ELLA
Evidence and lessons from Latin America

Waste management is typically viewed as a resource intensive activity. Yet some urban areas in Latin America have managed to turn this idea on its head by converting waste into energy and profit.

TURNING WASTE INTO RESOURCES: LATIN AMERICA'S WASTE-TO-ENERGY LANDFILLS

SUMMARY

Latin America has experienced rapid economic growth, associated with urban migration and unplanned expansion of infrastructure and public service provision. Municipalities face the dual challenge of providing infrastructure that improves quality of life but that does so at an affordable cost. Effective municipal waste management practices are limited in the developing world, causing public health problems and potent greenhouse gas (GHG) emissions. Waste to energy landfills are a solution that harnesses this duality, providing numerous benefits such as proper disposal of waste and reduction of disease, plus capturing biogas which can be put to productive use in the form of electricity generation, while also reducing the emission of harmful greenhouse gases. In turn, this electricity could potentially substitute traditional forms of energy used for public lighting or to fuel public works. This Brief examines how cities in Latin America have turned the problem of waste management into an opportunity. It documents one of the first experiences of low-carbon waste-management infrastructure - a waste to energy landfill - in the region, through a case study from Monterrey, Mexico's second largest city. The story of Monterrey shows how the city turned its landfill waste into electricity that moves its subway and provides safer streets through public lighting, while at the same time shrinking municipalities' operating costs and tackling climate change by reducing GHG emissions.

CHALLENGES IN MUNICIPAL WASTE MANAGEMENT IN DEVELOPING COUNTRIES

Cities in the developing world are growing quickly. Between 2000 and 2050, urban populations in Asia and Africa are expected to double, from 36% to 62% in Africa, and from 37% to 65% in Asia.[1] This migration creates growing demand for public services, from health and education, to transport, sanitation and waste management.

In developing countries it is common to find waste on the streets and in gutters, resulting in unpleasant odours, multiplying the quantity of pests, blocking drainage systems, and negatively impacting public health, not to mention emitting GHGs and

[1] Data from the United Nations Statistics Division, 2011, Municipal Waste Treatment.

contributing to climate change (see Text Box). Typically, Latin American cities have limited resources to provide adequate public services and infrastructure for citizens. This problem is compounded by the new challenge of providing public services with a low-GHG or low-carbon approach. Waste management services can consume up to a third of a municipality's resources, so it is common to cut corners, resulting in inefficient service provision.[2] There is a further social dimension: the absence of adequate waste management creates low-skill jobs for populations living nearby dumps, who make a living out of separating recyclable materials.

Figure 1 illustrates levels of waste treatment in different countries. Darker tones mean that a higher proportion of waste is collected, while lighter tones represent lower levels of waste collection. Africa has the most limited provision of municipal waste management, followed by Asia and then by Latin America. In Latin America, only 23% of the urban population's waste is safely disposed, while 60% of the total waste ends up in dumps or inadequate landfills.[3]

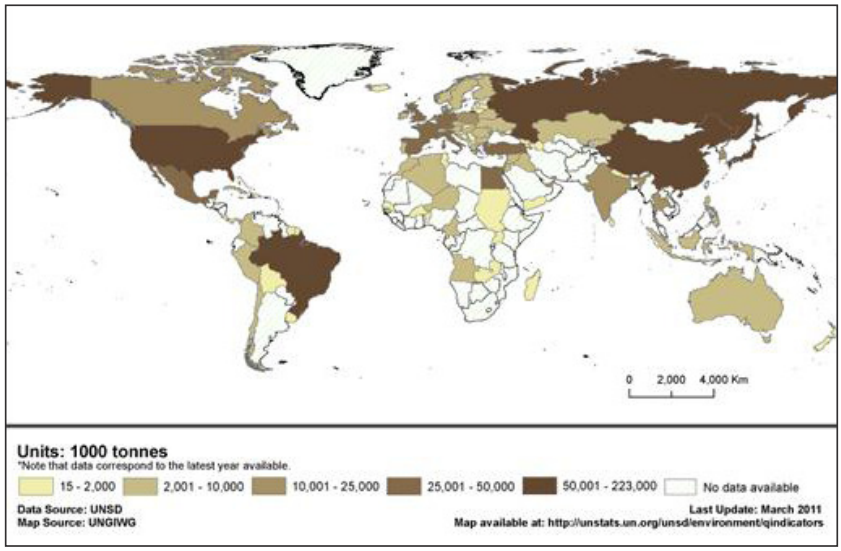
Figure 2 shows how waste management practices vary from region to region. Of the 27 countries included in the study, results show that 95% of waste goes to landfills in Africa, 83% in Latin America, and 26% in Asia. It is important to note that data collection only covers a fraction of all waste produced in these regions. Countries with a higher level of income tend to have higher levels of recycling and incineration.

