

# Financing Landfill Gas Projects in Developing Countries





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# Urban Development Series

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Produced by the World Bank's Social, Urban, Rural & Resilience Global Practice, the Urban Development Series discusses the challenge of urbanization and what it will mean for developing countries in the decades ahead. The Series aims to explore and delve more substantively into the core issues framed by the World Bank's 2009 Urban Strategy *Systems of Cities: Harnessing Urbanization for Growth and Poverty Alleviation*. Across the five domains of the Urban Strategy, the Series provides a focal point for publications that seek to foster a better understanding of (i) the core elements of the city system, (ii) pro-poor policies, (iii) city economies, (iv) urban land and housing markets, (v) sustainable urban environment, and other urban issues germane to the urban development agenda for sustainable cities and communities.

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A landfill gas flaring system.

Managing the gases produced in municipal landfills and dumpsites is a growing challenge around the world. Landfill gas (LFG), a byproduct of decomposing waste, is flammable, potentially explosive, hazardous to human health, and a significant source of methane, a short-lived climate pollutant (SLCP) that exacerbates climate change in the near-term<sup>1</sup>. Some countries have mainstreamed the technologies that capture and combust LFG before it is released into the atmosphere or convert it into an alternative energy source. However, financing these LFG management systems is a major hurdle in much of the world.

Recognizing that landfill emissions are expected to rise into the foreseeable future, this report outlines a variety of ways that city governments, private landfill owners, or other project developers finance LFG management systems that mitigate these emissions. It is intended to offer policy-makers and practitioners an overview of financing models that have been used around the world and insights from existing projects, including key enabling conditions and risk mitigation strategies.

The report is not, however, a ‘how-to guide’ on financing these projects. Each project has a set of site-specific factors that determine technical and financial viability. As a result, there is not a standard financial architecture that is consistently applied. Rather, any number of different types of financing may or may not be accessible or appropriate at different points in project development.

Thus, readers with a basic understanding of landfill gas collection systems<sup>2</sup> may use this report to gain a general sense of financing options for LFG projects, but every project requires customized financial plans developed by experts that take into account unique environmental, political, and economic conditions. Throughout the document, real-world examples are intended to illustrate aspects of financing strategies that may relate to the reader’s specific situation.

Though each project’s financial arrangement is unique, the basic building blocks for financing LFG projects are not substantially different from those used in other infrastructure or energy projects. Often, these projects are developed using a combination of public or municipal finance, private sector lending or investment, and some forms of environmental finance. Other types of support, including tax benefits or public guarantees, may also play a crucial role in a project’s success.

While both technically and financially complex, LFG projects are often attractive because—unlike many other types of infrastructure investments—they can generate revenue from energy or carbon credit sales. This may allow for cost recovery and even profits, though not all projects can or will be financially self-sustaining.

Discussions of low-carbon infrastructure finance often center on the promise of new financial instruments or products that might increase financial flows to a sector. While some innovative financial mechanisms have gained prominence in the last decade or so (e.g., green bonds, low-carbon investment funds, and others), there is not yet a silver bullet for LFG finance. In fact, the current uncertainty in carbon markets calls into question whether LFG collection is a realistic option in many low- and middle-income countries.

Nonetheless, governments, landfill owners, and other stakeholders recognize the pressing need for both climate mitigation tools in the waste sector and the additional energy that existing landfills can provide. While not always the perfect solution, LFG collection systems can begin to address both these issues in cities around the world—provided they can be sustainably financed.

*This report, as well as a complementary report entitled “Sustainable Financing and Policy Models for Municipal Composting” has been prepared in a collaboration with the Climate and Clean Air Coalition to Reduce Short-Lived Climate Pollutants (CCAC). The CCAC is a global partnership of governments and organizations that works to reduce short-term climate pollutants in a number of sectors, including solid waste. The CCAC and the World Bank generously provided financing for the work conducted.*

*Information in the report is based on both primary sources, including practitioner interviews and public records, and secondary source material, including a number of guidance reports written in the last decade on LFG systems, which are cited throughout.*

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# Acronyms

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<b>BOO</b>	Build-Own-Operate
<b>BOOT</b>	Build-Own-Operate-Transfer
<b>CDM</b>	Clean Development Mechanism
<b>CER</b>	Certified Emission Reduction
<b>CH<sub>4</sub></b>	methane
<b>CO<sub>2</sub></b>	carbon dioxide
<b>CO<sub>2</sub>e</b>	carbon dioxide-equivalent
<b>ERPA</b>	Emission Reduction Purchase Agreement
<b>FDI</b>	Foreign Direct Investment
<b>FIT</b>	Feed-in-Tariff
<b>GHG</b>	greenhouse gas
<b>IBRD</b>	International Bank for Reconstruction and Development
<b>IDA</b>	International Development Association
<b>IEA</b>	International Energy Agency
<b>IFC</b>	International Finance Corporation
<b>IFI</b>	International Financial Institution
<b>IPCC</b>	Intergovernmental Panel on Climate Change
<b>ITC</b>	Investment Tax Credit
<b>kWh</b>	kilowatt hour
<b>LFG</b>	landfill gas
<b>LFGE</b>	landfill gas-to-energy
<b>LMOP</b>	Landfill Methane Outreach Program
<b>MIGA</b>	Multilateral Investment Guarantee Agency
<b>NPV</b>	net present value
<b>ODA</b>	Official Development Assistance/Aid
<b>OECD</b>	Organisation for Economic Co-operation and Development
<b>PPA</b>	Power Purchase Agreement
<b>PPP</b>	Public-Private Partnership
<b>PRI</b>	Political Risk Insurance
<b>PTC</b>	Production Tax Credit
<b>RFP</b>	Request for Proposals
<b>RPS</b>	Renewable Portfolio Standards
<b>SLCP</b>	Short-Lived Climate Pollutant
<b>SPV</b>	Special Purpose Vehicle
<b>UNFCCC</b>	United Nations Framework Convention on Climate Change

# Executive Summary

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The world's landfills and dump sites contain a significant amount of biodegradable waste, including food scraps and agricultural refuse. When these organic materials break down in landfills, various gases known collectively as landfill gas (LFG) are produced and either build-up within a landfill or discharge into the atmosphere. Because of its chemical make-up, LFG is flammable, odorous, and a potent source of greenhouse gases (GHG). LFG management systems that collect and either burn (flare) or convert these gases into energy can help mitigate these problems and contribute to the overall safe operation of a landfill.<sup>3</sup> As an additional benefit, the energy or carbon reductions that are produced by LFG systems can—in some cases—be sold to generate revenue. However, finding the resources to finance these systems can be a challenge, particularly in low-resource settings.

Assessing the value of a prospective LFG project is one of the first steps in determining whether to undertake a project and is critical to attracting financing. Though the process of project valuation is complex, it can be done in a step-wise fashion. At a very basic level, this process requires:

A **technical feasibility assessment** to determine the quantity and quality of gas available over the course of decades; point to best options for gas usage or sales; and highlight whether a landfill needs retrofitting.

An **initial financial feasibility assessment** that gives a scenario analysis of likely costs and revenue for each of the gas usage options identified in the technical assessment; and potential incentives or assistance that might be available.

A **detailed financial & economic assessment** that gives context-specific information including material cost estimates based on manufacturer quotes; various tax liabilities; financing options and payback periods; cash flows, etc.

This report is applicable if the initial technical and financial feasibility assessments conclude that the LFG project can meet stakeholders' environmental and/or financial goals. This detailed assessment describes—as accurately as possible—project-specific financial elements over the lifetime of the system. Ultimately, this process should produce a *pro forma* financial statement with project-specific financial information over the lifetime of the project. Both private sector investors and public sector backers frequently expect this type of information in order to make investment decisions. With this detailed assessment as a base, project owners can compare various scenarios with different system design and financing options.

Assessing financial and economic feasibility requires detailed knowledge of the various resources available for funding or financing an LFG project and knowledge of market opportunities and challenges. While there is no standard financial architecture used in financing LFG projects, there are four main sources of capital and/or operating funds often used in combination to develop and maintain LFG systems:

- **Energy sales or offsets** from selling LFG as a substitute for natural gas or heat; electricity generated from the gas; or using the LFG products on-site to off-set energy expenditures.
- **Public sector funding or financing** via municipal direct investment; municipal bonds; intergovernmental transfers; development aid; and others.
- **Private sector investment**, including commercial loans; equity investments; specialized credit facilities; and a variety of public-private partnerships.
- **Environmental attributes**, which are project characteristics valued for their environmental benefits and may either directly contribute to the project's bottom line (e.g., through sale of offsets on carbon markets) or attract specific types of funding/finance (e.g., environmentally-focused pension funds).

Whether these sources of finance are available largely depends on project-specific characteristics and larger economic or policy factors, such as the current market rate for natural gas or electricity, the availability of tax credits or renewable energy incentives, and even the global price of carbon. Risk mitigation techniques, such as purchasing risk insurance, can sometimes help fill gaps in the enabling environment or improve the overall profile of a project in order to obtain better financing terms. This report offers a detailed discussion of the types of risks often found in LFG projects and provides mechanisms to help manage them. However, without a technically solid project as the base and a supportive legal/regulatory environment, adequate financing can be difficult to acquire.

## Report Structure

This report offers an overview of the range of financial resources that may go into a financial assessment of an LFG system. This includes major sources of capital and operating funds, revenue from energy sales, and descriptions of incentives or support that may contribute to a project's bottom line. Risk mitigation techniques, which are integral to successful financing, are also detailed and may be among the most important aspects to understand when undertaking an LFG project. The report is structured as follows:

- **Chapter 1** gives an introduction to LFG project development and discusses opportunities and challenges faced in developing-country contexts.
- **Chapter 2** outlines the process of evaluating an LFG project's feasibility.
- **Chapter 3** details three broad categories of financing or funding (public sources, private sources, and sources based on environmental attributes of a project) that have been used in various permutations to facilitate the development of LFG infrastructure around the world.

- **Chapter 4** outlines incentive schemes, such as feeder tariffs, beneficial tax structures, public guarantees, subsidies, and co-financing, that are typically essential to a project's development.
- **Chapter 5** describes various types of risk at different stages of project development and offers mitigation techniques based on the advice of experts and practitioners.
- **Chapters 6-8** offer case studies from landfill gas projects in Thailand, Latvia, and Brazil. Shorter case examples intended to illustrate aspects of successful projects or combinations of the financing or funding methods are found throughout the document.

For ease of reading, key messages and lessons are highlighted at the beginning of relevant chapter or section headings.



Drilling to install vertical LFG wells at an existing landfill.

# 1

## Background for Financing Landfill Gas Projects

### Key Messages

While each LFG project has a unique set of factors that influence which sources of finance are available and appropriate, there are some overarching lessons to take away. Key points from experience developing LFG systems in developing countries include the following:

Collecting and utilizing landfill gas is an important means of mitigating GHG emissions and can provide an alternative energy resource—though financing these projects can be complex and may only be profitable under specific conditions.

While there are sometimes good reasons to build LFG systems in developing countries, there are challenges that must be addressed as well.

- Increasing use of municipal landfills and a high content of ‘wet’ or organic waste in rapidly developing countries is leading to increasing emissions from landfills around the world.
- The current and historical waste management practices employed in a landfill are critical to the success of LFG systems, as retrofits can be expensive.
- Finance options may be unavailable or prohibitively expensive in some markets, though demand for new energy resources may help overcome these issues in some cases.

Though financing for every landfill gas project is unique, the process of evaluating the technical and financial options has a general format that can be replicated across contexts.

- A comprehensive analysis of likely costs and revenue under several scenarios is the backbone of a financing strategy—this is complex because technical and financial aspects of LFG projects are interdependent.

The sources of capital for LFG projects are similar to other infrastructure projects, but their availability is context-dependent.

- Public funds or finance may appear to be the least expensive source capital, but onerous procurement rules and lack of existing expertise may make more expensive private sector financing appealing.
- Given the current state of carbon markets, carbon finance may only provide a marginal amount of revenue for LFG projects.
- Long-held principles of infrastructure finance—such as the importance of clear and consistently applied laws and a stable political environment—are key to attracting risk-averse financial institutions and private lenders.

Government incentives and specific risk mitigation tactics are key to achieving viable, bankable projects.

- Price premiums for renewable energy, priority access to the electrical grid and assistance with interconnection, and other incentives may turn an unbankable LFG project into a marginally profitable one.
- Employing proper due diligence, proven technologies, experienced vendors and consultants, and structuring contracts well are the most effective risk mitigation techniques.
- Accurately determining how much gas is accessible and signing a long-term off-take agreement with a utility or other buyer are the two most basic ways to secure an LFG project financially.

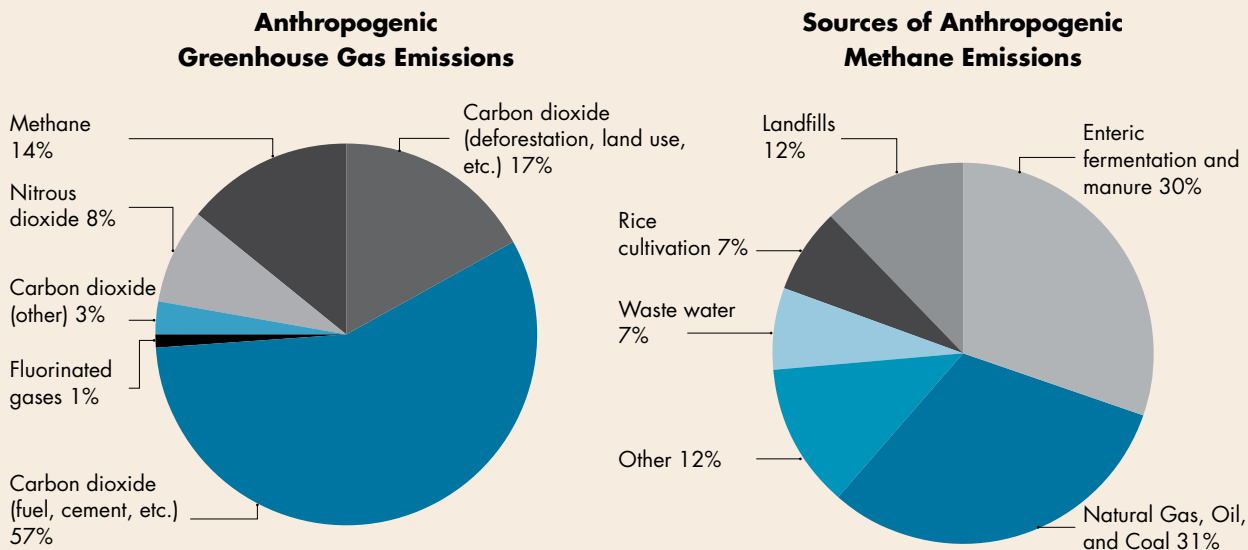
## 1.1 Introduction

Cities produce more than 1.3 billion tons of municipal solid waste every year (Hoorweg and Bhada-Tata 2012), roughly half of which is food scraps or other readily biodegradable organics.<sup>4</sup> When mixed municipal waste accumulates in landfills or open dumps, the organic materials break down anaerobically<sup>5</sup> and produce an assortment of landfill gases (LFG). By volume, LFG is roughly half methane and half carbon dioxide with trace amounts of other organic compounds.<sup>6</sup> Globally, this combination of gases is a significant source of anthropogenic greenhouse gases (GHG) (box 1), with the contribution from landfills estimated to be 2-4 percent of total GHG emissions. However, the effects of LFG production are not confined to the climate change impact. The gas is flammable, potentially explosive, and exposure to carcinogenic compounds found in LFG

may be detrimental to human health.<sup>7</sup> While diverting organic waste entirely from landfills would obviate the need to manage these emissions, a second-best solution is the capture and combustion of LFG before it is released into the atmosphere. Flaring (burning) or converting methane gas into an alternative energy source both reduce harmful emissions<sup>8</sup> and have the potential to generate revenue for local governments or other landfill owners. Though there are many technologies available for LFG collection and combustion, the challenges involved in financing these systems continues to present a major obstacle to mitigating emissions from waste.

Developing landfill gas-to-energy (LFGE) or flaring systems requires a financial investment that is often beyond

**Box 1.** Anthropogenic Greenhouse Gases (2004) and Sources of Methane (2010)



Methane is the second most prevalent greenhouse gas by volume (after carbon dioxide), making up approximately 14% of global anthropogenic GHGs. Of this, landfills are estimated to contribute approximately 12% of methane emissions. Release of methane is of particular concern because it absorbs heat (infrared radiation) that would otherwise escape the planet. In its fifth assessment report (2013), the Intergovernmental Panel on Climate Change (IPCC) determined the 100-year global warming potential of methane to be 28 times that of carbon dioxide.

Sources: IPCC (2007) based on 2004 emissions, U.S. EPA (2012) based on 2010 estimates

the reach of local governments or landfill owners alone (KPMG 2011). In some cases, installing LFG collection pipes<sup>9</sup> and flaring or energy generation equipment can cost tens of millions of US dollars. Obtaining financing typically requires a host of public and private actors (e.g., local government, landfill owners or operators, commercial banks, developers, local utilities) to agree on how to incentivize development, equitably assign risk, divide potential project revenue, and support ongoing operations. Adding further complexity, the profitability of LFG systems is subject to volatility in natural gas, electricity, and carbon markets, as well as other factors such as regional variation in the cost of maintenance, availability of skilled labor, and ability to obtain spare parts. Consequently, LFG is a largely untapped municipal asset across both developing and many developed countries.

Because financing options are highly context-dependent—reliant on the conditions of both the landfill (e.g., gas availability, quality) and the larger economy (e.g., local energy demand, global price of carbon)—there is no single standard financial architecture that can be widely applied to LFG projects around the world. In many instances, the particular goals of a landfill gas program may determine how the project’s financing is structured.<sup>10</sup> For example, if a landfill gas project is motivated by compliance with greenhouse gas emission regulations, the target capital return may be low, as compared to projects that are primarily concerned with generating profit or offsetting energy expenditures. Similarly, the division of ownership over landfill assets (landfills and attendant gas rights may be public, private or jointly controlled) and operations (e.g., whether there is internal capacity to develop LFGE infrastructure) will define implementation options and directly impact the means of funding. That said, project goals and even asset ownership may themselves be altered to adapt to available financing tools.

How then does a landfill owner or other developer raise funds for the capital investment and operations and maintenance (O&M) of a landfill gas system? Some LFG systems have been funded by public sector resources and central government transfers, while others have been

financed entirely through private debt or equity. More often than either a fully governmental or fully private operation, a mixture of both innovative and traditional infrastructure-finance methods—including municipal infrastructure bonds, public-private partnerships, and leveraged government incentives—have been used to build LFG systems.

Key project characteristics that influence both revenue generation and finance options vary widely from landfill to landfill. Further, as in many long-lived infrastructure projects, the most appropriate types of financing may change over the course of project planning, construction, and operation. However, recognizing that LFG projects typically rely on customized financial arrangements, this paper outlines four broad categories of financing or funding,<sup>11</sup> and specific enabling conditions that have been used successfully in various permutations to facilitate the development of LFG infrastructure around the world:

- Public funding, including sub-sovereign or municipal direct investment, municipal bonds, intergovernmental transfers and assistance from public financial intermediaries;
- Private sector investment, such as commercial loans, equity investments, and public-private partnerships;
- Environmental attribute finance and/or energy sales, including carbon finance from both compliance and voluntary markets, emerging financing options linked to the climate or broader environment, and direct LFG or energy sales; and
- Publicly-backed incentives schemes such as feeder tariffs, beneficial tax structures, public guarantees, subsidies, and co-financing.

Beyond financing sources, this document outlines areas of risk inherent to LFG project development and operation that impact a project’s financial viability; provides techniques for minimizing or off-loading risk based on practitioner advice; and offers case-studies of financing approaches from projects around the world.

## 1.2 Landfill Gas Investments in Developing Country Contexts

While recent efforts in wealthy countries have slowed the overall rate of growth for methane emissions globally (U.S. EPA 2012), emissions from landfills in developing regions are expected to grow into the foreseeable future (IEA 2009). Thus, targeting LFG projects outside high-income countries may be an important means of abating future global methane output and of capturing new energy resources for developing markets.

Financiers and project developers cite a number of challenges, as well as potential upsides, to working outside the highly regulated markets of developed countries. Countries with rapidly growing populations, increasing energy needs, and large volumes of organic waste may offer substantial support for LFG project development. The following are issues to consider when developing LFG systems in developing country contexts:

- *Waste management practices.* While waste in developing countries tends to have a high biodegradable content—a desirable characteristic for landfill gas recovery projects—the existing and historical waste management practices of a landfill also play a major role in determining the volume of gas any landfill will produce. Accurately modeling gas production potential from an improperly designed or managed landfill or dump site with little or no historical data on the volume and composition of waste is often impossible, and thus a serious impediment to investment. LFG systems are most productive in sanitary or engineered landfills that have liners, leachate management systems, active compaction and covering in confined areas, and capping. In open or minimally managed dumps, waste

is often spread thin without cover materials or liners, leading to more aerobic decomposition and less ability to control factors that impact gas production, such as rainwater content.

Some practitioners believe that it is only advisable to consider an LFG project in landfills that have a record of proper management unless one or more stakeholders is able to retrofit the site and commit to appropriate landfill maintenance moving forward. Though this paper focuses on financing the landfill gas collection and combustion systems themselves, it is worth noting that the expense of capping or otherwise upgrading a dumpsite may be cost-prohibitive from the outset<sup>12</sup> or rely on substantial public funding or development aid to prepare the site.

- *Material and labor.* While labor and materials may be inexpensive in some developing countries as compared with many highly industrialized nations, practitioners have cited the lack of a supply chain for certain materials and a dearth of in-country experience developing LFG systems as major roadblocks. This lack of knowledge of or exposure to LFG projects has been an issue at all levels—from the ability to hire experienced construction workers to gaining support from policy-makers.
- *Political, legal, and regulatory environment.* As in any infrastructure project, LFG projects are most easily financed in markets that support a dynamic financial sector that allocates financing efficiently. This is typically achieved when sound financial regulation, robust institutions, and clear and predictable signals from the government are able to allay the real or perceived risk that is often associated with investment in developing markets. While a change of political party or leadership may impact the viability of any LFG project in both

**Table 1. Change in Methane Emissions by Country Income Group (1990-2010)**

	Total thousand MtCO <sub>2</sub> e (2010)	Percent Change (1990-2010)
World	7,515,150	+16.9
Low income countries	494,111	+8.4
Middle income countries	4,901,207	+35.8
High income countries	2,119,832	-10.2

Source: World Bank World Development Indicators (2014)

developed and developing countries, a predictable legal and regulatory framework around landfill operations, contracts, and other ancillary activities or industries (e.g., energy markets) act as a backstop to this type of risk.

- *Carbon finance and other saleable environmental attributes.* Generating revenue for LFG projects via carbon markets held great promise in the early 2000s, particularly for projects in developing countries that could sell carbon credits to wealthy countries through the Kyoto Protocol's Clean Development Mechanism (CDM). While carbon markets have proven less profitable than once expected, these markets can still provide some added incentive to invest. Further, in both developed and developing countries, governmental actions that incentivize LFG recovery (e.g., tax breaks, feeder tariffs) can be crucial to attracting investment.
- *Energy infrastructure.* Existing energy infrastructure may require upgrades before it can accommodate electricity or gas produced by LFG systems. Selling methane gas for direct use and selling electricity onto a local grid are important means of recovering costs in LFG projects, though they require transmission infrastructure and consistent regulation around distributed energy production. Some landfill operations may find value in direct usage of the gas. However, the availability of a grid connection and consistent government regulation around the small-scale production of energy is a clear signal to investors that there is potential for ongoing profit to be made.
- *Community engagement.* Beyond purely financial considerations, employing appropriate social and environmental safeguards as well as obtaining the support of communities surrounding LFG abatement

sites are key to overall project success in both developed and developing country contexts. A history of mismanaged community relations by LFG developers may be a red flag to potential investors.

In addition to these considerations, the choice of technology for processing LFG may be dictated by the income level and maturity of the LFG industry in a particular region. Some countries with established LFG sectors are experimenting with novel uses for the gas—for example, as vehicle fuel. However, this report mainly considers three technologies—gas capture and flaring, direct-use of gas, and electric power or co-generation of heat and power—that are the most prevalent uses in developing country contexts (box 2). There are less common examples in developing countries of LFG being scrubbed for use as pipeline-quality gas and so it is mentioned here, but not elaborated on.

