Draft Final

Study of the Market Potential for Recovered Methane in Developing Countries

Prepared For:

United States Agency for International Development

Bureau of Economic Growth Agriculture and Trade

Global Climate Change Team

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Acronyms and Abbreviations

ATAD	autothermal thermophyllic aerobic digestion
Btu	British thermal units (measure of heat energy)
C	Centigrade
CBM	coalbed methane
CDM	Clean Development Mechanism, under UNFCCC
CHP	cogeneration of heat and power
CMM	coal mine methane
CNG	compressed natural gas
CO2	carbon dioxide
CO2eq	equivalent amount of CO2 required for same greenhouse gas effect
DSS	decision support system
EIT	economy in transition
EOI	expression of interest
FPA	fuel purchase agreement
GHG	greenhouse gas
GJ	gigajoule (metric measure of energy)
GWP	global warming potential
HFC	hydrofluorocarbon
ICE	internal combustion engine
IR	infrared
IPCC	Intergovernmental Panel on Climate Change
Kg	kilogram
kW	kilowatt
kWhr	kilowatt hour
LCNG	liquefied compressed natural gas
LDC	less developed country
LEL	lower explosive limit (of concentration)
LFG	landfill gas
LNG	liquefied natural gas
LOI	letter of interest
LPG	liquefied petroleum gas
m3	cubic meter
M2M	Methane to Markets Partnership (USEPA)
MM	million
MRF	materials recovery facility
MSW	municipal solid waste
MT	metric ton (1,000 kg.)
Mt/y	metric tons per year
MW	megawatt (1,000,000 Watts)
MWhr	megawatt hour
N2O	nitrous oxide

NGO	nongovernmental organization
NGV	natural gas vehicle
NMHC	non-methane hydrocarbon
NMVOC	non-methane volatile organic compounds
NOX	oxide of nitrogen
PM	particulate matter
POTW	publicly owned (water) treatment works
PPA	power purchase agreement
ppm	parts per million, may be on mass of volume basis, as indicated by subscripted "m" or "v"
PSA	pressure swing absorption
ROI	return on investment
SO2	sulfur dioxide
SSL	small-scale liquefaction LNG
T	ton (US, 2,000 pounds)
UEL	upper explosive limit
UNFCCC	United Nations Framework Convention for Climate Change
USAID	US Agency for International Development
USEPA	US Environmental Protection Agency
USSR	Union of Soviet Socialist Republics (former Soviet Union)
VOC	volatile organic compound
WAGP	West Africa Gas Pipeline
WRI	World Resource Institute
WTE	waste to energy

With over 40 years of on-the-ground experience in building long-tem relationships in developing countries around the world, the United States Agency for International Development (USAID) is uniquely qualified to provide a leadership role in the development and execution of methane to market projects in countries that have methane-generating resources, specifically landfills, coalmines and coal beds, oil and gas operations, and/or agricultural activities. The Global Climate Change Team within USAID's Bureau of Economic Growth Agriculture and Trade, in particular, is well positioned to leverage the Agencies' activities, collaborate with M2M stakeholders, and catalyze market opportunities for capturing methane. To this end the Global Climate Change Team engaged Nexant, Inc. to assist them in preparing for this role and for this desk assessment – *Study of the Market for Recovered Methane in Developing Countries.*

This report provides an overview of methane characteristics, sources, environmental impacts, and possible markets; identifies approaches for screening potential methane projects; and, provides recommendations for proceeding in selected geographic locations and methane source sectors. The report also provides the tools for understanding the sources, markets and other factors that may influence the capture and use of methane as well as the enablers, barriers, and bases for a systematic approach to identifying and successfully developing opportunities.

The approach for bringing methane to markets – for heating, home use, cooling or power generation – in developing countries is based on technology transfer, equipment sales, hands-on technical and financial assistance, institutional building conducive laws and regulations, and the establishment of partnerships with the private sector and nongovernment organizations (NGOs).

The text of Administrator Natsios' address to the first Ministerial Meeting of the Methane to Markets Partnership, as presented in Attachment 1, provides a succinct summary of USAID's current position and approach.

The issues and opportunities, however, are complex, as countries served by USAID represent a wide range of circumstances on methane source types and locations, feasibility and cost-effectiveness of methane capture , and receptiveness and proximity of markets for the captured methane. Further, there are critical differences between what might be considered appropriate, feasible and profitable technology in the more advanced M2M member countries versus industrialized but less developed countries and countries with economies in transition. All along this continuum of economic development there is a critical difference between large and small-scale projects, e.g., coalbed methane or landfill gas extraction and power generation vs. small-scale biodigestion of animal and other organic wastes for production of household cooking gas. While there are indeed opportunities to apply large-scale technologies in developing countries, there are also opportunities to simplify the more complicated technologies for scaled down applications in less developed countries.

An internally consistent knowledge base and systematic approach would facilitate the screening of potential markets to determine the technical and commercial feasibility of methane capture and commercialization projects. In the majority of countries served by USAID, capital resources and external funding are limited, and a near immediate return on investment (ROI) to the host country and investors is often required. This latter point is a touchstone for determining the prospects of success. Incomplete and/or outdated laws and regulations, generally result in protracted development times and increased risks, and often exacerbate the private sector's involvement. Unsuccessful projects represent opportunity costs of capital and loss of government and public support, costs that may compromise future development of M2M opportunities in the host country and beyond. A cost that most developing countries can ill afford.

While USAID has enjoyed success in work to date on the West Africa Gas Pipeline (WAGP) project, the Greenhouse Gas Pollution Prevention– Climate Change Supplement Project in India, and a wide variety of landfill gas (LFG) characterization and coalbed methane (CBM) projects, much work remains to be done, on both large-scale projects and smaller scale projects, which may be more appropriate in less developed countries. A mutually beneficial collaboration in which M2M objectives are furthered in USAID-served countries and USAID's Strategic Objectives are supported, is the desired outcome of USAID's participation in the M2M program.

The countries that appear to be better candidates for recovering methane are: Brazil, Colombia, India, Indonesia, Kazakhstan, Mexico, Pakistan, Peru, Russia, South Africa, and Ukraine. While Nigeria also has much potential for capture of methane previously vented or flared (burned) by the oil and gas industry, much of this gas is now being flared or captured for sale (WAGP). Each country presents various market opportunities and barriers. All countries share one characteristic: market opportunities are site specific and will require additional investigation to ensure that projects are viable.

2.1 PURPOSE

The purpose of this report is to provide a summary of the sources and uses of captured methane, a factual basis for assessing the potential for commercializing recovered methane in developing countries, and a first-order identification of potential market opportunities. An overview of the sources and uses of recoverable or avoidable current and future methane emissions (primarily from coal beds, coal mines, flaring of natural gas and livestock operations) is presented as background. The report also provides a proposed methodology for assessing opportunities as a function of location of methane sources relative to possible uses (thermal energy for heating, cooking or other uses, storage and shipment for local use, and production of electricity for expanding the radius of possible markets). The study presents recommendations on how to best link supply and demand and promote productive and profitable uses of captured methane emissions, while reducing net emissions of this powerful greenhouse gas (GHG). Finally, the report also includes an annotated inventory of past, present and proposed projects by USAID, other development assistance agencies, governments and technical organizations.

Information presented in this report will support informed decision making, as USAID determines how its experience, presence and resources can be best integrated into the Methane-to-Markets Partnership.

2.2 ORGANIZATION OF REPORT

The following sections provide the details of the study:

- Methane Sources – Overview
- Markets for Methane – Overview
- Methane Sources and Markets in Target Countries
- Commercialization of Methane Capture and Use
- Conclusions
- Recommendations
- Attachments

2.3 BACKGROUND

The Methane to Markets Partnership is a new global initiative designed to promote cost-effective, near-term methane recovery internationally through partnerships between developed countries, developing countries, and countries with economies in transition (EIT) in coordination with the private sector, multilateral development banks, and other relevant non-government organizations. The Partnership is expected to contribute to improved environmental quality, reduced GHG emissions, and enhanced energy security and economic growth throughout the world.

Active participation from the private sector and non-government organizations is central to the success of the Partnership. It is anticipated that private and public sector partners will work together in undertaking a variety of activities aimed at advancing opportunities for methane recovery and use. Some of these activities could include:

- Developing reliable systems to monitor methane emissions and identify emission sources
- Identifying and undertaking cost-effective projects that capture and use, as a clean energy source, methane emissions from coal mines, oil and gas systems, landfills, biological systems and other sources
- Identifying and removing barriers to project development and strengthening energy markets to support methane recovery and use

USAID's Global Climate Change (GCC) Team within the Bureau of Economic Growth Agriculture and Trade (EGAT) has engaged Nexant to provide an initial assessment of the market potential for recovering methane in developing countries.

The first Ministerial Meeting of the Methane to Markets Partnership took place in Washington, DC, on November 15-17, 2004. Estimated committed funding by the US government is currently $US 53 million over a five-year period. For reference, the Agenda of the Ministerial Meeting is provided as Attachment 1. The text of the Administrator's presentation is presented as Attachment 2.

2.4 METHANE CHARACTERISTICS AND SOURCES

Methane is the primary component of natural gas and a powerful greenhouse gas. Its sources are both natural and human. Natural sources include anaerobic digestion processes occurring in peat bogs, termite guts, swamps, and other wetlands. Human sources include rice paddies, domesticated livestock, landfills, biomass burning, and the production, handling and burning of fossil fuels. Fossil fuels account for about 20 percent of total methane emissions, including leakage from natural gas pipelines, oil wells, and coal mines and seams. Between 60 and 80 percent of all methane emissions are a direct or indirect result of human activities. Atmospheric methane concentrations have been increasing in the atmosphere at about 0.6 percent per year and have more than doubled since the Industrial Revolution in the 18th century. .

On a mass basis, methane is 23 times as effective in trapping heat in the atmosphere as CO_2. Methane remains in the atmosphere 12 to 17 years. Of the anthrpopogenic GHG emissions, methane accounts for about 20 percent of greenhouse warming effects from human sources. (World Resource Institute (WRI), Research Topics "Climate Change, Energy and Transportation, 1997).

Methane sources include:

- Fossil sources (coal beds, coal mines, coal use, petroleum production and use, and leaks from natural gas wells)
- Biological or "renewable" sources

- Man-made (anaerobic biodigesters, pyrolysis or gasification)
- Point-source fugitive emissions from anaerobic conversion processes such as publicly owned (water) treatment works (POTWs) and landfills
- Area emissions from biological systems such as bacterial processes in the stomachs of livestock and guts of termites, anaerobic degradation of biomass in swamps and wetlands, and rice paddies
- Biomass burning (incomplete fuel combustion in the burning of municipal solid wastes (MSW) and crop residues, municipal incinerators, and controlled or uncontrolled burns of grasslands, forests and cropland

Not all methane sources present feasible opportunities for methane recovery. For example, there is currently no practical way to recover methane generated by termites. Fossil fuel-related methane sources, such as coal beds and mines and oil and gas operations, present real opportunities for capture and productive use of methane, with concurrent reductions of GHG emissions as well as replacement of other, often dirtier fossil fuels. Capture of methane from biological sources, such as POTWs and landfills, also reduces GHG emissions and can offset fossil fuel use when used as a fuel or fuel supplement. Purposely produced biodigester methane is generally GHG-neutral since it converts plant biomass that recently captured CO_2 from the atmosphere through photosynthesis. Thus, the re-release of CO_2 will have no net effect on global warming. If biomass wastes from agricultural and livestock operations is decomposed by naturally occurring anaerobic processes and methane is released to the atmosphere, its capture and diversion for use as a fuel is highly desirable as a means of overall reduction of GHG emissions. Agricultural wastes, for example, rather than being allowed to decay anaerobically in the field, can be collected and digested in receptacles that allow the capture and use of methane. The residues can be returned to the field as beneficial organic matter and low-grade fertilizer. Depending on conditions, allowing anaerobic biomass decay in or on the soil can also remove beneficial nitrogen from the soil, rendering it less fertile. Further, otherwise uncontrolled biomass burning often takes place under relatively primitive conditions, which tends to generate more methane emissions than digestion of the biomass and utilization of the generated methane. Therefore, centralized processing and digestion of agricultural wastes may be beneficial from several perspectives.

Strategies for methane capture, marketing and use are the subject of this paper - emissions avoidance is not, except where biomass is used as a feedstock for methanogenesis (the process that transforms biomass into methane, which can be used as a fuel) and offsets the use of the raw fuel and subsequent methane emissions.

2.5 METHANE RECOVERY

Geography, topography, logistics, quality, quantity, production rate, scale, concentration of the emission as a point source as well as commercial and institutional concerns are key factors in determining the feasibility of methane recovery.

2.5.1 Technical Issues

The technical variables affecting the feasibility of methane recovery are often site specific.

Landfill Gas (LFG), for example, is generally located near population centers but often has a lower heating value and greater impurities than coalbed methane. The delivery of coalbed methane is often affected by the terrain (mountainous vs. flat) and existing infrastructure (road and rail systems).

Concentration, quality, and size of methane sources have a significant bearing on project development. Certain development activities and, of course costs, are necessary regardless of project size.

When an energy source is: more remote or there are constraints in delivery; limited in quantity; poorer quality; and/or diffused, the cost is increased. If the potential rewards do not merit this threshold, the project will not be seriously considered.

2.5.2 Commercial, Cultural, and Institutional

Commercial, cultural, and institutional factors are often obstacles to exploiting energy resources in developing countries. Conversely, an open and encouraging government and private sector are facilitating factors that offer differentiating attributes. Obstacles range from intransigent governments to ingrained cultural practices.

When there are political, institutional or civil *instabilities*, the investment risk increases. This risk increase usually brings a demand for a larger return on investment or, when weighed against other investments, a decision to invest elsewhere. Where uncertainties exist in a country, for example, political risk increases and foreign exchange discounts are also generally applied.

Government, at all levels, should strive for transparency and objectivity. If transaction costs are high then greater returns will be required for investment. Many sound projects in the past were abandoned due to protracted negotiations. Worse yet for all parties are projects that were abandoned during construction or after completion. Perceptions by the investment and development community can be long last

Laws and regulations, be they environmental, permitting, financial, ownership, or tax, affect how investment decisions are viewed. Clear, objective, enforceable, consistent, and comprehensive laws and regulations facilitate investment decisions and help to differentiate one country from another.

The *objectives of government* can be at odds with the private sector. Employment is a classic example of how government would seek to create jobs at the expense of an efficient operation.

Cultural Differences

Views are often resistant to change. Agriculture and the use of pesticides or planting practices, for example, are often marked by d*eep-seated practices that* can hamper changes. Ultimately, the feasibility of capturing methane in any developing country will depend upon the evaluated and perceived risks versus the potential reward. Various options exist to mitigate risk, but these options usually increase the cost of the project. Especially when developing a resource initially, public-private partnerships and motivated stakeholders can facilitate investment.

2.5.3 Environmental Impacts of Methane

2.5.3.1 Air Quality Impacts

Methane does not have a significant impact at “normal” ambient levels, which only consist of trace amounts (~ 1.75 ppm). Methane is also not considered an “air toxic”. However, at high concentrations (as is the case in underground coal mining), in anaerobic conditions and in certain industrial and petrochemical settings, methane is a well-known simple asphyxiant.

Exposures to methane as an air pollutant are more critical in industrial settings and at levels far exceeding the trace ambient levels (currently levelized at approximately 1.75 ppm on average). The primary cause of death or injury as an air pollutant is simple asphyxiation: volumetric displacement of oxygen in the respired air. Other secondary impacts, when at levels above the lower explosive limit (LEL) and below the upper explosive limit (UEL) and in the presence of sufficient oxygen, are explosion and fire. These are not uncommon in poorly ventilated mines or other places where methane may accumulate as a result of seepage into structures located over sources of methane.

2.5.3.2 Impacts on Climate Change

It is estimated that among anthropogenic emissions of all greenhouse gases since the start of the Industrial Age, methane is responsible for approximately 17% of total CO_2eq emissions, about the same as the combined effect of nitrous oxide (N_2O) at 5% plus chlorofluorocarbons (CFC)s at 12%.. On a mass basis, methane is about 23 times more potent than CO_2 as a greenhouse gas, but hundreds of times less so than problematic hydrofluorocarbons (HFCs) (refrigerants, blowing agents and solvents) and other fluorinated GHGs, which are emitted at far lower rates.

Once in the atmosphere, methane absorbs re-radiated infrared radiation that would otherwise escape to space. This property can contribute to the warming of the atmosphere.

Methane's lifetime in the atmosphere is approximately 12 years. Methane’s relatively short atmospheric lifetime, coupled with its potency as a greenhouse gas, makes it a good candidate for climate change mitigation in the near term (the next 25 years).

For comparison purposes, the global warming potentials (GWP) of methane (relative to CO_2), and other non-CO_2 GHGs, as determined by the IPCC in 1996 and as amended in 2001, are presented in Table 2.1.

Table 2.1 Comparison of 100-Year GWP Estimates from the IPCC Second (1996) and Third (2001) Assessment Reports

Gas	1996 IPCC GWP(1)	2001 IPCC GWP(2)
Carbon dioxide	1	1
Methane	21	23
Nitrous oxide	310	296
HFC-23	11,700	12,000
HFC-125	2,800	3,400
HFC-134a	1,300	1,300
HFC-143a	3,800	4,300
HFC-152a	140	120
HFC-227ea	2,900	3,500
HFC-236fa	6,300	9,400
Perfluoromethane (CF4)	6,500	5,700
Perfluoroethane (C2F6)	9,200	11,900
Sulfur Hexafluoride (SF6)	23,900	22,200

(1) Intergovernmental Panel on Climate Change 1995: the Science of Climate change (Cambridge, UK: Cambridge University Press, 1996)
(2) Intergovernmental Panel on climate Change, Climate Change 2001: the Scientific Basis (Cambridge, UK: Cambridge University Press, 2001)

2.6 MARKETS FOR METHANE

Markets for methane are comprised primarily of fuel and chemical feedstock uses. Both are diverse, but fuel use is more relevant to developing countries. The primary markets for methane are:

2.6.1 Residential

Applications for residential or domestic use, whether in single-family homes or multi-family dwellings, include use as fuel for

- cooking
- water heating
- space heating
- absorption refrigeration for air conditioning.

2.6.2 Commercial

Applications include those identified under Residential, plus:

- central refrigeration

Examples include refrigeration in supermarkets and food storage facilities, distributed generation/emergency-backup power, and internal combustion engines (ICE). Any or all may be critical for hotels, office buildings, communication centers, shopping complexes, refrigerated storage, etc.

2.6.3 Institutional

Applications are essentially the same categories as for Residential and Commercial and may also be critical for hospitals, prisons, nursing homes as well as police and military facilities.

2.6.4 Industrial

Applications are the same as Residential and Commercial, plus:

- boilers
- furnaces
- process heaters
- ovens
- cookers
- flares
- incinerators
- compressed natural gas (CNG) for fork lifts and other off-road vehicles
- cogeneration of heat and power (CHP)

2.6.5 Transportation

There are potential market uses of methane in the forms of CNG, LNG, and LCNG (liquefied CNG) as alternative fuels for taxis, jeepneys, buses, trucks, private autos, jitneys, 3-wheelers, boats, and rail locomotives.

2.6.6 Agricultural

Applications include:

- natural gas vehicle (NGV) tractors
- heat for crop drying
- refrigeration systems
- backup power for greenhouses

2.6.7 Industrial Feedstock or Energy Source

Methane can be the source of carbon, hydrogen, or both for making synthetic chemicals.

Applications include use as a feedstock for production of ammonia, methanol, and acetic acid, synthetic gas (syngas), industrial use of byproduct CO_2 (including edible oil hydrogenation, petroleum refining, certain specialty chemicals, metal working, and electronics), and gas-to-liquids (GTL) syntheses. Methane can also fuel boilers, gas turbines for cogeneration of electricity, and steam for heat-intensive processes such as chloralkali cells or air separation, carbon black production, and production of cement, asphalt, and glass.

2.7 PRODUCT TRANSPORTATION AND DISTRIBUTION

Markets can be served by:

- Complex pipeline/storage systems (including LNG systems large and small)
- Truck/rail transported LNG/LCNG re-vaporization systems
- Mobile CNG systems
- Conversion to liquid fuels or chemicals

3.1 LANDFILL GAS (LFG)

3.1.1 Solid Waste Overview

Solid waste found in various landfills around the world is comprised of several categories and subcategories, each with distinctive characteristics:

- Municipal solid waste (MSW), including most non-hazardous industrial and commercial wastes, classified as:
  - Organic (combustible) fraction
    - Putrescible – food waste (from wholesale and retail handling, industrial, commercial or home preparation, and post-meal discards), yard waste (grass clippings, leaves and plants trimmings), animal carcasses and personal sanitary articles.
    - Non-putrescible – paper, wood, fabrics, plastics, rubber, wax, solvents, oils, etc. (note, each of these has some potential for aerobic and/or anaerobic biodegradation, but at very low rates)
  - Inorganic fraction– metals, glass, ceramics, stone, ashes
- Sewage treatment sludge
- Hazardous industrial waste:
  - Toxic, corrosive, flammable, reactive, or radioactive
  - Bio-hazardous
  - Asbestos
  - Industrial sludge (biopond waste treatment or other process sludge)
- “Special” wastes, including:
  - Spent batteries
  - Fluorescent and other special lighting containing heavy metals
  - Out-of-date pharmaceuticals
  - Computers, cell phones and other electronic wastes
  - Rubber tires and automobile demolition “fluff” (non-metals, excluding liquids, mostly plastics and mixed materials)
  - Industrial filters, painting and coating wastes

Sewage treatment sludge is often “landfarmed”, or spread out on forest, grassland, or farmland as a soil amendment, or composted, usually in combination with other organic materials, but it is also sometimes put in landfills. This type of sludge, even when mechanically dewatered to the practical limit, contains a high percentage of water (60-90%) and so, through its moisture contribution, can affect the rate of conversion of other MSW co-disposed in the landfill, leading to greater LFG generation rates. It should be noted that composting, mandated in India and several European countries, reduces LFG output potential by reducing the feedstock for methanogenesis in the landfill environment.

Hazardous wastes are usually incinerated, neutralized, encapsulated or disposed of in separate, specially designed and managed landfills. In the US and in a number of other countries, there is severe discouragement for the disposal of hazardous wastes, except as a last resort to other relevant types of treatment. These types of waste are generally not biodegradable, and the types of landfills used for them are more tightly sealed against water infiltration and leachate production.

The primary wastes resulting in methane generation ("methanogenesis') in landfills, therefore, are in the putrescible fraction and, under certain conditions, paper. All other non-putrescible organic waste components are minor factors in LFG generation. Inorganics do not contribute to LFG methane content. Food preparation practices, culture, climate, and higher poverty levels in many emerging economies result in MSW streams that have a greater organic fraction than those of more developed economies (particularly food preparation wastes), but are often lower in terms of per capita volume. Organic fractions can be as high as 85-90% in some of the less advanced economies where there is limited use of disposable packaging, but daily food preparation by hand from raw ingredients at home is common. The bulk of packaging is limited to paper and plastic films and fabrics, with some glass and plastic bottles and metal cans. The latter types of packages are largely either recycled, reused, informally scavenged from the MSW, or can be readily hand-picked using cheap labor in a materials recovery facility (MRF) associated with landfilling, composting, or combustion (waste-to-energy).

A major problem with many landfills in emerging economies is typically their informal, haphazard design, without proper impervious linings for leachate collection, daily capping with earth of isolated landfill "cells" containing the waste materials, compaction, or venting to prevent LFG migration and to collect LFG for flaring or use. Scavengers often frequent these open dumps and create hazards for themselves by exposing themselves to toxic, contagious, or otherwise hazardous materials, and often to others by setting fires to recover metals. Emerging economies in North and South Asia, Southeast Asia, Africa, and Latin America are working towards improving these conditions and installing properly engineered landfills.

The generation of MSW and the resultant waste stream analysis varies greatly among regions, national economies, regions, and localities, as does the percentages and the types of waste stream fractions that are disposed of or treated in ways other than landfilling.

As a point of reference, Shanghai, the largest city in China, has about 15 million people and generates about 5 million tons of MSW per year (far more if industrial waste is included). Shanghai, in contrast to New York, has a vast, long-standing recycling/materials reclaiming industry and infrastructure, with hundreds of centers and facilities and thousands of workers. A large fraction of the waste (over 30%) is recycled, but only some of the disposed material is put into covered landfills, the rest being put into open dumps at one extreme, or treated in waste-to-energy (WTE) facilities at the other extreme. The city administration has set goals for a high level of treatment or covered landfill disposal.

As another point of reference, New York City generates about 9.5 million tons of MSW per year (not including construction demolition debris or industrial waste), some of which is collected by the municipal Department of Sanitation and the rest by private garbage carriers. Subsequent to the recent closure of the Fresh Kills Landfill on Staten Island in New York City, all of New York City's garbage from both municipal and private collection is shipped out of the city by barge, truck and rail to landfills in other parts of the country at a cost of about US$100/(metric) ton.

New York had in the last few years ceased its curbside pickup of glass, plastic and metal containers and paper for recycling, but has more recently reinstated recycling. In contrast, not only has a high percentage of packaging waste in the US, Europe and Japan been recycled for over a decade, but a large percentage of the remainder has been combusted in WTE facilities to generate electricity and for district heating. Tipping fees for WTE in Europe vary from US$30/ton in Sweden to US$130/ton in Switzerland and Germany. (Waste-to-Energy Trends in Europe, Wastes Management, January 1999, Pgs. 35-36, published by Juniper Consultancy Services).

In general, because of high water content, the putrescible fraction of MSW is a liability in WTE. In an ideal, integrated waste disposal strategy:

- Ozone depleting and GHG refrigerants, lubricating and transformer oils and solvents would be recovered and recycled by special means.
- Good quality paper and textiles would be recycled for papermaking.
- Certain plastics (such PET and HDPE), aluminum and steel would be recovered for materials recycling.
- Some glass bottles might be scavenged or otherwise returned for cleaning and reuse.
- Other glass could be separated by color (usually at a central facility, such as a bottling plant or distributor to which they are returned in a deposit rebate program) or crushed as mixed color cullet for glass making or used as roadbed or aggregate in road paving materials.
- Miscellaneous paper, plastics and other non-putrescible organics would be separated for WTE.
- Putrescible wastes would be separated for:
  - Composting, anaerobic or aerobic digestion, or
  - Disposed of, along with any remainders from the above, including large items such as appliances, in landfills designed for LFG collection and use.

In such an ideal setting, the emissions of LFG methane would be minimized, as would the cost of building, maintaining, and closing landfills, if used. In Europe, an EC Directive requires composting of putrescible household and yard waste, thereby institutionalizing and systematizing the process of landfilling by regulatory requirement, and increasing the opportunities for subsequent efficient extraction and use of LFG.

3.1.2 LFG Methane Generation

Locations of other sources of recoverable fugitive methane - oil and gas production and midstream handling, coal mining, agricultural biomass generation, and livestock operations - may have little or no relationship to the location of population centers, which usually comprise the primary market outlets for recovered methane. Landfills and sewage treatment facilities are generally in or near populated areas. As can be seen from the chart in Figure 3.1, solid waste (LFG) is one of the largest sources among those that are practically recoverable for use and/or for control of GHG emissions by flaring. Though the scale of livestock and other enteric generation are estimated to be somewhat larger, control of these emissions is relatively impractical. While coal mine and coal bed sources may represent a substantial source of emissions, they may not be logistically suited to commercialization, other than for onsite generation of power or heat, of production of LNG or CNG for onward delivery. Landfills and resultant LFG production have a close relationship to population, and therefore this resource should be, and is, an early target for consideration and development.

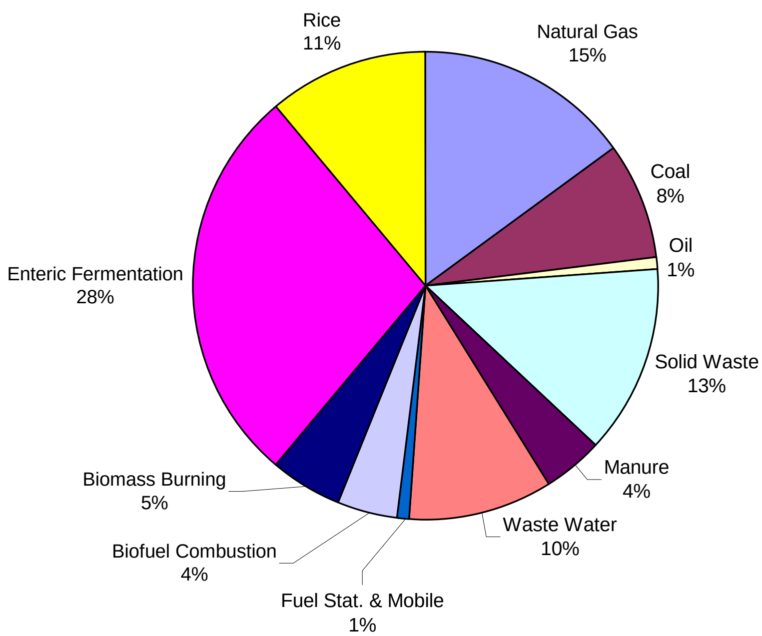

Figure 3.1 Anthropogenic Sources of Methane

Methanogenesis, or methane generation in landfills, is a result of anaerobic decomposition of organic materials. Major factors affecting emission rates are:

- Amount and “quality” of organic material deposited in landfills
- Rate and distribution of anaerobic decomposition in different zones of the landfill

- Moisture and oxygen levels (which may be controlled in "bioreactor" type landfills)
- Landfill design and construction
- Landfill methane collection and combustion, if any (energy use or flaring)

Methanogenesis of carbohydrates, including cellulose, produces a mixture of approximately 50% methane and 50% carbon dioxide (CO_2), rendering LFG a low-to-medium Btu (heating value) gas. Sulfur and nitrogen found in food wastes and other putrescible solids may also lead to contamination of the gas with hydrogen sulfide, other odorous sulfur compounds, and ammonia, which require removal for most applications. Organic material deep within landfills takes many years to completely decompose. Therefore, past landfill disposal practices greatly influence present day emissions.

There are many other factors that influence the rates of methanogenesis – factors that vary across societies and cultures. For example, as suggested above, in developed and industrialized countries the waste stream tends to be drier and contains many materials that, in developing countries, are often recovered or informally scavenged before disposal from landfills (e.g., plastics, paper, wood, rags, etc.) Further, if landfills (rather than central or random, roadside dumps) are used at all in developing countries, per capita rates of waste generation tend to be much lower. The putrescible solids (primarily wet vegetable wastes) content is much higher, they are rarely built to expensive design specifications as they are in developed countries, and they are often not lined, resulting in loss of moisture in the form of leachate. Loss of leachate may result in drier conditions within the landfill, which slows the rate of methanogenesis. Leachate can also pose a serious health problem and contaminate surface and subsurface groundwater.

Options for the disposition of LFG are:

- Flaring
- Industrial use as low-to-medium Btu piped short distances for power or heat generation, after removal of impurities
- District heating
- On-site power generation
- Removal of CO_2 and other impurities and addition to a distribution pipeline
- Heating and lighting of greenhouses near the site

The same market options apply to Biogas, which has similar characteristics to LFG, and are discussed in Section 3.4.

3.1.3 LFG Recovery

A landfill gas system is used to collect and control gas emissions through a system of wells and prevents subsurface migration of gas off site. If not controlled, gas can build up pressure to an explosive level and/or cause methane as well as harmful air pollutants to be emitted into the atmosphere.

The Fresh Kills Landfill has become a major generator of LFG and has an advanced LFG recovery system. It is also one of the largest manmade structures in the world. Figure 3.2 is an aerial view of Fresh Kills Landfill with the LFG collection, flare and utilization system shown in schematic overlay.

Figure 3.2 Aerial View of Fresh Kills Landfill, New York City

The New York Department of Sanitation (DOS) has been recovering and processing gas from a portion of Section 1/9 since 1982. Currently, a system of flares operates to burn off the portion of the gas that is not recovered from sections 3/4, 2/8 and 6/7. The LFG recovery plant and related systems, when complete, are estimated to provide enough fuel for the cooking and heating needs of approximately 25,000 homes.

Typically, a large number of vertical gas wells (10-200) are constructed on a large landfill to extract the landfill gas as it is produced. Gas is drawn from the wells through pipework to treating equipment, which removes moisture and harmful components such as sulfur compounds, ammonia, traces of halogenated solvents, etc. After appropriate cleaning and treating, the gas can be used, for example, for electricity generation in either a reciprocating ICE or a microturbine, with any surplus gas being flared.

An active recovery system collects the LFG from the extraction wells under vacuum pressure. This system moves the gas through a network of pipes. The pipes increase in size as they move toward the perimeter of the landfill, reaching flare stations or the gas recovery plant.

A typical collection system, such as Fresh Kills, consists of approximately one LFG extraction well per acre of landfill. A pipe extends down through the depth of the refuse or to groundwater table, if higher. Beyond roughly the first 20 feet below the surface, the well pipe is perforated. The well and the geomembrane landfill cover are sealed with synthetic rubber and stainless steel fixtures. Above the topsoil, the well is typically attached to flexible tubing connected to a network of lateral header pipes, lying on top of the geomembrane or clay lining. Water in the LFG condenses, is collected in tanks and is pumped out. Figure 3.3 is a schematic of a typical LFG extraction well, taken from a USEPA report, "Turning a Liability into an Asset: A Landfill Gas-to-Energy Project Development Workbook", EPA 430-B-96-0004, Sept. '96, pg. 3-2.

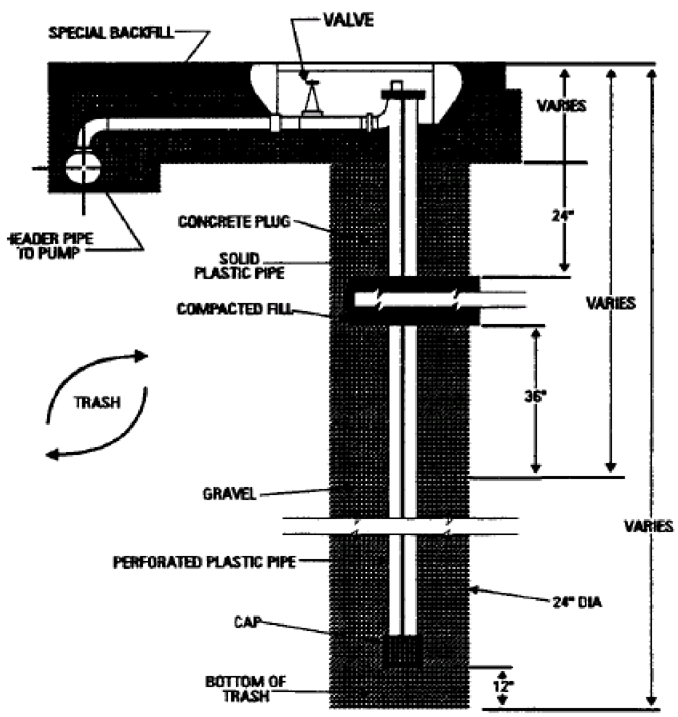

Figure 3.3 Typical LFG Extraction Well

The gas moves to the gas recovery plant or to flares via the lateral pipes. Flares, if used, typically oxidize the LFG at temperatures of between 1600°-2000°F. Methane, NMOCs, hazardous air pollutants and odors are reduced by almost 100%. When LFG is recovered for use, flares serve as a safety back-up measure in the event the recovery system is down. LFG production decreases over time, and the active extraction system ceases to be productive, at which time the remaining methane can either be flared or vented passively into the atmosphere through the previously fitted vents.

