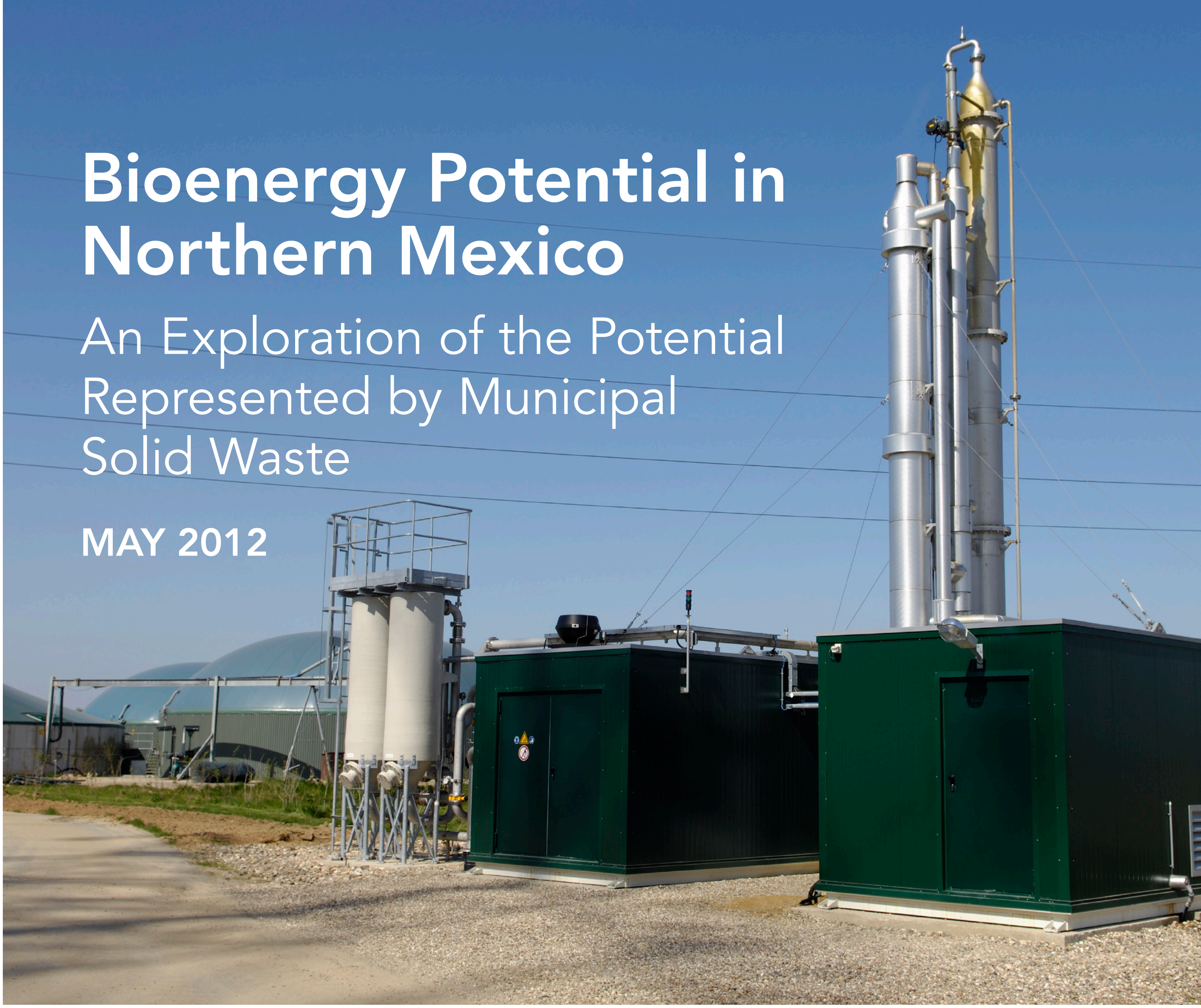
RE-ENERGIZING THE BORDER: RENEWABLE ENERGY, GREEN JOBS AND BORDER INFRASTRUCTURE PROJECT



Bioenergy Potential in Northern Mexico

An Exploration of the Potential Represented by Municipal Solid Waste

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INTRODUCTION

The growing potential for renewable energy (RE) exports from Mexico to the United States has attracted public and private sector interest in recent years. It has become clear that Mexico has structural factors, especially land and labor costs, that make the cross-border trade in RE an exciting and potentially highly profitable sector.

The U.S. and Mexican governments, individually and jointly, have both noted the possibilities for making a positive impact on the border region through mutually beneficial RE projects. The effective coordination of efforts from both the private sector and governments operating at all levels stand to overcome the significant barriers that exist to the large-scale development of this potential. Mexican, U.S., and European energy firms are already involved in developing RE resources at the border in the expectation that demand will continue to rise. What is lacking is a comprehensive strategy to both integrate these efforts and identify the most effective paths forward.