With this introduction as a base, the following chapters will present more detailed considerations of the range of commonly used financing mechanisms described above. Chapter 2 briefly outlines the process of financial evaluation of an LFG project. Chapter 3 describes three major sources of funding or financing for LFG projects—public, private, and environmental attribute-based. Chapter 4 addresses the range of incentives for LFG development, typically enacted by a local or national government, which can enhance overall project timelines and revenue. Chapter 5 describes the various types of risk that a typical LFG project, particularly in a developing country, is exposed to and proposes means of mitigating or distributing these risks. Last, Chapters 6-8 offer a series of case studies to present lessons that have been learned from prior attempts at LFG projects in a range of countries.

**Box 2.** Relevant End-Products of Landfill Gas Processing Systems

System	Description
<b>Capture and flaring</b>	Open or enclosed flaring systems are used to combust the methane content of landfill gas, converting it into carbon dioxide and water. Though flare systems require monitoring and assessment, <sup>13</sup> they are generally less expensive to install than power-generating alternatives. However, options for monetizing the end product are limited to carbon finance markets. Enclosed (shrouded) flame flares tend to be more reliable and efficient than open flame flares, though they are somewhat more expensive (Cheremisinoff 2003).
<b>Direct-use</b>	Landfill gas can be used on-site or piped to nearby industry (<10 km) (World Bank 2004) to be used as a substitute for conventional fuels. Medium-grade or low-grade fuel (denoting level of treatment of raw LFG) is the form most often used in direct applications. These grades of LFG are typically used in fuel-intensive activities such as in firing water boilers, heating cement kilns, running microturbines). LFG is sometimes combined with standard natural gas if a higher energy value is required. Depending on the quality of fuel generated, some direct-use applications may require greater O&M to manage the effects of impurities in the gas. End-users may also have to make hardware adjustments so that methane can be used instead of LFG or other gases. Boilers are among the least expensive technologies and have the least carbon monoxide and nitrogen oxide emissions of the available combustion technologies (Cheremisinoff 2003).
<b>Electric power and/or cogeneration</b>	Electricity generation can be a lucrative use of LFG, provided there is demand and sufficient capacity within existing utilities to accommodate distributed energy providers. Reciprocating or internal combustion engines and micro- and combustion turbines are typically chosen, based on the volume of gas and emissions considerations. Cogeneration of electricity and thermal energy, which is typically used in steam production, is possible, so long as there is a local, year-round use for the product. Internal combustion engines are considered the 'dirtiest' technology in terms of emissions (Cheremisinoff 2003). Gas turbines are comparatively more environmentally friendly.
<b>Pipeline gas</b>	After purification to create a high-grade fuel, LFG can be injected directly into existing natural gas pipelines that go to homes/businesses for heating or cooking. A similar level of processing is required for other advanced applications, such as creation of auto fuel additives or industrial chemicals. Natural gas is nearly entirely methane, whereas unprocessed LFG contains only about 50 percent. The carbon dioxide, hydrogen sulfide, water vapor and other impurities must be scrubbed from LFG and the remaining gas then needs to be pressurized before it is connected to the pipeline distribution network. This is not currently a widely-used option due to the expense of cleaning the gas, though it may become an area of expansion if the price of natural gas increases.

# 2

## Assessing Project Value

### Key Messages

- While the financing for every landfill gas project is customized, the process of evaluating the best technical and financial options has a general format that can be replicated across contexts.
- A comprehensive analysis of likely costs and revenue under several scenarios is the backbone of a robust financing strategy.
- Initial technical and financial feasibility of LFG projects may be assessed using freely available models, though experts in LFG project design and finance are vital to obtaining comprehensive project valuations.
- Potential financiers typically need to understand financial and economic performance indicators such as:
  - Annual and lifetime capital and O&M costs
  - Internal Rate of Return (IRR)
  - NetPV of annual and project lifetime cash flows
  - Simple Payback Period
  - Debt Coverage Ratio

### 2.1 Overview of Financial Analysis in LFG Projects

Assessing the value of a prospective LFG project is one of the first steps in determining whether to undertake an LFG project and how to finance it.<sup>14</sup> Not only do private-sector investors and public sector backers often expect detailed financing projections in order to make investment decisions, evaluating the lifetime costs and revenues of different system designs is important for selecting among the available technologies. Producing this detailed financial analysis to compare the options is an iterative process that relies first on the following:

**A. A technical feasibility assessment** that includes the quantity and quality of gas available in each landfill cell over the project lifetime; best potential options for gas usage or sales; and information about whether landfill retrofitting is necessary. Often, a first pass at this type of study can be done using any one of a number of freely available landfill gas modeling tools,<sup>15</sup> though a thorough study should follow up.

**B. An initial financial feasibility assessment** that includes analyses of likely costs and revenue for each of the gas usage options identified in the technical assessment, often based on models or typical costs/revenue; estimated financing costs; potential incentives, assistance or other support; and estimated tax liability in addition to other aspects.<sup>16</sup>

If these analyses are satisfactory, the next step is a detailed financial and economic assessment, which describes project finances over the lifetime of the LFG system as accurately as possible.

**C. A detailed financial and economic assessment** includes project-specific information on capital and O&M costs, project revenue, financing costs, inflation rates, tax liabilities, and other financial considerations. From this assessment, potential investors will look at factors such as annual and lifetime capital and O&M costs, Internal Rate of Return (IRR), Net Present Value (NPV) of annual and project lifetime cash flows, and debt coverage ratio.

Typically, these measures of economic performance are generated using a financial *pro forma*, a spreadsheet-based

### Key Steps Leading to Detailed Assessment of LFG Project Economics and Finances

#### A. Technical feasibility assessment

- Gas quality and quantity over time
- Potential gas utilization options
- Landfill retrofit needs



#### B. Initial Financial Feasibility Assessment

- Costs and revenue of each gas usage option, typically based on models
- Other revenue streams, incentives, etc.

Is it likely the project will meet the environmental and/or financial goals of the stakeholders?



#### C. Detailed Financial & Economic Assessment

- Context-specific cost and revenue estimates based on actual bids, quotes, etc.
- *Pro forma* financial statement with total expected capital costs, IRR, debt-coverage ratio, NPV, etc.
- Financing resources and associated cost of capital
- Scenario analyses of different gas usage options

tool used to estimate annual and lifetime cash flow of a project. Experts in LFG finance often have *pro forma* models that account for conditions of a specific place and time, though few are publicly available.

### 2.1.1 Assessing Financial and Economic Feasibility

The initial and the detailed financial analyses rely on similar information, though they require different depths of knowledge. The U.S. EPA, in their *LFG Energy Project Development Handbook*,<sup>17</sup> breaks down the financial assessments into the following required steps:

**Step 1** Quantify total capital and O&M costs (for every system design option)

**Step 2** Estimate total revenue

**Step 3** Assess financial feasibility using performance measures (IRR, NPV, etc.)

**Step 4** Compare all the feasible options and choose winning designs

**Step 5** Assess the project financing options for the chosen designs

**Cost factors for LFG (Step 1).** Quantifying the costs of different LFG systems requires information that is specific to a landfill and economic factors in its location. For example, the lengths of pipes required will depend on landfill depth and the cost of purchasing and installing those pipes depends on the existing market factors. However, common capital and O&M expenses (U.S. EPA 2015b) across all systems include:

- LFG collection infrastructure
- System design and engineering
- Construction and materials
- Labor
- Financing costs
- Taxes
- Permitting costs
- Insurance coverage
- Administration and oversight
- Site preparation

**Estimating Revenue (Step 2).**<sup>18</sup> The products generated by LFG systems are monetized in a number of ways, ranging from the sale of greenhouse gas emissions reduction credits on carbon markets to off-setting on-site energy expenditures at the landfill (table 2). Identifying one or more off-taking entities that will commit to a medium- or long-term purchase agreement (in the range of 5-20 years) is among the most important means of securing the project's financial sustainability and attracting outside investment. Identification of an off-taking entity early in the project cycle may also inform what type of processing system is used.

**Assess financial feasibility (Step 3).** As described in the previous section, a detailed financial assessment is most often carried out using a specialized *pro forma* that details costs and revenue over the lifetime of a project and includes information or assumptions based on economic, environmental, political, and landfill-specific conditions.<sup>19</sup> Cost and revenue information from prior two steps should be included, as well as costs of financing, inflation rates, tax considerations, expected product price escalation rates, risk sensitivity, etc. (U.S. EPA 2015b). From this analysis, the following indicators are often used to assess financial feasibility:

- Annual and lifetime capital and O&M costs

- IRR
- NPV of annual and project lifetime cash flows
- Simple Payback Period
- Debt Coverage Ratio

**Compare feasible options and assess financing (Steps 4 & 5).** Once the financial assessment is complete, different project design scenarios can be compared and ranked based

on their economic indicators. Non-price factors, such as likely investor preferences or appetite for risk, may be considered as well. Often, project designs are not selected purely based on the financial assessment, but based on different stakeholder requirements. Sources of finance are then fully analyzed to find the right mix of funds over the course of the project life time. The following chapter details key sources of financing for LFG projects.

**Table 2. Revenue Considerations of Different Processing Systems**

System	Monetization	Revenue Considerations
<b>Capture and flaring</b>	<ul style="list-style-type: none"> <li>• Sale of emissions reduction credits on carbon markets</li> <li>• Cost savings from adhering to regulations</li> </ul>	<ul style="list-style-type: none"> <li>• Funds available from carbon markets, if applicable</li> <li>• Ability to undertake the documentation and verification requirements for registering for carbon credits</li> <li>• Expense of verifying output for carbon markets</li> <li>• Gas-rights royalties expected from third-party developers</li> <li>• Annual estimated O&amp;M of 4-8% of investment costs (Terraza and Willumsen 2009)</li> </ul>
<b>Direct-use</b>	<ul style="list-style-type: none"> <li>• Avoided on-site energy expenses</li> <li>• Sale of gas to nearby industry</li> <li>• Sale of emissions reduction credits</li> </ul>	<ul style="list-style-type: none"> <li>• Year-round demand for the gas from nearby off-taker and/or ability to use gas to displace on-site energy needs</li> <li>• Modification of existing equipment for burning of LFG</li> <li>• Level of refinement needed by off-taker, as determined by higher- or lower-grade methane requirements</li> <li>• Cost (or terms of cost-sharing arrangement) for delivery infrastructure/piping</li> <li>• Replacement of parts due to corrosive elements in low-grade gas</li> <li>• Price of conventional or competing fuels (California Energy Commission 2002)</li> <li>• Available subsidies and gas-rights royalties</li> </ul>
<b>Electric Power and/or Cogeneration</b>	<ul style="list-style-type: none"> <li>• Avoided on-site energy expenses</li> <li>• Sale of electricity onto the grid</li> <li>• Sale of heat to local industry/utility</li> <li>• Sale of emissions reduction credits</li> </ul>	<ul style="list-style-type: none"> <li>• Electricity buy-back rate and terms of power-purchase agreement, especially length</li> <li>• Subsidies or governmental incentives for energy production</li> <li>• Ability to and cost of connecting to the grid, including connection lines, step-up transformer, etc.</li> <li>• Expected price of competing electricity over the lifetime of the LFG system</li> <li>• Year-round off-taker for heat/steam, if applicable</li> <li>• Available gas-rights royalties</li> <li>• Annual estimated O&amp;M of 10-12% of investment costs, depending on technology used (Terraza and Willumsen 2009)</li> </ul>
<b>Pipeline Quality Gas</b>	<ul style="list-style-type: none"> <li>• Avoided on-site energy expenses</li> <li>• Sale of purified gas to local utility</li> <li>• Sale of emissions reduction credits</li> </ul>	<ul style="list-style-type: none"> <li>• Price of refined LFG compared to natural gas</li> <li>• Added expense for purification</li> <li>• Cost (or terms of cost-sharing arrangement) for delivery infrastructure/piping</li> <li>• Expense of avoiding the intake of oxygen into the landfill system (ex-post removal of extra nitrogen and oxygen is cost prohibitive) (California Energy Commission 2002)</li> <li>• Price of conventional or competing fuels</li> <li>• Available subsidies and gas-rights royalties</li> <li>• Annual estimated O&amp;M of 17-21% of investment costs (Terraza and Willumsen 2009)</li> </ul>



A condensate knockout pot and pumping system at the Orange County MSW landfill, North Carolina. If condensate is not removed, it can block the collection system and disrupt energy generation.

# 3

## Sources of Funding and Financing for Landfill Gas Systems

### 3.1 Public Funds: Municipal Finance for LFG Systems

#### Key Messages

- While public sector financing is typically an inexpensive source of financing, local governments are often not able to fully fund or finance LFG projects through own-source revenue or public debt.
- Most local governments have not developed a knowledge base around LFG projects, which necessitates bringing on experienced partners and investors, despite the potential loss of control and revenue.
- Obtaining some public backing is often useful in attracting other resources.
- Though municipal bond financing can be an important source of inexpensive financing, bond markets are not well-developing in most places in the world.
- Access to international aid or financial assistance is often mediated through governments and may not be available to fully private operations.

Local governments around the world are facing the mounting challenge of providing infrastructure for growing urban populations. While capital-intensive infrastructure investments such as LFG plants were once predominantly the domain of national governments, the trend of devolving fiscal responsibilities from central to local governments has left municipalities to bridge the gap between limited local revenue and the long-term requirements of growing populations. In many places, local government revenue is already stretched to cover the basic operation and maintenance of existing infrastructure. Finding room in municipal budgets to finance LFG projects is difficult under these conditions, particularly because gas collection does not constitute a core part of municipal waste service

delivery. Aside from exceptional cases in which cities or utilities are able to take on the full financial risk of developing LFG systems, public money usually only covers a portion of capital expenditure.

Nonetheless, motivated by profit or compelled by regulation, some local entities have found ways to mobilize financing for LFG capture and combustion systems. Securing local funds through direct municipal investment or municipal debt, or tapping government policies that support investment (e.g., mandated price guarantees for renewable energy) can be an important first step in leveraging other sources of finance. At a sub-sovereign level, there are three main channels used to support landfill gas operations:

- municipal own-source revenue, which is mostly generated through local taxes, fees, and the lease or sale of municipal assets;
- debt or borrowing through bonds and special financial facility assistance; and
- central government transfers

#### 3.1.1 Own-Source Funds

**Own-source revenues.** Direct municipal funding of LFG projects relies on own-source revenues, or those funds that are raised directly by a local government through taxes, fees, and the lease or sale of municipal assets (e.g., property tax, parking fines, business licenses, land-lease fees). These are funds that make up part of a city, county, or public utility's operating budget. In principle, funding an LFG project entirely through own-source revenues is an attractive option. It eliminates the debt servicing required in conventional borrowing, making it among the cheapest sources of capital, and seemingly gives a local authority greater control over the project timeline. Further, without third-party investors, all project revenue reverts to the city or landfill owner.<sup>20</sup> However, there are very few examples of cities self-financing entire LFG projects. The primary reason is that most municipalities do not have the funds on-hand and are not likely to be able to raise funds from the local tax base.

### Box 3. Using Own-Source Revenues to Attract Private LFG Developers

Wake County, North Carolina, located in the southeastern United States, developed one of the largest landfill methane-to-power facilities in the region by starting with **own-source revenue**. The county spent US\$2.0 million installing vertical gas wells and a blower/flare station for its landfill and, with that infrastructure in place, found a private developer to commit to installing a 6 megawatt electricity-generation system that has the potential to be expanded to 12 megawatts over time. The private company, Ingenco, sells electricity onto the local grid and will pay the county approximately US\$17.7 million over 15 years for rights to the landfill gas.

The initial own-source revenue investment was generated by the county's division of solid waste through tipping fees, selling recyclables, and from a county-wide annual waste fee of US\$20 per-household. With a population of nearly one million, the division has seen a surplus of approximately US\$1.0 million per year for the past few years and chose to invest in the beginnings of an LFG project. The county's solid waste management division put in place an **enterprise fund**, which separates its own-source revenue from the county government's general operating budget. These funds are then able to feed back into the solid waste program to pay for capital investment projects.

*Source:* Roberson (2014)

Local governments typically have not developed deep knowledge regarding LFG projects. Assuming the full project risk without adequate technical and financial-management capacity effectively increases risk and costs. Thus, municipal governments often seek to distribute the risk by involving experienced partners and investors, despite the potential loss of control and revenue. As illustrated in box 3, however, own-source revenue may be used as part of a financing mix. In particular, a city may choose to invest own-source revenues in landfill upgrading (e.g., repairing a leachate collection system or adding an impermeable layer) to make it a more attractive investment opportunity.

**Land-based finance.** Among the methods of generating own-source revenue, land-based finance may hold some promise for generating revenue that is directly related to LFG development. Land-based financing instruments are used to generate public revenue while encouraging specific kinds of urban development through incentives, taxes, or exactions. In some cases, proceeds from the sale or lease of public land are simply earmarked for the provision of basic municipal services.<sup>21</sup> Betterment levies, in which land owners are assessed a one-time fee based on the increase in land value that results from a public work (Peterson 2009) may be a source of revenue that could be directed to LFG systems. When constructed properly with adequate cover and leachate control, LFG projects can reduce odor and decrease the release of gases that pose a threat to human health.<sup>22</sup> Depending on the location of the landfill and

whether occupants of the surrounding area stand to benefit substantially in terms of increasing land value, this one-time fee could generate some of the up-front capital needed to develop LFG infrastructure.

### 3.1.2 Municipal Debt

**Sub-sovereign bonds.** Subnational borrowing through municipal bonds<sup>23</sup> or an emerging asset class called "green bonds" are sometimes a source of capital finance,<sup>24</sup> though subnational-level bonds are very rarely used in developing country contexts to fund this type of infrastructure. Municipal bonds are debt obligations issued by public entities, such as cities or public utilities, which are used to finance public facilities and infrastructure.<sup>25</sup> Depending on the policies of the local and national government, publicly issued bonds may be tax-deferred or exempt from national taxes entirely. A well-structured bond issued by a creditable source has a longer maturity and lower interest rate than most other forms of debt (often 1-2 percent less than commercial debt) (U.S. EPA 2015b). These features are particularly helpful in financing landfill gas and other infrastructure projects that have a natural lag between when capital investment is required and when the project begins to generate revenue.

In general, bond issuance specifically for LFG projects is rare, likely because the transaction costs associated with a bond tender are often too high to justify the relatively

### Note on Municipal Capacity and Market Access

Accessing debt markets or attracting private sector participation often requires advanced capacity within local governmental or public utilities to manage municipal finances, as well as legal and institutional frameworks that protect the assets and interest of both the public entity and outside partners. As a result, municipalities of different sizes and capacities are able to access different kinds of financing.

For example, small or semi-rural localities in Colombia are less able than their larger counterparts to generate substantial own-source revenue and, as a result, depend largely on national government transfers to finance infrastructure. Mid- to large-size Colombian cities, on the other hand, are able to generate more own-source revenue in both absolute and per capita terms. Partially as a result of this, the larger cities have greater access to international capital markets and can more effectively finance infrastructure without sovereign intervention.

*Source:* Kim et al (2012)

small amount of capital required for the project.<sup>26</sup> As in the example from Johannesburg (box 4), however, bonds may be structured so that an LFG project constitutes one of several infrastructure investments covered by a large issue. Though there are no hard and fast rules, bonds that generate less than tens of millions of dollars are often not considered cost-effective (Winpenny 2008).

**Green bonds.** Green bonds or climate bonds comprise a relatively new subset of the bond market that focuses

specifically on financing projects with an environmental or climate change impact. Though not necessarily tendered by municipalities, green bonds and climate bonds are an increasingly popular means of attracting finance for environmentally conscious infrastructure development, including LFG projects.<sup>27</sup> Green bonds finance environmentally-focused infrastructure and may be linked with either a specific project or, as in the case with the World Bank's Green Bonds,<sup>28</sup> they may be put toward an overall portfolio of green infrastructure projects.<sup>29</sup> In concept and in practice, green bonds do not differ significantly from other bonds—they are weighted by risk and the cost of capital is largely predicated on whether the issuer is creditworthy. However, with an environmental theme, they appeal to sovereign wealth funds, pensions, and other large institutional investors that want to choose climate-friendly investments over similarly valued options.

### 3.1.3 Quasi-Public, National, and Supra-National Finance

**Public banks and financial intermediaries.** Though commercial bank lending is well established in many cities around the world, municipal infrastructure projects often fall outside the scope of these lenders, both in terms of the amount of money a local bank is able to lend and period of time for which they are willing to sustain debt (PPIAF 2013). In some places, municipal development funds (MDFs) or specialized financial intermediaries exist to fill this lending gap and provide local authorities with the funds to make necessary capital investments. They provide any of a range of financial products and services, including advisory services, loans, guarantees and underwriting,

#### Box 4. First Municipal Green Bond in Africa Issued by Johannesburg

In June 2014, the city of Johannesburg listed a US\$140 million green bond on the Johannesburg Stock Exchange. The bond—which has a 10.18 percent annual interest rate and reaches maturity in 2024—was oversubscribed by 150 percent. It is the first of its kind listed by any government in the C40 Cities Climate Leadership Group, a network of cities from both developed and developing countries committed to addressing climate change. Though the city invested in landfill gas infrastructure prior to the issuance of this bond, proceeds will fund the city council's green agenda, which includes addressing the climate impact of transportation, buildings, and waste. The city has a history of issuing municipal bonds for infrastructure projects dating back to 2004, but it is only one of a few municipalities on the continent to have ever successfully issued a bond.

*Source:* City of Johannesburg (2014); Standard Bank (2014)

equity investment, and bond preparation (Alam 2010). Some of these institutions serve as conduits of public funds, administering or on-lending national government funds or foreign aid to local governments. Others serve as a bridge for local governments to access private investment from both domestic and foreign markets.

In some instances, financial intermediaries may be able to play an important role in assisting several municipal governments pool risk to finance an LFG system in a jointly used or held landfill. Not all subnational entities will be able to issue bonds or access acceptably cheap financing, no matter how large their infrastructure finance needs are. Because small- and medium-size cities generally have less access to domestic or international credit markets than their larger counterparts, pooling their resources may allow smaller participants to engage in issuing debt. This can be facilitated by specialized banks or facilities dedicated to organizing financing for multiple parties.<sup>30</sup> While pooling debt is not a common practice because of its complexity, it practice may be particularly relevant for regional landfills that accept waste from a number of small municipalities that individually lack the ability to finance an LFG system independently.<sup>31</sup>

**Intergovernmental transfers.** In many countries, national government institutions have traditionally been the primary or exclusive sources of funds or financing for infrastructure investment. Though decentralization in many places has devolved responsibility down to local governments, concurrent powers to raise funds are often not granted. This creates a heavy dependence in some places on intergovernmental transfers for infrastructure investment. There are various types of intergovernmental transfers, including ad hoc grants, formulaic recurrent transfers, and capital transfers—any of which may be used to support LFG projects, depending on national-level requirements.

Performance- or output-based transfers are also gaining popularity as a tool for promoting financial solvency or service provision goals among municipal governments. Performance-based transfers differ from conventional transfers in that they rely on performance assessments and only once a specified performance or output is verified

### Note on Development Aid in LFGE

Interest in LFG projects by national and multinational development institutions grew after mechanisms of the Kyoto Protocol made it possible to generate carbon revenue from LFG systems. In 2002, approximately 0.007 percent of all international aid projects involved landfill gas recovery (exclusive of Kyoto-related emissions reduction purchases). However, development aid flows to LFG – which does not include funds that go to meet a country's requirements under the Kyoto protocol – decreased in the mid-2000s when the compliance carbon market grew in prominence.

*Source:* Michaelowa, Axel and Katharina (2010)

the transfer is disbursed (Kim et al 2012). Tanzania, for example, has linked local government performance in financial management, planning, and transparency to capital development grants since 2005 (Alam 2010). Depending on national prioritization of methane mitigation, performance-based transfers could be used as effective tools to encourage local landfill gas system development.

**Official Development Assistance (ODA).** For both national and subnational governments, international development aid has been an important source of co-financing or support for landfill gas projects in developing countries and is cited in examples throughout this paper. International development organizations have assisted in developing public-private partnerships around landfill gas operations, undertaking pre-project environmental assessments, funding emissions verification studies, and building capacity within local utilities to manage power purchase agreements. Development agencies also provide a range of credit-enhancing products, such as loan guarantees, that are discussed in the next chapter.