3.1.4 Other Elements of a Managed Landfill

3.1.4.1 LFG Migration Control

Independent of the active gas extraction network, as a safety measure to ensure that no gas migrates off site, a passive venting system is sometimes placed around the perimeter of the landfill. Passive vents keyed to low permeability soils or below the seasonal low groundwater table form an effective barrier to the movement of gas off site. Such a system often appears on the surface as a channel of coarse stones mounded up around the perimeter. Additionally, subsurface cut-off walls for the leachate can be placed to further prevent migration of gas off site. Monitors are often placed outside the trench to ensure that gas has not migrated off site. In addition, utility trenches should be sealed to eliminate potential off-site routes for LFG.

3.1.5 Leachate Control System

Leachate is created as water comes in contact with garbage. The goal of the leachate management system is to contain, collect and treat leachate before it reaches adjacent surface waters and groundwater, or damages the topmost landfill cover. This is achieved both by minimizing the amount of water that comes in contact with refuse and treating the leachate that is created. As the final cover is placed on the landfill, the production of leachate will diminish; however, water remaining in the landfill will cause the continued production of leachate. Storm water management systems are also designed to prevent the production of leachate by removing water as quickly as possible from the landfill face.

An integral part of the leachate control system is often silt or clay layers beneath the landfill that form a relatively impermeable barrier between refuse and the groundwater table below. The leachate that gravitates through the refuse mass downward and outward to the perimeter is collected before it can escape from the landfill. Perimeter collection drains are located outside the footprint of each section. The drains are placed below groundwater level (typically from 5 to 50 feet below the surface). This positioning of the drains establishes higher pressure on the outside of the drain so water and any escaped leachate is pushed inward toward the landfill. The drains are connected to trenches that are connected to collection wells and pumps.

Leachate is pumped from the collection pumping wells to a pump station and conveyed to a leachate treatment plant. The leachate is treated to remove pollutants before being discharged and is monitored to ensure that effluent levels are acceptable. The plant can have a large treatment capacity (1,000,000 gallons per day in the case of Fresh Kills).

3.1.6 Cost Factors

The detailed cost information below is based largely on a USEPA report, “Turning a Liability into an Asset: A Landfill Gas-to-Energy Project Development Workbook”, EPA 430-B-96-0004, Sept. ’96, chapters 3.0 and 5.0, with capital and operating costs escalated to a 2004 current US$ basis (2004/1994 O&M=1.36; 2004/1994 CAPEX=2.28).

3.1.6.1 LFG Collection and Cleaning

Total LFG collection system costs can vary widely as a function of several site-specific factors. If the landfill is deep, collection costs will tend to be higher because well depths and volumes of LFG generated per well are greater. Collection costs also increase with the number of wells installed. Table 3.1 presents estimated capital, operating and maintenance costs for collection systems (including flares) at typical landfills with 1, 5, and 10 million metric tons of waste contained. As a point of reference, New York City would fill the largest of these typical landfills, with one year's collections currently at about 9.5 million tons per year.

Table 3.1 Typical LFG Collection Costs and Energy Availability (1)

Landfilled MSW in place, million metric tons	1.0	5.0	10.0
Estimated gas generation (mcf/day)	642	2,988	5,266
Collection System Capital cost (US$000)	804	2,673	4,607
Collection System Annual O&M (US$000)	121	207	296
LFG Output (million Btu/year)*	100,000	490,000	850,000
* assumes a 90% availability factor			

(1) Assuming a heat rate of 11.4 million Btu / MWhr for power generation with LFG (in a typical small ICE, the typical landfills considered of 1.0, 5.0, and 10.0 million metric tons of MSW in place could generate 7.8 GWhr/yr (989 kW), 38.2 GWhr/yr (4,845 kW), and 66.2 GWhr/yr (8,397 kW), respectively.

Flaring costs are incorporated into the estimated costs of LFG collection systems because excess gas may need to be flared at any time, even if an energy recovery system is installed. Flare systems typically account for 5 to 15 percent of the capital cost of the entire collection system (i.e., including flares). However, flare costs will vary with local air pollution control and emissions monitoring requirements and the owner's own safety requirements. For example, if the flare is enclosed in a building for security or climate reasons, the proceeding cost figures would increase by approximately $166,000 [Nardelli, 1993, escalated to 2004 basis]. Annual operation and maintenance costs for flare systems are typically less than 10 percent of the total collection system costs, and thus range from approximately $10,900 for a 1 million metric ton landfill, increasing to $20,400 for a 5 million metric ton landfill and $28,600 for a 10 million metric ton landfill.

After the landfill gas has been collected, and before it can be used, it must be treated to remove any condensate that is not captured in the knockout tanks as well as particles and other impurities. Treatment requirements and costs depend on the end-use application. Minimal treatment is required for direct use of gas in boilers, while extensive treatment is necessary to remove CO2 for injection into a natural gas pipeline or for conversion to vehicle fuel. Power production typically involves cleaning in a series of filters to remove impurities that could damage engine components and reduce system efficiency. The cost to filter the gas and remove condensate for power production is considerably less than the cost to remove carbon dioxide and other constituents for injection into a natural gas pipeline or for CNG or LNG use in vehicles.

3.1.6.2 On-site Power Generation

Table 3.2 presents a sample on-site power generation project for a 10.0 million metric ton landfill. The LFG collection system costs are approximately as assumed above, and the power generation is assumed to be in a packaged system costing less than US$1,000/kW installed. This project is also assumed to have an effective annual capital burden of about 18.4% on capital investment, calculated as an 8-year loan made to the project with a 10% interest rate. If the project were financed on the basis of a typical industrial project, with an expected 20% return on investment (ROI) and including 20% depreciation (more typical of private, short-term investment scenarios in high-risk situations), the cost of the electricity would be approximately US$0.0422/kWh. Such a project might be financially attractive, depending on local conditions such as power costs and grid reliability.

Table 3.2 Economics of a Hypothetical LFG-to-Energy Project

Cost items	
Annual generation (GWhr)	67.8 GWhr
Estimated total cost of project (million US$)	12.2
Annual debt service payment (8-year loan, 10% interest) on a per kWh basis (US$/kWh)	0.0326
Operations & Maintenance – O&M (US$/kWh)	0.008
Administration & Insurance (US$/kWh)	0.0016
Total generation cost (US$/kWh)	0.0422

Source: THE PROTOTYPE CARBON FUND -Durban, South Africa Landfill Gas to Electricity -Project Design Document, July 2004 Report

3.1.6.3 Upgrading LFG to Pipeline Gas Quality

The most common set of market options for LFG are on-site power generation to supply on-site power needs (leachate handling, lighting, etc.) as well as power export to the grid, and short distance transmission of low-to-medium heating value gas to adjacent industrial users. However, it is possible to remove most or all of the contaminants in raw LFG, including CO_2, to produce a high methane concentration for blending with pipeline gas in an existing pipeline for longer distance transmission to market. Upgrading LFG to pipeline gas quality is relatively expensive due to substantial processing requirements to remove CO_2, nitrogen and other constituents of raw landfill gas. This option is currently viable for larger landfills (i.e., more than 4 million cubic feet per day or, typically, with 8-10 million metric tons of MSW contained). At such capacities, significant economies of scale are possible. It is estimated (based on the USEPA LFG report cited herein, pg. 5-26) that gas prices required to support such a project would be in the range of US$4.50 to $5.60 per MMBtu (2004 $US). Tax credits may be needed to assist qualifying projects to show attractive enough economics to attract private investors to this type of project.

Landfill owners/operators owning vehicles, garbage collection fleet operators or other nearby fleets (e.g., municipal vehicles, delivery trucks) can achieve fuel cost savings and major environmental benefits by converting these fleets to run on compressed natural gas (CNG), liquefied natural gas (LNG), or LCNG (LNG used to make CNG by pumping and vaporization, rather than by compression, during refueling). LNG can be stored to save on CNG compression system power and capital costs. Key factors in the economic evaluation of this option are:

- Costs of installing a fueling station for either:
  - CNG - compressors and ballast pressure tanks
  - LNG - cryogenic storage and pumps, or
  - LCNG - small scale liquefaction (or SSL) plus cryogenic storage and pumps and vaporizers
- Costs of making and storing LNG for LNG or LCNG - cleaning the gas for the cryogenic cycle plus small scale liquefaction (or SSL)
- Costs of retrofitting vehicles to run on the alternate fuel – including either a larger number of heavier CNG pressure tanks or smaller, more expensive cryogenic LNG tanks

LFG has a logical and convenient relationship to garbage truck refueling, since these frequent the landfill. Issues addressed with an LNG-based system and the reasons why LNG has been preferred over CNG by fleet operators and is more attractive than diesel are:

- The fuel has no energy cost
- CNG tanks are more difficult than LNG tanks to mount on a garbage truck, with a limited body geometry
- LFG is generated continuously, but garbage trucks have limited weekly schedules, so LNG is a demand-leveling strategy

The cost of installing a compressed landfill gas fueling facility can be significant — the installation of the Puente Hills Landfill fueling station in California cost approximately $1 million in 1994. Vehicle conversion costs, which currently run well over $5,000 for trucks, can also be offset by tax deductions and other government supports, as they usually are in the USA where there are incentives for using natural gas as an alternative fuel due to its environmental benefits.

Fleet vehicles are an especially good application for alternate fuels because these vehicles usually travel less than 200 miles per day, and they return to a central location at night for refueling and storage. Also, having a fleet of vehicles will increase fuel usage and therefore decrease average fuel costs, since capital recovery of fueling station construction costs represents the majority of fuel production costs (operation and maintenance costs for alternate fuel vehicle stations are minimal).

The technology for small scale liquefaction useful for converting cleaned LFG to LNG is available from a number of sources, either developed for this purpose or adapted from gas distribution system LNG “peak shaving” system designs:

- Black & Veatch Pritchard Inc. (BVPI) (USA and International)

- NexGen Fuelling / Chart Industries, Inc. (USA and International)
- Kryopak Inc. (USA and International)
- CNG SERVICES International, Inc. (USA and International)
- CryoFuel Systems, Inc. (USA and International)
- Applied LNG Technologies / Jack B. Kelley Group (USA)

There are also emerging (prototype and demonstration (small-scale liquifaction (SSL) coming on the market:

- Idaho National Engineering and Environmental Laboratory (INEEL) (USDOE) – based on turbo-expanders - versions of this system can work directly on raw LFG and remove the impurities mechanically as an icy "slush" from the LNG
- Gas Technology Institute (GTI) (USDOE)

The developing market for natural gas vehicles provides an opportunity for LNG and LNG-CNG fueling systems that lower fuel cost at the station. Other markets for smaller scale LNG liquefiers include flare gas from stranded gas and oil wells, coal mine and coal bed methane, and the other M2M targets discussed in this report.

SSL is fundamentally a well-demonstrated technology. Over 55 small to medium–sized "peak-shaver" LNG plants were built in the U.S. over 40 years. These were mostly plants built by gas utilities to gradually build up inventories of LNG in cryogenic storage tanks during slack demand periods for re-vaporization during periods of peak demand or pipeline problems.

Typical costs of liquefaction facilities of various sizes of interest are shown in Figure 3.4.

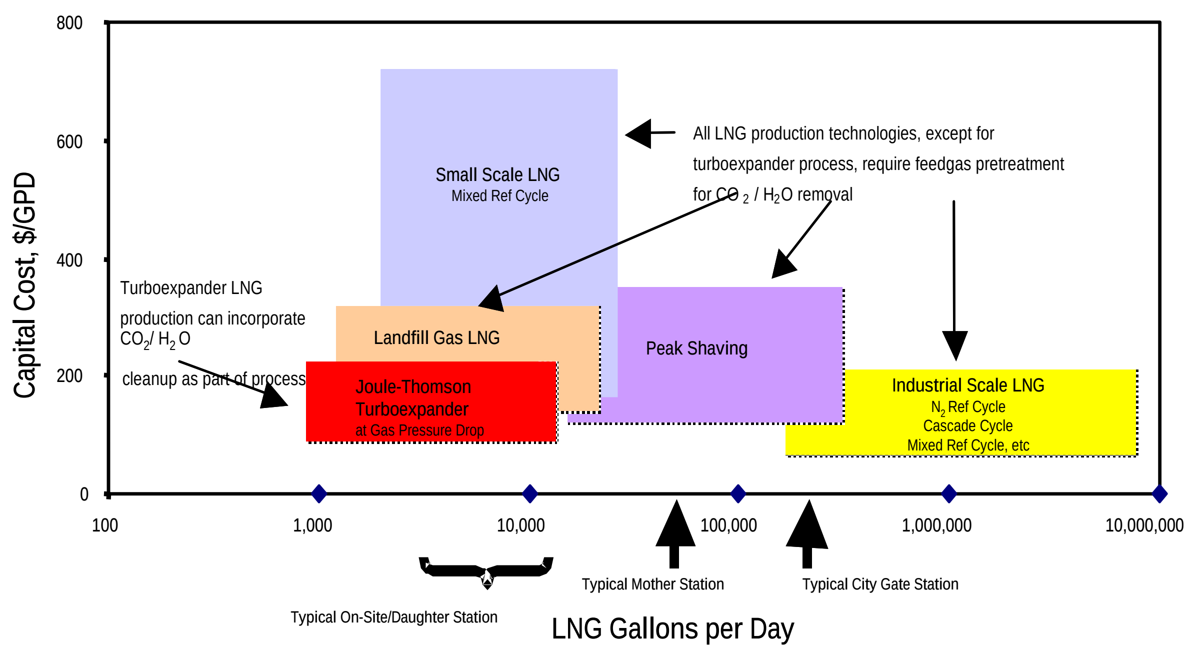

Figure 3.4 Typical Ranges of Capital Costs for LNG Production

Typical refueling systems costs for various types of fleets utilizing LNG are shown below in Table 3.3.

Table 3.3 Costs and other Factors for LNG Fleets

Fleet Type	Transit Bus Fleet		Refuse Hauler Fleet		Other Return to Base	
Fleet Size	50	200	25	100	25	100
LNG gals*	10,000	38,000	6,000	23,000	5,000	21,000
Station Cost	$520K	$1,609K	$377K	$1,037K	$355K	$948K
O&M, $/yr	$19.8K	$44.9K	$16.6K	$31.7K	$16K	$29.7K
Maintenance	$0.45/mi		$0.528/mi		$.048/mi	

*Storage is for 3 days of operation

Add $70K for garage modifications (ventilation, CH_4 detection) if vehicles are indoors

[1] Source: A.D. Little

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3.2 COAL-RELATED METHANE

As vegetation is converted to coal in geologic formations, substantial quantities of methane are produced. It is estimated that as much as 200 m^3 of methane per metric ton of coal can be generated in this process (Smith, 1992). Subsequent processes, particularly in coal seams near the surface, generate additional methane. Most of the methane gradually migrates out of the seam through the surrounding rock strata. Nonetheless, up to 25 m^3 of methane per ton of coal may remain adsorbed within the pore structure of undisturbed coal seams and is typically emitted when the coal is mined, handled and used.

Although some methane can be emitted at each step along the supply chain from mine to end use (mostly for power generation but also for metallurgy), most is emitted during mining, surface handling, and preparation.

3.2.1 Coal Mine Methane

Underground mining is the dominant source of coal mine-related methane emissions. Approximately 70 percent of all coal-related emissions are as methane released by mine ventilation systems, which are required for safety. An additional 20 percent arises from methane drainage handling, designed to reduce the requirements for ventilation. Most of the remaining emissions, which are from surface handling, arise from crushing and washing of mined coal.

Open cast mining releases methane directly to the atmosphere but is a minor emitter because the mined seams are generally close to the surface and have retained little methane.

3.2.2 Coal Bed Methane

Coal bed methane (CBM) is exists in the undisturbed coal seam and may be extracted in preparation for or during mining or from seams that are not mined.

3.2.2.1 Production

CBM is produced commercially in the USA and elsewhere and is most often used as an alternative natural gas source and to reduce methane releases from mining. Wells are drilled into the coal seam from the surface. To increase permeability, the coal seam is fractured near the well. This is usually done hydraulically, with coated sand or other porous and permeable fillers to keep the fractures open and productive.

Water is also often pumped from each well. Recently, petroleum industry directional drilling has been used to produce multiple horizontal boreholes in the coal seam from a single well without fracturing. This approach reduces installation costs compared to multiple vertical wells with hydraulic fracturing. Directional drilling is estimated to reduce the cost of CBM production by 50 percent. However, CBM greenhouse gas abatement presents a number of difficulties:

- Not all seams that may be producers of CBM are candidates for mining (this methane would otherwise never be emitted to the atmosphere). In North America, Russia, China and other coal-producing countries elsewhere, some seams producing CBM are either in inaccessible locations, are of an inappropriate size and geometry, or are overburdened in a manner which makes mining impractical, e.g., too deep, or having a friable overburden making shaft mining too dangerous if not impossible
- Large-scale production of coal-bed methane might not be compatible with later mining of the seam, as the required fracturing may leave the seam in poor mechanical condition for later mining.
- Not all mineable seams are suitable for CBM production. Again, geometry, overburden and other conditions contribute to this impracticality

Therefore, the potential of CBM methane production for methane emissions abatement from coal mining must be assessed on a case-by-case basis.

Methane "drainage" is another problem with CBM. Methane released during underground mining can be more than 100 m^3 per ton of coal produced. This is much more than the methane actually contained within the mined coal because methane can migrate into the active mine from adjacent coal formations. For safety, methane concentrations in the mine atmosphere must be controlled, generally to less than 1 percent. In mines with high methane emissions, methane must be "drained" from the mine and adjacent formations to reduce the amount of methane that needs to be removed by the ventilation system. There are several different approaches to underground methane drainage. Usually the mine and adjacent formations are "drained" before mining by drilling in the area of the coal to be mined. Because of migration, methane emissions continue after an area has been worked. Post-mining drainage may be affected by drilling into the intact areas of coal. Modern mining typically recovers up to 40 percent of the coal in place. Alternatively, exhausted areas of the mine may be sealed and used as collectors of gas.

3.2.2.2 Quality

CBM is generally of high purity, with methane concentrations of over 90 percent, particularly if recovered from seams that have never been mined, and it generally contains less sulfur than natural gas from gas wells or gas associated with petroleum production (associated gas). It is often produced specifically to supply a natural gas distribution system, for power generation, as a feedstock for some chemical processes, or for heating requirements and is piped directly to the users. Methane drainage gas, however, is of highly variable quality. At a given mine, its composition may vary considerably over time, depending upon which areas and seams are in production. The major impurities are air and CO_2. Air is the most common, being drawn into the drainage system that operates under negative pressure.

3.2.2.3 Uses

Potential uses for methane drainage gas depend on its quality. The most common application is as boiler fuel for electricity or steam generation and heating, usually on the mine site, or for sale to nearby industries or facilities requiring process steam, fuel or heat. It may also be used to fire dryers, kilns and coke ovens. The minimum methane concentration for these applications is set by the need for flame stability and to avoid air-methane explosions. Usually, the lower limit is 25-40 percent, depending on burner technology and national safety codes. Conventional tube type boilers require a methane content of 60 percent or more. (Babcock & Wilcox “Steam/Its Generation and Use”, 39th Edition).

The most efficient use for CBM and drainage gas is in gas turbines, preferably in combined cycle or combined heat and power (CHP) systems. Such systems require fuel gas compression, a relatively constant gas composition and a fuel gas with a minimum methane content of approximately 40 percent. Gas turbines can either be large, land-based systems, smaller aircraft-derivative units, or packaged microturbine units. For flexibility, heavy duty (diesel-type) spark ignition reciprocating engines may also be used. These, like microturbines, are available as relatively small, mass-produced modules. Spark-ignited engines with closed loop ignition control systems can tolerate large variations in fuel gas composition and require a minimum methane content of only about 30 percent. Despite these options, less than 40 percent of the methane captured by mine drainage schemes is currently used as fuel; the rest is flared or vented to the atmosphere.

Even in mines where underground methane drainage is used, most of the emitted methane is usually removed through ventilation of the mine. With low methane content, direct use as fuel is impossible, and with rare exceptions, ventilation air is simply exhausted to the atmosphere. However, methane emissions from ventilation air could be reduced in several ways.

- Use the ventilation air as an augmentation of combustion air in surface installations at the mine site in microturbines using other primary fuels, ICEs or boilers, but this is unlikely to use more than a small part of the total.
- Oxidize the methane to CO_2 through catalytic incineration, however, catalyst poisoning may occur in presence of certain interfering contaminants, and unless the incinerator is recuperative, there may not be a consistent enough fuel Btu value to

maintain steady operation. Additional fuel would be required for start up and to support combustion during periods when the concentration of methane was low and could come from an associated methane drainage scheme. An alternative to incineration may be biological oxidation using bacterial systems ('methanotrophs'), which are capable of converting methane to CO_2. These could be used in an installation such as a soil bed or biomass filter, which, although large, would be relatively cheap to install. There is, however, limited practical operating experience with such systems.

- Methane content of the ventilation air could be enhanced by one of several adsorption-based techniques. Regenerative incinerators of various kinds (adsorption wheels or switch beds, with either catalytic or passive elements) can also be used to oxidize methane to form CO_2 and water.

3.2.2.4 Costs and Feasibility

Most mine methane currently captured is primarily for purposes of mine safety. Any increase in extraction must, therefore, be justified based on economics or specifically for GHG mitigation (for tradable emission reduction credit production). Coal is a bulk commodity, with low profit margins, and it may be difficult for producers to justify additional operating and investment costs that do not generate income.

Methane drainage schemes offer the best prospects for cost-effective mitigation. Drainage installation and operating costs vary from under $US 100/t to over $US 350/t methane, depending on the permeability of the coal. There are further additional upside and downside considerations to these costs. For example, these costs may be offset by a reduction in ventilation requirements and by the avoided cost of fuel purchase, which can range from about US$ 2.00/MMBtu to $ 16.00/MMBtu for gas or distillate (current US market gas price ranges from approximately US$ 5.50 to 6.50/MMBtu (Bloomberg, January 2005)). On the upside, there may be other expenses (e.g., gas or mineral royalties) involved to obtain this gaseous fuel. For comparison, at a typical thermal efficiency for large utility power generation of 35% (or a heat rate of about 9,740 Btu/kWhr), overall generating costs are estimated to be US$ 0.023 to US$0.045/kWhr.

In this case, however, with fuel costs based on $100 to $350/ton of methane, for small-scale power generation, the generating fuel cost would be between $0.0215 /kWhr, based on a 30%-efficient generation, and $0.113/kWhr, based on a worst case of 20% efficiency. Given these effective fuel costs, and assuming operating and maintenance costs of $0.005 to $0.01/kWhr and capital costs ranging from $200 to $1000 / kW (with a 20% depreciation and a 20% return on investment, for short-term generation scenarios), overall generating costs are estimated to fall in the range $US 0.0365 to $US 0.173/kWhr, for an 8000-hour operating year.

Photovoltaics (PV) and wind turbines under the same economic conditions, but with only a nominal 2000 operating hours per year assumed for each, would produce power at $US 1.326/kWhr and $US 0.21/kWhr, respectively. Therefore, if a wind turbine system is feasible in a given location, it might be a more attractive option than the coal-based project and would likely have a longer project life. PV would probably not be competitive with power generation using recovered coal mine methane anywhere until costs come down significantly. However, under less severe project economic criteria than we have assumed here, PV and wind energy might be much more attractive than using recovered methane, depending on the meteorology of the location.

Table 3.4 Economics of a Hypothetical Coal Methane-to-Energy Project

	IC engine	Micro-turbine	Photovoltaics	Wind Turbine
Easily Dispatched / Continuously Available?	Yes	Yes	No	No
Capacity Range	50 kW-5 MW	25 kW-25 MW	1 kW-1 MW	10 kW-1MW
Efficiency - percent	35	29-42	6-19	25
Capital Cost ($/kW)	200-350	450-1000	6,600*	1,000
O&M Cost ($/kW)	0.01	.005-.0065	.001-.004	.01
Technology status	Commercial	Commercial	Commercial	Commercial

Source: Distributed Electrical Generation Technologies and Methods for Their Economic Assessment - ASHRAE DA-00-7-1, J.F. Kreider, P.S. Curtiss, 2000

* Rapidly reducing

Where utilization is impractical, flaring would reduce CO2eq emissions by over 98 percent in comparison to the current practice of venting, with little increase in cost. In principle, a combination of coal bed methane production and methane drainage could capture up to 70 percent of the methane that would otherwise be emitted through mining (Thakur, 1996).

In practice, local economic, technological and political barriers are likely to restrict the portion captured to no more than 40-50 percent, of which only half would be utilized as fuel. Nevertheless, if the other half was flared rather than vented, this could represent a reduction in methane emissions of up to 10 million tons/year from current figures. The prospects for the income-generating utilization of ventilation gas are small, with the possible exception of its use as combustion air (air used in boilers or power engines). However, the costs for methane oxidation, whether thermal or biological, are likely to be lower than those for improved drainage in cases where the drainage gas cannot be utilized. Oxidation of ventilation gas could reduce emissions by up to 12 million tons/y.

3.2.2.5 Conclusions—Coal -Related Methane and Its Uses

Emissions of methane from the coal industry are estimated to be 22 million tons/year and are expected to rise to 28 Mt/y by the year 2010 as coal production increases. Approximately 90 percent of emissions are attributable to underground mining activities. The largest source is mine ventilation, a situation that is expected to continue. Technologies for methane capture via drainage schemes, both from the surface and underground, are well developed. Methane drainage is used at present principally for reasons of mine safety. There are wide variations between producing regions, but on a global basis, only about 25 percent of emissions are captured. Much of the captured methane is vented or flared, with only about 10 percent of total emissions being utilized. In principle, up to 70 percent of methane that would be released by mining could be captured by drainage schemes, with all of the captured gas being utilized. In practice, more realistic targets would be 50 percent capture and 50 percent utilization, with all unutilized gas being flared rather than vented. The main obstacles to the implementation of improved mitigation measures are likely to be financial, since coal production is a low-margin industry.

The costs of methane capture vary from less than $100/t to over $350/t of methane. At the lower end of this range, utilization can provide a positive net income. In many cases the most cost-effective use will be power generation, where costs are estimated to lie in the range of US$.023-.045/kWh.

Emissions from ventilation systems are currently vented to the atmosphere, with very rare exceptions. They cannot be flared because their concentration is too low, but in many cases, they could be oxidized in thermal systems. Technology improvements in this area are expected to enable air with lower methane concentrations to be treated. Net costs are estimated at up to about $50/t of methane oxidized. Biological systems may also be attractive but have limited demonstration.

3.3 OIL AND GAS

The supply chains of the oil and natural gas industries consist of several distinct steps - exploration, production, transport, storage and distribution. Methane emissions arise at all points of this supply chain. Usually, there are associated higher hydrocarbons, termed non-methane volatile organic compounds (NMVOCs), which will also be emitted and generally captured or mitigated at the same time as methane.

The most important sources of methane emissions are unused associated gas, emissions from natural gas compressor stations, use of gas-operated pneumatic devices and leakage from gas transportation and distribution systems.

The relative importance of methane emissions from the different operations can vary considerably among different oil and gas producing countries and regions, depending on regulatory, operational and other factors. In Nigeria and Venezuela, for example, venting or flaring of the associated gas from oil production has been the major source, since there was no infrastructure for gas collection and transportation. This situation is being ameliorated in many on-shore fields. In the USA and Russia, gas transportation is a more important source, with emissions from gas compression and control systems being the major contributors.

Overall, methane emissions from the natural gas industry are much larger than those from the oil industry and are estimated at 73 percent of the total (Houghton 1995). Most of the methane emissions from the oil industry are due to the venting or flaring of unused associated gas, the contribution from oil transportation, refining and distribution being relatively small. During exploration, methane emissions can occur as a result of accidents such as blowouts. They may also arise during well testing, although it is common practice to flare) gas emitted in this way.

Lack of routine maintenance of natural gas installations may be a significant source of methane emissions, particularly where the equipment is subsequently purged with natural gas.

Maintenance-related emissions occur at all points of the production and distribution chain, and up to several tons of methane may be released each time.

Many oil and gas installations use turbines or reciprocating engines for power generation and heating. These are commonly fired by natural gas and may be a significant source of methane emissions due to incomplete combustion. Reciprocating engines operating intermittently may result in additional emissions, since they are generally flushed with gas before start-up. The amount of methane emitted per engine may be tens of tons per year.

Gas compression is an essential feature of gas transmission systems, with booster compressors required on pipelines at intervals of typically 100-150 km. Methane emissions from purging, valve leakage and leakage through seals may be substantial in older installations or may result from poor operation, since many are remote field units that are generally monitored but not attended.

In some regions, valve actuators and similar equipment in the production and transmission system are pneumatically powered by natural gas. Estimates for the USA in the past, where the practice was common, suggest emissions of approximately 0.5 tons of methane per year per km of pipeline occurred from this source (USEPA 1993).

System upsets may lead to emergency pressure relief events, similar to those for routine maintenance. Other fugitive emissions arise mainly from chronic leakage of gas transmission and distribution systems, mostly from joints, flanges and valve seals. Individual leaks are frequently small and difficult to detect but contribute substantially in the aggregate. Estimates for gas transmission systems vary considerably, but methane emissions may be as high as 10-20 tons per km of pipeline in the former USSR. Similarly, emissions from gas distribution systems may vary widely, with leakage from new plastic piping being much lower than from old cast iron systems.

3.3.1 Upstream

The majority of oil and gas-related methane emissions arise from the countries of the former USSR, which may account for up to 53 percent of all methane emissions in this sector, although reliable data is limited. The Middle East, Africa and the Americas account for a further 36 percent, with lesser contributions from Europe, Asia, China and the Pacific Rim.

Associated gas is a by-product from many oil wells. It is not always possible for this gas to be used on site. In areas where there is no infrastructure for natural gas collection, it must be disposed of by reinjection, flaring or venting. In venting, methane and non-methane organic compounds (NMOC) s are released directly into the atmosphere. Flaring reduces methane emissions by 98 percent in the best modern installations. Emissions during reinjection of gas are relatively low and are mainly associated with compressor operations.

Methane emissions resulting from associated gas during oil production can most effectively be reduced by the recovery and utilization of this gas. This is not always practical, particularly in remote locations where large infrastructure investments may be required for pipelines or liquefied natural gas (LNG) production. Where oil is transported by pipeline, it may be possible, in some cases, to inject the gas into the same pipeline for later separation and recovery. Alternatively, small-scale liquefaction (SSL), LNG or gas-to-liquids (GTL) plants may be viable options for "small" resources at the higher end of production.

If recovery of associated gas is not feasible, then the preferred alternative is re-injection. This is already in common use as a means of enhancing oil recovery by maintaining the formation pressure, with an estimated 6-7 percent of world production of methane currently being re-injected. However, not all oil-producing formations are suitable for re-injection. The final option, therefore, is flaring or venting the gas on site. Clearly, flaring will reduce net GHG emissions in comparison to venting. There are many regions where venting is still practiced.

3.3.2 Downstream

3.3.2.1 Opportunities

Methane, usually as a result of phase changes, is also released by flaring or venting from processes used during oil and gas treatment and refining. For example, the headspace of storage vessels contains gaseous hydrocarbons, which are displaced and vented when the vessels are refilled. Safety valves are another source, allowing gas to be released to prevent the over-pressurization of equipment. Methane is also used as a purge gas in many vent and flare systems to ensure that air cannot enter them. Emissions from flare stacks purged in this way may be up to several hundred tons of methane per stack per year. Opportunities for reducing emissions from downstream process vents and flares will be case-specific. Valves contribute a substantial proportion of these emissions, and it is estimated that up to 30 percent could be eliminated by improved monitoring and maintenance. Purge gas streams could also be reduced in many cases, although safety considerations may make this difficult to implement even when technically justifiable. Again, an estimated 30 percent of emissions from this source could be avoided. A general observation is that recompression of vented gases, for re-injection into the main process stream or for separate fuel use, can be effective in reducing emissions. Emission reductions of up to 75 percent are possible.

Recent research indicates that it is unnecessary to flush gas transportation compressors and other equipment before start up, since the high pressure in the system prevents the formation of an explosive mixture (Coors 1993). Gas emitted during the decompression of equipment for maintenance can be captured, recompressed and rerouted to the downstream system using a portable compressor. In principle, up to about 80 percent of such emissions could be avoided in this way. In practice, an average reduction in maintenance-related emissions of approximately 20 percent should be achievable.

The use of gas turbines rather than reciprocating engines for on-site power generation would reduce exhaust and purging emissions substantially. However, gas turbines require a relatively constant fuel quality, which may prohibit their use with process off-gases. Furthermore, at the small sizes likely to be required, they are less efficient than reciprocating engines.

Compressor seals are a significant source of methane leakage. Older compressors use oil-type seals, which typically emit 5-10 times as much methane as the more modern gas seals and have lower efficiency. The associated valves may also be old and have high leakage rates as a result of inadequate maintenance. Replacing obsolete compressors and associated valving, together with improving inspection and maintenance, could reduce leakage in many cases by up to 90 percent. Globally, this source of methane emissions has the greatest potential for reduction, with an estimated reduction of 10.6 million tons/year overall. For comparison, the potential reduction from minimizing the venting and flaring of associated gas is estimated at 9.5 million tons/year.

Emissions from gas-powered pneumatic actuators can easily be reduced by their replacement with other designs. Where feasible, the use of electrically or air-operated devices will reduce emissions by up to 98 percent. Otherwise, the selection of low-bleed devices, already available but not marketed as such, can reduce emissions by up to 80 percent. Most pneumatic devices have a lifetime of approximately 7 years, allowing these improvements to be phased in relatively rapidly. A global potential reduction of 75 percent, or 5.0 million t/year, is achievable.

System upsets caused by damage to pipelines and distribution networks can be minimized by good control of subsequent construction and civil engineering works in their vicinity. Combined with the wider use of automatic excess flow valves, at least 70 percent of emissions from this source should be avoidable. Other fugitive emissions may be addressed in a variety of ways, including materials selection, corrosion protection and improved inspection, monitoring and maintenance. Replacing old distribution networks may be particularly effective, with reductions of over 95 percent expected when cast iron pipework is replaced by polyethylene. Effective repair procedures are important. Some progress has been made in reconditioning joint seals using a non-intrusive technique involving the use of additives in the gas stream.

3.3.2.2 Costs and economic feasibility

Various parties have made cost estimates of avoiding methane emissions from each of the main types of sources. These indicate that a major fraction of present emissions could be avoided by measures that would be of financial benefit to the industry, making a positive contribution to net income streams. While many of the measures described above do not capture new methane for introduction to the market, they do indeed bring additional methane to existing markets, methane that would otherwise be emitted into the atmosphere, de facto achieving one of the objectives of M2M.

