



Draft Outline of International Landfill Gas Best Practices Guide

The following list of topics of interest for international LFGE projects. Each resource in the attached matrix was reviewed for relevancy and was categorized by the following list of major topics and subtopics. Yellow highlighted topics indicate those with gaps in the literature reviewed.

- i. Brief Introduction of Landfill Gas
 - a. This chapter would briefly discuss the importance of methane, the international landfill industry, and the purpose of this best practices guide. Information on these topics is readily available from previous Methane to Markets support work.
1. International Landfill Design and Landfill Operation to Improve Gas Recovery
 - a. Comparing and contrasting the ability to collect gas from open dumps, controlled landfills, and sanitary landfills.
 - b. Types of liners, final capping systems, and their impact on LFG generation/collection
 - c. Daily/weekly/intermediate cover and waste compaction practices, thickness and frequency of cover
 - d. Re-grading landfill slopes to create appropriate slope
 - e. Leachate management.
 - f. Fires. Techniques to identify and control subsurface fires
2. Landfill Gas Modeling
 - a. Documents that discuss/compare values predicted from different landfill gas models
 - b. Documents that compare model predicted values to actual gas collection measurements for LFG projects
 - c. Documents that discuss how to customize models to different climates and waste compositions
 - d. Factors to consider in collecting data, performing gas generation modeling, and estimating gas recovery efficiency to avoid over-predicting recoverable methane.
3. Design and Operation of Existing Landfill Gas Collection and Flaring Systems Internationally
 - a. description of equipment
 - b. designs of gas extraction wells
 - c. header pipes
 - d. minimizing condensate in landfill gas header pipes
 - e. radius of influence for gas extraction wells
 - f. open vs. enclosed flares
 - g. managing and identifying leaks in the gas collection system
 - h. methods for optimizing and managing the system
 - i. construction QA/QC



Methane to Markets

4. Landfill Gas Energy Recovery Technologies (both electricity and thermal energy)
 - a. Discussion of suitable technologies
 - b. Treatment/cleaning landfill biogas to remove contaminants so it can be used for energy recovery. Documents that discuss how treatment options may need to be tailored for international conditions.
 - c. Innovative energy uses, successful energy technologies or uses for dumps/landfills with a small amount of gas
5. Landfill Regulations Covering Landfill Gas Generation in developing M2M Countries
 - a. Requirements to install gas collection systems from either an environmental or Health and Safety perspective.
 - b. Landfill ownership
 - c. Mineral rights/ land rights/ contracts in various countries
6. Other policy issues, barriers, and incentives.
 - a. Electric utility regulations and policies
 - b. Natural gas utility regulations
 - c. Barriers to transitioning landfill gas flaring clean development mechanism (CDM) projects to beneficial energy recovery projects and examples of where a project has converted a flare project into an energy recovery project.
 - d. Types of incentives that exist internationally for promoting landfill gas energy recovery/distributed generation/renewable energy in general.
7. Discussion of the types of project costs, revenue, and economic factors that should be considered and included in a preliminary economic feasibility analysis of an international landfill gas project.
8. Examples/Guidance on how to prepare RFP for landfill methane projects and/or guidance for evaluating proposals received from developers on landfill gas projects
9. Documents focused on big-picture regional landfill gas development strategies.
10. Other
 - a. Project finance
 - b. Companies and organizations involved in international renewable energy
 - c. International Solid Waste Management Planning
 - d. Negotiating contracts and securing incentives for renewable energy

