Characterization and Management of

Organic Waste

in North America

Foundational Report

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List of Abbreviations and Acronyms

ACR	American Carbon Registry
AD	anaerobic digestion, as refers to industrial-scale composting in closed containers
ASP	aerated static pile
Badesniarn	*Base de Datos Estadísticos* (Statistical Database) (Mexico)
BECC	Border Environment Cooperation Commission
BUR	Biennial Update Report (Mexico)
C$	Canadian dollar(s) (C$1 = US$0.81 as of September 2017)
CalRecycle	California Department of Resources Recycling and Recovery
C&D	construction and demolition (US term)
CAR	Climate Action Reserve
CCAC	Climate and Clean Air Coalition
CCME	Canadian Council of Ministers of Environment
CDM	Clean Development Mechanism
CEC	Commission for Environmental Cooperation
CEL	*Certificado de Energía Limpia* (Clean Energy Certificate) (Mexico)
CH_4	methane
CNG	compressed natural gas
Conacyt	*Consejo Nacional de Ciencia y Tecnología* (National Council of Science and Technology) (Mexico)
CO_2	carbon dioxide
CRD	construction, renovation, and demolition (Canadian term)
CUCEI	*Centro Universitario de Ciencias Exactas e Ingenierías* (University Center of Exact Sciences and Engineering) (Mexico)
DBGIR	*Diagnóstico Básico para la Gestión Integral de Residuos* (Baseline Diagnosis for Integrated Waste Management) (Mexico)
DOE	Department of Energy (United States)
DOPF	Dufferin Organics Processing Facility
ECCC	Environment and Climate Change Canada
EEA	European Environment Agency
EIA	Energy Information Association (United States)
EPR	extended producer responsibility
EREF	Environmental Research and Education Foundation (United States)
EU	European Union
Firco	*Fideicomiso de Riesgo Compartido* (Shared Risk Trust Fund) (Mexico)

FIT	feed-in tariff
FOG	fats, oil and grease
FY	fiscal year
Gg	gigagram
GHG	greenhouse gas
GMI	Global Methane Initiative
ICI	industrial, commercial and institutional
INE	*Instituto Nacional de Ecología* (National Institute of Ecology) (Mexico)
INECC	*Instituto Nacional de Ecología y Cambio Climático* (National Institute of Ecology and Climate Change) (Mexico)
INEGI	*Instituto Nacional de Estadística y Geografía* (National Institute for Statistics and Geography) (Mexico)
IPCC	Intergovernmental Panel on Climate Change
kg	kilogram
kW	kilowatt
kWh	kilowatt-hour
LCA	life-cycle analysis
LEAP	Long-range Energy Alternatives Planning System
LFG	landfill gas
LGEEPA	*Ley General del Equilibrio Ecológico y la Protección al Ambiente* (General Law of Ecological Equilibrium and Environmental Protection) (Mexico)
LGPGIR	*Ley General para la Prevención y Gestión Integral de los Residuos* (General Law on the Prevention and Comprehensive Management of Waste) (Mexico)
LMOP	Landfill Methane Outreach Program (US EPA)
m^3	cubic meter
MassDEP	Massachusetts Department of Environmental Protection
MOECC	Ministry of the Environment and Climate Change (Ontario, Canada)
MPCA	Minnesota Pollution Control Agency
MSW	municipal solid waste
$MTCO_2e$	metric tonnes of carbon dioxide equivalent
MW	megawatt
N/A	not applicable
NIR	National Inventory Report (Canada)
NMX	*Normas Mexicanas* (Mexican Standards)
NOM	*Normas Oficiales Mexicanas* (Official Mexican Standards)
NRA	National Renderers Association (United States)

OECD	Organisation for Economic Co-operation and Development
ORCR	Office of Resource Conservation and Recovery (US EPA)
OWMA	Ontario Waste Management Association
P$	Mexican peso(s) (P$1 = US$0.056 as of September 2017)
PAW	passively aerated windrow
PAYT	pay-as-you-throw
PCF	post-consumer fiber
PEPGIR	*Programas Estatales para la Prevención y Gestión Integral de Residuos* (State Programs for the Prevention and Comprehensive Management of Waste) (Mexico)
PET	polyethylene terephthalate
PIPGIR	*Programa Intermunicipal de Prevención y Gestión Integral de Residuos* (Intermunicipality Programs for the Prevention and Comprehensive Management of Waste) (Mexico)
PMPGIR	*Programas Municipales para la Prevención y Gestión Integral de Residuos* (Municipality Programs for the Prevention and Comprehensive Management of Waste) (Mexico)
PND	*Plan Nacional de Desarrollo* (National Development Plan) (Mexico)
PNPGIR	*Programa Nacional para la Prevención y Gestión Integral de los Residuos* (National Program for the Prevention and Comprehensive Management of Waste) (Mexico)
ppb	parts per billion
Promarnat	*Programa de Medio Ambiente y Recursos Naturales* (Environment and Natural Resources Sector Program) (Mexico)
Provar	*Proyecto de Apoyo al Valor Agregado de Agronegocios* (Added Value to Agribusiness Support Project) (Mexico)
RCRA	Resource Conservation and Recovery Act (United States)
REAP	Rural Energy for America Program (United States)
RFM	residual fertilizing material
RME	*residuos de manejo especial* (special-management wastes)
RNG	renewable natural gas
RPS	renewable portfolio standard
RSU	*residuos sólidos urbanos* (urban solid waste)
Sagarpa	*Secretaría de Agricultura, Ganadería, Desarrollo Rural, Pesca y Alimentación* (Secretariat of Agriculture, Livestock, Rural Development, Fisheries and Food) (Mexico)
Seciti	*Secretaría de Ciencia, Tecnología e Innovación de la Ciudad de México* (Mexico City Secretariat of Science, Technology and Innovation) (Mexico)
Sedema	*Secretaría del Medio Ambiente del Gobierno de Distrito Federal* (Secretariat of the Environment of the Government of the Federal District) (Mexico)

Semarnat	*Secretaría de Medio Ambiente y Recursos Naturales* (Secretariat of Environment and Natural Resources) (Mexico)
Senasica	*Servicio Nacional de Sanidad, Inocuidad y Calidad Agroalimentaria* (National Service of Health, Safety and Food Quality) (Mexico)
SIA	Subaru of Indiana Automotive
SINGIR	*Sistema de Información Nacional para la Gestión Integral de los Residuos* (National Information System for Integrated Waste Management) (Mexico)
SLCP	short-lived climate pollutant
SMM	sustainable materials management
SNAP	Supporting National Action and Planning on SLCP (CCAC)
SNIARN	*Sistema Nacional de Información Ambiental y de Recursos Naturales* (National Environmental and Natural Resources Information System) (Mexico)
SSO	source-separated organics
STA	Seal of Testing Assurance (US Composting Council)
SW	solid waste
SWMP	solid-waste management plan
SWRM	Solid Waste Resource Management (Canada)
TCMA	Twin Cities Metropolitan Area (United States)
tonnes	metric tonnes
UNAM	*Universidad Nacional Autónoma de México* (National Autonomous University of Mexico)
UNFCCC	United Nations Framework Convention on Climate Change
US$	United States dollar(s)
USCC	United States Composting Council
USDA	United States Department of Agriculture
US EPA	United States Environmental Protection Agency
WaRM	Waste Reduction Model (US EPA)
WERF	Water Environment Research Foundation
WRRF	water resource recovery facility
WWTP	wastewater treatment plant
ZWEDC	Zero Waste Energy Development Company
ZWIA	Zero Waste International Alliance

Glossary of Terms

Anaerobic digestion	The process by which micro-organisms break down organic matter in the absence of oxygen, releasing a gas called biogas and leaving an organic residue called digestate.
Biodigester	An apparatus which facilitates the decomposition of organic wastes through use of micro-organisms.
Biogas	A combination of methane and carbon dioxide released by the decomposition of organic wastes; used as a fuel.
Biosolid	Nutrient-rich solid organic matter recovered from a wastewater treatment process and used in a variety of applications, including: fertilizer; composting; mine reclamation; landfill alternative; daily cover; and gasification to produce energy.
Co-digestion	A process in which energy-rich organic waste materials such as fats, oils, grease, energy crops, crop residues, and/or restaurant food wastes are added to manure- or wastewater-digesters that have excess capacity.
Composting	The decomposition of organic materials (e.g., yard trimmings, food waste, paper) by aerobic (and anaerobic) micro-organisms into humus—a usable, soil-like by-product.
Digestate	Nutrient-rich material remaining after anaerobic digestion; can be used as a fertilizer; composed of indigestible residues and dead micro-organisms.
Digester	A large vessel or container used to facilitate decomposition or extraction.
Effluent	Liquid waste material discharged from industrial or wastewater plants; can be used as a liquid fertilizer or soil amendment.
Feedstock	Any raw material used as an input for industrial processing.
Humus	The organic portion of soil; a by-product of composting formed by the partial decomposition of plant materials.
Leachate	Contaminated liquid that drains from a landfill, open dump or other waste disposal site.
Rendering	The industrial processing of animal wastes into edible and inedible by-products that can be used as ingredients or feedstock for industrial products, health and beauty goods, and pet food.
Siting	The process of selecting a location for a facility.
Sludge	A muddy, viscous mixture of solid and liquid matter produced by wastewater- and sewage-treatment processes.

Windrow	Long rows of material in low piles that are regularly turned—either manually or mechanically—to blend material.

Abstract

Characterization and Management of Organic Waste in North America identifies challenges, opportunities and solutions related to increasing organic waste diversion and processing capacity in North America, with a focus on how to address challenges and opportunities in Canada, Mexico, and the United States, and identifies potential areas for regional cooperation. The project focuses on organic waste diversion, collection, and processing. Its scope includes organic waste generated in the residential and the industrial, commercial and institutional sectors. In Canada, Mexico and the United States, organic waste represents a significant component of the waste stream that can be diverted from landfills to other more sustainable waste management practices, including industrial uses and anaerobic digestion processes such as co-digestion and composting. Organic waste diversion will contribute to significant reductions in short-lived climate pollutants—such as methane—which affect human health and air quality, in addition to contributing to climate change. The report explores the current situation and potential areas for improvement—with accompanying environmental and other benefits. It also highlights strategies to reduce short-lived climate pollution and promotes green growth by encouraging the sustainable management of materials, in addition to sustainable consumption and production.

Executive Summary

Introduction

The North American Initiative on Organic Waste Diversion and Processing is a project launched by the Commission for Environmental Cooperation (CEC) as part of its 2015–2016 Operational Plan—to enhance North America's capacity to increase organic waste diversion and processing in the residential and the industrial, commercial, and institutional (ICI) sectors in Canada, Mexico and the United States. This report, *Characterization and Management of Organic Waste in North America,* explores the current situation and potential areas for improvement—with accompanying environmental and other benefits. The report includes recommendations to reduce short-lived climate pollution (notably methane emissions from landfills) and promote green growth, by encouraging sustainable management of materials and sustainable consumption and production. By examining successful programs, policies and facilities using sustainable practices to divert organic waste away from landfills, the report sheds light on country-specific efforts to improve public health and reduce greenhouse gas (GHG) emissions associated with landfilling organic waste. Moreover, the report identifies challenges and gaps that require additional research and attention. Finally, it offers recommendations and strategies to strengthen organic waste diversion and processing opportunities, including regional cooperation. This report focuses on specific types of organic waste materials, such as food waste (i.e., discarded food and any inedible parts of food), yard and garden debris (e.g., leaves, grass clippings), paperboard and other paper products, wood (except construction- and demolition-related debris), and pet waste. Organic waste, of course, does not include metals or glass. For the purposes of this report, organic waste does not include textiles, leather or petroleum-based plastic. Nor, herein, does it include livestock manure and wastewater treatment biosolids, except in cases where an organic waste type as specified above is co-digested with livestock manure or biosolids—and except when referring to Mexico, where these types of waste were specifically included as part of the analysis.

This report draws upon information from reputable sources and the expertise of noted professionals in the fields of organic-waste and solid-waste management. Beginning with a high-level review of published organic waste research, government and industry statistics, and initiatives in each country, a tailored research approach for each country was developed (e.g., identify data collection methods, summarize results and contribute to the report sections for each country). These approaches revealed commonalities and key differences among government, private-industry and nonprofit sectors, in: engagement; capacity and infrastructure; data availability; extent and type of measurement activity; and key environmental, economic and social challenges. Where information was not available, or needed enhancement, the authors conducted interviews with relevant North American stakeholders—including government officials, and representatives from industry, commerce, institutions and nonprofit organizations (up to 12 representatives each in Canada and the United States, and 24 in Mexico)—to help fill gaps and expand or clarify information in the report. In spite of these interviews, the authors were not able to fill all data gaps.

This report was prepared simultaneously and in conjunction with a companion CEC report, titled *Characterization and Management of Food Loss and Waste in North America* (CEC 2017). The companion report characterizes reduction and recovery of surplus food (for human consumption) from the industrial, commercial and institutional (ICI) sector, as well as diversion of wasted food and food scraps for animal feed from both the residential and ICI sectors. Combined, the two reports identify effective ways to reduce the problems that food waste and organic waste may cause in our society and ecosystems: reducing air quality and water pollution, mitigating climate change, reducing hunger, producing beneficial products, and improving food quality (i.e., feeding hungry people and animals with safe, quality surplus food).

Characterization, Quantification and Management of Organic Waste in North America

This report focuses on residential (single- and multi-family residences) and industrial, commercial and institutional (ICI) sources of organic waste, which can be generally characterized as food waste, paper,[1] yard waste,[2] and wood (mainly pallets). Other types of organic waste (e.g., manure, wastewater biosolids, and crop residues) are generally excluded from this report, since they are not typically part of the solid-waste stream. While the three countries define organic waste from residences differently, the primary waste streams are consistent and comparable. Note that there is some discussion of additional sources of organic waste in Mexico, where they are more common as part of the ICI waste stream.

Estimates of residential organic waste in North America are the most comparable, since all three countries track the residential solid-waste stream. Canada tracks source-separated

North American ICI Data Differences

ICI data collection efforts, especially in the measurement of the industrial portion of ICI, differ among the three countries. In Canada, national statistics capture most industrial waste; in Mexico, some industrial waste is measured; and in the United States, national statistics exclude industrial waste. The United States has measured food-processing waste, which is included in this analysis. Although data measurement differs, the term "ICI" is used throughout this report to represent the best data available.

[1] This analysis includes paper because paper is an organic material. Note, however, that the highest-end use for paper is recycling in the fiber market, rather than composting or anaerobic digestion (the organic waste management strategies discussed in this report). In this report, "recycled paper" refers to paper diverted to the fiber market. Since paper has a higher value in the fiber market, decision makers may prioritize paper recycling in the fiber market over composting or anaerobic digestion as part of the organic waste stream. Thus, paper remaining in the disposal stream may be targeted for additional diversion to the fiber market and not available as part of the organic waste stream.

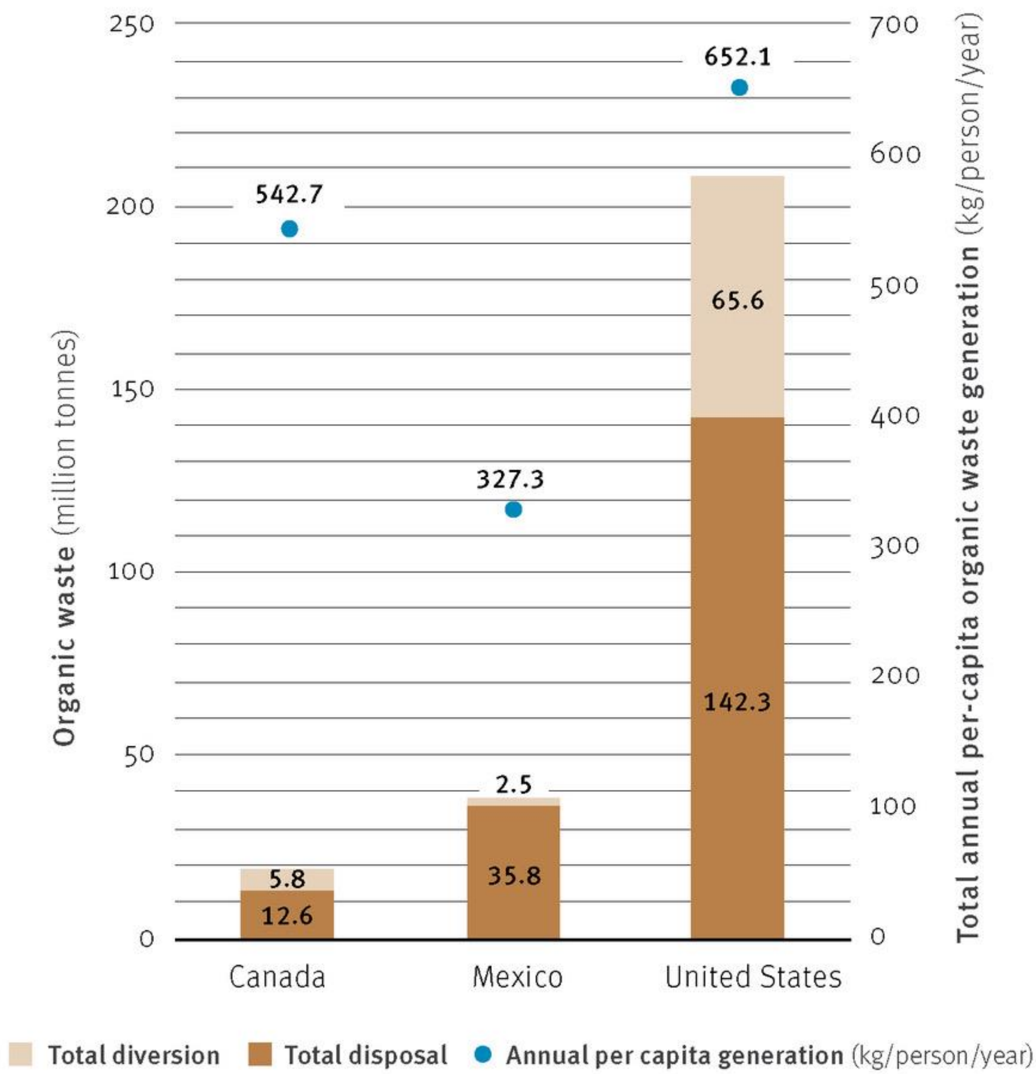
[2] Yard waste includes grass, leaf, and garden waste.

organics (SSO), including food waste, non-recyclable papers, and leaf and yard waste during the growing season. Mexico tracks food waste, garden waste and recyclable paper products. The US residential organic waste generation, diversion and disposal estimates include food waste, paper products, yard waste and wood waste. Neither Canada nor Mexico tracks wood waste generation or diversion from the residential sector.

ICI-sector comparisons are more difficult due to differing data collection programs. Large data gaps exist in both Canada and Mexico for ICI-sector organic waste generation and diversion. While the United States has the most complete institutional and commercial generation data series, there is a gap in the industrial portion of the ICI-sector data for the United States. Canadian and US ICI estimates do not include organic waste from sewage treatment plants; animal excrement and manure; or animal carcasses; as discussed previously. The Canada estimates also exclude animal-product waste diverted by the rendering industry to make protein and fat products. Mexico's estimates include sludges from sewage treatment plant; animal manures; slaughterhouse waste; and organic waste generated from harvest loss.

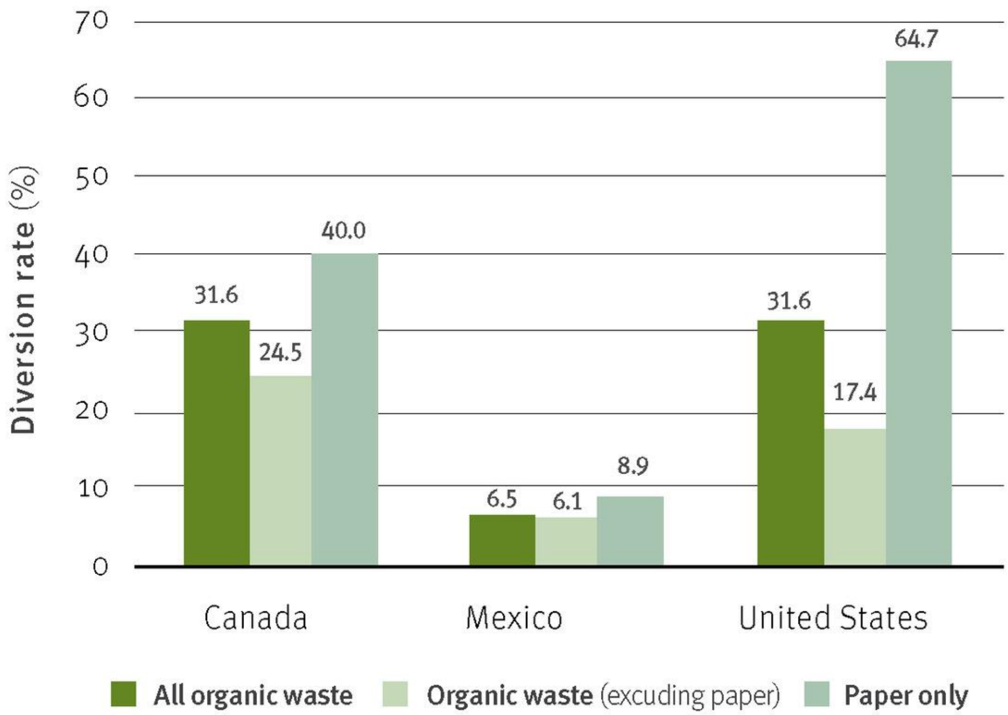
Limitations in the availability and quality of data for organic waste in Canada, Mexico and the United States exist at the national level (the focus of this report), particularly in the ICI sector. Comparing the data that are available is further complicated by the lack of consistent specifications for what constitutes organic waste, across the three countries. However, there is enough consistency in the country-specific data to estimate information on organic waste generation, diversion, and disposal in North America (see Figure ES-1). The established infrastructure, higher market value and market stability of paper, compared to other organic materials, are reflected in the higher diversion of that organic material (see Figure ES-2). Because of this higher value, paper remaining in the disposal stream may be targeted for additional diversion through the fiber market instead of for composting or anaerobic digestion (AD). In addition, organic waste diversion estimates for Canada and the United States were found to be similar to estimates of organic waste in Europe. Diversion estimates for Mexico are similar to those for Brazil.

Figure ES-1. Estimated organic waste generation, diversion, and disposal, and annual per-capita generation, by country



Note: Weights are in million tonnes unless otherwise noted. Mexican values include residential and food waste from harvest to commercialization, but not ICI generation, diversion or disposal estimates from any other sources.
Source: Table 24, this report.

Figure ES-2. Estimated diversion rates for all organic waste, organic waste without paper, and paper waste, in Canada, Mexico and US



Note: Mexican values include residential and food waste from harvest to commercialization, but not ICI generation, diversion or disposal estimates from any other sources.
Source: Table 24, this report.

Organic Waste Diversion, Processing and End-Product Considerations

The large volumes of organic waste in North America are primarily disposed of in landfills, but instead could be diverted and processed to yield economic, energy and environmental opportunities. Programs to divert, collect and process organic waste have emerged in recent decades. Composting was one of the earliest processing methods; today, thousands of composting plants operate in Canada and the United States (though many fewer operate in Mexico). Another method is anaerobic digestion (AD—in industrial-size closed containers): farm-scale manure AD is well established in North America, and organic waste AD is steadily increasing in Canada and the United States. As more provinces, states and communities enact policies or incentives, and bans on disposing of organic waste in landfills, increasing interest has begun to drive markets and infrastructure for diversion and processing of organic waste.

While diverting and processing organic waste has useful inputs and outputs (e.g., industrial feedstocks, biogas, digestate, compost), participation and compliance (e.g., proper separation, sufficient quantity) is critical. In that light, several jurisdictions and communities throughout North America are creating and implementing initiatives (e.g., curbside collection) and incentives (e.g., pay-as-you-throw [PAYT] systems, higher landfill tipping fees, low[er] organics tipping fees) to increase organic waste diversion and processing. Many programs, initiatives, incentives and markets encourage and advance organic waste diversion and processing in states, provinces and communities. While Mexico trails Canada and the United States in programs, initiatives and incentives, it has an opportunity to kickstart sustainable organic waste management and practices. Likewise, Canada and the United States have an opportunity to significantly expand and improve policies, programs and incentives for organic waste management and to share best practices among thousands of communities and businesses.