The oil and gas industry is estimated to lose, for example, about 47 Mt/year of methane. Emissions arise from many steps in the value chains, and the dominant source varies from country to country, depending on many technical and situational factors. It is has been estimated by the IEA Greenhouse Gas R&D Program that approximately 45% of all these emissions could be avoided by implementing cost-effective measures, mostly in improving pipeline equipment and maintenance. Much of the following is taken from reports of the IEA. Figure 3.5 shows statistics, from the IEA report, on the distribution of the oil and gas industry methane emissions among regions. This indicates that, through a combination of large-scale production and age and disrepair of infrastructure, the former USSR is the leading source of O&G-related emissions of methane.

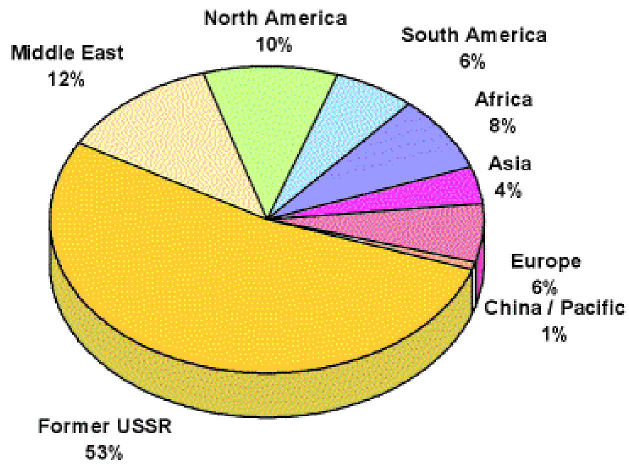

Figure 3.5 Methane Emissions by Region

Table 3.5 presents a general analysis of emissions reduction potential and the range of cost-benefit relationships for the different classes of opportunities.

Table 3.5 Economic Emission Reductions and Cost Ranges

	Estimated Emissions (MMt/yr)	Range of Net Mitigation Costs ($/t methane)*	Potential Emissions Reductions (MMt/yr)	Economically Attractive Reductions (% of Total)
Exploration	**	+300	1.9	0
Associated gas	12.7	-2000 to +400	6.3	50
Process vents & flares	3.8**	-90 to +500	0.2	60
Maintenance	**	-190	1.0	20
Electricity & fuel use	-	-215 to +350	0.7	15
Compressors	11.8	-215 to +35	2.3	80
Pneumatic devices	6.6	-375	1.6	75
System upsets	-	+1500	1.3	0
Fugitive emissions	8.5	-270 to +2235	8.1	5
Other / unclassified	3.8		2.4	0
TOTAL	47		25.8	45

* Negative value means a financial benefit, lifetime basis, 5% discount rate

Note that US$100/t of methane is equivalent to about US$2.10/million Btu.

The major areas in which investment in abatement measures would be most cost effective are pneumatic devices, compressors, reduction of fugitive emissions (leaks) and capture of associated gas. The first two options have the additional advantage of requiring low incremental investment, a particularly attractive feature for economies in transition and the majority of countries in which USAID is active.

A number of highly variable parameters will determine what makes economic sense in emerging economies (in more developed countries, the oil and gas industry faces regulatory costs of non-compliance, a cost which remains an externality in most USAID-served countries). These include the design and age of equipment, the level of preventive maintenance normally practiced, the quality of fuel, logistics, markets and prices. In general, it is advisable that investments be made in the most attractive options first (the "lowest hanging fruit"), and then only if incremental net profits realized are re-invested in the next level of emissions prevention or recovery, until the incremental investments reach the break-even point on investment versus beneficial methane recovery.

The analysis in Figure 3.6 shows that approximately 45% of all emissions could be avoided by measures that would financially benefit the industry, principally by improving pipeline equipment and maintenance. The total investment cost for these measures would be approximately US$8 billion, with resultant annual savings estimated at US$5 billion.

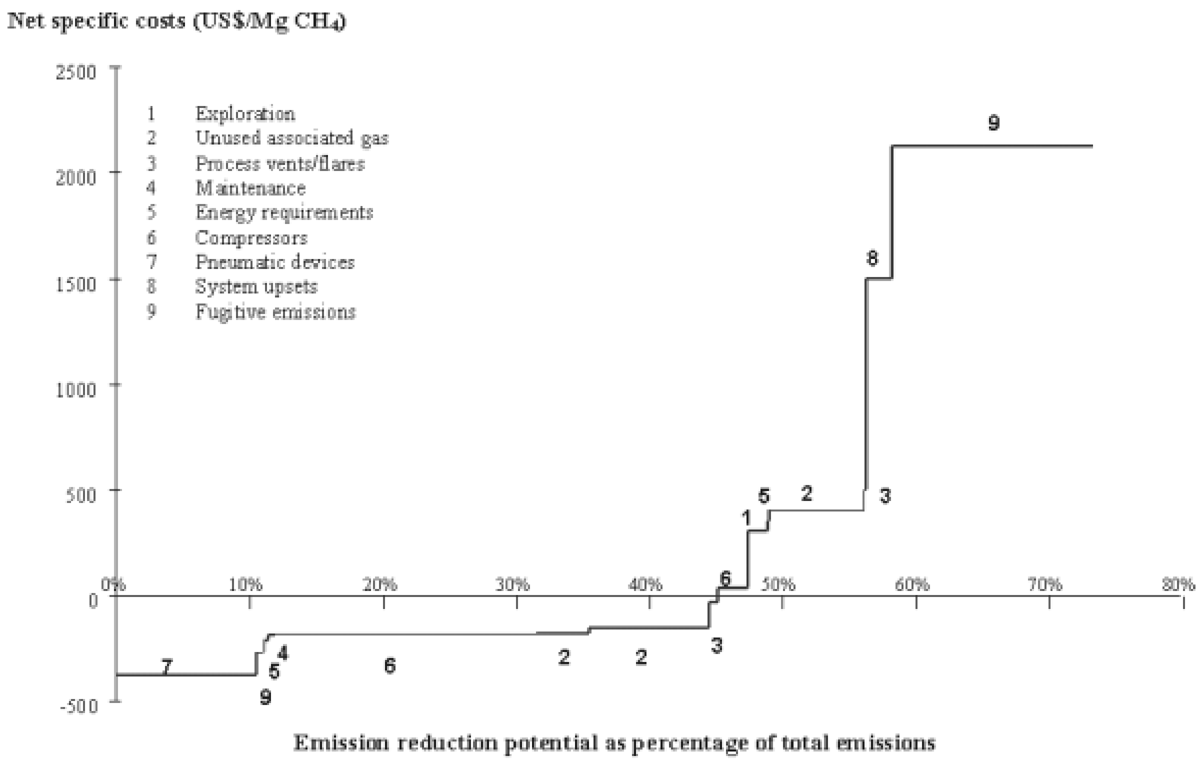

Figure 3.6 Potential Operational Benefits

3.4 BIOLOGICAL SYSTEMS

Biological sources of methane include sewage treatment, rice production, livestock operations, and biomass burning.

While vegetation and agriculture can be major sources of methane, in developing countries such activities are often spread over large areas, at low levels of intensity, which poses serious obstacles to organized collection of methane. However, in the case of organized livestock operations, livestock and required infrastructure can be centralized, and economical collection and use of methane may be possible. Each of the major biological sources of methane and possible uses or means of reduction of methane emissions are discussed in the following sections.

3.4.1 Sewage

Sewage arises from both domestic and industrial sources. Treatment methods, and therefore methane emissions, vary considerably among various treatment plant designs. In developed countries, most municipal and industrial wastewater is collected and treated in an integrated sewage system. Treatment involves an aerobic degradation step for oxidation of dissolved and suspended organic matter, and emissions of methane from this step are generally low. Following aerobic digestion, settled aerobic treatment sludge, together with undigested solids from the primary settlers and filters, are commonly reduced in volume by means of anaerobic digestion, which generates methane. The methane produced is either flared or used for power generation or CHP.

The primary consideration in sewage treatment is public health, although the recovery of water and the reduction in bulk are also important considerations. Apart from direct agricultural applications or secondary production of low-grade nitrogen fertilizers, all treatments produce sludges which must then be disposed of. Options for treating this include composting, aerobic or anaerobic digestion, incineration, pyrolysis or direct landfilling. Composting and digestion yield a residual solid product that may be spread on agricultural land as fertilizer. Further degradation is predominantly aerobic, although some methane may be produced.

In developing countries, integrated systems are uncommon. Urban areas generally rely upon cesspits, drainfields or septic tanks, which are more likely to produce methane as a result of anaerobic digestion. In rural areas it is more common for both liquid and sludge wastes to be applied to agricultural land. This is done to assist in irrigation and to make use of the nutrients as fertilizer. Methane emissions are relatively small, since aerobic degradation predominates. Estimates of regional methane emissions from sewage treatment are shown in Table 3.6. Most arise from industrial wastes, generally from food processing, pulp and paper industries, and the chemical industry.

Table 3.6 Methane Emissions From Sewage Treatment Sources

(Mt/y)	Methane Emissions	
	Industrial	Domestic
North America	2.3	0.1
Europe	4.5	0.3
Asia	19.7	1.2
Africa	4.1	0.3
Rest of World	2.5	0.1
World Total	33.0	2.0

Composting sewage sludge or other municipal waste reduces its volume and produces an easily handled product. It requires a larger site area than other treatment options and may therefore be unsuitable for large urbanized areas. Composting is an aerobic process and produces little methane.

Aerobic digestion may be more applicable in urban areas than composting. Sludge and agricultural manures can be aerobically composted at higher rates with smaller volumes (and lower capital cost) using a process known as autothermal thermophyllic aerobic digestion (ATAD), which runs at temperatures significantly above ambient. This process is used to reduce the volume of concentrated liquid wastes (slurries) and stabilize them more rapidly. Where there is an integrated sewage system, methane emissions arising before the sludge is fully stabilized may be captured more easily.

Anaerobic digestion of sewage produces methane. This methane may be flared or used as an energy source, to minimize emissions. The options available are similar to those for landfill gas but may be applied on a much smaller scale. Anaerobic digestion may be of particular interest in developing nations such as India and China, with several million single-household installations. The gas produced can be used for domestic lighting, cooking and heating.

Incineration of sludge is used principally by developed countries to reduce the disposal requirements (and costs) for solid waste, most commonly when land application is not practical due to industrial contaminants. The sludge is first dewatered and may also be processed in other ways. Methane emissions vary with the technology used but are generally low for the incineration step itself. In some cases, it is possible to recover useful energy via incineration, particularly when the sludge is co-incinerated, or even gasified, with another fuel such as municipal waste or coal.

Pyrolysis (gasification) may be used to produce a low-grade fuel oil and a char product from either raw or treated sludge by heating to temperatures in the range 300-450°C. Although methane is produced, it can be used as fuel for the process. However, the cost effective use of pyrolysis has not yet been demonstrated.

The likely costs of these technologies fall into two groups. Landfill and anaerobic digestion costs may be as low as US$ 50/t methane captured, while the others may be as high as $1,500-2,000/t if all costs are attributed to methane abatement. All of these costs could be reduced if methane, or other products, could be utilized profitably. In developed countries, technology selection may be largely driven by environmental regulatory requirements. For example, incineration may be preferred in developed countries because it minimizes the production of solid wastes and may provide the least-cost means of complying with regulatory requirements – requirements which often do not exist or are not enforced in developing countries. In developing countries, cost may be the most important factor, but increasingly sophisticated sewage treatment is likely to be a necessity as populations grow and urbanization increases.

Improvements in sewage treatment could reduce total methane emissions from this source slightly by the year 2020 to 32 million tons/year, compared to an increase to 58 million tons/year if current practices simply continue. (IEA Greenhouse Gas R&D Program, "Abatement of Methane Emissions", 1998)

3.4.2 Vegetation

Biomass burning results in direct emissions of methane and can also reduce the ability of the soil to act as a sink for methane. Current emissions from this source are estimated at 30 million tons/year. Of this total, approximately one half comes from tropical forest clearing. If current practices continue, total emissions are estimated to increase to 37 million tons/year by 2020. (IEA Greenhouse Gas R&D Program, "Abatement of Methane Emissions", 1998). A secondary source of emissions, directly related to vegetation, is the contribution of methanogenesis by bacteria found in termite guts. This source can be considerable in heavily forested areas and areas where substantial amounts of wood and wood wastes are left after cutting. However, this source type is obviously incompatible with any systematic means of collection of methane.

Methane is also formed when biomass is burned, as one component of the volatile matter is volatilized as the biomass is heated. Complete combustion would oxidize all the evolved volatiles to CO2 and water but, in practice, this is rare and overall emissions from this source are estimated at 30 million tons/year (IEA Greenhouse Gas R&D Program, "Abatement of Greenhouse Gases", 1998). The major contributing activities are shown in Table 3.7 (Delmas 1994). Of the total methane emitted, 80 percent originates in tropical countries, and 70 percent of this is attributable to forest clearing and to the open burning of savannah and agricultural crop residues. The fuel wood use, charcoal production and open burning of agricultural waste are now confined largely to developing countries.

Deforestation has increased rapidly in recent decades. Forest is often cleared for agricultural use after logging or mining operations have made the area accessible. Fire is commonly used to accomplish this. Forest and savannah soils act as important sinks for methane, but this capacity is lost after burning. The effect may be to increase atmospheric methane concentrations by reducing the rate of its biological removal. The options for reduction of deforestation involve government action, including improved forest management, the establishment of reserves and the promotion of alternative income sources such as ecotourism.

Table 3.7 Estimated Emissions from Biomass Burning

	Biomass Burned (dry Million tons/y)	Methane Emitted (Million tons/y)
Tropical forest clearing	1700	14.2
Temperate boreal forest	280	1.5
Savannah burning	2600	5.7
Fuel wood	900	5.8
Agricultural wastes	500	1.4
Charcoal making	140	1.8
World Total	6100	30.4

(IEA Greenhouse Gas R&D Program, "Abatement of Greenhouse Gases", 1998)

Savannah is burned at intervals of one to three years to control weeds, shrubs, tree seedlings and the accumulation of litter. It is then used for grazing. An estimated 750 million hectares are burned each year. Since the aim is to improve feed availability for grazing animals, changes in animal husbandry are the best way to reduce the area that must be burned annually.

The burning of cereal residues in the field is also widespread, although now relatively uncommon in developed countries. It is particularly prevalent in the rice growing areas of Southeast Asia. The main options for reduction of emissions from this source are incorporation of residues in the soil through plowing and the development of other uses. These may include livestock feed and bedding or energy recovery via gasification, pyrolysis or co-firing with other fuels in power stations.

Biomass, particularly wood, is the main source of household fuel for an estimated 3 billion people. Its use is increasing as a result of population growth and is an important factor in accelerating deforestation in some areas. It is usually used in inefficient, open fireplaces. The main option for reducing methane emissions (and overall consumption) is to introduce more efficient stoves and other fuels. Government initiatives may be effective here. In China, for example, 120 million masonry units with chimneys have been installed in recent years. These units burn coal, crop residues and wood.

Charcoal production is an extension of the use of wood as a domestic fuel. Its use is likely to increase as the developing world becomes more urbanized, since it is easier to transport than wood. Charcoal is produced by the slow heating and devolatilization of wood. During production, emissions of methane and other volatile organic compounds are high and are generally vented to the atmosphere. The most appropriate strategy for reducing overall emissions may be to encourage the use of agroprocessing residues and wood wastes in relatively large-scale carbonization plants.

The costs of reducing methane emissions from biomass burning are particularly uncertain. Some estimates are shown in Table 3.8. Overall, total emissions in 2020 could be reduced from 37 million tons/year to 24 million tons/year if suitable policies are introduced and vigorously implemented. Major decreases would come from reductions in fuel wood emissions and deforestation. (IEA Greenhouse Gas R&D Program, “Abatement of Greenhouse Gases”, 1998)

Table 3.8 Estimated Costs for the Reduction of Methane Emissions from Biomass Burning

	Cost ($/t methane)
Tropical forest	200
Fuel wood	150
Agricultural waste	50-1500
Charcoal	50-1500

(IEA Greenhouse Gas R&D Program, “Abatement of Greenhouse Gases”, 1998)

3.4.3 Crops

Wet cultivation of rice by the traditional paddy field method results in emission of an estimated 65 million tons/year of methane and is the primary source of crop-related methane emissions . Emissions from this source have leveled off in the last two decades because most of the suitable land is now in cultivation, and production is not expected to increase significantly in the future.

Rice is the staple diet of a large proportion of the world's population. In flooded paddy fields, where rice is grown, methane is generated by the anaerobic decomposition of organic matter in the submerged soil. It reaches the atmosphere mainly through the rice plant's vascular system, although some does escape directly through the water column. Emission rates depend on climate, soil characteristics, the rice strain being grown and on agricultural practices such as the use of organic fertilizers and the number of crops grown per year. Total emissions from rice production are estimated to have increased by 80 percent between 1940 and 1980 but have remained constant since then at about 65 million tons/year, almost wholly from developing countries, as shown in Figure 3.7 (US EPA, 1994).

As almost all land suitable for rice production is already in cultivation, when considering ways to reduce methane emissions from rice, it is therefore essential that rice yields are maintained. The traditional nature of rice growing means that there is substantial resistance to changes in agricultural practices and even to the introduction of new cultivars. To encourage the adoption of new techniques, it will therefore be necessary for the farmer to perceive and realize benefits from any change. These benefits may include a reduction in water or labor requirements, although higher yields are more likely to be an effective inducement.

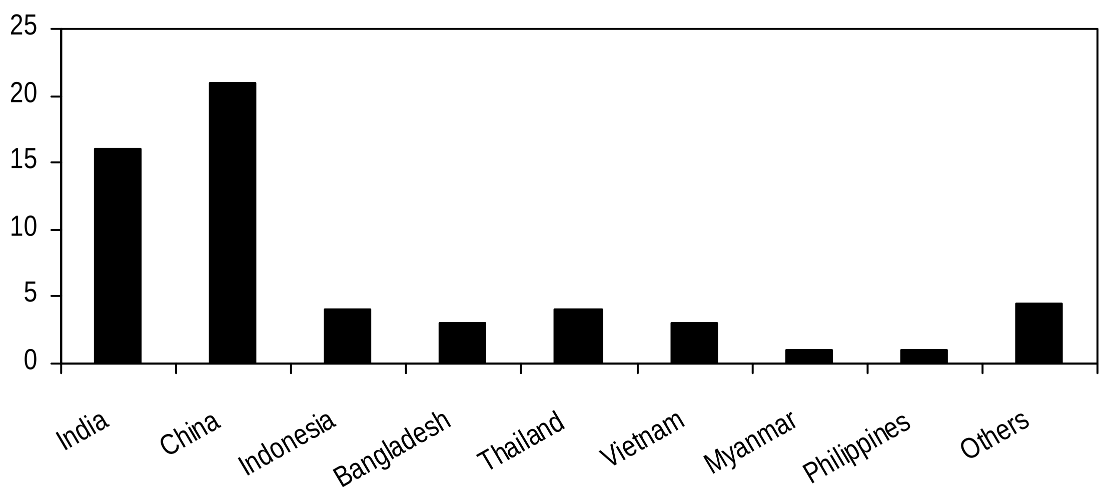

Figure 3.7 Average Annual Methane Emission Estimates (Mt/y) From Rice Cultivation

One approach to reducing emissions would be to alter cultivation practices. For example, dry land production of rice generates significantly lower methane emissions but currently accounts for only 10 percent of the total crop. However, yields are typically only 1 t/hectare compared to up to 7 t/hectare for wet rice. A significant shift to dry rice production would therefore be unacceptable. Changes in the varieties used for wet rice production may be more practical. Methane emissions are known to vary significantly among the most popular rice strains currently grown, possibly by as much as a factor of 10. It has been estimated that emissions from rice production could be reduced by 20-30 percent by careful selection of the cultivars to be grown. This is likely to be the easiest mitigation option to implement, but as noted in Table 3.4, one of the more costly options.

Methane emissions could also be reduced by substituting inorganic fertilizers for the organic fertilizers often used. This has been demonstrated to reduce methane emissions by up to 50 percent. However, the life cycle of synthetic nitrogen fertilizer production via the Haber method needs to be carefully examined to confirm this advantage is real overall. Also, some inorganic fertilizers may promote the emission of nitrous oxide. A complementary or alternative approach may be to use soil additives to suppress nitrifying bacteria, increasing soil fertility by preventing the loss of nitrogen as nitrous oxide. This has been shown to increase rice yields, making it an attractive prospect. This approach could be combined with soil chemistry modification to inhibit methanogenesis. Trials have shown promising results from the use of iron oxide, gypsum and sodium chloride. None of these additives is universally applicable, since the mechanisms of inhibition vary in each case.

Finally, changes in water management practices could be effective. Methane production occurs only during periods of prolonged flooding, when anaerobic conditions develop in the soil. When water is drained from paddy fields during the growing season, or between crops, methane emissions decline. Methane emissions may be reduced by shortening the percentage of the time during which fields are flooded. Intermittent irrigation, in which the land is irrigated to give shallow flooding every 3-5 days, has been shown to reduce methane emissions by up to 50 percent. Rice yields are not seriously affected and may increase in some circumstances (Wassman 1993). However, there is increased potential for denitrification and the production of nitrous oxide. This technique is likely to be difficult to implement, since in many cases it will involve a radical change in agricultural practices.

Estimated costs for the reduction of methane emissions from rice cultivation are shown in Table 3.9. Although unproven, the use of soil additives appears promising, since enhanced rice yields may reduce the effective cost to zero. However, the potential for their application may be low due to lack of infrastructure for production and distribution of additives. More significant reductions could be made by using inorganic fertilizers and changing to alternative rice cultivars. Costs are relatively low and would be further reduced if rice yields were increased as a result. Changes in water management practices would involve significant capital expenditure on irrigation systems and are less likely to be cost effective.

Table 3.9 Estimated Incremental Annual Costs for Methane Abatement in Rice Cultivation

Abatement technique	Cost ($/t methane)
Alternative rice strains	45
Fertilizers	5
Improved water management	225
Soil additives	0

IEA Greenhouse Gas R&D Program, “Abatement of Greenhouse Gases”, 1998

Overall, it is estimated that the use of these four techniques could reduce methane emissions by 40 percent, or 27 million tons/year, by the year 2020. The extent of their implementation, however, is likely to depend on the degree of support for such initiatives.

On a global basis, other crops are insignificant sources of methane when compared to rice. In the case of other crops, methane emissions result primarily from incomplete burning of wastes and residues and anaerobic decomposition of organic matter that is plowed under or piled such that anaerobic conditions exist in the inner parts of the piles.

3.4.4 Livestock

Domesticated livestock contributes an estimated 49 million tons/year of methane emissions (IEA Greenhouse Gas R&D Program, “Abatement of Greenhouse Gases”, 1998). Emissions of methane from agricultural livestock represent one of the largest single sources in both developed and developing countries. They arise from the anaerobic decomposition of animal wastes and from enteric fermentation, principally in ruminants (e.g., cattle) where they may represent up to 10 percent of the animal's total energy intake.

There is little reliable trend data on which to base expectations of future emissions, although it seems reasonable to expect that as world population increases, livestock population will also increase – though perhaps not in a linear fashion – as lower per capita consumption of meat can be expected in the fastest growing segments of the global population.

In developed countries, methane emissions from manure arise mainly from pig and dairy farming and are relatively large due to high animal densities and the widespread use of lagoons and anaerobic digestion. Elsewhere, range and pasture rearing is more common, and methane emissions are lower because manure is more likely to degrade aerobically.

Ruminant animals include cattle, buffalo, goats, sheep and camels. Methane emissions per head are much lower in other animals. In a first approximation, therefore, emissions from enteric fermentation are a reflection of the number of ruminant animals and of cattle in particular. For this reason, although total emissions from Asia are high, central Asia has the lowest per capita emissions because meat and dairy products constitute only a small part of the diet. Regional emission estimates are shown in Table 3.10.

Table 3.10 Regional Emissions From Livestock and Manure

(Mt/y)	Methane Emissions	
	Manure	Enteric
North America	2.3	5.8
Europe	5.9	14.7
Asia	4.2	10.5
Africa	0.3	0.8
Rest of World	1.2	3.0
World Total	13.9	34.8

Emissions of methane from manure are more amenable to abatement. In principle, any of the techniques applicable to sewage treatment could be used. Composting and land application are most common in developing countries. Small-scale anaerobic digestion, usually in combination with household wastes, is also common in these countries. On a larger scale, manure may be treated in lagoons, which may be operated either aerobically or anaerobically, or in a more sophisticated anaerobic digester. In both cases, methane may be collected and used for fuel purposes, either for domestic and agricultural heating or for electricity generation. However, the methane capture efficiency of lagoon systems is likely to be lower, particularly in developing countries. Manure, in the form of dung cakes, is also used as an energy source in some developing countries, reducing the available inputs for this possible form of methane production. Although this results in the emission of methane, estimates indicate that emissions are low in comparison to the use of other fuels. The use of dung in this way may therefore reduce overall methane emissions.

The most important factors affecting emissions from enteric fermentation are fodder quantity, quality and digestibility. Increasing fodder digestibility by mechanical, chemical or biological processing can reduce methane emissions by up to 75 percent while simultaneously increasing the productivity of the animal, i.e., its biomass conversion rate. Examples of treatments that are effective are the use of grass silage and the chopping, grinding or pelletizing of feeds such as hay or straw. Dietary supplements may also be effective if, for example, the available feeds are deficient in nitrogen. Ammoniated hay has multiple benefits, including the suppression of harmful digestive tract bacteria in cattle that lead to human food hazards (e.g., acid-resistant e-coli infected beef). Unfortunately, most of these approaches are only applicable where livestock is housed indoors or where there is effective supplementing of field grazing. In developing countries, these conditions are rare.

The costs of mitigating methane emissions from livestock are likely to be higher than those for many other sources. For manure, the costs are estimated at US$ 260/t methane. Costs will be reduced where, for example, anaerobic digestion is combined with that of sewage and the methane produced is used as an energy source. The costs of reducing emissions from enteric fermentation are likely to be much higher, up to $10 000/t methane when straw chopping and pelletization is used, if the costs are entirely attributed to methane abatement. However, feed modification is primarily aimed at improving animal productivity and is likely, for this reason, to be used increasingly in the future. Overall, it is estimated that methane emissions from livestock could be reduced from 49 million tons/year to 23 Mt/y by the year 2020. Of this reduction, 5 million tons/year would come from improved manure treatment.

There is much research underway at present on development of food additives that would greatly reduce methanogenesis in ruminants by reducing methane emissions, rather than capturing and marketing them. The concept is similar to that of commercial products currently used by humans to reduce flatulence. If CO_2eq credits can be claimed for avoided emissions, then this may in fact be a means of marketing methane through sale of credits earned for not producing it.

4.1 MARKETS AND OPPORTUNITIES

Market opportunities, by source type and sector, and the compatibilities of source type and uses are summarized in Table 4.1.

It should be noted that many of the potential applications and uses of captured methane are relatively new, and as such, there is not a large population of projects to evaluate for identification of successes and failures from which to draw lessons.

Table 4.1 Methane Source Categories and Compatible Uses, by Sector

	Sector				
Source Type	Heat (1)	Electric Power	Transportation	Feedstocks for Syntheses	CO2eq Credits
LFG	medium	high (~ 10 MW range)	high (for sanitation service vehicles and other)	low	high
Coal Mine Methane	low	high (local use)	high (onsite heavy machinery and local sales)	medium	high
Coal Bed Methane	low	high (local use)	Medium (onsite heavy machinery and local sales)	medium	high
Oil and Gas	low	high	high, if CNG market is or can be established	high	high
Sewage	high	medium (onsite use for pumps and other power)	low	low	low
Vegetation	medium to high	medium	low (biogas diesel tractors)	medium	medium (2)
Crops	medium to high	medium	low (biogas diesel tractors)	medium	medium (2)
Livestock	low to medium	low	low	low	medium (2)

(1) Depends on demand, logistics and proximity to end user
(2) Dependent on volume and centralization of operations and opportunities for collection

4.1.1 Energy

Thermal and electrical power generation uses can often be linked in cogeneration systems (combined heat and power or CHP), and fuel use is minimized when they are. Without steam or hot water demand, however, CHP may not make good sense. For the residential, commercial and institutional sectors in temperate climates, CHP is often a practical option, but it is less so in tropical countries. Even in temperate climates, local cogeneration or district heating and power systems are often configured flexibly with simple boilers alongside their cogeneration systems to provide extra steam or hot water in colder seasons. Except for petroleum-associated flare gas, which may have relatively low impurities, most biologically derived gas, including coal bed and coal mine gas, landfill gas, and biodigester gas, has about 50 percent CO_2 plus other impurities of various kinds, in addition to methane. This CO_2 level will reduce the heating value of the gas by about half, rendering it a “medium Btu” or “medium heating value” fuel gas. Such gas resources can be economically used close to the source without removing CO_2, but other impurities must often be removed because they are toxic or otherwise problematic.

The use of LFG and CBM/CMM as an alternative fuel for transportation is also well-established. Uses include powering or dual-fueling of heavy equipment trash collection and handling equipment, other onsite and local use vehicles, and certain heavy equipment on the mine site, in the case of CMM and CBM. Some local use may also be appropriate, particularly if CNG is already offered as an alternative fuel, and the distribution infrastructure is in place.

4.1.1.1 Thermal

Established thermal applications of recovered methane such as LFG and CBM include district heating, greenhouses, and process heating (salt and other mineral evaporation, wastewater concentration, etc.)

The simplest application of landfill gas is using it as a medium-Btu fuel and piping it directly from the landfill to nearby residential, commercial or industrial consumers that can use the gas in ovens, water heaters, boilers or other equipment that can be modified to utilize landfill gas. Using landfill gas directly requires removal of impurities (such as heavier hydrocarbons and trace amounts of inorganic compounds) and condensate at the landfill as well as a pipeline to transport the gas to the end-use facility. End users typically (but not always) need to be within 5 to 10 miles of the landfill, as the capital and operating cost of a dedicated pipeline longer than 10 miles can make the net cost of delivered landfill gas noncompetitive with traditional fuels. These geographic limitations can be a significant hurdle for those seeking landfill gas opportunities. (World Resources Institute,1997).

4.1.1.2 Electrical

Many types of recovered methane streams have been demonstrated for use in conventional boilers with steam turbine generators, internal combustion engines (ICEs), microturbines and fuel cell systems to generate power for local use or to provide grid power.

One growing application in the US links publicly owned treatment works (POTW) anaerobic sludge bio-digester methane with on-site reforming to hydrogen, which is used in fuel cells to generate electricity for use by the POTW. Or the methane may be co-fired outright for production of electrical power.

The geographic limitations and need for equipment modification associated with direct use can be overcome by using landfill gas to fuel electricity generation equipment (reciprocating engines, combustion turbines, fuel cells, or microturbines) located at the landfill. Electricity can be transmitted to the local electric grid or, potentially, directly to an end user facility. The most common technology for electricity generation, utilized in 82 percent of all landfill gas-to-electricity projects, is the reciprocating or internal combustion engine. In general, reciprocating engines have proven to be the most cost-effective and reliable technology for electricity generation from landfill gas, especially for moderately sized projects. Gas turbines are an option for landfill gas projects that can support generation capacity of at least 3 to 5 megawatts (MWs). In addition, several facilities are using microturbines and fuel cells for landfill gas applications. (World Resource Institute, 1997).

However, the recent experience of one major LFG-to-energy company which prefers to remain confidential indicates that successes in US have been slow to come. Two projects in developed countries (Taiwan and Greece) have been outright failures and have generated losses of such proportion to have caused a major scaling back of the company. The reasons cited for offshore failures were essentially corruption, facilitated by the developer's trust in and lack of knowledge of local contract laws and business practices.

4.1.1.3 Transportation

A rapidly growing application of landfill gas in the US is the fueling of garbage trucks on recovered, cleaned and pressurized LFG. Using small scale liquefaction (SSL) technology to allow storage of the gas for periodic refueling (and for getting over weekends and holidays when there is no garbage pickup) may enable this approach. This is in contrast to thermal and electrical applications, which tend to be more level and, if they do cycle, tend to cycle more seasonally than daily or weekly. However, LFG, CBM, biodigester gas and other recovered methane streams are under consideration in the US and elsewhere for other transportation Natural Gas Vehicle applications.

4.1.2 Chemicals Feedstock

Many methane resources are remote from markets or logistically "stranded". The typical way of getting the gas to market, by pipeline, may not be feasible because of physical barriers; the resource is on an island or just offshore or in limited supply. Limited scale also is an impediment to conventional LNG economics and logistics. However, substantial but smaller-than-world scale methane resources (such as currently flared gas from petroleum production) can be used for chemical manufacture. The most common chemicals made from methane by "reforming" it to syngas (a mixture of carbon monoxide and hydrogen gas) are ammonia and methanol. Ammonia has markets as a fertilizer, refrigerant, cleaner, and for other uses in practically every country in the world, including developing ones. It can be converted to solid urea, nitric acid, ammonium nitrate, etc., for ease of shipping and/or to add value. Methanol can be shipped and used as a gas turbine fuel or processed locally to make formaldehyde, melamine, and, with ammonia for urea, formaldehyde resins, all useful in converting biomass (wood chips, sawdust, straw, etc.) to building materials. Both ammonia and methanol have extensive value chains of derivative commodity and specialty chemicals. Methane can also be reformed to produce hydrogen steams for petroleum refinery use or to hydrogenate oils and fats or for other chemical and metallurgical uses. Such chemical manufacturing might not normally be economic on a limited scale, but if the feedstock is "free," then such production might be feasible. Often this methane resource is valued at between US$ 0.50 and 4.00/GJ in various gas-producing centers and markets, and if so, its value and economic benefits are marginal.

4.1.3 CO_2eq Credits

Carbon dioxide equivalent credits (CO_2eq) expressed as equivalent tons of CO_2 with respect to ability to absorb reradiated infrared radiation, are becoming an increasingly marketable commodity. Nascent markets are in fact emerging in the US, typically as ancillary and anticipatory offerings by firms that already broker and trade emission credits for other air pollutants regulated under the Clean Air Act (e.g., particulate matter (PM), sulfur dioxide (SO_2), oxides of nitrogen (NOX) and volatile organic compounds (VOC)).

4.1.3.1 NON-CDM

As USAID is a US government agency, and the US government is not signatory to the Kyoto Protocol, CDM CO_2eq credits are not considered in detail in this report. However, it must be recognized that CO_2eq sales to Annex I countries and in the context of the CDM, can be an additional source of revenue that can further support the collateralization of loans and the financial success of a project.

The non-CDM market is indeed small and tends to command a far lower price per ton of CO_2 equivalent. Even in the case of CDM credits, per ton prices are much lower than those traded within or between EU countries, where prices range from US$ 20 to US$ 50 (or more) per ton.

In either case, to secure transactable credits, the generating source must document and corroborate actual emission reductions or offsets through a process known as validation and certification.

As a matter of practicality, while the intent of this study is to identify markets for collected methane, there is in fact a very real market in the sale of avoided methane emissions. Such credits may be more appropriate for diffuse sources such as agriculture, open range livestock and general agrarian lifestyles that are more common in developing countries.