YELLOW TEXT INDICATES GAPS IN LITERATURE

Attachment 1 - International LFG Best Practices Literature Review

Country or Region	Organization	Name of Document	Summary	Type of Information Covered, Focus, Level of Detail & Usefulness	Limitations, Gaps, & Concerns	Relevancy Rating (1 -Very Relevant 4 - Not Very Relevant)
Latin America and the Caribbean	The World Bank, Energy Sector Management Assistance Programme (ESMAP)	Handbook for the Preparation of Landfill Gas to Energy Projects in Latin America and the Caribbean (2004)	This handbook has been developed for the World Bank to facilitate the development of landfill gas (LFG) management and landfill gas to energy (LFGTE) projects in Latin America and the Caribbean (LAC).	High level discussion of gas collection from different landfill types. High level discussion of liners and capping systems and implications. Impacts of waste compaction discussed.	Generally high level discussion of landfill design and operation Not much focus on landfill composition differences and adjusting design and operation to account for these differences. Compaction practices and thickness and frequency of cover are not discussed in this resources.	1-2
				Focus on one type of mathematical model for estimating the LFG generation potential at the site - Scholl-Canyon Model.	Only one model discussed and not much focus on adjusting the model for different landfill gas compositions and no focus on different climates.	2
				Detailed information for design and operation of collection and flaring information in LAC.	Focus only on LAC LFG systems.	2
				Detailed discussion of best management practices for operations of LFG projects to maximize energy recovery potential	No discussion of recovery technologies.	2-3
				High level discussion of importance of determined resource ownership and reduction credit ownership	No detailed provided about how to determine ownership.	2-3
				Resource is structured to outline the type of regulatory or policy issue that might be encountered, the rationale for this type of regulation or policy issue, and an example of the potential type of regulation or policy issue currently in place. At a high level it is mentioned throughout the document that incentives exist.	Not focused on specific energy regulations since energy regulations differ between countries most of the LAC countries are only beginning to establish regulations. Resource does not list country-specific incentives.	1-2
				Resource covers market and revenue risk factors Resource includes risks or uncertainties that relate to: the generation rate and availability of the LFG, the technology used to collect and utilize the LFG, and the potential source(s) of project revenue.	Does not cover in detail economic factors that should be considered and included in a preliminary economic feasibility except for market and revenue risk factors.	2
				Focuses on project development and contracting.	Does not cover RFPs or guidance on evaluating proposals.	1-2
				Resource includes an overview of the Kyoto Protocol and Carbon Markets. The CDM Project Cycle is extensively covered.		1

Attachment 1 - International LFG Best Practices Literature Review

Country or Region	Organization	Name of Document	Summary	Type of Information Covered, Focus, Level of Detail & Usefulness	Limitations, Gaps, & Concerns	Relevancy Rating (1 -Very Relevant 4 - Not Very Relevant)
Developing Countries	United States Agency for International Development (USAID)	Study of the Market Potential for Recovered Methane in Developing Countries (2004)	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.	Resource includes case studies of different landfill types and the collecting gas from these landfills.	Leachate management techniques or technologies not extensively covered.	1
				General information about how to manage leachate and the importance of doing so.		
				Resource presents studies of successful methane recovery projects located throughout the world and comments on differences, issues, and challenges for the developing world.		2
				General overview of recovery technologies.		2
				Resource presents systematic approach to the evaluation of opportunities for development of M2M projects	Economic and revenue informational resources are links to LMOP and CMOP sites.	1-2
Countries covered include: Brazil, Columbia, India, Indonesia, Kazakhstan, Mexico, Pakistan, Peru, Russia, South Africa, and Ukraine		1				
Sub-Saharan Africa	The World Bank, Energy Sector Management Assistance Program (ESMAP)	Landfill Gas Capture Opportunity -- Sub-Saharan Africa (2005)	This study analyzes urban waste in both quantitative and qualitative terms in selected Sub-Saharan African (SSA) countries to find out if the available methane from municipal waste could be used as a supplementary energy source. This resource also addresses opportunity for landfill gas (LFG) capture and use in SSA and studies if methane generated from landfills in SSA can be used as a sustainable source of energy.	High level discussion of different landfill types		3
				Resource discusses ways to identify successful LFGTE project locations such as: quantity of waste, moisture content and ambient temperature, and electricity price.		1
				Resource covers waste management regulations for collection, transfer and disposal. Also covers laws and regulation for foreign participation in energy project development and the status of power sector reform.	Only covers Conakry and Dakar.	2
				Resource covers investment costs, sensitivity analysis, and unit energy costs.		2-3
General	World Resources Institute	Corporate Guide to Green Power Markets: Opportunities with Landfill Gas (2002)	This report is intended to provide corporate energy managers with a basic understanding of the environmental, technical, and economic issues underlying a landfill gas to energy project.	General overview of U.S. landfill regulations.	International regulations are not covered by this resource.	4
				Resource covers tax credits, net metering, and standards for GHG accounting.	While some of the information covered may be applicable to international projects the focused of this resource is on the U.S.	3
				Resource covers factors to consider when conducting an economic evaluation and assessing viability of LFGTE projects	While some of the information covered may be applicable to international projects the focused of this resource is on the U.S.	3