Of bioenergy feedstocks, municipal solid waste (MSW) may represent the greatest potential for growth in Mexico and the U.S.-Mexico transborder region. With urban populations increasing in the border region, the management of MSW is rapidly becoming a challenge because the common approach of landfilling or incinerating waste often results in adverse environmental impacts. Conversion of MSW to bioenergy could minimize these negative externalities. However, industry and government have yet to transition towards large-scale MSW bioenergy development in this region. For example, currently no large-scale ethanol or biodiesel production facilities exist in Mexico.[1]

In 2005, bioenergy use in Mexico amounted to 350 petajoules (PJ) and accounted for 12 percent of the estimated potential, with MSW amounting to just one percent of the total bioenergy portfolio.[2] In 2004, MSW residues accounted for only 35 PJ per year of Mexican bioenergy sources.[3] Bioenergy as derived from MSW feedstock, which is readily available in volume, has the potential to become a fundamental piece in this RE system, thereby contributing to energy diversification strategies as well as reducing greenhouse gas (GHG) emissions and creating new jobs in rural areas along the border region.[4]

In conjunction with the Woodrow Wilson Center's *RE-Energizing the Border: Renewable energy, green jobs and border infrastructure* project, this paper will seek to identify first and second generation supply-side bioenergy potential of MSW as a feedstock in the border region. This paper will look at 1) MSW feedstock potential; 2) its availability; 3) relevant or necessary policy; 4) potential financing and investments; 5) current and necessary infrastructure; and 6) distribution.

WASTE'S FEEDSTOCK POTENTIAL

MSW and other waste derivatives have strong potential as bioenergy feedstock. MSW refers to the stream of waste and household garbage collected through community sanitation services.[5] Industry is actively moving towards the commercial-scale development of MSW fueled bioenergy facilities. As described by Jim Lane of Biofuels Digest, "MSW is hot." [6]

No other bioenergy feedstock, from dedicated energy crops to agricultural residues, is as sustainable, affordable, and available as MSW. MSW is a low to zero-cost feedstock — especially since it can currently be obtained in many areas with no more than a tip. MSW is not in competition with food for use as a fuel.[7] In both the United States and Mexico, municipalities are increasingly ready to welcome the potential of bioenergy.

MSW, however, does not come without challenges. MSW is not uniform in its composition, ranging from biomass to refrigerator parts. Many conversion technologies cannot handle such variation in feedstock. Few technologies and processes currently use mixed-stream MSW. However, as pointed to by Lane, "for near-term, small-scale projects, think MSW and other negative-cost feedstocks,"[8] as these barriers can often be overcome.

Bioenergy Potential: landfill gas capture and utilization

As a first generation (i.e. methane capture technology) feedstock, MSW landfill gas (LFG) represents significant bioenergy potential in the border region.[9] In the United States alone MSW landfills are the third-largest source of human-related methane emissions. As noted by the U.S. EPA, LFG not captured from landfills represents a lost opportunity to use a substantial bioenergy resource.[10]

Created as solid waste decomposes in a landfill, LFG consists of approximately 50 percent methane (CH_4), about 50 percent carbon dioxide (CO_2), as well as trace quantities of organic compounds. LFG has about half the energy density of natural gas, at around 500 British thermal units per square cubic foot (Btu/scf), the equivalent of 0.1465 kilowatt hours (kWh).[11]

LFG can be captured, converted, and used as a bioenergy source instead of simply allowing it to escape into the air. As a GHG source, LFG not captured represents a threat to global climate change efforts. In addition, capturing LFG can reduce odors and other hazards associated with landfills. LFG as a bioenergy source can be extracted from landfills using wells and blower/flare (or vacuum) systems. After being directed to a central collection point, LFG can then be processed and treated based on the need for the gas. LFG can be used to generate grid-level electricity that is used to replace petroleum-based fuels in industrial and manufacturing operations, or converted into an alternative transportation fuel. While there remains strong potential for LFG capture along the border region, second generation (i.e. MSW gasification technologies) biofuel production holds the most significant promise for meeting economic and environmental goals.

Second generation bioenergy potential: gasification/ anaerobic processes

Second generation technology represents the most significant potential for MSW derived bioenergy in the border region. Second generation biofuels have been recognized by the U.S. Government and others to be the way forward in bioenergy research because they promise real emissions savings over fossil fuel use.[12] Although few commercial-scale facilities currently produce bioenergy or biofuel derived from MSW feedstock, the technology, processes and market are all advancing rapidly.

Bioenergy derived from MSW feedstock has the ability to greatly reduce GHG emissions in the electricity and transportation sectors. Converting MSW to biofuel, at just 22 grams of CO_2 equivalent per Megajoule (gCO2e/MJ) considering indirect land-use change (iLUC), results in a very low carbon transportation fuel, with less than 75 percent the carbon intensity of petroleum or corn-based ethanol fuels.[13] Under second generation processes, feedstock is gasified at the front end in the path towards making fuels, chemicals or other biomaterials. [14] A number of technologies exist and are proving their market potential. These include Fisher-Tropsch, gas fermentation, pyrolysis,

catalysts conversions, hybrid fermentation and gasification approaches.

In the United States, the MSW biofuel market is beginning to see a shift toward commercial viability. Zero-cost or very-low cost MSW feedstock can provide significant competitive advantage over other feedstocks. Recently, Fulcrum BioEnergy successfully demonstrated the ability to economically produce ethanol from MSW. Under this model, Fulcrum's 10.5 million gallon per year (MG/yr) Sierra BioFuels Plant commenced operations in Nevada in 2011 with the ability to convert 90,000 tons of MSW into renewable fuel at the cost of around $1 a gallon, yielding 120 gallons per ton. Under Fulcrum's two-step thermochemical process, organic materials recovered from MSW are gasified in a plasma enhanced gasifier. The syngas is then converted to ethanol.[15] Fulcrum, in its S-1 filing, further stated intentions to produce 700 million gallons of renewable ethanol per year from MSW, which would take in nearly six million tons of MSW that would otherwise need to be landfilled.[16]

As Fulcrum's technology and similar technologies advance to full commercial-scale production, firms are likely to find that the Mexican border region has significant advantages, based on the availability of low cost labor, land and feedstock compared to other locations in the United States.

