.aspx?DocID=146286.

Community Development Carbon Fund (CDCF) (2008), ''Carbon Finance for Sustainable Development", http://wbcarbonfinance.org/docs/2008_Annual_Report_CF08_Final_printed_Low_Res_04-29-09.pdf.

Department for Environment Food and Rural Affairs (DEFRA) (2009), *Anaerobic Digestion – Shared Goals*, available at http://www.defra.gov.uk/environment/waste/ad/pdf/ad-sharedgoals-090217.pdf.

Energy Information Administration (EIA) (2004), *Analysis of Five Selected Tax Provisions of the Conference Energy Bill of 2003*, http://www.eia.doe.gov/oiaf/servicerpt/ceb/fuel.html.

HM Treasury (2002), Finance Bill, Clause 123: Climate change levy, http://www.hm-treasury.gov.uk/fin_bill02_clause123.htm.

IEA (2008a), *Energy Technology Perspectives,* IEA/OECD, Paris.

IEA (2008b), "Turning a Liability into an Asset: The Importance of Policy in Fostering Landfill Gas Use Worldwide", http://www.iea.org/textbase/papers/2009/landfill.pdf.

IEA (2008c), "Turning a Liability into an Asset: Landfill Methane Recovery in India 2008", http://www.iea.org/textbase/papers/2008/India_methane.pdf.

IEA (2008d), "Cogeneration and District Energy – Sustainable energy technologies for today…and tomorrow", http://www.iea.org/files/CHPbrochure09.pdf.

IEA (2009), "Coal Mine Methane in China: A Budding Asset with the Potential to Bloom", http://www.iea.org/textbase/papers/2009/china_cmm_report.pdf.

International Resources Group (IRG) (2004), "Analysis of Methane Mitigation Options using the MARKAL Model for the US", http://www.epa.gov/methane/pdfs/macc_analysis.pdf.

International Solid Waste Association (ISWA) (2008), Landfill Gas Position Paper, accessible at http://www.iswa.org/DocumentDownloadServlet?id=1960&language=en.

Johnson, M. (2009), Carleton University (Ottawa, Canada), personal communication.

Joint ISWA Work Group Meeting (2008), CDM Workshop Introduction: "CDM 101".

Lee, C., J. Bogner and A. Toefy (2007), "Landfill Gas CDM Projects: Current Trends and Future Opportunities for Developing Countries," Proceedings Sardinia 2007, Eleventh International Waste Management and Landfill Symposium, Cagliari Italy (1-5 October 2007).

Mendbayar, B. (2009), Government of Mongolia, personal communication.

Methane to Markets (M2M) (2008a), "Oil and Natural Gas System Methane Recovery and Use Opportunities", http://www.methanetomarkets.org/resources/factsheets/oil-gas_eng.pdf.

M2M (2008b), "Managing Animal Waste to Recover Methane", http://www.methanetomarkets.org/resources/factsheets/agriculture_eng.pdf.

M2M (2008c), "Mexico Profile: Animal Waste Management Methane Emissions", http://www.methanetomarkets.org/resources/ag/docs/mexico_profile.pdf.

(M2M) (2009a), "Landfill Subcommittee Report to Steering Committee", http://www.methanetomarkets.org/events/2009/all/docs/all-27jan09/steering/lf_to_steering_committee_012109.pdf.

M2M (2009b), Ongoing Projects and Activities,
http://www.methanetomarkets.org/projects/projects.aspx?type=ongoing.

Ministry of Environmental Protection of the PRC (2008), *Standard for Pollution Control on the Landfill Site of Municipal Solid Waste*.

Oven, M. (2008) “Support to Mexico’s M2M Agriculture Program: Promoting anaerobic digestion in pig and dairy farms,”
http://www.methanetomarkets.org/events/2008/ag/docs/ag23apr08_mark_oven.pdf.

Pew Center on Global Climate Change (2003), “Multi-gas Contributors to Global Climate Change”, available at
http://www.pewclimate.org/global-warming-in-depth/all_reports/multi_gas_contributors.

Roos, K. (2008), M2M, “Support to Livestock and Agro-Industrial Wastes: Developing Country Resource Assessments”.

Sims, R. *et al.* (2007), “Energy Supply”, in *Climate Change 2007: Mitigation of Climate Change – Contribution of Working Group III to the Fourth Assessment Report of the IPCC* [B. Metz *et al.* (eds.)], Cambridge University Press, Cambridge, UK and New York.

Strosher, M (1996), “Investigations of Flare Gas Emissions in Alberta”,
http://www.ercb.ca/docs/documents/reports/StrosherInvestigationOfFlareGasEmissions-1996.pdf.

United Nations (UN) (1998), Kyoto Protocol to the United Nations Framework of Climate Change.

United Nations Environment Programme Risoe Centre (UNEP Risoe) (2009), CDM/JI Pipeline Analysis and Database, http://www.cdmpipeline.org/index.htm.

United Nations Framework Convention on Climate Change (UNFCCC) (2009), Kyoto Protocol website, http://unfccc.int/kyoto_protocol/items/2830.php.

United States Climate Change Science Program (CCSP) (2006), Methane as a Greenhouse Gas CCSP Research Highlight 1, *http://www.climatescience.gov/infosheets/highlight1/default.htm*.

US CCSP (2007), Prospectus for Synthesis and Assessment Product 2.1, accessible at
http://www.climatescience.gov/Library/sap/sap2-1/finalreport/default.htm.

United States Environmental Protection Agency (U.S. EPA) (2003), *Assessment of the Worldwide Potential for Oxidizing Ventilation Air Methane,* available at
www.epa.gov/cmop/docs/ventilation_air_methane.pdf.

U.S. EPA (2006a), *Global Mitigation of Non-CO_2 Greenhouse Gases 1990-2020*
(EPA Report 430-R-06-003),
http://www.epa.gov/climatechange/economics/downloads/GlobalMitigationFullReport.pdf.

U.S. EPA (2006b), *Global Anthropogenic Emissions of Non-CO_2 Greenhouse Gases 1990-2020*
(EPA Report 430-R-06-003),
http://www.epa.gov/climatechange/economics/downloads/GlobalAnthroEmissionsReport.pdf.

U.S. EPA (2008), *Upgrading Drained Coal Mine Methane to Pipeline Quality,* available at
www.epa.gov/cmop/docs/red24.pdf.

U.S. EPA (2009), “Global Overview of CMM Opportunities”, available at
www.methanetomarkets.org/resources/coalmines/docs/overviewfull.pdf.

West, J. et al (2006) “Global health benefits of mitigating ozone pollution with methane emission controls,” available at http://www.pnas.org/content/103/11/3988.abstract

IEA Publications
9, rue de la Fédération
75739 Paris Cedex 15

Printed in France by the IEA
August 2009

Cover design: IEA

This report was prepared by the Energy Technology Policy Division. This paper reflects the views of the IEA Secretariat and may or may not reflect the views of the individual IEA Member countries. For further information on this document, please contact Tom Kerr at: **Thomas.Kerr@iea.org**