4.1.4 Targeting by Size of Opportunities

One potentially useful approach for ranking countries for the opportunities they may present is by the relative size of their GHG methane sources. The seventeen selected countries for this ranking represent three categories, as shown in Table 4.2:

- Large emitter countries, with established methane sources and markets – these large, industrialized "super-emitters" will be the source of technology transfer or lessons learned.
- Developing countries with substantial methane emissions from a variety of sources, some of which have implemented methane collection and use projects under USAID and/or other sources of funding or technical assistance and/or which will be the primary targets for future assistance.
- USAID-served developing countries in which methane collection and use may or may not present market opportunities.

Table 4.2 Country Ranking by Size of Methane Emissions

	Methane Source	Landfill	Coal Bed	Coal Mining	Oil and Gas	Rice Paddy	Biomass burning	Livestock manure	Livestock enteric	Sewage
	Country									
Super-emitters (technology sources)	USA	5	5	4	4	na	na	4	4	3
	China	4	5	5	3	5	4	4	5	4
	India	3	4	3	4	4	4	4	4	4
	Russia	4	5	4	5	na	na	3	4	3
Primary Assistance Targets	Indonesia	3	2	3	3	4	3	2	4	3
	Brazil	3	3	2	3	3	3	3	5	3
	Colombia	3	2	3	3	3	2	2	4	3
	Kazakhstan	4	4	4	4	na	2	3	3	3
	Pakistan	3	1	0	3	3	3	3	4	3
	South Africa	3	4	3	2	na	2	3	3	3
	Mexico	3	1	2	4	2	na	2	4	3
	Philippines	3	0	0	0	3	3	2	3	3
	Bangladesh	2	0	na	2	3	3	2	3	3
	Egypt	3	0	na	3	3	2	2	3	3
Limited Potential	Uzbekistan	3	2	3	na	na	-	2	3	3
	Peru	3	0	0	2	2	2	2	3	3
	Ecuador	2	0	na	2	3	2	2	3	2
	Armenia	2	0	na	0	na	-	0	2	2

Key: Annual methane emissions - 5 > 9,000 ktons; 4 > 1,000 ktons; 3 > 100 ktons; 2 > 10 ktons; 1 > 1 kton

Clearly, there is a diversity of emission sources among the countries in each category. For example, the USA and Russia have no significant rice paddies, nor do they significantly practice open-air biomass burning for agriculture or cooking and heating, while it is estimated that China and India continue to have large emissions from these sources, despite their rapid industrial progress. China and India continue to have some of the elements of advanced economies along with some primitive systems and practices, especially in rural areas. All four countries, however, have major emissions from all the other sources, which are related as much to their very large populations, territories and economies as to any unique practices in the relevant economic source sectors. Because each one of these four takes an aggressive stance towards technology development and exports, each can serve to some extent to provide models of solutions and exportable goods and services for bringing methane from the listed sources to markets.

There is far more diversity and scale of sources among the "Primary Assistance Targets" countries. For example, a number of these countries have little or no coal resources, and a few others have coal but do not have much mining. All have oil and/or gas resources, and all are producers, except the Philippines, which is just starting. Since all have large populations and significant agricultural sectors, all have large methane emissions from sewage, landfills, and livestock. Since crops and agricultural practices do vary among them, emissions from these sectors also vary somewhat.

Nexant concludes that the most generally relevant and transferable source opportunity among these countries is landfill gas utilization, followed by sewage. These two are also related to population centers and thus would more frequently provide both supply and market logistic feasibility in most cases.

4.2 OPPORTUNITIES AND BARRIERS

Major opportunities and barriers to marketing, sales and use of methane, regardless of its source, are presented in the following table. Corrective measures and possible USAID roles are also provided.

Table 4.3 Opportunities for Sustainable Recovery and Use of Methane in Developing Countries

Opportunity	Leveraging and Replication	Possible USAID Role
Logistics		
Infrastructure for delivery CNG and LPG may already be in place	Engage gas suppliers in supply chain for methane sales and delivery.	Survey, retrofit and upgrade existing systems to optimize distribution of LFG
Residential areas often close to coal mines and organized livestock operations	Establish sustainable demonstration projects	Install low-technology demonstration systems for local distribution on pilot scale.
Economics		
Generation of CO2eq credits for commercial sale	Establish a brokerage function that can aggregate credits in sufficient volume to attract interests of buyers from industrialized countries.	Support development of systematic, accurate and defensible means of estimating GHG emission reductions
Increased productivity through better health and possible nighttime lighting	General desire for cleaner indoor air and increased productivity and security through provision of low-cost, residential and community lighting	Pilot scale distribution through pipe or tank to residential customers. Pilot project for street lighting, using recovered methane.
Health		
Reduced indoor air pollution if methane substituted for wood, coal and animal wastes	Establish baseline and track health impacts through simple epidemiological studies. Compare to prior programs under which CNG, or other less polluting energy source, has been supplied to replace coal, dung and wood waste fuels.	Synthesis of results of past studies, gap analysis, and additional studies to promote positive health effects associated with use of methane vs. dirtier fuels.
Social		
Reduced labor burden for collection of fuels	Reduced labor demands will free up segment of society (particularly women) to engage in other, more productive and possibly value-added activities and to contribute to household and local economies.	Perform studies to quantify labor savings realized through avoidance of biogenic fuel scavenging and collection. Monetize benefits in terms of additional income possible through freed-up labor. Engage community through NGOs.

Opportunity	Leveraging and Replication	Possible USAID Role
Legal		
Assignment of legal responsibility for GHG emissions	Clear legal ownership and specified tax advantages will promote collection and use of methane	Establish model "mineral rights" regulations, standard non-disclosure agreement, memoranda of understanding, LOIs, FPAs, and PPAs.
Technical		
Adaptation and transfer of proven technologies from prior successful projects	Establishment and demonstration of precedents will remove one major barrier in that proof of concept will have already been established.	Establish knowledge base for identification, investigation and assessment of feasibility of appropriate technologies
Commercial and Institutional		
Clear and legally binding contracts and agreements will facilitate success	A compendium of standard agreements that can be modified and used in a variety of countries, for a variety of purposes will serve to strengthen investor confidence and reduce opportunities for project failure on basis of contractual disputes.	Develop a standard set of agreements based on successful projects.

Table 4.4 Barriers to Sustainable Recovery and Use of Methane in Developing Countries

Barriers	Removing the Barriers	Possible USAID Role
Logistics		
Tropical cities seldom have Local Distribution Centers.	(1) concentrate LFG, CBM, biodigester gas in membranes, PSAs, or regenerative absorbers for more economical piping for medium distances	Feasibility studies and pilot projects
Medium/Low Btu gas is expensive to move by pipe.	(2) Use small-scale natural gas liquefaction ("peak shaver" LNG technology) to move gas to market as LNG by truck or barge from remote areas	Feasibility studies and pilot projects
Economics		
Threshold capital may not be readily available.	(1) Small projects can be financed on a lease basis, using skid-mounted equipment (2) GHG emission reduction credits can make even incineration options viable. Some NGOs will finance based on credits	Fund feasibility studies and pilot projects
Health		
Health impacts are not monetized or properly tracked.	(1) LFG-enabling projects (lined, vented landfills, leachate management, etc.) are also public health-enhancing	Feasibility studies and pilot projects
Social		
Social acceptance of a new technology	Public education and economic analyses, demonstrating cost savings, and improvement in quality of life.	Public information programs, and development of infrastructure for replication of such programs
Legal		
Ownership of feedstock (waste) or recovered methane	Establish enforceable (and enforced) regulations at the national and state level for establishment of rights, similar to mineral or land-use rights.	Development of draft legislation for consideration, revision and adoption by cognizant regulatory authorities
Fuel and power purchase agreements for fair	Establish enforceable contracts for use in sales and purchase of captured methane or power, including	Development of draft commercial contracts, in English and local

Barriers	Removing the Barriers	Possible USAID Role
compensation for delivery of fuel or power	legal recourse for non-payment.	language, to facilitate commercial transactions
Technical		
Not all technologies are scalable downward to the size appropriate to developing country waste streams or amenable to dramatically different waste stream analyses or methane contents.	Develop screening system which provides upper and lower limits on size, process inputs, and feedstock or fuel quality to rule out inappropriate matches of methane sources and technologies.	Establish knowledge base for identification, investigation and assessment of feasibility of appropriate technologies.
Local operating environments and economies may not be adequate for sustained operation of more advanced technologies.	Develop screening system, which compares O&M requirements, recurring costs, availability of parts and service, and technical resources to requirements of technologies considered.	Establish knowledge base for identification, investigation and assessment of appropriateness of technologies in target operating environment.
Commercial and Institutional		
Investors and lenders will not lend to risky economies without sufficient recourse and risk insurance.	Develop tools for managing risk through contract law, project risk insurance and other legal recourse, including sovereign guarantees.	Assist in the development of a systematic approach to risk management and dissemination of details thereof.
Repatriation of capital is often impeded or precluded by host country banking laws.	Execute contracts in hard currencies and through bank accounts in neutral and stable countries.	Develop and update a listing of third-party banking establishments that have proven to be solid providers of banking services for project cash flow and operations.

4.3 IMPROVING MARKET POTENTIAL

4.3.1 Means of Getting Methane to Market

The broad possibilities for getting methane to markets are:

- Power generation at the point of capture – for use at the site, for a dedicated user at a distance, or for general sale to the electrical grid
- Use as fuel in nearby industrial, commercial, institutional or power generation facility; whether and to what extent inert components of the gas are removed to increase heating value depends on relative pipeline/processing system economic tradeoff.
- Connection with a pipeline grid, which can comprise complex pipeline/storage systems (which can include peak shaving and/or large-scale logistic LNG systems, underground or aboveground pressurized storage, propane-air peak shaving, etc.)
- Truck/rail transported LNG produced by small scale liquefaction units for use as an LNG source or with liquified compressed natural gas re-vaporization systems (e.g., use as transportation CNG, or in gas turbine combustors)

- Mobile CNG systems (tank trailers and barges)
- Conversion to liquid fuels or chemicals at the site or nearby

Each of these possibilities involves demonstrated technologies and operating systems, but there is more experience in some than in others. For others, there is greater experience at the large scale. Each needs further demonstration and experience at the small-to-medium scale to be able to address the types of opportunities discussed here.

Enabling strategies include:

- Organizing “Centers of Excellence” to serve as collectors and gatekeepers of data, experience and references to experts and knowledgeable financing organizations and relying on M2M members as primary contributors to the effort.
- Assist in adapting each technology to smaller scale and more “appropriate” configurations (simplify to make more repairable on a local level, avoid complex, sophisticated systems if simpler, more labor-intensive ones will do [even if somewhat less efficient]) – this adheres to the “small is beautiful” model of appropriate technology, while maintaining high safety standards
- Assist in developing standards and regulations to enable use of non-ubiquitous technologies such as LNG, LCNG, microturbines, natural gas-fueled heavy duty (spark-fired diesel type) ICEs, adsorption refrigeration, etc
- Assist in developing Distributed Generation and CHP programs in the target countries for potential users of the recovered gas resources
- Develop GHG reduction credit monetization / trading mechanisms for the target countries

5.1 SCREENING FOR SUCCESS

The range of permutations of opportunities for coupling methane supply to energy demand are as diverse as the economies, natural resources, industries and overall operating environments of countries served by USAID. To maximize return on investment by USAID and project developers, it is essential that a systematic screening approach be developed and employed to assure that projects satisfy M2M requirements and the three Principles described by USAID in the Administrator's presentation of 15 November 2004 at the M2M Ministerial Conference held in Washington, D.C. In summary, the Principles are:

- Promotion of Private Sector / Non-Governmental partnerships
- Establishment or further development of a business climate that promotes economic sustainability (of the project and in general), and
- Creation of sustainable markets (for methane and the resultant products)

5.1.1 Systematic Approach

A systematic approach is essential to minimizing errors and omissions in the evaluation of opportunities for development of M2M projects that satisfy USAID's stated Principles. Such an approach could be embodied in a Guidebook or better, in an electronically maintained and distributed Decision Support System (DSS). The DSS would be maintained by headquarters and would be updated as new information, links and strategies are developed.

The elements of such a system would include:

- Format for entry of required data
- Primary sources of energy, industrial, agricultural and natural resource data
- Development of inventory of location and extent of methane sources exceeding predetermined threshold amounts
- Assessment of generation rates, including max/min and seasonal variability
- Estimation of duration of supply at required levels
- Guidance for estimation of values if field data are unavailable
- Inventory of real or potential demand above predetermined threshold amounts
- Determination of fuels that might be replaced by or blended with methane
- Identification of proper technologies and suppliers
- Cost comparison with existing fuels
- Environmental, social and financial fatal flaw analysis
- Identification of potential private sector and non-government partners

- Economic screening analysis for feasibility of multiple uses and rule-out of unacceptable options
- Identification of potential sources of funding
- Template for DRAFT EOI if outside funding or support is desired
- Sample legal documents, such as nondisclosure agreements, letters of intent, memoranda of understanding and fuel or power purchase agreements.

A logic diagram of a possible DSS is presented in Figure 5.1.

5.1.2 Demonstration Use of the DSS Approach

By way of example, the approach presented in Figure 5.1 is exercised for a hypothetical landfill project in Pakistan to demonstrate how the systematic approach might be used to identify and quantify the project and then determine whether to proceed.

The process starts by identifying potential methane sources and concurrently establishing the energy balance within the geographic area of interest. Methane sources can be determined by examination of environmental and industrial permits, land use/ground cover maps, zoning maps, inventories provided by industrial associations, and tax records.

Optimally, industries will also be coded by the universally recognized International Standard Industrial Code (ISIC) as established and updated by the UN Department of Economic and Social Affairs, Statistics Division, which may be viewed in its most current form at http://unstats.un.org/unsd/cr/registry/regcst.asp?Cl=2&Lg=1 . ISICs are comprised of 4 digits, and are aggregated at higher levels of 3 and 2 digits. For example, the ISIC for "Sewage and Refuse Disposal, Sanitation and Similar Activities", is 900 (this Group is not yet further subdivided to the Landfill source level), as shown in the screenshot presented as Figure 5.2. Much technical literature and data are available based on ISIC. Specific ISICs can also be targeted based on a specific intent with respect to methane sources and/or potential markets.

The energy balance must also be established to understand what the demand currently is and where opportunities for substitution or additional use of methane might be possible. The energy balance presents the net imports and exports by fuel type, the internal production of refined fuels, and the energy input mix for power generation in a particular country. The most useful source of this type of data at the country level is the US Department of Energy (USDOE) Energy Information Agency (EIA). The Energy Balance for Pakistan for 2001 is shown in Figure 5.3. The most current Energy Balance for any country can be accessed at http://www.eia.doe.gov/emeu/international/. The annual quantity of vented and flared gas is also presented, which gives an idea of whether there is potential in that sector (there is very little in Pakistan, where associated gas is not routinely flared).

Once it is determined that a methane source of significant size exists – either as a single source of group of accessible smaller sources, which, in aggregate, can provide fuel or a fuel substitute – and that there is a potential market – be it for residential cooking gas, power generation, process heat or other – the technical feasibility should be examined.

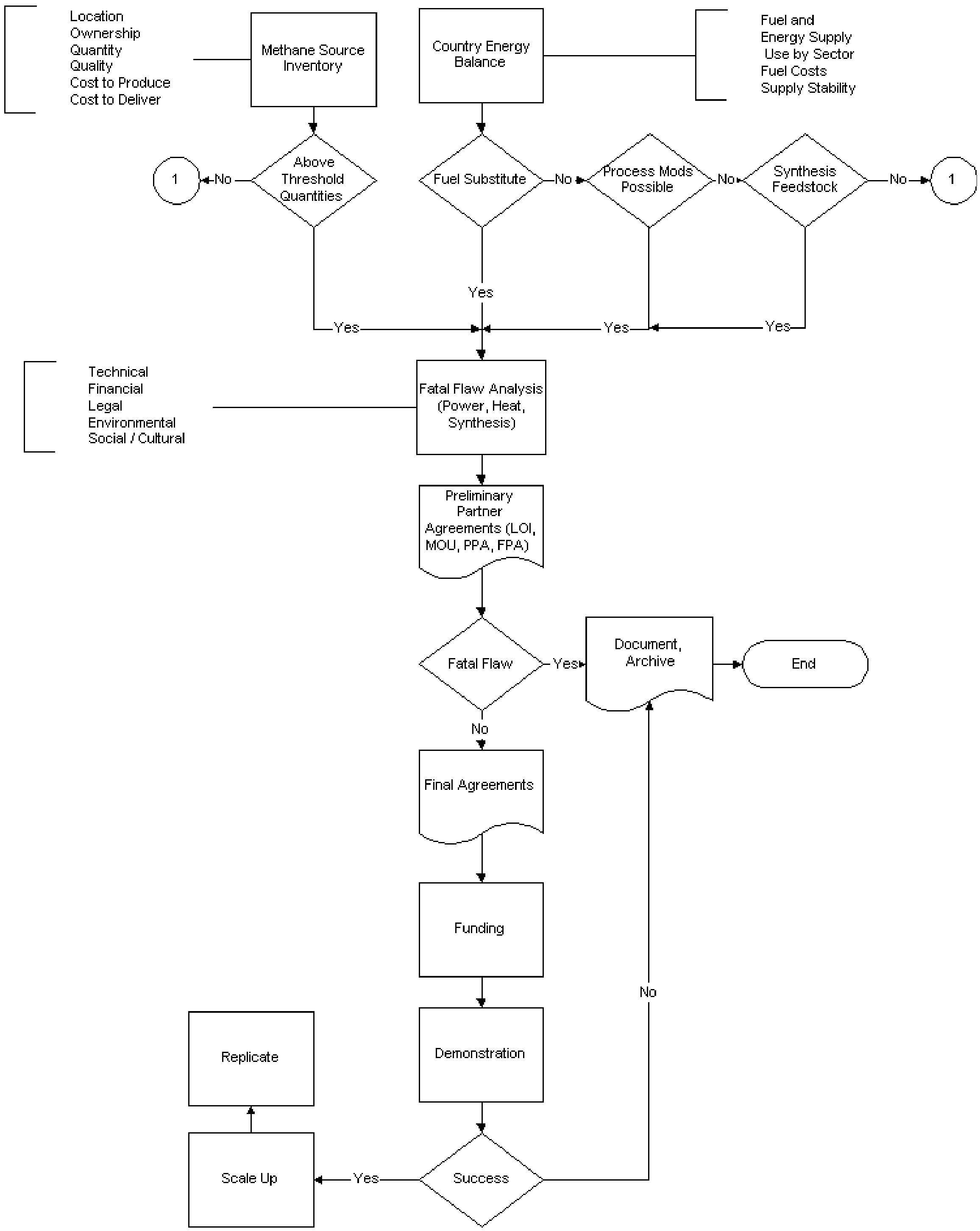

Figure 5.1 Logic Diagram of a Decision Support System for Identification and Screening of M2M Opportunities

Detailed structure and explanatory notes
ISIC Rev.3.1 code 900
Profile Structure

Hierarchy

- Section: O - Other community, social and personal service activities
- Division: 90 - Sewage and refuse disposal, sanitation and similar activities
- Group: 900 - Sewage and refuse disposal, sanitation and similar activities

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Breakdown:

This Group is divided into the following Classes:

- 9000 - Sewage and refuse disposal, sanitation and similar activities

---

No explanatory note available for this code.

Figure 5.2 UN ISIC Designation for Sewage and Refuse Disposal, Sanitation and Similar Activities

Figure 5.3 USDOE EIA Energy Balance for Pakistan, 2001

Pakistan

Year: 2001

Energy Production (Quads) = 1.1278 **Energy Consumption (Quads) = 1.8147**

Oil (Thousand Barrels per Day)

	Production	Refinery Output	Imports	Exports	Stock Build	Consumption
Crude Oil	59.87		141.50	4.91	0.00	0.00
NGL's	3.00		0.00	0.00	0.00	0.00
Other Oils	0.00		0.00	0.00	0.00	0.00
Refinery Gain	-1.23					
Gasoline		31.00	0.00	5.00	0.00	26.00
Jet Fuel		16.75	0.00	0.00	0.00	16.51
Kerosene		7.69	0.00	0.00	0.00	7.50
Distillate		49.79	98.00	0.00	0.00	147.20
Residual		60.01	84.26	0.00	0.00	146.60
LPG's		6.59	0.00	0.00	0.00	8.96
Unspecified		24.76	0.00	8.83	0.00	14.35
TOTALS	61.64	196.59	323.76	18.74	0.00	367.12

Natural Gas (Billion Cubic Feet and Quadrillion Btu)

Gross Production	(Billion Cubic Feet)	875.46	**Dry Imports**	(Billion Cubic Feet)	0.00
Vented and Flared	(Billion Cubic Feet)	0.00	**Dry Exports**	(Billion Cubic Feet)	0.00
Reinjected	(Billion Cubic Feet)	26.84			
Marketed Production	(Billion Cubic Feet)	848.62			
Dry Production	(Billion Cubic Feet)	774.46	**Dry Production**	(Quadrillion Btu)	.7233
Dry Consumption	(Billion Cubic Feet)	774.46	**Dry Consumption**	(Quadrillion Btu)	.7233

Coal (Thousand Short Tons and Quadrillion Btu)

	Production		Imports		Exports		Stock Build	
	(1000 Tons)	(Quads)	(1000 Tons)	(Quads)	(1000 Tons)	(Quads)	(1000 Tons)	(Quads)
Hard Coal			1011	.0251	0	0.0000	0	0.0000
--- Anthracite	0	0.0000						
--- Bituminous	3668	.0620						
Lignite	0	0.0000	0	0.0000	0	0.0000	0	0.0000
Coke			0	0.0000	0	0.0000	0	0.0000
Total Coal	3668	.0620	1011	.0251	0	0.0000	0	0.0000

Consumption : (1000 Tons) = 4679 **(Quads) =** .0872

Electricity (Million Kilowatts, Billion Kilowatt Hours, and Quadrillion Btu)

Capacity	Generation			
(Million kw)	(Billion kwh)	(Quads)	(Billion kwh)	(Quads)

Hydroelectric	5.010	18.752	.1903	**Total Imports**	0.000	0.0000
Nuclear	.462	1.981	.0211	**Total Exports**	0.000	0.0000
Geothermal and Other	0.000	0.000	0.0000	**Losses**	4.820	
Thermal	12.254	48.126				
Totals	**17.726**	**68.859**		**Consumption**	**64.039**	

For example, assume that a landfill of sufficient size and productivity is identified, and a fruit processing and drying plant nearby is currently using natural gas as its fuel (the LFG can be used to generate steam, for indirect heating, and never come into direct contact with the food process). The next question is, can the current heating process use LFG? Is it of sufficient Btu content, and quantity, and will it be available when needed? If modifications in the firing technique and heat delivery system must be made, are they technically possible and financially feasible? Further, can the switch in fuels meet environmental requirements? For the sake of demonstration, assume yes.

The next question is, can agreement be reached between seller and buyer, and at least as importantly, does the seller have clear legal rights to the LFG? The agreement would likely take the form of a fuel or power purchase agreement, by which the buyer agrees to purchase fuel or process steam at a given price – fixed or indexed to some economic indicator, – and the seller agrees to supply gas or steam at a given rate and quality, probably with a consequential damages clause in the event of failure to deliver. Assume that clear title to the LFG is guaranteed and that the seller and buyer are in agreement on terms.

Upon finalization of the agreement, the buyer and possibly the seller (if capital improvements are required) may require financing, if they are not capable of or inclined to self financing. At this point, any number of possibilities for financing may exist and will have probably been explored well in advance of arrival at this point in the process. Assume that financing can be secured.

Having cleared the technical and financial screening, assured environmental compliance, secured rights to the LFG and signed a binding agreement for sale and purchase, the project would then proceed to construction and operation. Assuming successful operation, the precedent will have been established, and replications are then likely to occur.

For the purposes of this study, the question is, where and how can USAID provide the most useful and highly leveraged assistance? Possibilities are as detailed below:

- Funding of the opportunity identification process
- Funding of or assistance in conducting the feasibility study
- Development of template contract and agreement documents, including mineral rights, and fuel and power purchase agreements
- Development of enabling and supporting legislation, creating a transparent and objective investment climate which could also include such specific actions as tax incentives, waiving of duties and other tariffs on imported equipment
- Support of demonstration-scale projects for proof of concept and scalability, and

- Dissemination of nonproprietary technical data for the purpose of encouraging propagation of the concept and project.

5.2 TARGET COUNTRIES

Countries considered in this report are divided into three categories:

- Developed countries, with established methane sources and markets – these are not the subject of this report except from the point of view of technology transfer and lessons learned.
- Developing countries that have implemented methane collection and use projects with USAID and/or other sources of funding or technical assistance.
- USAID-served developing countries in which methane collection and use may or may not present market opportunities.

The first category of countries, developed countries, can serve as a source of technology and experience, demonstration of source-market linkages, technology transfer, technical assistance and replication of successes. An important caveat must, however, be applied. The operating environment of the target country must be carefully assessed to assure that the technology is feasible, acceptable and truly sustainable in what will most likely be a very different operating environment from the perspectives of energy markets, fuel use patterns, economics, social and cultural aspects, logistics and legal and regulatory frameworks. Numerous case studies been identified and summarized, and links to a wide range of useful information have been established and are presented in this report.

The second category, developing and emerging industrial countries in which methane collection and marketing studies or projects have been undertaken, will allow ground-truthing of what can be expected to work in developing countries that have not pursued such methane collection and marketing opportunities. For the purposes of this study, these countries include Brazil, Colombia, India, Indonesia, Kazakhstan, Mexico, Peru, Russia, Republic of South Africa and Ukraine. USAID environmental officers in these countries have expressed interested in the M2M program, and inquiries have been filed with appropriate contacts in each of these countries to determine if work in addition to that discovered through literature searches and other inquiries has been undertaken by USAID or other organizations.

The third category, USAID-served countries that do not fit in to the preceding category, is being assessed from a ground-up perspective. Estimates of methane emissions are being collected or developed where data allow. Concurrently, possible markets are being defined. With estimates of emission levels and possible markets, opportunities for linking methane sources to methane markets will be explored. As part of this effort, a systematic process for identifying and evaluating opportunities is also under development.

6.1 PAST AND CURRENT PROJECTS IN DEVELOPED AND LESS DEVELOPED COUNTRIES

Examples of three types of projects are reviewed in this section: successes, failures, and projects that were deemed to not be feasible and abandoned, but which at current fuel and energy prices or with improved technologies may be worth revisiting. In each case, an explanation of why the project succeeded or failed and lessons learned is provided.

Because much work has been done on methane recovery and use in the past, the later category may be a particularly interesting one early on, as much of the groundwork and analysis of feasibility has been done.

Many more methane capture projects, undertaken by USAID and other organizations and identified in this study, are summarize in Attachment 2 for reference. Points of contact are also provided, should additional information be desired.

6.1.1 Methane Recovery Project Successes

West Africa Gas Pipeline (WAGP)

USAID's long-running WAGP project is an outstanding example of how associated gas in the Nigerian Escravos oil fields will be redirected to commercial markets in Ghana, Togo, and Benin by way of a 1,000 kilometer-long gas pipeline. Previously, the excess gas not used by an LNG production facility and nearby power plants had been flared as a waste product. With USAID's technical assistance, the gas will now be redirected to commercial markets and will reduce CO_2 emissions by roughly a factor of two by replacing fuels previously burned rather than simply being flared.

Sweetening (removal of contaminants, including sulfur-containing compounds such as hydrogen sulfide (H_2S) and other reduced sulfur compounds) of the gas and redirection for combustion elsewhere will also have a favorable impact on local agricultural operations that have in the past been adversely impacted by SO_2 and acid deposition resulting from flaring.

There are many examples of reasonably successful methane-to-markets projects in industrialized countries. However, most are dependent on two factors that are not typically present in countries served by USAID, specifically: 1.) cost of environmental noncompliance and 2.) a sufficiently large and extractable source of methane with stable and compatible user(s) nearby.

Companies like General Motors, BMW, and S.C. Johnson are buying landfill gas in the US to reduce energy costs. Methane from landfill gas sites is less expensive than natural gas when such large and reliable sources are available and reduces the amount of methane emitted.

General Motors

GM burns landfill gas at five assembly plants, making it the largest industrial user of waste gas. Each plant cuts GM's energy bill by about $500,000 a year, says Joseph Bibeau, who is in charge of GM's energy usage. Landfill gas is considered green power by the World Resources Institute, a non-government organization that works with companies like GM on environmental practices. New technologies to trap and transport landfill gas have made such efforts more economical. The EPA says that 150 new landfill gas projects have begun since 1999, for a total of 375. Another 600 garbage dumps could be tapped as energy sources. "Until they stop adding waste to those landfills, there's no end in sight," says Bibeau.

BMW

BMW Manufacturing's Landfill Gas-to-Energy Project is designed to use methane gas from the nearby Palmetto Landfill (South Carolina, USA) to generate electricityfor its automobile plant. BMW Manufacturing indicates this energy source reduces carbon dioxide emissions that are equivalent to 61,000 automobiles. The LFGused also equals the amount necessary to heat 15,000 homes a year. Additional project facts follow:

- The energy provided by LFG supplies BMW Manufacturing Company with 25% of its energy needs.
- To utilize the gas, a 9.5-mile pipeline was built from Palmetto Landfill to BMW.
- BMW's landfill project is the only project that co-generates electricity and hot water for use at an industrial location remote from the landfill.
-
- BMW's landfill gas-to-energy project reduces carbon dioxide emissions equivalent to those released by driving 105 million miles per year or more than 4,000 times around the Earth.
- Ameresco designed, built and owns the pipeline, gas processing and gas compression facilities and manages the overall operations of the project.
- Waste Management, which owns and operates the Palmetto Landfill, has been developing landfill gas-to-energy projects for more than 15 years and currently supplies landfill gas to 69 gas-to-energy projects in 21 states.

S.C. Johnson

SC Johnson hired Northern Power Systems to engineer, build and install a sophisticated co-generation power system at the company's Waxdale plant in Racine, Wisconsin. Northern's system burns methane gas from a nearby landfill to generate up to 3.2MW of electricity (one half of the facility's power demand) and recover the waste heat from the exhaust to make 17,000 pounds of plant steam per hour (or 17 million BTUs/hour). In addition, the new system reduces the plant's CO_2 emissions by 32,000 tons per year, or 47%, the equivalent of taking 5,000 cars off the road annually. The new cogeneration system utilizes a 3,200 kW turbine with a heat recovery steam generator (HRSG), proprietary Northern system controls, power electronics, conditioning equipment, storage, environmental systems and housing. The system yields $750, 000 in annual energy savings based on electricity demand reduction and natural gas savings. In addition to generating cost savings and a favorable return on investment, the system reduces atmospheric emissions and supports environmental management and climate.change mitigation

In the new system, the methane is piped a distance of 2/3 mile from the landfill to the Waxdale facility and used to fire the turbine generator, which produces electricity for use in the plant. The waste heat from this process is then recovered via the HRSG to produce steam. Using the methane as a fuel source for the Waxdale plant not only prevents the methane energy from being wasted in a flare, it also supplants the facility's need for natural gas and other fossil fuels.

In developing the Waxdale plant system, Northern used its "open technology" system design that provides customers with a full range of different technology and system options. After a rigorous evaluation process, the S.C. Johnson project team chose the turbine solution because it delivered the greatest environmental benefits and cost savings. By enabling virtually all of the waste heat to be recovered and converted to high-pressure steam for the plant's production and heating needs, the system yields an overall efficiency of 70%. By serving as the sole, turn-key provider for the project, Northern was able to work on an accelerated timeline and deliver the project ahead of schedule, thereby enabling S.C. Johnson to achieve its greenhouse gas emissions reduction goals for 2003.

The Waxdale landfill gas system demonstrates that concerns for the environment and the bottom line are not mutually exclusive. In embarking on this project, SC Johnson was able to meet its internal rate of return requirements while continuing a long history of corporate citizenship that other companies can emulate.

By 2005, the environmental improvements resulting from the Waxdale plant's co-generation system will contribute to overall net emissions reductions of 8% from 2000 levels. The project supports both companies' commitment to the environment: Northern, as part of the World Wildlife Fund Climate Change Program, and S.C. Johnson, as a partner in the U.S. EPA Climate Leaders Initiative, which challenges corporations to make voluntary reductions in their GHG emissions. "This is a unique project due to the combined heat and power application," said Chris Voell, program manager of the EPA's Landfill Methane Outreach Program, of S.C. Johnson's plan. Voell added that Northern's design is one of the most energy efficient systems in the country and one of only two projects of its kind to be run on landfill gas.

A system overview of the Waxdale facility is as follows.

- Power Application: power to provide renewable, reliable electricity for facility
- System Type: 3.2 MW cogeneration system consisting of one gas turbine and one heat recovery steam generator
- Location: Racine, Wisconsin
- Customer: S.C. Johnson

System Configuration

- One 3.2 MW landfill gas-fired turbine
- Heat recovery steam generator providing steam for process loads

- Supplies 24,900 Volt 3 Phase electricity to power S.C. Johnson plant in parallel with local utility, WE Energies
- Net CO2 reduction of 32,000 tons per year
- Integrated supervisory controls
- SmartView™ remote monitoring and control system
- Landfill gas compression system

SWI Korat - Thailand

This project model may be applicable to large agricultural operations in USAID-served countries and involves the production of methane in tropical and subtropical climates from high-starch effluents from processing plants handling foods such as tapioca, rice and potatoes. The Sanguan Wongse Industries (SWI) Waste-to-Energy project located near Korat, Thailand, produces methane from cassava (tapioca) starch is a high profile and successful case in point. The project is summarized below. However, it must be noted that the agricultural processing component must be sufficiently large and centralized to support such an undertaking, a criterion not often satisfied in most USAID countries. There are, however, certainly opportunities in USAID countries that can be identified through more detailed examination of agro-industrial operations at the country level.

Project Summary:

The Korat Waste To Energy Company (KWTE) is the Project Operating Company (POC). KWTE will implement an Anaerobic Baffled Reactor (ABR) at the largest Thai starch production facility, Sanguan Wongse Industries (SWI) in Korat, central Thailand. The ABR will utilize organic material currently emitted in wastewater to a series of failing facultative ponds. The pond system is failing to aerobically reduce the organic material released, and a number of early ponds are anaerobic in nature, producing vast amounts of biogas methane. The ABR will remove the organic material in the wastewater and hence, reduce the chemical oxygen demand and subsequent fugitive CH_4 emissions. Biogas produced will be used in the SWI facility to dry the wet starch cake to the final dry starch product, a process which currently employs fuel oil. Nearly 8 million liters of fuel oil will be displaced with renewable biogas. Excess biogas will be utilized in generators to produce electricity and displace grid-supplied electricity. Three MW of generation capacity capacity will be installed, with another 1 MW potentially added later. Initially, surplus biogas, where produced, will be flared rather than released to the atmosphere. Where possible, further generator sets may be added, with excess generation exported to the grid when Power Purchase Agreements (PPAs) can be negotiated with the local utility.