Among the North American countries, organic waste diversion programs vary by implementation strategy (e.g., municipality- or corporate-sponsored, privately contracted) and elements (i.e., number of households, diversion rate, sustainability goals) but share some commonalities between the residential and ICI sectors (e.g., SSO). To encourage organic waste diversion, several Canadian and US communities have used economic incentives, such as PAYT programs, that require residents to pay for volume-based waste disposal (i.e., the more you throw away, the more you pay). Many municipal landfills or disposal sites have imposed tipping fee surcharges or fines on loads that contain organic waste (see the Regional District of Nanaimo example, in Section 4.1.1) and/or are not source-separated (Federation of Canadian Municipalities 2009). Several municipalities have also instituted organic waste bans or created incentives for both businesses and residents, while some US states have imposed organic waste bans on businesses, that are generally not applicable to residents.[3] And over 200 North American municipalities tackle organic waste from residential sources, ICI sources or both. Mexico's capital city requires both residents and the ICI sector to segregate organic waste and has achieved considerable success in the residential sector. Although ICI organic waste diversion is more established in Canada and the United States than in Mexico, publicly available information on the topic is limited. Sufficient data exist, however, to demonstrate how organic waste from the residential sector is typically managed.

While the North American countries might approach implementation of organic waste diversion programs differently, the collection methods (e.g., source separation into bags or bins, curbside versus drop-off) and processing technologies (i.e., rendering, AD, composting) are similar, as well as the challenges encountered (e.g., public education/participation, contamination and pre-treatment, moisture and weight issues). This report highlights various methods and considerations for collecting, treating and processing SSO depending on end-products desired (e.g., industrial feedstock, biogas, compost). It discusses both residential and ICI collection methods, as well as pretreatment requirements. Organic waste processing options, including animal rendering, AD, and composting, are all discussed. An overview of each process is provided, including advantages, disadvantages and country-specific considerations, where applicable. Co-digestion of organic waste with animal waste or biosolids from wastewater treatment is also discussed, along with associated pros and cons.

While there are similarities in how the North American countries process organic waste, each nation has unique capacities and opportunities, given geography (i.e., urban versus rural areas), infrastructure, and program/policy evolution (e.g., lessons learned). For example, the United States reportedly has significantly more composting facilities than Canada, which has many more than Mexico, though the number of facilities alone is not the only measure of their efficacy. The report discusses the commonalities and differences in processing capacity of organic waste, among Canada, Mexico and the United States, and the reasons for the differences (e.g., quantity and quality of feedstocks, infrastructure, operating costs).

Less is known about the extent to which AD is used to treat organics in all three countries (i.e., there are no centralized databases and/or volume-based studies). AD treatment of organic solid waste is a relatively new and emerging technology in North America (outside of manure AD on farms or industrial AD); however, it is gaining acceptance in Canada and the United States, due primarily to

[3] California's organic waste ban applies to multi-family dwellings with more than five units, but there is an exemption for food waste (including food-soiled paper). See "Mandatory Commercial Organics Recycling (MORe)," CalRecycle, last updated 8 May 2017, <www.calrecycle.ca.gov/recycle/commercial/organics/FAQ.htm - Q14>.

provincial, state and local drivers, including disposal bans, policies, incentives and sustainability initiatives.

A primary benefit of organic waste diversion and subsequent processing is an end-product (e.g., feedstock, biogas, compost) that can be used in other applications (e.g., manufacturing, energy generation, soil enhancement). The North American countries are cultivating markets for both public and private uses of these end-products. The animal rendering industry yields both edible and inedible animal byproducts that can be used as ingredients or feedstock for many industrial products (e.g., paints and varnishes, explosives, lubricants), health and beauty goods (e.g., soaps, cosmetics, toothpaste, pharmaceuticals), apparel (e.g., leather, textiles) and pet food (NRA 2016b). Demand for rendering byproducts is anticipated to increase, as biodiesel production (i.e., hydrolysis and subsequent fermentation of carbohydrates) continues to require more raw materials, including animal fats and greases as well as vegetable oils from sustainably grown crops and/or waste oil and grease associated with food preparation. AD produces biogas (useful as an energy source) and digestate (useful as a fertilizer).

How the products are used, however, varies by country and those differences are discussed. There are many markets and end-uses for compost, depending on its quantity and quality. Canada and the United States have well-established composting programs, many of which accept food waste; but markets for the end-products still poses a challenge. While Mexico lags behind in implementation, the potential for robust composting of organic waste is clear. Diverting the organic waste component of the solid-waste stream not only conserves valuable—and diminishing—landfill space, but also provides economic and environmental benefits such as renewable energy, reduced GHG emissions, and improved water and soil conditions. While each country manages its organic waste differently, they have similar policies and challenges when it comes to increasing organic waste diversion. One of most common themes is the lack of consistent or sufficient data on the generation and collection of organic waste—particularly in the ICI sector. Better data could help inform and design future programs, and thereby secure processing capacity and ensure markets for end-products (e.g., biofuels, biogas, compost).

Policies, Programs, Regulations and Best Practices

As North America embarks on new or additional initiatives to increase organic waste diversion and processing (e.g., grant-funding for new projects; landfill disposal bans), it is important to review and examine the policies, programs, regulations and best practices that are already in place. Some of these initiatives are outgrowths of national policy (e.g., Mexico's General Law on the Prevention and Comprehensive Management of Waste), while others—in the absence of federal policy, as in Canada and the United States—have been developed and implemented at the provincial, territorial, state or municipal level. Presently, these individual efforts occur independently, but there might be opportunities to better share or leverage expertise and experiences to increase organic waste diversion and processing across the continent.

Provinces, states, counties and municipalities across North American have undertaken various efforts to collect and process organic waste. Although Canada currently lacks a federal organic waste policy, initiatives at the provincial or municipal level show promise. For example, the provinces of Prince Edward Island and Nova Scotia, in addition to several municipalities (e.g., the Regional District of Nanaimo and the Metro Vancouver Regional District, in British Columbia), have banned organics from landfills. Many Canadian municipalities are phasing in various types of waste collection methods to allow for better transition, while applying lessons learned from communities that have gone before them. Mexico's waste management—including organic waste management—is regulated under a country-wide waste prevention and management mechanism that requires state authorities to issue regulations to comply with the comprehensive scheme. While the United States has no federal policy geared toward managing or diverting organic waste, individual states have established their own, differing policies (e.g., organics are banned from landfills in 24 states). Moreover, cities such as San Francisco enacted a goal of zero waste by 2020 that, in part, requires residents and businesses to separate organic waste into colored bins.

This report provides an overview of the more successful policies and regulations (e.g., waste bans, renewable portfolio standards, or carbon offset markets), programs (e.g., PAYT, zero-waste goal, or sustainability goals), and best practices (e.g., phased approach, early and ongoing participant involvement) within each of the countries, as well as notable gaps or challenges to greater organic waste diversion and processing.

Provincial/state and municipal governments throughout North America have undertaken efforts to implement policies, programs or practices targeting organic waste. Among these efforts are unit-pricing programs like PAYT, which help waste generators reduce disposal costs by diverting a portion of their waste—thereby reducing the overall volume of waste they pay to dispose of. Other efforts include financial incentives aimed at encouraging voluntary diversion (e.g., lowering tipping fees for organics at drop-off facilities), and mandatory recycling laws requiring generators to divert organic waste to composting or AD. Curbside collection of SSO by the public or private sector is gaining traction as one of the best ways to increase diversion volumes by providing customers with flexibility; variables—such as the size and availability of containers, and collection frequency—make it easy to customize or adjust for the population.

All-out bans on organic waste in landfills are challenging to implement. Successful enforcement, penalties and transition strategies must be in place, and individual jurisdictions often have to take the initiative and introduce bylaws, larger penalties and tipping fees to discourage disposal of recyclable materials.

Development and implementation of options for organic waste management typically comprises several steps and/or occurs in phases over years—or decades, in some instances. This report presents selected case studies in Canada, Mexico and the United States that emphasize the timeframes involved with selected policies and programs, as well as some of the best practices (e.g., community and stakeholder engagement/input, diagnostics/decision-making tools) that have helped to ensure success and can serve as models for the countries. Also included is an overview of organic waste management experience around the world, with featured regions (such as northern Europe) and/or cities (such as Copenhagen) that could serve as models worth emulating.

Although organic-waste-related policies, regulations and programs do not always happen quickly, Canada, Mexico and the United States have individually worked over recent years to develop and implement efforts targeting organic waste diversion and processing, with some success. Early and ongoing public participation and education proves critical to advancing organic waste diversion policies and best practices. But there are still gaps to fill (e.g., lacking ICI data), challenges to overcome (e.g., political, administrative, technical barriers), and lessons to be learned/shared, to divert and process greater volumes of organic waste in North America.

Climate Pollutants and Other Environmental Impacts

In April 2015, the Intergovernmental Panel on Climate Change released a report (IPCC 2015) showing that global emissions of GHGs have risen to unprecedented levels despite a growing number of policies to mitigate climate change. Emissions grew more quickly between 2000 and 2010 than in each of the three previous decades. The US Environmental Protection Agency estimates that the waste sector is the third-largest source of non–carbon dioxide (CO_2) GHG emissions globally, accounting for 13 percent of total non-CO_2 GHG emissions (US EPA 2012c).

Methane is the second most important human-made GHG (after CO_2) and is responsible for more than a third of total anthropogenic climate forcing. It is also the second most abundant GHG, accounting for

14 percent of global GHG emissions. Methane is considered a short-lived climate pollutant (SLCP), meaning that it has a relatively short lifespan in the atmosphere—about 12 years. Although it stays in the atmosphere for less time and is emitted in smaller quantities than CO_2, its ability to trap heat in the atmosphere (its "global warming potential") is 25–36 times greater (IPCC 2015). As a result, methane emissions contributed to about one-third of today's anthropogenic GHG warming (GMI 2015).

As the organic fraction of solid waste decomposes under anaerobic conditions, such as those in landfills, landfill gas (LFG) is produced. LFG contains roughly 50 percent CO_2 and 50 percent methane, along with small amounts of non-methane organic compounds—the exact content depends on waste and landfill conditions. Without a collection and control system, LFG escapes to the atmosphere, where it acts as a heat-trapping GHG and contributes to other local air quality and public health impacts (e.g., smog, premature deaths). Globally, landfills are the third largest human-caused source of methane, accounting for about 11 percent of estimated global methane emissions, or nearly 799 million tonnes of CO_2 equivalent ($MTCO_2e$), in 2010 (GMI 2015).

Data and estimates for emissions from solid-waste disposal vary in availability and quality. This report presents the available data and assumptions for each country, as well as the estimated GHG emissions from solid-waste disposal in each country, as summarized in Table ES-1.

Table ES-1. Estimated annual GHG emissions from solid-waste disposal

Canada	Mexico	United States
26 million $MTCO_2e$[a] (0.73 $MTCO_2e$ per capita)	18–25 million $MTCO_2e$[b] (0.15 to 0.21 $MTCO_2e$ per capita)	148 million $MTCO_2e$[c] (0.46 $MTCO_2e$ per capita)

Sources:
[a] Table 63, this report.
[b] Table 64, this report (Gg methane converted to $MTCO_2e$ using a global warming potential of 25).
[c] Table 68, this report.

Based on these combined estimates, solid-waste disposal in North America accounts for up to 200 million $MTCO_2e$ of SLCP emissions annually. Note that the estimate for Mexico is likely far too low, based on the amounts of waste produced in Mexico. Obtaining reliable estimates of emissions in Mexico is hampered by the lack of consistent and reliable data, and by the higher number of uncontrolled landfills and open dumps in that country.

Even landfills with LFG collection and control systems cannot capture 100 percent of LFG. Since it is the organic fraction of solid waste that generates LFG during decomposition in a landfill, diverting that organic waste away from landfills to other management options such as industrial uses and AD and/or composting could significantly reduce the SLCP emissions from landfills that contribute to climate change. Food waste decomposes more rapidly than yard trimmings in the landfill environment; this presents opportunities to reduce methane emissions during landfills' early years of operation (before LFG collection) by diverting organic waste to other, more controlled treatment/mitigation (industrial and AD) or avoidance (compost).

Estimating potential emission reductions from organic waste diversion in each country is a complicated, highly variable endeavor. Zero emissions is the ultimate emission reduction goal, but achieving that would require completely eliminating waste generation or diverting all waste to a management option that does not produce emissions. Since neither of those scenarios is realistic in the near term, models are used to estimate emission reductions through diversion from landfills to options such as composting or AD. Differences in the types of models, assumptions within models, and assumptions of waste diversion rates and alternative management all affect how potential reductions can be quantified and achieved over time.

The estimated potential emission reductions from diversion and management of organic waste in each country, based on the assumptions and data available, are summarized in Table ES-2.

Table ES-2. Estimated annual potential GHG emissions reduction

Canada	Mexico	United States
3.4 million $MTCO_2e$[a] (0.09 $MTCO_2e$ per capita)	2–38 million $MTCO_2e$[b] (0.02 to 0.32 $MTCO_2e$ per capita)	60 million $MTCO_2e$[c] (0.19 $MTCO_2e$ per capita)

Sources:
[a] Section 5.2.2, this report. (Based on current organic waste generation and disposal rates.)
[b] Table 65, this report. (38 million $MTCO_2e$ is an estiamte of future potential reductions in 2030.)
[c] Table 69, this report. (Based on current organic waste generation and disposal rates.)

While the basis for these emission reduction estimates varies by country, there is potential for a reduction up to 100 million $MTCO_2e$ annually from organic waste diversion in all three countries combined. This reduction would account for about half of the current total annual emissions from solid-waste disposal, particularly organics.

Organic waste diversion and processing has other benefits as well:

- It reduces the human health and safety issues associated with LFG generation and control, as well as odors and other nuisances that affect local communities.
- It is estimated to have significant positive effects on job creation and local economies.
- It produces compost, which has various beneficial applications. Compost can be used as a soil amendment for agriculture, landscaping and horticulture. It can also be used to decrease the need for fertilizer use, for erosion control, or to prevent loss of topsoil. Compost also helps protect the climate by capturing carbon.
- Biogas from AD can be used as a source of electricity, heat or renewable natural gas, without the need for a potentially more costly LFG collection system. Producing energy using biogas offsets the use of fossil fuels at traditional power plants, resulting in additional environmental benefits due to the reduction in GHG and other pollutant emissions.

Challenges, Recommendations and Strategies for Enhancing Organic Waste Diversion and Processing in North America

The research found many challenges, recommendations and strategies that should be assessed to establish greater North American cooperation. This executive summary focuses on regional challenges and recommendations, but the report itself also discusses country-specific recommendations and strategies.

- Because the requirements and standards for measuring, monitoring and reporting solid waste are different in each country, the availability and consistency of data also differ. This makes it challenging to design national, state/provincial or local actions to expand diversion and processing of organic waste. For example, the primary official sources of organic waste data for Canada and Mexico were last published in 2012. Official national organic waste data should be updated more often (i.e., annually or biannually). (Since the early 1990s, the US Environmental Protection Agency [US EPA] has measured residential, commercial and institutional municipal solid waste on an annual or biannual basis.) Having up-to-date and accurate data is critical to the developing of baselines, metrics, policies, programs, incentives, markets and regulations.

- Planning an organic waste diversion and processing program is complex, involving an array of factors:
  - the quantities and composition of the feedstock
  - the number of residents or businesses to be serviced
  - the amount of waste they produce
  - infrastructure in place
  - capital and equipment costs
  - the collection methods to be used
  - schedule delays
  - stakeholder engagement
  - markets for the end-products
  - diversion rates achieved

  A smaller-scale pilot project can reveal issues in these areas that might appear at full scale—for example, problems with feedstock composition, contamination, collection routes, participation rate or regulatory requirements.
- Economics (i.e., capital and operational expenses; revenues; savings) are critical to a project's success or failure, but finding public financial information is a challenge. Many organic waste projects are publicly owned, but cost data on them are lacking; meanwhile, privately owned projects typically do not share their financial information. Information found for this report was mostly limited to tipping fees, incentives used, pricing of products like compost, and savings realized. This situation makes it difficult to develop a complete understanding of the economics of diversion and processing. Nonetheless, this report does make it clear that many organic waste diversion and processing projects have benefitted from policies, programs, incentives and other financial initiatives.
- The markets for compost, biogas and digestate are limited, and not well understood across North America. The products' quantity and quality are certainly critical to the marketplace. Incentives such as feed-in tariffs or carbon markets, as well as the lack of federal composting regulations (in Mexico and the United States) can also positively or negatively affect market development.
- As demonstrated by all three countries, education, participation and public perception are critical to the success of residential and ICI programs. Although less is known about ICI diversion, savings associated with reduced waste-management fees—as well as the environmental goodwill that corporate sustainability goals can create among consumers—likely contribute to program success. There is a need for ongoing and consistent outreach and education to inform residents of pending plans to develop an organic waste processing site, addressing their potential concerns, explaining how to properly separate organics to minimize contamination, and advertising the benefits of composting and AD (e.g., end-products). In addition, there is a need to address certain perceptions that some residents have, such as that organics collection should be free since recycling is free or that landfill disposal is still the cheapest waste-management option.

As more communities and companies embrace diversion as a means to reduce waste management costs or increase environmental benefits, North America will reap the benefits.

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1 Introduction

The North American Commission for Environmental Cooperation (CEC) is an intergovernmental organization comprising Canada, Mexico and the United States, under the North American Agreement on Environmental Cooperation. The CEC was created to address regional environmental concerns, help prevent potential trade and environmental conflicts, and promote effective enforcement of environmental law. The CEC's Council[4] approved the North American Initiative on Organic Waste Diversion and Processing to enhance North America's capacity to increase organic waste diversion and processing in the residential and industrial, commercial and institutional (ICI) sectors in Canada, Mexico and the United States. The goal of the Initiative is to identify challenges, opportunities and solutions related to increasing organic waste diversion and processing capacity in North America.

Today's global population is over 7 billion, and human activities are estimated to generate almost 1.3 billion tonnes of solid waste world-wide each year; that figure is expected to grow to 2.2 billion tonnes per year by 2025 (Hoornweg and Bhada-Tata 2012). Countries face mounting pressures from growing population and rising consumerism, and these pressures strain waste infrastructure and services (i.e., costing cities millions of dollars per year in waste collection and treatment).

In North America, the total generation of organic waste in Canada, Mexico and the United States combined is estimated to be about 265 million tonnes per year (see Table 24), as the population of the three countries together continues to rise toward a half billion people. This growth, combined with an expected increase in urbanization and prosperity, will only intensify organic waste generation in North America in the coming decades, unless further progress is made toward more-sustainable waste management.

Organic waste comprises a variety of materials, including food waste, yard and green waste, and paper. Organic waste is generated from residences and from ICI sources, which include food and beverage producers, schools, businesses, restaurants and markets. Note that food waste makes up approximately 30 percent of the organic waste stream in Canada and the United States and up to 80 percent of organic waste in Mexico (see Chapter 2).

As solid waste decomposes in anaerobic conditions, it emits greenhouse gases (GHGs), including methane—a potent heat-trapping gas with more than 25 times the global-warming potential of carbon dioxide (CO_2) (GMI 2015). Methane is responsible for more than a third of total anthropogenic climate forcing (GMI 2015), making its reduction an issue of critical importance.

North American ICI Data Differences

ICI data collection efforts, especially in the measurement of the industrial portion of ICI, differ among the three countries. In Canada, national statistics capture most industrial waste; in Mexico, some industrial waste is measured; and in the United States, national statistics exclude industrial waste. The United States has measured food-processing waste, which is included in this analysis. Although the criteria for their measurement differ among the countries, the data used for the term "ICI" throughout this report represent the best data available from this sector.

[4] The CEC Council is composed of the heads of Environment and Climate Change Canada, the US Environmental Protection Agency, and Mexico's Secretariat of Environment and Natural Resources (*Secretaría de Medio Ambiente y Recursos Naturales*).

The global atmospheric concentration of methane has grown from a pre-industrial value of about 715 parts per billion (ppb) to 1,782 ppb in 2007—more than doubling during that period and far exceeding the natural range of the last 650,000 years. The US EPA estimates that global anthropogenic methane emissions could increase by an additional 20 percent. to 8,522 million tonnes of carbon dioxide equivalent ($MTCO_2e$) by 2030 (GMI n.d.).

In the landfill environment, organic waste decomposes under anaerobic conditions, creating landfill gas (LFG). LFG contains roughly 50 percent CO_2 and 50 percent methane, along with small amounts of non-methane organic compounds. Without a collection and control system, LFG escapes to the atmosphere, where it acts as a heat-trapping GHG and contributes to other local air-quality and public health impacts (i.e., smog, premature deaths). Globally, landfills are the third-largest anthropogenic source of methane, accounting for about 11 percent of *estimated* global methane emissions, or nearly 799 million tonnes of carbon dioxide equivalent ($MTCO_2e$), in 2010 (GMI 2015).

Since it is the organic fraction of solid waste that generates LFG during decomposition in a landfill, diverting that organic waste away from landfills to other management options such as anaerobic digestion (AD—in large-size, closed containers) and/or composting could significantly reduce the methane emissions from landfills that contribute to climate change. The estimated annual GHG emissions from solid-waste disposal are 26 million $MTCO_2e$ in Canada (see Table 63), 18–25 million $MTCO_2e$ for Mexico (Table 64), and 148 million $MTCO_2e$ for the United States (Table 68). Organic waste diversion strategies show significant promise for reducing these GHG emission rates. Diverting a year's worth of available organic waste from landfills could result in an estimated potential GHG emissions reduction of up to 3.4 million $MTCO_2e$ for Canada (if 100 percent diversion of organic waste from landfills is achieved) (see Section 5.2.2), 2–38 million $MTCO_2e$ for Mexico (the high end an estimate of potential reductions in 2030) (Table 65), and nearly 60 million $MTCO_2e$ for the United States (if 100 percent diversion of organic waste from landfills is achieved) (Table 69).

The Food and Agriculture Organization of the United Nations estimated the 2007 global carbon footprint, excluding land-use change, of food waste at 3.3 gigatonnes of CO_2 equivalent (FAO 2013). Based on this estimate, food waste would appear third after the US and China if incorporated into a country ranking of top emitters of CO_2 equivalent (FAO 2013). GHG emissions from organic waste disposal have environmental effects on the whole world, not just the area where the waste is disposed of.

In addition to the issue of LFG emissions, mismanaged or untreated solid waste can cause a host of human health problems and disease (e.g., groundwater and drinking water contamination, unsafe food), ecological damage, and emissions of other air pollutants, such as non-methane organic compounds, that contribute to smog formation.

But organic waste also represents an opportunity, if it is managed properly, to create a more closed-loop system that achieves greater sustainability, lower environmental impacts, and emphasizes beneficial uses. Organic waste can be holistically managed to provide various energy, climate, and water- and air-quality benefits. Instead of simply trying to collect and control GHG emissions from organic waste decomposition in landfills to some degree, organic waste can be diverted from landfills or combustion to industrial and commercial uses (to create products such as animal feed, pharmaceuticals, cosmetics, paints and varnishes); anaerobic digestion (AD), including co-digestion (creating biogas to power homes, businesses and vehicles, and creating digestate for fertilizer); and composting (creating nutrients, soil amendment). Recent efforts to divert organic waste from landfills have spurred interest in establishing and promoting policies, incentives, practices and technologies that advance diversion and processing of organic waste. However, many challenges remain in order to maximize organic waste diversion from landfills or incineration.

1.1 Definition of Organic Waste

The specifications for what constitutes organic waste are not consistent across Canada, Mexico or the United States. To guide the scope and content of this report, a definition was created: "organic waste" is any material originating from a plant or animal that can be decomposed by microorganisms or consists of the remains, residues or waste products of any organism. This definition drew on several sources, including the US Environmental Protection Agency (EPA), the United Nations, and the ReFED Roadmap (ReFED 2016).

This report focuses on specific types of organic waste materials, such as food waste (i.e., discarded food and any inedible parts of food), yard and garden debris (e.g., leaves, grass clippings), paperboard and other paper products, wood (except construction and demolition-related debris), and pet waste. Organic waste, of course, does not include metals or glass. For the purposes of this report, organic waste does not include textiles, leather or petroleum-based plastic. The use herein also excludes livestock manure and wastewater treatment biosolids, except in cases where an organic waste type as specified above is co-digested with livestock manure or biosolids—and except when referring to Mexico, where these types of waste were specifically included as part of the analysis.

1.2 Purpose and Scope

Characterization and Management of Organic Waste in North America explores the current situation and potential areas for improvement—with accompanying environmental and other benefits—regarding the diversion, measurement, recycling and processing of organic waste from residential and ICI sources in Canada, Mexico and the United States. It includes recommendations to reduce short-lived climate pollution (notably methane emissions from landfills) and promote green growth, by encouraging sustainable management of materials (SMM) and sustainable consumption and production. It also aims to support country-specific efforts to improve public health and reduce GHG emissions associated with landfilling organic waste, by examining successful programs, policies and facilities already diverting organic waste away from landfills to more-sustainable practices.

Definition of Sustainable Materials Management

"An approach to promote sustainable materials use, integrating actions targeted at reducing negative environmental impacts and preserving natural capital throughout the life-cycle of materials, taking into account economic efficiency and social equity"

Source: OECD 2012.