Attachment 1 - International LFG Best Practices Literature Review

Country or Region	Organization	Name of Document	Summary	Type of Information Covered, Focus, Level of Detail & Usefulness	Limitations, Gaps, & Concerns	Relevancy Rating (1 -Very Relevant 4 - Not Very Relevant)
General	IEA Bioenergy by the Energy Research Centre of the Netherlands (ECN), E4tech, Chalmers University of Technology, and the Copernicus Institute of the University of Utrecht.	Bioenergy – a Sustainable and Reliable Energy Source: A review of status and prospects (2009)	This resource is a review of the entire bioenergy sector aimed at policy and investment decision makers. The brief to the contractors was to provide a global perspective of the potential for bioenergy, the main opportunities for deployment in the short and medium term and the principal issues and challenges facing the development of the sector.	Resource describes the availability and cost of feedstock as well as the environmental and social issues associated with their production.	This resource focuses on bioenergy as a whole and does not cover landfill gas specifically in much detail.	3
				Resource covers current and future technology pathways (R&D status and deployment horizon, preferred scale, feedstock, conversion efficiency, reliability and lifetime, cost, etc.).		3
				Resource reviews the different support mechanisms and regulatory frameworks affecting the bioenergy value chain and lessons relevant to bioenergy policy making		3
General, but focus on developing countries	The World Bank	Strategic Planning Guide for Municipal Solid Waste Management (2001)	The Guide's purpose is to provide comprehensive information, supporting methodologies and tools to assist development of Strategic MSWM Plans at the local and regional level. The primary target audience is municipalities and regional authorities in developing countries and economies in transition, but much of the material in the Planning Guide will also be relevant and of use to all countries.	High level discussion of the steps involved in developing and implementing a MSWM plan at the local and regional level. Briefly discussed leachate management and the need to control landfill gas emissions if installing a sanitary landfill (shows schematic of simple landfill gas collection systems that go to flare)	Very little discussion about landfill gas collection and issues.	4
				Good high level discussion on need to review the financial policy framework and what's involved with economic/financial assessment of MSWM options. Has good high level discussion on how capital expenditures can be financed.	Does not specifically address landfill gas collection or use.	3
Mexico, India, Bulgaria	Organisation for Economic Co-operation and Development	Institutional Capacity and Climate Actions: Case Studies on Mexico, India, and Bulgaria (2003)	These country-specific capacity assessments provide useful insights on each country's institutional challenges and how they might affect the development of current and future actions.	Mexico: Discussion of capacity for climate change mitigation in Mexico. Some good info on the energy structure in Mexico with specific info about Ministry of Energy, PEMEX, Federal Electricity Commission (FCE)-including electricity policy. Also discusses legal/policy framework related to climate change. India: Discussed air pollution abatement regime (not specific to GHG), high-level discussion of policy options for climate change mitigation, and barriers to policy implementation. Bulgaria: Presents survey results of institutional capacity for climate change mitigation. Main findings=obstacles to an effective long term climate policy in Bulgaria are the lack of personnel and training, lack of funds, lack of sufficient authority of the organizations assigned with the national climate change policy, lack of co-operation among institutions.	No discussion about landfill gas energy projects	4