What are Waste-to-Energy Landfills?

Waste-to-energy landfills not only store waste for final disposal but also capture gas which can be converted into energy as a result of the decomposition process. Waste is compacted with bulldozers into layers, separated by alternate layers of dirt. A cover over the landfill, which can be made out of concrete or a flexible material known as a liner, serves to capture landfill gas (LFG), a by-product of organic decomposition. LFG contains methane, a potent greenhouse gas (GHG); methane contains 21 times more global warming potential than carbon dioxide (CO_2), comprises up to 14% of global GHG emissions, and is the second largest contributor of GHG emissions after CO_2 (CO_2 represents 77% of the worldwide total measured in global warming potential).[4] Methane, however, is also a fuel that can be processed and used to power a motor to generate electricity.

A relatively simple set of technologies enables this process, using biogas capture pipes and a gas-fuelled engine. The technology has proven to be easy-to-operate and has been used extensively in developed countries. In Europe, more than 10,000 biogas plants are recovering and utilizing biogas from agriculture, industry and waste water treatment, producing heat, steam, electricity and vehicle fuels.[5]

Figure 1: Treated Municipal Waste



Source: United Nations Statistics Division. 2011. Municipal Waste Treatment. Online publication.

[2] Bartone, C., Bernstein, J., Wright, F. 1990. *Investments in Solid Waste Management: Opportunities for Environmental Improvement*. World Bank, Washington, DC.
[3] Public-Private Infrastructure Advisory Facility (PPIAF). 2007. *Managing Municipal Solid Waste in Latin America and the Caribbean*. Gridlines, Note No. 28. PPIAF, World Bank, Washington, DC.
[4] Baumert, K., Herzog, T., Pershing, J. 2005. *Navigating the Numbers: Greenhouse Gas Data and International Climate Policy*. World Resources Institute, Washington, DC.
[5] European Biogas Association (EBA). 2011. *Biogas*. EBA, Brussels.

Figure 2: Waste Management in Different Regions

	Municipal waste collected	Landfills	Incineration	Recycling	Compost
	1,000 tonnes	%	%	%	%
Africa	3,644	95	1	1	0
Asia	25,459	26	9	17	0
Latin America	4,829	83	9	4	1

Own Elaboration
Source: Data from the United Nations Statistics Division, 2011, Municipal Waste Treatment.

Countries with lower levels of income tend to use more landfills, or dump sites with some informal material recovery.

Why Waste-To-Energy Landfills Are Appropriate For Cities in Developing Countries

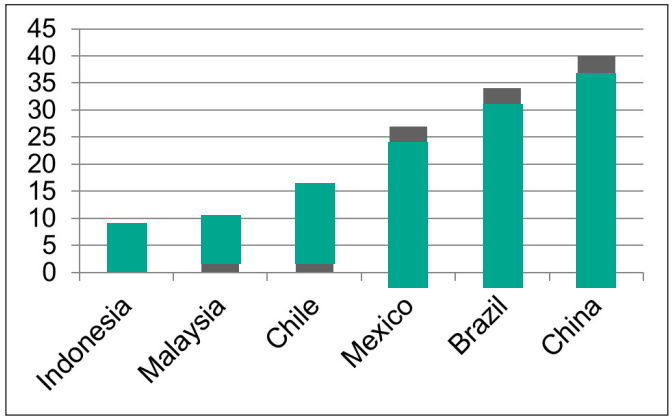
In the face of budget constraints, city authorities are taking a second look at low-carbon development. By employing low-carbon infrastructure, such as waste-to-energy landfills, governments can access international carbon finance for GHG mitigation and enter the global carbon market. With the rising profile of climate change, governments are coming to see climate-proof infrastructure as more attractive, as it provides long-term solutions and reduces vulnerabilities and risks. Nonetheless, investments in infrastructure compete with other spending priorities, meaning the cost-benefit balance of initiatives like waste-to-energy landfills needs to be convincing.