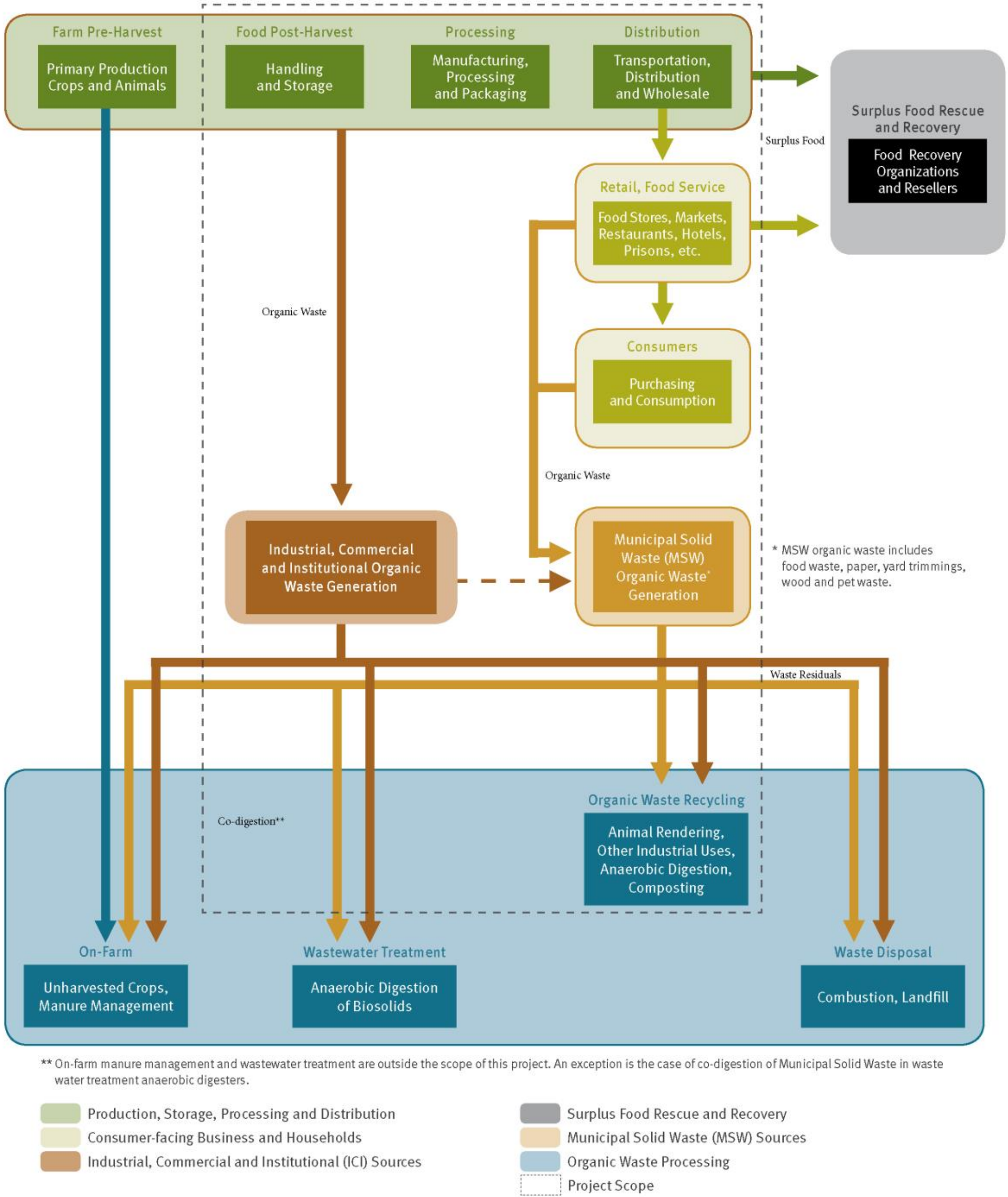
As Canada, Mexico and the United States are increasingly interested in promoting the advancement of SMM practices by encouraging organic waste diversion and processing, this report identifies gaps, challenges and opportunities; recommends actions; and shares best practices in the countries (and internationally), among key organizations and decision makers that have important roles to play in bolstering organic waste diversion and processing from residential and ICI sources.

In addition to post-consumer organics generated from the residential (single- and multi-family dwellings) solid-waste stream, this study includes waste specifically from ICI sources:

- food waste generated upstream from post-harvest handling and storage; manufacturing, processing and packaging; and transportation, distribution and wholesale
- commercial sources such as grocery stores, markets, restaurants and hotels
- institutional sources such as schools, prisons and hospitals (non-medical waste)

Figure 1 shows how these sources of organic waste interact and are, ultimately, treated and disposed of. It also shows which elements are included in the scope of this report. Because manure and biosolids are not typically found in residential or ICI organic waste (or only in minor amounts), this report does not specifically include them in its scope. However, the report does explore organic waste co-digestion in farm-scale or water resource recovery facilities and other types of wastewater treatment (e.g., industrial onsite AD).

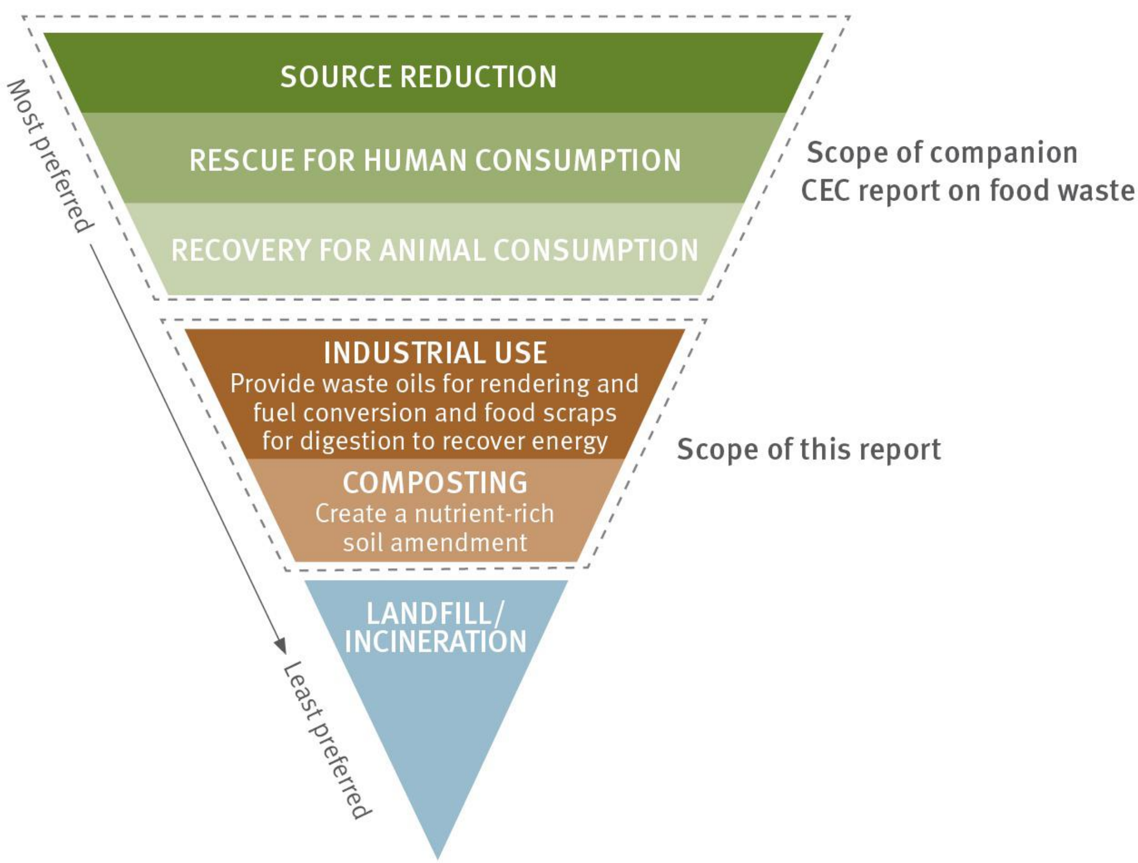
Figure 1. Overview of organic waste generation, diversion and processing



1.3 Approach

Where possible, this report identifies and quantifies waste materials at each stage of their life cycles, including generation, recycling and diversion, and ultimately disposal or processing, as shown in Figure 1. This report does not include upstream activities such as source reduction and feeding hungry people; rather, it highlights downstream practices and programs that encourage organic waste diversion and processing. It is organized in descending order from the most to least preferred processing method, focusing on industrial uses such as rendering animal byproducts for animal feed or for producing beneficial products such as cosmetics, paints and varnishes, and such as anaerobically digesting organic waste to generate biogas and digestate; and then next looking at composting organic materials to produce soil amendments and fertilizer. Note that these two broad methods—industrial uses and composting—are equivalent to the fourth and fifth tiers of the US EPA food recovery hierarchy, as shown in Figure 2.

Figure 2. Food recovery hierarchy



Source: Adapted from US EPA 2016d.

This report draws upon information from reputable sources and the expertise of noted professionals in the fields of organic-waste and solid-waste management. Beginning with a high-level review of published organic waste research, government and industry statistics, and initiatives in each country, a tailored research approach for each country was developed (e.g., identify data collection methods, summarize results and contribute to the report sections for each country). These approaches revealed commonalities and key differences in government, private industry and nonprofit engagement; capacity and infrastructure; data availability; extent and type of measurement activity; and key environmental, economic and social challenges.

Where information was not available or needed enhancement, the authors conducted interviews with relevant North American stakeholders, including government officials, and industry, commercial, institutional, academic and nonprofit organizational representatives (up to 12 each in Canada and the United States and 24 in Mexico), to help fill gaps and expand or clarify information in the report. In spite of these interviews, the authors were not able to fill all data gaps.

1.4 Companion Report on Food Waste Reduction and Recovery

This report was prepared simultaneously and in conjunction with a companion CEC report, titled *Characterization and Management of Food Loss and Waste in North America.* The companion report characterizes reduction and recovery of surplus food (for human consumption) from the ICI sector (e.g., food production, grocers and restaurants, hospitals, schools and universities), as well as diversion of wasted food and food scraps for animal feed from both the residential and ICI sectors (Figure 2). The companion report focuses on upstream activities: reducing waste and recovering food through source reduction and feeding hungry people and animals. This report complements that approach with a focus on food and other organic materials after they have been discarded. It examines opportunities to divert, collect and process residential and ICI organic waste through methods such as rendering, AD and composting. Food waste and other organic materials are commonly mixed in these applications.

Combined, the two reports identify effective ways to reduce the problems that food waste and organic waste may cause in our society and ecosystems: reducing air quality and water pollution, mitigating climate change, reducing hunger, producing beneficial products, and improving food quality (i.e., feeding hungry people and animals with safe, quality surplus food). They aim to reduce methane emissions from landfills by reducing organic and food waste disposal. (Reducing food waste from ICI at the source contributes to a reduced amount of organic waste disposal.) The intent of these reports is to raise awareness regarding best practices, policies and other approaches for reducing food and other organic waste.

1.5 Structure of Report

This foundational report is organized into seven chapters, as follows:

- Chapter 1 outlines the background, purpose, scope, approach and structure of the report.
- Chapter 2 describes the sources and causes of organic waste, then estimates and compares organic waste quantities and management in each North American country.
- Chapter 3 discusses organic waste diversion and processing, including benefits, methods and considerations for source-separating organic waste; organic waste diversion programs in North America; technologies for processing organic waste; processing infrastructure and opportunities in North America; and markets for end-products of organic waste processing.
- Chapter 4 presents an overview of successful policies, programs, regulations and best practices for organic waste diversion and processing in North America, including implementation of selected policies and case studies.
- Chapter 5 discusses the environmental impacts of organic waste, including estimates of current GHG emissions from organic waste decomposition, and potential ways to reduce GHG emissions by diverting and processing organic waste. Other environmental benefits and socio-economic impacts are also discussed.

- Chapter 6 presents recommendations for each country for enhancing organic waste diversion and processing, as well as opportunities for cross-border cooperation.
- Chapter 7 discusses limitations of the analyses, and potential areas for improvement.

Each chapter presents findings on related topics in Canada, Mexico and the United States, as well as comparing the findings across the three countries.

2 Characterization, Quantification and Management of Organic Waste in North America

This chapter describes the characterization and quantification of organic waste generation, diversion, and disposal in North America, past and present. Because the requirements and standards for tracking and reporting solid waste are different in each country, the availability and consistency of data also differ. This chapter discusses the data available in each country, and in Section 2.5 summarizes the data for comparison.

> "The most common alternatives for landfilling food waste are composting and anaerobic digestion, both of which are considered recycling when the residues are reused as compost or fertilizer. Banning food waste from landfills may also have the impact of reducing waste and possibly encouraging food reuse programs, even better than recycling."
> —Michael Van Brunt, Covanta Energy
>
> *Source:* Greenwalt 2016.

2.1 Sources and Causes of Organic Waste

Solid waste sources contribute varying amounts, compositions, and quality of organic waste. Each source point in the supply chain shown in Figure 1 contributes organic materials that can be diverted away from landfills and processed more beneficially. This report focuses on residential and institutional, commercial and industrial (ICI) sources of organic waste, which can be generally characterized as food waste, paper,[5] yard waste,[6] and wood (mainly pallets). Other sources of organic waste (e.g., manure, wastewater biosolids, and crop residues) are generally excluded from this report since they are not typically part of the solid-waste stream. The report does discuss these additional sources of organic waste in Mexico, however, because they are more common in its ICI waste stream. Organic waste from construction, renovation and demolition (CRD)[7] debris (such as stumps from land clearing operations) is excluded from this analysis.

Ideally, organic waste would be measured at every point in the supply chain; however, the ability to measure varies among the three countries. Data presented in this chapter represent the best national-level data available. Statistics Canada and Environment and Climate Change Canada provided most of the Canadian data, through publicly accessible data tables and reports. Several government databases and reports were combined for the estimate of Mexico's organic waste, including data from the National Environmental and Natural Resources Information System (*Sistema Nacional de Información Ambiental y de Recursos Naturales*—SNIARN) and the National Institute of Statistics and Geography (*Instituto Nacional de Estadística y Geografía*—INEGI). The US Environmental

[5] This analysis includes paper because it is an organic material. Note, however, that the highest-end use for paper is recycling in the fiber market rather than composting or anaerobic digestion (the organic waste management strategies discussed in this report). In this report, "recycled paper" refers to paper diverted to the fiber market. Since paper has a higher value in the fiber market, decision makers may prioritize paper recycling in the fiber market over composting or anaerobic digestion as part of the organic waste stream. Thus, paper remaining in the disposal stream may be targeted for additional diversion to the fiber market and be unavailable as part of the organic waste stream.

[6] Yard waste includes grass, leaf and garden waste.

[7] "CRD" is the Canadian acronym for construction, renovation and demolition debris. The US acronym for the same waste stream is "C&D."

Protection Agency (EPA), through published reports and research studies, provided the data for the US organic waste estimates.

2.1.1 Residential Sources and Causes

Estimates of residential organic waste presented in this chapter are the most comparable, since all three countries track the residential solid waste stream. Canada tracks source-separated organics, including food waste, non-recyclable papers, and leaf and yard waste during the growing season. Mexico tracks food waste, garden waste and recyclable paper products. The US residential organic waste generation, diversion and disposal estimates include food waste, paper products, yard waste and wood waste. Neither Canada nor Mexico tracks wood generation or diversion from the residential sector.

2.1.2 ICI Sources and Causes

ICI-sector comparisons are more difficult, due to differing data collection programs. Large data gaps exist in both Canada and Mexico for ICI-sector organic waste generation and diversion. While the United States has the most-complete institutional- and commercial-generation data series, the industrial portion of the ICI-sector data is a gap for the United States. Although there are data gaps for each country, use of the term “ICI” throughout this chapter refers to the best data available.

As discussed previously, Canadian and US ICI estimates presented in this chapter do not include organic waste from sewage treatment plants, animal excrement and manure, and animal carcasses. Canadian estimates also exclude animal product waste diverted by the rendering industry to make protein and fat products. Mexico’s estimates include sewage treatment plant sludges; animal manures; and slaughterhouse waste. Mexico is the only country to estimate organic waste generated from harvest loss.

The following sections provide detail on data sources, waste types included, and quantities of organic waste generated, diverted and disposed of, in each country.

2.2 Estimation of Organic Waste in Canada

2.2.1 Quantification Methodology

Canada has no federal solid waste policy framework. Instead, each province and territory has established its own guidelines, policies and regulations specifying how waste should be managed. Residential waste is generally controlled by the municipalities; ICI waste is generally controlled by the entity that generates it. Therefore, individual municipalities are the primary source of detailed data on the residential generation and characterization of organic waste. Detailed data on the generation and characterization of ICI across the country are very limited.

Statistics Canada is the Canadian federal government agency commissioned with producing statistics to better understand Canada’s population, resources, economy, society and culture. Statistics Canada has published residential and ICI[8] waste management diversion and disposal data biannually since 2002, through the Waste Management Industry Survey. Its key socioeconomic database is the

[8] Statistics Canada classifies solid waste as either residential or non-residential. For this analysis, non-residential waste minus CRD waste was assumed to be ICI waste.

Canadian Socio-Economic Information Management System (CanSIM). The following three CanSIM summary tables were used to estimate residential and ICI organic waste disposal and diversion:

- Table 153-0041, "Disposal of waste, by source, Canada, provinces and territories, every 2 years (tonnes), 2002 to 2014"
- Table 153-0042, "Materials diverted, by source, Canada, provinces and territories, every 2 years (tonnes), 2002 to 2012"
- Table 153-0043, "Materials diverted, by type, Canada, provinces and territories, every 2 years (tonnes), 2002 to 2012"

Data for Newfoundland and Labrador, Prince Edward Island, Yukon, Northwest Territories and Nunavut are not available, due to confidentiality requirements of the Statistics Act (Statistics Canada 2015a, 2015b, 2015c). Altogether, these provinces and territories make up about 2.3 percent of the Canadian population, so the omission of their waste data is not considered significant.

Note that Statistics Canada's Waste Management Industry Survey does not capture waste diversion and disposal activities from the following:

- Food and animal wastes from rendering plants used to make protein meals and fat products
- Food wastes or other wastes sent to farms for use as animal feed or bedding
- Food wastes from the food services industry that are sent to shelters or food banks

There is also no separate collection database to inventory organic waste from septage, sewage, biosolids, animal excrement and manure, and animal carcasses. Thus, even though Statistics Canada is the only reliable survey that tracks waste streams, opportunities exist to expand this survey to include organic waste data.

Quantity and composition data for the ICI sector are limited. There is a lack of consistent data on the amounts of organics available in the waste stream and the quantities currently being diverted from disposal. In recent years, individual municipalities and provinces across Canada have conducted studies to help quantify the amount of organic waste available from the ICI sector—specifically the Metro Vancouver Regional District, Waste Diversion Ontario, and the province of Nova Scotia. The organic waste composition data from these studies were used to estimate the percentage of organic waste in ICI and/or residential waste.

Residential Quantification Methodology

The total solid-waste generation estimates used in this report were compiled using the sum of Statistics Canada's total solid-waste diversion and disposal data. National data on waste composition are not available (though the national data do quantify residential waste separately from ICI waste); therefore, this analysis applied municipal curbside and disposal sorting data to the national data to estimate the organic waste portion of total residential solid waste.

Using available sort data, analyses were conducted for 2002 and 2012 (the start and the end of the data series). Depending on the nature of the data, estimating the residential organic waste for these two years involved a combination[9] of three steps: 1) estimating the food, yard and paper waste fractions of residential solid-waste generation; 2) estimating the food, yard and paper fractions of the residential diversion stream; and 3) estimating the food, yard and paper fractions of the residential

[9] For 2012, the available composition data expressed the three wastes as percentages of generation. For 2002, the available composition data expressed the three wastes as percentages of diversion and disposal.

disposal stream. For each year from 2004 to 2010, an organics composition factor was interpolated between 2002 and 2012 and applied to Statistics Canada data.

Six studies and data from Statistics Canada were used to estimate the food, yard and paper fractions in 2002 and 2012:

- A four-season waste composition sort, with data indicating food waste at 20 percent, yard waste at 27 percent, and paper at 24 percent of residential generation (2015 data used for 2012 analysis) (City of Edmonton 2016a).
- A curbside material composition study by Stewardship Ontario, with data indicating paper at 67 percent of the blue box diversion and 10 percent of residential disposal (used for 2012 analysis) (Stewardship Ontario 2013).
- 2012 Ontario residential diversion rates from Waste Diversion Ontario, with data indicating food and yard waste at 37 percent and blue box at 39 percent of diversion (used for 2012 analysis) (WDO 2014).
- Alberta Environment and Park's Provincial Waste Characterization Framework, with data indicating food waste at 21 percent, yard waste at 31 percent, and paper at 22 percent of residential disposal (2001 data used for 2002 analysis) (Alberta Environment and Parks 2005).
- A 2006 residential GAP diversion rate by municipal grouping, from Waste Diversion Ontario, with data indicating food and yard waste at 30 percent and blue box at 47 percent of residential diversion (2006 data used for 2002 analysis) (WDO n.d.).
- A statistical analysis of Stewardship Ontario's residential waste audit program, with data indicating paper at 66 percent of blue box diversion (2005 data used for 2002 analysis) (Wilson 2009).
- National residential diversion and disposal data from Statistics Canada, used for all years (Statistics Canada 2015a, 2015b).
- National total diversion data, used for 2002 and 2012 (Statistics Canada 2015c).

ICI Quantification Methodology

As with residential organic waste, estimating ICI organics waste was a multi-step process. Using available sort data, analyses were conducted for 2002 and 2012. Depending on the nature of the data, estimating the ICI organic waste for these two years involved a combination of three steps: 1) estimating the food, yard and paper fractions of the diversion stream; 2) estimating the paper fraction of the disposal stream; and 3) estimating the food, yard, paper and wood waste fractions of ICI generation. The following studies and data were used to estimate the food, yard, paper and wood fractions in 2002 and 2012. For each year from 2004 to 2010, an organics composition factor was interpolated between 2002 and 2012 and applied to Statistics Canada data.

- Data indicating food waste at 15 percent, yard waste at 2 percent, and wood waste at 1 percent of ICI waste generation (2013 data used for 2012 analysis) (Biogas Association 2014).
- Alberta Environment and Parks' Provincial Waste Characterization Framework, with data indicating food waste at 11.4 percent, yard waste at 1.6 percent, paper at 44.9 percent and wood at 7.8 percent of ICI waste generation (2002 data used for 2002 analysis) (Alberta Environment and Parks 2005).
- EBA Engineering Consultants' 2013 report on the waste composition monitoring program, with data indicating paper is 18 percent of ICI waste disposed of (2013 data used for 2012 analysis) (EBA 2013).
- A report on a Nova Scotia waste audit, with data indicating paper is 18 percent of ICI waste disposed of (2011 data used for 2012 analysis) (CBCL Limited 2012).

- National ICI diversion and disposal data, used for all years (Statistics Canada 2015a, 2015b).
- National total diversion data, used for 2002 and 2012 (Statistics Canada 2015c).

Non-residential waste data provided by Statistics Canada include CRD waste. For this report, CRD diversion was subtracted from the non-residential generation tonnages before the ICI sector's food, yard, paper and wood waste generation was estimated. CRD waste disposed of is included in the Statistics Canada data for total disposal. Insufficient data were available to remove tonnes CRD waste disposed of from the national statistics.

The Statistics Canada diversion data (Table 153-0043) presents total diversion (residential and non-residential) by material. ICI diversion was assumed to equal total diversion minus CRD diversion minus residential diversion, by material.

2.2.2 Estimated Quantity and Composition of Organic Waste Generated, Diverted and Disposed of in Canada

Organic Waste Generation

In 2012, Statistics Canada reported about 33.5 million tonnes of solid waste generated from residential and non-residential sources. The organic fraction of that solid waste—food, yard, paper and wood wastes—makes up over 50 percent of the total generated from these sources (Statistics Canada 2015a, 2015b) (see Chapter 2, Table 24). In 2002, Canada's residential and ICI sectors generated about 19.5 million tonnes of organic material. Food, yard and wood generation represented 43 percent of this total, and paper accounted for 57 percent. In 2012, generation in the ICI sectors decreased to 18.4 million tonnes, of which 54 percent was food, yard and wood waste and 46 percent was paper. As noted, most paper generated in Canada is diverted from disposal via the fiber market.

Residential Sources

As shown in Table 1, Canada's residential sector generated 6.7 million tonnes of food and yard waste and another 3.5 million tonnes of paper, in 2012, the most recent year for which data are available. Of the total 10.2 million tonnes, 28 percent is food waste, 38 percent is yard waste, and 34 percent is paper, as shown in Figure 3. Together, food waste and yard waste make up 69 percent of the organics measured and represent the largest potential targets for diversion to anaerobic digestion or composting. The per-capita trend lines in Figure 4 show all three materials increasing between 2002 and 2012. The growth rates are greater for food and yard waste, compared to paper.