## 3.2 Private Sector Finance of Landfill Gas Projects

### Key Messages

- Private sector involvement in LFG projects may add value in terms of experience and efficiency, but will often demand higher returns than public sector financing options.
- Equity investment partners can typically move projects forward faster than other lenders, though equity is typically an expensive means of acquiring capital and project developers may lose control over aspects of project design.
- While project finance offers nonrecourse project development, transaction costs and private sponsor revenue expectations can be high and lenders may require added protections, such as minimum debt coverage requirements.
- PPP contracts must be negotiated carefully in order to avoid lock-in to terms that may not be advantageous in the long-run.

In the infrastructure sector broadly, private finance is typically more expensive than public finance options.<sup>33</sup> While some governments are able to provide relatively inexpensive financing or funding for LFG projects, a variety of factors (e.g., public procurement rules, start-up costs associated with insufficient existing expertise) may render public money less efficient or less flexible than private options (Delmon 2009). Thus, private funds are sought (in addition to or in place of public funds) with the expectation that private sector involvement will increase efficiency in the overall project such that it outweighs any added cost.

There are a number of hurdles to private sector investment that apply to both landfill gas projects specifically and infrastructure investment more generally in developing economies. For example, the ability to leverage market-based funds at a reasonable rate depends in large part on the quality of local and national governance and the level of real or perceived risk in a particular location (Freire 2014). Investors are hesitant to commit large amounts of money to projects such as LFG systems in the face of legal,

political, and economic uncertainty and a shallow history in the local credit markets.<sup>34</sup>

### 3.2.1 Private finance mechanisms

There are a handful of finance mechanisms and techniques commonly employed by the private sector to engage in LFGE projects. The primary means of obtaining funds for a project are through debt or equity with vital supporting roles played by insurance providers or guarantors and, in some instances, rating agencies.

**Project finance.** Project finance is a commonly used method of structuring ownership and financing in infrastructure projects. It relies on the success or failure of a specific project (as opposed to the balance sheets of a specific company) to pay debt holders and equity owners. Typically, shareholders of a project set up a new legal entity or in-country company—a special purpose vehicle (SPV)—intended to channel funds to the project and capture revenue or cash flow. This new entity is often the primary point of contact for a host of contracts, including the equity agreements with shareholders, concession contracts with local governments, operation and maintenance contracts with contractors, and others (see box 5). Project assets are typically used to securitize debt from bank loans or other sources. Because there is often no recourse to the balance sheets of a larger company, project finance requires a great deal of investigation by lenders to ensure the quality of the project and verify the financial projections made by project sponsors.<sup>35</sup> Often, small finance companies, banks, and landfill or energy developers will use this approach. Disadvantages of this method of financing include high transaction costs and that lenders have a high ‘hurdle rate’ or minimum rate of return, sometimes requiring 4-5 percent above a corporate loan (California Energy Commission 2002).

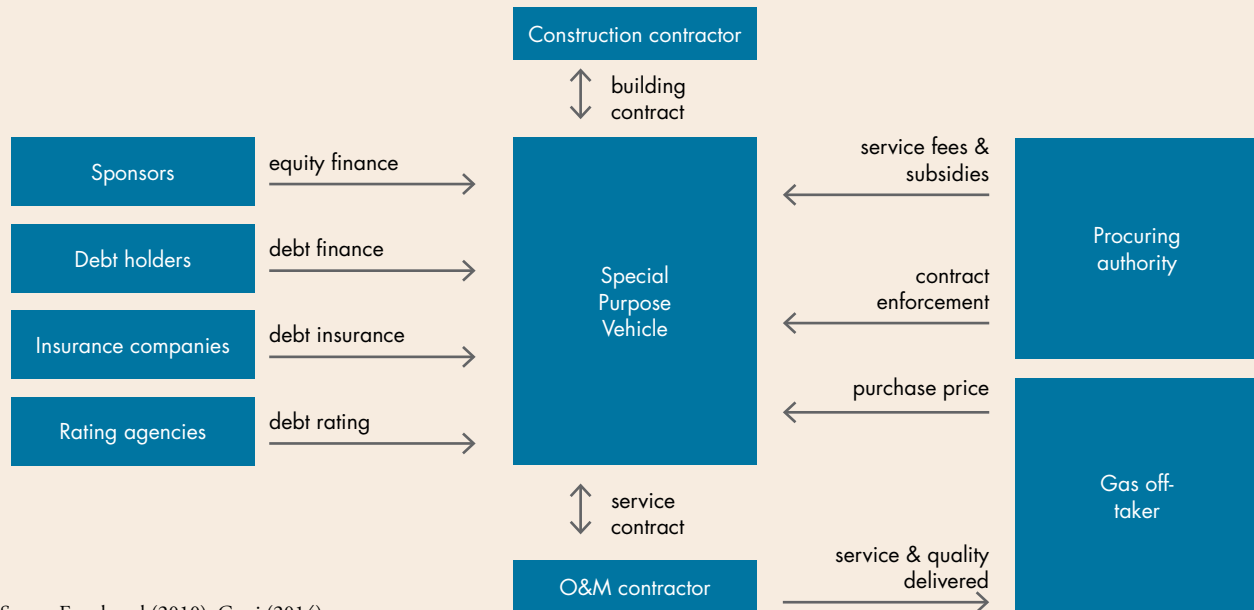
**Retail bank loans and other debt.** Debt is often a crucial part of the initial financing of LFG projects and can remain important throughout the project lifecycle.<sup>36</sup> Syndicated loans are among the most widely used source of financing for infrastructure projects, though obtaining sufficient credit guarantees over the lifetime of a project can be a challenge for LFG project developers. The terms of loans are dependent on the risk of the borrowing entity or project and may include the project sponsor’s



Drilling to install vertical LFG wells at an existing landfill.

### Box 5. Typical Structure of Project Finance for LFGE Projects

Project finance is not unique to LFG, though it is often an important mechanism in financing these projects. Below is a graphical representation, modified slightly from Engel et al (2010), that shows the variety of contractual relationships that are generally managed through a special purpose vehicle (SPV) in landfill gas projects using project finance.



Source: Engel et al (2010); Gatti (2014)

experience in the sector, the status of permitting, and factors such as the stability of the regulatory environment around the project.

Amortization periods from bank loans are often short relative to the lifespan of an LFGE project and to other financing options, as commercial banks tend not to hold long-term assets on their balance sheets. However, some development banks have special financing options for specific sectors or borrowers that suit the longer lifetime needs of infrastructure projects. Corporate or project bonds offer a longer term option for financing, however the transaction costs involved with engaging a rating agency and finding investors (often large institutional investors) may be too high for the relatively small amounts of money required to undertake most LFGE projects.

**Private Equity.** Equity investors purchase partial ownership of a project with their investment. Thus, these investors take on more project-related risk than other types of financiers and stand to gain proportionally to

the risk they take on and the financial success achieved by the project. The project preparation and construction phases of LFGE projects are complex and often require highly specialized technical expertise. Thus, construction companies or other firms with the ability to oversee changes in LFGE project design, manage construction delays, and monitor the costs may often provide equity (Ehlers 2014). A high hurdle rate is expected by a private investor and is often on the order of 15-25 percent (California Energy Commission 2002). Most projects, including those structured using project finance, involve a mix of debt and equity.<sup>37</sup>

### 3.2.2 Public-Private Partnerships (PPPs)

Though PPPs may be considered an ownership structure rather than a mechanism of finance, they are discussed here because the two are often intertwined. As discussed previously, one of the main goals in partnering with the private sector is to increase both the technical efficiency of a project and prevent the wasteful use of inputs (OECD/TUAC 2010). Functionally, this means creating a risk-

balanced project in which each party has been designated risks and responsibilities in line with their comparative advantages—which is a difficult task for both public and private sector participants. This section briefly highlights a number of PPP arrangements that are used in LFGE projects, beginning with the least amount of private control:

- **Primarily public ownership.** When the public sector is able to maintain primary ownership over an LFGE project's financing and operation, cooperation with the private sector may be limited to public procurement of private firms through **Design-Bid-Build (DBB)** or **Design-Build (DB)** contract<sup>38</sup> and/or **service contracts**, in which private sector operators are typically hired to do environmental assessments, independent analysis of gas availability, design of the LFG collection system, construction, and sometimes limited management some aspects of the project. Within these models, most risk lies with the government or project owner, though private contractors take on some liability for the design and construction. These private sector participants do not hold equity in the project.
- **Public/private ownership.** Though ownership is retained by the public sector, slightly greater control of a project may be given to the private sector through **management contracts** or **O&M contracts**, which are broad categories that generally give contractors a short-term (2-5 years) responsibility for aspects of an LFG project. There is usually a fixed fee that includes the cost of labor, though it can also be performance-based. O&M contracts are typically more sophisticated and may include incentives for better performance. **Design-Build-Operate (DBO)** contracts are similar to turnkey contracts with the addition of an operations agreement. A private sector partner will design, build, and operate a public-sector asset for a fee and may be responsible for some infrastructure maintenance, but these contracts typically do not require the private sector to manage any financing for the project. In these cases, the government or landfill owner is usually responsible for the off-take agreement and for the interconnection costs associated with that off-take agreement.

### Box 6. PPP Contract at Odds with Unanticipated Waste Reduction Targets

A landfill in the city of Vancouver, Canada provides a useful example of a public-private partnership (PPP) that was able to successfully distribute capital expenditures and risk, as well as some of the potential pitfalls of relying on the private sector to provide a public good (i.e. GHG emissions reductions in the context of increasingly “green” municipal policy) when private revenue generation motives are not fully checked.

Since 1991, the city has funded and maintained an LFG collection and flaring system in their landfill. In 2001, seeking better use of the LFG, the city tendered an RFP seeking private firms that might be able to productively utilize the LFG. The tender stipulated that the proposed system should be financed with a **Build-Operate-Transfer (BOT)** structure, but left the specifics to the firms to propose. The winning firm, Maxim Power Corporation, invested approximately CA\$10 million to construct a pipeline and co-generation power plant producing 7.4 MW of electricity and heating a greenhouse. Under the terms of the 20-year contract, the city continues to maintain and operate the LFG extraction system that provides LFG to the privately operated pipeline and receives 10% of electricity revenue.

Pursuant to the PPP contract, the city has an ongoing obligation to produce and extract a minimum quantity of LFG for its private partner. However, subsequent to the start of this LFGE project, the city committed to significant waste reduction goals, including increased recycling and diversion of organic waste to composting sites, potentially imperiling the LFG production rate of the landfill. Should the diversion plan significantly cut the LFG production rate before the contract term ends, the city will be either required to maintain waste delivery to the landfill in excess of its own goals or be financially liable for the contractual breach. In this way, the case both offers a clear example of the successful distribution of finance and operational responsibility with a private enterprise as well as the risks in attempting to align multi-layered public sector goals with private enterprise.

Source: Colverson, Samuel and Oshani Perera (2012)

PPPs that are structured as **Build-Operate-Transfer (BOT)** and **Build-Operate-Own-Transfer (BOOT)** require that a private sector contractor build and operate an LFG facility for a pre-agreed period, after which time it is transferred back to the public sector. The terms of these arrangements may allow the private sector operator to have functional control of the gas or facility for decades, though the public sector is responsible for providing long-term finance and maintains ownership throughout. These PPPs transfer a variety of risks, including design, construction and operating risk, though they incentivize a lifecycle costing approach (as opposed to DB/DBB/DBO) because of the long span of control the developer is assuming from the outset. However, these contracts are complex and there is significant expense if the private operator is unable to fulfill their obligations under the contract.

In terms of projects with greater private participation in financing, **lease arrangements** for some or all of an LFG project can be financed through a private lease of some aspect of operations for a specified period of time. Depending on local tax and environmental law, the investor may lease rights to the environmental attributes

or rights to claim tax benefits from the government entity or landfill owner over some period. **Design-Build-Finance-Operate (DBFO)** PPP arrangements resembles BOT and lease arrangements, though this is the first instance discussed thus far that requires the private sector to take responsibility for financing the project. DBFOs are arrangements in which the private sector participants take primary ownership of design, construction, operation, and finance risk for a negotiated period, at which point the facility reverts to the public sector. This model often utilizes private equity and debt. However, the tendering process is complex, given the risk involved in handing an operation fully over to the private sector for an extended period of time. The government may be expected to offer credit guarantees and other incentives.

- **Primarily private ownership.** In a privately owned and developed LFG operation—sometimes called **Design-Build-Own-Operate (DBOO)** or **Build-Own-Operate (BOO)**—the private sector project owner or group of shareholders is often responsible for the project end-to-end. This likely includes both acquiring debt and putting in equity, as described previously.

### Box 7. Non-standard PPP Arrangement in South Korean Landfill

The Sudokwon landfill is the largest landfill in South Korea and the largest sanitary landfill in the world. It houses the largest landfill gas fired power plant in the world, a 50 MW steam turbine plant. It is located approximately 40 minutes from Seoul and receives around 18,000 tons of waste daily from the Seoul Metropolitan Area. The Korean Ministry of Environment, which oversees the landfill, incorporated the Sudokwon Landfill Site Management Company (SLC), a governmental corporation, in 2000 to manage the disparate operations of the site. Seeking novel methods of revenue generation and a means of reducing greenhouse gas emissions, the SLC held an open bidding process and awarded a contract for landfill gas extraction and use to Hyundai Mobis with SCS and KOPEC as subordinate awardees. These organizations incorporated the new entity Eco Energy Holdings to administer the project. The landfill gas contract was awarded as a Built-Operate-Transfer (BOT) contract to Eco Energy. According to Eco Energy Holdings, financing was obtained from an number of private organizations, including: Hyundai Mobic Corp., Korea Power Engineering Co., Doosan Heavy Industries and Construction Co., and Eco Energy Holdings. The project additionally applied for and received CER credits with the UNFCCC CDM starting in 2010. Due to its public nature, SLC has remitted revenue to the Korean treasury when its power sales have exceeded 100% of projections. The landfill is expected to continue generating landfill gas through 2040.

Source: Goldman (2008); UNFCCC (2015); SLCorp (2014, 2015); KDI (2010); Korean MOE (2015)

### 3.3 Carbon Finance and Other Environmental Attribute-Based Funds

#### Key Messages

- Carbon markets are currently not as dynamic as once hoped or expected.
- Carbon finance can help increase marginal revenue or bring down project risk profiles—it should not be expected to cover capital costs of a project in addition to generating profit.
- Because carbon finance is output-based, LFG projects that underperform in terms of gas output will also fall short in terms of expected revenue.
- Revenue from renewable energy price premiums are often key factors in LFG project success.
- The World Bank's Pilot Auction Facility (PAF) is one of a few credible sources of carbon finance dedicated to the sector (see box 10).

Carbon markets—which came to prominence in the 1990s and early 2000s—have been among the most important means of channeling funds toward LFGE projects around the world and sparking interest in the concept of saleable environmental attributes. The advent of carbon markets and the introduction of schemes to limit emissions (e.g., emissions trading schemes, renewable energy premium pricing) shifted the financial incentives of LFG projects by introducing additional revenue sources that, in many cases, could make the difference between a bankable or non-viable project. There is a general misconception that carbon finance will pay the full capital costs of a project in addition to generating profit (Clapp et al 2010). In recent years, the price of carbon has fallen such that carbon markets are infrequently a major source of funds for these projects. In addition, revenue generated by these carbon finance mechanisms often does not directly provide capital as they are largely output-based—that is, purchasers ultimately only pay for the carbon credits generated or gas produced by a project after it is in operation. However, the prospect of carbon or environmental attribute sales as a future revenue source has been an important factor in leveraging both public and private finance early in a project,

despite the recent downturn in the markets. This section provides an overview of environmental-based sources of revenue used in LFG projects.

#### 3.3.1 Carbon Markets: Compliance and Voluntary

Carbon markets exist on a number of scales—there are markets that mediate sales of carbon credits or offsets internationally and those that operate on a national, regional or local basis. These markets may either be compliance-based or voluntary. **Compliance markets** are based on regulation or other legal mandates or agreements that bind countries, states, or other entities to lower GHG output and allow for trading carbon offsets to help do this. **Voluntary markets** are open to a broader field of participants and mediate the sale of carbon offsets or carbon credits to organizations and individuals seeking a lower carbon footprint. Unlike compliance markets, voluntary markets are not necessarily tied to a mandated or capped emissions output.

A carbon credit typically represents a metric tonne of carbon dioxide (tCO<sub>2</sub>) or its equivalent measured in other greenhouse gases (tCO<sub>2</sub>e). These credits are generated in a landfill through flaring methane or by collecting the gas and putting it to a productive use, such as electricity generation. In both compliance and voluntary markets, there are usually required third-party verification processes to ensure the amount of carbon offsets claimed are accurate. However, the stringency of these requirements varies between markets and the level of rigor used to verify the offset will often be reflected in its price. Once emissions reductions from a landfill gas system are verified, they are commoditized and sold on a compliance or voluntary market. Depending on the volume of gas produced, the credits from an LFG project may be sold to an aggregator who would bundle the project output with others and act as broker within the chosen carbon market. Each market typically has a set of criteria the project must meet and many markets require a demonstration of additionality, meaning that the project would not have been undertaken without carbon finance. For small landfills, it is important to note that CDM may be one of the few sources of revenue, as the output of gas may be too small to justify electricity generation. In these cases, additionality is automatic. However, verification requirements may prove

expensive or onerous and must be weighed against the projected benefit of obtaining this type of revenue.

One of the most basic difficulties in LFGE financing is the gap between when funds are needed (often the outset of the project) and when the project begins to generate revenue. Carbon markets can help address this issue, as banks or other creditors may be willing to lend to LFG projects based on the present value of revenue expected from carbon finance. This is likely only possible if the project is in an advanced planning stage and an Emissions Reduction Purchase Agreement (ERPA) or

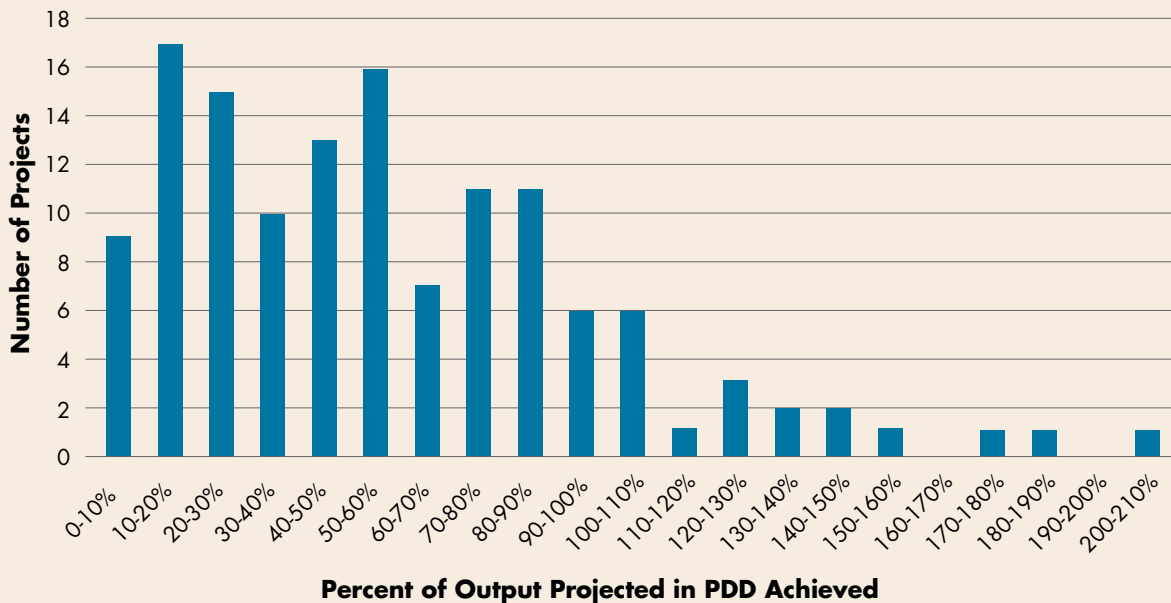
other contract that guarantees the purchase of a given number of carbon credits or has been obtained. Some purchasers have been willing to make up-front payments on a percentage of the expected return, though usually of no more than 50 percent (Economic Commission for Europe 2010). However, as demonstrated by data from the CDM pipeline, the projected emission reductions are not always delivered in the quantities expected from the initial planning (box 8).

**Box 8. CDM Pipeline Shows Performance Risk in LFG Power/Flaring Projects**

Though the methods and models for determining the availability of gas in a given landfill has been steadily evolving, under-delivery of landfill gas is a frequent issue in the field and can affect the finances of a project significantly. Terazza et al (2007) anecdotally attribute this to poor management and operation of landfills.

The frequency chart below shows the number of LFG flaring or power CDM projects that have produced the emissions reductions that were expected from the project outset, as noted in the project design document (PDD). For CDM projects, the emission reduction is called a Certified Emission Reduction (CER). Most projects in this dataset produce between 0 and 50% of the expected output, though a few projects exceeded expectations. One project in the dataset more than doubled its expected output.

**Frequency of LFG Flaring & Power Projects Achieving Projected CER Output**



Source: UNEP DTU (2015)

**Compliance markets.** There are a number of compliance markets around the world, including those that cover multi-country regions (e.g., EU Emissions Trading System) and sub-national domestic markets (e.g., Regional Greenhouse Gas Initiative in the northeastern United States). The largest international compliance market and the most pertinent example for the purposes of landfill gas finance in developing countries falls under the CDM, which operates under the auspices of the United Nations Framework Convention on Climate Change (UNFCCC). The CDM validates emission reductions and allows wealthy countries to meet their Kyoto obligations by purchasing CERs from projects located in developing countries. The first LFG flaring project was registered with CDM in January 2003. Since then, a total of 291 landfill gas power or flaring projects have been registered and 28 are undergoing the validation process.<sup>39</sup> The CDM requires a rigorous process of calculating and verifying the number of CERs a project produces using a set of UNFCCC-approved methodologies. CDM requires producers to show additionality—or proof the project would not have taken place without the benefit of carbon finance. The CDM market has slowed significantly in recent years—after trading for tens of Euros for several years, CERs now trade for tens of cents (World Bank Group 2015b).

**Voluntary market.** Voluntary carbon markets differ from compliance markets in that there is no over-arching government or group that imposes mandatory regulatory

standards on emitters of carbon. Participants in this market range from multi-national corporations to individuals interested in offsetting their carbon emissions. The bidders in these markets are often motivated by a number of factors, including demonstrating corporate social responsibility, individual concern over emissions impacts, marketability as ‘green’, and demand from clients. There are several standards that are used to monitor and verify the quality of the carbon credits, though often not as extensive as those in the compliance market. As in the compliance market, demand in the voluntary market has declined recently. From 2012 to 2013, the market size fell from 101 MtCO<sub>2</sub>e to 67 MtCO<sub>2</sub>e and the price dropped by 17 percent to US\$4.9/tCO<sub>2</sub>e (Ecofys and World Bank 2014).

**Costs of engaging with the carbon markets.** Whether carbon credits are issued under a compliance or voluntary market, there are additional costs associated with monitoring, verifying, and registering emissions reductions that must be factored into the decision about whether to pursue carbon finance.<sup>40</sup> In particular, the project preparation process to register a CDM project can be extensive and time consuming, usually requiring a specialized consultant.<sup>41</sup> As estimated by the World Bank in 2004, it may cost between US\$150,000 and \$250,000 to complete the full CDM process for an LFG project (World Bank 2004). Another estimate (2009) puts this range for all CDM projects at between US\$58,000 and \$500,000 per year, depending on the project’s complexity and size (Reed

### Box 9. Combining Carbon Finance and PPPs in Brazil

Belo Horizonte, Brazil’s third largest city, opened a public landfill in 1972. It was the city’s first sanitary landfill and provided landfill methane to a subsidiary of the local energy company (CEMIG) from 1989 through 1995 until output dropped and the extraction equipment was removed. After the landfill officially closed in 2007, municipal authorities sought a means to mitigate the GHG emissions of the site and opened a bidding process for domestic and international firms to extract landfill gas. One of the requirements was that the firm would register the project with the UNFCCC’s Clean Development Mechanisms (CDM) carbon marketplace.