Attachment 1 - International LFG Best Practices Literature Review

Country or Region	Organization	Name of Document	Summary	Type of Information Covered, Focus, Level of Detail & Usefulness	Limitations, Gaps, & Concerns	Relevancy Rating (1 -Very Relevant 4 - Not Very Relevant)
General	The World Bank, Energy Sector Management Assistance Programme	How to Design a World Bank Carbon Finance Project	Summary information on the World Bank Carbon Finance Project Cycle.	Summary information only.	Summary information only. No links. Not helpful.	4
General	United Nations Environment Programme	Cogeneration	Fact sheet on cogeneration of electricity.	Focuses purely on cogeneration and not on cogeneration opportunities using LFG	No focus on LFG. Not very helpful. There are better documents available about CHP (e.g. EPA CHPP Biomass Catalog of Technologies discussed CHP issues related to LFG - http://www.epa.gov/chp/basic/catalog.html).	4
General	United Nations Environment Programme	Financial Risk Management Instruments for Renewable Energy Projects (2004)	Appropriate risk management tools can help remove some of the barriers to financing Renewable Energy Technology (RET) projects, particularly in developing countries where risk and risk perceptions are highest. That is why UNEP is working on a comprehensive overview of currently available and potential financial risk management instruments for Renewable Energy Technology (RET) projects. This study will pave the way for an upcoming GEF project that will promote the use of financial risk management instruments that favor the development of RETs	Good information on financial risk management instruments for RE projects, but report is more of a summary of what currently exists and what needs to be done for improvement. It's more of an academic type paper and not a guide for RE project developers. It does have one quote related to LFGE projects though: "Methane capture from landfills and combustion to generate energy offer the greatest returns and opportunities for carbon financing. At prices currently paid by the World Bank Prototype Carbon Fund (PCF), carbon revenues from a typical landfill gas to energy project, for example, can contribute about USD15 per megawatt hour, potentially increasing project internal rates of return by five percentage points or more."	More academic in nature. Not really a guide for project developers. Information is from 2004, and progress has most likely been made since then.	3-4

Attachment 1 - International LFG Best Practices Literature Review

Country or Region	Organization	Name of Document	Summary	Type of Information Covered, Focus, Level of Detail & Usefulness	Limitations, Gaps, & Concerns	Relevancy Rating (1 -Very Relevant 4 - Not Very Relevant)
General	World Energy Council	Renewable Energy Projects Handbook (2004)	The Handbook is a succinct and user-friendly reference publication intended to serve as a manual and an information source to facilitate the successful identification and implementation of viable renewable energy projects in different categories, both in developed and developing countries. It provides a brief overview of the leading renewable energy resources: biomass, geothermal, hydro, solar and wind, and presents the state-of-the-art technologies for their use. It also contains a summary of the existing policies and drivers, as well as the barriers common to renewables and suggests ways of dealing with them. Price £30.00 plus VAT for nonmembers.	Provides a brief overview of biomass energy resources and technologies. Specifically addresses the technologies suitable to convert biomass feedstocks into usable energy.	LFG is briefly discussed as part of broader biomass discussion but not in a lot of detail.	3-4
				Contains tables of country specific policies that promote RE projects (in both developed and developing countries). Also has some info on Schemes by International Organisations to Promote Renewable Energy in Developing Countries.	Policies and drivers are discussed in context of 2004 (when report was published). Some policies may be out of date. LFG is not discussed specifically.	2
				Good discussion of financial, technical, and other criteria for selecting and evaluating renewable energy projects (e.g., resource considerations/demand Side considerations for various grid markets in developed and developing countries; cost effectiveness, affordability, profitability, and subsidies--including installed capital costs, specific daily delivered electricity/specific capital cost; development, installation and O&M; social and environmental aspects; risk analysis and risk management; development of local expertise; stakeholders' buy-in). Also contains a Renewable project development checklist, and a sample cost evaluation for a biomass project.	LFG is discussed specifically for some of these topics, but for others biomass is discussed more generally	2-3
				Annex 1 lists companies and organizations involved in various types of RE projects. Companies with LFG expertise are called out.	List may be out of date	2-3
General	United Nations Environment Programme	Waste Management Planning: An Environmentally Sound Approach for Sustainable Urban Waste Management An Introductory Guide for Decision-makers (2004)	This booklet provides a short introduction to the importance of waste management planning, specific waste Management problems in developing countries, and a short guide on what to be aware of when drafting a waste management plan.	High-level overview of the importance of waste management planning and the basic steps involved	No detailed info about landfill design for LFG.	4