AVAILABILITY OF MSW AS A FEEDSTOCK

There are many obstacles to collecting and storing MSW in Mexico. Despite government efforts to contain MSW to more sophisticated, closed storage facilities, the final disposal of more than 50 percent of the MSW generated in Mexico is carried out in open-air dumps or landfills. These methods are unlikely to result in significant sources of biofuel feedstock unless they are collected more efficiently. On the other hand, the rest of the MSW collected is deposited in sanitary landfills in a manner that would be appropriate for use as feedstock.[17]

Due to the limited range of waste collection services and the costs of adequate disposal, there are a great number of clandestine dumps in ravines and empty lots of land all over the country. These sites are created mostly by two sources: private waste collection companies and villages in areas lacking collection. The collection of this waste could provide biofuel producers with an economic advantage, as many homes will pay a small fee to have their trash collected regardless of whether it is then turned into biofuel or not.

At present, in Mexico there are 40 sanitary landfills in mid-sized cities and metropolitan areas and 13 in small cities. The rest of the sites are considered open-air dumps.

The 83,831 tons of waste produced in Mexico each day require 111,775 cubic meters of space for disposal.[18] This huge volume gives an idea of the strong need to find land and the importance of designing strategies for the integral management of waste, which should include actions such as reducing the amount of waste from the source and biofuel production. The operation costs of a sanitary landfill in Mexico represent approximately 18% of the total cost of the entire trash collection and storage process. The high cost of landfill operation means margins are slim on the whole and another revenue stream would be extremely valuable. Providing MSW for fuel achieves the dual goal of allowing waste control companies the opportunity to delay opening new landfills or enlarging those that already exist while finding a strong revenue stream with which to grow and reinvest elsewhere.

MSW Generation and Composition

Per capita waste generation in Mexico varies between 0.680 Kg per day to 1.33 Kg, the lowest estimations corresponding to the rural areas and the highest ones to metropolitan areas.[19] The mean waste generated per capita is 0.870 kg per day.[20] The amount of waste per inhabitant that is generated is also linked to the size of a city. In Mexico, from the total MSW generated daily, estimated at 86,300 tons, nearly 87% belongs to areas with more than 15,000 inhabitants. This could positively impact the availability of biofuel feedstock and thus lower the price of production in places where local demand for energy is highest. The increase of MSW generation is estimated to vary between 1 and 3 percent yearly according to the area. It is also important to note that Mexico City and the northern border are the areas with the highest per capita generation of MSW in Mexico.[21]

There is significant data regarding the composition of MSW in Mexico, although not all data sets agree. This variation in the results of the waste studies may be due to the techniques used to perform the studies or to the time of year in which the studies were performed. Table 1 shows the data of the composition of MSW in Mexico for the year 2003 according to IVEX (2003).[22]

Organic matter is the most common type of waste in Mexico's MSW mix, which makes it a particularly appealing place to harvest biofuel feedstock. However, recent literature has reported the existence of a gradual change in the composition of the solid waste.[23] For example, a reduction of organic waste and an increase in plastic and paper waste has been observed due to the increasing availability and demand for both durable and disposable consumer goods. Biofuel derived from biogenic material, which still comprises much of the available MSW in the border region, such as paper, food scraps and yard waste, is classified as renewable and qualifies for the renewable credit trading program (REC). Under a REC program, a renewable energy facility earns one credit for every kilowatt-hour (kWh) or

Table 1: Mexican Municipal Solid Waste Production by Region

Zone	# population	MSW generation KG/ Capita/Day	tonnes per day	tonnes per year	% total
Border Zone	7,674,643	0.645	4,993	1,800,545	8.7
North	16,628,750	0.698	11,607	4,236,555	20.6
Center	34,646,270	0.617	21,377	7,802,605	37.9
Federal District (DF)	11,354,005	0.960	10,995	4,011,350	19.5
South	11,366,670	0.663	7,536	2,750,640	13.4
Total	81,643,380	0.718*	56,448	20,601,695	100

* weighted average

Source: Waste management system in Mexico: history, state of the art and trends. Carolina Armijo de Vega. Proceedings, The Twenty-First International Conference On Solid Waste Technology and Management pp 354–364, 2006. The Journal of Solid Waste Technology and Management.

Table 2: MSW Composition: Percentages for Select Waste Types by Region

	Border		North		South		Center		DF	
	'74–'88	'91–'97	'74–'88	'91–'97	'74–'88	'91–'97	'74–'88	'91–'97	'74–'88	'91–'97
Cardboard	2.96	3.97	4.2	4.37	4.08	1.83	4.43	4.84	3.28	5.36
Bone	0.51	0.5	0.58	0.64	0.93	0.27	0.6	0.25	0.82	0.08
Rubber	0.7	0.28	0.77	0.2	0.89	0.09	0.3	0.35	0.21	0.2
Can	3.07	2.93	2.42	1.4	2.06	1.7	2.75	2.97	1.59	1.58
Ferrous material	0.5	1.18	0.45	1.48	0.85	0.29	1.35	0.4	0.51	1.39
Paper	13.83	12.13	9.98	10.6	8.63	13.68	6.77	8.85	12.34	14.58
Diapers	4.87	6.55	2.54	8.31	2.74	6	3.94	5.72	3.	3.37
Plastic Film	2.63	4.79	3.72	5.12	3.26	1.66	3.89	1.72	5.04	6.24
Rigid plastic	2.75	2.9	2.34	3.15	1.93	1.95	2.34	1.23	4.79	4.33
Yard residues	15.05	16.1	7.34	19.76	6.92	7.11	7.73	26.98	3.97	5.12
Food residues	25.22	26.97	37.73	21.27	37.46	38.54	40.26	16.34	44.14	34.66
Garments	2.48	1.97	1.91	2.4	1.97	0.81	1.23	2.16	2.37	0.64
Color glass	3.91	2.06	3.3	0.93	2.81	4.25	3.88	0.6	2.5	4
Transparent glass	4.14	4.59	4.19	5.25	4.07	5.05	4.2	3.72	4.32	6.67