An Italian firm, Asja Ambiente Italia SpA, won a 10 year exclusive contract to extract the LFG and sell energy to CEMIG in exchange for: (1) building the extraction infrastructure; (2) registering the methane destruction as a CDM project; and (3) paying the city 6% of the value of energy sales. The project was registered and began receiving Carbon Emission Reduction (CER) credits in 2011. It is expected to sell 1.3 millions CERs over the 10 year project period. By combining the profit generated from energy production with CER revenue, the city of Belo Horizonte was able to offer an LFG extraction project that could competitively attract private financing and partnership.

*Source:* Oliveira de Medeiros (2012); Gruppo Asja

2010). This very broad range must be further investigated in light of the particular characteristics of a given project.

### 3.3.2 Other Saleable Environmental Attributes

In general, carbon markets are currently less dynamic than once hoped or expected and a falling price of carbon

means that LFG operations must rely increasingly on other sources of finance. As detailed previously, there are some enabling conditions—including tax structures, regulatory requirements, cost of capital/materials/labor—that facilitate the development of LFG programs. Local governments can also help LFG projects capitalize on environmental attributes, as detailed in box 11.

#### Box 10. Methane Pilot Auction Facility

Donor organizations have struggled to address the current weakness in carbon markets that has put many LFG sites at risk of decommissioning. Among the proposed answers by development institutions, the World Bank announced in 2014 the Pilot Auction Facility for Methane and Climate Change Mitigation (PAF), a new program to auction off the rights to carbon credits from methane-reduction projects and provide a minimum price guarantee to investors for these credits.

Because the carbon markets are not currently offering significant incentive for private investors to complete methane-mitigating projects, many have gone dormant or have been left incomplete. In the program's first year, the PAF will focus on this kind of methane-producing projects—those registered under CDM involving methane from landfills or animal/water waste that could be re-started fairly easily, but need the right incentive to do so.

The program will use an auction system in which project developers can bid on a put option that will allow the right to sell their credits at a guaranteed price. The put option acts as insurance against the price of carbon credits sinking below a certain level. That is, the purchaser pays a premium for purchasing the put option, but has the option (not the obligation) to sell their future carbon credits to the PAF if there is not a better alternative available on the market.

The facility is backed by several donors and expects to be capitalized by donors at \$100 million. It will target around 800 projects in its first year, though new solutions for sustainably funding LFG systems are still required.

*Source:* World Bank Group (2015b)

#### Box 11. Potential Environmentally-Focused Revenue Sources

Landfill gas flaring or energy generation projects may be able to take advantage of one or more environmentally-focused revenue streams in order to boost the overall project return. Some added revenue might be generated from:

##### Renewables Premium Pricing

In some places, energy produced from LFG is considered renewable and commands a premium price. Voluntary green pricing programs or compliance-based programs, such as Renewable Portfolio Standards at the local level, may require a percentage of energy purchases come from renewable sources, which may provide ongoing revenue.

##### Renewable Energy Certificate

Businesses, institutions, and private citizens seeking to reduce their environmental footprint or demonstrate corporate social responsibility may seek renewable energy certificates through a voluntary market or even through bilateral agreements in which project funding is exchanged for future carbon offsets.

##### Lease Agreements

Some organizations or institutions may be interested in leasing the rights to claim tax benefits associated with environmental activities from LFGE producers. If there is a difference in the value of the benefit for this LFGE operation and the prospective purchaser, this can be an ongoing source of income and benefit for both parties.



Digital gas monitoring enables regular and precise measurements.

# 4

## Incentives Schemes and Enabling Conditions

### Key Messages

- Public sector financial and policy interventions are often essential to supporting LFG projects at the margins of profitability and leveraging outside finance.
- Key support mechanisms that are widely cited as useful to LFG projects include:
  - Renewable energy premium pricing, including feed-in-tariffs
  - Priority access to the electrical grid and assistance with interconnection
  - Direct tax benefits
  - Fast-tracked permitting processes
  - Credit guarantees
  - Concessional loan programs
- In the long run, enhancing the overall enabling environment—especially ensuring predictable policy/regulation, a strong legal system, and economic stability—supports investment in LFG.

### 4.1 Investment Support Mechanisms for LFG Projects

LFGE projects tend to be complex, capital intensive, and often carry a heavy risk profile,<sup>42</sup> making it challenging for investors to find an appropriate, risk-adjusted investment vehicle in the sector. Further, hurdle rates for private sector investment can be considerably higher in developing-country contexts. Governments are singularly positioned to address these issues through a range of public interventions that reduce or share risk, improve lending terms, decrease tax burdens, or directly subsidize a project. This chapter offers an overview of existing incentives, both those that are explicitly intended to increase the value of an LFGE system and those that may augment the larger enabling environment for private investors. The following are covered:

- **Direct subsidization and fiscal support**, including renewable energy generation incentives, tax abatement schemes, and grant/investment programs;
- **Indirect support**, including risk-sharing through credit enhancements or mechanisms that improve the terms of loans, fast-tracked permitting processes, and property rights benefits; and

- **Enhancing the larger enabling environment**, including support of tradable permitting schemes and broader education around LFGE.

#### 4.1.1 Direct Subsidization and Fiscal Support

**Renewable energy generation incentives.**<sup>43</sup> Renewable energy generation incentives are financial incentives for specific energy production modalities that are typically offered for a set number of years to encourage the development of energy sources that would not be financially sustainable in the absence of such programs (Kerr 2009). LFGE around the world have benefitted under a number of such incentives, including:

- *Feed-in-Tariffs (FITs)*. FITs are a widely used incentive mechanism (Tongsopit and Greacen 2013) designed to channel funds to renewable energy generation technologies for a specified period of time and price that will allow them to gain a foothold in an energy market. FITs typically involved assured access to a local grid, rates that reflect the higher costs of some renewable technologies, and medium- to long-term contracts (10–20 years) that offer a predictable income stream (Kerr 2009). FITs can either take the form of a fixed price for

a certain type of energy or a premium (or ‘adder’) paid above the prevailing price of a non-renewable source. Adder schemes, which are a subset of FITs, also provide an incremental increase in the price paid per unit of energy above the prevailing market price.

- *Renewable Portfolio Standards (RPS)*. An RPS mandates an increase in renewable energy usage for a given area, typically through a regulation that obliges utilities to purchase energy from renewable sources. An RPS may be instrumental in giving an LFGE operations more business, but they may not offer a guarantee of this because they allow for price competition among the providers.
- *Green Pricing Programs*. Green pricing programs are typically opt-in services that allow consumers to purchase a portion of their power from renewable sources via a premium on their utility bills. LFGE may be within the array of energy providers available in such a program.

**Direct tax benefits.** LFGE operations may benefit from a number of tax exemptions, deductions, subsidies, and exclusions. Depending on the tax regime in place, the prospect of tax credits may entice investors. Tax credits and abatements may reduce operating costs and provide investors greater return (Meyers 2009). For example:

- *Tax reduction or exemption on equipment purchases*. In some locations, LFGE projects have qualified for exemptions from international customs duties on energy production-related construction materials. Tax exemptions or reductions are also sometimes offered for projects using domestically produced equipment.
- *Value-added and sales tax exemption or reduction*. Reducing or removing value-added taxes on LFG projects that make electricity from biogas can add to the project’s lifetime value and incentivize private investment.
- *Accelerated depreciation tax deductions*. In some jurisdictions (e.g., under U.S. federal law) (Burkett 2008), various capital expenditures on LFGE projects may be eligible for accelerated depreciation—that is, a deduction on project income that is higher than would otherwise be taken based for typical asset depreciation can be taken within the initial early years of project development.

- *Renewable energy investment and/or production tax credits*. Under some tax law, investment costs for LFGE projects and/or their energy production costs are eligible for a tax credit. For example, the Investment Tax Credit (ITC) in the U.S. may allow investors to obtain a tax credit that offsets 35 percent of the initial capital investment (Li et al 2014).

**Direct investment grants or concessional financing.** In many countries and at the international level, there are special funds available for improving green or distributed energy technologies. Loans with concessional terms (including extended tenures, partial debt forgiveness, and below market-rate interest) are sometimes offered by municipal development corporations, non-profit organizations, regional agencies, and multinational institutions for LFGE projects. Similarly, full or partial investment grants may be offered to assist in initial development or technology enhancement. This type of assistance can provide the funding necessary to get a project off the ground as well as reduce overall project risk and attract other lenders.

#### 4.1.2 Indirect Support and ‘Hidden’ Subsidies

**Special land-use rights and property tax abatement.** Governments are sometimes able to provide land-based benefits to LFG operations. These benefits may include long-term development rights on government land, inexpensive land-lease of government property, land grants, access to and/or usage of government land or facilities, and reduction or elimination of property taxes. Land-based assistance may also include changes in zoning to allow specific types of renewable energy generation, as well as government investment in remediation of landfill sites in preparation for an LFGE project.

**Limited liability contracts.** Offering project developers environmental indemnities or limited liability for the sanitary landfill after the project has been closed helps reduce long-term investor risk.

**Utility interconnection assistance and priority grid access.** While some LFGE project enjoy priority grid access as part of a power purchase agreement (PPA), many projects find interconnection costs and unclear regulation

**Box 12.** National-Level Government Support for LFGE in Turkey

Partly in response to EU-wide efforts to increase the proportion of energy produced from renewable sources, the government of the Republic of Turkey enacted legislation intended to incentivize the construction of new renewable energy projects, including LFGE. The Turkish Law on Utilization of Renewable Energy Sources for the Purpose of Generating Electrical Energy went into effect in 2005 and was amended in 2010. The law establishes six means by which investment in LFGE projects initiated between 2005 and 2015 are supported:

- **Purchase guarantees:** Local electricity suppliers to end-users are required to purchase a certain percentage of electricity from renewable sources.
- **Feed-in Tariff:** This guarantees a minimum price, though electricity producers are free to obtain a higher market price. The 2005 price set was €0.05-0.055/kWh. This was revised to US\$0.133/kWh for biomass energy (inclusive of LFG, per Turkish law).
- **Registration Discounting:** The government will discount the initial registration fees for power plants by up to 85 percent.
- **Domestic Equipment Incentives:** Further operational discounts are offered for projects using domestically produced equipment.
- **Priority Grid Access:** Renewable energy producers are entitled to priority access to local electricity distribution systems
- **Land Access Protection:** The law restricts development of undeveloped land, which could be used for renewable energy generation.

Sources: Gonen & Can (2013); Republic of Turkey (2005); Akat

can present a major hurdle.<sup>44</sup> Clear information on the technical requirements and/or restrictions for connecting to the grid (current, voltage, etc.) (World Bank 2004) can help reduce project delays during the application process. Renewable energy producers can be granted priority access to local electricity grids. Similarly, the U.S. EPA suggests a screening process that allows large or small energy providers to have different processing times, fees, insurance requirements, etc. (U.S. EPA 2006).

**Credit enhancements.** Credit enhancements are mechanisms used in debt transactions to mitigate risk that investors or creditors are unwilling to take (Kehew et al 2005). Guarantees,<sup>45</sup> subsidized credit lines, and co-financing provided by a creditworthy municipal government, national government, or multinational institution can help project developers diversify risk and attract other financing for LFG projects:

- *Comprehensive and partial credit guarantees.* Comprehensive guarantees cover interest and principal irrespective of the reason for default while partial credit guarantees are structured so that risk is shared between the guarantor and the borrower.
- *Co-financing and debt subordination.* Co-financing of projects by a trusted partner can enhance the general creditworthiness of a project. Debt subordination can be used in the case where a partner wants to enhance the creditworthiness of the primary borrower, but the secondary partner's funds will be tapped last if a project falters.

**Programs/policies that promote the sector.** Promotion of the LFG sector can be useful for project developers seeking exposure and greater assistance from policy-makers in making projects work. There are a variety of ways this can be done:

- *Donation of government staff time.* Government staff with a high level of knowledge about LFG projects can help expedite permitting, play a liaison role between different levels of government, assist in the general improvement of waste management by a city and its contractors.
- *Technology innovation support.* Public-sector policies for improving technology development can

contribute to research and speeding the evolution of LFG technologies. As the IEA notes in its report of LFG policy, in France, “grants are available for demonstration projects in the renewable energy sector [and] Finland’s well-known technology innovation agency has a programme dedicated to waste-related projects including biogas from landfills” (Kerr 2009).

- *Awareness campaigns and educational efforts.* An LFG-focused program, such as the U.S. EPA’s Landfill Methane Outreach Program (LMOP), can develop technical assistance, create guidance materials and feasibility studies, and enhance partnerships that may deliver financing. This kind of work may also help raise awareness in local engineering universities about the need for training in this field and allow policy-makers to gain a basic understanding of the important issues around LFG (Kerr 2009).

### 4.1.3 Larger Enabling Environment

**Plans to improve local capital markets.** LFGE and other infrastructure projects benefit from an improved overall investment environment. Lowering both political and commercial risk and bolstering the substructure (legal, institutional) that underpins a healthy financial sector will help capital markets mediate money effectively. Demonstrating to credit rating agencies that, for example, a city has a plan to improve its creditworthiness can pay dividends in the long run. This would mean that bonds and other municipal debt that could be put toward infrastructure projects like LFGE systems will be less expensive.<sup>46</sup> Part of doing this is focusing on predictable regulation, removal of perverse policy incentives, and support of transparency, as policy risk is lowered when laws are clearly written and consistently applied.

**Creation of tradable permit schemes.** The development of local carbon emissions trading or permitting schemes may open the door for higher value to be obtained from reducing carbon emissions. These markets can be facilitated by local, regional, or national regulation of carbon emissions, but the scope is much wider than LFGE projects.

**Development of high-level or national-level planning around mitigation.** Planning for mitigation action in an

integrated way requires both the national and local level to align priorities and set broad targets that are appropriate for a country's level of development and ability to limit emissions. This alignment is intended to broadly assist in the creation of a funding environment that is coordinated and more effective. High-level climate talks led by the United Nations have offered several means of developing such high-level planning in developing countries, beginning with Nationally-Appropriate Mitigation

Actions (NAMAs), which are discussed as part of the Bali Road Map (2007). NAMAs are a mechanism by which a national-level government can transparently outline policies and mitigation actions that are domestically appropriate. Similarly, Intended Nationally Determined Contributions (INDCs) were proposed in Warsaw (2013) as a means of outlining a country's proposed actions vis-à-vis climate change (Boos et al 2014).



Gas pipe installation in Cumberland County, North Carolina.

# 5

## Risk Identification and Mitigation

### Key Messages

- Mitigating risk is key to gaining investor confidence, keeping the cost of financing down, avoiding cost overruns, and ultimately limiting the possibility of a failed venture.
- Employing proper due diligence, proven technologies, experienced vendors and consultants, and structuring contracts well are the most effective risk mitigation techniques.
- Apportioning risk appropriately between project partners is more important than trying to mitigate all risk.
- The two most important means of mitigating financial risk are (1) obtaining accurate gas availability estimates and (2) getting off-take agreements for end-products. Others include:
  - Conservative estimates of LFG availability
  - Warranties and performance guarantees for equipment
  - Output-based payment schedule to incentivize on-time construction and project delivery
  - Political risk guarantees/insurance to hedge against policy/regulatory changes
  - Fixed-price or turnkey contracts that shift some risk to contractors
  - Delay guarantees (delay penalty) and/or incentives for faster delivery of project components

Due to their high upfront costs and long investment timelines, LFG projects—like many infrastructure projects—are perceived to carry elevated financing and/or liquidity risk. The nature and significance of these and other project-specific risk factors directly affect the cost of capital and, in many cases, the overall viability of a project.<sup>47</sup> Addressing risk is key to gaining investor confidence, keeping the cost of financing down, avoiding cost overruns, and ultimately limiting the possibility of a failed venture. A crucial aspect of initial project planning is to anticipate the project's risk profile at different stages so that it can be managed over the course of implementation, as well as actively mitigated when risk factors emerge unexpectedly. This chapter offers advice from LFG project-developers, financiers, legal counsel, and engineering professionals on risk mitigation techniques that are specific to different stages of landfill gas project development.<sup>48</sup>

### 5.1 Overview of Risk in LFG Projects

**Political Risk.** In concept, risk in landfill gas projects can be roughly divided between political risk and commercial risk (Matsukawa and Habeck 2007). Political risk<sup>49</sup> is a broad category that may be particularly relevant in developing or fragile contexts (Kosoy 2005). It can include the possibility of government expropriation of property or gas rights, restrictions on currency conversion, civil unrest, policy changes that eliminate key subsidies, or even the non-payment of a sovereign guarantee. Though this type of risk may impact the project's profitability or viability, there is often little a project implementer can do beyond obtaining third-party Political Risk Insurance (PRI)<sup>50</sup> to improve an LFG project's overall risk-return profile (box 13).

Adding this insurance to a project can decrease its overall financial risk profile, likely lowering the cost of borrowing and potentially increasing the tenure of loans. Ideally, the savings a company might see from a lowered cost of borrowing would be greater than the purchase price of the PRI, but sometimes adding insurance is the only means of acquiring any other financing and is necessary even if the expense is not recouped in lower financing costs (Boza 2015). The premium paid for this insurance is typically calculated based on the type of project or sector, the financial risk level, and the location. Predictably, these factors have major implications for investment. In fact, there is evidence that the country risk rating in emerging markets and developing economies is a reliable predictor of overall infrastructure investment levels (Araya et al 2013).

Project implementers have greater control over the factors that make up commercial risk, which include all of the production-related activities such as site construction and the ability to sell a product at a competitive price. These are discussed at greater length in the following sections.

**Risk-ownership.** A key part of mitigating risk is setting up an explicit risk-ownership structure to divide it appropriately between project implementers based on each party's ability to assume and manage risk. A well-considered risk allocation strategy can offer benefit to all project participants, reducing both overall uncertainty and the potential for decision-making that may lead to an increased cost of bids and longer estimated schedules. Risk-ownership plans must be structured cautiously, as poorly-designed risk transfer strategies can create perverse incentives that lead to cost overruns or inefficiencies.<sup>51</sup>

Profits or gains from jointly-executed projects should, in principle, be divided proportionately based on the risk allocation and the material contribution to the project (California Energy Commission 2002). However, negotiating a fair division among stakeholders at various stages of the project is a complex process, as each party's capacity to bear risk may fluctuate over the course of implementation. Identifying the specific competencies of different partners early on allows for planning and compensation

### Box 13. Shifting Risk and Increasing Profitability Through a Public Sector Guarantee

Though many emerging markets have dynamic investment climates, addressing political risk through purchasing a third-party financial guarantee may play a key role in attracting investors and lenders. In 2006, BioEnergia, a subsidiary of a Canadian energy technology company, began construction on an LFGU system in El Salvador. As part of its financial calculation, BioEnergia expected to earn profit from selling Certified Emission Reductions (CERs) on the international carbon market through the Kyoto Protocol's Clean Development Mechanism. While the company received a necessary letter of support from the Salvadoran government and successfully registered the project with the UNFCCC, there remained some political and Kyoto-related risk of under-delivery of CERs that had the potential to negatively impact the project's financing.

To obtain better financing terms, the company sought to address the risk by purchasing insurance from the World Bank's Multilateral Investment Guarantee Agency (MIGA). MIGA makes financial guarantees for companies investing in developing markets. MIGA provided an equity guarantee of US\$1.8 million, covering expropriation or damage of assets, the potential for political or regulatory action that might decrease the amount of waste going to the landfill, war and civil disturbance, and breach of contracting, including a breach of the Salvadoran government's letter of support to the UNFCCC. With this risk mitigated, BioEnergia was able to obtain financing and sold their emissions reductions to the government of Luxemburg in 2007.

A MIGA guarantee can be up to US\$200 million (though more through special arrangement) and will cover up to 90% of equity and 95% of debt. The premium is based on country-specific factors, but MIGA requires a US\$5,000-\$10,000 application fee that is credited toward the premium and a processing fee of up to US\$25,000.

MIGA is a major multi-lateral political risk insurer but there are also regional development banks and bilateral insurers, such as Australia's Export Finance and Insurance Corporation (EFIC) and the U.S. government's Overseas Private Investment Corporation (OPIC), that provide these services. Private insurers also provide these guarantees.

Sources: Marais (2013); Biothermica Technologies, Inc; Matsukawa and Habeck (2007); Quintrell

that will help avoid risk from materializing and leading to financing shortages at later stages.

Typically, those parties holding long-term debt are the most risk adverse and will seek to off-load risk through requiring collateral, debt guarantees, and recourse to other stakeholders' assets. Project developers or other equity investors will anticipate taking on most of the financing risk—in exchange for a higher return<sup>52</sup>—though they also will likely seek to spread the risk broadly among project participants.<sup>53</sup>

There is an extensive literature on risk allocation in energy infrastructure development, which is not replicated here. Rather, the remainder of this chapter offers advice on risk mitigation in LFG projects based on the experience of practitioners. Risk mitigation instruments and strategies exist at various phases of the investment lifecycle, beginning in the feasibility planning stage and continuing through critical milestones in the project development process. However, a good management strategy requires an end-to-end or lifecycle assessment of risk, as the handling of risk at one stage will often impact levels of risk later.

This section outlines various strategies used to moderate political, technological, partnership and market risk at each stage of the process and is based on practical suggestions from developers, legal counsel, engineers, and other practitioners in the field. The major stages of LFG projects outlined in this section are:

- Feasibility or Planning Stage
- Engineering, Procurement, and Construction Stage
- Operation and Distribution Stage

## 5.2 Mitigation Across Stages of LFG Projects

### 5.2.1 Risk Mitigation in the Feasibility or Planning Stage

As in many infrastructure projects, risk in LFG projects is typically highest during the development phase and tends to decrease as the project moves toward operation (Schwartz et al 2014). Thus, risk mitigation during the feasibility analysis—which often takes the form of proper due diligence—is critical to the overall success of the project. The chief purpose of this phase is to determine whether the project is viable based on the condition of the landfill, the availability of LFG, the predicted generation rate and lifetime, and the potential for financing. A full feasibility assessment should allow project developers to make basic decisions about the most appropriate end-use of the gas. Though there are examples of projects that rely primarily on desk-reviews to model the amount of gas a landfill might produce, a feasibility assessment should always include a pump test as a risk-mitigating measure. This entails gathering gas from test wells for a sufficient period of time (up to 3 months<sup>54</sup>) to allow for a definitive assessment of gas quality and quantity (Flores and Stege 2005). Identifying the project partners and explicitly developing a risk-ownership strategy is also a key part of this phase. The primary areas of project risk at this stage include:

- Gas availability risk
- Financial risk
- Partnership or counterparty risk
- Permitting and regulatory risk

**Table 3. Gas Availability Risk**

Over-estimating the amount of gas available during the project lifetime has caused many projects to fail in the last two decades. Underperformance is a known problem in the sector, though many of the issues that plague developers might be avoided with proper due diligence from the outset.

Risk	Mitigation Technique	Considerations
<b>Gas Availability</b>	<i>Contract a reputable firm to undertake the initial gas potential analysis.</i>	<ul style="list-style-type: none"> <li>• Avoid the tendency to push for LFG recovery projections as quickly or cheaply as possible.</li> <li>• Considerable expertise is required in site-specific coefficients that feed into the models used to make initial estimates of gas availability. For example, climatic conditions and organic content of the waste will be different for models in different regions.</li> <li>• Both a desk review of historic landfill data and an on-site verification of the landfill systems (flow meter, operations practices, etc.) should be undertaken (Pierce 2003).</li> </ul>
	<i>Verify gas-availability studies presented by other project stakeholders.</i>	<ul style="list-style-type: none"> <li>• Before taking on any project risk, ensure a high-level of comfort with gas-production estimates, including those produced by project partners.</li> <li>• An independent auditor or other third-party verifier and can validate gas availability through a pump test.</li> <li>• Test wells should be drilled and gas output should be monitored over time.</li> </ul>
	<i>Decouple feasibility assessment contracts from other project development work.</i>	<ul style="list-style-type: none"> <li>• This avoids situations in which contractors are incentivized to overestimate the gas available—e.g., in a competitive bid that is partially based on promised output.</li> </ul>
	<i>Obtain a conservative estimate of LFG availability by using a low multiplier in estimation models (World Bank 2004).</i>	<ul style="list-style-type: none"> <li>• This helps avoid planning around overly-optimistic estimates. This should be done in each landfill cell.</li> </ul>
	<i>Always build in funds to perform a pump test as part of the feasibility assessment.</i>	<ul style="list-style-type: none"> <li>• Once a satisfactory desk review has been completed, a test drilling of several gas wells should be done with special attention to the location of the wells. In developing countries, historical data may not be available and a pump test will help mitigation some of the risk associated with this lack of information.</li> <li>• Pump testing should include at least three vertical test wells and some pressure probes to test suction.</li> <li>• The duration of the test should be as long as practicable (some suggest 6-8 weeks while others suggest up to 3 months<sup>55</sup>).</li> <li>• Gas content, especially methane and oxygen content, should be analyzed prior to moving forward with the project.</li> <li>• Moving forward should be contingent on the results of the pump test. This should be reflected in any agreements with other contractors.</li> </ul>

**Table 4. Financing Risk**

The primary financial risks from the outset of a project relate to (1) the availability of funds and (2) the cost of capital or lending terms. Identifying an off-taker and obtaining a purchase agreement from the eventual end-user of LFG or energy, such as the local power utility, is one of the most important aspects of financially securing the project.