This project will be the first of a series on this site, as the facility expands its production of modified starch. Current plans at SWI are to build a large, new facility on the same site to cope with increased demand for modified starch, with the current facility continuing to produce native starch. Wastewaters - and hence organic flows to the ponds - will dramatically increase if no project intervention occurs. However, neither the plans for the new modified starch plant nor the design specifications for an extension of the KWTE Build Own Operate Transfer (BOOT) concession are yet finalized. Therefore, any future elements will be dealt with through an amendment to this baseline or as a new baseline assessed as a separate project activity.

A series of sustainable development benefits are expected from the implementation of KWTE, including:

- The project will act as a clean technology demonstration project, which could be replicated across Thailand and the region;
- It will act as an important capacity building project, nationally and locally, by demonstrating the use of a new financial mechanism for funding renewable energy and waste management activities;
- It increases diversity and security of energy through energy self sufficiency, reducing the import of energy from overseas, which will have a positive effect on Thailand's balance of payment;
- The multiplier effect of this investment is likely to bring additional benefits, such as employment opportunities, particularly in the rural area where the project is located; with an estimated 12 people required to run the project;
- It provides additional value for cassava production, a valuable export commodity for Thailand.
- The project will make use of material currently considered waste because it gives rise to a considerable hazard through the flammable methane gas emitted;
- Technology will be sourced locally where possible and transferred from overseas where required;
- A fund will be established from the cost savings generated to fund the KWTE foundation.

6.1.2 Methane Recovery Project Failures

While most projects that would fit under the M2M program have not been active long enough to be resounding successes (or failures),several projects have been cancelled, for a variety of reasons. Several projects having to do with methane recovery and use, in which the Global Environment Facility (GEF) was a participant and which were cancelled during the period January 1993 to November 2004, are summarized in Table 6.1.

Table 6.1 Methane Recovery Project Cancellations, 1993-2004

Country	Implementing Agency	Project Title	Date Cancelled	Reason
Brazil	The World Bank	Biomass Power Commercial Demonstration	July 2004	Project was expected to start in 2000, however, the original project sponsor, a consortium formed by Electrobras, Companhia Hidro-Elétrica do São Francisco (CHESF), Brasil and Shell of Brazil, with participation of the Ministry of Science and Technology, was dissolved. Efforts continue to identify a new project sponsor, but this will require major changes in sponsorship and revisions to project costs and the financing structure.
Cote d'Ivoire	The World Bank	Cote d'Ivoire Crop Waste Power	November 1994	Discovery of indigenous natural gas resources made the project financially unattractive.
Hungary	The World Bank	Szombathely Co-generation of Heat and Power (CHP)/Biomass Project	February 2002	Volatility of the electric power market and institutional weaknesses were the primary causes of cancellation. The local power distribution company and the district heating company were not able to sign a power purchase agreement. The municipality of Szombathely also failed to commit to financial support and "ownership" of the project.
Hungary	The World Bank	Renewable Energy and Regional Development Project – Szekefehervar Biomass – gas CHP Project	February 2001	The project was cancelled due to (a) a lawsuit between the City of Szekefehervar and the electric distribution company EDAZ, causing delays and lack of strategic investors, (b) reluctance of the City to assume debt financing in absence of strategic investor(s), and (c) the stated desire of the City to proceed with a project of its own design at its own pace.
Nigeria	The World Bank	Escravos Flared Gas Reduction	August 1994	Suspension of all World Bank lending activities in Nigeria.
Pakistan	The World Bank	Waste-to-energy: Lahore Landfill Gas Recovery ad Use	February 1999	Problems with the procedures of land acquisition at the Mehmood Booti landfill site.
Syria	The World Bank	Increasing the Efficiency of the Hydrocarbon Sector by Using Waste Gases	October 2002	Project sponsor did not initiate activities specified under the grant for a period of two years, so the project was cancelled.
Tanzania	United Nations Development Prgramme (UNDP)	Electricity, Fuel and Fertilizer from Municipal and Industrial Waste in Tanzania: a Biogas Plant for Africa	December 1999	Undisclosed implementation difficulties caused all stakeholders to agree to terminate the project.
Ukraine	The World Bank	Coalbed Methane Recovery	March 2001	Required co-financing could not be secured from private investors, nor could a bank loan be secured for the operating mines.

Causes of cancellation vary, but many could have been anticipated by performance of a more rigorous screening assessment of legal issues regarding power purchase agreements, contracts and site or resource ownership, interests of private investors, and commitment or ability of local counterparts to support the projects.

There are few outright failures to cite at present, as the methane collection and use concept, on a large scale in EITs, is a relatively new concept. Several ad hoc smaller scale projects involving collection and anaerobic digestion of livestock wastes have been undertaken. One notable, albeit small scale, failure was in northern Pakistan, where livestock manure was collected for methane generation. However, winter, the season in which methane would have been most useful, was also when methanogenesis came to a near halt due to subfreezing temperatures. Further, the previously dried manure patties were not available as a fuel, and soil quality was compromised by the withdrawl of ashes and manure. The approach has nonetheless worked in a variety of locations around the world, though typically at lower elevations and latitudes.

6.1.3 Reviving Abandoned Methane Recovery Projects

Lake Kivu

The Lake Kivu Methane Project, based on abundant long-known methane in the sediments of Lake Kivu, was originally undertaken by The World Bank. However, to date, only a small power generation plant uses the methane for production of power for a nearby brewery. The project was developed but put on hold, leaving the region to continue to purchase power at very high rates, primarily from the Democratic Republic of Congo.

Recently, USAID funded a reassessment of the project and determined that using smaller scale, barge-mounted extraction systems, methane could be cost-effectively extracted and used for power generation. The proposed smaller scale project, coupled with the newly developed Rwandan Investment Promotion Authority (RIPA) and wholly financed locally, is moving ahead on a pilot scale. Contingent on the demonstration of environmentally friendly extraction technologies, confirmation of the reserve capacity and regeneration rates, and increased power costs and local interests, the World Bank is now apparently prepared to reassess the project for large-scale development.

It must be noted that the linking of methane sources to markets is a highly variable undertaking – and depends on location, local operating environment, energy balances and source-specific dynamics. As such, the best opportunity for USAID to contribute to local and sectoral successes probably lies in supporting the identification of possible linkages, the establishment of public/private partnerships for opportunities of mutual interest, and the performance of complimentary feasibility studies that consider not only technical feasibility, but financial, environmental and social concerns as well.

Based on the research undertaken for development of this document, the following conclusions and recommendations are made.

7.1 PROPOSED INTERVENTIONS, GENERAL

A large fraction of fugitive methane emissions in developing countries are from agricultural and other biological sources, coal beds, biomass fuel burning, and oil and gas production. To manage these, countries need technical assistance in the form of:

- Identifying and developing motivated public sector stakeholders
- Facilitating public-private partnerships and identifying demonstrated and economically viable solutions to match their needs
- Identifying sources which do or may provide methane of sufficient quantity and quality and which are favorably located with respect to potential or existing markets
- Facilitating public-private partnerships and identifying demonstrated and economically viable solutions to match their needs
- Identifying and facilitating financing
- Developing, implementing, and documenting demonstration and pilot projects
- Developing legally enabling legislation and regulations to provide assurance and a hospitable climate for domestic and foreign investors.

The Methane-to-Markets Partnership can help provide for these needs globally by promoting cost-effective, near-term methane recovery internationally through partnerships between developed countries, developing countries, and countries with economies in transition in coordination with the private sector, multilateral development banks, and other relevant non-government organizations. Partnership countries include Argentina, Australia, Brazil, China, Colombia, India, Italy, Japan, Mexico, Nigeria, Russia, Ukraine, the United Kingdom and the United States. The Partnership is expected to improve environmental quality and energy security, reduce greenhouse gas emissions, and enhance energy security and economic growth throughout the world.

Among the partner countries, those that are potential recipients of technology transfer and other assistance in reducing their methane emissions and bringing captured fugitive methane to market are Colombia, India, Mexico, Nigeria, and Ukraine. In the middle, Russia, China, Argentina and

Brazil each have potential to be either sources or recipients of technology transfer, depending on the issue and conditions. For example, Russia is a developer and implementer of small-scale LNG liquefaction and utilization systems; China has implemented a number of coal bed methane recovery projects; Argentina is the world leader in natural gas vehicle fleet development; Brazil has long been a leader is many aspects of biofuels and biomass utilization; and India and China have long histories of successful rural farm and village-level biogas generators fueled by dung and, to a lesser extent, plant waste for the production of cooking gas. However, each of these countries needs assistance in other areas. Australia, Italy, Japan, the United Kingdom and the United States are among the world's leading industrial economies, and are the sources of much relevant technology transfer for M2M.

Beyond the Partnership, there are over eighty other nations, mostly with economies in transition, that receive assistance from USAID. There are also a number of other nations that are sources of relevant technology, including Germany, France, Canada, Korea, Switzerland, the Netherlands, and Norway.

7.2 USAID'S ROLE IN M2M

USAID's experience, in-country presence, and resources can be integrated into the M2M Partnership by providing technical skills, knowledge, and equipment to partner countries, with a special emphasis on encouraging the flow of private investment capital and expertise to developing nations in the area of methane capture and gas market development.

There are several feasible approaches to mobilize private capital and expertise in support of the M2M initiative:

- The Global Development Alliance – This is USAID's public-private partnership program that has stimulated great private sector interest and achieved success in forming over 200 alliances with companies and non-profits to work together in achieving development goals.
- Working to demonstrate and assure economic viability - This has been the basis for the success of methane programs in the United States and includes helping establish a regulatory climate and business environment to attract private sector investment. No energy program can be sustainable if it is not economically viable. The governments in the M2M Partnership can play an important role by creating the proper incentives and policies, which will involve pricing, taxation, rule of law, fighting corruption, and promoting a good investment climate. This will encourage the flow of private investment capital, management skills, and the technology needed for methane capture and utilization.
- Creating sustainable markets for gas producers. - Improving and expanding existing markets and creating new markets is a key priority for the countries involved in the M2M Partnership. In cases where it is feasible to develop methane gas for electricity or gas network supply, the market design and regulatory framework will be important factors influencing an investor's perception of risk. These factors will include not only tariff issues but also questions of non-discriminatory access to the network and

whether suppliers can enter into bilateral contracts with third parties. USAID is working in outheast Europe to implement such a system and create full retail market opening for non-residential electricity and gas customers by 2008 under a legally binding Treaty for all Southeastern European countries (Albania, Bosnia, Bulgaria, Croatia, Macedonia, Romania, Serbia & Montenegro, and UNMIK [Kosovo]). Key to this market development process is establishing both a strong, independent energy regulator and an independent transmission system operator that is separated (unbundled) legally and managerially, if not in ownership, from distribution and supply companies.

7.3 LEVERAGING THE M2M PARTNERSHIP TO MUTUAL BENEFIT

The first Ministerial Meeting of the Methane to Markets Partnership took place in Washington, DC, on November 15-17, 2004. Estimated committed funding by US government is currently $US 53 million over 5 years. Leveraging this commitment can include such strategies as:

- Engaging private sources of capital and technical and market know-how, such as international energy service companies and ESCOs
- Aligning USAID's goals and priorities with those of the USTDA in promoting US technology transfer to the more advanced economies in transition to serve as demonstration projects for meeting M2M goals, whenever possible and relevant.
- Engaging the US National Laboratories with environmental and energy missions, that will provide relevant technologies and evaluate opportunities for technology transfer

7.4 PROPOSED INTERVENTIONS, SPECIFIC

Active participation from the private sector and non-governmental organizations is central to the success of the Partnership. It is anticipated that private and public sector partners will work together in undertaking a variety of activities aimed at advancing methane recovery and use opportunities.

Our assessment of the countries, economic conditions, industrial and agricultural bases, current power generation mix, energy balance (fuels and power generation) and possible markets for methane provide an initial prioritization of opportunities having a higher probability of success.

General comments applicable to the majority of the specific recommendations include:

- Successful M2M projects in countries served by USAID will likely require transfers of technology from more developed countries, including members of the M2M Partnership. Types of projects considered will vary greatly with the economies, natural resources and operating conditions of the USAID-served countries. Technologies employed must be sustainable, locally serviceable, appropriate to the local operating conditions and sensitive to cultural biases.
- Proposed projects must have a solid, acceptable and near-term ROI to attract internal and foreign investment.

- M2M projects in USAID-served countries will be either relatively large scale or small scale. In many instances small-scale projects will be the more likely approach, given the possible sources of methane, energy consumption patterns, and technologies that can be expected to be sustainable in the local economy and operating environment.
- Countries that have lower per capita incomes and lower fossil fuel resources will likely also be more suited to small-scale, agriculture-related M2M projects.
- A systematic approach for identification and evaluation of opportunities must be developed to support USAID in identifying, screening and ranking projects in accordance with USAID's budgetary and geopolitical priorities.
- A highly motivated public and/or private sector is essential.
- Given the variables involved, viable methane recovery projects are likely to be site specific.

Table 7.1 presents the general economic, industrial and agricultural segments, methane sources and market opportunities that emerged from this assessment for Brazil, Colombia, India, Indonesia, Kazakhstan, Mexico, Pakistan, Peru, Russia and Ukraine. The narrative which follows Table 7.1 presents specific sources, sectors and markets that bear further investigation, based on the sources, potential markets, and general economies of the respective countries.

Table 7.1 Methane Source Categories and Opportunities by Country

Country	Electrical Power Supply, by % Total Capacity (1)	Economy (2)	Generalized Potential Demand for Methane, by Sector				
			Heat	Electric Power	Transpor-tation	Synthe-ses	CO_2eq Credits
Brazil	Hydro - 84 Nuclear - 3 Geothermal - 4 Thermal – 9 (primarily oil and gas) Total capacity: 73,600 MW	Possessing large and well-developed agricultural, mining, manufacturing, and service sectors, Brazil's economy outweighs that of all other South American countries and is expanding its presence in world markets. From 2001 to 2003, real wages fell and Brazil's economy grew, on average, only 1.1% per year, as the country absorbed a series of domestic and international economic shocks. That Brazil absorbed these shocks without financial collapse is a tribute to the resiliency of the Brazilian economy and the economic program put in place by former President Cardoso and strengthened by President Lula da Silva. The three pillars of the economic program are a floating exchange rate, an inflation-targeting regime, and tight fiscal policy, which have been reinforced by a series of IMF programs. The currency depreciated sharply in 2001 and 2002, which contributed to a dramatic current account adjustment: in 2003, Brazil ran a record trade surplus and recorded the first current account surplus since 1992. While economic management has been good, there remain important economic vulnerabilities. The most significant are debt-related: the government's largely domestic debt increased steadily from 1994 to 2003, straining government finances, while Brazil's foreign debt (a mix of private and public debt) is large in relation to Brazil's modest (but growing) export base. Another challenge is maintaining economic growth over a period of time to generate employment and make the government debt burden more manageable. Important agricultural products include coffee, soybeans, wheat, rice, corn, sugarcane, cocoa, citrus and beef. Primary industries are textiles, shoes, chemicals, cement, lumber, iron ore, tin, steel, aircraft, motor vehicles and parts, other machinery and equipment	.Space Heating and Cooking Low (temperate to subtropical environment) Some local, small-scale for cooking gas. Industrial Processes Low to Medium, for small applications and centralized processing such as co-firing or anaerobic digestion of sugar cane bagasse	Low Well-established hydroelectric power system and much GT and CCGT fired by indigenous gas and oil	Low Possibility for fueling waste collection vehicles from LFG Gasohol and other alternativ e programs already using biomass.	Variable Other sources of feedstock more readily available	Medium An established "player" in GEF, CO_2eq CER develop-ment and other GHG reduction project programs, primarily in biomass and renewable energy

Country	Electrical Power Supply, by % Total Capacity (1)	Economy (2)	Generalized Potential Demand for Methane, by Sector				
			Heat	Electric Power	Transpor-tation	Synthe-ses	CO_2eq Credits
Colombia	Hydro – 63 Nuclear – 0 Geothermal –0 Thermal – 37 Total capacity: 12,715 MW	Colombia's economy suffers from weak domestic and foreign demand, austere government budgets, and serious internal armed conflict but seems poised for recovery. Other economic problems facing President Uribe range from reforming the pension system to reducing high unemployment. Two of Colombia's leading exports, oil and coffee, face an uncertain future; new exploration is needed to offset declining oil production, while coffee harvests and prices are depressed. On the positive side, several international financial institutions have praised the economic reforms introduced by Uribe, which include measures designed to reduce the public-sector deficit to below 2.5% of GDP in 2004. The government's economic policy and democratic security strategy have engendered a growing sense of confidence in the economy, particularly within the business sector, and GDP growth in 2003 was among the highest in Latin America. Main agricultural products are coffee, cut flowers, bananas, rice, tobacco, corn, sugarcane, cocoa beans, oilseed, vegetables, forest products and shrimp. Primary industries are textiles, food processing, oil, clothing and footwear, beverages, chemicals, and cement, as well as gold, coal, and emerald mining.	Space Heating and Cooking Low (temperate to subtropical environment except at higher elevations) Some local, small-scale for cooking gas Industrial Processes Low to Medium, for small applications and centralized processing such as co-firing or anaerobic digestion of sugar cane bagasse	Low Well-established hydroelectric power system and much indigenous gas and oil	Low Cheap local petroleum products	Variable Other sources of feedstock more readily available	Low Not an established provider of CO_2eq CERs. Contract law and ownership may also make execution of agreements difficult.

Country	Electrical Power Supply, by % Total Capacity (1)	Economy (2)	Generalized Potential Demand for Methane, by Sector				
			Heat	Electric Power	Transpor-tation	Synthe-ses	CO_2eq Credits
India	Hydro – 22 Nuclear – 3 Geothermal - 1 Thermal – 74 Total capacity: 111,777 MW	India's economy encompasses traditional village farming, modern agriculture, handicrafts, a wide range of modern industries, and a multitude of support services. Government controls have been reduced on foreign trade and investment, and privatization of domestic output has proceeded slowly. The economy has posted an excellent average growth rate of 6% since 1990, reducing poverty by about 10 percentage points. India is capitalizing on its large numbers of well-educated, English-speaking people skilled to become a major exporter of software services and software workers. Despite strong growth, the World Bank and others worry about the continuing public-sector budget deficit, running at approximately 60% of GDP. Main aproducts include rice, wheat, oilseed, cotton, jute, tea, sugarcane, potatoes, cattle, water buffalo, sheep, goats, poultry, and fish. Primary industries are textiles, chemicals, food processing, steel, transportation equipment, cement, mining, petroleum, machinery, and software.	Space Heating and Cooking Low (temperate to subtropical environment except at higher elevations) Some local, small-scale for cooking gas. Industrial Processes Medium, for small applications, LFG and centralized processing such as co-firing or anaerobic digestion of sugar cane bagasse	Low to Medium Well-established thermal power system. Good possibilities for distributed generation on and off grid, irrigation and captive generation applications	Medium May find a localized niche in areas already served by CNG for vehicle fueling	Low to Medium Must import most petro-chemical feedstocks	Medium to High Low to medium opportu-nities, but high volume, resulting in large quantity of possible marketable CO_2eq CERs

Country	Electrical Power Supply, by % Total Capacity (1)	Economy (2)	Generalized Potential Demand for Methane, by Sector				
			Heat	Electric Power	Transpor-tation	Synthe-ses	CO_2eq Credits
Indonesia	Hydro – 17 Nuclear – 0 Geothermal –2 Thermal – 81 Total capacity: 25,635 MW	Indonesia, a vast, diverse nation, faces economic development problems stemming from recent acts of terrorism, unequal resource distribution among regions, endemic corruption, lack of reliable legal recourse in contract disputes, weaknesses in the banking system, and a generally poor climate for foreign investment. Indonesia withdrew from its IMF program at the end of 2003 but issued a "White Paper" that commits the government to maintaining fundamentally sound macroeconomic policies previously established under IMF guidelines. Investors, however, continued to face a host of on-the-ground microeconomic problems and an inadequate judicial system. Keys to future growth remain internal reform, assuring the confidence of international and domestic investors, and strong global economic growth. Agricultural products include rice, cassava (tapioca), peanuts, rubber, cocoa, coffee, palm oil, copra (dried white flesh of the coconut, from which coconut oil has been extracted), poultry, beef, pork, and eggs. Primary industries are petroleum and natural gas, textiles, apparel, footwear, mining, cement, chemical fertilizers, plywood, rubber, food, and tourism.	Space Heating and Cooking Low (Subtropical to tropical environment except at higher elevations) Some local, small-scale for cooking gas. Industrial Processes Low to Medium, for small applications and centralized processing such as co-firing or anaerobic digestion of agricultural wastes.	Low Well-established thermal power system and much indigenous gas and oil	Low Cheap local petroleum products, possibly LFG for waste collection and heavy machinery.	Variable Other sources of feedstock more readily available	Low Not an established provider of CO_2eq CERs. Contract law and ownership may also make execution of agreements difficult.

Country	Electrical Power Supply, by % Total Capacity [1]	Economy [2]	Generalized Potential Demand for Methane, by Sector				
			Heat	Electric Power	Transpor-tation	Synthe-ses	CO_2eq Credits
Kazakhstan	Hydro – 13 Nuclear – 0 Geothermal -0 Thermal – 87 Total capacity: 17,220 MW	Kazakhstan possesses enormous fossil fuel reserves as well as plentiful supplies of other minerals and metals. It also is a large agricultural (livestock and grain) producer. Kazakhstan's industrial sector rests on the extraction and processing of these natural resources and also on a growing machine-building sector specializing in construction equipment, tractors, agricultural machinery, and some defense items. The breakup of the USSR in December 1991 and the collapse in demand for Kazakhstan's traditional heavy industry products resulted in a short-term contraction of the economy, with the steepest annual decline occurring in 1994. In 1995-97, the pace of the government program of economic reform and privatization quickened, resulting in a substantial shifting of assets to the private sector. Kazakhstan enjoyed double-digit growth in 2000-01 - and a solid 9.5% in 2002 - thanks largely to its booming energy sector but also to economic reform, good harvests, and foreign investment. The opening of the Caspian Consortium pipeline in 2001, from western Kazakhstan's Tengiz oilfield to the Black Sea, substantially raised export capacity. The country has embarked upon an industrial policy designed to diversify the economy away from overdependence on the oil sector by developing light industry. Additionally, the policy aims to reduce the influence of foreign investment and foreign personnel; the government has engaged in several disputes with foreign oil companies over the terms of production agreements, and tensions continue. Agricultural products include grain (mostly spring wheat), cotton, and livestock. Primary industries are oil, coal, iron ore, manganese, chromite, lead, zinc, copper, titanium, bauxite, gold, silver, phosphates, sulfur, iron and steel, tractors and other agricultural machinery, electric motors, and construction materials.	Space Heating Medium (Temperate to alpine), in more remote and otherwise unserviced areas Industrial Processes Low, for small applications and centralized processing such as co-firing or anaerobic digestion of agricultural wastes	Low Well-established thermal power system and much indigenous gas and oil	Low Cheap local petroleum products	Low Indigenous sources of feedstock available	Low to Medium Not an established provider of CO_2eq CERs. Possibility in area of gas flaring offsets.

Country	Electrical Power Supply, by % Total Capacity (1)	Economy (2)	Generalized Potential Demand for Methane, by Sector				
			Heat	Electric Power	Transpor-tation	Synthe-ses	CO_2eq Credits
Mexico	Hydro – 23 Nuclear – 3 Geothermal -2 Thermal –72 Total capacity: 42,300 MW	Mexico has a free market economy with a mixture of modern and outmoded industry and agriculture, increasingly dominated by the private sector. Recent administrations have expanded competition in seaports, railroads, telecommunications, electricity generation, natural gas distribution, and airports. Agricultural products include corn, wheat, soybeans, rice, beans, cotton, coffee, fruit, tomatoes, beef, poultry, dairy products, and wood products Primary industries are food and beverages, tobacco, chemicals, iron and steel, petroleum, mining, textiles, clothing, motor vehicles, consumer durables, tourism	Space Heating and Cooking Low (Temperate to subtropical environment except at higher elevations) Some local, small-scale for cooking gas. Industrial Processes Low to Medium, for small applications and centralized processing such as cofiring or anaerobic digestion of agricultural wastes.	Low Well-established thermal power system and much indigenous gas and oil	Low Cheap local petroleum products, possibly LFG for waste collection and heavy machinery.	Variable Other sources of feedstock more readily available	Low Becoming an established provider of CO_2eq CERs, along with other countries in Latin America. Contract law and ownership well-established.

Country	Electrical Power Supply, by % Total Capacity (1)	Economy (2)	Generalized Potential Demand for Methane, by Sector				
			Heat	Electric Power	Transpor-tation	Synthe-ses	CO_2eq Credits
Pakistan	Hydro – 34 Nuclear – 3 Geothermal -0 Thermal –63 Total capacity: 17,726 MW	Pakistan, an impoverished and underdeveloped country, has suffered from decades of internal political disputes, low levels of foreign investment, and a costly, ongoing confrontation with neighboring India. However, IMF-approved government policies, bolstered by generous foreign assistance and renewed access to global markets since late 2001, have generated solid macroeconomic recovery. The government has made substantial inroads in macroeconomic reform since 2000, although progress on more politically sensitive reforms has slowed. For example, in the third and final year of its $1.3 billion IMF Poverty Reduction and Growth Facility, Islamabad has continued to require waivers for energy sector reforms. While long-term prospects remain uncertain given Pakistan's low level of development, medium-term prospects for job creation and poverty reduction are the best in nearly a decade. Islamabad has raised development spending from about 2% of GDP in the 1990s to 4% in 2003, a necessary step towards reversing the broad underdevelopment of its social sector. GDP growth is heavily dependent on rain-fed crops, and the end of a four-year drought should support moderate agricultural growth for the next few years. Foreign exchange reserves continued to reach new levels in 2003, supported by robust export growth and steady worker remittances. Primary agricultural products include cotton, wheat, rice, sugarcane, fruits, vegetables, milk, beef, mutton, and eggs. Primary industries are textiles and apparel, food processing, pharmaceuticals, construction materials, paper products, fertilizer, and shrimp.	Space Heating and Cooking Medium (Subtropical to Alpine environment) Much dependence on cooking gas, wood and vegetable matter. Industrial Processes Low to Medium, for small applications and centralized processing such as co-firing or anaerobic digestion of agricultural wastes.	Low Well-established thermal power system, relatively low per capita demand. Some possibilities for distributed generation.	Medium May find a localized niche in areas already served by CNG for vehicle fueling	Low to Medium Must import most petro-chemical feedstocks but not much major chemical synthesis outside of the Karachi area.	Low to Medium Not an established provider of CO_2eq CERs. Contract law and ownership may also make execution of agreements difficult.

Country	Electrical Power Supply, by % Total Capacity [1]	Economy [2]	Generalized Potential Demand for Methane, by Sector				
			Heat	Electric Power	Transpor -tation	Synthe- ses	CO_2eq Credits
Peru	Hydro – 47 Nuclear – 0 Geothermal –0 Thermal –53 Total capacity: 6,070 MW	Peru's economy reflects its varied geography: an arid coastal region, the Andes further inland, and tropical lands bordering Colombia and Brazil. Abundant mineral resources are found in the mountainous areas, and Peru's coastal waters provide excellent fishing grounds. However, overdependence on minerals and metals subjects the economy to fluctuations in world prices, and a lack of infrastructure deters trade and investment. After several years of inconsistent economic performance, the Peruvian economy was one of the fastest growing in Latin America in 2002 and 2003, growing by 5% and 4%, respectively, with a stable exchange rate and annual inflation below 2%. Agricultural products include coffee, cotton, sugarcane, rice, wheat, potatoes, corn, plantains, coca, poultry, beef, dairy products, wool, and fish. Primary industries are mining of metals, petroleum, fishing, textiles, clothing, food processing, cement, auto assembly, steel, shipbuilding, and metal fabrication	Space Heating and Cooking Medium (temperate to Alpine) Some local, small-scale for cooking gas and space heating Industrial Processes Low to Medium, for small applications and centralized processing such as co-firing or anaerobic digestion of sugar cane bagasse	Low Established thermal hydroelectric power system and much indigenous gas and oil	Low Cheap local petroleum products	Variable Other sources of feedstock more readily available	Low Not an established provider of CO_2eq CERs. Contract law and ownership may also make execution of agreements difficult.

Country	Electrical Power Supply, by % Total Capacity [1]	Economy [2]	Generalized Potential Demand for Methane, by Sector				
			Heat	Electric Power	Transpor-tation	Synthe-ses	CO_2eq Credits
Russia	Hydro – 21 Nuclear – 10 Geothermal - 1 Thermal – 68 Total capacity: 204,165 MW	Russia ended 2003 with its fifth straight year of growth, averaging 6.5% annually since the financial crisis of 1998. Although high oil prices and a relatively cheap ruble are important drivers of this economic rebound, since 2000, investment and consumer-driven demand have played a noticeably increasing role. Real fixed capital investments have averaged gains greater than 10% over the last four years, and real personal incomes have averaged increases of over 12%. Russia has also improved its international financial position since the 1998 financial crisis, with its foreign debt declining from 90% of GDP to around 28%. Strong oil export earnings have allowed Russia to increase its foreign reserves from only $12 billion to approximately $80 billion. These achievements, along with a renewed government effort to advance structural reforms, have raised business and investor confidence in Russia's economic prospects. Nevertheless, serious problems persist. Oil, natural gas, metals, and timber account for more than 80% of exports, leaving the country vulnerable to swings in world prices. Russia's manufacturing base is dilapidated and must be replaced or modernized if the country is to achieve broad-based economic growth. Other problems include a weak banking system, a poor business climate that discourages domestic and foreign investors, corruption, local and regional government intervention in the courts, and widespread lack of trust in institutions. In addition, a string of investigations launched against a major Russian oil company, culminating with the arrest of its CEO in the fall of 2003, have raised concerns by some observers that President Putin is granting more influence to forces within his government that desire to reassert state control over the economy. Agricultural products include grain, sugar beets, sunflower seeds, vegetables, fruits, beef, and milk. Primary industries include a complete range of mining and extractive industries producing coal, oil, gas, chemicals, and metals; all forms of machine building, from	Space Heating and Cooking Medium (temperate to Arctic) Some local, small-scale for cooking gas and space heating. Industrial Processes Low to Medium, for small applications and centralized processing such as co-firing or anaerobic digestion of crop residues and wastes. Ample supplies of coal in eastern Russia and oil and gas in western Russia.	Low Established thermal hydroelectric power system and much indigenous gas and oil. Captive and distributed generation from CMM/CBM and otherwise flared gases.	Low Solid supply of fossil fuels and hydroelec tric, and establishe d nuclear power industry.	Variable Other sources of feedstock more readily available	High High potential in gas-flaring and CBM/CMM. Not an established provider of CO_2eq CERs. Contract law and ownership may also make execution of agreements difficult.

Country	Electrical Power Supply, by % Total Capacity [1]	Economy [2]	Generalized Potential Demand for Methane, by Sector				
			Heat	Electric Power	Transpor-tation	Synthe-ses	CO_2eq Credits
		rolling mills to high-performance aircraft and space vehicles, shipbuilding, road and rail transportation equipment, communications equipment, agricultural machinery, tractors, and construction equipment, electric power generating and transmitting equipment, medical and scientific instruments, consumer durables, textiles, foodstuffs, and handicrafts.					
South Africa	Hydro – 1 Nuclear – 4 Geothermal - 0 Thermal – 95 Total capacity: 44,683 MW	South Africa is a middle-income, emerging market with an abundant supply of natural resources, well-developed financial, legal, communications, energy, and transport sectors, a stock exchange that ranks among the 10 largest in the world, and modern infrastructure supporting an efficient distribution of goods to major urban centers throughout the region. However, growth has not been strong enough to lower South Africa's high unemployment rate, and daunting economic problems remain from the apartheid era, especially poverty and lack of economic empowerment among disadvantaged groups. High crime and HIV/AIDS infection rates also deter investment. South African economic policy is fiscally conservative but pragmatic, focusing on targeting inflation and liberalizing trade as means to increasing job growth and household income. Agricultural products include corn, wheat, sugarcane, fruits, vegetables, beef, poultry, mutton, wool, and dairy products. Primary industries are mining (world's largest producer of platinum, gold, and chromium), automobile assembly, metalworking, machinery, textile, iron and steel, chemicals, fertilizer, and foodstuffs.	Space Heating and Cooking Low (temperate to subtropical environment) Some local, small-scale for cooking gas. Industrial Processes Low to Medium, for small applications and centralized processing such as co-firing or anaerobic digestion of sugar cane bagasse	Low Well-established indigenous coal-fired thermal power system	Medium Possibility for fueling waste collection vehicles from LFG, particularly in Cape Town, Durban and Johannes-burg	Variable Other sources of feedstock more readily available	Medium High potential CBM/CMM. Not an established provider of CO_2eq CERs. Contract law and ownership well-established.

Country	Electrical Power Supply, by % Total Capacity (1)	Economy (2)	Generalized Potential Demand for Methane, by Sector				
			Heat	Electric Power	Transpor-tation	Synthe-ses	CO_2eq Credits
Ukraine	Hydro – 9 Nuclear – 24 Geothermal -0 Thermal – 67 Total capacity: 53,710 MW	After Russia, the Ukrainian Republic was far and away the most important economic component of the former Soviet Union, producing about four times the output of the next-ranking republic. Its fertile black soil generated more than one-fourth of Soviet agricultural output, and its farms provided substantial quantities of meat, milk, grain, and vegetables to other republics. Likewise, its diversified heavy industry supplied unique equipment (for example, large diameter pipes) and raw materials to industrial and mining sites (vertical drilling apparatus) in other regions of the former USSR. Ukraine depends on imports of energy, especially natural gas, to meet approximately 85% of its annual energy requirements. Shortly after independence in December 1991, the Ukrainian Government liberalized most prices and erected a legal framework for privatization, but widespread resistance to reform within the government and the legislature soon stalled reform efforts and led to some backtracking. Output by 1999 had fallen to less than 40% of 1991 levels. Loose monetary policies pushed inflation to hyperinflationary levels in late 1993. Ukraine's dependence on Russia for energy supplies and the lack of significant structural reform have made the Ukrainian economy vulnerable to external shocks. Now in his second term, President Kuchma has pledged to reduce the number of government agencies, streamline the regulatory process, create a legal environment to encourage entrepreneurs, and enact a comprehensive tax overhaul. Reforms in the more politically sensitive areas of structural reform and land privatization are still lagging. Outside institutions - particularly the IMF - have encouraged Ukraine to quicken the pace and scope of reforms. GDP in 2000 showed strong export-based growth of 6%, the first growth since independence, and industrial production grew 12.9%. The economy continued to expand in 2001, as real GDP rose 9% and industrial output grew by over 14%. Growth of 4.1% in 2002 was more moderate, in part a reflection of faltering growth in the developed world. In general, growth has been undergirded by	Space Heating and Cooking Medium (temperate environment) Some local, small-scale for cooking gas and space heating Industrial Processes Low to Medium, for small applications and centralized processing such as co-firing or anaerobic digestion of crop waste and residues	Low Well-established indigenous coal-fired thermal power system	Medium Possibility for fueling waste collection vehicles from LFG	Variable Other sources of feedstock more readily available	Medium High potential CBM/CMM. Not an established provider of CO_2eq CERs. Contract law and ownership well-established.