Source: Minimization and environmental management of solid waste (Minimización y manejo ambiental de los residuos sólidos). Published by SEMARNAT. Victor Lichtinger Waisman, 2001.

megawatt-hour (MWh) of electricity that is generated in a given year.[24]

POTENTIAL ENERGY OUTPUT FROM BIOFUELS

As seen in the table below, based on 2010 population statistics and assuming that municipalities were able to collect the mean quantity of waste produced per citizen — .87 KG per capita per day — and that 50 percent of the waste collected could be used for the purpose of biofuel production, the border region generates enough MSW feedstock to potentially make between 210 million to 380 million gallons per year of biofuel. [25]

The MSW mix in Mexico is attractive for biofuel production and is expected to be for the foreseeable future. With the expected conversion rate of MSW to biofuel ranging from approximately 120 gallons per metric ton of MSW feedstock (as exemplified by Fulcrum BioEnergy) to 70 gallons per ton based on conversion efficiency and feedstock composition, the border region could readily become a major biofuel production.[26]

Table 3: MSW Feedstock Potential in the Border Region

State	Population	MT MSW Daily	MT MSW Annually	Potential at 120 Gals. per MT	Potential at 70 Gals. per MT	Potential at 40 Gals. per MT
Nuevo León	4,653,458	2,024	738,852	88,662,325	51,719,689	29,554,108
Chihuahua	3,406,465	1,481	540,861	64,903,365	37,860,296	21,634,455
Tamaulipas	3,268,554	1,421	518,964	62,275,716	36,327,501	20,758,572
Baja California	3,155,070	1,372	500,946	60,113,529	35,066,225	20,037,843
Coahuila	2,748,391	1,195	436,375	52,365,090	30,546,302	17,455,030
Sonora	2,662,480	1,158	422,734	50,728,196	29,591,447	16,906,800
Total	19,894,418	8,651	3,158,735	379,048,222	221,111,463	126,304,600

Note: MT: Metric Ton, Gal.: Gallon
Source: *Instituto Nacional de Estadística y Geografía (INEGI)*.

CURRENT MEXICAN POLICY ON BIOFUELS

Mexico has taken significant steps to promote a domestic biofuel industry. Although Mexico has only limited practical experience in implementation, the adoption of biofuels is perceived as an opportunity to develop alternatives to petroleum, to foster economic development and to reduce GHG emissions.[27]

An important step in fostering the development of a domestic biofuel industry at the federal level was made by the Mexican Congress in April 2007 with the Law for the Promotion and Development of Biofuels.[28] This law was approved by Congress and was published and enacted in the same year. It provides a legal framework to encourage the use of biofuels at the national level.[29] In February 2008, Mexico passed the national Promotion and Development Law for Biofuels; yet this framework has not been further developed with elements such as blending targets or financial support for biofuels production and consumption, which has limited the impact of the law. In 2010, the Federal Ministry of Agriculture mandated a blending of 7% ethanol in gasoline for the metropolitan zone of Guadalajara in the state of Jalisco. There are not any specific promotion policies for second-generation biofuels, but they might become included in a new national research program on biofuels, which is being designed by the National Council for Science and Technology (CONACYT).[30]

On the whole, programs and activities related to biofuels in Mexico are very limited. Policy is constructed on three normative levels: the Constitution, statutory law issued by the federal and local legislatures, and administrative provisions that include regulations issued by the federal executive power and other rules created by administrative agencies, such as technical norms, directives and other sector-specific binding instruments. This policy framework is a top-down structure with national plans at the top that are linked to several sector and ministerial plans, which are ultimately

linked to specific programs implemented at the local level. These programs include strategies and subprograms that are meant to target feedstock, production and trade. The programs also focus on a broad range of sustainability objectives, such as sustainable production of feedstock for biofuel production, establishment of a national program for biofuel research and technology development, design of system-product chains, investment plans, employment creation in rural areas, contribution to increased reconversion and productive diversification of primary sectors and contribution to the preservation of natural resources and biodiversity. This activity is seen by the government as falling within the general framework of reducing GHG emissions.

However, most of these programs and plans are not mature, and very few laws specifically target biofuels. Most are directed towards the energy sector and traditional feedstocks, ignoring the potential for MSW-based fuel production. Even the most recently created programs are, in effect, only a list of guidelines, structured under the logic of a business plan (vision, mission, objectives and actions). Mexico has documented lists of tasks and goals, but documentation containing program details or in-depth analyses of plans (beyond simple statements) is not fully available. In addition, there is a need for long-term planning. For example, the Bioenergy Penetration Program merely lays out a strategic vision to the year 2012 — clearly a new set of forward-looking plans is required. Mexico is several steps behind other Latin American countries — particularly when compared to Brazil — regarding the establishment of a well-developed and stable biofuels market. Further efforts are required in the areas of agriculture and environment if the large-scale development of biofuels is to be promoted in Mexico. Clear provisions and integrated mechanisms that foster the roles of the forestry and agriculture sectors in developing bioenergy whilst avoiding environmental damage have yet to be put into practice.[31] Additionally, the government must be made aware of the availability and environmental advantages associated with utilizing MSW as the primary feedstock strea.