Risk	Mitigation Technique	Considerations
	<i>Obtain an off-take agreement for the end product—electricity, gas, steam, etc.</i>	<ul style="list-style-type: none"> <li>• In terms of project security, identifying a market for the end product is second in importance only to obtaining an accurate estimate of gas availability.</li> <li>• Pre-screen the off-taker’s creditworthiness.</li> <li>• The kind of product needed will determine the type of technology purchased. If a purer gas is required by the end-user, this has upfront cost implications for the infrastructure developer.</li> <li>• Note that market access for power distribution is not always a given in all jurisdictions.</li> </ul>
	<i>Signing long-term off-take contracts can increase the financial stability of the project.</i>	<ul style="list-style-type: none"> <li>• When negotiating with utilities or other off-takers, achieving a long-term off-take arrangement of 10-20 years is optimal, though not always possible.</li> <li>• If the market value of LFG is expected to increase, a shorter obligation time and room for renegotiation may be an advantage.</li> </ul>
	<i>Ensure that supply obligations and contingencies are spelled out.</i>	<ul style="list-style-type: none"> <li>• Initial estimates of gas supply should be conservative.</li> <li>• Understand where responsibility lies for supplying energy to off-takers if the LFG generator has to be shut off for some period of time.</li> </ul>
<b>Financing</b>	<i>Limit finance risk and/or acquire better financing terms through credit enhancements.</i>	<ul style="list-style-type: none"> <li>• Obtaining third-party guarantees or insurance on equity or other investments is a standard method of risk mitigation. These may include support from private, local, national, or international bodies, if available.</li> <li>• Enhancements can also include providing collateral or a letter of credit from a bank or other backer.</li> <li>• Public policies that support renewable energy may guarantee some future revenue and may help secure loans and lines of credit. Note that not all jurisdictions classify LFG as ‘renewable.’</li> </ul>
	<i>If applicable, begin documenting the project development process for registering with compliance and/or voluntary carbon markets.</i>	<ul style="list-style-type: none"> <li>• Acquiring carbon finance can help ensure the overall financial sustainability of a project and moderate the overall project risk profile.</li> </ul>
	<i>Identify sources of funding/financing whose repayment periods coincide with the expected period of project revenue generation.</i>	<ul style="list-style-type: none"> <li>• This is to ensure, to the extent possible, on-time repayment and limit the prospect of default.</li> </ul>
	<i>Consider using project finance to avoid exposure to greater liability.</i>	<ul style="list-style-type: none"> <li>• If projects are funded on a non-recourse basis, financiers do not absorb project risk as an equity investor might, thus it has to be distributed among the other project participants.</li> <li>• Separate or local limited liability companies or a single-purpose subsidiary may shield assets of a parent company or municipality in the event the project fails.</li> </ul>
	<i>Use output-based financing (results-based financing) where possible.</i>	<ul style="list-style-type: none"> <li>• Types of output-based financing (e.g., agreements that base payments to financiers, contractors, and others based on the production of gas) can be used in some situations to incentivize active problem solving that is in all participants’ self-interest.</li> <li>• This can be as simple as developing a payment schedule based on LFG quantities produced.</li> <li>• Carbon finance is a form of output-based finance, in which project owners are paid upon delivery of CERs.</li> </ul>

**Table 4. Financing Risk** (cont.)

Risk	Mitigation Technique	Considerations
Financing	<i>Comprehensively investigate the potential for renewable energy tax incentives or other benefits (as well as tax liabilities).</i>	<ul style="list-style-type: none"> <li>Landfill gas projects may not always qualify for ‘renewables’ benefits and that should not be presumed.</li> <li>Find out if the national or local energy policy obligates purchase of ‘green’ power.</li> <li>Review the terms under which power might be purchased (e.g., the feed-in tariff rates).</li> <li>If land is leased for the LFGE project, payment of property or other taxes may be required over the course of the project.</li> </ul>
	<i>Diversify the funding/financing sources.</i>	<ul style="list-style-type: none"> <li>Projects with too much reliance on a single public entity for guaranteeing loans may be seen as suffering from elevated policy risk.</li> </ul>
	<i>Consider possibilities for denominating both debts and revenue in the same currency.</i>	<ul style="list-style-type: none"> <li>If debts exist in a hard currency (e.g., USD) and revenues are generated in a local currency, there is risk of devaluation of a local currency that could cost investors enormously. Obtaining financing in local currency could help eliminate this issue.</li> </ul>

**Table 5. Partnership Risk**

Identifying project-implementation partners with adequate expertise in their field and divvying up rights and responsibilities early will help ensure coordination issues do not impede the project development.

Risk	Mitigation Technique	Considerations
Partnership	<i>Ensure adequate planning and project-structuring expertise/experience in the core project management team.</i>	<ul style="list-style-type: none"> <li>An experienced project manager can undertake adequate due diligence of contractors before they are selected and anticipate issues before they materialize.</li> </ul>
	<i>Develop a risk-ownership strategy early in the process that anticipates potential problems.</i>	<ul style="list-style-type: none"> <li>Outlining responsibilities with regards to risk ensures ongoing accountability and may help drive partner or contractor behavior (Beckers et al 2013).</li> </ul>
	<i>Spell out site access and any shared infrastructure rights with the landfill owner/operator.</i>	<ul style="list-style-type: none"> <li>A site lease agreement between the existing owner-operator of the landfill and the LFGE operator/developer may prevent territorial disagreements.</li> <li>The site lease should include site access rights to the LFGE facilities on landfill property and any usage of other infrastructure that will be used in common with the landfill owner/operator and other participants.</li> <li>For example, if the LFGE system needs to process condensate through the landfill’s leachate control system, this arrangement should be explicit within the site lease contract.</li> </ul>
	<i>Review all site lease documents and management contracts for the landfill, and ensure the landfill is up to code.</i>	<ul style="list-style-type: none"> <li>Investigate the landfill owner by ensuring there are no pending requirements (e.g., environmental) to be fulfilled and there is not a history of censure by the regulatory authority.</li> </ul>
	<i>Clearly define the existing ownership structure of the landfill and resources.</i>	<ul style="list-style-type: none"> <li>Sometimes, ownership over gas rights or site-use rights are not clearly understood or enforced by law.</li> <li>All existing concessions connected with the landfill operation should be identified at this stage.</li> </ul>

**Table 5. Partnership Risk** (cont.)

Risk	Mitigation Technique	Considerations
<b>Partnership</b>	<i>Ensure landfill operators have incentives to maintain the landfill in manner that is conducive to gas-collection.</i>	<ul style="list-style-type: none"> <li>• Revenue sharing can offer some incentive for proper maintenance and care for LFGE infrastructure (e.g., not running over well-pipes with backhoes).</li> <li>• For example, structuring a project so that any payments from the LFGE project to the landfill operator are tied to payments from delivery of gas offers this incentive. Payments may even start only after a large portion of the gas is delivered.</li> <li>• Agreements should include requirements for well-trained landfill technicians to adjust the gas collection system and maintain a flow of LFG with a good quality (% of oxygen) to prevent unintended consequences to the landfill such as landfill fires.</li> <li>• Greater assurance may be obtained by putting a recognized environmental management system in place (e.g., ISO 14000).</li> </ul>
	<i>Make an agreement with the landfill owner/operator about gas rights that disallows building a second LFG system that competes for gas.</i>	<ul style="list-style-type: none"> <li>• Though landfill owners may be able to split large landfills geographically and offer different parcels to different LFGE operators, LFG migration patterns are not always known and two operators may be in competition for the same gas.</li> </ul>
	<i>Ensure that with equity partnerships, the roles and areas of responsibility of each partner are clearly delineated from the outset and there are contracts that spell out which parties are paid first.</i>	<ul style="list-style-type: none"> <li>• Investors and equity owners must decide which lenders take priority in repayments, particularly in the event of default.</li> </ul>
	<i>Project owners may be able to negotiate shared interconnection costs and eventual network upgrade costs with the local utility.</i>	<ul style="list-style-type: none"> <li>• For smaller LFGE projects, interconnection costs (step-up transformer, etc.) could significantly affect the profitability of a project (Jaramillo and Matthews 2005). Different utilities will have different expectations and potential cost-sharing options for power transmission infrastructure.</li> <li>• Note that it may take some time (3-6 months or longer) (Pierce 2003) for an interconnection application to be accepted.</li> </ul>
	<i>Ownership of infrastructure and other project property (e.g., gas rights) should be clearly spelled out.</i>	<ul style="list-style-type: none"> <li>• Both for a planned end date and in the event of early project termination, it is necessary to clearly define which parties have rights to liquidate gas pipelines, generators, and other infrastructure or project property.</li> </ul>
	<i>The general public should be viewed as a partner and community outreach is advisable.</i>	<ul style="list-style-type: none"> <li>• Even if community outreach is not required by law, public acceptance of the project may make the difference between bankable and non-bankable project.</li> </ul>

**Table 6. Permitting and Regulatory Risk**

Moving through the permitting process quickly may avoid lost profits and holding costs. Extended permitting processes have a history of impacting the delivery of carbon reduction credits from LFG projects.

Risk	Mitigation Technique	Considerations
Permitting and Regulatory	<i>Use political risk guarantees/ insurance to hedge against regulatory changes that affect profitability.</i>	<ul style="list-style-type: none"> <li>• This type of guarantee can run less than one percent of project costs, though it may be much higher depending on the existing political situation and other risk factors.</li> </ul>
	<i>Comprehensively investigate relevant local and national ordinances, including which agency makes them (or gives permits), the associated timelines, and the potential for them to change.</i>	<ul style="list-style-type: none"> <li>• Developers sometimes overlook existing leachate control regulations, air quality measurement requirements, standards for gas purity, and noise ordinances. For example, reciprocating generators can be very loud and if noise limitations exist, they may require the added expense of building surrounding structures to dampen noise. Further, there may be required air quality or other tests that will add to the cost of the project in the long-run.</li> <li>• In some jurisdictions, independent power producers are unable to sell electrical power onto the grid or are otherwise limited in their abilities to use, for example, transmission infrastructure.</li> <li>• Public consultation may be a requirement in some jurisdictions.</li> <li>• LFG may not be considered ‘renewable’ in some jurisdictions and therefore may not be eligible for tax or other presumed benefits.</li> <li>• If LFG collection is required by existing authorities, that may limit the value of emissions reduction credits because of a lack of additionality.</li> </ul>
	<i>Comprehensively investigate the relevant regulator(s) (national level, local level, provincial level) and determine the potential for political change to impact operations.</i>	<ul style="list-style-type: none"> <li>• Understanding when and how the relevant authority might impact operations can allow a project developer to anticipate and head-off potential problems. This is both in terms of the landfill itself and the relevant energy regulators.</li> <li>• The existing authority should be able to identify other existing concessions on a landfill site.</li> </ul>
	<i>Make binding agreements in order to limit financial impacts from regulatory changes (“change-of-law”).</i>	<ul style="list-style-type: none"> <li>• Project stakeholders from the public sector can most easily mitigate change-of-law risks.</li> <li>• As an example, upgrading direct-use landfill gas to reduce the oxygen content can be an expensive, but could be required by a change in local utility policies. A long-term (10- to 20-year) off-take agreement with a utility is ideal, but may not be feasible.</li> </ul>
	<i>Those working on the application and validation processes involved in carbon credit registration/sales should have experience in the field.</i>	<ul style="list-style-type: none"> <li>• The application process for the UNFCCC and others can be time-consuming and delay project profitability.</li> <li>• The verification process for voluntary markets can be shorter than for compliance. Existing projects have sold initially to voluntary markets and then later to compliance markets.</li> </ul>
<i>Request environmental indemnification.</i>	<ul style="list-style-type: none"> <li>■ Contractors or other implementers may ask the landfill owner (or vice versa) for an environmental indemnity to protect against financial loss as it relates to environmental degradation.</li> </ul>	

### 5.2.2 Risk Mitigation in the Engineering, Procurement, and Construction Stage

Following the feasibility assessment stage, risk must be addressed during the process of engineering, procurement and construction. During this phase, careful selection of project contractors and partners will help ensure the project is delivered as expected and, as such, financially protected. Some of the risks in this phase are common across all construction projects, while others identified here by practitioners are specific to LFGE work.

As the work in this phase of project development typically involves specialized contractors, many activities lend themselves to results-based contracting, in which payments are remitted based on the successful completion of pre-defined activities. Some of the financial risk that can be anticipated in project development (e.g., from construction delays or increases in the price of materials) can be off-loaded to contractors using a results-based approach, so long as contingencies are built into contracts.

When working in countries with little or no history or LFGE project development, project developers must be cognizant of deficits in the experience of potential engineering or construction companies. Addressing this area of risk may require that a developer bring experienced staff from abroad or invest in training local staff. There are always risks that cannot be avoided. For example, in many cases, those countries that are new to LFG collection do not have supply chains to deliver necessary construction materials and a labor pool that is familiar with the operations. Some of the risk inherent in these contexts may be diffused among project participants, though it is reasonable to expect that the primary project developer may absorb them to a large extent.

The principal areas of project risk at this stage can be grouped in to:

- Contracting risk
- Procurement risk
- Engineering & construction risk

**Table 7. Contracting Risk**

Proper due diligence during contracting for various aspects of an LFGE project is important for identifying and hiring suitable contractors/sub-contractors; ensuring work is properly completed on a specified timeline; confirming that certain types of risk (e.g., financial risks based on late completion of tasks) are either mitigated or borne by the contractors to the extent possible; and clearly spelling out the responsibilities of project participants. All contract negotiations include the possibility of deliberate contract manipulation, hedging, the inclusion of perverse incentives, and other activities that may erode the value of the relationship. Often, specific requirements in written contracts can limit risk.

Risk	Mitigation Technique	Considerations
<b>Contracting</b>	<i>Sign long-term (as opposed to buy-as-needed) off-take agreements.</i>	<ul style="list-style-type: none"> <li>• “Buy-as-needed” contracts are considered less secure (financeable) than longer-term contracts (Szymanski et al 2013).</li> <li>• A contract that does not allow the energy buyer to default for any reason is the most secure type for the seller (Szymanski et al 2013).</li> </ul>
	<i>Develop a thorough construction specifications document outlining and defining all work and expectations.</i>	<ul style="list-style-type: none"> <li>• An initial bid document should outline the project and include very specific information including definitions of terms, payment schedules, legal restrictions, insurance requirements, timelines, site usage allowances, and other relevant information.<sup>56</sup></li> </ul>
	<i>Require a proposal security or bid bond from major project contractors.</i>	<ul style="list-style-type: none"> <li>• Described in Appendix J, a proposal security can be used to pre-screen engineering/construction firms and dissuade under-qualified firms from putting in an application or bid.</li> <li>• A highly qualified bidding pool will increase the likelihood of hiring a contractor capable of designing and/or executing LFG plant construction.</li> </ul>
	<i>Consider requiring surety bonds that cover performance and payment.</i>	<ul style="list-style-type: none"> <li>• Surety companies do prequalification for services and will evaluate a contractor.</li> <li>• Performance bonds compensate the project owner if the contractor fails to perform in accordance with a contract.</li> <li>• Payment bonds ensure that materials suppliers, workers, and other subcontracted firms or individuals are paid even if the contractor defaults.</li> </ul>
	<i>Fixed-price or turnkey contracts can shift much of the risk of project implementation and completion to contractors.</i>	<ul style="list-style-type: none"> <li>• There is usually a premium to be paid for shifting risk via turnkey contracts.</li> <li>• Fixed-price contracts should be entrusted to experienced LFGE developers only and there should be mechanisms to ensure adequate quality-for-money.</li> </ul>
	<i>Ensure that contractors/subcontractors have appropriate insurance coverage based on local laws.</i>	<ul style="list-style-type: none"> <li>• Often, a subcontractor may be asked to have professional liability insurance to account for omissions and negligence.</li> </ul>
	<i>Write into contracts a delay guarantee (delay penalty) and/or incentives for faster delivery.</i>	<ul style="list-style-type: none"> <li>• If there is a delay in completion or specified tasks, a delay guarantee is designed to cover interest costs on a construction loan.</li> <li>• Faster delivery can be a win-win for all stakeholders and can be incentivized through pay.</li> </ul>
	<i>A feedstock supply agreement can help ensure that organic waste is not diverted elsewhere during the course of the project.</i>	<ul style="list-style-type: none"> <li>• If gas is expected to be collected from a series of cells over the course of 20+ years, a lender and project developer will want assurances that the feedstock will continue to be provided (Szymanski et al 2013).</li> </ul>

**Table 8. Procurement Risk**

Procurement risk originates from (1) uncertainty or disruptions in the material supply chains that interrupt construction timelines or threaten operational continuity and (2) the selection of equipment and warranties. Often, vulnerabilities in global supply chains are out of the control of small operators, such as those that might be undertaking an LFG project. However, rather than reacting to issues as they arise, a sound procurement risk strategy anticipates disruptions and identifies alternate suppliers. Some 'technology risk' is covered in this section.

Risk	Mitigation Technique	Considerations
<b>Contracting</b>	<i>Select proven technologies and require references from technology suppliers.</i>	<ul style="list-style-type: none"> <li>Proven reliability of the LFG technology and infrastructure is paramount, though cost per kWh of installed capacity is often the primary criteria used when selecting energy generation technology.</li> <li>References and data on the projects of similar size and fuel type should be provided by technology suppliers.</li> </ul>
	<i>For technologies, obtain warranties and performance guarantees, and review the maintenance agreement terms with an eye toward the warranty restrictions.</i>	<ul style="list-style-type: none"> <li>Request of a fee schedule for service and maintenance in order to plan accordingly.</li> <li>Project developers/partners should transfer all warranties for major machinery to the project owners.</li> <li>Note that maintenance agreements may require project owners to pay for some aspects of repair, such as flying repair-people to the landfill location.</li> </ul>
	<i>Take stock of expected O&amp;M based on grade of gas.</i>	<ul style="list-style-type: none"> <li>Depending on the level of impurities in the gas, infrastructure may corrode at a faster or slower pace—a factor that should be input in the lifetime costs of the project but is often forgotten.</li> <li>Ensure that product warranties do not exclude corrosion-related repairs.</li> </ul>
	<i>Maintain some liquidity to address “non-routine” equipment failures.</i>	<ul style="list-style-type: none"> <li>While it is easy to do financial planning around routine maintenance, major equipment failures that fall outside warranty (California Energy Commission 2002) or outside the purview of insurance can stall or halt projects.</li> </ul>
	<i>Consider purchasing property and business income insurance.</i>	<ul style="list-style-type: none"> <li>While routine maintenance and the costs of operating machinery can be predicted with a fair amount of certainty, unexpected repair or replacement costs that fall outside the scope of a reasonable warranty can be very expensive.</li> <li>Product warranties cover costs of repair/ replacement of specific pieces of machinery, but do not typically cover income losses resulting from gas supply disruptions—these are borne by project owners/investors.</li> <li>This type of insurance can also cover costs incurred when supply chains are disrupted (e.g., if the supplier becomes insolvent).</li> <li>There is also third-party insurance covering economic loss from product malfunction, breach of contract with product suppliers, etc.</li> </ul>
	<i>Early in the process, outline procurement responsibilities (and attendant risk) that can be shifted to a construction firm.</i>	<ul style="list-style-type: none"> <li>Outlining responsibilities by accounting for procurement risk ensures ongoing accountability and may help drive partner or contractor behavior (Beckers, et al 2013).</li> <li>Procurement risk is difficult for any entity to control in many instances.</li> <li>In turnkey projects, contractors can be expected to take on the risk of procurement, though a thorough analysis of the firm’s ability to take on this risk will ensure the best outcome.</li> <li>Contractors can fail to procure materials for legitimate reasons—a lack of local market for certain goods, a global supply shortage, customs hold-ups.</li> <li>Penalties for inability to deliver based on procurement should be reasonable and taking on this risk should be compensated.</li> </ul>
<i>When possible, develop relationships with more than one supplier.</i>	<ul style="list-style-type: none"> <li>This helps hedge against one supplier that has a shortage of equipment/materials and the potential for late delivery of materials.</li> </ul>	

**Table 9. Engineering and Construction Risk**

Once engineering and construction have commenced, many of the risks inherent in this stage of project development should have been anticipated and accounted for in prior stages. For example, delay guarantees on construction should have been written into contracts. The additional risks at this stage largely relate to (1) carrying out work that has been detailed in previous stages and (2) assessing that the work has been done properly and on time.