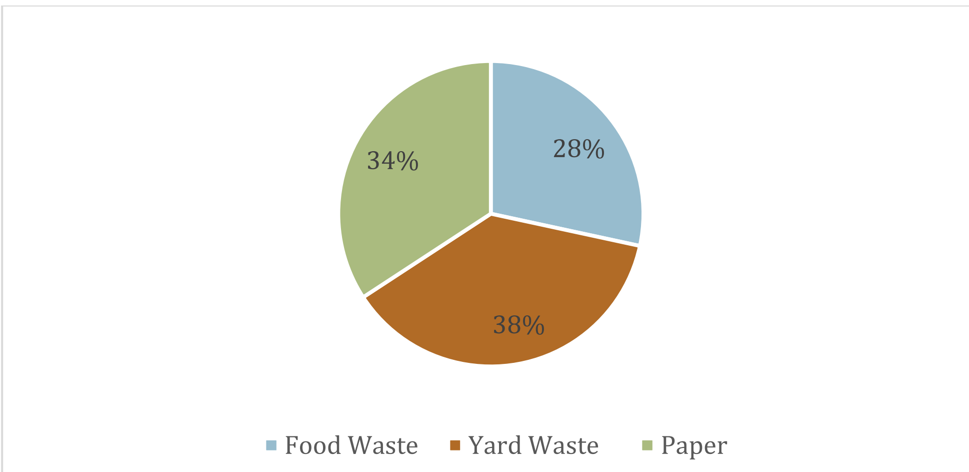
Table 1. Estimated organic waste generated in Canada's residential sector

Year	Food Waste (million tonnes)	Food Waste (kg/person)	Yard Waste (million tonnes)	Yard Waste (kg/person)	Paper (million tonnes)	Paper (kg/ person)	Food Waste, Yard Waste, Paper (million tonnes)	Food Waste, Yard Waste, Paper (kg/person)
2002	1.77	57.97	2.62	85.57	2.72	88.79	7.11	232.33
2004	2.06	65.96	2.96	94.83	2.99	95.80	8.01	256.59
2006	2.37	74.45	3.32	104.47	3.27	102.83	8.96	281.75
2008	2.52	77.66	3.46	106.56	3.32	102.27	9.30	286.49

Year	Food Waste (million tonnes)	Food Waste (kg/person)	Yard Waste (million tonnes)	Yard Waste (kg/person)	Paper (million tonnes)	Paper (kg/person)	Food Waste, Yard Waste, Paper (million tonnes)	Food Waste, Yard Waste, Paper (kg/person)
2010	2.71	81.48	3.64	109.48	3.41	102.54	9.76	293.50
2012	2.89	85.09	3.81	112.15	3.48	102.56	10.18	299.80

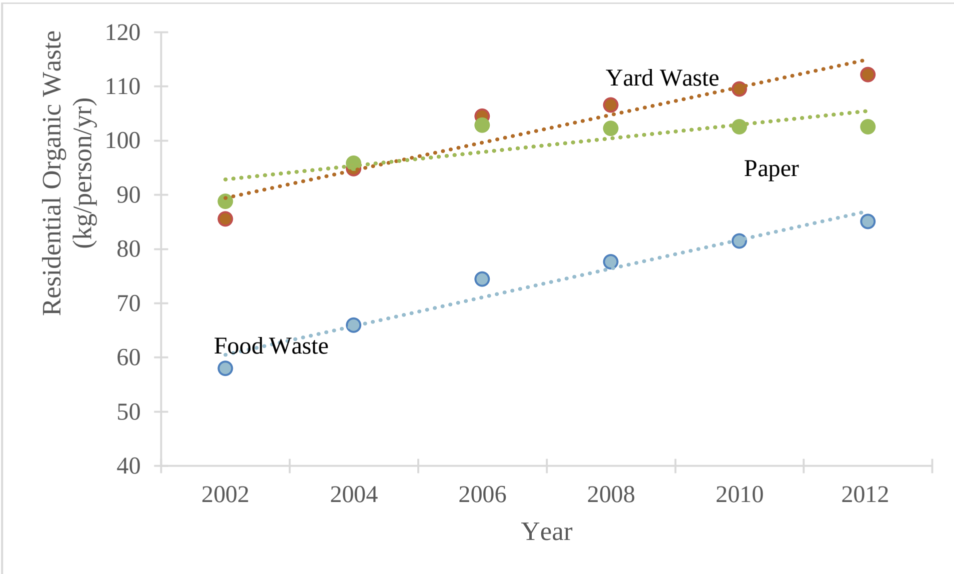
Note: Paper includes newspaper, writing paper, mixed paper, corrugated containers, folding boxes, cartons, and other paper.
Sources: Alberta Environment and Parks 2005; Statistics Canada 2010, 2015a, 2015b, 2015c; City of Edmonton 2016a; Stewardship Ontario 2013; WDO 2014, 2016; Wilson 2009.

Figure 3. Composition of organic waste generated in Canada's residential sector, 2012



Source: Table 1, this report.

Figure 4. Organic waste per-capita generation in Canada's residential sector, 2002–2012



Source: Table 1, this report.

ICI Sources

As Table 2 shows, the ICI sector generated an increasing tonnage of food waste between 2002 and 2012; generation of yard waste, in tonnes, remained about the same, while paper and wood waste decreased. In 2012, the ICI sector generated about 8.2 million tonnes of organic waste. About 34 percent of this total consisted of food waste; 5 percent was yard waste, 59 percent was paper, and 2 percent was wood, as shown in Figure 5. Although paper is shown as the largest component of the materials measured (Figure 6), paper has a higher value if recycled in the fiber market (outside the scope of this report) rather than through anaerobic digestion or composting. Therefore, food waste at 34 percent represents the largest potential target for diversion to industrial uses, anaerobic digestion or composting, from the ICI sector.

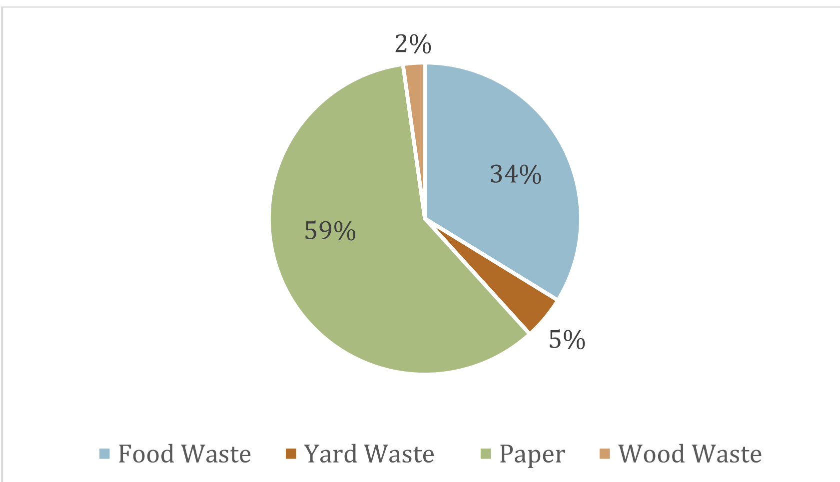
Table 2. Estimated organic waste generated in Canada's ICI sector

Year	Food Waste (million tonnes)	Food Waste (kg/ person)	Yard Waste (million tonnes)	Yard Waste (kg/ person)	Paper (million tonnes)	Paper (kg/ person)	Wood Waste (million tonnes)	Wood Waste (kg/ person)	Food Waste, Yard Waste, Paper, Wood Waste (million tonnes)	Food Waste, Yard Waste, Paper, Wood Waste (kg/ person)
2002	2.15	70.19	0.30	9.85	8.46	276.44	1.47	48.02	12.38	404.50
2004	2.32	74.50	0.32	10.33	7.90	253.28	1.23	39.59	11.77	377.70
2006	2.55	80.14	0.35	10.98	7.45	234.09	1.01	31.71	11.36	356.92

Year	Food Waste (million tonnes)	Food Waste (kg/ person)	Yard Waste (million tonnes)	Yard Waste (kg/ person)	Paper (million tonnes)	Paper (kg/ person)	Wood Waste (million tonnes)	Wood Waste (kg/ person)	Food Waste, Yard Waste, Paper, Wood Waste (million tonnes)	Food Waste, Yard Waste, Paper, Wood Waste (kg/ person)
2008	2.69	82.84	0.37	11.24	6.71	206.54	0.74	22.73	10.51	323.35
2010	2.63	79.28	0.35	10.66	5.56	167.17	0.44	13.10	8.98	270.21
2012	2.79	82.03	0.37	10.94	4.91	144.46	0.19	5.47	8.26	242.90

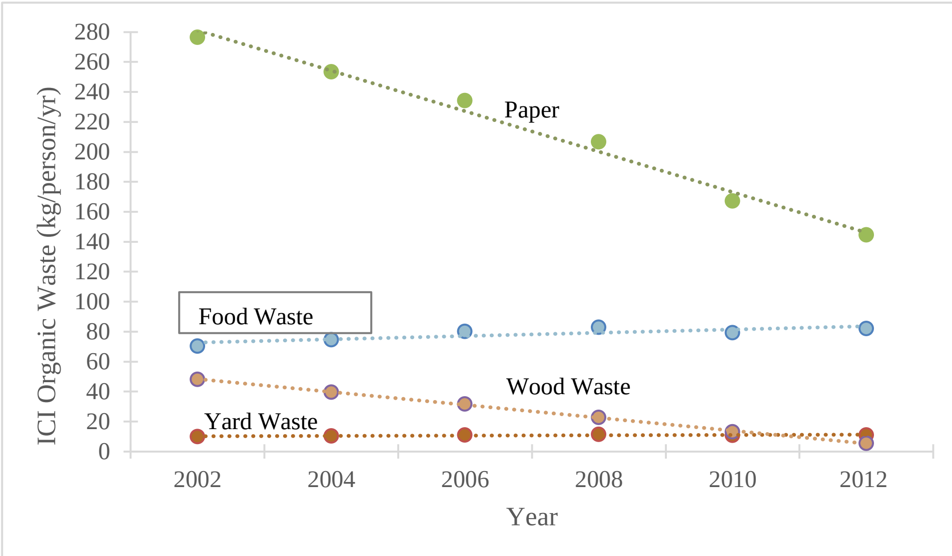
Note: Paper includes newspaper, writing paper, mixed paper, corrugated containers, folding boxes, cartons, and other paper.
Sources: Alberta Environment and Parks 2005; Statistics Canada 2010, 2015a, 2015b, 2015c; Biogas Association 2014; EBA 2013; CBCL Limited 2012.

Figure 5. Composition of organic waste generated in Canada's ICI sector, 2012



Source: Table 2, this report.

Figure 6. Estimated organic waste per-capita generation in Canada's ICI sector, 2002–2012



Source: Table 2, this report.

Organic Waste Diversion

In 2002, about 6.6 million tonnes of all material types were diverted from the residential and ICI sectors in Canada. Food, yard and wood diversion represented 20 percent of this total, and paper (diverted through fiber markets) accounted for 47 percent. In 2012, about 8.4 million tonnes of material were diverted. Diversion of food, yard and wood waste represented 29 percent of this total, and paper accounted for 40 percent (Statistics Canada 2015a, 2015b, 2015c).

Organic Waste Diversion in Canada

From 2002 to 2012, organic waste represented between 60 and 70 percent of the material diverted from Canada's waste stream. The quantity of organic waste diverted in Canada from residential and ICI sectors has increased from about 4.4 million tonnes in 2002 to 5.8 million tonnes in 2012.

Source: Statistics Canada 2015a, 2015b, 2015c.

Residential Sources

As shown in Table 3, Canada's residential sector diverted nearly 3 million tonnes of organic waste in 2012.

Table 3. Estimated organic waste diverted in Canada's residential sector

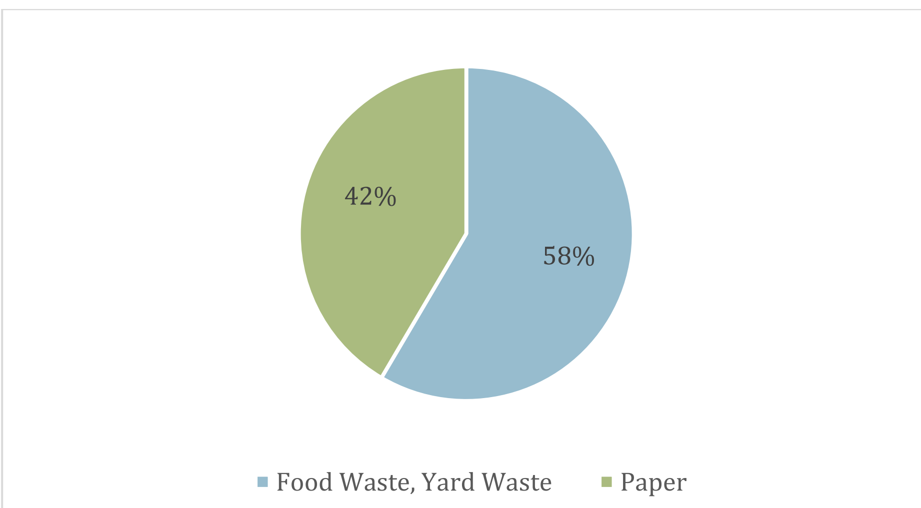
Year	Food Waste, Yard Waste (million tonnes)	Food Waste, Yard Waste (kg/person)	Paper (million tonnes)	Paper (kg/person)	Food Waste, Yard Waste, Paper (million tonnes)	Food Waste, Yard Waste, Paper (kg/person)
2002	0.84	27.35	0.86	28.06	1.70	55.41

Year	Food Waste, Yard Waste (million tonnes)	Food Waste, Yard Waste (kg/person)	Paper (million tonnes)	Paper (kg/person)	Food Waste, Yard Waste, Paper (million tonnes)	Food Waste, Yard Waste, Paper (kg/person)
2004	1.06	33.88	1.01	32.24	1.07	66.12
2006	1.22	38.38	1.08	33.92	2.30	72.30
2008	1.47	45.28	1.21	37.18	2.68	82.46
2010	1.61	48.32	1.23	36.90	2.84	85.22
2012	1.73	50.81	1.23	36.10	2.96	86.91

Note: Paper includes newspaper, writing paper, mixed paper, corrugated containers, folding boxes, cartons, and other paper.
Sources: Alberta Environment and Parks 2005; Statistics Canada 2010, 2015a, 2015b, 2015c; City of Edmonton 2016a; Stewardship Ontario 2013; WDO 2014, 2016; Wilson 2009.

From 2002 to 2012, residential food and yard waste diversion increased from 27.3 kg/person to 50.8 kg/person—an 86-percent increase in diversion since 2002. Paper diverted to fiber markets increased 28 percent, from 28.1 to 36.1 kg/person. Figure 7 shows paper makes up 42 percent of the diversion of residential organic materials; food waste and yard waste are 58 percent.

Figure 7. Composition of organic waste diverted in Canada's residential sector, 2012



Source: Table 3.

ICI Sources

As shown in Table 4, Canada's ICI sector diverted nearly 3 million tonnes of organic materials in 2012. From 2002 to 2012, ICI food, yard and wood waste diversion increased from 15.5 kg/person to 21.4 kg/person. This is a 38-percent increase since 2002. Paper diverted to fiber markets decreased about 15 percent, from 73.6 to 62.7 kg/person. Although not observed in the residential sector, this decrease in paper diversion may reflect a general trend of reduced consumption of paper products by end-markets (Natural Resources Canada 2016).

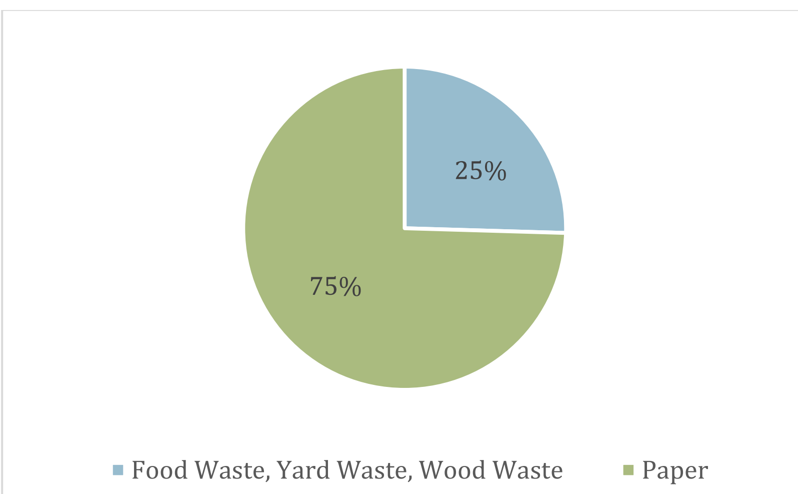
Figure 8 shows paper diverted to fiber markets makes up 75 percent of the organic materials diversion from the ICI sector; all other organics make up 25 percent.

Table 4. Estimated organic waste diverted in Canada's ICI sector

Year	Food Waste, Yard Waste, Wood Waste (million tonnes)	Food Waste, Yard Waste, Wood Waste (kg/person)	Paper (million tonnes)	Paper (kg/person)	Food Waste, Yard Waste, Wood Waste, Paper (million tonnes)	Food Waste, Yard Waste, Wood Waste, Paper (kg/person)
2002	0.47	15.49	2.25	73.56	2.72	89.05
2004	0.46	14.86	2.12	68.03	2.58	82.90
2006	0.69	21.53	2.34	73.62	3.03	95.15
2008	0.86	26.51	2.23	68.64	3.09	95.15
2010	0.61	18.26	2.02	60.80	2.63	79.06
2012	0.73	21.42	2.13	62.70	2.86	84.12

Note: Paper includes newspaper, writing paper, mixed paper, corrugated containers, folding boxes, cartons, and other paper.
Sources: Alberta Environment and Parks 2005; Statistics Canada 2010, 2015a, 2015b, 2015c; Biogas Association 2014; EBA 2013; CBCL Limited 2012.

Figure 8. Composition of organic waste diverted in Canada's ICI sector, 2012



Source: Table 4, this report.

Organic Waste Disposal

Organic waste disposed of in Canada is the waste remaining after diversion (i.e., generation minus diversion). In 2002, about 15.0 million tonnes of residential and ICI organic waste were disposed of; decreasing to 12.6 million tonnes in 2012 (Tables 5 and 6).

Residential Sources

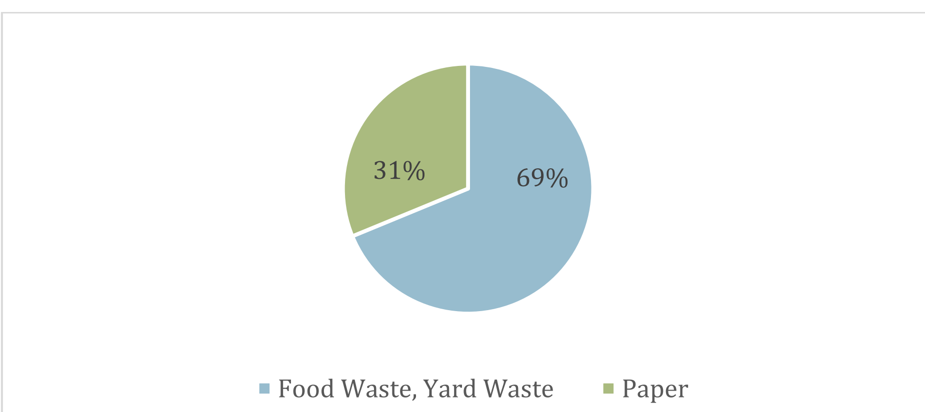
Table 5 summarizes the organic waste disposed of in Canada, by the residential sector, from 2002 to 2012. The table also highlights the average kilograms of food and yard waste disposed of per person, which increased 26 percent from 2002 to 2012. Disposal of paper increased about 10 percent from 2002 to 2012, on a per-capita basis. Figure 9 shows food waste and yard waste make up 69 percent of the residential organic materials disposed of; paper makes up 31 percent.

Table 5. Estimated organic waste disposed of in Canada's residential sector

Year	Food Waste, Yard Waste (million tonnes)	Food Waste, Yard Waste (kg/person)	Paper (million tonnes)	Paper (kg/person)	Food Waste, Yard Waste, Paper (million tonnes)	Food Waste, Yard Waste, Paper (kg/person)
2002	3.56	116.19	1.86	60.73	5.42	176.92
2004	3.96	126.91	1.98	63.56	5.94	190.47
2006	4.47	140.54	2.19	68.91	6.66	209.45
2008	4.51	138.94	2.11	65.09	6.62	204.03
2010	4.74	142.63	2.18	65.64	6.92	208.27
2012	4.97	146.43	2.25	61.45	7.22	212.88

Note: Paper includes newspaper, writing paper, mixed paper, corrugated containers, folding boxes, cartons, and other paper.
Sources: Tables 1 and 3, this report.

Figure 9. Composition of organic waste disposed of in Canada's residential sector, 2012



Source: Table 5, this report.

ICI Sources

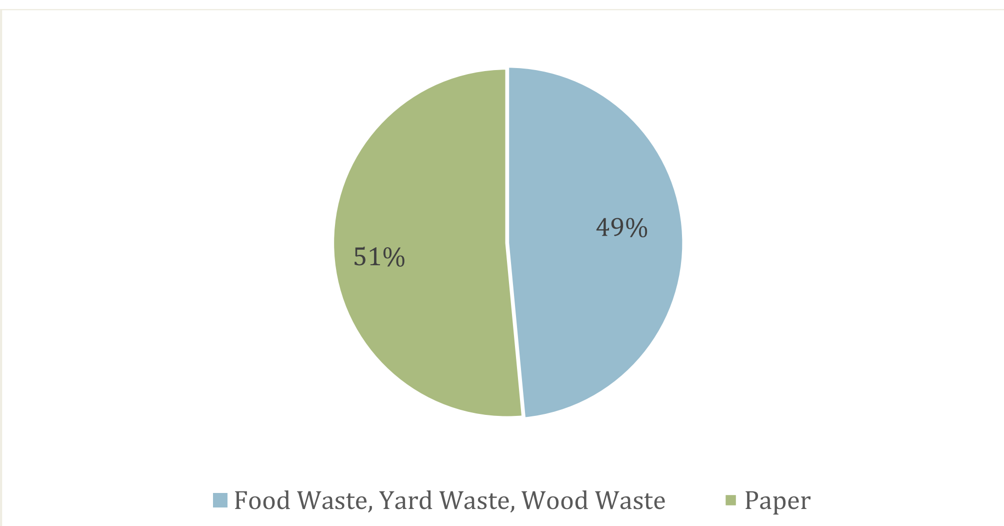
Table 6 summarizes the organic waste disposed of in Canada, by the ICI sector, from 2002 to 2012. The table also highlights the average kilograms of food, yard and wood waste (decreasing 32 percent from 2002 to 2012) and paper (decreasing about 60 percent) disposed of per person. Figure 10 shows that food, yard and wood waste constitutes 49 percent of the ICI organic materials disposed of; paper is 51 percent.

Table 6. Estimated organic waste disposed of in Canada's ICI sector

Year	Food Waste, Yard Waste, Wood Waste (million tonnes)	Food Waste, Yard Waste, Wood Waste (kg/person)	Paper (million tonnes)	Paper (kg/person)	Food Waste, Yard Waste, Wood Waste, Paper (million tonnes)	Food Waste, Yard Waste, Wood Waste, Paper (kg/ person)
2002	3.44	112.58	6.21	202.88	9.65	315.46
2004	3.42	109.56	5.78	185.25	9.20	294.81
2006	3.22	101.30	5.11	160.47	8.33	261.77
2008	2.93	90.29	4.48	137.90	7.41	228.19
2010	2.82	84.78	3.53	106.37	6.35	191.15
2012	2.62	77.02	2.78	81.76	5.40	158.78

Note: Paper includes newspaper, writing paper, mixed paper, corrugated containers, folding boxes, cartons and other paper.
Sources: Tables 2 and 4, this report.

Figure 10. Composition of organic waste disposed of in Canada's ICI sector, 2012



Source: Table 6, this report.

Total Organic Waste Available

Table 7 summarizes the amount of organic waste available in 2012, calculated from the amount of organic waste generated and diverted by the residential and ICI sectors. In Canada, about 7.6 million tonnes of food, yard and wood waste were disposed of in 2012, with about 2.5 million tonnes diverted to organic waste management facilities. About 3.4 million tonnes of paper were diverted to fiber markets, with about 5.0 million tonnes going to disposal. In Canada, the paper remaining in the disposal stream will continue to be targeted, to the extent practical, for diversion through the fiber market.