FINANCING AND INVESTMENT

A wave of investments and government plans in the past few years have emerged in Latin America to boost biofuel production in the short and medium term.[32] According to the International Energy Agency (IEA), developing states such as Mexico would be

Key Objectives of the Bioenergy Penetration Program:

- to promote related R&D activities and adoption of clean technology;
- to diversify the energy mix to incorporate more renewable energy;
- to work closely with all sectors involved in the bioenergy supply chain;
- to generate new opportunities that foster agriculture and industry sectors, specifically cluster creation for small and medium enterprises; and
- to foster information exchange and quality, including new websites, and open access to government studies and databases

able to provide domestic financing or attract foreign investments for commercial second generation biofuel plants in the range of USD 125–250 million.[33] Mexico has a medium-risk but stable investment grade of BBB+.[34] Although second generation biofuel production facilities require high capital investment, lack of financial resources should not constrain implementation of bioenergy industries in Mexico due to stable investment grades and considerable foreign direct investments annually.[35]

Private Investment

The global picture for private investment in the cleantech industry remains strong. In 2010, total cleantech venture investment totaled $7.8 billion, up by 28% compared to $6.1 billion in 2009.[36] As of the third quarter of 2011, cleantech venture investment totaled $6.63 billion.[37] In 2011, numerous biofuel companies went forward with initial public offers (IPO).

Investment in commercial grade MSW to fuel facilities is beginning to happen outside of Mexico. In September 2011, Fulcrum BioEnergy, which produces renewable ethanol from MSW in the U.S. state of Nevada, filed an S-1 registration statement for a proposed $115 million IPO. While the number of shares to be offered and the price range for the offering had not yet been determined at the time of this writing, this decision shows strong market confidence in bioenergy production from MSW.[38] In addition to its IPO, Waste Management (WM) announced an equity investment in Fulcrum BioEnergy. WM agreed to a secured loan facility that provides for WM's funding of up to $70 million for Fulcrum's proposed Sierra BioFuels plant.[39] This level of market activity, both for IPOs and venture as well as direct investments, demonstrates that financing exists for competitive projects.

INFRASTRUCTURE

Roadways and Transportation

No country can have a first-rate economy without first-rate infrastructure. In July 2007, President Calderón launched the National Infrastructure Program (NIP) designed to increase the coverage, quality, and competitiveness of Mexico's infrastructure. The projects include modernization and construction of new highways and rural roads along with a wide scope of projects across other sectors of the economy.

Few people in the United States realize how much progress Mexico has made in expanding and modernizing its interstate highway system. The expansion of these systems will make a significant difference to Mexico's economy, promoting trade with the United States and between disparate locations within Mexico itself. When completed, this new highway network will facilitate the easier, faster and safer movement of goods and will be ideal for manufacturers of biofuels who are trying to access feedstock and consumer areas that may be in a multitude of locations. Under those conditions, Mexican manufacturing throughout the country will be able to adopt the lean and just-in-time practices that have become standard in much of the world, especially in terms of petroleum supply logistics.[40]

Additionally, this modernized interstate highway network will also facilitate a tighter integration of the regions of Mexico. Previously, central Mexico, which includes Mexico City, was fairly isolated from the manufacturing hubs located near the U.S.-Mexico border (e.g., cities like Reynosa, Juárez, and Monterrey). Previously, the entire northwest corner of the country encompassing Tijuana and Mexicali was much more tightly integrated into the San Diego and Southwest U.S. markets than it was with the rest of the Mexican economy.

In short, this new network of interstate highways will increase connectivity among coastal cities, central Mexico, and northern border cities — facilitating the integration of the multitude of disjointed local economies — and will allow biofuel producers in northern Mexico to take advantage of underserved consumer bases in central and southern parts of the nation.[41]

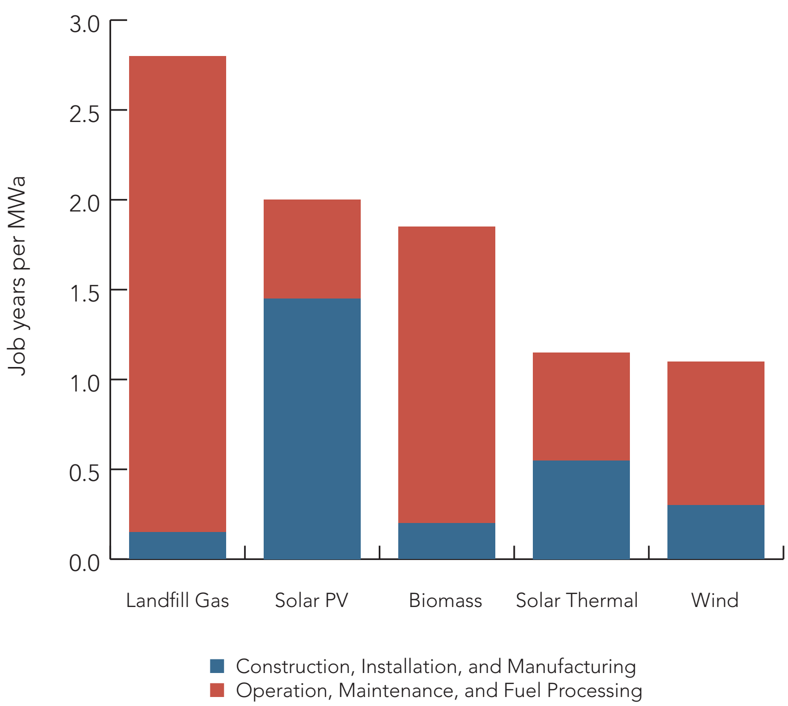
The Mexican government developed is National Infrastructure Program (NIP) in order to ensure that all its plans are implemented. It allocated US$230 billion to fund the NIP during 2007–2012. Transportation infrastructure projects will account for 18 percent of the total, or US$41 billion; and the lion's share is being used to modernize and upgrade the nation's 17,598 km of highways and rural roads. When the road-building projects are completed in 2012, Mexico will then have two new, modern north-south transportation corridors to complement the existing NAFTA Highway, along with two new east-west corridors.