Risk	Mitigation Technique	Considerations
<b>Engineering &amp; construction</b>	<i>Create a construction schedule with installation payments based on progress.</i>	<ul style="list-style-type: none"> <li>• The project scope and quality expectations should be well-defined within this document.</li> <li>• These milestones should be clear and thoroughly understood by all parties.</li> <li>• Bonus or penalty clauses should be clear, as well.</li> </ul>
	<i>Seek guarantees or warranties on those aspects that are under the control of the design/architecture/engineering firm hired.</i>	<ul style="list-style-type: none"> <li>• For example, there should be financial guarantees in place that cover the schedule and plant performance for a specified period.</li> <li>• Traditionally, these contractors have given only warranties limited to re-designing inadequate infrastructure, but many—especially turnkey operators—are increasingly willing to take on added project risk (California Energy Commission 2002).</li> </ul>
	<i>Monitor construction costs and estimated timelines closely throughout the project.</i>	<ul style="list-style-type: none"> <li>• This monitoring is the responsibility of both the project owner and the contractor.</li> <li>• Detailed records and cost accounting is a ‘best practice’ that is not always followed.</li> <li>• Accurate and realistic estimates of both cost and timeline should be encouraged.</li> </ul>
	<i>Subcontractors on the project should be accountable (just as contractors) to the project owner in terms of quality and insurance.</i>	<ul style="list-style-type: none"> <li>• This accountability can be mediated through the primary contractor, given sufficient trust exists between the contractor and project owner.</li> </ul>
	<i>Require a performance test once construction is complete.</i>	<ul style="list-style-type: none"> <li>• A performance test is intended to demonstrate the LFGE plant meets its emissions criteria or the heat rate expected.</li> <li>• A longer performance test (&gt;7-10 days) is best, though it is in the contractor’s interest to push for a shorter test (e.g., 24-hour).</li> <li>• A performance bond may be required from the contractor to guard against under-performance.</li> </ul>
	<i>Re-enforce the expectation of site safety and quality workmanship through contractual requirements and ongoing contact with contractors.</i>	<ul style="list-style-type: none"> <li>• A close, working relationship between a contractor and employer can make identifying potential problems easier and more timely.</li> <li>• The specifications document should include requirements for insurance and employee safety.</li> </ul>

### 5.2.3 Risk Mitigation in the Operation and Distribution Stage

Risk mitigation at the operation and energy distribution stage relies heavily on monitoring to ensure that systems that were set up in prior stages are operating as expected. Technology service contracts and landfill O&M agreements should be in place at this point. Failure to carefully monitor the day-to-day operations can lead

to power disruptions that would put the project in financial jeopardy—a significant disruption may mean the project loses the contract price for undelivered energy and potential compensation, any renewable energy credits it was expecting, and associated production tax credits (EUCI 2010). Ongoing assessments ensure that O&M can be proactive and adaptable. Disruptions in energy production can also occur as a result of failure

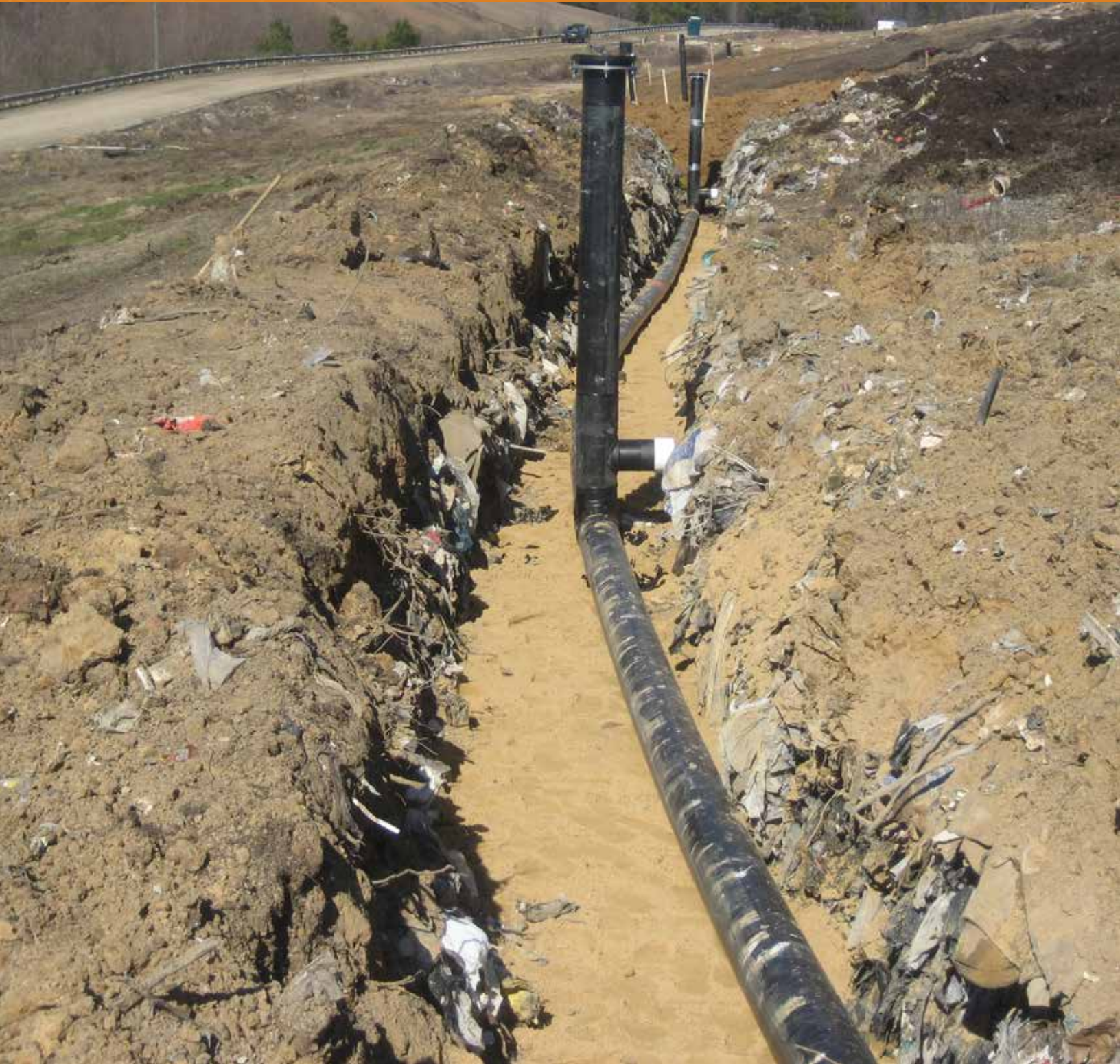
in distribution technology or infrastructure, such as a downed power line, which may or may not be under the control of project owners but can be anticipated. The residual value of the technology—including the price for

equipment sold on a secondary market and/or the cost of dismantling and disposing of the equipment—comes into play at the end of the project lifecycle, but should be assessed as part of a project exit strategy.

**Table 10. Curtailment, Distribution, and Residual Value Risk**

The risk of curtailing gas collection and energy production is foremost at this stage of project development. Residual value should be assessed as part of a project exit strategy.

Risk	Mitigation Technique	Considerations
<b>Curtailment, Distribution, &amp; Residual Value</b>	<i>Ensure proper monitoring and maintenance of LFG collection and energy production technologies.</i>	<ul style="list-style-type: none"> <li>• An expected maintenance schedule should be in place. A technology provider and current users of a specific technology can help create a reasonable schedule.</li> <li>• Some service agreements include remote monitoring and diagnostics.</li> <li>• If the technology provider does not have in-country technicians, provisions need to be made to (a) bring in mechanics on short notice or (b) develop capacity in-house.</li> <li>• Stakeholders should seek a trusted local supplier for replacement parts or preemptively establish a network that can ensure speedy delivery of parts.</li> </ul>
	<i>Budget for periodic equipment overhauls and have a plan in place to work with off-takers if there will be disruption in output.</i>	<ul style="list-style-type: none"> <li>• If the project does not already have a fixed-price service agreement with the technology provider for all annual operations and maintenance, there should be a reserve account for these expected overhauls. It should be periodically re-capitalized.</li> </ul>
	<i>Ensure that landfill operation practices align with the goal of gas collection.</i>	<ul style="list-style-type: none"> <li>• Many operations issues impact the amount or quality of gas that is available. This includes daily capping and the final cap of a landfill, leachate management, pump pressure, and how waste compaction is done (Terraza et al 2007).</li> </ul>
	<i>Use pumps in gas wells to remove excess leachate that may block LFG extraction holes.</i>	<ul style="list-style-type: none"> <li>• Removable pumps can be used at different sites, as needed (Terraza and Willumsen 2009).</li> </ul>
	<i>Negotiate potential energy delivery curtailment scenarios with energy-buyers in the PPA before situations arise.</i>	<ul style="list-style-type: none"> <li>• Assigning curtailment risk can be contentious.</li> <li>• A seller can sometimes, though not often, fully shift the risk to the buyer via a contract that requires the buyer pay for a specific time period of energy production whether or not the agreed-upon energy is fully delivered.</li> <li>• Sometimes the seller will be expected to absorb the costs for a certain period of time, after which the buyer is expected to pay whether or not energy is delivered.</li> <li>• Some make arrangements to treat curtailment scenarios differently based on the reason behind the curtailment (e.g., emergency versus operator error) (Stoel Rives LLC 2010).</li> <li>• Expected curtailment for maintenance should be scheduled and understood by the buyers.</li> </ul>
	<i>If generating carbon credits, be vigilant about specific documenting requirements based on the carbon market being used.</i>	<ul style="list-style-type: none"> <li>• Depending on the carbon market, the process of verification may require specific types of data that are not collected for normal business purposes. Failing to collect the proper data in the required manner may risk losing all carbon credit funding.</li> </ul>
	<i>Factor the expected residual value of infrastructure into the overall project finances and negotiate the items that might be left on site.</i>	<ul style="list-style-type: none"> <li>• Residual value of the infrastructure may depend on how the infrastructure is maintained over the course of the project.</li> <li>• Some comprehensive risk guarantees may cover residual loss (Schwartz et al 2014).</li> </ul>



Installation of a LFG conveyance pipeline: The gas is conveyed through this pipeline to a station where it is used to produce electricity.

# 6

## Case Study: Thailand's Kamphaeng Saen East & West LFGE Projects

Located approximately 80 km outside Bangkok, the Kamphaeng Saen East and West landfills serve much of the area's waste needs and—with the technical and financial support of a third-party developer and the international carbon market—began to generate significant quantities of electricity from landfill gas in 2011. These two 8 MW electricity-generation projects highlight how financing of LFGE can be successful when public and private sector incentives are aligned. Key components of the project's success are:

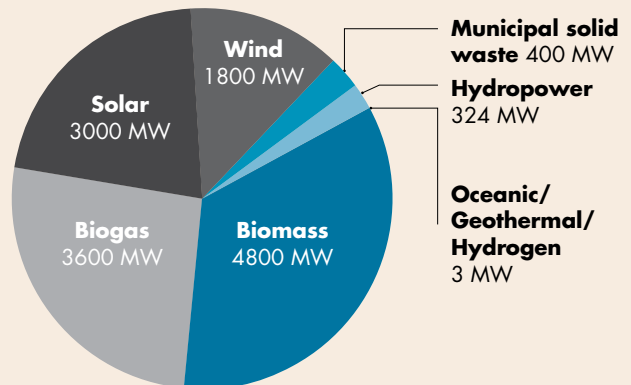
- An experienced private developer with the ability to self-finance and access outside capital beyond the municipal budget
- Functioning international compliance and voluntary carbon markets
- National energy policy reforms including tax exemptions on imported equipment used for renewable energy systems
- Local feed-in tariff incentive schemes for electricity generated from renewable sources

### 6.1 Context

As Thailand develops economically, the country's demand for electricity is increasing dramatically. Faced with an inefficient electricity sector and insufficient domestic power production capabilities in the early 1990s (EPPO 1992), the country began to promote the development of small, independent power producers—especially those that prioritize renewable energy sources (World Alliance for Thai Decentralised Energy Association 2013). Among a series of national-level reforms, the government set renewables standards and enacted new policies and incentive schemes intended to attract foreign direct investment (FDI) to fill gaps in the country's existing capacity. As part of these schemes, the government introduced capital grants in 2003 for renewable<sup>57</sup> energy equipment and subsequently offered tax exemptions for the import of equipment used to produce renewable energy (World Alliance for Thai Decentralised Energy Association 2013). Thailand was among the first countries in Asia to institute an 'adder' or feed-in tariff (Tongsopit and Greacen 2013), which pays a premium above the wholesale price of electricity to renewable energy providers in select industries, including landfill gas production.

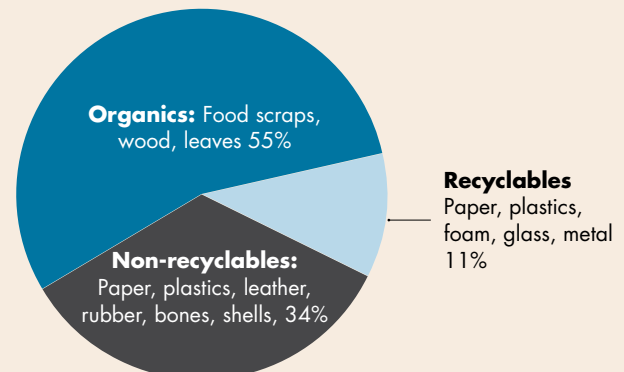
Thailand's landfills hold major potential for methane production—there are a number of well-managed

#### Renewable Energy Targets 2012-2021



Source: Thailand's Updated (2013) 10-year Alternative Energy Development Plan (AEDP 2012-2021)

#### Waste Composition in Bangkok



Source: Bangkok Metropolitan Administration (2011)

sanitary landfills in the country and the composition of waste is heavily organic (BMA 2011). The national energy development plan anticipates municipal solid waste contributing up to 3 percent of Thailand's renewable electricity by 2021 (Tongsopit 2014). However, achieving this goal requires the right incentives to be aligned at the appropriate time and, in the case of the Kamphaeng Saen landfills, it took many timely factors to make the project financially viable. Nonetheless, the example of investment in the Kamphaeng Saen landfills offers some insight into the complex systems that are often required to make financing LFGGE possible in developing country contexts.

## 6.2 Deciding to Invest in Kamphaeng Saen East & West Landfills

Located about 40 minutes by car outside Nakhon Pathom, Thailand (Group 79 Co., Ltd. 2014), the East and West Kamphaeng Saen landfill sites are among the largest landfills in the region, taking in approximately 5-7,000 tonnes of waste per day between them. The landfills are owned and managed by two private Thai companies that have contracted with the Bangkok Metropolitan Administration (BMA) (Sasomsub and Charmondusit 2009) to take in the area's trash for over two decades (Chomsurin 1997).

As early as 2003, the owner-operators of the landfills were actively seeking ways to generate revenue from the gas at their waste facilities. Though the local universities had constructed a few LFG demonstration projects, there was a dearth of practical experience with LFG systems in Thailand at that time. The owners of Kamphaeng Saen briefly connected with the World Bank in 2003 and began the process of preparing financing for an LFGGE system. However, Bank staff were uncertain about the technical viability of the project with the resources available in the country and ultimately opted not to invest (Mariyappan 2014).

Several years later, a UK-based investor/developer called Sindicatum Carbon Capital was also shopping for investment opportunities in the sector. The company was managing a fund capitalized mainly by institutional investors based around climate change, energy, and environmental commodities. With this fund, Sindicatum sought to

### Project Drivers and Risks in Thailand

From the project developer perspective, the primary project drivers include:

- Strong market for carbon reduction credits through CDM at the time
- Relatively inexpensive construction materials and labor
- Feed-in tariffs for renewable power
- Tax incentives for renewable power projects
- Expectation of a more stable political situation than neighboring countries
- Ability to sign a power-purchase agreement

The primary project risks include:

- Legal enforceability of contracts in Thailand
- Local climate of humidity/rain causing excess leachate
- Realized political unrest
- Permitting uncertainty

Sources: Wood (2011), Mariyappan (2014)

finance and develop projects that both reduce greenhouse gas emissions and produce revenue streams. Not only could Sindicatum bring money to the table, the company was already an experienced LFGGE system developer. They came ready to try a proprietary LFG extraction technology that the company developed in China and took into account the high organics content of the waste typically generated in southeast Asia, as well as the region's warm, moist climate.

Partnering with an outside firm was a natural move for the landfill owners, as they lacked any experience with LFG capture and power generation and would, therefore, almost assuredly be unable to attract unsecured or non-recourse financing. From the perspective of an outside developer, the Kamphaeng Saen landfills were attractive investment options for several reasons, not the least of which was the government's renewable energy policies. Through the country's 'adder' fee, renewable electricity producers could receive a bonus of about 8 cents (USD) per kWh above the regular wholesale electricity rate, guaranteed for 7 years (Tongsopit

### Major Project Obstacles and Solutions

The Kamphaeng Saen LFGE projects' major challenges stem largely from the relative newness of the LFG sector in the country. The primary obstacles included:

- No in-country experience with engineering or operations & maintenance of LFGE systems, which required a UK-based team to train a local group over the course of months and/or undertake maintenance themselves
- A lack of available high density polyethylene piping, which had to be imported from the UK, China and the Middle East
- No construction firms had experience installing LFG pipes and wells, so a team from China had to be brought in
- LFG flares were not supplied in-country and had to be sourced from China
- A political situation that closed the Thai Department of Energy, causing up to two years of delays in the CDM application process, though carbon credits were sold to the voluntary market in the interim

Sources: Wood (2011), Mariyappan (2014)

and Greacen 2012). The policies also encouraged the country's utility companies to sign power-purchase agreements with renewable energy providers, which give long-term income security to gas producers. PPAs, in turn, offer assurance to financiers who might otherwise see the income earning potential as too risky.

Sindicatum also looked into a similar potential project in Indonesia, though felt that the political situation in Thailand was more settled and so decided to invest in Kamphaeng Saen.

## 6.3 Financing and Developing the LFGE Systems

As a multi-national investor, Sindicatum was largely able to self-finance the development of the Kamphaeng Saen

LFGE systems. The company did not have to manage bank loans or other forms of debt but rather, it was able to directly inject equity into the project, expecting to be repaid through the sale of (1) electricity onto the local grid and (2) carbon emission reductions credits on the international carbon markets.

In order to work in-country, Sindicatum created two local subsidiary companies, Bangkok Green Power (for the eastern landfill) and PS Natural Energy Co. (for the western landfill), which is a standard practice used to shield the assets of parent organizations from liability. The total project cost of an estimated US\$16.4 million was invested through local and subsidiary contracting companies who managed the building and operations of the LFGE plants. Sindicatum purchased gas rights from the landfill owners for 77,500,000 Thai baht each (the equivalent of US\$4.6 million in 2009).<sup>58</sup>

Beyond collection and generation infrastructure, the landfills also required technical upgrades to the leachate capture system, including collection lagoons, a major but necessary expense in the wet climate. Further, the company was responsible for building grid connections, which meant constructing cables 13 km long for one LFGE system and 15 km for the other.

For Sindicatum, carbon finance was key to mitigating some of the financial risk typically associated with developing new energy projects in emerging markets. Prior to even beginning construction of the LFG system, Sindicatum began project preparation materials to submit to the United Nations under the Clean Development Mechanism (CDM) in order to earn CERs that could be sold to countries seeking to meet their obligations under the Kyoto protocol. Pre-selling some of these expected credits generated a portion of the initial capital needed for the initial capital investment. Because the CDM project approval and verification process is time consuming, Sindicatum also sought Gold Standard approval for the projects in order to sell on the voluntary market, as well. Often, selling on the voluntary market can generate revenue quickly while waiting on verification by the UNFCCC.



A landfill gas flaring system.

## 6.4 Project Challenges

Like all complex financing and construction projects, developing these LFGE system in Thailand had their share of challenges. Engineers with experience in landfill gas extraction are in short supply in Thailand and the local supply chain for the materials required to construct LFGE systems is not well developed. As a result, Sindicatum sourced many of their engineers and construction materials abroad, hiring a team of experienced landfill gas developers from the UK. Further, because of political protests, the national government—including the Department of Energy—was shut down for a period, resulting in major delays (up to two years) in permitting and in registering CDM.

## 6.5 Moving Forward

The current climate for investing in renewable energy is difficult for many firms. As the international price of carbon is low, many projects that rely on carbon credits to supplement that revenue streams from selling electricity to the grid are unable to survive. However, Sindicatum recently signed an agreement with TMB Bank, one of the largest retail banks in Thailand, to begin work on yet another LFG project. As of August 2014, discussions about purchase power agreements with the utility are ongoing and though carbon finance may not be a huge part of the expected return, Sindicatum's mandate includes taking on some of the risk of a downturned market.

# 7

## Case Study: Latvia's Getlini Landfill Gas Project

The largest landfill in Latvia, Getlini landfill, has served residents in the city of Riga and the surrounding municipalities since 1972. As part of an effort to improve waste management throughout the country, the landfill was upgraded in 2001-2002 and now produces both electricity and heat—products that are used to offset power costs onsite and to heat a nearby greenhouse. This project highlights how regulatory pressure for landfill upgrading can create a favorable financial incentive structure for landfill gas extraction and utilization. Key components of the project's success are:

- Incentives provided by EU environmental regulations
- Investment from the local city council of existing own-source revenue into the project
- Co-investment from development aid grants and loans for upfront capital costs and technical assistance from the Global Environment Fund, World Bank, and others
- Project revenue generation through a combination of electricity sales and heat used in a local greenhouse to produce tomatoes sold at local markets

### 7.1 Context

Following independence from the Soviet Union in 1991, the government of Latvia began a process of enacting environmental legislation to reduce pollution and contamination. In addition, during the late 1990s, Latvia was in the process of applying for European Union (EU) membership when the “EU Landfill Directive” was passed, providing additional regulatory motivation for the upgrading of Latvia's landfills (European Commission 1999). Within this emerging regulatory context was Getlini landfill, the largest landfill in the country. Operated continuously since 1972-73, it was a conventional open pit—a non-sanitary landfill that had been plagued for years with open fires and concerns of local groundwater and aquifer contamination. The site occupies 87 hectares approximately 12 km south-east of Riga City in lightly populated marshland. At the time of project initiation, the site received approximately 250,000 tons of waste annually, 80 percent of which was household waste (Getlini EKO b).

### 7.2 Investing in LFGE in Getlini Landfill

The early 1990s was characterized by intense investment by the World Bank in developing newly independent Eastern

European states. The World Bank, in collaboration with a consultancy called SWECO, provided technical assistance to Latvia and Riga City regarding the development of modern sanitary landfills (World Bank 1997). They assessed the feasibility of remediating and updating Getlini versus establishing a new dump site and concluded that maintaining the Getlini site was feasible from both economic and environmental protection perspectives.

The primary project driver for the Getlini site upgrade was to reduce groundwater contamination and reduce the greenhouse gas emissions of the landfill. Utilization of LFG for energy or heat, though not the primary driver of the project, was included from the outset as a means of recouping investment costs. The overall project consisted of three major objectives (Getlini EKO b; Mergner et al 2012):

1. Reduce groundwater contamination from leachate production.
2. Achieve EU regulatory compliance
3. Extract landfill gas for energy and/or heat

For the original landfill site, this involved capping the landfill with clay 50 cm thick and installing a leachate



Installation of a horizontal landfill gas collection pipe.

collection system. Landfill gas was to be collected from the newly capped landfill in addition to the new landfill cells.

In order to undertake this project, the Latvian government created a new corporation, Getlini EKO Ltd, in whom Riga City Council has an 80 percent stake with the remaining 20 percent split between a nearby municipality and the Latvian Ministry of Environment (World Bank 2003). Power production from the landfill gas commenced in 2002 and had increased by nearly six-fold by 2011 (Getlini EKO 2012).

**Table 11. Getlini Landfill Power Production and CO<sub>2</sub> Emissions Reductions**

Year	Power Production (MWh)	CO <sub>2</sub> Equivalent Converted (Tons)
2002	5,098	18,984
2003	17,887	67,200
2004	25,748	96,726
2005	25,425	95,529
2006	26,331	98,931
2007	27,361	102,795
2008	28,742	107,982
2009	31,130	116,949
2010	31,099	116,844
2011	31,295	117,620

Source: Zaļoksnis

## 7.3 Financing and Revenue Generation

As opposed to many other projects described in this report, the Getlini Landfill project was not primarily focused on developing LFGE. Rather, within the context of required leachate reduction and landfill capping, landfill gas offered a revenue generation system to be used to help service the outstanding debt.

Getlini EKO obtained a number of funding sources. The total funds required to complete the project was \$25.21 million, approximately \$5 million of which was earmarked for debt service (Getlini EKO b). The financiers were:

- World Bank Loan: US\$7.95 million
- GEF grant: US\$5.12 million
- SIDA grant: US\$1.5 million
- Riga city council investment: US\$6 million
- Getlini EKO investment: US\$4.64 million

The LFG processing system initially consisted of the landfill gas treatment plant, gas pumping station and five Jenbacher gas engines that each have a power capacity of 1.05 MW and heat capacity of 1.23 MW (Mergner et al 2012). A sixth engine was added in 2009. Each of these cost approximately EUR1 million (Breiksa 2014). The project developers did not apply for CER credits to offset the costs of the renovation, as is common for LFGE projects.

Getlini EKO pursued electricity sales and in 2011, reportedly earned EUR5.6 million selling electricity onto the grid. Initially, the company negotiated a 2-year power-purchase agreement with the local electric utility with a premium price for green power (World Bank 2004). Under this initial agreement, the sale price for electricity was US\$52/MWh—about US\$12 higher than standard pricing (World Bank 2004). However, the project was delayed and the agreement expired. In the second round of negotiations, the power utility did not provide the premium. The Latvian parliament did subsequently pass a law establishing higher payments for green electricity producers, but the law was not made retroactive (Mergner et al 2012; EMCC 2013). Nonetheless, the income from energy sales allowed Getlini EKO to subsidize the rest of the landfill operation, keeping tipping fees at 2007 levels (Mergner et al 2012).

Additionally, the company was initially unable to successfully monetize a significant portion of the excess heat produced by the generators even after using it for all on-site buildings. Because there was not nearby industry interested in making an off-take arrangement, the unusual decision was made to install a series of greenhouses on the landfill site to make use of this heat to grow tomatoes. Begun in 2011, the greenhouse effort is on track to produce 165 tons of tomatoes this year (Breiksa 2014).

## 7.4 Project Challenges

From the perspective of financing LFGE projects, the difficulties that Getlini Eko has faced in obtaining the favorable electricity rates are perhaps most instructive. The primary take-away is that basing a financing model on government subsidies that are not guaranteed rather than prevailing market prices contains significant risk. According to the World Bank, significant disagreements between the municipal shareholders—Riga City Council and Stopini Pagast—as well as lack of initial agreement with Getlini EKO on some key project components were responsible for the project delays that jeopardized the favorable electricity purchase rates.

The project also has encountered some technical challenges in the form of significant chemical residue from siloxanes, hydrogen sulfide, chlorine and fluorine that has damaged various components of the engine and generation system requiring the installation of new gas filters (Getlini EKO 2012).

## 7.5 Moving Forward

The Getlini site continues to receive waste at the rate of approximately 300-400k tons per year. It has been producing 2000-2200 m<sup>3</sup>/hour of LFG with an average methane content of 52-54 percent. The company anticipates continuing to produce electricity at a rate of 35,000 MWh through at least 2020. The Getlini Eko company, created for this project, now offers consulting services on sanitary landfill management and LFG extraction. Additionally, this case study highlights that an LFGE project need not be a stand-alone endeavor but is sometimes used to add value to a larger landfill upgrade project.