According to the data presented in the section, in Canada about 24 percent of the food, yard and wood waste in the residential and ICI organic waste streams is diverted from disposal—leaving 76 percent destined for disposal.

Table 7. Estimated total organics available in Canada, 2012

Waste Source	Food Waste, Yard Waste, Wood Waste (million tonnes)	Paper (million tonnes)	Total (million tonnes)
Residential generation	6.70	3.48	10.18
ICI generation	3.35	4.91	8.26
Total generation	10.05	8.39	18.44
Residential diversion	1.73	1.23	2.96
ICI diversion	0.73	2.13	2.86
Total diversion	2.46	3.36	5.82
Residential disposal	4.97	2.25	7.22
ICI disposal	2.62	2.78	5.40
Total disposal	7.59	5.03	12.62

Sources: Tables 1 through 6, this report.

2.3 Estimation of Organic Waste in Mexico

2.3.1 Quantification Methodology

National organic waste generation data in Mexico are not available from a single source. Accordingly, estimates were developed through a combination of datasets within SNIARN (Semarnat 2015a).

SNIARN includes several databases on environmental topics such as water and waste management, air quality, and hazardous waste. Furthermore, the statistical database (*Base de Datos Estadísticos*—Badesniarn) (Semarnat 2012a) includes estimates of residential solid-waste generation, and data on waste management, generation, collection, management and disposal. The Badesniarn website provides top-down generation estimates, which are based on average per-capita generation factors. The site presents estimates, in thousand metric tonnes, from 1992 to 2012, and estimates by type of waste (paper and paper products, textiles, plastics, glass, aluminum, ferrous metals, non-ferrous metals, food, garden and various organic wastes, other), by type of locality (urban, rural), by geographic region (Central, Northern, Southern, Northern Border, Mexico City), and by state.

These databases can also be obtained from the Environmental Statistics Compendium (*Compendio de Estadísticas Ambientales*) (Semarnat 2016a).

The following sources of information were used to validate or complement SNIARN's residential organic composition data and organic waste generation, diversion and disposal data.

- The 2012 Baseline Diagnosis for Integrated Waste Management (*Diagnóstico Básico para la Gestión Integral de Residuos*—DBGIR). This publication presents organic waste estimates derived from the National Census of Municipality and Delegation Administrations, Module 6, "Urban Solid Waste" (INEGI 2016a).
- The baseline waste data reported by the State Programs for the Prevention and Comprehensive Management of Waste (*Programas Estatales para la Prevención y Gestión Integral de Residuos*—PEPGIR), 19 Municipality Programs for the Prevention and Comprehensive Management of Waste (*Programas Municipales para la Prevención y Gestión Integral de Residuos*—PMPGIRs) and three Intermunicipality Programs for the Prevention and Comprehensive Management of Waste (*Programas Intermunicipales de Prevención y Gestión Integral de Residuos*—PIPGIRs), supplied by the Secretariat of Environmental and Natural Resources (*Secretaría de Medio Ambiente y Recursos Naturales*—Semarnat). In some cases, these reports include organic waste estimates derived from waste sampling and data on local waste separation and diversion programs.
- Household surveys. The 2015 intercensus survey (INEGI 2016c) includes a section on residential waste management.

Semarnat hosts most of these information sources, though estimates of waste generation were developed by the Secretariat of Social Development (*Secretaría de Desarrollo Social*) until 2013. Estimates of waste generation have not been updated since 2012 (Semarnat 2015a).

Residential Quantification Methodology

As with Canada, estimates on residential organic waste in Mexico were calculated in three steps. First, total solid waste was quantified; second, the material composition (organics and recyclable materials) was estimated; and third, the paper portion of the recyclable materials was determined.

For step one, the research team developed factors on residential solid-waste generation (per-capita generation, in kg/person/day) for each of six regions: Northwest, Northeast, West, Center, South and Southeast.[10] These factors were based on estimates of urban solid-waste generation (from DBGIR) and municipality populations (from INECC and Semarnat 2013, Chapter 2, Annex 9.1). The factors were then applied to each municipality, according to region and size category, for 2002 through 2012.

Step two was to determine the percentage of organic waste in total residential solid waste. For Mexico, the best representations of national solid-waste composition appear in five data sources: SNIARN, and the 2012 DBGIR, PEPGIRs, PMPGIRs and PIPGIRs. These all measure solid-waste composition by using methodology based on two Mexican standards: NMX-AA-015-1985 and NMX-AA-022-1985 (Sedue and Departamento del Distrito Federal 1992a, 1992b). These standards describe the quartering method of sampling and the selection and quantification of byproducts in waste. Table

[10] Northwest: Baja California, Baja California Sur, Sinaloa and Sonora; Northeast: Chihuahua, Coahuila, Durango, Nuevo León and Tamaulipas; West: Aguascalientes, Colima, Guanajuato, Jalisco, Michoacán, Nayarit, Querétaro, San Luis Potosí and Zacatecas; Center: Estado de México, Hidalgo, Morelos, Puebla, Tlaxcala and Ciudad de México (formerly Distrito Federal); South: Chiapas, Guerrero, Oaxaca and Veracruz; Southeast: Campeche, Quintana Roo, Tabasco and Yucatán.

8 compares the waste compositions reported in the five sources. As it shows, four of the five sources report organic waste between 45 and 56 percent of solid waste. Paper was not included, as it is reported among recyclable waste. Data from SNIARN and DBGIR are national estimations, while data from state, municipal and intermunicipal programs only apply to the communities studied.

Table 8. Organic waste composition in Mexico according to five different data sources

Source	Organic Waste (%)	Recyclable Waste (%)	Non-recyclable Waste (%)
SNIARN	52.42	35.47	12.11
2012 DBGIR	37.57	39.57	22.46
PEPGIRs (average of 22)[a]	45.31	30.59	23.88
PIPGIRs (average of 3)[b]	56.95	25.74	14.28
PMPGIRs (average of 22)[c]	49.32	27.79	22.79

[a] State plans from Baja California, Baja California Sur, Chihuahua, Durango, Guanajuato, Guerrero, Hidalgo, Nayarit, Nuevo León and Oaxaca are not included because they did not include composition or because their estimates were based on national composition.
[b] The PIPGIR from Sierra de Tabasco (Jalapa, Tacotalpa and Teapa municipalities) did not specify organic composition.
[c] Programs from the municipalities of the states of Chihuahua and Tabasco were not included because there was no evidence of composition studies.

Sources:

- SNIARN: Semarnat 2015a.
- 2012 DBGIR: INECC and Semarnat 2013.
- PEPGIRs: Gobierno del Estado de Aguascalientes, Instituto del Medio Ambiente, and Universidad Autónoma de Aguascalientes 2010; Jefatura de Gobierno del Distrito Federal 2010; Gobierno del Estado de Coahuila and Secretaría de Medio Ambiente 2013; Secretaría de Desarrollo Urbano and Gobierno del Estado de Colima 2011; Gobierno del Estado de Chiapas n.d.; Secretaría de Medio Ambiente y Desarrollo Sustentable n.d.; Secretaría de Urbanismo y Medio Ambiente del Estado de Michoacán 2008; Gobierno del Estado de Morelos n.d.; Gobierno del Estado de Puebla 2016; Gobierno del Estado de Querétaro 2011; Gobierno del Estado de Quintana Roo 2009; Gobierno del Estado de San Luis Potosí n.d.; Gobierno de Estado de Sinaloa n.d.; Cesues and CEDES n.d.; Gobierno del Estado de Tabasco 2014; Secretaría de Desarrollo Urbano y Medio Ambiente de Tamaulipas 2014; Gobierno del Estado de Tlaxcala n.d.; Gobierno del Estado de Veracruz 2013; Gobierno del Estado de Yucatán n.d.; and Gobierno del Estado de Zacatecas 2014.
- PIPGIRs: Rubí León et al. n.d.; SIMAR Sureste 2009; Universidad Autónoma de Tamaulipas n.d.
- PMPGIRs: Municipio de Ixtlahuaca n.d.; Universidad Autónoma del Estado de México n.d.; Celaya n.d.; URMO Ingeniería Integral n.d.-a, n.d.-b, n.d.-c, n.d.-d, n.d.-e; PIESA, S.A. de C.V. n.d.-a, n.d.-b; Municipio de Heróica Ciudad de Huajuapan de León n.d.; Villavicencio & Asociados n.d.; Semarnat et al. 2010; Semanay, Gobierno municipal de Tepic, and Taaf Consultoría Integral 2009; ITESO, Municipio de Atemajac de Brizuela, and Gobierno de Jalisco n.d.; Aipromades, Gobierno de Jalisco, and Semarnat 2012; Gobierno del Estado de Hidalgo n.d.; Municipio de Ezequiel Montes et al. n.d.; Gobierno del Estado de Campeche n.d.

For step three, SNIARN provided the level of detail necessary to estimate the paper fraction of residential solid waste. As Table 9 shows, that fraction—defined as paper, corrugated boxes and paper products—is 13.83 percent. Note that SNIARN does not categorize wood, biosolids, animal excrement and animal carcasses as residential solid waste.

Table 9. Composition of residential solid waste in Mexico

Composition	Material	% of Residential Solid Waste
Organics (52.42%)	Food, garden and other similar organic waste	52.42
Recyclable (35.47%)	Paper, corrugated boxes, paper products	13.83
	Other recyclables	21.64
Non-recyclable (12.11%)	Other type of waste (fine debris, disposable diapers, etc.)	12.11

Source: Semarnat 2015a.

To estimate residential diversion, the percentage of households with collection service was calculated by using surveys from INEGI, reported by SNIARN, which show that 86 percent of households transfer their solid waste to regular collection services. The remaining 14 percent do not have access to collection services and instead burn their waste or dispose of it in open dumps or other sites (INEGI 2016d; Semarnat 2015a).

According to INEGI (2016e), 57 percent of households in Mexico separate some portion of organic waste from inorganic waste. SNIARN state data show that an average 10.4 percent of the residential organic waste is separated (based on 12 states' PEPGIR data). Although not all PEPGIRs report residential organic waste diversion data, most PEPGIRs as well as PMPGIRS include strategies and projects to increase organic waste separation and diversion. This indicates an interest in developing diversion options for organic waste.

ICI Quantification Methodology

For this report two data sources were used to estimate the ICI sector's solid waste: the 2012 DBGIR and the 32 PEPGIRs—developed by 31 states and Mexico City. Following an analysis, it was determined that data were insufficient to estimate national ICI organic waste generation. The two ICI data source estimates are presented for comparison in Section 2.3.2. That section also discusses a third source—an estimate by the Technical Group on Food Loss and Food Waste (Grupo Técnico de Pérdidas y Mermas de Alimentos) of the amount of food lost between harvesting and commercialization of food products.

The data from these three sources are presented as they were in their original sources, but no attempt to combine data therein was conducted since they are not comparable.

2.3.2 Estimated Quantity and Composition of Organic Waste Generated, Diverted and Disposed of in Mexico

Organic Waste Generation

In addition to presenting estimates for organic waste generation in Mexico's residential sector, this section includes estimates for food product waste generated in Mexico, from harvest to commercialization, and includes limited generation data for other ICI organic waste.

Residential Sources

Table 10 presents the results of the residential analysis. To obtain these results, the authors multiplied total solid waste by the percentage of organic material, then separated out the organic portion into food and yard waste, and paper. As the table shows, organic materials in residential solid waste increased over 30 percent from 2002 to 2012; on a per-capita basis, they increased about 16 percent over the same period. Mexico's population increased about 23 percent during that period (Worldometers 2015).

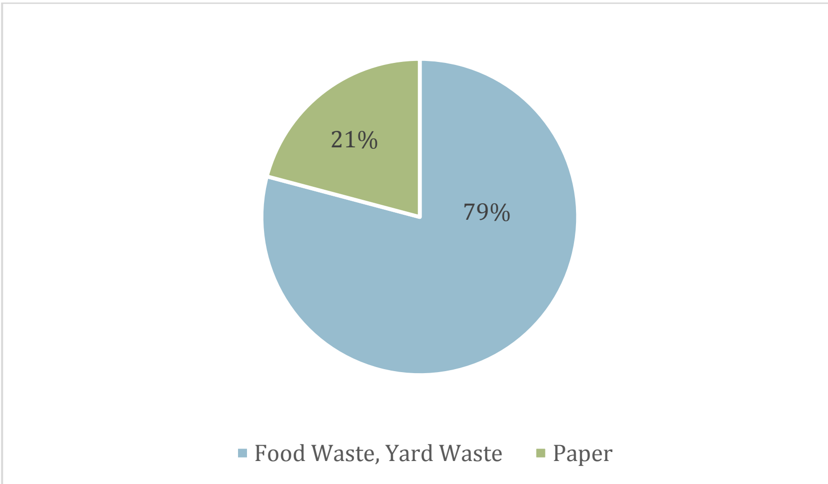
Food and yard wastes make up 79 percent of total residential organic waste; paper accounts for the remaining 21 percent (Figure 11). Since 2002, the per-capita rates of organic waste have trended upward for food and yard waste and stayed about the same for paper (Figure 12).

Table 10. Estimated organic waste generated in Mexico's residential sector

Year	Food Waste, Yard Waste (million tonnes)	Food Waste, Yard Waste (kg/person)	Paper (million tonnes)	Paper (kg/person)	Food Waste, Yard Waste, Paper (million tonnes)	Food Waste, Yard Waste, Paper (kg/person)
2002	16.87	163.10	4.45	43.00	21.32	206.10
2003	17.25	164.80	4.55	43.50	21.80	208.30
2004	18.14	171.20	4.79	45.20	22.93	216.40
2005	18.56	173.20	4.90	45.70	23.46	218.90
2006	18.94	174.70	5.00	46.10	23.94	220.80
2007	19.32	176.00	5.10	46.40	24.42	222.40
2008	19.71	177.10	5.20	46.70	24.91	223.80
2009	20.09	178.00	5.30	47.00	25.39	225.00
2010	21.00	183.80	5.54	48.50	26.54	232.30
2011	21.53	186.10	5.68	49.10	27.21	235.20
2012	22.07	188.50	5.82	49.70	27.89	238.20

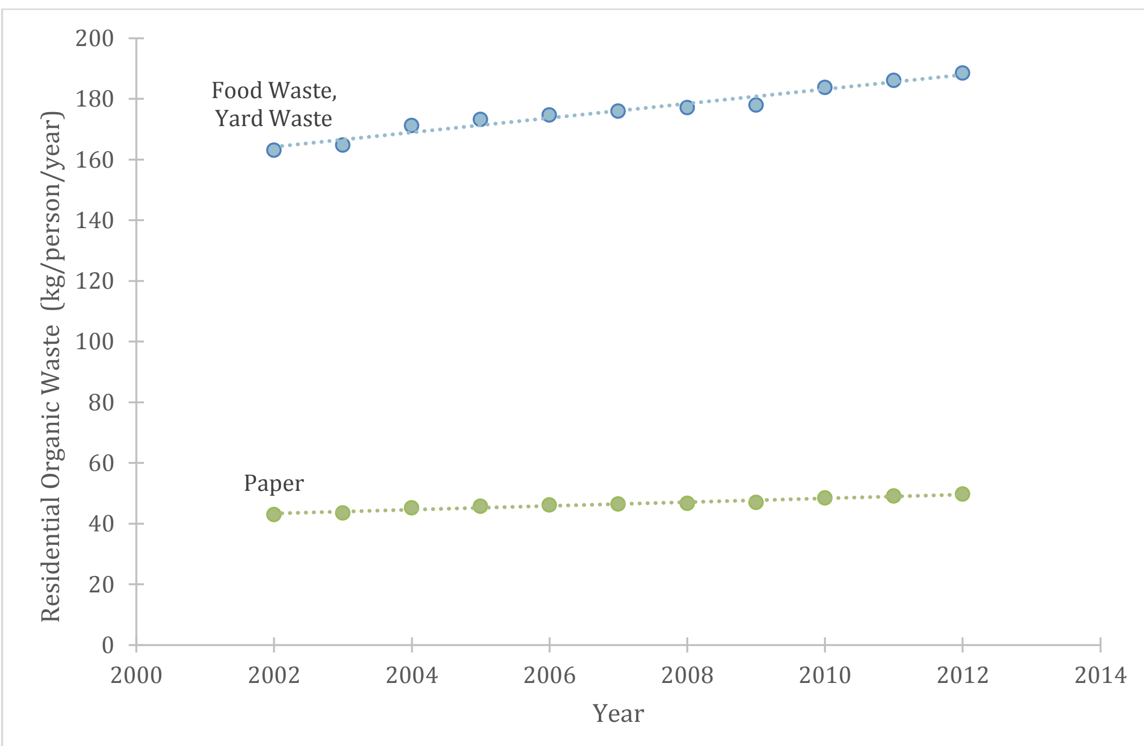
Source: Calculations based on data from SNIARN (Semarnat 2015a).

Figure 11. Composition of organic waste generated in Mexico's residential sector, 2012



Source: Table 10, this report.

Figure 12. Estimated per-capita generation of organic waste in Mexico's residential sector, 2000–2014



Source: Table 10, this report.

ICI Sources

In Mexican legislation, wastes from ICI sources are considered "special management wastes" (*residuos de manejo especial*—RME), as described in Section 3.3.2. The legislation treats the following as RME (i.e., ICI) sources:

- industrial sources
  - paperboard and paper production
  - wood industry (e.g., wood sawdust and wooden pallets)
  - food and beverage production (human and animal)
  - municipal and industrial wastewater treatment plants (sludges)
  - intensive agricultural, poultry, cattle-raising and fishing activities (organic wastes)
  - forestry (forest residues)
- commercial and institutional sources
  - transportation centers (airports, railroads, subways)
  - offices
  - hotels (in the primary tourist areas)
  - restaurants
  - food supply centers, public markets, street markets
  - supermarkets
  - slaughterhouses and fish stores

ICI-sector solid waste was estimated from two sources: the 2012 DBGIR and the 32 PEPGIRs.

Table 11 lists available organic waste estimates from the 2012 DBGIR. Due to a lack of data, these estimates do not capture 100 percent of Mexico's ICI generators. Those generators have not fully complied with their obligation to report their waste management plans to state authorities, and there is no official national method for classifying and quantifying special-management wastes from these sources. As a result, state programs do not regularly, systematically provide information about quantities and composition of these wastes. Chapter 4's case studies provide details on organic waste generation and management by some key ICI generators, obtained from documented sources or interviews as a reference.

Table 11. Estimated organic waste generated in Mexico's ICI sector, from five sources (average from 2006 to 2012)

Waste Type	Quantity (million tonnes /year)
Manure (porcine, bovine)	66.71
Fisheries	0.80
Sludge (municipal wastewater resource recovery facilities)	0.23
Paper, cardboard	6.82
Hotels	0.12

Note: The data shown do not represent 100 percent of ICI organic waste generation: the DBGIR mentions other sources (e.g., supermarkets, airports), but does not estimate the organic fraction of wastes from those sources.
Source: INECC and Semarnat 2013, 61.

Table 12 shows organic waste generation estimates from the second source, the PEPGIRs.

Table 12. Estimated organic waste generated in Mexico's ICI sector from 11 sources

Organic Waste	Livestock Manure	Fisheries	Agriculture	Food Manufacture	Slaughter-houses	Hotels	Restaurants	Sludge	Commerce	Wood Manufacture	Paper Manufacture
Total (million tonnes /year)	22.16	0.01	0.49	0.05	0.04	0.10	1.10	0.14	0.02	0.04	11.04

Note: The companion CEC report *Characterization and Management of Food Loss and Waste in North America* (CEC 2017) estimates food processing/manufacturing and packaging waste at 5.1 million tonnes, compared to this table's 0.05 million tonnes for food manufacture. This shows that the data in this table do not represent 100 percent of ICI organic waste generation. (The companion report's results and the estimates above could not be compared overall, due to differing methodologies, data sources and generating categories.)
Sources: Gobierno del Estado de Chihuahua, and Universidad Autónoma de Ciudad Juárez 2012; Gobierno del Estado de Coahuila, and Secretaría de Medio Ambiente 2013; Secretaría de Desarollo Urbano, and Gobierno del Estado de Colima 2011; Gobierno del Estado de Durango n.d.; UNAM 2014; Gobierno del Estado de Oaxaca n.d.; Gobierno del Estado de San Luis Potosí n.d.; Gobierno del Estado de Tabasco 2014; Secretaría de Desarrollo Urbano y Medio Ambiente de Tamaulipas 2014; Gobierno del Estado de Tlaxcala n.d.; Gobierno del Estado de Veracruz 2013; Gobierno del Estado de Yucatán n.d.

These two ICI data sources are incomplete datasets and should not be used to represent 100 percent of the ICI organic waste. Manures, fisheries, sludge from the resource recovery facilities for municipal wastewater, and hotels are the only sources that are similar for both datasets. Within these four similar sectors, only the annual estimates for hotels match.

A third data source—the Technical Group on Food Loss and Food Waste (*Grupo Técnico de Pérdidas y Mermas de Alimentos*)—estimates food waste generated between harvesting and commercialization of food products. The Technical Group made this estimate as part of the National Crusade against Hunger (*Cruzada Nacional contra el Hambre*). The Technical Group estimated that about 37 percent of agricultural and food production in the country is wasted between harvesting and commercialization. Most of this waste is due to inadequate harvesting or transport processes or infrastructure, deficient packaging, inappropriate handling procedures, and extended transport times (Grupo Técnico Pérdidas y Mermas de Alimentos de la Cruzada Nacional contra el Hambre 2013).

The Technical Group developed a general food waste index for 34 agricultural products; Table 13 shows estimates of waste from these 34 products at over 10 million tonnes per year. This is considerably higher than the agriculture waste estimate shown in Table 12.

Table 13. Estimated food waste generated in Mexico, for 34 food products

Food	Waste **(percent of total food available)**	Food Waste **(million tonnes per year)**
Tortilla	9.39	0.66
Bread (wheat products)	45.31	1.63
Rice	46.87	0.25
Meat—beef	34.87	0.40

Food	Waste **(percent of total food available)**	Food Waste **(million tonnes per year)**
Meat—pork	40.91	0.35
Meat—chicken	39.36	0.72
Tuna	23.43	0.02
Fish and sardines	54.07	0.13
Shrimp	37.77	0.03
Cow's milk	37.14	1.60
Egg	37.66	0.54
Potato	37.11	0.34
Avocado	53.97	0.21
Garlic	21.35	0.01
Pumpkin and zucchini	14.65	0.04
Onion	32.08	0.25
Chile	44.14	0.41
Tomato	28.86	0.47
Cactus (*nopal*)	63.26	0.08
Cucumber	45.46	0.05
Green tomato	17.78	0.08
Carrot	19.01	0.05
Bean	24.96	0.23
Guayaba	57.73	0.06
Lime	33.38	0.08
Mango	54.54	0.30
Apples	49.07	0.20
Melon	41.24	0.05
Orange	23.22	0.63
Papaya	22.80	0.07
Pineapple	32.78	0.05
Green plantain and bananas	53.76	0.35
Watermelon	19.44	0.04
Grape	45.53	0.05
	National average 37.02	**Total 10.43**

Note: For comparison, the companion CEC report, *Characterization and Management of Food Loss and Waste in North America*, estimates pre- and post-harvest food waste from plants and animals at more than 14 million tonnes. Data in Table 13 represent plant waste only.
Source: Grupo Técnico Pérdidas y Mermas de Alimentos de la Cruzada Nacional contra el Hambre 2013.

As discussed in the methodology description (Section 2.3.1) above, due to incomplete and inconsistent data the amount of organic waste generated from the ICI sector in Mexico is presented as obtained from original data sources. The authors could not combine the data from these differing sources or prepare a national estimate from all ICI sources. Although the authors reached out to experts in different regions and sectors to close this data gap, sufficient data were not available.

Organic Waste Diversion

This section only presents organic waste diversion data for the residential sector. Publicly available data are not available to estimate national organic waste diversion from the ICI sector.

Residential Sources

The diversion of organic waste is estimated by applying the INEGI factor for solid-waste collection (86 percent of households have collection service) and the SNIARN diversion factor (10.4 percent) to the organic waste shown in Table 10. Table 14 shows that about 2 million tonnes of food and yard waste and 0.5 million tonnes of paper were diverted in the residential sector in 2012. As in Canada, paper is diverted to higher-value fiber markets. Mexico's diverted waste is 79 percent food and yard waste and 21 percent paper.

Table 14. Estimated organic waste diverted in Mexico's residential sector, 2012

Organic Waste Average of 12 States	Generated		Collected		Diverted	
	Food Waste, Yard Waste	Paper	Food Waste, Yard Waste	Paper	Food Waste, Yard Waste	Paper
Million tonnes	22.07	5.82	18.98	5.00	1.97	0.52
Kg/person/year	188.55	49.72	162.15	42.72	16.83	4.44

Sources: Table 10, this report; INEGI 2016d; Semarnat 2015a.