Municipal waste management is a sector with relatively low levels of required investment compared to other low-carbon investment alternatives, and it has a high environmental, social and economic impact. Municipal waste management has a high GHG reduction potential and financial profitability when it is linked with electricity generation, in part because it uses a technology that has already proven to be successful in many developed country cities. It also provides multiple local and global benefits, such as climate change mitigation and improvements in sanitation and public health. Finally, the income generated by GHG certificates, electricity generation and other income streams can actually fund its operations. Furthermore, by converting the methane from landfill gas into electricity, it can then substitute traditional forms of energy, saving money and resources for the local administration, or may even be sold to the grid to generate revenue.

THE LATIN AMERICAN APPROACH

Latin America generates more than 369,000 tonnes of urban waste daily.[6] Of this total, 56% is generated in large cities, 21% in intermediate cities, and 23% in small cities, with 60% of the total being residential waste on average.[7] More than 99 projects to launch waste-to-energy landfills have been approved and financed in the Latin American region, through carbon markets associated with the Clean Development Mechanism (CDM), resulting in the reduction of more than 19 million tonnes of CO_2 equivalent[8] from 2007 to 2012.[9]

Figure 3: Number of Landfill Gas Projects Under the Clean Development Mechanism – Global Distribution



Own elaboration
Source: Data from UNFCCC portal on the CDM: CDM Insights.

The Case of Monterrey, Mexico

Monterrey, Mexico became the first city in the Latin America region to successfully adopt waste-to-energy landfills. The project began in the 1990s and proved to be so successful that other cities in Mexico have since replicated the approach. Given the municipal waste management problems faced throughout Mexico, the Mexican central government had been seeking solutions through decentralisation and privatisation of waste management. Integrated municipal waste management, with resultant GHGs reductions, proved to be a source of income through carbon credits. Such projects were so effective that they triggered an increase in investment in

[6] PPIAF 2007, above n 3.
[7] Pan-American Health Organization (PAHO). 2005. *Report on the Regional Evaluation of Municipal Solid Waste Management Services in Latin America and the Caribbean*. PAHO, Washington, DC.
[8] CO^2 equivalent or CO^2eq is a metric measure used to compare the emissions from various GHGs on the basis of their global-warming potential (GWP), by converting amounts of other gases to the equivalent amount of CO^2 with the same GWP. Source: Eurostat. 2013. Glossary: Carbon dioxide equivalent.
[9] Data from UNFCCC portal on the CDM: CDM Insights.

waste management, putting the country in fourth position in terms of GHG mitigation projects worldwide, with 13% of all waste-to-energy landfill installations in the developing world. In the following sections, we look at how the project evolved and which factors enabled its success.

The metropolitan area of Monterrey is the second largest city in Mexico, with a population of more than 4.5 million. It is the most industrial city in Mexico, with high levels of migration and of waste generation (see Figure 4). Beginning in the mid-1990s, various institutions and nine municipalities from the metropolitan area of Monterrey sought to change the business model for the operation of waste management, to transform the landfill from a cash-consuming installation into a source of income.

In the early 1990s, the World Bank began a pilot project to assess the viability of using waste-to-energy landfills in Monterrey. City officials were interested in the idea, since they were already seeking a better system for waste collection and disposal, as only 2.4% of waste was recycled at that time.[10] They also were looking for more affordable electricity sources, as Monterrey is located in an area with some of the highest electricity prices in Mexico, and legal limitations (described below) restricted independent power generation.