Country	Electrical Power Supply, by % Total Capacity (1)	Economy (2)	Generalized Potential Demand for Methane, by Sector				
			Heat	Electric Power	Transpor-tation	Synthe-ses	CO_2eq Credits
		strong domestic demand, low inflation, and solid consumer and investor confidence. Growth was a sturdy 8.2% in 2003 despite a loss of momentum in needed economic reforms. Agricultural products include grain, sugar beets, sunflower seeds, vegetables, beef, and milk. Primary industries are coal, electric power, ferrous and nonferrous metals, machinery and transport equipment, chemicals, and food processing (especially sugar).					

(1) USDOE Energy Information Agency, "Country Energy Balance, 2001" (2002 for Mexico

(2) CIA World Factbook 2004

7.4.1 Brazil

The best opportunities in Brazil are not in offsetting already abundant hydroelectric energy supplies, but in the provision of thermal energy at the home and agro-industrial levels as well as in distributed generation for local supply of electricity to urban and suburban areas not well served by electric utilities or to areas where synchronization and sale to the grid can be effected on mutually agreeable terms. Opportunities may also exist for sale of gas and power to major industrial concerns, although many of these sorts of projects, modeled on US, European and Australian successes, have already been investigated and/or undertaken by local and international developers. Areas of focus should include:

- Methane as a cooking fuel in remote areas that have sufficient biomass inputs to support anaerobic production of methane;
- Co-firing of boilers in the sugar industry, using bagasse, distributed generation at the facility level, and possibly, development of excess capacity for the sale of power to the grid or to the local distribution system;
- Use of LFG from landfills near or in major urban areas for the purpose of fueling associated heavy machinery and for local generation of power using methane-fired or co-fired diesel generator sets;
- Commercial and institutional considerations are generally favorable.

7.4.2 Colombia

Based on initial assessments, the best opportunities in Colombia appear to be in the areas of:

- Methane as a cooking fuel in remote areas that have sufficient biomass inputs to support anaerobic production of methane;
- Co-firing of boilers in the agricultural industry, using crop wastes and residues, distributed generation at the facility level, and possibly, development of excess capacity for the sale of power to the grid or to the local distribution system.
- Commercial and institutional considerations need to be more fully assessed.

7.4.3 India

Initial assessments indicate that the best opportunities in India are in the areas of:

- Production of methane from LFG at the urban level and from dung and, to a lesser extent, crop residues at the rural level, for use as cooking fuel and to displace the use of destructively collected wood and other plant materials is already well established in India. Opportunities for introduction of a less expensive and/or more efficient system for broader distribution, perhaps at a small scale, may hold promise.
- LFG collection projects are already underway or at various stages of development in India. Engineering expertise and feed stocks for anaerobic digestion are generally abundant. One issue that may put an upper limit on LFG production, however, may be the government requirement for composting of certain organic wastes, which

means that they will not be landfilled. They will, however, produce methane, but at a much lower amount per ton if composted properly (aerobically).

- Co-firing of boilers in the agricultural industry, using crop wastes and residues, distributed generation at the facility level (already common practice in many areas and industries), and possibly, development of excess capacity for the sale of power to the grid or to the local distribution system.
- Commercial and institutional considerations are generally favorable.

7.4.4 Indonesia

- Production of methane from LFG at the urban level and from dung and, to a lesser extent, crop residues at the rural level for use as cooking fuel and to displace the use of destructively collected wood and other plant materials is not as well established as in India. Opportunities for introduction of a less expensive and/or more efficient system for broader distribution, perhaps at a small scale, may hold promise.
- LFG collection projects are already underway or at various stages of development in Indonesia. Engineering expertise and feed stocks for anaerobic digestion are generally abundant. One issue that may put an upper limit on LFG production, however, may be the government requirement that certain organic wastes be composted, which means that they will not be landfilled. They will, however, produce methane, but at a much lower amount per ton if composted properly (aerobically).
- Co-firing of boilers in the agricultural industry, using crop wastes and residues, distributed generation at the facility level, and possibly, development of excess capacity for the sale of power to the grid or to the local distribution system.
- Commercial and institutional considerations need to be more fully assessed.

7.4.5 Kazakhstan

Kazakhstan has an abundant supply of natural gas, which is widely used throughout the country. Based on initial assessments, the best opportunities for linking methane to markets in Kazakhstan are in the areas of:

- Use of LFG or otherwise-flared gas for district heating, cooking, and local power generation or distributed generation.
- Assessing operations and maintainance of natural gas pipelines, compressor stations and distribution networks.
- Commercial and institutional considerations need to be more fully assessed.

7.4.6 Mexico

Initial assessments indicate that the best opportunities in Mexico are in the areas of:

- Methane from LFG and crop residues as a cooking fuel to displace use of destructively collected wood and other plant materials. Engineering expertise and feed stocks for anaerobic digestion are generally abundant.
- LFG presents a major opportunity in the urbanized areas of Mexico, where landfills are well established, and new landfills are being built.
- There is also a growing interest in renewable energy projects in Mexico, including biomass and other forms not addressed in this study (e.g., wind power), which nonetheless result in the desired outcome: a reduction of methane emissions per unit of electrical output.
- Commercial and institutional considerations are generally favorable, except mineral rights.

7.4.7 Pakistan

Pakistan is problematic in that it has few natural resources other than hydroelectric power, agricultural land, and sparse high-grade mineral resources, including copper in the far east, near Sandak and the Iranian border, and assumed and untapped massive deposits of low-grade anthracite, deep below the Thar Desert. Major opportunities at present include:

- Methane from crop residues as a cooking fuel to displace use of destructively collected wood and other plant materials (landfills are not yet common in Pakistan due to low MSW/capita and scavenging from the waste stream).
- As there is a well-established (but underserved) vehicular CNG demand in Pakistan, future development of properly engineered landfills, such as bioreactors, would have a ready market for LFG produced.
- Contract law, legal recourse and uncertain property rights continue to discourage potential foreign investment in Pakistan.

7.4.8 Peru

Based on initial assessments, the best opportunities in Peru appear to be in the areas of:

- Methane as a cooking fuel in remote areas that also have sufficient biomass inputs to support anaerobic production of methane and as an alternative or supplemental source of heat at higher elevations.
- Co-firing of boilers in the agricultural industry, using crop wastes and residues, distributed generation at the facility level, and possibly, development of excess capacity for the sale of power to the grid or to the local distribution system.
- Commercial and institutional considerations need to be more fully assessed.

7.4.9 Russia

Russia, due to its wide range in latitude and longitude and diverse natural resource base, presents a wide range of opportunities, similar to most other major industrial countries having indigenous supply of most necessary fossil, mineral, agricultural and forestry resources. Based on initial assessments, the best opportunities in Russia are in the areas of:

- Flaring for power generation or industrial use of associated gas in gas-producing regions.
- Assessing operations and maintainance of natural gas pipelines, compressor stations and distribution networks.
- Collection and localized use of CBM and CMM in coal-mining regions. This has proven to be problematic given the ambiguities of contract law and establishment of ownership and/or responsibility by the government. Enron, for example, unsuccessfully attempted to develop CBM in the Kuzbass during the mid-1990s and more recently attempted to organize flaring or industrial/power generating use of associated gas.
- Uncertain contract law, legal recourse, property rights and rule of law in general continue to discourage potential foreign investment in Russia.

7.4.10 South Africa

The primary near-term opportunities for collection and marketing of methane in South Africa include:

- Given South Africa's substantial coal resources and the fact that coal is mined primarily underground, CMM and CBM are strong possibilities for methane capture and use. Such use could be for on-site power needs, process heat for coal processing, and/or local distribution or sale to Eskom Enterprises (Pty) Ltd. (the currently restructured, state-owned South African power company) grid.
- Several of the major cities in South Africa are also experiencing problems with increased demand for landfill capacity and present opportunities both in collection of LFG from existing closed cells and in design of new landfill facilities that will optimize LFG output for commercial purposes while providing the double benefit of more rapid subsidence of the landfill (providing additional landfill capacity) and complete control of leachate.
- In the rural areas of South Africa, crop waste and residue as well as livestock manure can be harnessed for production of methane for heating, cooking, and small-scale distributed generation.
- Commercial and institutional considerations are generally favorable. Cost of electricity to the consumer is currently low.

7.4.11 Ukraine

The situation in Ukraine is in many regards similar to that of the industrial, agricultural and coal-producing sectors of Russia in that similar technologies and opportunities for capture and use of CBM and CMM exist. Opportunities for capture and marketing of methane in Ukraine include:

- Improved CMM and CBM extraction (a double benefit could be realized here, as Ukraine also has the highest coal mining mortality rate in the World due, in part, to mine explosions).
- Co-firing of boilers in the agricultural industry, using crop wastes and residues, distributed generation at the facility level, and possibly, development of excess capacity for sale of power to the grid or to the local distribution system.
- Commercial and institutional considerations need to be more fully assessed.

Given this perspective, USAID, other US Government stakeholders, and the Partnership member countries, marshalling their respective resources, can initiate a course of action to develop markets for methane. A key aspect will be developing or identifying champions within the country and those that undertake an intervention. The champions need to have the will, resources, and influence to facilitate commercializing methane. USAID has a distinct advantage with in-country resources (Missions) that can be tapped for specific information to identify likely sectors and specific locations for capturing methane as an energy source. The Missions can also provide a realistic perspective on the policy, legal, regulatory and commercial aspects facing investments. Once this information is obtained, a more focused effort can be developed. An effort that also has an increased probability of success. The private sector will join this initiative provided the returns are commensurate with the risk.

Text of USAID Administrator Andrew Natsios's Presentation at Methane to Markets Ministerial Meeting

Washington, DC
15-17 November 2004

Andrew S. Natsios
Administrator
United States Agency for International Development
Remarks to the Methane to Markets Ministerial
Washington, DC
November 15, 2004

"Sustainable Markets for Methane Gas"

I am pleased to be here today because the Methane to Markets Partnership represents an opportunity to protect the global environment by reducing methane emissions into the atmosphere while providing the clean energy needed to power economic growth in developing countries and countries with economies in transition. As I look out at the audience, I recognize representatives from countries that have a long history of working together with USAID and other U.S. Government agencies on market reforms, particularly in the energy sector. Some of these relationships go back almost 60 years to some of USAID's predecessor agencies, at the time of the Marshall Plan.

The Methane to Markets Partnership will provide technical skills, knowledge, and equipment to partner countries, with a special emphasis on encouraging the flow of private investment capital and expertise to developing nations in the area of methane capture and gas market development.

How can private capital and expertise be mobilized in support of the Methane to Markets initiative? One approach that has stimulated great private sector interest and achieved success at USAID is our public-private partnership program called the Global Development Alliance.

USAID has formed over 200 alliances with companies and non-profits to work together in achieving development goals. I'm very proud to say that on November 1st we awarded our first "Global Development Alliance Excellence Award" to an energy company, "Chevron-Texaco", and their non-profit partners.

When the Council on Environmental Quality asked USAID to participate in the Methane to Markets Partnership, we saw the opportunity to advance several of the Administration's development principles. The first principle, which I've already mentioned, is the importance of involving private sector and non-government participants.

The second principle, which is the basis for our success in methane programs in the United States, is economic viability. That is, establishing a regulatory climate and business environment to attract private sector investment. No energy program is going to be sustainable if it's not economically viable.

This is where the governments in the Methane to Markets Partnership can play an important role. If they create the proper incentives and policies, which will involve pricing, taxation, rule of law, fighting corruption, and promoting a good investment climate, then the flow of private investment capital, management skills, and the technology needed for methane capture and utilization will occur. USAID is already providing assistance in these areas to many of the developing and transition countries in the ministerial.

The third principle is the creation of sustainable markets for gas producers. When President Bush called upon his advisors "to consider [new] approaches to reduce greenhouse gas emissions," he emphasized that ways had to be sought that "tap the power of markets, help realize the promise of technology, and ensure the widest possible global participation." Improving and expanding existing markets and creating new markets is a key priority for the countries involved in the Methane to Markets Partnership.

So, how do we develop and improve markets? In cases where it is feasible to develop methane gas for electricity or gas network supply, the market design and regulatory framework will be important factors influencing an investor's perception of risk. These factors will include not only tariff issues but also questions of non-discriminatory access to the network and whether suppliers can enter into bilateral contracts with third parties.

USAID is working in Southeast Europe to implement such a system and create full retail market opening for non-residential electricity and gas customers by 2008 under a legally-binding Treaty for all Southeast Europe countries [Albania, Bosnia, Bulgaria, Croatia, Macedonia, Romania, Serbia & Montenegro, and UNMIK (Kosovo)]. Keys to this market development process are the establishment of a strong, independent energy regulator and an independent transmission system operator that is separated (unbundled) legally and managerially if not ownership-wise from distribution and supply companies.

As an example of developing new methane markets I'd like to bring up one of USAID's current projects, the West Africa Gas Pipeline, where USAID has partnered with a private sector consortium and the country of Nigeria, plus the three neighboring countries of Benin, Togo, and Ghana. We've already invested about $5 million over 5 years of technical assistance to facilitate this project, including working on the intergovernmental agreements between the countries. This technical assistance effort assisted policymakers, regulators, and private sectors in these countries to create the market conditions that would attract private sector investment to this major project.

Arguably, this project could be considered one of the most important environmental and development projects in Africa today. Three countries, which do not currently have gas reserves or access to natural gas, will have a new energy source when the pipeline is completed. Nigerian gas, currently being flared or vented, and contributing to greenhouse gas emissions without providing any economic benefit, will instead be brought to new markets where it can be used productively for development projects such as power generation. This project, when completed, will reduce over 100 million tons of carbon emissions.

USAID has also had some experience with the capture of methane from coal mining and landfill methane recovery projects. In Ukraine, USAID, working with the US Department of Labor, is spending $1.5 million on an innovative project in capturing methane released during coal mining. Horizontal drilling of up to 1500 meters will be used to drain the maximum methane possible from the coal seams.

Combining this drilling with methane collection techniques will greatly improve mining safety and could provide Ukraine with a new energy resource. However, such technology demonstrations will not be replicated broadly in Ukraine or in any other countries if sustainable markets are not created to provide incentives for the private sector to invest in additional methane recovery projects.

In India and several other countries, USAID has worked on ways to reduce greenhouse gas emissions while improving solid waste management practices. But, before we could proceed with a project we needed to work with the governments to clarify the regulations and ambiguities in institutional responsibilities for solid waste management between various agencies at the local, state, and national levels. Currently we have projects in India underway where methane from solid waste will be used to generate electricity for local users using microturbines.

And in Latin America, the U.S. Government is demonstrating the potential for methane recovery from landfills. USAID, together with two USDOE National Laboratories, evaluated the methane potential of the El Trobal landfill near Guatemala City and determined it could potentially generate as much as 50 Megawatts in electrical power for almost 20 years. USAID and the U.S. Environmental Protection Agency are now drilling 3 wells to test the quality of the recovered methane. An EU company that operates similar projects in Latin America is interested in purchasing the rights to extract the methane for as much as $8 million if the testing is successful. This first project, which might involve only a 1.5 hectare section of the 40 hectare landfill, would generate up to 8 Megawatts of electricity or 25% of the electricity demand of Guatemala City.

The provision of energy services is a capital-intensive business, and over the International Energy Agency estimates that $200 billion will be needed just to supply electricity to 600 million more people by 2015 to meet the Millennium Development Goals. Meeting the Methane to Markets Partnership goal of reducing emissions by 50 million metric tons per year will cost far less, but even the funds needed to accomplish this goal are not available from governments or from official development assistance. Thus, we come back to the urgent need to encourage private capital investments, often in conjunction with groups like export credit agencies and multi-lateral development banks.

We might look at the recent Caspian oil and gas pipeline projects as examples, since these projects involved financing and risk insurance from a number of sources, including commercial banks and shareholders, IFC, EBRD, and export credit agencies from Methane to Markets Partnership countries such as the U.K., Japan, Italy, and the U.S.

So we feel there are many opportunities out there to strengthen markets and thereby foster more opportunities for private sector investment in projects to recover methane and provide energy for economic growth. In fact, USAID's Global Development Alliance program just issued a public call for proposals to encourage the development of just such opportunities. We're looking forward to working with the other countries, private and non-government organizations, and our other U.S. government agencies on achieving the goal of the Methane to Markets Partnership of reducing methane emissions by 50 million metric tons per year by 2015. We hope you find the contacts and information at this ministerial conference useful and that after this meeting we'll jointly develop sound approaches on moving forward.

Preliminary Agenda—
Methane to Markets Ministerial Meeting
Washington, DC

15-17 November 2004

Methane to Markets Ministerial Meeting

15-17 November 2004
Mayflower Hotel
Washington, DC

Preliminary Agenda
Monday, 15 November 2004

07:00 – 09:00 Registration and Continental Breakfast

Public-Private Dialogue on Methane Recovery and Use Opportunities and Issues

09:00 – 09:30 Opening Plenary
Welcoming Remarks
Jim Connaughton, Chairman, White House Council on Environmental Quality

Vision for the Methane to Market Partnership
Steve Johnson, Deputy Administrator, US Environmental Protection Agency

09:30 – 10:30 Science and Policy Perspectives
Methane Science and Policy
Henry D. Jacoby, Co-Director, Joint Program on the Science and Policy of Global Change
Massachusetts Institute of Technology

Global Energy Markets
Marianne Haug, Director
Office of Energy Technology and R&D
International Energy Agency

Overview of Methane Recovery and Use Opportunities
Dina Kruger, Director, Climate Change Division, US Environmental Protection Agency

10:30 – 11:00 Break

11:00 – 12:30 Technical Breakout Sessions (See next page for details)

12:30 – 14:00 Lunch

14:00 – 16:00 Terms of Reference Discussions (closed to public)

14:00 – 16:00 Technical Breakout Sessions (See page 3 for details)

17:00 – 18:30 General Reception

Technical Break Out Session - Monday Morning, 15 November 2004

Track 1 - Coal		Track 2 - Landfill		Track 3 - Oil and Gas	
Start Time	Topic	Start Time	Topic	Start Time	Topic
11:00	Recent Trends in Recovery and Use of Coal Mine Methane: A Global Perspective Ray Pilcher, Raven Ridge Resources	Opportunities for Global Landfill Methane Capture and Use Session Moderator: John Skinner, CEO, Solid Waste Association of North America		11:00	Overview of Oil and Gas Sector Methane Emissions and Potential Projects Roger Fernandez, US EPA, GasSTAR Program
		11:00	Evolution of Global Solid Waste Management N.C. Vasuki, President, International Solid Waste Association		
11:25	Australia - Developing a Diverse CMM Industry including VAM Utilization Cliff Mallet, CSIRO	11:20	Overview of Landfill Methane Capture and Use Technology Greg Vogt, Chair, International Solid Waste Association Working Group on Sanitary Landfill and Vice President, SCS Engineers	11:20	Panel Discussion: Financing and Market Challenges and Opportunities Panel Members: Sascha Djumena, World Bank, Oil and Gas Policy Division Jim Williams, Overseas Private Investment Corporation (invited) Paul Tumminia, Export-Import Bank, US (invited) Daniel Chartier, Emissions Marketing Association (invited) Representative from Global Environment Facility (invited)
11:50	Opportunities and Barriers for CMM Development: A Perspective from Developing Countries and Transition Economies Huang Shengchu, President of the China Coal Information Institute and National Institute of Occupational Safety and Health Oleg Tailakov, President, Coal and Methane Research Center (Uglemetan) – Russia	11:50	US Perspectives on Global Opportunities for Landfill Methane Capture and Use Brian Guzzone, US EPA, Landfill Methane Outreach Program and Alexandria Panehal, US Agency for International Development		
		12:00	Developing Country Perspective on Landfill Gas Recovery and Use Opportunities Sandra Cointreau, Solid Waste Management Advisor, The World Bank		
12:20	Questions and Answers	12:20	Questions and Answers		
12:30	LUNCH				

Technical Break Out Session - Monday Afternoon, 15 November 2004

Track 1 - Coal		Track 2 - Landfill		Track 3 - Oil and Gas	
Start Time	Topic	Start Time	Topic	Start Time	Topic
14:00	Upstream: Design and Operation of Mine Degasification Systems and Integration with Mining Operations Mario Alberto Santillan Gonzales, MIMOSA, Mexico	14:00	Waste Management Industry Perspective on Developing Landfill Methane Recovery Projects Internationally Gary Crawford, Director - Environmental Quality, CGEA ONYX	14:00	Inventory of Methane Emissions and Reduction Opportunities in Russia ; Methane Emissions Estimations from the Russian Gas Transmission Network Vladimir Berdin, National Pollution Abatement Facility (invited)
14:25	Downstream: Technical and Economic Potential for Use of Coal Mine and Abandoned Mine Methane Petro Sporer, Managing Director, G.A.S. Energietechnologie GmbH	14:20	Barriers and Opportunities for Landfill Methane Capture and Use Howard Robinson, Chartered Institute for Wastes Management, UK	14:20	Methane Recovery and Use Opportunities for Natural Gas Transmission Dave Picard, Engineer, Clearstone Engineering, Canada
14:50	Questions and Answers	14:40	Questions and Answers	14:40	Production and Processing: Shell's International Activities to Reduce Methane Emissions Greg Southworth, Shell Americas (invited)
15:00	Panel Discussion: Financing Opportunities and Challenges for Methane Projects Moderator: Karl Schultz, Energy Edge, UK Panel Members: Matt Inamuro, World Bank Carbon Finance Team and Mitsui & Co. Ltd, Japan John Palmisano, Energy & Communications Solutions LLC Speaker to be Announced, UNEE	14:50	Panel Discussion: Project Case Studies and Lessons Learned Panel Topics and Members: Energizing Monterrey: Mexico's First Landfill Methane Energy Project Horacio Terraza, Environmental Specialist The World Bank Landfill Methane Utilization Opportunities in Ukraine Georgiy Geletukha, Director, Scientific Engineering Centre "Biomass" Analysis of Landfill Methane Capture and Use Opportunities in Asia Augustine Koh, Director - Environment Department, Asian Productivity Organization	15:00	Production and Processing: BP's International Activities to Reduce Methane Emissions Reid Smith, BP (invited)
				15:20	Transmission and Distribution: Ukrainian Gas Transmission Compressor Station Methane Emissions Reduction Programs Nalisnyy Mykola, First Deputy Director and Chief Engineer, Cherkasytransgaz (invited)
				15:40	Natural Gas Transmission: TransCanada's Emission Reduction Practices and Experiences in Canada and Russia James Cormack, Advisor, Climate Change (invited)
16:00	ADJOURN				

Methane to Markets Ministerial Meeting

15-17 November 2004
Mayflower Hotel
Washington, DC

Tuesday, 16 November 2004
Ministerial Program

07:30 – 09:00 Continental Breakfast

09:00 – 09:15 Opening of Ministerial Meeting – Welcoming Remarks
Paula J. Dobriansky
Under Secretary, Global Affairs, US Department of State

Spencer Abraham (unconfirmed)
Secretary, US Department of Energy

09:15 – 09:30 Keynote Address
Michael O. Leavitt
Administrator, US Environmental Protection Agency

09:30 – 10:30 Summary and Key Outcomes from Public-Private Dialogue on 15 November

10:30 – 11:00 Break

11:00 – 12:00 Ministerial Statements

Australia	India
Brazil	Italy
CanadaJapan	
China	Mexico
Colombia	Nigeria

12:00 – 14:00 Lunch

14:00 – 14:30 Ministerial Statements

Poland	Ukraine
Russia	United Kingdom
South Africa	United States

14:30 –16:00 Cross-cutting Issues for Project Development

16:00 – 16:30 Terms of Reference Signing Ceremony

17:00 – 19:00 General Reception

19:30 Minister's Dinner

Methane to Markets Ministerial Meeting

15-17 November 2004
Mayflower Hotel
Washington, DC

Wednesday, 17 November 2004
Committee Meetings

07:00 – 08:00	Continental Breakfast
08:00 – 9:00	Meeting of Steering Committee (closed)
9:00 – 10:00	Meetings of Technical Subcommittees (closed)
10:00 – 10:15	Break
10:15 – 12:00	Steering Committee Meeting (closed) Coal Subcommittee Meeting (open) Landfill Subcommittee Meeting (open) Oil and Gas Subcommittee Meeting (open)
12:00 – 13:00	Lunch
13:00 – 15:00	Meeting of Steering Committee (closed) Coal Subcommittee Meeting (open) Landfill Subcommittee Meeting (open) Oil and Gas Subcommittee Meeting (open)
15:00 –16:00	Closing Plenary Steering Committee Chairs and Technical Subcommittee Chairs present summaries and next steps
16:00	Adjourn

USAID Missions

Mission	Person	Email
USAID/Brazil	Alexandre Mancuso and Eduardo Freitas	efreitas@usaid.gov
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Organizations

Organization	Person	Email
AfDB	**Mr. Anoma**	afdb@afdb.org
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GEF	**Zhihong Zhang,** Senior Climate Change Specialist Program Manager, Climate Change Global Environment Facility	zzhang2@thegef.org
World Bank	**Todd Johnson**, Climate Change Program Team Leader	tjohnson@worldbank.org
ADB	**Nessim J Ahmad**, Director, Environmental and Social Safeguard Division **Toru Kubo**, CDM Specialist, RSFI	njahmad@adb.org tkubo@adb.org
Private Sector	**Various – US, Australia, India, South Africa, Europe, Brazil**	N/A

USAID Projects

USAID Region	Country	Agency(ies)	Project Name	Status	Hotlink
Sub-Saharan Africa	Nigeria (Ghana, Benin and Togo)	USAID	West Africa Gas Pipeline Project	Active	http://www.dec.org/search/dexs/index.cfm?fuseaction=order.dexs& DocId=PD-ABX-675&cfid=594041&cftoken=13288328&httpReferer= (USAID DEC ordering link)
Sub-Saharan Africa	Rwanda	USAID, Rwandan Investment Promotion Authority (RIPA)	Lake Kivu Methane Project	Complete	http://www.usaid.gov/regions/afr/success_stories/ rwanda.html#story2
Sub-Saharan Africa	South Africa	USAID, South African Cities Network (SACN)	Methane Emission Reduction Opportunities in Twelve South African Cities	Active	
Latin America & the Caribbean	Brazil	USAID	Characterization of Landfill Sites in Brazil for Landfill Gas Recovery	Complete	http://www.dec.org/search/dexs/index.cfm?fuseaction=docsresults.citation.dexs& Rec_no=92979&cfid=601938&cftoken=32100176&httpReferer=http://www.dec.org/ default.cfm?CFID=601804&CFTOKEN=31893044
Latin America & the Caribbean	Guatemala	USAID	Guatemala City Landfill Gas Recovery and Power Generation Feasibility Study	Complete	http://bioproducts-bioenergy.gov/pdfs/bcota/abstracts/28/z351.pdf
Latin America & the Caribbean	Mexico	USAID	Gas Recovery and Utilization Feasibility Study Prados De La Montana Landfill Mexico City	Complete	http://www.dec.org/search/dexs/index.cfm?fuseaction=docsresults.citationdexs&Rec_no=93029&cfid=602153&cftoken=14737032&httpReferer=http://www. dec.org/default.cfm?CFID=602147&CFTOKEN=38648113
Asia & the Near East	Asia	USAID, United States Asia Environmental Program (US-AEP)	US-AEP the Technology Cooperation Agreement Pilot Project TCAPP & Salem District of Tamil Nadu	Active	http://apocalypse.usaep.org/update/2000/up022100.htm
Asia & the Near East	India	USAID	Greenhouse Gas Pollution Prevention Project – Climate Change Supplement (GEP-CCS)	Active	http://www.dec.org/search/dexs/index.cfm?fuseaction=docsresults.citation.dexs& Rec_no=128372&cfid=602194&cftoken=78313612&httpReferer=http://www. dec.org/default.cfm?CFID=602147&CFTOKEN=38648113

USAID Region	Country	Agency(ies)	Project Name	Status	Hotlink
Asia & the Near East	Morocco	USAID	Conceptual Landfill Design for the Urban Community of Meknes Morocco	Active	http://www.dec.org/search/dexs/index.cfm?fuseaction=docsresults.citation.dexs&Rec_no=88899&cfid=635849&cftoken=67545451&httpReferer=http://www.dec.org/default.cfm?CFID=635806&CFTOKEN=61929002
Europe & Eurasia	Bulgaria	USAID, EcoLinks, Brown, Vence & Associates, Inc.	Landfill Biogas Extraction and Energy Utilization System at the "Bratovo" Landfill in Bourgas, Bulgaria	Complete	http://www.dec.org/pdf_docs/PNADA717.pdf
Europe & Eurasia	Ukraine	USAID	Ukraine: Coal Sector Technical Assistance	Complete	http://www.dec.org/search/dexs/index.cfm?fuseaction=docsresults.citation.dexs&Rec_no=101898&cfid=602388&cftoken=15722793&httpReferer=http://www.dec.org/default.cfm?CFID=602371&CFTOKEN=45721084 = (USAID DEC ordering link) http://www.usaid.gov/pubs/cp2000/eni/ukraine.html
Europe & Eurasia	Ukraine	USAID, EcoLinks, Indaco Air Quality Services, Inc.	Program for Saving Fuel and Energy Resources at Cherkassytransgas	Complete	http://www.dec.org/pdf_docs/PNADA660.pdf

Organizations-Projects

USAID Region	Country	Agency(ies)	Project Name	Status	Hotlink
Sub-Saharan Africa	South Africa	Municipality of Durban, PCFplus	Durban Landfill Gas to Energy Project	Active	http://carbonfinance.org/pcf/router.cfm?Page=Projects&ProjectID =3132
Latin America & the Caribbean	Argentina	Canadian International Development Agency (CIDA)	Institutional Capacity Building for Climate Change and the Development of Sustainable Practices in the Argentine Solid Waste Management Sector	Complete	http://www.acdi-cida.gc.ca/cida_ind.nsf/0/0A34A5CC17A97FBD85256DDC00560756?OpenDocument
Latin America & the Caribbean	Latin America & the Caribbean	Canadian International Development Agency (CIDA), ESMAP (UNDP/World Bank)	Energy from Landfill Gas Project	Active	http://www.acdi-cida.gc.ca/CIDAWEB/webcountry.nsf/vLUDocEn/9B264C4397E1AB6B85256D95004926D6?OpenDocument#17
Latin America & the Caribbean	Mexico	World Bank & GEF	Mexico: Methane Capture and Use (Landfill Demonstration) Project	Active	http://www.gefonline.org/projectDetails.cfm?projID=784
Asia & the Near East	Algeria	Gesellschaft für technische Zusammenarbeit (Gtz), Adelphi Consult	Program for integrated environmental management Algeria	Active	http://www.adelphi-consult.com/#/en/projects/0.html
Asia & the Near East	China	GEF and UNDP	Development of Coalbed Methane Resources in China	Approved	http://www.gefonline.org/projectDetails.cfm?projID=380 http://www.gefweb.org/Outreach/outreach-PUblications/Project_factsheet/China-deve-3-cc-undp-eng-ld.pdf
Asia & the Near East	China	Canadian International Development Agency (CIDA)	Development of China's Coalbed Methane Technology CO2 Sequestration	Active	http://www.acdicida.gc.ca/cida_ind.nsf/vLUAllDocByIDEn/5695CCB3EC3813FA85256DDC00689E64?OpenDocument
Asia & the Near East	China	UNDP & GEF	China: Promoting Methane Recovery and Utilization from Mixed Municipal	Complete	http://www.gefweb.org/COUNCIL/council7/wp/chiname.htm http://www.undp.org/energy/prodocs/rbap/china.htm

USAID Region	Country	Agency(ies)	Project Name	Status	Hotlink
			Refuse		
Asia & the Near East	China	ADB & Shanxi Provincial Government	Coalmine Methane Development Project	In-planning	http://www.adb.org/Documents/ADBBO/LOAN/30403013.ASP
Asia & the Near East	Egypt	Canadian International Development Agency (CIDA)	GHG Inventory and Emission Strategies for Solid Waste Sector in Egypt	Complete	http://www.acdi-cida.gc.ca/cida_ind.nsf/0/6494db221523c4db85256dff00574423?OpenDocument
Asia & the Near East	India	UNDP, GEF, Winrock & Ministry of Environment and Forests (MoEF) – India	The Clean Development Mechanism and Biomethanation	Active	http://www.undp.org/energy/prodocs/rbap/ind02m01.htm http://www.winrockindia.org/clc/cdmhrbp.htm
Asia & the Near East	India	UNDP, UNIDO, Government of India, & GEF	India Coalbed Methane Recovery and Commercial Utilization	Complete	http://www.gefweb.org/Outreach/outreach-PUblications/Project_factsheet/India-coal-3-cc-undp-eng-ld.pdf http://www.unido.org/en/doc/4577
Asia & the Near East	India	PCFplus, Asia Bioenergy India Limited	Municipal Solid Waste Management Project	Active	http://carbonfinance.org/pcf/router.cfm?Page=Projects&ProjectID =3125
Asia & the Near East	Jordan	UNDP, Government of Jordan	Jordan: Reduction of Methane Emissions and Utilization of Municipal Waste for Energy in Amman	Active	http://www.undp.org/energy/prodocs/rbas/jor96g31.htm http://www.undp-jordan.org/undp_in_jordan/project%20documents/Enviroment/ENV3.doc
Asia & the Near East	Palestine	Gesellschaft für technische Zusammenarbeit (Gtz), Solid Waste Management Council Gaza Center, Ministry of Local Government (MoLG), & UNEP	Solid Waste Management in Central Gaza (including construction of landfill site for waste disposal)	Complete	http://www.skat-foundation.org/activities/ws/cwg/pdf/cwg-42.pdf http://www.unep.or.jp/ietc/Publications/TechPublications/TechPub-17/palestine1.asp
Asia & the Near East	Palestine	Gesellschaft für technische Zusammenarbeit (Gtz), Solid Waste Management	Solid Waste Management in Northern Gaza (including construction of landfill site for	Active	

USAID Region	Country	Agency(ies)	Project Name	Status	Hotlink
		Council Gaza Center, MoLG	waste disposal)		
Asia & the Near East	Pakistan	Japan International Cooperation Agency, Quetta Municipal Corporation (QMC)	Project for Improvement of Environmental Conditions in Quetta City	Complete	http://www.jica.go.jp/english/evaluation/report/expost/14-4-47.html
Asia & the Near East	Pakistan	Japan International Cooperation Agency, Rawalpindi Municipal Corporation	Project for Improvement of Garbage Collection and Disposal in Rawalpindi City	Complete	http://www.jica.go.jp/english/evaluation/report/expost/14-4-45.html
Asia & the Near East	Vietnam	PCFplus, Ho Chi Minh City municipal government, Grontmij Climate & Energy	Grontmij Landfill in Ho Chi Minh Project	In-planning	http://carbonfinance.org/pcf/router.cfm?Page=Projects&ProjectID =3144
Europe & Eurasia	Bulgaria	Performed by Biomass Technology Group, Financing by PCFplus	Methane and Nitrous Oxide Emissions from Biomass Waste Stockpiles	Complete	http://www.btgworld.com/references/pdf/leaflet-bulgaria-ch4.pdf
Europe & Eurasia	Bulgaria	Performed by Biomass Technology Group, Financing by PCFplus	Monitoring Methane and Nitrous Oxide Emissions from Biomass Waste Stockpiles	Complete	http://carbonfinance.org/pcf/router.cfm?Page=Projects&ProjectID =3118 http://www.btgworld.com/references/pdf/leaflet-bulgaria-ch4-monitoring.pdf
Europe & Eurasia	Latvia	PCFplus, Government of Latvia, World Bank Loan	Liepaja Solid Waste Management Project	Active	http://carbonfinance.org/pcf/router.cfm?Page=Projects&ProjectID =3105
Europe & Eurasia	Russia	UNDP & GEF	Removing Barriers to Coal Mine Methane Recovery and Utilization	Active	http://www.undp.ru/index.phtml?iso=RU&lid=1&cmd=programs&id=22 http://www.gefweb.org/Documents/Council_Documents/GEF_C20/CC_-_Russian_Federation_-_Removing_Barriers.pdf
Europe & Eurasia	Ukraine	World Bank & GEF	Coalbed Methane Recovery	Cancelled	http://www.gefonline.org/projectDetails.cfm?projID=450

USAID Region	Country(ies)	Agency(ies)	Project Type	Project Name, Timeframe and Link	Funding Level or Value	Status
Sub-Saharan Africa	Nigeria (Ghana, Benin and Togo)	USAID	TA	West Africa Gas Pipeline Project, 2000-present http://www.dec.org/search/dexs/index.cfm?fuseaction=order.dexs&DocId=PD-ABX-675&cfid=594041&cftoken=13288328&httpReferer= (USAID DEC ordering link)	$US 4.9 million	Active

Summary

Gas flaring in Nigeria's Delta Region is a major environmental problem and research by ecologists suggests that routine flaring of gas has stunted plant growth and reduced crop yields in the region. The reason the gas is flared is because it is produced in association with oil production and collection is cost-prohibitive without a ready market. The only markets at present are Nigeria's power plants and an LNG export facility. The West Africa Gas Pipeline project, to which USAID has provided technical assistance, will find a market for Nigeria's gas. The nearly 1,000-kilometre long gas pipeline that will stretch across West Africa will run from Nigeria's Escravos oil field, where it will capture gas flared by Chevron, to Ghana. It will also provide gas to Benin and Togo. The major positive environmental impact of WAGP will be the development and use of gas currently flared in Nigeria. Cleaner-burning gas supplied by the WAGP will replace petroleum products used in the generation of electricity. (2000-present); $4.9 million

Contact

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USAID Region	Country(ies)	Agency(ies)	Project Type	Project Name, Timeframe and Link	Funding Level or Value	Status
Sub-Saharan Africa	Rwanda	USAID, Rwandan Investment Promotion Authority (RIPA)	TA	Lake Kivu Methane Project 2001-2004 http://www.usaid.gov/regions/afr/success_stories/rwanda.html#story2		Complete

Summary

USAID's review of Rwanda's Oil & Gas law enabled the development of the Lake Kivu methane gas resource. Lake Kivu's waters harbor billions of cubic liters of unexploited methane gas. The existence of the methane has been known for over 50 years but aside from one tiny pilot electricity generating plant that provides some of the power for a nearby brewery, the potential of the lake to provide power has gone unrealized. What little power there is now in the region is very expensive and being generated primarily by hydroelectricity, much of it imported from the DRC. Economic growth of the region, Rwanda's breadbasket, is being seriously constrained by the lack of affordable power. Interest in exploiting the methane gas in the lake has waxed and waned, but a World Bank study completed last year injected new enthusiasm into efforts to tap its potential.