Mexico's federal government has made substantial progress in implementing its ambitious highway infrastructure plans — much more so than many observers realize. Although the 2008–2009 global financial crisis and worldwide economic slowdown did necessitate some adjustments and compromises in those plans, Mexico's Transport and Communication Ministry has forged ahead and succeeded in attracting substantial private funding to complement the public-sector investments. At year-end 2010, Mexico's road-building program appeared to be on track to be completed as scheduled by 2012.[42]

Workforce

Job creation is important in driving emerging and developing countries to

Figure 1. Jobs created by type of Renewable Energy



Source: Electric Power Research Institute, 2001

promote second-generation biofuels. New jobs for highly skilled labor could be created in biofuel plants and where dedicated energy crops would be cultivated or aggregated as in the case of MSW. For both current- and second-generation biofuels, there are opportunities for new jobs along the entire supply chain, from biomass production or collection, to biomass transport, biomass handling, conversion and product distribution as the last stage. Staffing levels, including technical competence, management and administrative resources will vary depending on the size and technology. For example, existing biofuel production facilities that utilized 100 kilotons per annum (KPTA) plant have had staffs of approximately 24 people.[43] The construction phase for biofuel or bioenergy facilities, however, will undoubtedly result in higher levels of local construction jobs.

Based on required investments estimated by the IEA (see Section 6.1) and a conversion factor of 6 job per million dollar invested, the number of new job-year potentially created is 750–1500. The type of technology used plays a role in this estimation. Accordingly, the Electric Power Research Institute carried out a project to estimate the number of job-years created as a consequence of power generation. The research highlights landfill gas as the most job intensive renewable energy source (see Figure 1). The blue portions are job-years created in construction, installation, and manufacturing (CIM), and the red portions are job-years created in the power plant's operation, maintenance, and fuel processing. The numbers shown are job-year per average megawatt of power output (MWa).

Due to its highly developed oil, gas and petrochemical industries, Mexico possesses the means to produce highly skilled engineers. The nation can supply highly skilled labor through programs at top-level universities and agricultural and technological institutions.[44]

Mexico's national petrochemical company, Pemex, is going through a period of decline in both its proven reserves and its barrel per day output. Daily petroleum production across all of Mexico peaked in 2003 at about 3.5 million barrels per day, yet by 2009 this number had shrunk to 2.5 million barrels per day. During that same period of time, Pemex was largely stagnant in terms of developing new proven reserves meaning that, as oil was extracted from existing fields, the total proven reserves in the country have also declined significantly. Unfortunately, due to the nationalized nature of Pemex, and the fact that it is not always run as efficiently as it could be, this decrease in output was not accompanied by a decrease of paid employees. This resulted in a situation in 2009 in which many analysts believed Pemex's payroll of 140,000 employees was almost 30,000 more than the company needed. The Mexican Government should seriously consider creating policies that help to build the nations biofuels sector as a landing place for displaced Pemex workers. Not only would it provide an immediate industry for those workers to apply already existing skill sets, it would also provide a much more sustainable avenue for continued economic growth in the country.[45]

MARKETS FOR DISTRIBUTION

Processing and distribution value chains are quite efficient in Mexico. The country is also well connected to export markets within NAFTA, which provides options to export biomass for second-generation biofuels.[46]

Local Markets

Northern Mexico has some sizeable cities that would be ideal candidates for the development of biofuel operations. These sites are areas that possess populations large

enough to produce a significant amount of MSW to feed biofuel production but also to consume a good amount of the energy created to serve local needs. The cities that might have the appropriate characteristics for this type of situation would be Monterrey, Torreón, Juárez, Tijuana and, to a lesser extent, Chihuahua. All of these cities boast over five hundred thousand inhabitants, making them large and complex enough to be able to potentially host a MSW biofuel facility and utilize much of its fuel output.

The city of Monterrey provides an example of one of the few MSW projects in Mexico today. Monterrey pays among the highest electricity rates in Mexico, so high that it eventually pushed the city to look for alternative and cheaper sources of energy. In 2003, Bioenergía de Nuevo León, a joint venture between a private energy company and a waste management organization belonging to the Nuevo León state government, started producing electricity through biogas combustion at a local landfill. The plant is planned to operate for at least the next 25 to 30 years. Its biogas system is composed of a collection system of 248 extraction wells with monitoring valves, covering 44 hectares (ha) of the landfill (total landfill area: 212ha), about 25 km of collecting pipes, three vacuum pumps and filter units and two flare stations for burning excess gas. The actual power plant has seven modular generating units, seven step-up transformers, automated control equipment and switchgear to feed the grid.[47] The city of Monterrey — along with several other municipalities in the Monterrey metropolitan area and other governmental entities — signed a renewable five-year contract with the company to purchase electricity from the plant. Since 2003, Monterrey has been using this renewable source of electricity to power its public street lighting network.