Landfill gas pipes aesthetically masked as palm trees at the Sudokwon landfill near Seoul, Korea.

# 8

## Case Study: Brazil's Santa Rosa Landfill Flaring Project

Landfill gas collection and flaring systems were installed in 2012 at Central de Tratamiento de Residuos (CTR) Santa Rosa, Brazil's largest landfill located within the state of Rio. The project was initially conceptualized by the landfill developer and operator, a private concessionaire. Lacking expertise, the private operator sought partners with greater technical know-how and access to carbon finance. The financing, technical assistance, and project oversight were facilitated by a large Brazilian semi-private bank, Caixa Economica Federal, using funds from a World Bank loan coupled with domestic funding earmarked for municipal solid waste projects. Key points are as follows:

- Brazil lacked domestic regulatory or financial incentives for LFG collection at the time of this flaring project's installation
- Financing for the project flowed from a semi-private national bank acting as a government representative for a development project to the private landfill developer
- Carbon finance through the UNFCCC and support from a bank with international market access were critical to the development of this project
- Despite initial plans to do so, Caixa has not yet replicated this model in other landfills

### 8.1 Context

The CTR Santa Rosa landfill is one of the largest landfills in South America, occupying over 2.2 million square meters. It is a modern sanitary landfill with linings, leachate collection and management, compaction and coverings. It is situated 9 km from the city center of Seropedica, west of Rio de Janeiro. The landfill was constructed to receive waste from the greater Rio de Janeiro region as well as two nearby municipalities. It was developed by a private consortium called Ciclus Ambiental<sup>59</sup> as a concession from Rio de Janeiro's solid waste company. The initial contractual term is 15 years with options to extend and the landfill itself has an initial operating license of 18 years. The landfill began receiving waste in 2011 but, recognizing the potential uses of landfill gas, Ciclus sought a partner with expertise and market access to carbon finance to help develop landfill gas operations (Druetra 2013; Ciclus Ambiental; World Bank Carbon Finance Unit).

At the time of project initiation, there were no Brazilian laws or regulations directly addressing the flaring or collection of landfill gas (Bureau Veritas 2012). The 2010

National Waste Management Law and Brazil's National Energy Plan 2030 both provided general incentives for landfill improvements and reduced pollution. However, nationally the majority of landfills were small and managed by local municipalities highly constrained in their ability to make significant infrastructure investments.

Also at the time of construction of the landfill, the only LFG extraction systems in Brazil were financed with CER credits and undertaken by private landfill concessions, a relatively new development in Brazil (UNFCCC 2013). In addition, due to the lack of any supportive pricing or financing mechanisms within Brazil, even the extraction and direct sale of LFG or energy derived from LFG was not considered profitable for a corporation without the additional revenue provided by carbon finance.

### 8.2 Infrastructure Costs and Financing

With the assistance of partners, as discussed below, the landfill gas collection and flaring system at Santa Rosa landfill became operational in November 2012. The system consists of a networked series of vertical and

horizontal gas extraction wells, condensate extraction, LFG pre-treatment and two flares. The first flare went live in 2012, while the second was added in 2013. Together, the flares can burn 7,500 m<sup>3</sup> per hour of landfill gas. The project partners intend to build either LFGE systems or purified LFG piping systems to maximize the usefulness of the extracted LFG, but as of the most recent reporting period only flaring is being conducted (UNFCCC 2015).

The initial investment costs for the LFG collection and flaring infrastructure were approximately US\$16.6 million, though the total project costs include insurance, administration and other costs that are associated with project development. In 2014, the expected IRR was listed as 3.4 percent.

The development of the Santa Rosa landfill fortunately coincided with the implementation of a large-scale Brazilian development project focused on municipal solid waste and carbon finance. In 2010, the World Bank approved a five-year US\$50 million loan to Brazil's designated recipient and coordinator, Caixa Economica Federal. Caixa is a large, semi-private Brazilian bank with experience implementing other large-scale government lending and disbursement projects. Caixa subsequently created a large-scale Program of Activities (PoA) with the UNFCCC CDM to establish a framework for carbon finance for projects within the program's scope.

Caixa is the Coordinating/Managing Entity responsible for all coordination, financial and technical assistance, oversight, validation and verification of carbon emissions. The PoA is a large-scale agreement that authorizes Caixa to facilitate LFG projects involving flaring, combustion for heat, energy generation, or direct piping of LFG for sale. Caixa also specifies that, given its analysis of the Brazilian LFG market, it does not believe that any large-scale LFG projects were likely to be undertaken without both technical assistance and financing facilitated by carbon markets. The PoA was established to enable Caixa

to provide blended sources of financing that use future carbon revenues either as partial loan guarantees or to reduce future interest rate payments in order to make the financing more enticing to private firms (UNFCCC 2013).

The CTR Santa Rosa landfill was thus the first Component Project Activity, or CPA, to be implemented as a component of the Caixa PoA (UNFCCC 2013). Caixa provided technical training to Ciclus staff and continues to play an active role in reporting carbon emissions reductions to the UNFCCC and overseeing the progress of efforts to expand beyond LFG flaring.

### 8.3 Progress and Expectations

The project was registered with the UNFCCC in May 2012 and flaring began that November. The second flare came on-line in August, 2013. During its first monitoring period through December 2013, flaring activities achieved GHG emission reductions of 132,000 tons of CO<sub>2</sub>, approximately one quarter of the predicted value in the initial project design. GHG reductions increased slightly over 2014 but remained approximately one quarter of the anticipated value (UNFCCC 2015). The crediting period is for seven years beginning 2012, with the first CER received by Caixa in 2014 (Caixa Economica Federal 2014). Though the terms of the CPA state Ciclus' intent to develop electricity generation or LFG cleaning and direct sales, neither had been developed or were in process as of this last 2014 monitoring period. This is notable, given the UNFCCC analysis within the project documents indicating that for such a project to be economically viable, it would need both carbon finance and the income from energy or LFG sales. In addition, the Santa Rosa landfill remains the only LFG project as yet created under the large-scale PoA being administered by Caixa.

**Table 12. Initial Costs for Santa Rosa LFG Collection and Flaring Systems Infrastructure (2014)**

<b>Item/Activity</b>	<b>Cost (USD)</b>
LFG collection system (Drilling + Pipeline Network)	\$4,530,154
Vertical Wells	\$6,337,778
Leachate Pump System	\$2,732,472
Welding and assembly	\$1,120,000
Flare and Blower System	\$1,855,000
<b>Total collection and flare infrastructure</b>	<b>\$16,575,404</b>
Annual Operation & Maintenance	\$288,427

Source: UNFCCC (March 2014)



A leachate cleanout manhole at the Ann Street Landfill in Cumberland County, North Carolina. Regular maintenance of the leachate system is important for the success of a landfill gas project.

## 9

# Appendix A. Timing a Landfill Gas Project

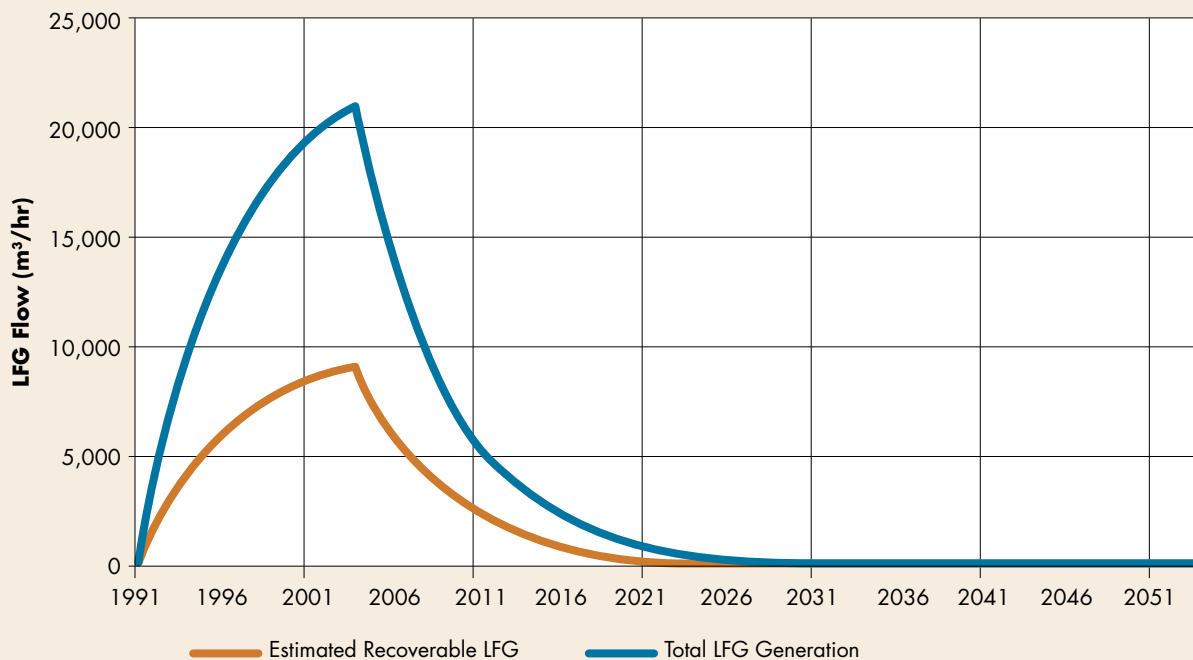
## Box 14. Timing a Landfill Gas Project

Because the breakdown of organic waste into methane is a natural process dependent on a host of site-specific factors, there is significant spatial and temporal variability in landfill gas production. Failure to take this variability into account when calculating the potential biogas reserves leads to errors in system design and puts investments at risk. Tapping the landfill prior to its peak methane production years allows the project to have the greatest impact, both environmentally and in terms of revenue generation. Ascertaining the gas production potential of a landfill and developing a temporal production curve is the first step in deciding whether to take on an LFG project.

Landfills or landfill cells begin to produce methane gas as early as the first year organic waste is deposited and may continue to generate methane for 10 to 60 years. In well-managed sanitary landfills, peak gas production typically occurs within 10 years of deposit, though gas will continue to be emitted over 20 years or more. The initial increase and then decline in gas production are gradual processes and their duration depends largely on:

- Quantity and composition of waste
- Age of the deposit
- Annual rainfall/ landfill permeability
- Moisture and local climate
- Cover and compaction techniques used by the landfill operators
- Landfill's oxygen content and pH levels
- Availability of nutrients within the waste

**Landfill Gas Generation Curves (Hypothetical)**



Sources: U.S. EPA 2013; McBean et al 1995; U.S. DHHS 2001; Model for graph from U.S. EPA (2013)

## Appendix B. Project Partnerships

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LFG operations require the coordination of public and private actors to manage finance, construction, design and engineering, and regulatory aspects of the project. Though not all actors are directly involved in acquiring project financing, all participants may have a role in taking on some project risk, as described in Chapter 5. In general, the following participants are involved in the development of an LFG project:

- Municipal government or landfill owner
- Regulatory bodies
- Landfill operator or gas-rights owner
- Electricity or gas off-taker (public utility, local industry, etc.)
- Engineer or facility designer, construction firm, and equipment manufacturer
- Equity and/or debt holders, including commercial banks or bond holders
- Loan guarantors, such as international organizations or national government
- Community liaison or participation coordinator
- Legal advisor

Structuring the project partnerships, including the ownership of various parts of the project (e.g., establishing gas rights, access rights, long-term operations responsibility) should be among the initial considerations in undertaking an LFG project. The ability of each stakeholder to manage aspects of the project, as well as raise funds and take on risk will largely determine how the

project partnerships are structured. The primary project developers—those with the greatest stake in the outcome—are usually local governments, private landfill owner-operators, public utilities, end-users of energy, outside third-party developers, or some combination of these (Godlove et al 2010).

A combination of each partner's material support for the project and exposure to downside risk (the likelihood of losing money) or upside risk (reasonable expectations of profit or other material gain) (OECD 2010) will determine how they are compensated. Different implementation structures will require different compensation approaches for each participant, as described in the next section. These approaches are highly variable from project to project. However, under each of the four owner-partnership models described in box 15, the landfill owner (public or private) will most likely receive compensation in the form of one or more of the following:

- Land-lease fees and/or gas rights royalties
- Avoided cost of landfill upgrading to meet regulatory requirements
- Avoided energy expenditure if the LFG or its product (electricity) is sold to the landfill owner at a price lower than other available options
- A percentage of gross revenue from the sale of power
- A percentage of net revenue over the lifetime of the project
- Tax deductions or credits

### Box 15. Ownership-Partnership Models by Primary Developer

The U.S. Environmental Protection Agency's Landfill Methane Outreach Program (LMOP) identifies four ownership/partnership structures that are typically used in LFG projects.

#### Landfill owner /operator financed

A conventional landfill owner/operator project involves self-financing and managing development and operations in the absence of a third-party developer but usually with outside technical consultation for the design, engineering, and construction of the plant.

#### End-user or public utility financed

The end-user (e.g., industry) or a public utility opting to secure a renewable or more reliable source of energy may self-finance and operate a LFG system. In this model, a municipality and user may share some costs, but the end-user takes on financing and operation risk.

#### Third-party developer financed

An outside developer finances, manages, and operates a project for a profit. This is sometimes a build-own-operate (BOO) model and sometimes a build-own-operate-transfer (BOOT) model if ownership and operational responsibilities remit to the landfill owner after a specified period.

#### Hybrid or turnkey financing

A combination of owners, end users, and developers financing, constructing, and operating. For example, in a design-build model, an owner might retain ownership of the project, while a developer takes on construction/financing risk in return for profit-sharing.

Source: Godlove, Ganguli, and Singleton (2010); Terraza and Willumsen (2009/10)

## Appendix C.

# Selling Products of LFG: Frequently-Used Contracts Types

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There are a handful of contractual off-take arrangements that are used in LFG projects:

- 1) Projects that flare gas or generate electricity and/or direct-use fuel have the potential to generate funds through **carbon offset contracts**, depending where the project is located and what type of international or regional carbon markets cover it. Purchase agreements for emissions reduction credits can be made via voluntary or compliance markets before a project has begun operations. For example, an Emissions Reduction Purchase Agreement (ERPA) can be made between a project owner and off-taker under the Kyoto Protocol to sell future emissions reduction credits. If the potential emissions reduction is small, these may be sold to a broker or an aggregator.
- 2) **Direct-use contracts** are typically made directly with an off-taker located near to the landfill (e.g., an industrial user that adds LFG to its fuel mix), rather than through a utility. Direct-use gas is often less process gas (lower grade) than pipeline-quality gas. This type of gas is typically less expensive than natural gas, as it offers lower thermal value and may require more equipment maintenance due to impurities in the gas (U.S. EPA 2010).
- 3) Both electricity and gas can be sold via a **Power Purchase Agreement (PPA)** with local utilities, direct power purchasers, or any number of other distributed energy brokers, depending on the make-up of local energy markets. Typically utilities require highly purified gas. High-grade gas should receive a price equal to

natural gas, though there may be negotiations around gas transmission infrastructure and maintaining standards of purification. Electricity off-take agreements provide a consistent and predictable revenue stream and are viewed as secure by investors. However, for electricity generators, an interconnection agreement should be negotiated carefully as the costs associated with connecting to an electric grid (including time investment for LFG staff) may be substantial and prohibitive.

Within direct-use contracts or PPAs, the price of the gas may be fixed or indexed to the price of other fuels. Fixed price off-take arrangements establish a price for gas paid to the producer for a specified period of time (may be adjusted for inflation). Indexed price arrangements track LFG with the price of natural gas, though the price is typically 20-50 percent less (U.S. EPA 2010). Indexed price contracts are riskier than fixed price because of the volatility in natural gas prices, but they can be put in place with floor/ceiling prices to protect both the seller and the buyer.

Within each of these contracts, financial responsibilities for building the piping infrastructure to transport gas, contingencies for unexpected outages, and responsibility for maintenance, and ownership of emissions reductions or other attributes should be clearly spelled out. As in other agreements, ownership of emissions reductions or other attributes, contingencies for outages, and responsibility for purchasing/installing and monitoring transmission equipment must be identified early in the project.

## Appendix D. Revenue Sharing Among Project Partners

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Revenue generated from off-take agreements is divided between debt repayment and among project stakeholders based on a negotiated revenue-division profile. Listed below are some compensation approaches that have been used among project stakeholders in hybrid ownership models. These may be used in combination within a partnership agreement, when appropriate:

- *Fixed or recurring development lease fee.* A landfill owner may charge a developer a lump-sum fee during construction for the rights to enter and use the landfill. They also may charge a monthly or annual fee for these rights. The timing of these payments may require up-front liquidity on the part of the developer.
- *Fixed or percentage royalties.* A landfill owner or the holder of gas-rights may lease or sell the right to extract/sell the gas to a developer. Royalties paid to the owner may be a fixed agreed fee or a percentage of profits from gas sales. An informal survey of LFGGE projects in the U.S. found that the royalty payments ranged from 10 to 30 percent, varying largely based on the relative bargaining power of project participants (Batiste et al 2010).
- *Indexed price or minimum guaranteed royalties.* A landfill owner or holder of gas-rights may sell a developer the use of gas based on a price indexed against the prevailing natural gas rates or the royalties may be a minimum guaranteed amount with a negotiated percent of revenue when revenue is above a certain threshold.
- *Sharing tax benefit or renewable energy credits.* If tax benefits are available based on the environmental attributes of a project, these can sometimes be shared between the owner of the landfill and the project developer (e.g., one party retains the state or local rights while the other receives the federal or national-level benefits), though this largely depends on the tax law of a specific locality. Similarly, landfill owners and developers may negotiate a split of profits (e.g., an 80/20 split) from the sale of voluntary emissions reduction credits.

## Appendix E.

# Pooled Development Funds

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### Box 16. Pooled Debt Instrument in Tamil Nadu, India

The Tamil Nadu Urban Development Fund aims to help local governments in Tamil Nadu, India access finance for public infrastructure, including water, sewage, and solid waste. In 2002, the Fund helped 13 small- and medium-size urban local bodies (ULBs) come together to access bond funding for water and sanitation projects. Alone, none of these local bodies could afford the transaction costs associated with tendering a bond. However, when organized together under Fund's umbrella, the costs were spread among all parties and the credit risk was diversified among stronger and weaker ULBs, making a bond issue possible.

The Fund used a **structured bond** in which each ULB transferred a tenth of its annual repayment commitment into an independent **escrow account** that took priority over all other financial obligations. A separate fund devoted to servicing the bond was invested in low-risk securities. USAID provided a 50 percent guarantee and the state government guaranteed the remaining principal and interest. With these **credit enhancements**, both Fitch and the Indian Credit Rating Agency deemed the pooled debt instrument safe for investment. With the technical assistance of national-level financial institutions, the World Bank and USAID, they were able to successfully issue a 15-year bond.

Though the municipal governments would have had a 12 percent interest rate from other sources, the bond coupon—or interest rate—was 9.2 percent. This was the first bond acquired through pooled financing in India and it set a precedent that has in subsequent years led to a stronger overall bond market in the country, including a significant increase in bond tenure throughout.

*Source:* U.S. Department of Commerce (2008), USAID (2009), Alam (2010)

# Appendix F.

## Baseline Study

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The following list outlines the key points to be assessed in a baseline study for an LFG project. It is sourced from the World Bank's 1999 "Guidance Note on Recuperation of Landfill Gas from Municipal Solid Waste Landfills" by Lars Mikkel Johannessen.

Before considering commercial recovery of LFG, a baseline feasibility study should:

- Assess the waste composition, with an indication of the expected proportion of organic components, their biological half-life,<sup>60</sup> moisture content, and concentrations of hazardous materials. It is important to determine the amount and type of materials that could be hazardous, or those that will inhibit biological activity in the waste (e.g., large quantities of gypsum).
- Compute and predict the annual LFG yield and the reduction over time, using the organic half-life determined above. Predictions of LFG generation should also take into consideration the total amount of waste disposed of over time. If the computed LFG generation proves feasible<sup>61</sup> for existing landfills, the results may be verified by test pumping from several wells on-site over an appropriate time period (at least 2 months) to level out natural fluctuations such as atmospheric pressure.
- Determine the anticipated methane content in the LFG and the LFG calorific value and calculate the potential power to be produced.<sup>62</sup>
- Identify potential buyers of the power (or heat) produced and the distance to distribution networks, whether an electric power grid or heating facility (industry or district heating). After refinement, the LFG could potentially be converted to natural gas and sold to a gas utility.
- Assess the potential energy buyers' willingness to enter into a long-term contract (not shorter than 10 years) for buying power.
- Determine the sales price for the energy to be sold, the conditions for selling energy, and the means for securing selling prices.
- Assess private partnerships' involvement in commercial recovery of the LFG.
- Calculate the feasibility of LFG recovery, where environmental benefits (e.g., reduction of greenhouse gases, replacement of fossil fuel) may be included.
- Review the socioeconomic implications of removing scavengers from the landfill. A bioreactor landfill cannot operate with scavengers on the landfill site, since extensive waste compaction is required and fires on the landfill will interfere with the bioreactions.

# Appendix G.

## Risk Management Framework

There is an extensive literature on risk management in construction projects. For example, this diagram illustrates a generic risk management process, as outlined by Karim et al (2012). The steps are as follows:

Developing a risk management strategy the essential first step in undertaking any construction project.

Identifying the risk is next. According to the authors, can be done by “brainstorming, prompt list, checklist, work breakdown structure, Delphi technique, or by asking expert.”

Next is assessing the risk to evaluate each risk and its effects on the project.

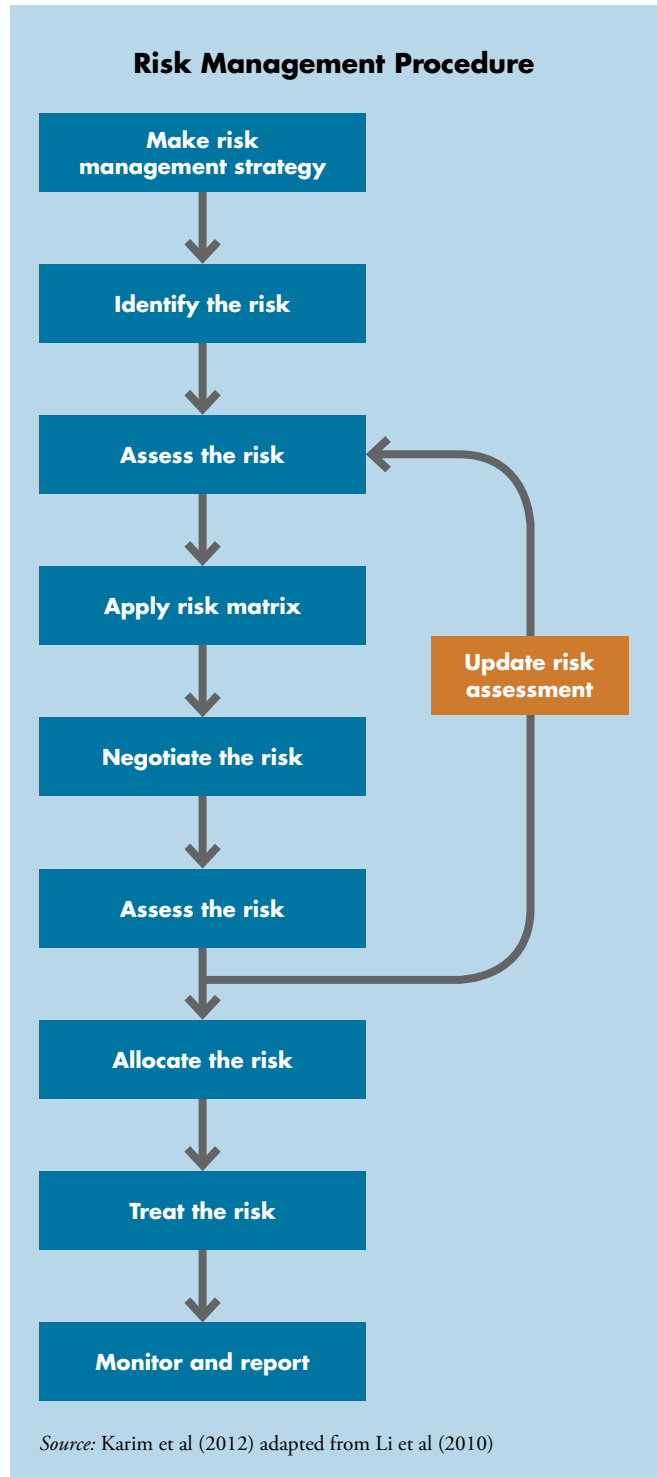
The authors say, risk “can be evaluated based on the possibility of risk occurrence and severity of its impact by developing risk matrix.”