Working with the newly created Rwandan Investment Promotion Authority (RIPA), USAID asked an expert to take another look at state-of-the-art, environmentally friendly alternatives for exploiting the huge reserves of methane. He corroborated that the gas is produced by a bacteria that keeps renewing the reserves. Once it was determined that the gas can be safely exploited without endangering the environment, the expert recommended that the most practical and financially viable method of extracting the gas was to use swimming pool sized barge mounted floating modules. Each module could extract 12.5 cubic meters of gas and turn it into 2.5 MW of electricity, which can then be "wheeled" onto the existing power grid system in the region. A pilot project could be completed for less than $5 million in two years, and if successful could be replicated many times over cookie cutter style to generate enough power for the entire region. This is far less costly and much quicker than waiting for the large scale World Bank financed project originally envisioned by the experts. Most exciting of all was his conclusion that the entire pilot program could be financed by the Rwandan private sector.

Rwanda's private sector is still in its infancy. There are a mere handful of manufacturing and service firms of any appreciable size. However, the Rwandan Investment Promotion Authority (whose director is former USAID Foreign Service National Bonaventure Nyabizi) pursued the concept, shopped the idea around and soon found several entrepreneurs willing to take a risk and put up about $500,000 of completely domestic capital to get the project going. The investors include the brewery, a textile plant, an insurance company, and a bank. In February 2001, just six months after the idea was floated, the Gisenyi Gas and Electric Company was born-the country's first independent power producer.

RIPA Director Bonaventure and his colleagues at the Ministry of Energy and Natural Resources hope that within two years time, the lake area, gateway to the world famous mountain gorilla park, will have a wholly new source of environmentally friendly cheap energy to boost tourism, industry, and commerce throughout the region.

Contact

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USAID Region	Country(ies)	Agency(ies)	Project Type	Project Name, Timeframe and Link	Funding Level or Value	Status
Sub-Saharan Africa	South Africa	USAID, South African Cities Network (SACN)	TA	Methane Emission Reduction Opportunities in Twelve South African Cities, 2004	$58,000	Active

Summary

Palmer Development Group was appointed by the South African Cities Network (SACN) and the United States Agency for International Development (USAID to undertake an investigation into the possibilities for methane emission reductions at the municipal level in South Africa. Certain municipal services, primarily waste-water treatment and solid waste disposal generate significant amounts of methane gas, which enter the atmosphere.

This project is aimed at evaluating the potential that methane reduction offers as a new resource for South African municipalities. The project investigated methane emission reduction and use opportunities in the nine SACN cities, as well as Richards Bay, Polokwane and Nelspruit. This was supported by an investigation into the financial and institutional options available to municipalities in developing methane reduction projects.

The objectives of the project are to identify, and quantify where possible, current methane emissions from municipal facilities in the twelve selected cities. Further objectives are to identify the possibilities for emission reductions, particularly the productive use of the methane as an energy source.

The project also provides an evaluation of the role that the sale of carbon credits, under the clean development mechanism (CDM) of the Kyoto Protocol or in other forms, can play in supporting identified methane reduction projects.

Methane, historically viewed simply as a hazardous waste gas, has the potential to be a new resource for South African municipalities. It is an important objective of the project to demonstrate the new opportunities made available to municipalities by carbon finance and the scope that municipalities have to simultaneously meet domestic environmental and energy targets and benefit financially under the emerging global emissions trading regime.

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USAID Region	Country(ies)	Agency(ies)	Project Type	Project Name, Timeframe and Link	Funding Level or Value	Status
Latin America & the Caribbean	Brazil	USAID	Study	Characterization of Landfill Sites in Brazil for Landfill Gas Recovery, 1997 http://www.dec.org/search/dexs/index.cfm?fuseaction=docsresults.citation.dexs& Rec_no=92979&cfid=601938&cftoken=32100176&httpReferer=http://www.dec.org/ default.cfm?CFID=601804&CFTOKEN=31893044 = (USAID DEC ordering link)	$150,000	Complete

Summary

In December 1996, as part of the Energy Technology Innovation Project (ETIP), at team of U.S. and Brazilian experts assembled to selected and visit key landfill sites throughout Brazil which offer the greatest promise for (i) accruing environmental health and safety benefits, and (ii) the commercial scale recovery and utilization of LFG. The team visited Brazil during the first two weeks of December and conducted site assessments at thirteen major landfill sites in Brazil. In addition, members of the team also visited several state, municipal, and federal government officials and held discussions on policy, financial, and institutional issues linked to a more effective management of the country's landfill sites and the recovery and sale of LFG.

The study objectives were to (i) identify and characterize candidate landfill sites that are representative of major population centers and high secondary growth area in Brazil, (ii) identify commercial potential, potential markets, and economic benefits of LFG recovery and utilization, (iii) develop options for private participation in this sector, thereby reducing the burden on the cities and municipalities, increasing efficiency, and generating employment, and (iv) identify policy and institutional barriers and make recommendations for policy and institutional changes that will facilitate LFG recovery and commercial utilization.

Based on visits to the thirteen landfill sites, discussions with senior federal, state, and municipal government officials in Brazil, and a review of the pattern of assistance offered by international donors and lenders, the Energy Technology Innovation Project (ETIP) team concluded that municipal solid waste management sector in Brazil requires considerable attention by all parties and represents and opportunity for not only significant environmental benefits but also attractive economic and commercial opportunities.

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USAID Region	Country(ies)	Agency(ies)	Project Type	Project Name, Timeframe and Link	Funding Level or Value	Status
Latin America & the Caribbean	Guatemala	USAID	FeS	*Guatemala City Landfill Gas Recovery and Power Generation Feasibility Study* 1998 – 2000 http://bioproducts-bioenergy.gov/pdfs/bcota/abstracts/28/z351.pdf	$150,000	Complete

Summary

Guatemala City's El Trebol landfill emits significant quantities of methane, a potent GHG, as well as other noxious gases. The El Trebol landfill consists of a large, existing, unmanaged landfill that does not meet current sanitary landfill design standards and a new managed landfill that is under development. A techno-economic feasibility study was conducted aimed at capturing the methane from the existing landfill, after closure, and on the new landfill generating electricity to the local grid. The feasibility study included the following tasks:

- Studying design options to close the existing landfill and recover methane from the closed landfill and the new managed landfill to maximize gas production;
- Evaluating the economics of generating power using reciprocating engines, gas turbines, and fuel cell technologies against market electricity prices; and
- Assisting the municipality with developing a Program Opportunity Notice to attract private investors.

The completed feasibility study showed that 9.2 MW of power could be generated economically using simple-cycle gas turbines. Support was also provided to the municipality in developing a Program Opportunity Notice for attracting private investors to the project. In addition USAID supported the municipality's participation in the U.S. Trade and Development's Power & Energy in the Americas Conference (October 23-25, 2000, Houston, Texas) to attract investors to the project. If successfully developed, the project will serve as a model for replication throughout the Latin America and Caribbean region.

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USAID Region	Country(ies)	Agency(ies)	Project Type	Project Name, Timeframe and Link	Funding Level or Value	Status
Latin America & the Caribbean	Mexico	USAID	FeS	Gas Recovery and Utilization Feasibility Study Prados De La Montana Landfill Mexico City, Mexico, 1997 http://www.dec.org/search/dexs/index.cfm?fuseaction=docsresults.citationdex s&Rec_no=93029&cfid=602153&cftoken=14737032&httpReferer=http://www. dec.org/default.cfm?CFID=602147&CFTOKEN=38648113 = (USAID DEC ordering link)	$85,000	Complete

Summary

The Departamento del Distrito Federal (DDF), the authority responsible for waste disposal in Mexico City, requested USAID/Mexico's technical assistance in performing a prefeasibility study for recovery and use of methane from landfill gas (LFG) for power generation at the Prados de la Montana Landfill in Mexico City, Mexico (Site). In response to this request, the Center for Environment's Energy Technology Project (ETIP) was called upon to assist the DDF. As part of its technical assistance to DDF, ETIP designed and implemented an initial landfill gas (LFG) recovery investigation at the Prados de la Montana Landfill. The purpose of the investigation was to assess the Site's LFG quality and potential generation and recovery rates.

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USAID Region	Country (ies)	Agency(ies)	Project Type	Project Name, Timeframe and Link	Funding Level or Value	Status
Asia & the Near East	Asia	USAID, United States Asia Environmental Program (US-AEP)	TA	US-AEP the Technology Cooperation Agreement Pilot Project TCAPP & Salem District of Tamil Nadu, 1992-present http://apocalypse.usaep.org/update/2000/up022100.htm		Active

Summary

Formed in 1992, the United States-Asia Environmental Partnership (US-AEP) is a public-private initiative implemented by several U.S. government agencies under the leadership of USAID. US-AEP works with a wide array of partners—governments, non-governmental organizations, academia, and the private sector—to provide Asia with the tools it needs for cleaner and more efficient cities and industries. The bulk of US-AEP efforts to mitigate emissions of greenhouse gases (GHGs) focus on resource efficiency in the industrial and urban sectors. Improving the efficiency with which a society makes use of its resources means that for each product or service a society produces to advance itself, it depletes fewer of the resources needed for current and future generations and emits fewer pollutants, including GHGs. It is from this economic and public health perspective that Asian entities work with US-AEP to improve the efficiency with which they use resources such as fossil fuels, heat, electricity, materials for manufacturing, natural resources, water, and waste. Examples of US-AEP activities that focus on the mitigation of methane emissions follow:

- In 2001, U.S. and Korean teams defined specific opportunities to advance the market development for methane recovery from municipal waste and low temperature heat recovery using heat pumps. This particular USAEP activity was part of a larger U.S. Government effort, called the Technology Cooperation Agreement Pilot Project (TCAPP), to test a model by which the U.S. can meet its commitments on technology transfer under the U.N. Framework Convention on Climate Change (UNFCCC). Implemented in six countries by the National Renewable Energy Lab (NREL), the USAEP program in South Korea has been by far the most successful. The Korean partners chose two areas on which to focus: energy management and the capture of methane from landfills. For the landfill methane component, TCAPP engaged the expertise of the USEPA's Landfill Methane Outreach Program (LMOP). Working with LMOP, TCAPP brokered two partnerships of U.S. and Korean companies to do methane recovery projects in the cities of Taegu and Ulsan, and a third site in Cheong-Ju. Furthermore, a pilot project was identified for methane gas recovery in the city of Taegu with a Korean company, and several U.S. ESCOs (particularly Duke Engineering) expressed interest in assisting in the project.
- The USAEP office in Chennai, India generated interest on the part of starch manufacturing facilities in the Salem District of Tamil Nadu for the recovery of methane emissions from their effluents. (Sago is processed from the roots of tapioca, a major agricultural crop of the Salem District.) The New Jersey Institute of Technology (NJIT) conducted a feasibility study, which found that manufacturing facilities in Salem, which number over 800, produce enough methane to generate about 80 MW of power. Thus, NJIT recommended a process that will not only treat the wastewater but also recover energy from the effluents in the form of methane gas. Based on NJIT's recommendation, the Salem Chamber of Commerce and Industry (SCCI) implemented a demonstration project in partnership with one of the local Sago industries, demonstrating the generation of energy from methane emissions to the local industries, public and the media. The SCCI pilot project was given the 1999 "Energy Project of the Year-International" award from the Association of Energy Engineers (AEE), the first Indian organization to receive the award. (AEE is the world's largest international association of energy and environmental professionals). Inspired by this success, the Tamil Nadu Energy Development Agency (TEDA) invited public bids for the construction of a 0.2 MW biomethanation plant (estimated at $720,000) for energy recovery from starch effluents. This plant was commissioned in 2001.

Other US-AEP methane-related activities included a study tour for the Asia Region, which provided training in recycling, source reduction, materials recovery, and methane recovery from landfills.

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USAID Region	Country(ies)	Agency(ies)	Project Type	Project Name, Timeframe and Link	Funding Level or Value	Status
Asia & the Near East	India	USAID	TA	Greenhouse Gas Pollution Prevention Project – Climate Change Supplement (GEP-CCS), 1999-March 2005 http://www.dec.org/search/dexs/index.cfm?fuseaction=docsresults.citation.dexs&Rec_no=128372&cfid=602194&cftoken=78313612&httpReferer=http://www.dec.org/default.cfm?CFID=602147&CFTOKEN=38648113	$39 million ($19 m for GEP and $20 m for CCS)	Active

Summary

The Greenhouse Gas Pollution Prevention Project – Climate Change Supplement (GEP-CCS) was initiated in May 2000. Funded by USAID/India, the project is being implemented by the Louis Berger Group Inc. (LBG) Global Environment Team. The main purpose of the project is to provide technical assistance to build capacity and facilitate demonstration projects that result in the reduction of greenhouse gas (GHG) emissions. The project has six components covering the emissions reduction initiatives in various sectors including industry, utilities, transport, and municipal solid waste management.

Under CLIN 8, the GEP-CCS project linked urban development and the rate of growth of greenhouse gas emissions with a focus on methane emissions and the re-use potential in cities.

In Agra under the Clean Technology Initiative program Louis Berger Group (LBG) took the lead to demonstrate the potential of utilizing methane as a fuel from a bio-methanation plant using bio-degradable waste. The half-ton per day, demonstration project uses péthä[1] waste to generate methane gas, which is used as fuel for cooking purposes by the péthä manufacturer.

After data gathering and discussions with petha manufacturers and the municipal corporation, USAID helped to set up a waste disposal effort. The effort, as a by-product, generates clean-burning methane gas to be used in place of coal. The pilot bio-methanation plant that is a result of a collaboration with local government, Panchi Petha Stores and Mailhem Engineers Pvt. Ltd. of Pune. They have developed an indigenous technology for processing of similar food waste materials. The plant was installed in May 2004. Trials have shown environmentally sound disposal of petha waste with concurrent biogas generation and utilization. Based on these results, it is likely that other petha manufacturers will install similar plants, or the municipal corporation will set up a community-scaled plant to handle 35 tons of waste per day, with private sector collaboration. USAID is facilitating negotiations with potential private sector partners to structure such an arrangement.

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[1] A fruit from which a sweet with the same name is made in Agra

USAID Region	Country(ies)	Agency(ies)	Project Type	Project Name, Timeframe and Link	Funding Level or Value	Status
Asia & the Near East	Morocco	USAID	FS	Conceptual Landfill Design for the Urban Community of Meknes Morocco, 1995 http://www.dec.org/search/dexs/index.cfm?fuseaction=docsresults.citation. dexs&Rec_no=88899&cfid=635849&cftoken=67545451&httpReferer=http:/ /www.dec.org/default.cfm?CFID=635806&CFTOKEN=61929002	Value$217, 892.46	Active

Summary

The preliminary Assessment of Solid Waste Management Systems, completed in July 1995, identified significant problems in the subject cities of Meknes, Azrou and Sefrou. These problems included technical issues dealing with collection and disposal as well as institutional and financial problems associated with improved waste management services. Action plans were prepared for each city that summarized the technical assistance team's recommendations. Of all the problems encountered in the three cities, the Meknes landfill was considered the most severe. The Meknes action plan recommended an interim program for landfill closure and sitting of a new long-term landfill. The City responded to these recommendations in a timely manner and located an interim landfill site and completed a review of potential new sites. The interim landfill plan proposed by the City provided an estimated 12 months of additional landfill capacity, while providing sufficient final cover soil for both the existing and interim areas.

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USAID Region	Country(ies)	Agency(ies)	Project Type	Project Name, Timeframe and Link	Funding Level or Value	Status
Europe & Eurasia	Bulgaria	USAID, EcoLinks, Brown, Vence & Associates, Inc.	TA	Landfill Biogas Extraction and Energy Utilization System at the “Bratovo” Landfill in Bourgas, Bulgaria, January 2000 – March 2001 http://www.dec.org/pdf_docs/PNADA717.pdf	Total Project Investment: $67,000; Ecolinks Grant Support: $43,000; Project Team Cost Share Contribution: $24,000	Complete

Summary

The Municipality of Bourgas, which includes the fourth largest city in Bulgaria, operates of the few sanitary landfills in the nation. Due to the decomposition of biological waste, the landfill produces landfill biogas (LBG). The biogas emitted from the Bravoto landfill is in sufficient quantities to create health, safety, and environmental problems. Decomposing biological material at Bravoto Landfill emits carbon dioxide, hydrogen, and high levels of methane directly into the atmosphere. One of the outcomes of this study revealed that the total methane production for the year 2000 at the Bravoto Landfill was approximately 2.4 million cubic meters.

With the support of an EcoLinks Challenge Grant, the Municipality of Bourgas and an US consulting form, Brown, Vence & Associates, Inc., collaborated to conduct an assessment of Bravoto landfill biogas emissions and review options for capturing the biogas or converting it into a useable energy resource. Implementation of a landfill biogas system would reduce methane emissions buy 17,300-29,400 tons over a period of 20 years. In addition, the capture and conversion of biogas allows the Bravoto landfill to turn biogas into a useable energy resource and to generate revenue from energy sales.

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USAID Region	Country(ies)	Agency(ies)	Project Type	Project Name, Timeframe and Link	Funding Level or Value	Status
Europe & Eurasia	Ukraine	USAID	TA	Ukraine: Coal Sector Technical Assistance1998-2003 http://www.dec.org/search/dexs/index.cfm?fuseaction=docsresults.citation.dexs& Rec_no=101898&cfid=602388&cftoken=15722793& httpReferer=http://www.dec.org/ default.cfm?CFID=602371&CFTOKEN=45721084 = (USAID DEC ordering link) http://www.usaid.gov/pubs/cp2000/eni/ukraine.html		Complete

Summary

USAID played a lead role in promoting health and safety awareness and practices regarding methane gas risks. USAID is promoting the development of coal-bed methane (CBM) as a commercially-viable alternative source of energy. To that end, USAID has identified the key legislative and regulatory issues affecting commercial exploitation of CBM (which has been treated in the past as a hazardous by-product of coal mining with no commercial value). USAID collaborated with the Government of Ukraine in the creation of the Alternative Fuel Center to coordinate CBM activities, including information dissemination on CBM to assist private domestic and foreign interests in securing investment opportunities.

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USAID Region	Country(ies)	Agency(ies)	Project Type	Project Name, Timeframe and Link	Funding Level or Value	Status
Europe & Eurasia	Ukraine	USAID, EcoLinks, Indaco Air Quality Services, Inc.	TA	Program for Saving Fuel and Energy Resources at Cherkassytransgas, March 2002-February 2003 http://www.dec.org/pdf_docs/PNADA660.pdf	Total EcoLinks Project Investment: $83,328 EcoLinks Grant Support: $49,976 Project Team Cost-share Contribution: $33,352	Complete

Summary

The project "Reducing Methane Gas Leaks at Cherkassytransgas" is an EcoLinks Best Practice. Through this Ecolinks funded project one of Ukraine's largest natural gas transmission companies teamed with Indaco Air Quality Services (USA) to develop and implement a methane gas leak mitigation program for Cherkassytransgas gas compressor stations. Measurements taken after project implementation and repair works at two selected Cherkassytransgas compressor stations demonstrated that gas leaks were reduced by 1,953,900 m3/year, resulting in an annual savings of $80,000. Environmental fees were also significantly reduced. These savings will multiply as Cherkasytransgas expands the leak mitigation program to all of its 23 compressor stations during the coming year.

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USAID Region	Country(ies)	Agency(ies)	Project Type	Project Name, Timeframe and Link	Funding Level or Value	Status
Sub Saharan Africa	South Africa	Municipality of Durban, PCFplus	TA	Durban Landfill Gas to Energy Project, 2002-2017 or 2022http://carbonfinance.org/pcf/router.cfm?Page=Projects&ProjectID =3132	Total cost $53,077,600	Active

Summary

The Durban Landfill Gas to Energy project consists of an enhanced collection of landfill gas at three landfill sites in eThekwini Municipality and the use of some of the recovered gas to produce electricity. The electricity produced will be fed into the municipal grid and replace electricity that the municipal electricity company is buying from other suppliers. Currently, the Mariannhill and the Bisasar Road landfills collect and flare a portion of the methane generated for local, site-specific reasons. The third landfill site, La Mercy, which is located far away from residential areas, only has passive venting in place to ensure that the concentration of landfill gas does not reach hazardous levels. The proposed project will substantially upgrade the current low efficiency of the partial collection system currently in place, rising to about 80% collection efficiency at the peak in 2012, and then progressively dropping over the long-term.

The PCF will purchase 3.8 million tons of Carbon Dioxide equivalent (CO_2e) from the project at a price of US$3.75 per t/$CO_2e$. An additional 20 cents per t/CO_2e will be paid into a Carbon Credit Community Fund, to be designed in consultation with the local communities. This payment is conditional upon approval of the design and implementation of the Community Fund.

The project will be implemented by Durban Solid Waste (DSW), which is the municipal solid waste department of eThekwini Municipality. The electricity produced from the landfill gas will be sold to the municipal electricity department, eThekwini Electricity. Power purchase discussions have been initiated between DSW and eThekwini Electricity with no technical hurdles identified. eThekwini Electricity purchases its electricity primarily from Eskom, the national electricity utility company.

The proposed project comprises the installation of approximately 180 production wells for landfill gas extraction at the three landfill sites. While some of the wells will be put in place at project start, other wells will be added later on as the landfills' working surface expands. Adequate flare capacity would also be installed while waiting on engine-generator delivery and installation. Also, with the exhaustion of older wells new wells have to be added to ensure a sufficient amount of gas for electricity production. The wells will be spread throughout the whole landfill site and be located especially at the deepest parts of the landfills where the greatest amount of methane can be expected. Besides the gas extraction purpose, the wells will also be equipped for leachate removal. The project further involves the installation of a total capacity of around 10 MW gas-fired electricity generators (spark-ignition piston engine generators) over time, which will be located in units of 1 MW at all three sites. At an 85% annual capacity factor a maximum of 74.5 GWh per year will be delivered to the grid.

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USAID Region	Country(ies)	Agency(ies)	Project Type	Project Name, Timeframe and Link	Funding Level or Value	Status
Latin America & the Caribbean	Argentina	Canadian International Development Agency (CIDA)	Demo	Institutional Capacity Building for Climate Change and the Development of Sustainable Practices in the Argentine Solid Waste Management Sector, 3/12/2002 – 3/31/2004 http://www.acdi-cida.gc.ca/cida_ind.nsf/0/0A34A5CC17A97FBD85256DDC00560756?OpenDocument	Canada Climate Change Development Fund Contribution: $1,985,000	Complete

Summary

The goal of the project is to strengthen Argentina's institutional and technical capacity under the Clean Development Mechanism (CDM). A "Demonstration Bio-cell Bio-reactor" will be built and operated. Specific capacity-building activities and tools will improve abatement of greenhouse gas emissions from municipal landfills in Argentina. The project will develop an extensive capacity building program based on Canadian technology and know-how.

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USAID Region	Country(ies)	Agency(ies)	Project Type	Project Name, Timeframe and Link	Funding Level or Value	Status
Latin America & the Caribbean	Latin America & the Caribbean	Canadian International Development Agency (CIDA), ESMAP (UNDP/World Bank)	TA	Energy from Landfill Gas Project2002-2005http://www.acdi-cida.gc.ca/CIDAWEB/webcountry.nsf/vLUDocEn/9B264C4397E1AB6B85256D95004926D6?OpenDocument#17	Canada Climate Change Development Fund Contribution: $1.1 million	Active

Summary

Description: The goal of this regional project is to support the reduction of greenhouse gas emissions in Latin America and the Caribbean through reduced methane emissions from municipal landfills. The Energy from Landfill Gas Project will assist countries in the region, including Bolivia, to better understand the best practice business models and institutional arrangements for development of non-conventional energy sources at large municipal landfills by means of methane recovery and utilization systems. The project will also include two feasibility studies that will identify and assess potential land fill gas recovery projects.

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USAID Region	Country(ies)	Agency(ies)	Project Type	Project Name, Timeframe and Link	Funding Level or Value	Status
Latin America & the Caribbean	Mexico	World Bank & GEF	TA	Mexico: Methane Capture and Use (Landfill Demonstration) Project, 2001-2004http://www.gefonline.org/projectDetails.cfm?projID=784	Total cost $23. 15 million	Active

Summary

The Methane Gas Capture and Use at a Landfill Demonstration Project, seeks to demonstrate a proven technology for landfill gas (LFG) capture, and use, and reduce barriers to development of future LFG projects. Furthermore, it will demonstrate an institutional structure for the implementation of LFG projects, with private sector participation, and strengthen regulatory, and social frameworks for LFG introduction in Mexico. Project components call for: 1) funding provision for the design, and construction of a LFG collection system, and power plant at the Metropolitan Solid Waste Processing System (SIMEPRODESO) landfill. Implementation of this facility will be under a public-private partnership, which will include as well the construction of methane monitoring wells; 2) capacity building, to promote replication of the LFG collection, and facility use. Training, workshops, and information dissemination designed to build capacity of government entities, and private contractors, in the promotion, and management of LFG projects, will be funded, as will the development of a national replication strategy; 3) technical assistance (TA) to identify legal, policy, and regulatory reform necessary to LFG management; 4) appropriate regional dissemination of the LFG design, and experiences gained from the project, mainly through workshops, and, in addition, funds will be provided to develop twinning arrangements, including capacity building; and, 5) project management, supervision, and monitoring support.

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USAID Region	Country(ies)	Agency(ies)	Project Type	Project Name, Timeframe and Link	Funding Level or Value	Status
Asia & the Near East	Algeria	Gesellschaft für technische Zusammenarbeit (Gtz), Adelphi Consult	TA	Program for integrated environmental management Algeria, 2004-2007http://www.adelphi-consult.com/#/en/projects/0.html		Active

Summary

Adelphi Consult has been requested to conduct a Project Progress Review (PPR) for the environmental programme of the GTZ in Algeria. The results are being utilized to reorient the programme conception and to draw a new programme proposal for a possible extension period till December 2007. The main focus of the project progress review will be on identifying the program's contributions and its development impact.

The Programme is being supported by the GTZ ever since April 1997. The "Programme for integrated environmental management" aims for a reduction of environmental pollution and resource consumption in Algeria. With German support the country should be enabled to integrate ecological concerns better into its national policy in terms of a sustainable development. To this end the capacities of the Algerian ministry of the environment (MATE) get strengthened to facilitate a better coordination and implementation of Algeria's environmental policy. Another focal point of the programme is to establish environmental management systems in the region / city of Blida and on the level of small and medium-sized industry.

Adelphi Consult offers in this context to head the PPR-Mission for the entire PPR process. This will include the lead management in the writing of the report as well as the preparation and presentation of the results.

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USAID Region	Country(ies)	Agency(ies)	Project Type	Project Name, Timeframe and Link	Funding Level or Value	Status
Asia & the Near East	China	GEF and UNDP	TA	Development of Coalbed Methane Resources in China, 1991-1997 http://www.gefonline.org/projectDetails.cfm?projID=380 http://www.gefweb.org/Outreach/outreach-PUblications/Project_factsheet/China-deve-3-cc-undp-eng-ld.pdf	$10 million GEF grant, 19.845 million total	Approved

Summary

To support the Government of China's Eighth Five-Year Plan in its goals to explore alternative energy resources and reduce air pollution caused by massive use of coal. The objectives will be achieved through: improved mine safety and productivity; decreased methane-based atmospheric environmental impacts associated with underground coal mining; and production of high-quality methane fuel to be used as a replacement of coal in power generation, industry and the domestic sector.

The project has been operationally completed. The final activities included the production and distribution of the publication "A Guide to Investment In Coalbed Methane Development in China" (7/99) and video tape documentary about the project. The project was successful in providing to the government technologies to recover and utilize methane to be a new source of energy, while in the past methane was released and contributed to global warming. CBM became a new industry and attracted US$50 million foreign investment for exploration in 1998.

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USAID Region	Country(ies)	Agency(ies)	Project Type	Project Name, Timeframe and Link	Funding Level or Value	Status
Asia & the Near East	China	Canadian International Development Agency (CIDA)	TA	Development of China's Coalbed Methane Technology CO2 Sequestration 3/15/2002-3/31/2005http://www.acdicida.gc.ca/cida_ind.nsf/vLUallDocByIDEn /5695CCB3EC3813FA85256DDC00689E64?OpenDocument	Canada Climate Change Development Fund Contribution: $5 million	Active

Summary

The goal of the project is to promote environmentally sustainable development in China by enhancing its capacity to manage its environment. The purpose of the project is to transfer Canadian enhanced coalbed methane (CBM) recovery/CO2 sequestration technology to China. This technology will effectively exploit coalbed methane, a cleaner source of energy. At the same time, it will store CO2, a greenhouse gas (GHG), in unminable deep coalbeds in poorer areas of China's interior. This project addresses climate change by promoting a cleaner source of energy and sequestering CO2.

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USAID Region	Country(ies)	Agency(ies)	Project Type	Project Name, Timeframe and Link	Funding Level or Value	Status
Asia & the Near East	China	UNDP & GEF	Full-Scale	China: Promoting Methane Recovery and Utilization from Mixed Municipal Refuse, 1996-2000 http://www.gefweb.org/COUNCIL/council7/wp/chiname.htm http://www.undp.org/energy/prodocs/rbap/china.htm	$19.57 million	Complete

Summary

The project's long-term objectives were to promote widespread adoption of landfill gas recovery technology in China based on the technical and organizational experience gained from the three pilot landfills proposed in this project. Specifically, these include 1) significant reduction of emissions of methane; 2) reduction in air, water and land pollution associated with refuse dumping; and 3) promotion of indigenous enterprises that will build and operate recovery systems and utilize the energy.

This UNDP-GEF project formulated a three-pronged strategy to: formulate a national strategy to develop the methane industry; introduce and demonstrate a wide range of technologies and techniques to control and use methane emissions; and sensitize policy-makers at both the central and local levels to the environmental and economic significance of using methane as an energy resource. At three mining sites, the project demonstrated a wide variety of technologies that Chinese coal mines could employ to recover clean-burning methane as a fuel source. It also created a policy and institutional climate supporting development of a coal-bed methane industry, and trained personnel from various research institutes, the central government, coal corporations, mining administrations, coal geology committees, and municipal gas companies.

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USAID Region	Country(ies)	Agency(ies)	Project Type	Project Name, Timeframe and Link	Funding Level or Value	Status
Asia & the Near East	China	ADB & Shanxi Provincial Government	Full-Scale	Coalmine Methane Development Project, http://www.adb.org/Documents/ADBBO/LOAN/30403013.ASP	Loan Amount: 117.40	In-Planning

Summary

The main objective of the Project is establish a CMM demonstration project that covers all aspects of effective and efficient CMM and CBM production, capture, and utilization by applying the latest technologies, i.e., improved CBM production from vertical surface wells and directionally drilled wells from the surface, improved CMM drainage through the use of underground directional drilling and other modern equipment and materials, CMM-based power generation using gas engines, and transmission and distribution of CMM for residential, commercial, and industrial use. In this manner the Project will also contribute to improving mine safety, reduce GHG emissions, and improvement of the environment. Part A of the Project is to demonstrate the more efficient production of CBM, drainage and capture of CMM, and their use for power generation as a least-cost alternative using new technologies; Part B of the Project is to demonstrate the efficient use of CMM on a commercial basis for transmission and distribution to consumers; and Part C of the Project is to provide institutional strengthening to the concerned companies involved in the Project and promote the establishment of similar projects in the PRC.