ICI Sources

Although diversion of ICI organic waste does occur in Mexico, publicly available data are not available to estimate the national diversion rate from this sector. Management and reporting of waste are still developing in Mexico, particularly for the ICI sector. To date, the state reports on and inventories of waste generation and handling (PEPGIRs) are not uniform in data quantity or quality. Very few states report on ICI sources and the organic portion of ICI waste. Most state reports mention plans or policies pertaining to ICI waste, even though these wastes are not quantified. To date, Semarnat has not issued guidelines to assist ICI waste generators in estimating waste amounts or reporting this information. Once these guidelines and

ICI Diversion in Mexico

While available ICI data are limited, one example of ICI diversion occurs in La Nueva Viga. This fish and seafood distribution market—the largest in Mexico and Latin America—sells fish and seafood waste to the secondary industrial products market, for fishmeal production, providing both environmental and economic benefits.

Source: McCarthy 2016.

methodologies are issued, it is expected that state authorities will start reporting regularly and will allocate resources to improve their waste inventories in order to comply with the regulatory requirements established in the LGPGIR (see Section 4.1.2).

Waste from the ICI sector is regulated and controlled by state authorities. At present, most of the ICI special management wastes are collected by public and private waste-management services and sent to landfills, or by enterprises interested in recyclables. These entities do not systematically report the wastes' fate to state or municipal authorities.

While large ICI generators of organic wastes are required to report how they handle waste, composting facilities that receive organic wastes are not required to report the origin and amount of waste they process or the fate and amount of compost produced. Therefore, these data are not available. The same holds true for paper and cardboard recycling companies that have registered a national waste management plan with Semarnat to improve the efficiency of recovery of paper fibers for recycling, and/or for companies that buy and process agricultural and other similar organic waste.

Organic Waste Disposal

As well as presenting waste disposal estimates for Mexico's residential sector, this section includes estimates for Mexico's food product waste, from harvest to commercialization. Other ICI organic waste disposal data are a data gap for Mexico.

Residential Sources

Most organic waste in Mexico is sent to disposal sites, including landfills, controlled disposal sites, and open dumps. Available sources do not consistently report the amounts of organic waste sent to the different types of sites; Table 15 shows these amounts, according to INEGI (2015b). As the table illustrates, 79 percent of the residential organic waste disposed of is food and yard waste and 21 percent is paper. These percentages are similar to those for residential organic waste generation.

Table 15. Estimated organic waste disposed of in Mexico's residential sector, 2012

Disposal Option	Percent of Total	Food Waste, Yard Waste (million tonnes)	Food Waste, Yard Waste (kg/person)	Paper (million tonnes)	Paper (kg/person)
Landfills	70	14.07	120.20	3.71	31.69
Controlled disposal sites	8	1.61	13.75	0.42	3.59
Open dumps	22	4.42	37.76	1.17	10.00
Total	100	20.10	171.72	5.30	45.28

Note: Landfills, in this table, are disposal sites that partially comply with landfill environmental requirements established in environmental standards.
Sources: Tables 10 and 14, this report; INEGI 2015b.

ICI Sources

As noted above, information about ICI waste is limited as not all states have issued requirements for submitting reports nor has Semarnat issued associated guidance. State PEPGIRs are inconsistent in data reporting and many do not include ICI waste. Most ICI organic waste, like residential organic waste, is likely sent to landfills for disposal; as with collection, though, there is no regular and systematic reporting of sources.

Total Organic Waste Available

Table 16 summarizes the amount of organic waste available in Mexico in 2012, calculated from the amount of organic waste generated and diverted by the residential sector, and the amount of food waste estimated, from harvest to commercialization. ICI generation, diversion and disposal from other ICI sources are data gaps for Mexico.

In Mexico, about 31 million tonnes of organic waste are disposed of, with 2 million tonnes diverted in the residential sector to facilities for organic waste management. Less than 1 million tonnes of residential paper is diverted to fiber markets, with about 3 million tonnes going to disposal. Based on the data presented in this section, about 9 percent of the food, yard and paper waste in the residential organic waste stream is diverted from disposal in Mexico, leaving 81 percent of residential organic waste destined for disposal.

Table 16. Estimated total organics available in Mexico, 2012

Waste Source	**Food Waste, Yard Waste** (million tonnes)	**Paper** (million tonnes)	**Total** (million tonnes)
Residential generation	22.07	5.82	27.89
ICI generation	N/A	N/A	N/A
Harvest to commercialization	10.43	N/A	10.43
Total generation	*32.50*	*5.82*	*38.32*
Residential diversion	1.97	0.52	2.49
ICI diversion	N/A	N/A	N/A
Total diversion	*1.97*	*0.52*	*2.49*
Residential disposal	20.10	5.30	25.40
ICI disposal	N/A	N/A	N/A
Harvest to commercialization	10.43	N/A	10.43
Total disposal	*30.53*	*5.30*	*35.83*

Sources: Tables 10, 13, 14 and 15, this report.

2.4 Estimation of Organic Waste in the United States

2.4.1 Quantification Methodology

The Resource Conservation and Recovery Act (RCRA), enacted by the US Congress in 1976, ensures waste is managed in a manner that is protective of human health and the environment. RCRA promotes energy and resource conservation and waste minimization (40 CFR Part 256). The US EPA's Office of Resource Conservation and Recovery (ORCR) implements RCRA's framework for the national management of non-hazardous solid wastes. From the earliest days of RCRA, the US EPA has measured non-hazardous solid-waste generation,[11] diversion and disposal. Since the early 90s, it has measured residential, commercial and institutional municipal solid waste (MSW) on an annual or biannual basis. More recently, it has gathered statistics for the measurement of food processing (manufacturing) waste. ORCR is the main data source for the US organic generation, diversion and disposal analyses presented in this section.

The US EPA's Advancing Sustainable Materials Management report series was used to compile the residential, commercial and institutional data used in this analysis. Two other US EPA publications (US EPA 2013b, 2014) provided statistics on organic material (e.g., food processing waste) for non-MSW generation, diversion, and disposal estimates. These two publications incorporate data from other federal agencies (e.g., US Department of Agriculture), industry associations (e.g., National Renderers Association) and state environmental agencies.

The US EPA's national data do not distinguish between residential, commercial and institutional sectors, so one methodology was used for the US residential, commercial, and institutional analyses. To distinguish between residential, commercial and institutional sectors, the national data were supplemented by state and local sampling studies recording sector-specific measurements.

Pre-consumer (non-MSW) wastes excluded from this analysis include industrial scrap (except for food manufacturing); sludges; construction, renovation and demolition debris; liquid and oil wastes; and source-reduction activities (e.g., backyard composting of yard waste or donation of excess food).

2.4.2 Estimated Quantity and Composition of Organic Waste Generated, Diverted and Disposed of in United States

Organic Waste Generation

In 2014, the US EPA reported about 234 million tonnes[12] of solid waste generated in the United States from residential, commercial and institutional sources. The organic fraction of that solid waste—food, yard, paper and wood wastes—makes up over 60 percent of the total generated from these sources (US EPA 2016e).

Residential Sources

Table 17 shows historical total generation of the residential organic wastes included in this study (food, yard, paper and wood wastes), in million tonnes and in kilograms per person. As the table illustrates, the total tonnage of paper waste has decreased from 2000 to 2014; all other materials included in this study have increased over the same period. Food, yard and paper wastes each make up about one-third of the total residential organic waste (Figure 13). Since 2000, the per-capita organic waste rates have trended downward for paper, increased slightly for food and yard waste, and stayed about the same for wood waste (Figure 14).

[11] "Generation" refers to the point in a material's life-cycle when waste is ready for management through diversion or disposal.

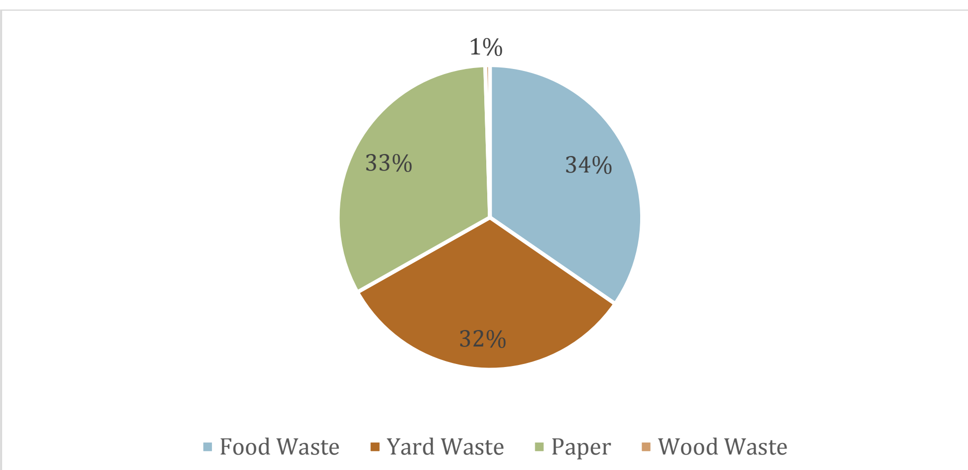
[12] US EPA's published tons are converted to tonnes in this analysis.

Table 17. Estimated organic waste generated in the US residential sector

Year	Food Waste[a] (million tonnes)	Food Waste[a] (kg/person)	Yard Waste (million tonnes)	Yard Waste (kg/person)	Paper[b] (million tonnes)	Paper[b] (kg/person)	Wood Waste[c] (million tonnes)	Wood Waste[c] (kg/person)	Food Waste, Yard Waste, Paper, Wood Waste (million tonnes)	Food Waste, Yard Waste, Paper, Wood Waste (kg/person)
2000	20.20	71.79	20.22	71.84	29.63	105.27	0.30	1.05	70.34	249.96
2005	21.44	72.33	21.24	71.65	28.65	96.65	0.32	1.09	71.65	241.72
2009	22.52	73.36	21.99	71.62	23.11	75.26	0.34	1.11	67.95	221.35
2011	23.20	74.47	22.32	71.65	23.62	75.80	0.34	1.11	69.49	223.03
2012	23.28	74.17	22.49	71.64	23.17	73.81	0.35	1.10	69.29	220.72
2013	23.68	74.92	22.65	71.64	23.15	73.23	0.34	1.09	69.83	220.88
2014	24.54	76.96	22.85	71.65	23.17	72.66	0.35	1.10	70.91	222.38

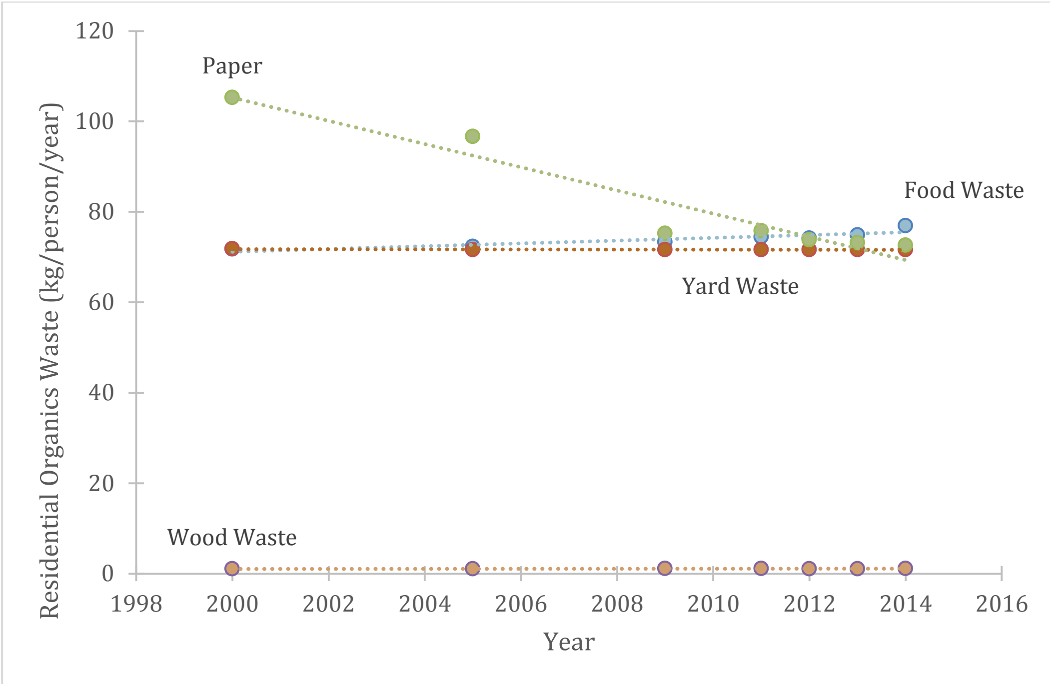
[a] Includes food waste lost to the sewer system through garburator (disposal) (US EPA 2013b, Table 4). 2011–2013 estimated by applying annual growth in MSW food waste to 2010 garburator data (latest available).
[b] Paper includes newspaper, writing paper, mixed paper, corrugated containers, folding boxes, cartons, and other paper.
[c] Wood includes wood packaging (mainly pallets) and wood found in furniture. Construction and demolition debris wood is not included in this analysis.
Note: The US EPA's published tons have been converted to tonnes.
Sources: US EPA 2015a, 2016e. Residential portion estimated from IRA 2015; Connecticut DEEP 2016; Seattle Public Utilities 2016; CIWMB 2009; US EPA 2013b, Table 4.

Figure 13. Composition of organic waste generated in the US residential sector, 2014



Source: Table 17, this report.

Figure 14. Estimated organic waste per-capita generation in the US residential sector, 2000–2014



Source: Table 17, this report.

ICI Sources

This section presents ICI-sector organic waste. The waste shown in Table 18 represents the US EPA's national total residential, commercial and institutional data minus the residential portion shown in Table 17, plus fats, oils and grease (FOG); industrial liquid food waste; and industrial food processing waste.

In 2013, the US EPA published a supply chain analysis of food waste generated, diverted through source reduction (food to feed people and animals), recovered by renderers, composted by municipal programs, and disposed of in landfill. The study (US EPA 2013b) used both US EPA–generated data and 2010 loss-adjusted datasets from the US Department of Agriculture's Economic Research Service.

In a second study, the US EPA (2014a) quantified restaurant grease generated and collected for rendering from 2000 to 2010. The results of this analysis were assumed to represent FOG. The quantity of other ICI FOG is a data gap.

Table 18 shows historical total generation of organic waste included in this study (food, yard, paper and wood wastes), in million tonnes and kilograms per person. Total tonnes of paper have decreased from 2000 to 2014; all other materials included in this study have increased over the same period. Institutional and commercial food waste, industrial food processing waste, and paper are the largest components of ICI organic waste generation (Figure 15). Since 2000, the ICI per-capita rate for paper has trended downward; per-capita rates for all other material stayed about the same until increasing slightly in 2014 (Figure 16).

Table 18. Estimated organic waste generated in the US ICI sector

Year	Institutional and Commercial Food Waste[a] (million tonnes)	Institutional and Commercial Food Waste[a] (kg/person)	Industrial Food Processing Waste[b] (million tonnes)	Industrial Food Processing Waste[b] (kg/person)	Yard Waste (million tonnes)	Yard Waste (kg/person)	Paper[c] (million tonnes)	Paper[c] (kg/person)	Wood Waste (million tonnes)	Wood Waste (kg/person)	Food (All Sources), Yard Waste, Paper, Wood Waste (million tonnes)	Food (All Sources), Yard Waste, Paper, Wood Waste (kg/person)
2000	37.99	134.98	30.90	109.79	7.48	26.57	49.97	177.56	12.01	42.69	138.35	491.59
2005	37.98	128.12	32.30	108.96	7.86	26.50	48.32	163.01	13.09	44.18	139.55	470.77
2009	37.98	123.71	31.74	103.39	8.13	26.49	38.97	126.94	13.80	44.96	130.62	425.49
2011	38.79	124.48	32.35	103.82	8.26	26.50	39.84	127.85	13.97	44.84	133.21	427.49
2012	38.92	123.97	32.46	103.39	8.32	26.50	39.08	124.49	14.01	44.62	132.79	422.97
2013	39.59	125.23	33.02	104.45	8.38	26.50	39.05	123.51	13.96	44.17	134.00	423.86
2014	41.02	128.65	34.21	107.30	8.45	26.50	39.07	122.55	14.27	44.76	137.02	429.76

[a] Includes commercial and institutional food waste as reported by the US EPA (2015a), plus commercial and institutional FOG (US EPA 2014a, Table 5) and industrial liquid food waste (US EPA 2013b, Table 4). FOG and industrial liquid food waste for 2011–2014 estimated by applying annual growth in MSW food waste to 2010 data (latest available).

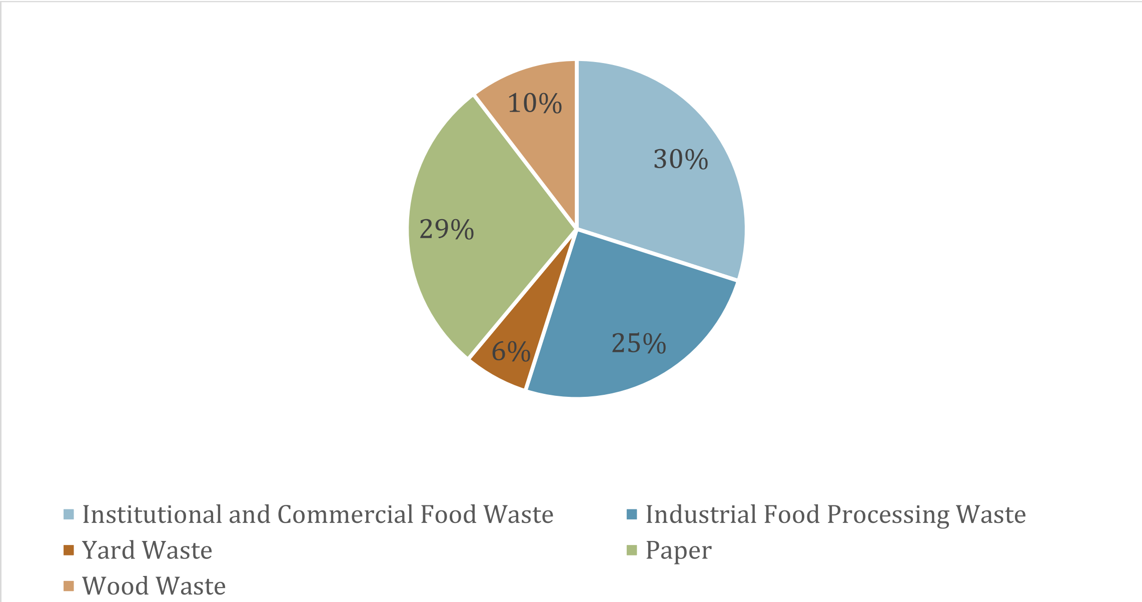
[b] Industrial food processing and distribution waste for 2000–2010 from US EPA (2013b, Table 4). 2011–2014 estimated by applying annual growth in MSW food waste to 2010 data (latest available).

[c] Paper includes newspaper, writing paper, mixed paper, corrugated containers, folding boxes, cartons, and other paper.

Note: The US EPA's published tons have been converted to tonnes.

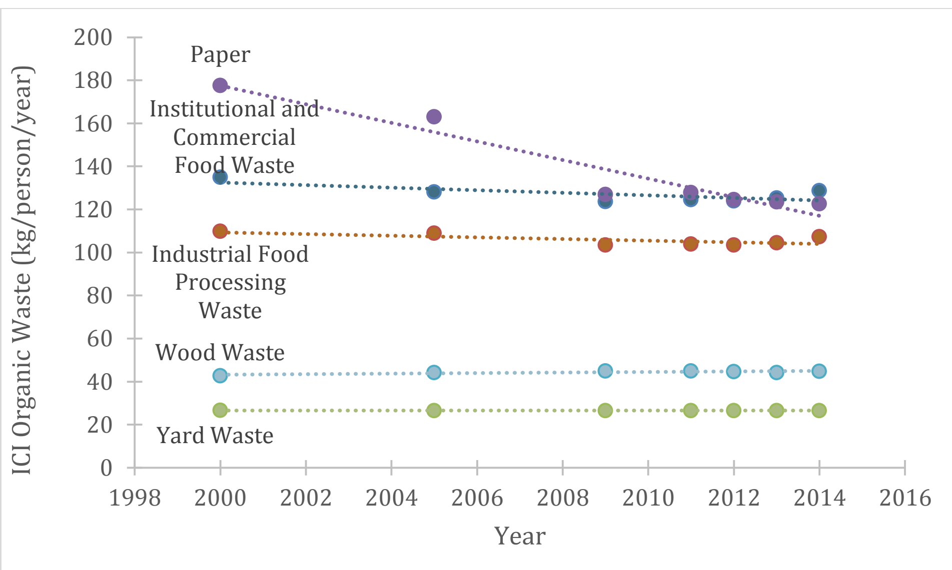
Sources: US EPA 2015a, 2016e. ICI portion estimated from IRA 2015; Connecticut DEEP 2016; Seattle Public Utilities 2016; CIWMB 2009; US EPA 2013b, Table 6. Industrial data: US EPA 2013b, Table 4; US EPA 2014a, Table 5.

Figure 15. Composition of organic waste generated in the US ICI sector, 2014



Source: Table 18, this report.

Figure 16. Estimated organic waste per-capita generated in the US ICI sector, 2000–2014



Source: Table 18, this report.

Organic Waste Diversion

The US EPA emphasizes preventing waste generation, re-using where possible, and then recycling or composting whatever is left. In this context, reducing and re-using are called “source reduction”—keeping material from entering the waste stream altogether (US EPA 2015a). Measuring material that does not enter the waste stream is difficult and no national estimate of source reduction is available. Food recovery through donations to feed people and animals is addressed in the companion CEC study *Characterization and Management of Food Loss and Waste in North America*.

This section examines diversion through recycling; composting; and industrial use through rendering. National anaerobically-digested food waste is excluded from the diversion estimates because it has not been quantified. Data on AD food waste at the regional, state and local levels are also lacking. The US EPA maintains a database of AD facilities processing food waste. Currently, its list shows 103 facilities, comprising 41 stand-alone digesters, 38 on-farm digesters, and 24 wastewater resource recovery facilities (US EPA 2016f). The US EPA is currently gathering additional data to expand the information in the AD database (US EPA 2016f).

Residential Sources

Table 19 shows historical diversion of residential food, yard, paper and wood waste through recycling and composting, in million tonnes and in kilograms per person. From 2000 to 2014, the number of tonnes diverted in the residential sector has increased for both food and yard waste, generally increased for paper products, and remained fairly constant for wood waste. As in Canada and Mexico, residential paper products are diverted to high-value fiber markets. Forty-eight percent of residential diversion is yard waste destined for composting (Figure 17).

Organic Waste Diversion in the United States

Organic waste recovery increased from over 50,000 tonnes in 2000 to over 65,000 tonnes in 2014. Yard trimmings recovered through composting increased 26 percent from 2000 to 2005 (then remained fairly consistent). Food waste composting grew more quickly after 2009 (Tables 19 and 20).

Table 19. Estimated organic waste diverted in the US residential sector

Year	Food Waste (million tonnes)	Food Waste (kg/ person)	Yard Waste (million tonnes)	Yard Waste (kg/ person)	Paper[a] (million tonnes)	Paper[a] (kg/ person)	Wood Waste[b] (million tonnes)	Wood Waste[b] (kg/ person)	Food Waste, Yard Waste, Paper, Wood Waste (million tonnes)	Food Waste, Yard Waste, Paper, Wood Waste (kg/person)
2000	0.29	1.03	10.99	39.05	10.60	37.66	0.03	0.11	21.91	77.85
2005	0.30	1.00	13.60	45.89	12.39	41.79	0.04	0.13	26.33	88.81
2009	0.36	1.18	13.67	44.53	13.27	43.24	0.05	0.16	27.35	89.11
2011	0.54	1.74	13.31	42.73	14.50	46.54	0.05	0.16	28.40	91.17
2012	0.74	2.37	13.51	43.02	13.97	44.51	0.05	0.17	28.27	90.07
2013	0.79	2.49	14.15	44.75	13.61	43.05	0.05	0.17	28.60	90.46
2014	0.83	2.60	14.46	45.34	13.99	43.87	0.06	0.18	29.34	91.99

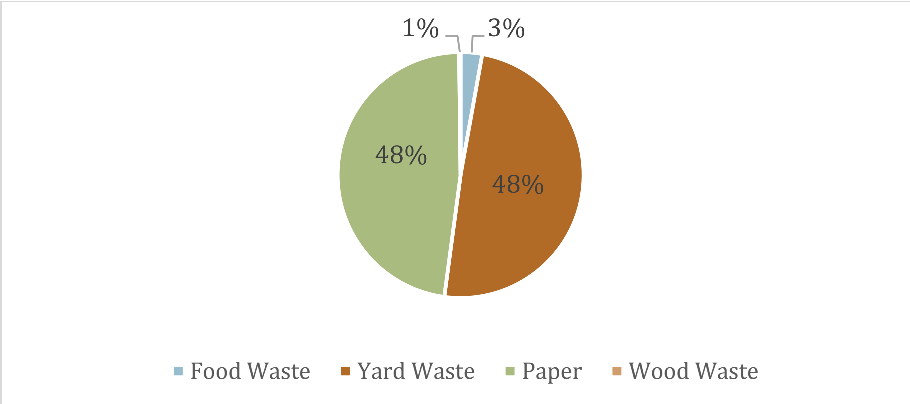
[a] Paper includes newspaper, writing paper, mixed paper, corrugated containers, folding boxes, cartons, and other paper.