The municipality realised that a more integrated waste-to-energy approach to municipal waste management could add value to public investments and reduce operational costs. Separating waste was seen to have a number of benefits: recycling materials such as paper, plastics, tyres, oil, glass and metals can generate income; and by separating non-organic from organic waste, landfills become more productive, generating more biogas and resultant electricity. With the increase in income generated by the landfill, the public investment in waste management actually proved to be profitable.[11] Further benefits included formal job creation, a reduction of waste on the streets and a reduction of groundwater and air pollution.

Monterrey's pilot project resulted in a public-private partnership with a mandate for integrated waste management in the nine participating municipalities. This mandate required landfill operators to collect recyclable materials, and use biogas to generate electricity at a more competitive price than the national grid.[12] The landfill and equipment would remain the property of the municipality, but with some participation of the private sector. A private company called *Bioeléctrica de Monterrey* won the competitive bid to manage the operations, maintenance and investments associated with electricity generation in a public-private partnership with the municipalities that were part of the Metropolitan Area of Monterrey. The bidders had been pre-qualified based on their experience in design, construction and operation of LFG facilities, their personnel and financing capabilities.[13] The bidding process generated 17 submissions, of which 5 were short listed and then judged on the highest net present value (NPV) of their business models.[14]

In Mexico, electricity generation and distribution is a state-owned monopoly. At the time the initiative was launched, the only legal way to employ independent renewable energy was by establishing a partnership between electricity producers and consumers, a so-called 'society of self-consumption', in which producers use a private grid to provide electricity to their partners at a lower cost than that of the national grid. Companies and organisations with a large and stable demand for electricity, such as the Monterrey subway, public lighting system, childcare centres and public offices, had an incentive to

Monterrey Case Study Timeline

1996	Land use permits
1997	Landfill siting permits
2000	Landfill gas engineering
2001	Global Environmental Facility (GEF) grant formulation
2002	Environmental impact assessment approved
2002	Energy generation permit
2002	GEF grant approved
2003	GEF grant first disbursal
2003	Connection to the national electric grid
2005	Emission reduction purchase agreement with World Bank
2008	Official inauguration
2020	Expected closure

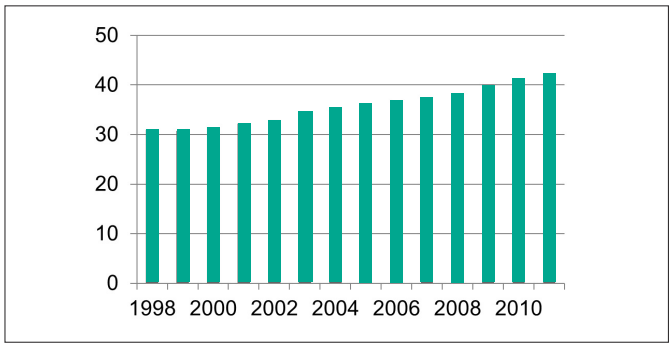
Own elaboration.
Sources: Bioenergía de Nuevo León. 2012. *Monterrey III. Waste-to-Energy Project Extension (Monterrey III: Proyecto de Ampliación de Generación de Energía Eléctrica a Través de la Basura)*. Online publication.; Vergara, W., Haeussling, S. 2013. Mitigation of GHG through Solid Waste and Wastewater Management: The World Bank Experience in Latin America. Presentation. World Bank, Washington, DC.; Padilla, J., Saldaña, J. 2007. Monterrey´s Landfill Gas-to-Energy Project. Presentation. Bioenergía de Nuevo León, Washington, DC.

[10] World Bank. 2007. *Mexico: Methane Gas Capture and Use at a Landfill - Demonstration Project*. Implementation Completion and Results Report. World Bank, Washington, DC.
[11] CalRecovery Incorporated, UNEP. 2005. *Solid Waste Management: Volume II: Regional Overviews and Information Sources*. UNEP, Osaka.
[12] CEC. 2008. Case Study: Renewable Energy Procurement, Monterrey, Nuevo León, Mexico. In: *Best Energy Management Practices in 13 North American Municipalities*. CEC, Montreal.
[13] World Bank 2007, above n 10.
[14] Vergara, W. 2006. *Case Study of GEF and Carbon Finance in Mexico*. Presentation. World Bank, Washington, DC.

join the partnership in order to access electricity at lower costs.