Attachment 1 - International LFG Best Practices Literature Review

Country or Region	Organization	Name of Document	Summary	Type of Information Covered, Focus, Level of Detail & Usefulness	Limitations, Gaps, & Concerns	Relevancy Rating (1 -Very Relevant 4 - Not Very Relevant)
General	International Solid Waste Association (ISWA)	Key Issue: Management of Landfill Gas (2007)	The purpose of this Key Issue paper is to highlight the issues associated with the management of landfill gas at sites used for the disposal of wastes whether they be open dumps or sanitary landfills. Resource supports initiatives that reduce the environmental impacts from landfill gas and any efforts associated with the reduction of its global warming potential.	High level overview of active landfill gas extraction systems and design General discussion of LFG.	This paper is broad and generic, and is intended only to provide a framework of issues that need to be addressed and potential solutions in reducing the environmental impact of landfill gas. May be a helpful primer to ISWA publication "Field Procedures Handbook for the Operation of Landfill Biogas Systems" (described below).	2-3
General	International Solid Waste Association (ISWA)	Waste and Climate Change: ISWA WHITE PAPER (2009)	The goal of this resource is to redefine waste and to set forth the technologies and mechanisms which can transform the waste sector into a net global reducer of GHG emissions.	Resource discusses GHG emissions sources, GHG reduction technologies, and energy recovery technologies Resource highlights that there is unrealized CDM potential within the waste sector, in terms of technology solutions as well as host country coverage. Resource gives a very brief overview of incentives for increasing the use of waste as a renewable energy resource.	Covers all reduction GHG reduction technologies, small focus on LFG technologies. Covers energy recovery technologies for landfill gas in detail. Resource offers suggestions for changes to the CDM program, but does not cover current barriers in detail. Resource does not indicate specific resources that are available, just presents an overview types of incentives.	1-2 2-3
European Union	International Solid Waste Association (ISWA) Working Group for Sanitary Landfills	Field Procedures Handbook for the Operation of Landfill Biogas Systems (2005)	The objective of this resource is to provide EU landfill managers, site operators, and field technicians with a practical reference guide that can be used on a daily basis and contribute toward efficient, safe landfill biogas operations. This handbook is not intended to replace site-specific operation and maintenance manuals.	Resource covers the proper running of: LFG monitoring, using probes typically placed around the landfill perimeter; LFG extraction and collection, using wells and piping; The collection, pumping, storage, and treatment of LFG condensate. The treatment, disposal, or use of LFG using blower, flare, and/or energy recovery equipment. Resource covers description, components, date collection, operation and maintenance of landfill biogas wellfield, conveyance systems, condensate systems, landfill blower systems and biogas flare systems. Provides design detail drawings for many of the system components. Resource covers biogas energy recovery systems - system description, typical components, data measurements, operation and maintenance.	Focus is EU landfills, but material covered is applicable to a wide range of landfills internationally. Resource does not cover treatment of cleaning of biogas.	1 1 1