[b] Mainly wood pallets.

Note: The US EPA's published tons have been converted to tonnes.

Sources: US EPA 2015a, 2016e. Residential portion estimated from IRA 2015; Connecticut DEEP 2016; Seattle Public Utilities 2016; CIWMB 2009; US EPA 2013b, Table 4.

Figure 17. Composition of organic waste diverted in the US residential sector, 2014



Source: Table 19, this report.

ICI Sources

Diversion of ICI waste is shown in Table 20. Like residential diversion, ICI organic diversion generally increased from 2000 to 2014. Paper increased from 2000 to 2011, followed by a decrease in 2012, 2013 and 2014. The ICI data shown in Table 20 represent organic waste diverted from commercial and institutional sources (US EPA data exclude industrial diversion). Quantification of industrial food processing waste, shown below as not available (N/A), is a data gap for the United States.

Figure 18 shows the composition of organic waste diverted in the United States' ICI sector. Paper makes up the largest fraction, at 73 percent, followed by yard waste at 13 percent, institutional and commercial food waste at 8 percent, and wood waste at 6 percent.

In 2015, the US EPA summarized an industry study estimating that about 95 percent of food processing waste was diverted from disposal through donations to people, animal feed, composting or digestion (US EPA 2015b; BSR 2014). The industry study, based on a small sample size, should not be extrapolated to the national level. The survey respondents, representing only 17 percent of the food manufacturing sector, generated about 3.2 million tonnes—about 10 percent of the total food processing waste estimated in the organic waste generation section above (see Table 18).

Table 20. Estimated organic waste diverted in the US ICI sector

Year	Institutional and Commercial Food Waste[a] (million tonnes)	Institutional and Commercial Food Waste[a] (kg/person)	Industrial Food Processing Waste[b] (million tonnes)	Yard Waste (million tonnes)	Yard Waste (kg/person)	Paper[c] (million tonnes)	Paper[c] (kg/person)	Wood Waste (million tonnes)	Wood Waste (kg/person)	Food (All Sources), Yard Waste, Paper, Wood Waste (million tonnes)	Food (All Sources), Yard Waste, Paper, Wood Waste (kg/person)
2000	2.39	8.49	N/A	3.32	11.78	23.48	83.42	1.21	4.31	30.40	108.00
2005	2.33	7.87	N/A	4.41	14.89	25.68	86.63	1.62	5.47	34.04	114.86
2009	2.39	7.78	N/A	4.38	14.27	25.28	82.35	1.95	6.35	34.00	110.75
2011	2.60	8.35	N/A	4.19	13.46	27.14	87.10	2.08	6.68	36.01	115.59
2012	2.83	9.03	N/A	4.27	13.59	26.27	83.69	2.13	6.80	35.50	113.11
2013	2.92	9.23	N/A	4.54	14.37	25.76	81.49	2.19	6.92	35.41	112.01
2014	3.04	9.53	N/A	4.67	14.64	26.29	82.46	2.28	7.14	36.28	113.77

[a] Includes spoiled and outdated meat and seafood products recovered for rendering (US EPA 2013b, Table 6) and FOG collected for rendering (US EPA 2014a, Table 5). Spoiled and outdated meat and seafood products recovered for rendering in 2000–2013 were estimated by applying annual growth in MSW food waste to 2010 rendering data. FOG collected for rendering in 2011–2013 was estimated by applying annual growth in MSW food waste to 2010 data.

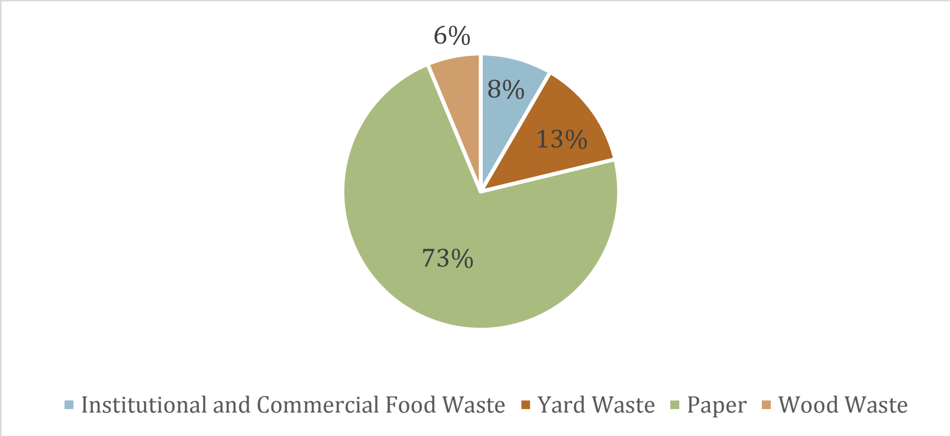
[b] Industrial processing waste diverted is not available.

[c] Paper includes newspaper, writing paper, mixed paper, corrugated containers, folding boxes, cartons, and other paper.

Note: The US EPA's published tons have been converted to tonnes.

Sources: US EPA 2015a. ICI portion estimated from IRA 2015; Connecticut DEEP 2016; Seattle Public Utilities 2016; CIWMB 2009; US EPA 2013b, Table 6. Industrial data: US EPA 2013b, Table 4; US EPA 2014a, Table 5.

Figure 18. Composition of organic waste diverted in the US ICI sector, 2014



Source: Table 20, this report.

Organic Waste Disposal

The solid waste remaining after diversion through recycling, composting or other methods (e.g., co-digestion)[13] is disposed of through combustion with energy recovery, or through landfilling. In 2014, 153 million tonnes of residential, commercial and institutional waste were discarded to combustion with energy recovery or to landfill facilities (US EPA 2016e).[14] Although the US EPA does not include waste going to the sewer system in its annual solid-waste data measurement, a separate study (US EPA 2013b) estimated that 7.5 million tonnes of residential food waste is disposed of through the sewer system via garbage disposals (garburators). Tables 21 and 22 show historical residential and ICI organic waste disposal in million tonnes and kilograms per person.

Residential Sources

Since 2000, as Table 21 shows, paper has seen the largest decrease in tonnes going to disposal—a drop of about 50 percent by 2014. This represents a decrease of about 4 percent per annum. Food waste, however, has steadily increased since 2000. In 2014, 19 percent more food waste was disposed of than in 2000. Yard and wood waste disposal rates have remained fairly constant: since 2000, yard trimmings decreased 10 percent and wood waste increased 11 percent.

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[13] National estimates of post-consumer food waste managed through AD with energy recovery are not available and included in the disposal estimates.

[14] Disposal quantities also include solid waste incinerated without energy recovery, illegally dumped, or littered. Data are not available to quantify these end-of-life methods separately.

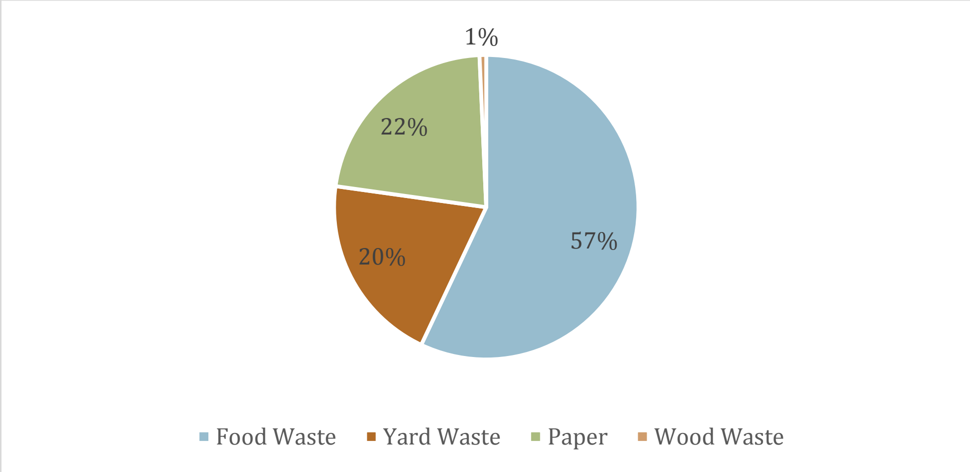
Table 21. Estimated organic waste disposed of in the US residential sector

Year	Food Waste[b] (million tonnes)	Food Waste[b] (kg/person)	Yard Waste (million tonnes)	Yard Waste (kg/person)	Paper[c] (million tonnes)	Paper[c] (kg/person)	Wood Waste (million tonnes)	Wood Waste (kg/person)	Food Waste, Yard Waste, Paper, Wood Waste (million tonnes)	Food Waste, Yard Waste, Paper, Wood Waste (kg/person)
2000	19.91	70.76	9.23	32.79	19.03	67.62	0.27	0.95	48.44	172.12
2005	21.14	71.33	7.63	25.76	16.26	54.86	0.28	0.95	45.31	152.90
2009	22.16	72.17	8.32	27.09	9.83	32.03	0.29	0.95	40.60	132.24
2011	22.66	72.73	9.01	28.92	9.12	29.27	0.29	0.94	41.08	131.86
2012	22.54	71.79	8.98	28.62	9.20	29.31	0.29	0.93	41.01	130.65
2013	22.90	72.43	8.50	26.90	9.54	30.18	0.29	0.92	41.23	130.43
2014	23.71	74.36	8.39	26.32	9.18	28.79	0.30	0.93	41.58	130.40

[a] Disposal equals generation minus diversion.
[b] Includes food waste lost to the sewer system through garburator (disposal) (US EPA 2013b, Table 4).
[c] Paper includes newspaper, writing paper, mixed paper, corrugated containers, folding boxes, cartons, and other paper.
Note: The US EPA's published tons have been converted to tonnes.
Sources: US EPA 2015a, 2016e. Residential portion estimated from IRA 2015; Connecticut DEEP 2016; Seattle Public Utilities 2016; CIWMB 2009; US EPA 2013b, Table 4.

Comparing the composition of residential organic waste disposal (Figure 19) with the composition of residential generation (Figure 14) shows that food waste is a larger portion of the disposal stream (57 percent compared to 35 percent). Yard waste and paper are about equal, at about 20 percent each; wood remains at 1 percent of the total organic waste stream.

Figure 19. Composition of organic waste disposed of in the US residential sector, 2014



Source: Table 21, this report.

ICI Sources

ICI paper, yard and wood wastes have trended similarly to residential organic waste. As Table 22 shows, paper has seen the largest decrease in tonnes going to disposal—a drop of about 50 percent by 2014. This represents a per-annum decrease of about 4 percent. Yard and wood waste disposal rates have remained fairly constant: since 2000, yard waste decreased 10 percent and wood waste increased 11 percent. Institutional and commercial food waste has increased slightly since 2000 (7 percent higher in 2014 than in 2000). Industrial food processing waste disposal has increased by 10 percent, from 2000 to 2014.

Table 22. Estimated organic waste disposed of in the US ICI sector

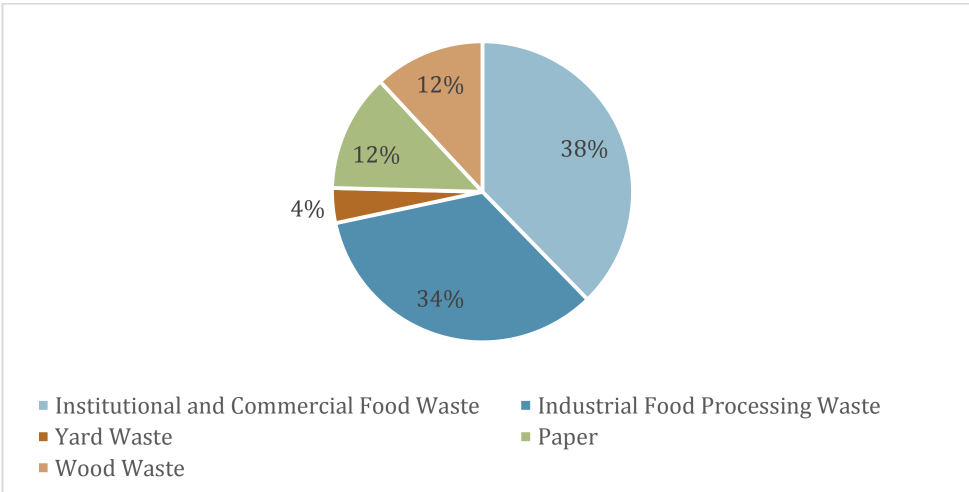
Year	Institutional and Commercial Food Waste (million tonnes)	Institutional and Commercial Food Waste (kg/person)	Industrial Food Processing Waste (million tonnes)	Industrial Food Processing Waste (kg/person)	Yard Waste (million tonnes)	Yard Waste (kg/person)	Paper[a] (million tonnes)	Paper[a] (kg/person)	Wood Waste (million tonnes)	Wood Waste (kg/person)	Food (All Sources), Yard Waste, Paper, Wood Waste (million tonnes)	Food (All Sources), Yard Waste, Paper, Wood Waste (kg/person)
2000	35.60	126.50	30.90	109.79	4.16	14.79	26.49	94.14	10.80	38.38	107.95	383.60
2005	35.64	120.25	32.30	108.96	3.44	11.61	22.64	76.38	11.47	38.71	105.49	355.91
2009	35.59	115.93	31.74	103.39	3.75	12.21	13.69	44.59	11.85	38.61	96.62	314.73
2011	36.18	116.13	32.35	103.82	4.06	13.04	12.70	40.75	11.89	38.16	97.18	311.90
2012	36.08	114.94	32.46	103.39	4.05	12.91	12.81	40.80	11.87	37.82	97.27	309.86
2013	36.67	116.00	33.02	104.45	3.83	12.13	13.28	42.02	11.78	37.25	98.58	311.85
2014	37.98	119.11	34.21	107.30	3.78	11.87	12.78	40.09	12.00	37.62	100.75	315.99

[a] Disposal equals generation minus diversion.

Sources: US EPA 2015a, 2016e. ICI portion estimated from IRA 2015; Connecticut DEEP 2016; Seattle Public Utilities 2016; CIWMB 2009; US EPA 2013b, Table 4. Industrial data: US EPA 2013b, Table 4; US EPA 2014a, Table 5.

Figure 20 shows the composition of ICI organic waste disposed of. Institutional and commercial food waste and industrial food processing waste combine to make 72 percent of the organic waste disposal stream. Paper constitutes 12 percent, wood 12 percent, and yard 4 percent of the organic waste disposal composition.

Figure 20. Composition of organic waste disposed of in the US ICI sector, 2014



Source: Table 22, this report.

Total Organic Waste Available

Table 23 summarizes the amount of organic waste available in 2014, calculated from the amount of organic waste generated and diverted by the residential and ICI sectors. In the United States, about 120 million tonnes of food, yard, and wood waste are disposed of, with 25 million tonnes diverted to facilities for organic waste management. About 40 million tonnes of paper are diverted to fiber markets, with about 22 million tonnes going to disposal.

Based on the data presented in this section, about 17 percent of the food, yard and wood waste in the residential and ICI organic waste streams is diverted from disposal in the United States, leaving 83 percent being disposed of.

Table 23. Estimated total organics available in the United States, 2014

Waste Source	Food Waste, Yard Waste, Wood Waste[a] (million tonnes)	Paper (million tonnes)	Total (million tonnes)
Residential generation	47.74	23.17	70.91
ICI generation	97.95	39.07	137.02
Total generation	*145.69*	*62.24*	*207.93*
Residential diversion	15.35	13.99	29.34
ICI diversion	9.99	26.29	36.28
Total diversion	*25.34*	*40.28*	*65.62*

Waste Source	Food Waste, Yard Waste, Wood Waste[a] (million tonnes)	Paper (million tonnes)	Total (million tonnes)
Residential disposal	32.39	9.18	41.57
ICI disposal	87.96	12.78	100.74
Total disposal	*120.35*	*21.96*	*142.31*

[a] Food waste includes waste from institutional, commercial and industrial food processing sources.
Sources: Tables 17 through 22, this report.

2.5 Comparison of Estimated Quantities of Organic Waste in North America

While it is beyond the scope of this report to compare North America to every other region in the world, this section presents a comparison between North America and Europe and Brazil.

2.5.1 Canada, Mexico and United States

As discussed in this chapter, these three countries show substantial differences in the availability and quality of data for organic waste. Data limitations exist at the national level within all three countries, particularly in the ICI sector. Comparing the data that are available is further complicated by the lack of a consistent definition of organic waste, across the three countries.

Table 24 summarizes this chapter's information on organic waste generation, diversion and disposal. Mexico values include residential and food waste from harvest to commercialization but exclude ICI generation, diversion or disposal estimates from any other sources. Due to lack of complete data, the estimates shown in Table 24 for Mexico are lower than expected.

Table 24. Estimated organic waste in Canada, Mexico and the United States

Category[a]	Canada (2012)	Mexico[b] (2012)	United States (2014)
Food waste, yard waste, wood waste generation (million tonnes)	10.05	32.50	145.69
Paper generation (million tonnes)	8.39	5.82	62.24
Total generation (million tonnes)	*18.44*	*38.32*	*207.93*
Total generation (kg/person/year)	542.70	327.37	652.14
Food waste, yard waste, wood waste diversion (million tonnes)	2.46	1.97	25.34
Paper diversion (million tonnes)	3.36	0.52	40.28
Total diversion (million tonnes)	*5.82*	*2.49*	*65.62*
Total diversion (kg/person/year)	171.03	21.27	205.76
Food waste, yard waste, wood waste disposal (million tonnes)	7.59	30.53	120.35

Category[a]	Canada (2012)	Mexico[b] (2012)	United States (2014)
Paper disposal (million tonnes)	5.03	5.30	21.96
Total disposal (million tonnes)	*12.62*	*35.83*	*142.31*
Total disposal (kg/person/year)	371.67	306.10	446.38

[a] Tonnes are approximate.
[b] Mexico values include residential and food waste from harvest to commercialization. The data do not include ICI generation, diversion or disposal estimates from any other sources. Due to lack of complete data, this table's estimates for Mexico are lower than expected.
Sources: Tables 7, 16 and 23, this report.

2.5.2 Comparison to Europe and Brazil

Of the total solid waste generated in the 27 states of the European Union (EU) in 2014, 28 percent was recycled, 27 percent was incinerated, 16 percent was composted, and 28 percent was landfilled (Eurostat 2016). In some countries, the diversion rate is much higher. Austria, Belgium, Denmark, Germany, Norway, Sweden and Switzerland diverted from landfills over 97 percent of the solid waste they generated in 2013. The overall diversion rate for Europe is similar to the approximately 32-percent diversion rate for organics in Canada and the United Sates.

Available statistics for Brazil are comparable to those for Mexico. With its residential solid waste consisting of approximately 51 percent organic materials, less than 2 percent of organic waste was composted (*Ministério do Meio Ambiente* 2012). Residential waste in Mexico has a similar organic content of 52 percent (Semarnat 2015a) and approximately 6.5 percent of organics was diverted from disposal.

3 Organic Waste Diversion and Processing

North America's organic waste could be better managed through increased diversion and processing, to yield economic, energy and environmental benefits. As more provinces, states and communities enact bans against landfill of organic waste, interest is growing and is driving markets and infrastructure for diversion and processing of organic waste.

As noted in Chapter 1, most organic waste is still disposed of by landfill or incineration. That said, recent emphasis on wasted food and on the effects of organic waste disposal on public health and the environment has spurred states and communities to take the lead and expand opportunities for organic waste diversion and processing. Farm-scale anaerobic digestion (AD) of manure is well established in North America; organic waste AD is steadily increasing in Canada and the United States. Thousands of composting plants currently operate in Canada and the United States (though many fewer operate in Mexico).

This chapter focuses on the benefits and challenges posed by diversion and processing of organic waste; country-specific programs; collection, pre-treatment, and technologies used; current capacity and opportunities to expand efforts; securing markets for end-products; and potential collaboration among the North American countries. The chapter is organized in descending order from the most to least preferred processing method, from industrial uses and AD (including co-digestion) to composting (see Figure 2).

3.1 Advantages and Challenges of Organic Waste Diversion

While diverting and processing organic waste produces useful inputs and outputs (e.g., industrial feedstocks, biogas, compost), participation and compliance (e.g., proper separation, sufficient quantity) is critical. In that light, several jurisdictions and communities throughout North America are creating and implementing initiatives (e.g., curbside collection) and incentives (e.g., pay-as-you-throw systems; low[er] organics tipping fees) to increase diversion and processing of organic waste.

Diversion and processing offers many advantages, among them the following:

- Organic wastes have industrial uses, such as rendering into pharmaceutical, cosmetic, household and industrial products.
- Animal feed can be produced by rendering, and from food scraps recovered in commercial (i.e., restaurant) and residential food-waste collection programs.
- Energy can be produced by conversion of organic waste (e.g., fats, oils and grease) into biofuels or by controlled recovery of biogas (in the case of AD).
- Avoidance of methane (via composting) reduces greenhouse gas (GHG) emissions (i.e., by avoiding the release of methane from landfills, and by displacing fossil-fuel-derived energy).
- Organic digestate and effluent from AD also has many uses and possibilities. Digestate can serve as a feedstock in compost production, or as animal bedding; effluent can be used as a liquid fertilizer.
- Compost has a number of beneficial uses—soil amendment (supplying nutrients, improving water retention), wetland restoration (increasing water filtration /plant growth) and erosion control (reducing runoff), to name a few. Applying compost also creates "carbon farming" opportunities by increasing soil carbon capture and its associated climate protection benefits (i.e., carbon sequestration), in addition to improving soil quality (see the "'Carbon Farming' in California" text box in Section 3.5.3).

There are a host of challenges to growth and investment in organic waste diversion and processing, among them the following:

- inexpensive landfill tipping fees in many areas (especially where landfill bans are not in place)
- securing a long-term commitment for feedstock
- potential for contamination of feedstock
- permitting and siting (increase in odor, noise, traffic)
- limited or less understood markets for end-products
- competition (e.g., organic fertilizers may cost more because they are typically less concentrated than synthetic fertilizers, requiring a greater quantity [Oregon State University 2008])
- limited infrastructure (e.g., facilities, access roads) to support organic waste diversion
- education for the public or employees (e.g., in restaurants) about the importance of organic waste separation
- contracts and agreements (feedstock, power, gas, digestate, compost, animal feed)

Many programs, initiatives, incentives and markets encourage and advance organic waste diversion and processing in states, provinces and communities. While Mexico trails Canada and the United States in programs, initiatives and incentives, it has an opportunity to kickstart sustainable organic waste management and practices. The following sections summarize the type(s) of current organic waste programs, initiatives, incentives and markets in Canada, Mexico and the United States.

3.2 Overview of Organic Waste Diversion Programs in North America

Among the North American countries, organic waste diversion programs vary by implementation strategy (e.g., municipality- or corporate-sponsored; privately contracted) and elements (i.e., number of households, diversion rate, sustainability goals), but share some commonalities between the residential and industrial, commercial and institutional (ICI) sectors (e.g., source-separated organics [SSO]). Several Canadian and US communities, for example, use economic incentives such as pay-as-you-throw (PAYT) programs, which require residents to pay for volume-based waste disposal (i.e., the more you throw away, the more you pay); or encourage diversion of organic waste by enacting tipping fee surcharges, or fines on loads that contain organic waste (see the Nanaimo Regional District example in Section 4.1.1) and/or are not source-separated (Federation of Canadian Municipalities 2009). Two Canadian provinces and several municipalities have also enacted bans against disposal of organic waste, for both businesses and residents; while some US states have imposed such bans on businesses, that are generally not applicable to residents.[15] Mexico's capital city has the country's only successful organic waste segregation policy, while its ICI programs are still emerging. Diversion of ICI organic waste is more established in Canada and the United States—but publicly available information on it is limited. Sufficient data exist, however, to demonstrate how organic waste from the residential sector is managed in the region.

The following sections describe diversion programs for residential and ICI organic waste in each country.