Technological and community involvement support was provided by the US Environmental Protection Agency (US EPA) through the Global Methane Initiative (GMI), which seeks to stimulate local economic growth, create new sources of affordable alternative energy, improve local air and water quality with associated public health benefits, and increase industrial worker safety.

Figure 4: Urban Waste Generation (million tonnes per year) in Mexico



Own Elaboration.
Source: Instituto Nacional de Ecología (INE). 2012. *México. Quinta Comunicación Nacional ante la Convención Marco de las Naciones Unidas sobre el Cambio Climático (Mexico: Fifth National Communication Before the United Nations Convention on Climate Change)*. INE, Mexico City.

Monterrey's waste-to-energy landfill initiative was eligible for funding from the CDM of the Kyoto Protocol. This partnership attracted the private sector given the profitability of bundling several activities together, including energy generation, recycling and public works, and the attractiveness for the local municipalities in having only one operator to manage the landfill and the associated tasks. Initial investments totalled more than US$ 24.5 million, with US$ 12.98 million (53%) private and US$11.52 million (47%) public.[15] A grant from the Global Environmental Facility of US$ 6.27 million was given to the partnership, improving the internal rate of return (IRR) of a project of this type from 13.4% to more than 27.6%, which was very attractive for a first-of-its-kind project.[16] The agreed price of carbon was US$ 4.99 per tonne reduced. Under carbon market conditions at that time, the value of the carbon alone meant the project was worth more than US$ 19.96 million, almost double the initial public sector investment.

Impact

Today the waste-to-energy project treats more than 19 million tonnes of waste annually,[18] and reduces CO_2eq by more than 4 million tonnes per year. It has an electricity generation capacity of 16 MW,[19] saving the group of municipalities more than US$ 2.5 million per year by powering a range of public services, including up to 80% of the 33 km subway system, with 470,000 users per day.[20] Further, the additional income coming from the CDM was reinvested in solar photovoltaic systems that reduced energy consumption in public schools, with additional savings for the local government. The experience of Monterrey triggered a transformational change in municipal waste management business models in Mexico. Monterrey's ability to attract private investment in public services proved to be a replicable business model. Monterrey is also considered a model for cities assessing the potential of renewable energy and energy efficiency projects that could reduce spending, improve quality of life and reduce emissions. Of the 22 new landfills that sought carbon finance in Mexico between 2006 and 2012, eight (36%) were equipped with waste-to-energy technology.[21] Today it is estimated that there are 85 potential sites for biogas recovery, with a mitigation potential of 31 million tonnes of CO2eq, representing a market value, only in carbon terms, of more than US$ 465 million.[222]

Other cities in Latin America have since installed similar systems. Cities with a population of 100,000 inhabitants or more seem to be most appropriate for implementing improved waste management systems, particularly when it comes to waste-to-energy facilities to power public works, such as street lighting, water pumping and other installations with a high-demand for electricity.[23] For example, the municipality of Maldonado in Uruguay installed a waste-to-energy project, with a treatment capacity of 145 tonnes of waste per day, and a capacity of 1 MW, capable of producing more than 4,818 MWh per year. However, the Ministry of Environment of Uruguay ultimately assessed that this technology actually carries a heavy financial burden when it serves small populations. The challenge is that in order to equip landfills with turbines that transform methane into electricity, they must be large in size and located in close proximity to customers of the electricity grid.