Next, risk must be negotiated between the stakeholders involved in the project. They authors say this “normally takes place after signing the contract. This is the most important step as it reflects the risk management assessment updates continuously.”

After updating the assessment, the risk should be divided among the project stakeholders or partners who are best equipped to handle it.

Treating the risk is next. One can find ways to “avoid, reduce, share, transfer, defer, mitigate, contingency, insurance or accept the risk.”

The last step is monitoring and controlling the risk through some sort of risk reporting mechanism—for example, “listing the details associated with risk such as type of risk, its probability of occurrences, its impact on project, possible treatment.” Monitoring of risk is an ongoing process throughout the lifetime of the project.



# Appendix H.

## Types of Private Participation in Infrastructure

### Box 17. Types of Private Participation in Infrastructure

Though a PPP arrangement implies each party has both an ownership commitment and financial stake in operations, the level of private or public control exists on a continuum and must be negotiated within each project. Engel et al (2010) divides private participation in infrastructure into three categories (public provision, concession/PPPs, and privatization) whereas Guasch (2004) sub-divides these categories into 12 types of private participation—ranging from total public provision with some contracted aspects to various hybrid public/private structures to full privatization. The demarcation of the different ownership categories is not strict. Depending on their characteristics, for example, some management contracts may fit better in the PPP category than the public provision category. The list below is not exhaustive, but simply an illustration of the range of options.

Ownership Grouping	Private Participation	
Public Provision	N/A–Public Supply and Operation	<p>Greater public control</p> <p>Greater private control</p>
	Outsourcing	
	Corporatization & Performance Agreement	
	Management Contracts	
Concession/PPPs	Leasing	
	Franchise	
	Concession	
	Build-Operate-Transfer (BOT)	
Privatization	Build-Own-Operate (BOO)	
	Divestiture by License	
	Divestiture by Sale	
	Private Supply and Operation	

Source: Guasch (2004); Engel et al (2010)

# Appendix I.

## Responsibilities of Private Sector Participants in LFGE

**Table 13. PPPs: Responsibilities of Private Sector Participants in LFGE Projects**

Project Ownership	Primarily Public	Public & Private	Primarily Private
<b>Types of private sector involvement</b>	<ul style="list-style-type: none"> <li>• DBB</li> <li>• DB</li> <li>• Service contract</li> </ul>	<ul style="list-style-type: none"> <li>• Management contracts</li> <li>• O&amp;M contracts</li> <li>• Performance contracts</li> <li>• DBO/DBFO</li> <li>• BOT/BOOT</li> <li>• Lease agreements</li> </ul>	<ul style="list-style-type: none"> <li>• BOO</li> <li>• Divestiture</li> </ul>
<b>Public sector role</b>	<ul style="list-style-type: none"> <li>• Financing capital expenditure</li> <li>• Maintaining full responsibility for the project and operations</li> <li>• Procuring contractors to fulfill essential roles (e.g., engineering)</li> <li>• Regulatory</li> </ul>	<ul style="list-style-type: none"> <li>• Financing capital expenditure, often</li> <li>• Maintaining responsibility for the project, as negotiated with private participants</li> <li>• Procuring contractors to fulfill essential roles (e.g., engineering)</li> <li>• Tendering and negotiating complex contracts with PSPs</li> <li>• Assisting with permitting</li> <li>• Regulatory Tax and policy incentives</li> </ul>	<ul style="list-style-type: none"> <li>• Regulatory</li> <li>• Tax and policy incentives</li> </ul>
<b>Private sector role</b>	<ul style="list-style-type: none"> <li>• Fulfill terms of contracts</li> <li>• Typically design, construction, maintenance of equipment</li> <li>• Take on some design and construction risk</li> </ul>	<ul style="list-style-type: none"> <li>• Fulfill terms of contracts</li> <li>• Often take on design, construction, maintenance of equipment</li> <li>• Take on some design and construction risk</li> <li>• In the case of lease or DBFO, take on finance risk or primary responsibility for acquiring adequate financing</li> </ul>	<ul style="list-style-type: none"> <li>• Full ownership stake, including financing, design, engineering, procurement</li> </ul>
<b>Sources of finance or assistance</b>	<ul style="list-style-type: none"> <li>• Municipal or national government funds (muni bonds, grant funding, etc.)</li> <li>• Government subsidies</li> <li>• IFI debt or finance</li> <li>• Tax exemptions</li> <li>• Traditional commercial debt</li> </ul>	<ul style="list-style-type: none"> <li>• Municipal or national government funds (bonds, grant funding, etc.)</li> <li>• IFI debt or finance</li> <li>• Tax exemptions</li> <li>• Traditional commercial debt</li> <li>• Private project developers</li> <li>• Equipment vendors</li> <li>• Investment banks or institutional investors</li> <li>• Royalties from lease of project/environmental assets</li> </ul>	<ul style="list-style-type: none"> <li>• Tax exemptions</li> <li>• Government subsidies</li> <li>• Private project developers</li> <li>• Equipment vendors</li> <li>• Investment banks or institutional investors</li> <li>• Private equity firms</li> <li>• Venture capital firms</li> <li>• Institutional investors</li> </ul>

**Table 13. PPPs: Responsibilities of Private Sector Participants in LFGE Projects** (cont.)

Project Ownership	Primarily Public	Public & Private	Primarily Private
<b>Advantages</b>	<ul style="list-style-type: none"> <li>Government or landfill owner maintains control of project</li> <li>Revenue reverts to government/landfill owner</li> <li>Some transfer of design and construction risk</li> <li>Draws on expertise from private sector</li> <li>Potential for tax exemption</li> </ul>	<ul style="list-style-type: none"> <li>Government or landfill owner maintain some level of control of project with some risk transfer to private sector</li> <li>Some revenue or ownership will revert to government or landfill owner at some point in the project lifecycle</li> <li>Full or partial transfer of design, construction risk, financial risk</li> <li>Draws on expertise from private sector</li> <li>Potential for tax exemption</li> </ul>	<ul style="list-style-type: none"> <li>Full risk and capital expenditure taken on by private sector</li> <li>Implementer with expertise</li> <li>Public sector able to facilitate production of public good without paying for full project</li> <li>Efficient use of capital</li> <li>No public responsibility for interconnection and off-take agreements</li> </ul>
<b>Drawbacks</b>	<ul style="list-style-type: none"> <li>No private investment</li> <li>Government or landfill owner take on most project risk, including responsibility for capital expenditure</li> <li>Potentially limited expertise in the sector</li> </ul>	<ul style="list-style-type: none"> <li>Potential for profit motivation to come in conflict with expectation of public goods provision</li> <li>Often extensive tendering process</li> <li>Often requires public subsidy (e.g., credit guarantees)</li> <li>PPPs entail lesser control by project owner</li> <li>Cost recovery not always possible</li> </ul>	<ul style="list-style-type: none"> <li>LFGE projects often require some form of subsidy</li> <li>Potential for profit motivation to come in conflict with expectation of public goods provision</li> <li>Public sees smaller share or no share of revenue</li> <li>Little accountability to public</li> <li>Long-term commitment to private sector</li> </ul>
<b>Design/engineering</b>	<ul style="list-style-type: none"> <li>Private sector (fee contract)</li> </ul>	<ul style="list-style-type: none"> <li>Private sector (fee contract or PPP)</li> </ul>	<ul style="list-style-type: none"> <li>Private sector</li> </ul>
<b>Construction</b>	<ul style="list-style-type: none"> <li>Private sector (fee contract)</li> </ul>	<ul style="list-style-type: none"> <li>Private sector (fee contract or PPP)</li> </ul>	<ul style="list-style-type: none"> <li>Private sector</li> </ul>
<b>Finance</b>	<ul style="list-style-type: none"> <li>Public sector responsibility</li> </ul>	<ul style="list-style-type: none"> <li>Largely public: management contracts, O&amp;M contracts, performance contracts, DBO, BOT</li> <li>Largely private: Lease agreements, concession contracts</li> </ul>	<ul style="list-style-type: none"> <li>Private sector responsibility, often augmented by public policies</li> </ul>
<b>O&amp;M</b>	<ul style="list-style-type: none"> <li>Public or private (fee contracted), depending on arrangement</li> </ul>	<ul style="list-style-type: none"> <li>Public or private, depending on arrangement</li> </ul>	<ul style="list-style-type: none"> <li>Private sector</li> </ul>

## Appendix J.

# Proposal Security Clause as a Pre-Screening Tool

### Box 18. Proposal Security Clause as a Pre-Screening Tool

Proposal securities are sometimes used to pre-screen for qualified engineering, procurement, and construction companies. In order to save time and limit the number of proposals from inexperienced contractors, governments or landfill owners will sometimes require that proposals for various aspects of an LFG project are securitized with a bond or cash. Those companies that wish to bid on the engineering, procurement, and construction aspects of an LFG project are required to submit a sum of money with their proposal.

If a proposal is selected, the bond or check will only be returned if the landfill owner (local government, in this case) and the contractor can come to an agreement on the contracting of the task. This helps ensure from the outset that the contracting company has the capacity to see a proposal through to contracting. Companies whose proposals are not selected receive their security back. Below is an example of specific language used by officials in the southeastern U.S. in a recent Request for Proposals (RFP).

#### 9. Proposal Security

A proposal bond or certified check in the amount of \$30,000 is required to accompany each proposal. Bonds or checks shall be made payable, without condition, to Wake County. Wake County reserves the right to retain proposal security of all reasonable proposals until 180 days after proposals are due. Proposal security for proposals deemed unreasonable shall be returned immediately. If a Prospective Bidder withdraws his proposal, fails to negotiate in good faith with the County, or if after the County and the Prospective Bidder agree on terms of a contract, the Prospective Bidder fails to sign a contract and provide the necessary bonds within 14 days after a copy of the contract has been presented to him, the entire amount of proposal security shall be forfeited to Wake County. Such forfeiture shall not constitute the limit of the respondent's liability.

*Source:* Roberson (2014), Wake County (2014)

## Appendix K. Estimated Emissions by Municipal Solid Waste Activity

The following is a comparison of carbon output (CO<sub>2</sub>e) per ton of waste based on the waste composition in Rio de Janeiro, Brazil. A similar chart appears in the companion

to this report, *Sustainable Financing and Policy Models for Municipal Composting*.

**Table 14. Estimated Emissions by Disposal Method**

Disposal Method	Emissions (million tonnes CO <sub>2</sub> e)
Landfill with no methane capture	5.2
Open dump (unmanaged, >5m deep)	4.6
Recycling all paper/cardboard, metal, glass, and plastic (assuming remaining waste is sent to landfill)	2.9
Composting all food waste, yard waste, and wood (assuming remaining waste is sent to landfill)	2.9
Landfill with 50% methane capture	2.6
Anaerobic digestion of all food waste, yard waste, and wood (assuming remaining waste is sent to landfill)	2.6
Open burning	1.7
Incineration (continuous with stoker)	1.5
Composting all food waste, yard waste, and wood	5.2

Source: CURB 2016

### Notes on methodology:

- These emissions estimates were calculated using the tool CURB: Climate Action for Urban Sustainability developed by the World Bank in partnership with AECOM Consulting, Bloomberg Philanthropies, and the C40 Cities Climate Leadership Group
- Emissions are primarily calculated using the Intergovernmental Panel on Climate Change methodologies
- Emissions are calculated for a proxy city: Rio de Janeiro, Brazil using waste composition and generation data collected by the World Bank in 2014. Total quantity generated was 3,665,600 tonnes which assumed 0.58 tonnes/capita/year
- The assumed waste composition was as follows:
  - Organic waste: 53% (Food: 48%, Yard: 3%)
  - Plastics: 16%
  - Textiles: 2%
  - Other: 2%
  - Paper/cardboard: 18%
  - Glass: 7%
  - Metal: 2%
  - Rubber and leather: 1%
  - Wood 1%
- Any residual waste that cannot be processed using the outlined method was assumed to be disposed in a landfill with no methane collection
- No energy capture was assumed for the treatment methods, unless otherwise mentioned
- Greenhouse gasses considered are methane, carbon dioxide, and nitrous oxide

## References

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## Endnotes

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- <sup>1</sup> Municipal solid waste is the third largest source human-generated methane. Source: CCAC UNEP Secretariat (2012)
- <sup>2</sup> Readers with limited knowledge of LFG systems may refer to any of several LFG project development handbooks cited throughout this report.
- <sup>3</sup> It should be noted that LFG systems do not ever collect all the gas generated by landfills. These systems can lose 30-50% of the overall gas produced depending on the type of cap. If a landfill has a geo-membrane liner cap, a landfill can get down to about 10% lost gas, but if it has an earth/clay cap, it can lose over half the gas. Based on comments by Farouk Banna (2016).
- <sup>4</sup> “Organic” or “organic waste” refers to plant or animal based waste, as opposed to synthetic materials, which are easily broken down by environmental bacteria.
- <sup>5</sup> In closed or sealed landfills, bacteria, which utilize oxygen will quickly deplete the supply of the gas. The resultant oxygen free, or “anaerobic” environment, promotes the proliferation of bacteria, which thrive in oxygen free environments, some of which release methane gas as a byproduct of their metabolism.
- <sup>6</sup> LFG is typically 50-56% methane with the remainder made up of carbon dioxide (~50%) and trace amounts of nitrogen, oxygen, hydrogen sulfide, hydrogen and other non-methane organic compounds.
- <sup>7</sup> Research findings are varied. See: Robertson, Thomas and Josh Dunbar. (Sept 2005). “Guidance for Evaluating Landfill Gas Emissions from Closed or Abandoned Facilities.” US EPA. <<https://clu-in.org/download/char/epa-600-r-05-123.pdf>>; Hamer, Geoffrey (Dec 2003). “Solid waste treatment and disposal: effects on public health and environmental safety.” *Biotechnology Advances*. Vol. 22, Iss. 1-2, p 71-9.; Vrijheid, M. (Mar 2000). “Health effects of residence near hazardous waste landfill sites: a review of epidemiologic literature.” *Environmental Health Perspectives*. 108 (Suppl 1), p 101-12.; State of New York Department of Public Health (2010). “Important Things to Know about Landfill Gas.” <[https://www.health.ny.gov/environmental/outdoors/air/docs/landfill\\_gas.pdf](https://www.health.ny.gov/environmental/outdoors/air/docs/landfill_gas.pdf)>.
- <sup>8</sup> Combustion converts methane into water and carbon dioxide, a less potent greenhouse gas.
- <sup>9</sup> A standard LFG system involves perforated gas wells installed vertically or horizontally in a covered waste pile that has at least one gas-impermeable layer. An extraction blower forces gas into a system that – depending on the use of the gas – may separate moisture, condense or compress gas, scrub impurities, and otherwise prepare it for use.
- <sup>10</sup> Provided those goals are predicated on what is possible given the existing landfill conditions, ownership structure, and legal/social/financial/technological conditions.
- <sup>11</sup> Financing, as opposed to funding, implies investment with the expectation of repayment and some return.
- <sup>12</sup> For further discussion of dump closure, see: International Solid Waste Association (2007)
- <sup>13</sup> For a more extensive discussion of flaring, see: Scottish Environment Protection Agency (2002).
- <sup>14</sup> There are a number of approaches to baseline feasibility studies, though the model outlined here focuses on financing. See Appendix F for another example of a general baseline feasibility assessment.
- <sup>15</sup> For example, the U.S. EPA offers seven country-specific gas modeling spreadsheets for regions around the world.
- <sup>16</sup> LFGcost-Web is a comprehensive Excel-based tool that offers a preliminary analysis of project financial feasibility. The cost estimates from this tool are based on American prices and so are not applicable to most scenarios outside the U.S. However, using the tool is an excellent way to understand the process of financial feasibility assessment and its component parts.
- <sup>17</sup> This model originated in LMOP’s 1996 landfill gas project development handbook (U.S. EPA 1996). It was updated and simplified it in a February 2015 revision of the handbook.
- <sup>18</sup> For more information, Appendix B describes contracts types frequently-used when selling LFG or energy.
- <sup>19</sup> LFG feasibility studies are often available in public records and, for example, a pro forma output can be found in Attachment 2 of the Sioux Falls study undertaken in 2006. Source: R.W. Beck (2006)
- <sup>20</sup> It may also, however, be problematic if the sources of

financing for a project are not sufficiently diversified. Investors may see a project that is heavily underpinned by a government entity as having a high degree of policy risk – that is, there is potential that a change in policy or a downturn in some government revenue streams could financially disable the project.

- 21 For example, in Ethiopia, 90 percent of the proceeds from public land-lease must go toward financing infrastructure investment. Source: Peterson (2009)
- 22 It is not always the case that LFG systems improve the state of the landfill, particularly if they are poorly managed, lack leachate control systems, fail to adhere to odor control regulations, etc.
- 23 A 2013 review of private participation in infrastructure in developing countries found that, with the exception of China's water sector, contracts are overwhelmingly tendered by the national government, as opposed to being led by sub-sovereigns. See: Jett and Verink (2013)
- 24 Corporations or multinationals also issue bonds, though those bonds are not discussed at length here.
- 25 Conventional wisdom holds that municipal borrowing should be used strictly for capital investments that contribute to the economic productivity of a locality, as opposed to ongoing operational expenses.
- 26 In addition, local authority to tender bonds is often subject to limitations by national governments that wish to avoid an implied sovereign guarantee. Further, municipal issuers that have a poor credit history or lack the capacity to predictably raise revenue may not be able to produce investment-grade bonds without special credit-enhancement schemes such as partial credit guarantees or collateralized escrow accounts used specifically for debt servicing.
- 27 There is some debate about whether LFG projects should be classified as 'renewable.' For a dive into this discussion, see: Chen and Greene (2003)
- 28 Since 2008, the World Bank has issued \$6.4 billion in green bonds with coupon rates ranging from less than 1 percent to 10 percent and maturity of between 3 and 10 years. As of mid-September 2014, there have been 68 transactions in 17 currencies. Source: World Bank Treasury (2014).
- 29 For more on World Bank green bonds, see: <treasury.worldbank.org/cmd/pdf/ImplementationGuidelines.pdf>.
- 30 For example, see the New Hampshire Municipal Bond Bank's pooled municipal bonding program: <www.nhmbb.org/pdf\_documents/marketingbrochure.pdf>.
- 31 For an example, see Appendix E.
- 32 For more on designing a transfer system, see: Bahl (April 2000)
- 33 Nonetheless, fiscal constraints in the public sectors are such that the World Bank estimates the private sector will need to provide up to 85 percent of the capital finance for green infrastructure projects. Source: Baintie et al (2012)
- 34 Bahl and Bird (2013) stress the importance of a sound public finance system in the creation of an efficient private market, stating that though commercial borrowing and PPPs "may have important roles to play in developing adequate infrastructure in some countries, they can neither substitute for a sound local revenue system nor realize their full potential in the absence of such a system."
- 35 In particular, lenders will verify the cash coverage, or amount of funding the project expects beyond the amount needed to service debt. The coverage is often expected to be in excess of 20 percent of the debt service amount though the life of the loan. Source: California Energy Commission (2002)
- 36 These are loans offered by a group of financial institutions (a 'syndicate'), but typically administered by one institution on behalf of the group.
- 37 New sources of equity financing have gained prominence in recent years, which may benefit LFGE operations. In particular, institutional investors, insurance companies, pension funds, and other organizations that carry long-term liabilities may be interested in LFGE projects, particularly as the technologies mature and gas availability predictions become more reliable. There appears to be growing interest from private equity funds that invest in infrastructure projects and those interested in green infrastructure more specifically. Source: Trade Union Advisory Committee (2012)
- 38 DBBs are distinguished from DBs in that the former entails hiring separate entities for the design/architecture and construction processes (a 'bid' is issued in order to acquire the construction contract).
- 39 As of 1 June 2015. Source: UNEP DTU (2015)
- 40 The U.S. EPA identifies four categories of added cost based on these requirements: (1) purchasing/installing

equipment to verify emissions; (2) additional monitoring and record-keeping; (3) verifying emissions; (4) registering and issuing credits. Source: Godlove and Singleton (2010)

- <sup>41</sup> There are numerous publications detailing the process of preparing a project for the CDM process. See section 6.2 of World Bank (2004) “Handbook for the Preparation of Landfill Gas to Energy Projects in Latin America and the Caribbean” for flow charts detailing the process.
- <sup>42</sup> Technology risks, financing risks, policy risks and others are outlined in Chapter 4. In terms of a risk-reward profile, electricity-generating LFG projects often produce relatively small amounts of electricity (more or less 1 to 15 MW), though their legal and development costs are comparable to larger projects.
- <sup>43</sup> It should be noted that energy derived from landfills is not always considered “green” and sometimes does not qualify for renewable energy incentive schemes. See Chen and Greene (2003).
- <sup>44</sup> For example, a U.S.-based study of electricity interconnection costs for renewable energy sources found an average cost of US\$77,560 per MW of installed capacity. Source: Jaramillo and Matthews (2005).
- <sup>45</sup> For variety of guarantees offered by the World Bank Group, including IBRD, MIGA and IFC see: World Bank Group (2015a)
- <sup>46</sup> Further, institutional investors, such as pension funds, often have strict rules around investing only in investment-grade (BBB- or higher) bonds. Source: Winpenny (2008)
- <sup>47</sup> Landfills in general are complex, adaptive systems whose operations contain high levels of endogenous uncertainty. The unique characteristics of each landfill make it difficult to trust risk that is modeled at a macro-level. Mavropoulos and Kaliampakos (2011) suggest a framework for assessing risk in biogas projects that acknowledges this complexity.
- <sup>48</sup> For a more general introduction to risk mitigation in infrastructure projects, Matsukawa and Habeck (2007) and Schwartz et al (2014) offer a broad overview of risk types in infrastructure development, mitigation techniques, and sources of financial assistance, including an extensive review of assistance available from development institutions.
- <sup>49</sup> Depending on who has done the categorization, political risk may overlaps in meaning with country risk, policy risk, civil risk, social risk, and others. Here, it is used as a catch-all for these.
- <sup>50</sup> Sometimes called political risk guarantees, depending on the provider. Can include partial or full coverage for agreed-upon events.
- <sup>51</sup> Ehlers (2014) notes that government cash flow guarantees that provide full insurance against any loss may “destroy the incentives for cost minimization and quality maintenance.” Thus, achieving an optimum risk distribution among project participants should be the goal, as opposed to maximally transferring risk to one party or another.
- <sup>52</sup> Often on the order of 15-25 percent. Source: California Energy Commission (2002)
- <sup>53</sup> There is an extensive literature on general risk management procedures for complex construction projects that can be referred to for a broader risk management architecture (see Appendix E).
- <sup>54</sup> Croce, Claudia comments on paper (2016).
- <sup>55</sup> Terraza, and Willumsen 2009 suggest 6-8 weeks, Claudia Croce in paper comments (2016) suggests up to 3 months.
- <sup>56</sup> For an example of a bid document and conditions of a construction contract document that lay out specifics, see: Engineers Joint Contract Documents Committee (2011).
- <sup>57</sup> Thailand has included LFG among the country’s ‘renewable energy’ sources and so for the purposes of this case, it is referred to as such.
- <sup>58</sup> 2009 USD, Based on 77,500,000 baht, number sourced from CDM PDD for Project 3462: Bangkok Kamphaeng Saen East: Landfill Gas to Electricity Project and Project 3483: Bangkok Kamphaeng Saen West: Landfill Gas to Electricity Project
- <sup>59</sup> Ciclus is also referred to in some documents as “SERB – Saneamento e Energia Renovável do Brasil S.A.”, or as a combined as “SERB/Ciclus.”
- <sup>60</sup> The time it takes through biodegradation to reduce the organic content of a material to half of its original organic content.
- <sup>61</sup> i.e., there is potential for generation of a minimum of 250 kW electricity [...]
- <sup>62</sup> Methane content should on average be higher than 40-45% and thus the LFG should have a lower heating value of 14-16 MJ/Nm<sup>3</sup> to be feasible for utilization.

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