Costing approximately 7 million dollars, the entirely self-financed plant manages over 19 million tons of garbage on more than 70 hectares of land that will produce methane gas for over twenty years. This results in an electricity generating capacity of over 7.4 MW, with about 40,000 MWh generated per year and supplying 40% of public lighting in the metropolitan area of Monterrey. Additional cash flows have been generated because the government of Denmark has bought carbon credits resulting from the plant's activities. Given the growing problem of municipal waste, as well as that of methane emissions from agricultural waste that contribute to overall levels of greenhouse gases, the development of plants throughout Mexico may have a growing number of avenues to generate profit.[48]

Monterrey's renewable energy procurement initiative has been supported by the city's 2006–2009 Municipal Development Plan. Two of the six "pillars" put forth in the plan refer to environmental sustainability: Pillar Four promotes an efficient public sector, including energy efficiency, and Pillar Six says that public works will be executed with a long-term vision, taking into account sustainable urban planning and ecological awareness. More specifically, Pillar Four states that local alternative energy sources should be used to reduce City expenditures related to electric energy consumption. This municipal initiative has also been supported by the State of Nuevo León's 2004–2009 Development Plan. Chapter Five of the Plan highlights the creation and development of alternative programs to generate energy through the processing of solid waste for public and social use.[49]

The original 7 MW generated at the landfill's power plant were sold at a rate 10 percent cheaper than the electricity available from the Federal Electricity Commission. However, as the energy produced at the landfill was divided among

several customers, Monterrey was limited to 700 kW, which corresponded to less than 10% of the energy needed to power its street lighting system. This created a clear market opportunity as Monterrey looked to increase its procurement of renewable energy from biofuels while also serving as an example to other cities of how to effectively use MSW. Due to this, Bioenergía de Nuevo León enlarged this biogas project in order to generate a further 5 MW at the end of 2008.

The procurement of cheaper energy has allowed the municipal government to save approximately 50,000 pesos each month since the beginning of the contract in 2003. These savings are invested in other municipal programs, such as the maintenance of green areas and city streets. This initiative has also produced positive environmental outcomes, including the mitigation of 800,000 tonnes of CO_2eq since 2003.[50]

Targeting project opportunities in cities the size and complexity of Monterrey could help the bottom line of biofuel companies looking to get started in northern Mexico. The city's large number of inhabitants, combined with its relative dearth of energy supply means that it has both feedstock and general consumer demand in one locality. This allows manufacturers to benefit from shorter distribution pathways, cheaper (or even cash flow positive) MSW off-take agreements and the risk minimization that accompanies those two factors being in place.

Other Domestic Markets

Biofuels developed in northern Mexico could easily find their way into the fuel mix in the southern part of the country. Mexico imports much of its refined oil and gas products from other countries (although has a fair amount of domestic crude production). This means there is a market opportunity for domestic biofuels to displace finished petroleum products imported from outside of the country as well as other fuels that are used to service the grid.

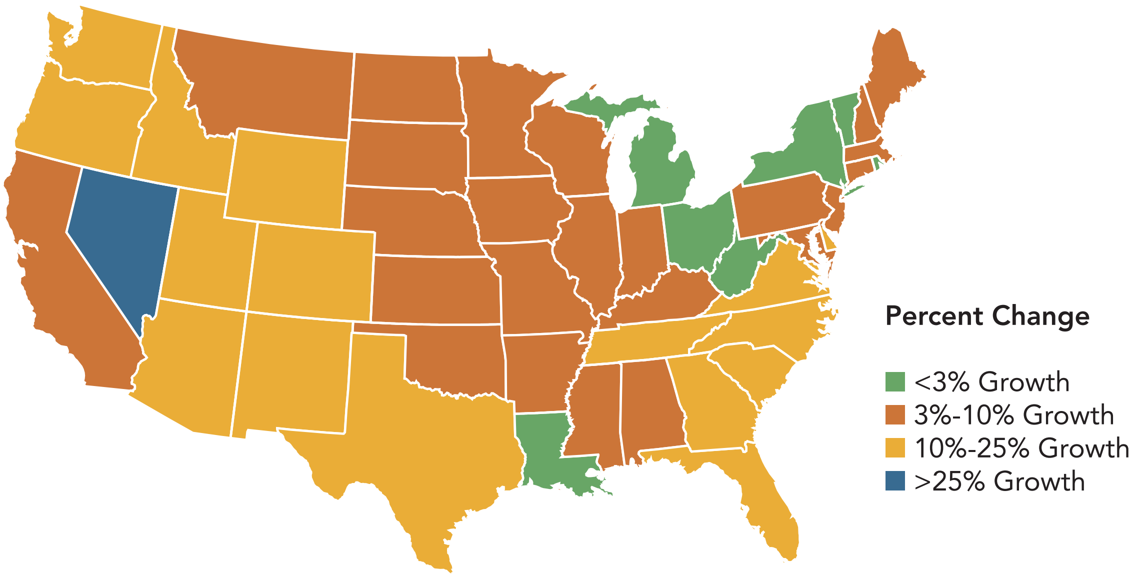
Facilities located south of the cities of Monterrey and Torreón but north of Mexico City and Guadalajara are also of particular interest. A production site located in this area would potentially be able to benefit from the waste and demand streams coming from all four of these municipalities to both create and sell fuel. The one drawback of this strategy would be a diminished opportunity to export to the southern United States.