[15] Saldaña, J. 2012: Una Asociación Público-privada Exitosa (A Successful Public-private Partnership). Presentation given 22 October 2012. Bioenergía de Nuevo León, Monterrey.
[16] World Bank. 2001. *Project Appraisal Document on a Proposed Grant from the Global Environment Facility for the Methane Gas Capture and Use at a Landfill - Demonstration Project*. World Bank, Washington, DC.
[17] Saldaña 2012, above n 15.
[18] World Bank 2007, above n 10, 13.
[19] Milenio. 2013. *Basura Hace Mover al Metro con Biogás (Garbage Makes the Subway Move with Biogas)*. Article published online 19 January 2013.; For a more detailed description of the facility, see: UNFCCC. 2009. *Monterrey II LFG to Energy Project*. UNFCC, Bonn.
[20] Results of a project search using the UNFCCC Project Search database of CDM projects.
[21] Calculated using the price of US$ 15.00 per tonne from the California Carbon Market.
[22] Inter-American Development Bank (IDB). 2013. *Emerging and Sustainable Cities Initiative*. IDB, Washington, DC.; Ministry of Environment of Uruguay. 2007. *Electricity Generation with Methane Gas: Landfill Methane Recovery Demonstration Project Located in Las Rosas*. Ministry of Environment, Montevideo.

CONTEXTUAL FACTORS

ENABLING LATIN AMERICA'S SUCCESSFUL RESPONSE

External financing was an important element to overcome technical, financial and institutional barriers, particularly as this project was the first of its kind in the Latin America region. The availability of World Bank technical support, funding from the Global Environmental Facility and resources from the Global Methane Initiative made the initiative possible and ultimately a model for other cities.

One key element that triggered action was the high electricity prices in Monterrey. The higher the electricity prices, the higher the profitability of these investments which ultimately reduce municipal costs, and eventually generate income. As these investments become more economically attractive, it is easier to attract private sector investors, leaving room for local government budgets to focus on other priorities.

At the time the initiative emerged, Monterrey was at a crossroads: on one side it was facing climbing electricity prices, and on the other, a growing demand for public services, from waste management to street lighting and public transport. This setting called for an integrated solution that could harness multiple priorities and the participation of multiple stakeholders at the same time. The result was a multi-tiered matrix of benefits that made possible largely by the political will of city officials, together with the support of international organisations. Today Mexico as a country has developed public policies based on this experience, making use of carbon and energy markets to turn landfill waste into a business opportunity.

The collaboration of various stakeholders was key to the success of the Monterrey waste-to-energy landfill project. City authorities were determined to improve waste management, the World Bank created a space for exchanging technical information, and local partners provided financing. The Global Methane Initiative worked to address technical and institutional barriers, allowing for the implementation of this first-of-its-kind project in the Latin America region.[24] Finally, federal-level public officials allowed the initiative to connect to the electricity grid, while multiple local organisations and agencies became customers of this new electricity source.

[23] For more technical information on methane recovery and use, see: Global Methane Initiative. 2012. *International Best Practices Guide for Landfill Gas Energy Projects*. Global Methane Initiative, Washington, DC.

LESSONS LEARNED

1. External funding from international cooperation agencies and development banks was key to removing technical and institutional barriers to create the first-of-its-kind waste-to-energy project in Latin America. By bringing together a multi-stakeholder group, the pilot project was able to respond to multiple priorities.

2. Cities now have a model to follow, but not only for waste-to-energy landfills. Perhaps more importantly, they have a new perspective on how to change business models to re-evaluate their own resources and design public-private partnerships in areas that could attract investment to improve public service provision. In Latin America, these partnerships have been shown to attract investments as they are relatively safe and bring a stable source of revenue.

3. The case of Monterrey, and the Latin American cities that followed it, demonstrate that urban areas with more than 100,000 inhabitants are probably the ideal setting for waste-to-energy landfills. These initiatives have been shown to be innovative business models, turning municipal waste management into an income source, while improving the city's environmental and social quality of life.

4. There are some limitations to waste-to-energy landfills that may hinder effective implementation, and which likely need to be overcome. These include low electricity prices, limited access to the electric grid, and local regulations that may impose restrictions to independent power producers.

ABOUT THE AUTHOR

Enrique Rebolledo is Programme Manager at *Bajo en Carbono Inc* (Low Carbon, in English), a consulting and advisory organisation that seeks opportunities for low-carbon sustainable investments and helps public and private sector manage risks associated with climate change and energy security. To learn more about this case, contact him at er@bajoencarbono.com.

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