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USAID Region	Country(ies)	Agency(ies)	Project Type	Project Name, Timeframe and Link	Funding Level or Value	Status
Asia & the Near East	Egypt	Canadian International Development Agency (CIDA),	TA	GHG Inventory and Emission Strategies for Solid Waste Sector in Egypt, 2002 – 2003http://www.acdi-cida.gc.ca/cida_ind.nsf/0/6494db221523c4db85256dff00574423?OpenDocument	Canada Climate Change Development Fund Contribution: $495,000	Complete

Summary

The goal of this project is to assist the Government of Egypt in contributing to the reduction of greenhouse gas (GHG) emissions from non-energy sources. The project will provide Egypt with state-of-the-art technologies to measure GHG emissions from solid waste disposal sites, and to estimate their direct impact on the environment and public health, as well as to develop strategies for solid waste management to reduce emissions.

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USAID Region	Country(ies)	Agency(ies)	Project Type	Project Name, Timeframe and Link	Funding Level or Value	Status
Asia & the Near East	India	UNDP, GEF, Winrock & Ministry of Environment and Forests (MoEF) – India	TA	The Clean Development Mechanism and Biomethanation, 2002-2004http://www.undp.org/energy/prodocs/rbap/ind02m01.htm http://www.winrockindia.org/clc/cdmhrbp.htm	Total Budget: $94,000	Active

Summary

The proposed strategy is to build upon experiences from the ongoing UNDP/GEF project entitled “Development of High-Rate Biomethanation Process as Means of reducing Greenhouse Gas Emissions”. As a number of investment projects were facilitated under the broader GEF initiative, the learning from the projects’ cycles would be used to determine human, institutional and systemic capacity requirements to package biomethanation projects for Clean Development Mechanism (CDM). This UNDP/GEF project will thus serve as a starting point in order to identify issues, transparent institutional and investment options for expanded financing for biomethanation projects. The ongoing efforts of the research organizations and industry federations to create awareness and disseminate information regarding CDM would be linked to the proposed project. By making biomethanation technology an attractive investment for private, public, and municipal financing sources, multiple benefits would be achieved. Besides reducing the greenhouse effect, the recovery and utilization of methane from the biomethanation processes leads to improvement of air and water quality at local level, access to a valuable new source of energy by the local communities, enhancement of quality of life for rural women as it has the potential to substitute firewood, and overall sustainability of benefits. It is expected that the project would facilitate mainstreaming Kyoto protocol and CDM aspects in the national master plan for biomethanation, which is under formulation. The integration of the CDM aspects into the master plan would lead to comprehensive policy formulations for realization of additional revenues in biomethanation, in the form of CERs (certified emission reduction).The lessons learned from the project would be disseminated to the Advisory Group on Climate Change and the national CDM committee, and thus have an impact on the formulation of a national CDM policy.

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USAID Region	Country(ies)	Agency(ies)	Project Type	Project Name, Timeframe and Link	Funding Level or Value	Status
Asia & the Near East	India	UNDP, UNIDO, Government of India, & GEF	TA	India Coalbed Methane Recovery and Commercial Utilization, 1998-2003http://www.gefweb.org/Outreach/outreach-PUblications/Project_factsheet/India-coal-3-cc-undp-eng-ld.pdf http://www.unido.org/en/doc/4577	Total Financing: $14.952 million	Complete

Summary

The objectives of this project were to control greenhouse gas emissions and demonstrate the economic viability of harnessing coalbed methane, an important greenhouse gas, in the Indian coal mining sector. The full project was intended to build national capacity in the field of coalbed methane recovery and utilization.

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USAID Region	Country(ies)	Agency(ies)	Project Type	Project Name, Timeframe and Link	Funding Level or Value	Status
Asia & the Near East	India	UNDP, UNIDO, Government of India, & GEF	TA	India Coalbed Methane Recovery and Commercial Utilization, 1998-2003http://www.gefweb.org/Outreach/outreach-PUblications/Project_factsheet/India-coal-3-cc-undp-eng-ld.pdf http://www.unido.org/en/doc/4577	Total Financing: $14.952 million	Complete

Summary

The objectives of this project were to control greenhouse gas emissions and demonstrate the economic viability of harnessing coalbed methane, an important greenhouse gas, in the Indian coal mining sector. The full project was intended to build national capacity in the field of coalbed methane recovery and utilization.

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USAID Region	Country(ies)	Agency(ies)	Project Type	Project Name, Timeframe and Link	Funding Level or Value	Status
Asia & the Near East	Jordan	UNDP, Government of Jordan	FS	Jordan: Reduction of Methane Emissions and Utilization of Municipal Waste for Energy in Amman, 1996 – 2005http://www.undp.org/energy/prodocs/rbas/jor96g31.htm http://www.undp-jordan.org/undp_in_jordan/project%20documents/Enviroment/ENV3.doc	Total budget: $5.377 million	Active

Summary

At a time when Jordan imports 95% of its energy requirements, a vital renewable energy resource is being left untapped. This resource is the landfill gas and bioenergy. Jordan relies on landfills as a final disposal method for its solid waste. Thus the landfill gas that results from the landfill processes may be utilized to generate electricity. Biogas from landfills has been used in several industrialized countries, and this project is the first of its kind to be implemented in the Middle East to demonstrate the success of using bioenergy to generate electricity in Jordan and the Middle East.

The goal of the project is to reduce emissions of greenhouse gases in Jordan by substituting fossil fuels with bioenergy, produced from anaerobic digestion of industrial and municipal waste in Amman. Additional greenhouse gas reduction will be achieved by reducing the uncontrolled release of methane from improperly disposed organic waste in a large landfill.

The project also aims to introduce biogas technology and to conduct a capacity training program to ensure project sustainability.

Project Status:

- The Biogas Plant was constructed, the plant started operation and producing electricity at current production of 1 MW.
- Jordan Environment Society (JES), conducted information dissemination and awareness in cooperation with the Jordan Hashemite Fund for Human Development.
- The Recycling Project of the Recycling Coalition carried out several recycling activities including the establishment of a segregation center. Work on this component is expected to be completed by end of 2004.
- A comprehensive training outreach program has been conducted.
- Contract was signed with the Jordan University for Science and Technology (JUST) for relevant curriculum modification.
- The Master Plan activity aimed to promote the utilization of biogas for the production of energy in the different parts of the country has been initiated in September 2004.

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USAID Region	Country(ies)	Agency(ies)	Project Type	Project Name, Timeframe and Link	Funding Level or Value	Status
Asia & the Near East	Palestine	Gesellschaft für technische Zusammenarbeit (Gtz), Solid Waste Management Council Gaza Center, Ministry of Local Government (MoLG), & UNEP	TA	Solid Waste Management in Central Gaza (including construction of landfill site for waste disposal), May 1994 - August 2004http://www.skat-foundation.org/activities/ws/cwg/pdf/cwg-42.pdf http://www.unep.or.jp/ietc/Publications/TechPublications/TechPub-17/palestine1.asp	Total Cost 12,68 million Euro	Complete

Summary

At the beginning of this project, in 1994, only one rudimentary waste disposal system existed in the two regional districts of Central Gaza, Khan Younis und Deir El Balah. Solid waste was unsystematically or only partially collected and none of the 11 communities with a total of 270,000 inhabitants had a proper waste disposal. Waste management in the government of Deir El-Balah and Khan Younis was organized with the participation of the community in an environment-friendly and cost-effective manner.

The role of GTZ was to provide the infrastructure of the project such as the garages, the waste dumps, the machinery and the technical support. The role of the Solid Waste Management Council Gaza Center (the Owner of the project) was to provide the working force cadre and the land, as well as implement the project and paying the full costs of operation. The heads of the eleven municipalities were members of this council.

The Council has been continuously improving the realization of its responsibility as the coordinating institution for the waste collection, and its deposition on the landfill with the support of GtZ experts. Information providing lectures in schools, through puppet theaters, at summer camps for children and youth, and through special women's programs are some of the activities aimed at community participation.

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USAID Region	Country(ies)	Agency(ies)	Project Type	Project Name, Timeframe and Link	Funding Level or Value	Status
Asia & the Near East	Palestine	Gesellschaft für technische Zusammenarbeit (Gtz), Solid Waste Management Council Gaza Center, Ministry of Local Government (MoLG)	TA	Solid Waste Management in Northern Gaza (including construction of landfill site for waste disposal), January 2002 - December 2004	Total Cost 2,198 million Euro	Active

Summary

The objective of the project is to improve the protection of the environment through a better solid waste management.
The following results are targeted:

- A formal institutionalized cooperation for waste management shall be established between communal administrations in the Northern Gaza Strip.
- Garbage collection, transport, and deposition from three municipalities Jabalia, Beit Lahia, and Beit Hanoun shall be performed in a cost-effective, environment-friendly, and sustainable manner.
- Solid waste disposal in the Northern Gaza Strip shall take place in close cooperation with the community.
    - The overburdened landfill in Beit Hanoun shall be closed down by halting the operation, and followed by environmentally protective cleaning activities.

Perspectives:
The new operating facilities were to be finished by autumn of 2004. The establishment of the infrastructure of the Council (personnel and equipment) will be completed by the end of 2004. The efficient deployment of vehicles and equipment will be planned, tested, and implemented. Materials for the creation and promotion of public awareness will be developed and produced. A work team will be in charge to mobilize community participation and to strengthen the cooperation between the communities.

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USAID Region	Country(ies)	Agency(ies)	Project Type	Project Name, Timeframe and Link	Funding Level or Value	Status
Asia & the Near East	Pakistan	Japan International Cooperation Agency, Quetta Municipal Corporation (QMC)	TA	Project for Improvement of Environmental Conditions in Quetta City, January 3, 2003 – January 31, 2003http://www.jica.go.jp/english/evaluation/report/expost/14-4-47.html	$6.26 million	Complete

Summary

Quetta City is the capital of Balochistan Province, with an annual population growth rate exceeding 7% and home to over 100,000 refugees from the neighboring country of Afghanistan. The Quetta Municipal Corporation (QMC) was not able to build up its city services and infrastructure enough to keep up with its population increase, and the inefficiency in cleaning operations became a serious social problem. Japan provided Grant Aid for procuring equipment to switch from garbage collection done manually to a container collection method and for transition from the open dump method to the sanitary landfill method, based on the Solid Waste Management Plan.

The improvement of the sanitary conditions in Quetta City, the equipment necessary for the container collection method and the sanitary landfill method were implemented, based on the SWM plan which aimed to improve QMC's ability to collect and dispose of garbage. The sanitary landfill method has not been fully introduced due to financial restraints. As a result, the surrounding environment suffered from air pollution caused by methane gas in the final disposal site.

The project provided the equipment necessary to switch from garbage collection done manually to a container collection method and from the open dump method to the sanitary landfill method. A new mechanical workshop cum parking lot is currently being constructed on about 16,000? of land in Chilton Town, and tools for the mechanical workshop were also procured in the project.

The planned activities have not been fully introduced, as evidenced by the fact that due to fiscal restraints the sanitary landfill method was not adopted and some of the container trucks are not in use. Accordingly they have not been able to hire enough container drivers. The realization of effects was thus smaller than expected. In addition, under the devolution plan each two town municipal administration (TMA) was responsible for its own cleaning work, but allocation of equipment has yet to be determined, which also influences cleaning work. For that reason, when the project was completed, the garbage collection rate improved to 77% temporally, but gradually decreased and reached an average of 59% in 2002.

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USAID Region	Country(ies)	Agency(ies)	Project Type	Project Name, Timeframe and Link	Funding Level or Value	Status
Asia & the Near East	Pakistan	Japan International Cooperation Agency, Rawalpindi Municipal Corporation	TA	Project for Improvement of Garbage Collection and Disposal in Rawalpindi City, November 30, 2002 - January 4, 2003, http://www.jica.go.jp/english/evaluation/report/expost/14-4-45.html	$6.46 million	Complete

Summary

The Rawalpindi municipal area generated about 700 tons/day in solid waste, which broke down to 510 tons per day of household waste, 80 tons/day from animals and 110 tons/day from commercial establishments in 1995. Twenty-two garbage collection and transportation trucks owned by the Rawalpindi Municipal Corporation (RMC) were operable, and of these vehicles seven had been purchased more than 10 years ago and the frequent breakdowns had lowered their utilization rate. RMC was able to collect 280 tons/day of garbage, or just 40%. Sanitary landfill practices were not carried out at the final disposal site, such as leveling the garbage, compacting it, or covering it with soil. Given this situation, the government of Pakistan announced the Rawalpindi Package (fiscal 1995/96), aiming to improve and beautify the city. As a part of the plan, the government of Pakistan requested Grant Aid from the government of Japan for the purchase of vehicles to be used for solid waste management.

RMC bought 300,000 square meters of land in Mouza Losar, 25 km southeast of Rawalpindi City, as the new final disposal site planned in the Rawalpindi Package and planned to fully adopt sanitary landfill methods for this site. However, the process was time consuming and the sanitary landfill method was only being used on a provisional site. Due to these delays, the old disposal site was still being used, although in the initial plans it was supposed to be closed. Therefore there was no improvement in the sanitary environment in that vicinity. Also, the equipment was damaged a great deal because it was used in inappropriate locations.

Garbage collectors stated that once the container method was adopted for garbage collection, there was a dramatic improvement in sanitary conditions and that odors and flies decreased. A questionnaire survey was administered to 100 residents selected arbitrarily from four areas where the RMC provides the garbage collection. They all responded that the garbage in the city had decreased and that there had also been improvements from an aesthetic viewpoint. By covering garbage with soil in the sanitary landfill method, four technicians and two managers from the Department of Sanitation stated that sanitary conditions of water had been improved and fires due to the release of methane gas had been eliminated. However it depends on residents' awareness whether they dispose garbage in the containers, and information has not been completely disseminated so there are many cases in which garbage is left around the containers. This has resulted in many complaints from nearby residents concerning odors and garbage scattering caused by dogs and birds. About half of the residents responded to the questionnaire stated that they had become used to disposing their garbage into the containers.

Since many external factors did not materialize, it was not possible to fully use the equipment procured immediately after the project was completed. After five years, it is expected that the new disposal site will be used soon. The new landfill system was adopted primarily at the temporary garbage disposal site, but this system does work and showed that the project had a significant impact. Although there is a problem with regards to the sustainability of the project, strategies to train workshop employees, and improve organizational methods, and technical and financial approaches have been basically secured.

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USAID Region	Country(ies)	Agency(ies)	Project Type	Project Name, Timeframe and Link	Funding Level or Value	Status
Asia & the Near East	Vietnam	PCFplus, Ho Chi Minh City municipal government, Grontmij Climate & Energy	TA	Grontmij Landfill in Ho Chi Minh Project, 2005http://carbonfinance.org/pcf/router.cfm?Page=Projects&ProjectID =3144	PCF Contract: 8.75 million	In-planning

Summary

The Ho Chi Minh City Landfill Gas project will install a gas collection system at four landfills and either flare the methane or utilize it for electricity generation, thereby reducing the emission of greenhouse gases while also helping to meet city's growing energy needs. This project comprises the rehabilitation of existing sites and the development of a large new site, which starts operations in 2005.The Ho Chi Minh City Landfill Gas project is being developed by the Ho Chi Minh City municipal government, with the consulting service of the Dutch company Grontmij Climate & Energy.

Gas recovery and combustion systems will be installed at four landfills in Ho Chi Minh City: the closed down site of Dong Thanh, the new sites of Cu Chi I and Cu Chi II, and the recently constructed Go Cat landfill. The combusted gas will then be used to produce energy for the local electric grid. The project will upgrade the four landfills by installing top covers, ground lining, piping and leachate treatment plants. These measures will reduce the flow of polluted water into the ground and shield the sites from disease-spreading vermin. Not only will all four landfills be brought up to international standards and electricity produced for the city, but by extracting methane from the sites the amount of greenhouse gases emitted into the atmosphere will be reduced. The project is expected to generate about6.5 million tons of carbon dioxide equivalent over the next ten years. The PCF is willing to buy up to 3.75 million tons out of the total amount, leaving part of the emission reductions to be negotiated by the sponsors with other buyers in the international market.

This project promotes sustainable development in Ho Chi Minh City in several ways. The project will transfer clean technology and build capacity in the city's solid waste management sector. Electricity generation will help meet the city's increasing energy needs and support its economic growth. Local people will be hired and trained to manage gas recovery systems and leachate treatment plants, creating skilled jobs for the growing population. Finally, the most immediate result of the project may be one its important: public health and the quality of life will improve in neighborhoods near the landfills, where residents will enjoy less stench, fewer vermin and safer water. Prototype Carbon Fund financing, through its emissions reductions purchase agreement, makes this Clean Development Mechanism project possible.

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USAID Region	Country(ies)	Agency(ies)	Project Type	Project Name, Timeframe and Link	Funding Level or Value	Status
Europe & Eurasia	Bulgaria	Performed by Biomass Technology Group, Financing by PCFplus	TA	Methane and Nitrous Oxide Emissions from Biomass Waste Stockpiles, 2001-2002http://www.btgworld.com/references/pdf/leaflet-bulgaria-ch4.pdf		Complete

Summary

Replacement of fossil fuel fired boilers with biomass-fired boilers, fired with biomass stockpiles would mitigate greenhouse gas emissions because of two reasons: 1) replacement of fossil fuels and 2) avoidance of methane (CH4) and nitrous oxide (N2O) emissions. While the estimation of the CO2 emission reductions as a function of environmental and physical variables make the estimates uncertain, especially over the project's lifetime.

The objective of the assignment was to build a general methodology for assessing CH4 and N2O emissions from wood residue stockpiles. The CH4 emissions were estimated by field measurements on two biomass stockpiles in Bulgaria.

Significant amounts of CH4 were found at both locations. High concentrations of CH4 were measured below 0.5-1.5 meter inside both piles using a probe. Together with the high CH4 emissions measured, this confirms that anaerobic conditions exist in large parts of both piles. With these results a model has been developed to predict CH4 emissions from biomass stockpiles.

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USAID Region	Country(ies)	Agency(ies)	Project Type	Project Name, Timeframe and Link	Funding Level or Value	Status
Europe & Eurasia	Bulgaria	Performed by Biomass Technology Group, Financing by PCFplus	TA	Monitoring Methane and Nitrous Oxide Emissions from Biomass Waste Stockpiles, 2003-2004 http://carbonfinance.org/pcf/router.cfm?Page=Projects&ProjectID =3118http://www.btgworld.com/references/pdf/leaflet-bulgaria-ch4-monitoring.pdf	PCF Contract:$ 1.75 million	Complete

Summary

The project will use the wood wastes produced at the plant to replace coal currently used, thereby substantially reducing the greenhouse gas emissions from coal burning, and the methane emissions from decomposition of the waste material. The plant produces more wood waste than any other site in Bulgaria. Using this waste for energy will:

- Reduce the company's energy costs in the long run, using biomass to replace the coal currently consumed;
- Reduce CO2 as well as other harmful emissions (SO2, NOx, particulates) by switching from coal to biomass;
- Reduce CH4 emissions from decomposition of the waste material; and,
- Reduce N2O emissions caused by the spontaneous combustion of the stockpiled woodwaste;
- Use the plant's biomass wood waste, which is currently stored on site, to provide alternative, clean energy, and reduce both greenhouse gas (GHG) emissions from decomposition, and reduce groundwater damage

One biomass boiler will be installed, with a capacity of 14 MW (18 tons per hour saturated steam at a pressure of between 12 and 15 bar). The biomass utilization in the proposed project will amount to 157,000 MWhr per year and will replace 117,000 MWhr of coal per year. In terms of CO2 emissions, this will lead to a real reduction of 54,000 tons per year. In addition to the CO2 mitigation effect from fuel switching, there will also be substantial reductions in methane emissions from the wood waste, which is stockpiled at the site and releasing significant quantities of methane each year.

The reduction in methane production from the existing waste will result in an average reduction of 100,000 tons CO2e per year.

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USAID Region	Country(ies)	Agency(ies)	Project Type	Project Name, Timeframe and Link	Funding Level or Value	Status
Europe & Eurasia	Latvia	PCFplus, Government of Latvia, World Bank Loan	TA	Liepaja Solid Waste Management Project, 2000-2006 http://carbonfinance.org/pcf/router.cfm?Page=Projects&ProjectID =3105	Total cost $16.75 million	Active

Summary

The Liepaja Solid Waste Management Project brings a state-of-the-art waste management system to the Liepaja region in Latvia. The project will establish a waste management facility demonstrating self-sustaining, modern management of municipal solid waste through maximum collection and utilization of landfill gas in the district of Liepaja. Other objectives include: a) demonstrating modern sanitary landfill techniques on a regional basis; b) strengthening institutional capacity at the local/regional levels on issues related to municipal solid waste management; c) arresting the on-going contamination of groundwater; d) reducing environmental disseminates for neighbors of existing disposal sites that would be closed; e) facilitating the separation of recyclable material; and f) reducing greenhouse gas emissions through an Emission Reductions Purchase Agreement with the PCF.

The contribution from the PCF has made it possible to install a state-of-the-art system—which would allow for the maximum collection of generated methane—that would not otherwise be affordable. This system would help to lower greenhouse gas emissions in two ways. First, it mitigates the methane emitted by decaying waste; and, second, it substitutes landfill gas—which will be used to generate electricity—for fossil fuels. Over a 20-year lifetime, the project will reduce greenhouse gas emissions by almost a million tons of carbon dioxide.

This project is covered by one of the first Joint Implementation activities under the Kyoto Protocol, and has allowed Latvia to take full advantage of the opportunities emerging from the nascent carbon market. Perhaps, of most immediate benefit to the environmental quality of life for people in the area, 22 of 26 existing obsolete dump sites have been closed under the project.

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USAID Region	Country(ies)	Agency(ies)	Project Type	Project Name, Timeframe and Link	Funding Level or Value	Status
Europe & Eurasia	Russia	UNDP & GEF	Full-Scale	Removing Barriers to Coal Mine Methane Recovery and Utilization, 1 June 2003, 48 months http://www.undp.ru/index.phtml?iso=RU&lid=1&cmd=programs&id=22 http://www.gefweb.org/Documents/Council_Documents/GEF_C20/CC_-_Russian_Federation_-_Removing_Barriers.pdf	$8.325 million, of which GEF – $3.1 million	Active

Summary

The overall project goal is to mitigate greenhouse gas emissions by removing barriers to the implementation and financing of coal mine methane (CMM) recovery and utilization projects in Russia. As one of the key mechanisms in that regard, the project will support the establishment of a specialized “Coal Mine Methane Recovery and Utilization Company”, which after the initial support for the start-up phase is expected to continue its operations as a self-sustaining entity.

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USAID Region	Country(ies)	Agency(ies)	Project Type	Project Name, Timeframe and Link	Funding Level or Value	Status
Europe & Eurasia	Ukraine	World Bank & GEF	TA	Coalbed Methane Recovery, Ukraine, http://www.gefonline.org/projectDetails.cfm?projID=450	Project Cost: $17.4 million	Cancelled

Summary

The project's objectives are to: (a) reduce emissions of greenhouse gases which are a byproduct of Ukraine's mining sector; (b) increase resource recovery and promote the commercial extraction of coalbed methane; and (c) help increase the productivity and safety of Ukraine's underground coal mines. The project has two components; the Mining component will undertake underground extraction of methane; and the second component will support the creation of a coalbed methane company, which will carry out field tests to verify the commercial potential of surface gas extraction.

The project has been officially stalled since March, 2000 after the government failed to fulfill conditions for resumption of preparation activities, including demonstration of adequate financing for the project. The project had been progressing slowly before this time, beginning with the bankruptcy of one of the original private co-financiers. Additionally, the Bank Coal sector loan, which was to be associated with, was eventually dropped for other reasons, thus eliminating another major source of associated co-financing for the project. Discussions of restructuring this project have focused on the possibility of separating the above ground and below ground methane capture components, however at this point an adequate financing package remains the most limiting factor.

Contacts

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Websites

Region	Country	Source	Topic	Web Link
Global	Global	USEPA	Methane to Markets Partnership Overview	http://www.epa.gov/methane/international.html

Summary of Contents

EPA is involved in a variety of international activities to better understand and quantify global methane emissions, assess the costs and benefits of emission reduction options, and to facilitate cost-effective, emission reduction opportunities. In addition, EPA is leading the United States commitment to the new Methane to Markets Partnership. Links to views and facts on methane

Region	Country	Source	Topic	Web Link
Americas	USA	USEPA	LFG-collection, use, other resources	http://www.epa.gov/lmop/

Summary of Contents

The U.S. EPA's Landfill Methane Outreach Program (LMOP) is a voluntary assistance and partnership program that promotes the use of landfill gas as a renewable, green energy source. Landfill gas is the natural by-product of the decomposition of solid waste in landfills and is comprised primarily of carbon dioxide and methane. By preventing emissions of methane (a powerful greenhouse gas) through the development of landfill gas energy projects, LMOP helps businesses, states, energy providers, and communities protect the environment and build a sustainable future.

Region	Country	Source	Topic	Web Link
Global	Global	USEPA	LFG-International program assistance	http://www.epa.gov/lmop/international.htm

Summary of Contents

Over the past 7 years, LMOP has assessed the technical and economic feasibility of LFG project development at selected landfills in a number of countries around the world. Specific cities that have been evaluated as potential hosts for LFG project development include Sao Paulo (Brazil), Manila (Philippines), Bangkok (Thailand), Seoul (Korea), and Mexico City (Mexico). The objective of these feasibility assessments is to identify economical and technically feasible project development opportunities, both in the host country and for international project developers, and to promote the benefits of LFG use as a local source of renewable energy.

Region	Country	Source	Topic	Web Link
Americas	USA	USEPA	Coalbed Methane	http://www.epa.gov/cmop/

Summary of Contents

EPA's Coalbed Methane Outreach Program (CMOP). CMOP is a voluntary program whose goal is to reduce methane emissions from coal mining activities. Its mission is to promote the profitable recovery and use of coal mine methane (CMM), a greenhouse gas more than 20 times as potent as carbon dioxide. By working cooperatively with coal companies and related industries, CMOP helps to identify and implement methods to use CMM instead of emitting it to the atmosphere. In turn, these actions mitigate climate change, improve mine safety and productivity, and generate revenues and cost savings.

Region	Country	Source	Topic	Web Link
Global	Global	USEPA	Coalbed Methane-International	http://www.epa.gov/cmop/international.html

Summary of Contents

CMOP works with organizations in many coal-producing countries to promote coal mine methane (CMM) development and use. This page provides overviews of these initiatives, and also includes links to selected country-specific CMM-related Web sites. In addition, this section of the Web site highlights topics of interest to those interested in international CMM/CBM development. Current countries include - Australia, Bulgaria, China, Czech Republic, France, Germany, India, Japan, Kazakhstan, Mexico, Poland, Russia, South Africa, Ukraine and United Kingdom

Region	Country	Source	Topic	Web Link
Americas	USA	USEPA	Emissions from Natural Gas Systems	http://www.epa.gov/gasstar/index.htm

Summary of Contents

The Natural Gas STAR Program is a flexible, voluntary partnership between EPA and the oil and natural gas industry. Through the Program, EPA works with companies that produce, process, and transmit and distribute natural gas to identify and promote the implementation of cost-effective technologies and practices to reduce emissions of methane, a potent greenhouse gas.

Region	Country	Source	Topic	Web Link
Europe & Eurasia	Russia, Ukraine & Kazakhstan	USEPA	EPA Workshop on International Emerging Markets for Coal Mine Methane Projects: Commercializing Advanced Technologies in Developing Countries and Economies in Transition	http://www.epa.gov/cmop/intl/workshopsummary.html

Summary of Contents

EPA held a half-day workshop in Tuscaloosa, Alabama in conjunction with the International Coalbed Methane Symposium at the University of Alabama. Approximately 50 people attended from numerous countries to identify barriers constraining development of coal mine methane (CMM) and coalbed methane (CBM) resources in developing countries and countries with economies in transition Three case studies presented experiences in Ukraine, Kazakhstan, and Russia. The fourth case study focused on implementing a specific technology in developing countries and EITs. The intent was to create a two-way dialogue so that representatives from developing countries/EITs and developed countries could understand the other's perspectives on barriers to implementing CMM/CBM projects.

Region	Country	Source	Topic	Web Link
Europe & Eurasia	Russia	USEPA	Reducing Methane Emissions from Coalmines in Russia	http://www.epa.gov/coalbed/pdf/int005.pdf

Summary of Contents

A handbook for expanding coalbed methane recovery and use in the Kuznetsk coal basin.

Region	Country	Source	Topic	Web Link
Global	Participating Developed Countries	USEPA	Non-CO2 GHG Emissions and Projections from Developed Countries, 1990-2010	http://www.epa.gov/ttn/chief/conference/ei10/ghg/scheehle.pdf
Summary of Contents Compilation of publicly available, country-submitted estimates. All projections based on "business estimated impacts" of additional climate policies. Excellent technical background on inventories and estimation procedures. NOTE: Report is still in DRAFT format, do not cite - do not quote				

Region	Country	Source	Topic	Web Link
Global	Developing Countries	USEPA	Emissions and Projections of Non-CO2 Greenhouse Gases from Developing Countries: 1990-2020	http://www.epa.gov/methane/pdfs/draftdevelopingcountries.pdf
Summary of Contents This analysis provides estimates for 48 developing countries and seven regions for 1990 through 2020, in five year increments. In addition to the individual country data, EPA presents overall trends by region and by gas. The regional groupings include Africa, China/Centrally Planned Asia, Eastern Europe, South and East Asia, Latin America, Middle East, and former Soviet Union. NOTE: Report is still in DRAFT format, do not cite - do not quote				

Region	Country	Source	Topic	Web Link
Global	Global	NY Times	U.S. and 13 Other States Agree on Push to Gather Methane Gas	http://www.nytimes.com/2004/11/17/politics/17enviro.html?ex=1101696569&ei=1&en=cb2ad3983d0f3700
Summary of Contents Press Release on the 13-country signing of an agreement in November 2004 to work together to capture methane emissions.				

Region	Country	Source	Topic	Web Link
Americas	Global	USEPA & ICF Consulting	International Opportunities for Cost-Effective Reductions of Methane Emissions	http://www.icfconsulting.com/Markets/Energy/doc_files/InternationalMethane-oilgasjournal.pdf

Summary of Contents
Since 1990, the U.S. oil and gas industry has achieved over 10 BCM of methane emissions reductions. These reductions have been made primarily as a result of communicating available technologies and efficiency improvements, the integration of which has been facilitated by Natural Gas STAR's efforts to increase understanding of these opportunities among its partners. This article seeks to encourage development of international methane mitigation projects by using the experience of the U.S. Natural Gas STAR Program to estimate the potential opportunities in several other countries with large and/or growing natural gas industries. In addition, the emerging emission reduction markets our examined that can offer an additional revenue stream beyond increased gas sales and some actual examples of international projects our sited that will achieve methane emission reductions.

Region	Country	Source	Topic	Web Link
Asia & the Near East	China	USEPA and the former State Administration of Coal Industry (SACI) of China	China Coalbed Methane Clearinghouse	http://www.coalinfo.net.cn/coalbed/coalbed.htm

Summary of Contents

China Coalbed Methane Clearinghouse is built jointly by the US Environmental Protection Agency and the former State Administration of Coal Industry (SACI) of China in August 1994, as a part of the China Coal Information Institute. The functions of the Clearinghouse include: 1) to improve the awareness of decision makers and mining officials to the coalbed methane potential in China, and help develop policy recommendations to encourage foreign investment and joint venture; 2) to provide information

support to American companies who are interested in coalbed methane projects in China by ways of collecting information, identifying opportunities for Chinese and foreign parties in the development of coalbed methane projects, and hosting technical seminars etc.

Region	Country	Source	Topic	Web Link
Asia & the Near East	China	USEPA	Investment Guide for China CMM/CBM	http://www.epa.gov/cmop/pdf/guildline3.doc

Summary of Contents

The aim of this guidebook is to describe CBM resources and the state of art in China, the preferential policies, market analyses, modes of international cooperation, etc. for development of CBM resources in China. The purpose is to let the foreign investors understand the great market potential for development of CBM in China, and their investment in CBM industry may be repaid.

Region	Country	Source	Topic	Web Link
Europe & Eurasia	Russia	Uglemetan	International Coal & Methane Research Center - UGLEMETAN	http://www.uglemetan.ru/HTML/GeneralEng.html

Summary of Contents Uglemetan - International Coal & Methane Research Center is a not-for -profit organization with an inspired and people-driven approach to promote CBM/CMM recovery and utilization in Russia and in the Commonwealth of Independent States. Extensive background information on coalbed methane projects in Russia.

Region	Country	Source	Topic	Web Link
Latin America & the Caribbean	LAC countries	World Bank	World Bank-ESMAP Landfill Gas (LFG) to-Energy Initiative for the Latin American Region	http://www.bancomundial.org.ar/lfg/default.htm

Summary of Contents

Landfill gas to energy initiative led by the Energy Sector Management Assistance Program (ESMAP) a global technical assistance program which helps build consensus and provides policy advice on sustainable energy development to governments of developing countries and economies in transition.

Region	Country	Source	Topic	Web Link
Global	Global	Alberta Energy and Utilities Board	Coalbed Methane Study	http://www.centreforenergy.com/outsideNav.asp?href=http%3A%2F%2Fwww%2Eeub%2Egov%2Eab%2Eca%2FBBS%2Fpublic%2FEnerFAQs%2FEnerFAQs10%2Ehtm&template=1,2

Summary of Contents

Coalbed methane (CBM), also known as natural gas from coal, is in the early stages of development. More research is necessary before the scale of its contribution to Alberta's natural gas supply is fully understood. Each coalbed basin in the world has proven to be unique, presenting its own set of issues and challenges. This EnerFAQs addresses these issues from an Alberta perspective and explains the Alberta Energy and Utilities Board's (EUB's) role in ensuring that CBM development is conducted in an orderly, efficient, and responsible manner.

Region	Country	Source	Topic	Web Link
North America	Canada	Alberta Energy and Utilities Board	The Potential for Coalbed Methane Development in Alberta	http://www.energy.gov.ab.ca/gmd/docs/Coalbed_Methane_Final_Report_Sept_2002.pdf

Summary of Contents

This technical report recommends review of a number of economic, land access, tenure, environmental and technical factors associated with NGC development. This report does not represent government policy. It is a report to the province providing potential producers' views on the likelihood of NGC development, the issues they see from their experience, and their recommendations as potential producers.

Since the report's completion, understanding of Alberta's coal seam geology has increased because of Alberta Geological Survey analysis and publicly available industry production data from initial NGC wells being drilled and produced.

Region	Country	Source	Topic	Web Link

Global	Global	DOE-EIA	Country Analysis Briefs	http://www.eia.doe.gov/cabs/contents.html

Summary of Contents

Energy situation overview for countries of current interest. Extensive energy-related background information of developing/developed countries.

Region	Country	Source	Topic	Web Link
Europe & Eurasia	Europe	European Network of Energy Agencies (EnR) on behalf of Directorate General XVII of the European Commission	Landfill Gas - Market Barriers	http://europa.eu.int/comm/energy_transport/atlas/htmlu/lfgmark.html

Summary of Contents

The current state of the art for this LFG technology is described in detail under the following:

Current market position and Future Potential

Competitiveness of EU-manufacturers

Market barriers and success factors

Technical development status

Environmental Impacts and Benefits

Current Research and Technology Development (RTD)

Future RTD needs