Trans-border Markets

Northern Mexico's proximity to the United States provides a strong market for MSW derived biofuels. In addition to base demand for fuels such as cellulosic biofuels, the United States has a number of volumetric and percentage mandates for the inclusion of low-carbon and advance biofuels into the fuel portfolio.

California is moving toward satisfying its need for unmet biofuel demand (non corn kernel based) biofuel while at the same time, striving to promote low carbon solutions. California enacted the Low Carbon Fuel Standard (LCFS) regulation in 2007 as part of the state's climate change mitigation efforts under the Global Warming Solutions Act of 2006. The LCFS requires that, by 2020, blenders, refineries, importers and distributors of transportation fuels reduce the "carbon intensity" (CI) of the fuels they sell by ten percent below a 2006 gasoline and diesel baseline. To meet the LCFS standard, California will need to turn to the importation of significant volumes of advanced biofuels.[51] With California currently using approximately 18 billion gallons of transportation fuel per year, the state will need to introduce

Map 1: Population Percent Change of the United States: 2000–2012



Source: U.S. Census Bureau, 2010 Census.

2.4 billion gallons (gasoline equivalent) of advanced biofuel to meet the ten percent carbon intensity reduction goal of the LCFS.[52] This significant demand would help to ensure and drive a biofuels market in northern Mexico. The southwest U.S. states offer another potentially huge market into which biofuel derived from MSW could be sold. As can be seen in the map above (from the U.S. Census Bureau), population growth in the southwest United States is among the fastest in the entire country. Arizona, New Mexico, and Texas grew more than 10% from 2000–2010 while Nevada surpassed 25%. The Southwest has been the fastest growing region of the United States and as such represents a market in need of an increasing energy supply. With trade between the U.S. and Mexico being very fluid thanks to NAFTA (North American Free Trade Agreement), producers should feel comfortable planning facilities in northern Mexico that take advantage of the growing opportunity north of the border.[53]

U.S.-MEXICO BIOFUEL COOPERATION

To date, there has been only minor cooperation between the United States and Mexico at the governmental level. The United States Department of Agriculture (USDA) has worked with its Mexican counterpart SAGARPA on a number of technical issues. They prepared a report on the Mexican biofuels sector in 2009 that pointed to the potential for growth in the market and to the national Renewable Fuel Standards in place in the United States as a key market driver. They also pointed out the potential for similar types of measures in Mexico.[54]

The bulk of interest has come from a U.S. private sector that is looking to invest in biofuels production in Mexico with an eye to exporting the product either back to the United States or to Europe. With small-scale projects popping up across the country, U.S. firms have begun to evaluate the potential for large-scale production of biofuels. Global Clean Energy (GCE), a Los Angeles-based

firm that specializes in feedstock for the production of biofuels, has recently invested in two jatropha farms in Mexico and one in Belize. While some of the attention is focused on biofuels derived from plant matter and other grown feedstocks, there are some very good examples of MSW energy generation.

NON-GOVERNMENTAL AND COMMUNITY GROUPS

Mexico has many non-profit and non-governmental groups that could play a role in building the domestic MSW energy industry. One particular group if interest would be Red Mexicana de Bioenergía (REMBIO), created in Morelia, Michoacán, in 2006. The REMBIO is a non-governmental, non-profit organization that promotes sustainable and efficient use of biomass for energy purposes in Mexico. It currently includes leading experts in bioenergy in Mexico, has partners in most U.S. states, and would be an ideal partner for bioenergy developers in Mexico seeking to engage the community.

REMBIO's goal is to become a Mexican leader in promoting the use of socially, economically and environmentally sustainable biomass for energy purposes. They seek to accomplish this through the generation and dissemination of information, human resource training, exchange of experiences and by strengthening links between the main social actors interested in the subject. REMBIO hopes this will lead to an equitable distribution of energy services and access, while supporting energy security and alleviating poverty and climate change issues.

In order to accomplish its objectives REMBIO engages in a variety of activities:

- Publication of documents and studies.
- Dissemination of updated information on bioenergy.
- Development of strategic studies in the areas of interest.
- Providing feasibility studies and expert advice on project management.
- Carrying out analysis and evaluation of public policies.
- Participating in forums, conferences and seminars.
- Organizing courses and seminars, including an annual national meeting.
- Facilitating project execution.

Groups such as REMBIO can advance a team looking to develop bioenergy projects in Mexico — especially as it relates to achieving buy-in from the community.[55]

CONCLUSIONS

Rising demand for energy in Mexico and the United States must be met with as many local, Earth-friendly fuels as possible. Biofuel derived from MSW offers the opportunity to turn an otherwise worthless material into power for the grid and motor vehicles. As Professor David Bransby of Auburn University recently remarked about the potential of MSW, *"the infrastructure for collection of municipal solid waste (MSW) is already in place and paid for, and those who collect and dispose of it get paid for their services. This results in very low cost and low risk, making MSW a no-brainer feedstock for launching the cellulosic biofuels industry."*[56]

The second generation conversion technologies such as gasification have been proven technically and are well along in the process of commercialization, as seen with companies that move towards IPOs. High demand, technical viability and the availability of capital are helping this industry to emerge.

Northern Mexico is an ideal location to center the growing MSW based biofuel industry. First and foremost, it has the advantage of cheap land, abundant MSW feedstock and inexpensive labor. Not only is labor inexpensive, but it is has industry-specific skills due to the wide employment footprint of Pemex. Additionally, with the improvements that have been and are continuing to be made to Mexico's roadway systems, manufacturers will be able to access a far wider range of feedstock opportunities and markets in which to sell finished products both domestically and abroad.

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