Attachment 1 - International LFG Best Practices Literature Review

Country or Region	Organization	Name of Document	Summary	Type of Information Covered, Focus, Level of Detail & Usefulness	Limitations, Gaps, & Concerns	Relevancy Rating (1 -Very Relevant 4 - Not Very Relevant)
General	World Bank	Sanitary landfill design and siting criteria (2004)	For two decades, solid waste components in Bank projects have focused on collection of solid wastes, with equipment provided to upgrade operations at existing open dumps. Since early 1990, the private sector has become increasingly involved in the collection, disposal, and treatment of solid waste, and Bank projects have placed greater priority on implementation of new sanitary landfills. The guidance provides an examination of some of the issues which need to be addressed in landfill siting and design.	Good overview information for sanitary landfill siting and design with discussion on what's appropriate for developing countries. Topics include: Minimizing Leachate Generation; Leachate Management; Gas Management; Stability; Composting; Construction Phasing; Sanitary Landfill Siting Criteria; World Bank Environmental Requirements; Private Sector Involvement.	Document is short (6 pages) so each topic is not covered in a high degree of detail.	3
General	SCS Engineers	Current Design Approaches for Landfill Leachate Removal Systems (2007)	Presents current design approaches available for removing leachate from landfills. Discusses: general site layout and pumping requirements; sump and pumping arrangement; pump sizing criteria; hydraulic analysis and pump selection; sump sizing; and controls and power supply.	Good discussion of leachate management techniques.	Does not address issues in developing countries	2
General	World Bank Carbon Finance Unit / SCS Engineers	Guidance Fact Sheet: Landfill Design (2008)	Guidance fact sheet on landfill design	Good overview information in fact sheet form.	Short descriptions of issues involved. Doesn't specifically address developing countries.	1
General	World Bank Carbon Finance Unit / SCS Engineers	Guidance Fact Sheet: Landfill Operations (2008)	Guidance fact sheet on landfill operations	Good overview information in fact sheet form.	Short descriptions of issues involved. Doesn't specifically address developing countries.	1
General	World Bank Carbon Finance Unit / SCS Engineers	Guidance Fact Sheet: Landfill Gas Collection, Flaring, and Energy Recovery Design (2008)	Guidance fact sheet on landfill gas collection, flaring, and energy recovery design	Good overview information in fact sheet form.	Short descriptions of issues involved. Doesn't specifically address developing countries.	1

Attachment 1 - International LFG Best Practices Literature Review

Country or Region	Organization	Name of Document	Summary	Type of Information Covered, Focus, Level of Detail & Usefulness	Limitations, Gaps, & Concerns	Relevancy Rating (1 -Very Relevant 4 - Not Very Relevant)
General	World Bank Carbon Finance Unit / SCS Engineers	Guidance Fact Sheet: Landfill Gas Collection, Flaring, and Energy Recovery Operations and Maintenance (2008)	Guidance fact sheet on landfill gas collection, flaring, and energy recovery operations and maintenance	Good overview information in fact sheet form.	Short descriptions of issues involved. Doesn't specifically address developing countries.	3-4
General	EPA Combined Heat and Power Partnership	Biomass CHP Catalog of Technologies (2007)	Provides resource owners, facility managers, developers, policymakers, and other interested parties with a detailed technology characterization of biomass CHP systems. The report reviews the technical and economic characterization of biomass resources, biomass preparation, energy conversion technologies, power production systems, and complete integrated systems.	Chapter 5 discusses biomass conversion technologies (direct fired systems, gasification systems, modular systems), many of which can use LFG. Chapter 6 discusses Power Generation Technologies (steam turbine, gas turbine, microturbine, reciprocating engine, fuel cell, stirling engine), many of which can use LFG.	Discussion is focused more generally on biomass as a whole and not specifically on LFG. However, LFG is discussed. Focus is also on CHP and not electric or thermal only applications.	3
General	IEA	Turning a Liability into an Asset: the Importance of Policy in Fostering Landfill Gas Use Worldwide (2009)	Identifies and examines global policies, measures, and incentives that appear to be stimulating LFG use. The report begins with background information on LFG and sanitary landfill practices, including a discussion of regional disparities, followed by a description of LFG mitigation technologies. Barriers to LFGE projects are then outlined. An explanation of the importance and effectiveness of policy measures leads into a discussion of types and examples of measures that are being used to overcome these barriers and encourage LFGE development. The report concludes with lessons learned, recommendations for further study, and resources where more information can be found.	Good discussion of primary barriers to LFGE development and policy options for removing barriers/expanding LFGE use. Good examples of policies countries have implemented to expand LFGE use.	Most examples are limited to developed countries. Report does touch on developing countries as well, primarily noting that they do not currently have the best of policies in place to promote LFGE.	3-4