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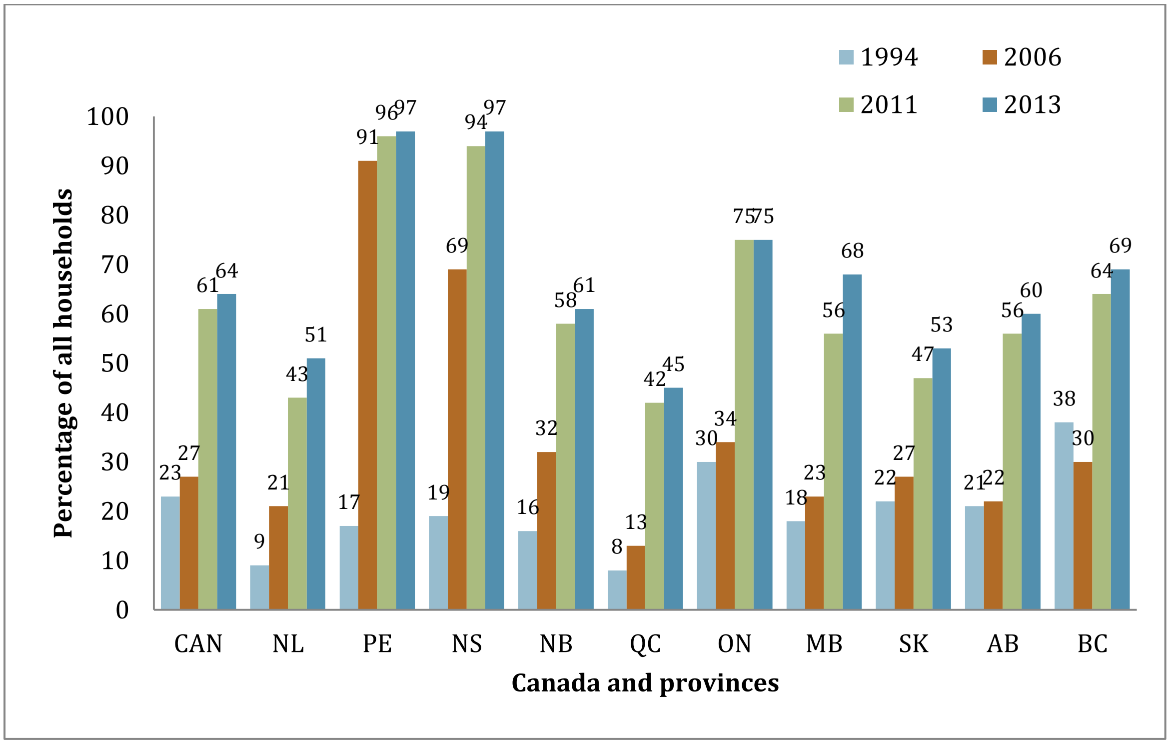
[15] California's organic waste ban applies to multi-family dwellings with more than five units, but there is an exemption for food waste (including food-soiled paper). See "Mandatory Commercial Organics Recycling (MORe)," CalRecycle, last updated 8 May 2017, <www.calrecycle.ca.gov/recycle/commercial/organics/FAQ.htm - Q14>.

3.2.1 Diversion Programs for Residential Organic Waste

Canada

Statistics Canada collects data on the number of households that participate in either source-separated organics (SSO) and/or leaf- and yard-waste composting programs in the municipalities they live in. Figure 21 shows how rates of household participation in organics programs have grown, across Canada from 1994 to 2013.

Figure 21. Household participation rates in organics programs across provinces in Canada, 1994–2013



Note: CAN: Canada overall; NL: Newfoundland and Labrador; PE: Prince Edward Island; NS: Nova Scotia; NB: New Brunswick; QC: Quebec; ON: Ontario; MB: Manitoba; SK: Saskatchewan; AB: Alberta; BC: British Columbia.
Sources: Mustapha 2013; Van Wesenbeeck 2015.

As shown above in Figure 21 (CAN), the number of households that used either SSO and/or leaf and yard waste programs increased from 23 percent in 1994 to 64 percent in 2013. This growth can be attributed to the introduction of new policies (e.g., landfill bans) and programs (e.g., PAYT) across the country. Although Canada does not have an overarching federal policy, program or regulation on organic waste diversion, provinces and municipalities have taken the initiative upon themselves. In 1998, for example, Prince Edward Island and Nova Scotia implemented bans on organic waste disposal in landfills. Notably, these two provinces have the largest percentage of households serviced by organic waste management programs, followed by Ontario and British Columbia. More recently, the province of Quebec has begun phasing in a ban on organic waste in landfills; and some municipalities in British Columbia have imposed their own bans, including the Metro Vancouver Regional District, the Capital Regional District and the Regional District of Nanaimo. PAYT programs are being developed on a municipal scale; an example of a successful PAYT program is the Regional Authority of Carlton Trail Waste Management District, in Saskatchewan.[16]

This increased participation has resulted in higher diversion of organic waste across the country. As discussed in Chapter 2 (Tables 4 and 5), about 7.2 million tonnes of residential organic waste is disposed of in landfills annually in Canada, with nearly 3 million tonnes diverted to organic waste management facilities annually. Currently, 27 percent of the organic material in the solid waste stream is diverted from landfills in Canada. From 2010 to 2012 alone, the total amount of organics diverted increased from 2.2 million to 2.4 million tonnes—a 9 percent increase in two years.

Mexico

Effective January 2004, Mexico's General Law on the Prevention and Comprehensive Management of Waste (*Ley General para la Prevención y Gestión Integral de los Residuos*—LGPGIR) requires state and municipal authorities to assess solid waste in their jurisdictions and describe their integrated solid-waste management plans (i.e., plans for waste reduction, segregation, selective recovery, re-use, recycling, treatment and disposal). States report this information in documents called State Programs for the Prevention and Comprehensive Management of Waste (*Programas Estatales para la Prevención y Gestión Integral de Residuos*—PEPGIRs). Municipalities submit this information in Municipality Programs for the Prevention and Comprehensive Management of Waste (*Programas Municipales para la Prevención y Gestión Integral de Residuos*—PMPGIRs).

While the submitted PEPGIRs indicate that most states are not yet separating organic materials for diversion, the majority are developing strategies to separate and divert organics in the future. Only Ciudad de México and the State of (Estado de) México provided data on segregation of organic waste. Table 25 describes organics separation programs and strategies identified in PEPGIRs.

Table 25. Separation programs and strategies for diverting organic waste, reported in PEPGIRs

State	Waste Separation Program	Strategies
Aguascalientes[a]	None reported	No information
Baja California[b]	None reported	No information
Baja California Sur[c]	Delegation of Guerrero Negro Municipality of La Paz, locality of Todos Santos Municipality of Los Cabos	Separation and composting
Campeche[d]	None reported	No information
Chiapas[e]	Tuxtla Gutiérrez has a waste separation plant	Separation and composting
Chihuahua[f]	The municipalities of Batopilas, Guerrero, Morelos and Santa Bárbara have a separated waste collection system	Separation and composting
Ciudad de México[g]	Waste separation program: in 2014, 1,690 tonnes/day of separated organic waste was reported	Separation, composting and AD
Coahuila[h]	None reported	Separation

[16] For further information on Canada's successful waste diversion polices, programs, regulations and best practices, see Section 4.1.1.

State	Waste Separation Program	Strategies
Colima[i]	None reported	Separation, composting and AD
Durango[j]	None reported	Separation and composting
Estado de México[k]	17 municipalities with separated collection; Environmental Technical State Norm NTEA-013-SMA-RS-20 Waste Separation (project)	Separation and composting
Guanajuato[l]	Environmental Technical State Norm NTA-IEG003/2001; industrial waste management	Separation and composting
Guerrero[m]	None reported	Separation and composting
Hidalgo[n]	None reported	Separation and composting
Jalisco[o]	Environmental Technical State Norm NAE-SEMADES-007/2008; waste separation	Separation and use of organic waste
Michoacán[p]	Waste separation programs in La Huacana, Pátzcuaro, Hidalgo, Ixtlán, Zitácuaro, Uruapan, San Juan Nuevo, Salvador Escalante, Huiramba, Sixtos Verduzco, Purúandiro, Zinapecuaro, Yurécuaro and Tangancicuaro	Separation and composting
Morelos[q]	Apply separation: Tetecala, Jantetelco, Zacualpan de Amilpas, Tepoztlán, Yautepec	Separation and composting
Nayarit[r]	None reported	Separation and composting
Nuevo León[s]	The municipality of Monterrey has a pilot program for separate collection	Separation and composting
Oaxaca[t]	None reported	No information
Puebla[u]	Waste separation campaigns and public waste separation containers	Separation, composting and vermicompost
Querétaro[v]	Waste separation in the municipalities of Amealco de Bonfil, Cadereyta de Montes, Ezequiel Montes, Huimilpan and Jalpan de Serra; the municipality of Querétaro has abandoned separated waste collection	Separation and composting
Quintana Roo[w]	None reported	Separation and composting
San Luis Potosí[x]	None reported	No information
Sinaloa[y]	None reported	No mention of objectives of waste separation or organic waste diversion
Sonora[z]	None reported	No information
Tabasco[aa]	None reported	Separation and composting
Tamaulipas[bb]	None reported	Separation and composting
Tlaxcala[cc]	None reported	Separation and composting
Veracruz[dd]	None reported	Separation and composting
Yucatán[ee]	None reported	Separation and composting

State	Waste Separation Program	Strategies
Zacatecas[ff]	None reported	Separation and composting

Sources:

[a] Gobierno del Estado de Aguascalientes, Insituto del Medio Ambiente, and Universidad Autonoma de Aguascalientes 2010.
[b] MICROBAJA Consultores, SC, Gobierno del Estado de Baja California, and Secretaría de Protección al Ambiente n.d.
[c] Dirección de Planeación Urbana y Ecología, Centro de Estudios de Urbanismo y Arquitectura, SA de CV, and Gobierno del Estado de Baja California Sur 2011.
[d] Gobierno del Estado de Campeche, 2010
[e] Gobierno del Estado de Chiapas n.d.
[f] Gobierno del Estado de Chihuahua and Universidad Autónoma de Ciudad Juárez 2012.
[g] Jefatura de Gobierno del Distrito Federal 2010.
[h] Gobierno del Estado de Coahuila and Secretaría de Medio Ambiente 2013.
[i] Secretaría de Desarollo Urbano and Gobierno del Estado de Colima 2011.
[j] Gobierno del Estado de Durango n.d.
[k] Gobierno del Estado de México 2009.
[l] UNAM 2014.
[m] Guerrero Secretaría de Medio Ambiente y Recursos Naturales 2009.
[n] Gobierno del Estado de Hidalgo 2011.
[o] Secretaría de Medio Ambiente y Desarrollo Sustentable n.d.
[p] Secretaría de Urbanismo y Medio Ambiente del Estado de Michoacán 2008.
[q] Gobierno del Estado del Estado de Morelos n.d.
[r] Gobierno del Estado de Nayarit 2009.
[s] Gobierno del Estado de Nuevo León 2009.
[t] Gobierno del Estado de Oaxaca n.d.
[u] Gobierno del Estado de Puebla 2016.
[v] Gobierno del Estado de Querétaro 2011.
[w] Gobierno del Estado de Quintana Roo 2009.
[x] Gobierno del Estado de San Luis Potosí n.d.
[y] Gobierno de Estado de Sinaloa n.d.
[z] Cesues and Cedes n.d.
[aa] Gobierno del Estado de Tabasco 2014.
[bb] Secretaría de Desarrollo Urbano y Medio Ambiente de Tamaulipas 2014.
[cc] Gobierno del Estado de Tlaxcala n.d.
[dd] Gobierno del Estado de Veracruz 2013.
[ee] Gobierno del Estado de Yucatán n.d.
[ff] Gobierno del Estado de Zacatecas 2014.

To date, Mexico City, DF, (Ciudad de México is the name of the new entity, with new powers, that replaced Distrito Federal in 2017) has most successfully implemented separation and diversion strategies. The primary motivator for success has been a shortage of landfill access: Mexico City's main landfill, Bordo Poniente, closed in 2011. In 2015, to revamp a declining waste diversion rate, the city's government approved a local environmental standard (NADF-024-AMBT-2013) with specifications on how to segregate waste at the source into five categories: biodegradable waste suitable for treatment, inorganic waste suitable for recycling, inorganic waste with limited recycling potential, special-management wastes and hazardous wastes (Sedema 2015b).

United States

The Resource Conservation and Recovery Act (RCRA) establishes a national framework for the proper management and disposal of non-hazardous and hazardous solid waste in the United States. While RCRA does not specifically address the management of organic waste, its Subtitle D, Section

4001, encourages disposal of solid waste in environmentally sound ways that maximize the utilization of valuable resources. It also states that the federal government will provide technical and financial resources to states; the US EPA developed its solid-waste program, including the waste management hierarchy, in response to this directive. Beyond the recent announcement of a US Environmental Protection Agency (EPA) / US Department of Agriculture (USDA) food waste reduction goal of 50 percent by 2030 (US EPA 2017c), the United States has no federal or nationwide organic waste diversion or processing protocol (USDA 2015). Instead, various counties and/or municipalities have implemented organic waste diversion programs (e.g., curbside collection) and several states have imposed organic waste bans on yard and/or food waste (see Figure 28) to encourage or manage the organic component(s) of the municipal solid waste (MSW) stream.

Residential diversion programs for organic waste—composed primarily of curbside food waste collection—can be found across the United States and are documented in several studies or reports. The US EPA identified 209 communities offering curbside food waste collection programs across 16 states in 2013; in all, these programs served about 2.7 million households, or about 2 percent of the US population (US EPA 2015a, 13). Other studies estimated 183 communities in 18 states and 198 communities in 19 states (Layzer and Shulman 2014, 1; Yepsen 2015). Table 26 shows a snapshot of some of the residential organic waste diversion programs identified in a 2015 *BioCycle* nationwide survey, covering programs that serve more than 100,000 households. Appendix B contains information on additional communities identified by *BioCycle*, as well as other sources.

Table 26. Snapshot of residential organic waste diversion programs serving more than 100,000 households, in the United States

State	Location/Program Description	Type of Processing		Year Started
		AD	Composting	
California	**Alameda County** Technology: composting Feedstock materials: food scraps, food-soiled paper, plant debris Population served: 420,000 single-family households[a]		✓	~2002
Minnesota	**Hennepin County** Technology: composting Feedstock materials: food scraps Population served: 106,000 single-family households		✓	2005
New York	**New York City** Technology: composting Feedstock materials: food scraps Population served: 100,000 households plus 151 apartment buildings[b]		✓	2013
Oregon	**Portland** Technology: composting Feedstock materials: food scraps Population served: 147,000 single-family households plus 50,000 multi-family units		✓	2010 (revised August 2014)
Washington	**King County** Technology: composting Feedstock materials: residential food scraps and soiled paper Population served: 319,500 single-family homes and 225,500 multi-family homes[c]		✓	2004

[a] StopWaste 2016.
[b] New York Department of Sanitation 2016.
[c] King County 2016.
Note: This table does not portray every organic waste processing program serving more than 100,000 households in the United States: it merely provides an overview.
Source: Yepsen 2015 (unless otherwise noted).

The examples below provide an overview of municipal curbside collection programs in the United States.

Multi-bin System: City of San Francisco, California

In 2002, San Francisco set an initial goal of 75-percent waste diversion by 2010 and zero waste by 2020. The city subsequently adopted a mandatory Recycling and Composting Ordinance, effective October 2009, which requires residents and businesses to sort recyclables from compostables and keep them out of the trash by placing them in the proper collection containers. The program uses a three-32-gallon-bin system: blue for recyclables, green for compostables, and black for landfill-bound trash. A municipal government team conducts extensive, multi-lingual, door-to-door outreach to educate stakeholders, and also to check residential curbside bins for improper materials, leaving reminders on how to manage each material. Residential customers pay about US$35/month for weekly collection, but a household that diverts enough material to recycling and composting may switch to a smaller 20-gallon black trash bin and decrease their monthly rate. Materials are collected and processed by the city's refuse hauler, Recology, which also manages the composting site. The city's color-coded bin system, policies (including financial incentives) and extensive public outreach have helped it divert about 80 percent of its waste from landfills—the highest diversion rate of any major North American city.

Program highlights:

- A convenient, color-coded system prevents confusion for residents and businesses.
- The program has achieved an 80-percent waste diversion, the highest in any North American city.

Source: SF Environment 2016.

Split- and Small-Cart Pilot Programs: Cities of Sunnyvale and San Jose, California

The city of Sunnyvale embarked on a nine-month food scrap recovery pilot program from March to December 2015. Roughly 500 households were provided with 64-gallon carts, with 32-gallon capacity on each side. Periodic field audits, load inspections and samplings (including sorting and weighing) revealed the following statistics:

- About 75 percent of all food scraps were properly placed in the correct side of the cart.
- Over 90 percent of single-family households in the pilot areas participated.

Based on Sunnyvale's success, the city of San Jose implemented a similar year-long pilot in September 2015. San Jose, however, is testing two types of systems: one using a 64-gallon split cart with 48-gallon capacity for garbage and 16-gallon capacity for food waste, and another using a separate 20-gallon cart for food scraps in conjunction with existing garbage and recycling carts. The split carts were provided to about 2,600 homes; the small additional carts were provided to about 4,000. Initial participation results (from September to October 2015) were as follows:

- The split-cart system yielded from roughly 100 tonnes to over 172 tonnes.
- The small-cart system yielded from nearly 30 tonnes to over 40 tonnes.

The food scraps from San Jose are delivered to the Sustainable Organics Solutions processing facility, which produces high-value, high-quality animal feed. This process not only provides a valuable use for recovered food, but also conserves valuable resources otherwise required to produce animal feed crops and negates the need for space for composting or AD facilities to process the same volume.

Source: Gertman 2016.

3.2.2 ICI Organic Waste Diversion Programs

Canada

Some of Canada's provinces and municipalities have organic waste diversion programs in place for the ICI sector. The majority of Canada's programs are voluntary, but there are a few that require mandatory actions. Table 27 presents a snapshot of ICI organic waste diversion programs. There is limited curbside waste pickup, and the amount of organic waste that is diverted from landfills is not tracked. Few waste composition studies have been performed, so this missing information is likely a key inhibitor to the implementation of organic waste diversion programs.

Table 27. Snapshot of ICI organic waste diversion programs in Canada

City, Province	Program Description	Type of Processing		Year Started
		AD	Composting	
Whitehorse, Yukon Territory	In 2015, the first phase of the commercial organics waste management bylaw was introduced, banning from disposal and garbage the organic waste from food service businesses. Mandatory participation by these businesses was later enforced, in September 2016. The city's Solid Waste Action Plan set out a goal of 50% waste diversion from the landfill by 2015; 31% was reached. The plan has a zero-waste goal set for 2040.[a]			2015
Prince Edward Island	Prince Edward Island has a comprehensive waste diversion program managed through the Island Waste Management Corporation. Since 1999, a province-wide mandatory composting program has been in place for all residents and the ICI sector. The corporation charges $99/tonne to businesses for disposal of source-separated waste, with a minimum fee of $5/tonne. There is a mixed-waste surcharge of $215/tonne for waste that is not source-separated, with a minimum charge of $40/tonne.[b]		✓	1999
Victoriaville, Quebec	The city is part of a partnership with 17 municipalities that collectively own 51% of a waste management company called Gesterra; the other 49% is owned by a private-sector waste management company. The aim is to reduce waste management costs and gain greater control over waste-management and disposal activities. The city offers a three-stream waste management system for both residential and ICI sectors. Participants receive a black 360-liter cart for garbage, a green 360-liter cart for recyclables, and a brown 360-liter cart for organics. Food and yard waste is processed at Gesterra's outdoor windrow facility.[c]		✓	1996
Halton, Ontario	The Region of Halton implemented the GreenCart composting and Blue Box recycling programs in all of its publicly funded elementary, middle, and secondary schools. As part of the program, the Region is responsible for providing schools with GreenCarts and kitchen catchers and the school is responsible for providing the appropriate liners. The region offers various waste minimization activities to the schools including workshops in which students learn how waste is composted, recycled, and disposed of. From 2007 to 2008, 163 workshops were delivered to 19,697 students in 62 schools.[d]		✓	2003

City, Province	Program Description	Type of Processing		Year Started
Victoria, British Columbia	The University of Victoria started composting food waste from operational activities on campus in 2003. In 2005, a voluntary office composting program was introduced to help divert more organic waste generated around campus. Compost bins are collected by ReFUSE and transported to the Fisher Road Recycling Facility (40 kilometers north of Victoria) for in-vessel processing.[e] Between 2011 and 2016, more than 2,800 tonnes of organic waste were diverted from landfill. The university planned to install more compost bins in August 2017 to help achieve the waste diversion target of 75% by 2019.[f]		✓	2003
Halifax, Nova Scotia	Halifax Regional Municipality has a residential and commercial organics waste collection program which began in 1998 and is governed by Halifax Bylaw S-600. Organics are collected from single-family, multi-unit and condominium residential homes as well as from ICI premises. The province-wide disposal ban on compostable organic material from 1998 helped achieve the 50% solid-waste diversion target in 2000.[g]		✓	1998

Note: This table does not describe every program in the country: rather, it provides an overview that highlights several approaches.

Sources:

[a] City of Whitehorse n.d.
[b] Giroux Environmental Consulting 2015.
[c] Federation of Canadian Municipalities 2009.
[d] Halton Region 2008.
[e] Sonnevera International Corp 2013.
[f] University of Victoria 2017.
[g] Resource Recovery Fund Board, Inc. 2001.

In 2012, the Canadian Council of Ministers of the Environment (CCME) completed work with major retailers, the restaurant and food sector, brand owners, and the packaging industry that has led to an industry-driven approach to reduce packaging in Canada. For example, Loblaw Companies Limited has implemented programs in British Columbia, Quebec, Nova Scotia and Prince Edward Island stores to divert organic waste. The amount of produce shipped in re-usable plastic containers instead of corrugated cardboard rose to 14.8 million cases in 2012—up from 3.5 million in 2011 (Loblaw Companies Limited 2012). Also, in 2011, Walmart Canada diverted 10,000 tonnes of organic waste from landfills (Walmart Canada 2012).

In June 2016, the province of Ontario passed the Waste-Free Ontario Act, to encourage greater recycling innovation while helping to lower costs for recycling and provide consumers access to more recycling options. The Act overhauls the former Waste Diversion Ontario mechanism and replaces it with the Resource Productivity and Recovery Authority, an oversight body with enhanced compliance and enforcement powers that will oversee the new approach and manage existing waste diversion programs until transition is complete. The strategy outlines Ontario's vision for a zero-waste future and suggests a proposed plan to implement the legislation; the plan includes specific elements related to organics. Action 10 of the proposed strategy calls for the province to implement an action plan to reduce the food and other organic waste going to landfills (MOECC 2016, 29). A stakeholder working group—likely composed of municipalities, waste management industry representatives, environmental groups, the agricultural community and the ICI sector—will help guide action-plan development, to ensure that considerations unique to organic wastes are addressed and to make recommendations to the provincial government.

Increasing landfill tipping fees for waste materials makes diversion programs more attractive. Introducing landfill bans for organic materials, like the ones used in the Metro Vancouver Regional District and the Regional District of Nanaimo, should be a future consideration for municipalities. The City of Calgary put forth an Industrial, Commercial, and Institutional Organics Waste Diversion Strategy, in 2015. According to a previous study by the city (City of Calgary 2011), 31 percent of its ICI waste is composed of organic food waste. It is estimated that 15 percent of that organic material is currently diverted. The private sector does most of the waste collection. The strategy includes mandatory organic waste diversion, differential tipping fees and an organics ban. Before implementing the strategy, the city conducted a second study on the capacity of its organic waste processing facilities. (It is important to know whether the processing facilities can accept more organic waste, before the implementation of a waste diversion program; if not, new processing facilities will have to be built and their budgets sorted out.) The study concluded that 11 out of the 27 facilities could handle the additional ICI waste. Another part of Calgary's strategy is to work with the private sector to develop a separate strategy for managing, monitoring and reporting ICI waste (Seidel-Wassenaar 2015).

As part of the development of its ICI waste diversion strategy, the City of Calgary also engaged stakeholders (Koole 2011), who brought up several challenges:

- limited access to co-mingled recycling processing capacity
- limited organics processing capacity
- generators without enough storage space for source-separated materials
- lack of regulations enforcing diversion
- high staff turnover, making training for proper waste management difficult
- sometimes, a higher cost for diversion than for disposal

In terms of addressing these challenges, the CCME *State of Waste Management in Canada* report (Giroux Environmental Consulting 2015) made the following recommendations:

- Jurisdictions could encourage the ICI sector to implement waste prevention policies such as bulk purchasing, paper usage reduction, initiatives to limit purchases of single-use or disposable products (e.g., plastic bags, disposable cutlery), and re-use programs.
- Waste policy frameworks need to have more direct engagement and requirements in the ICI sector—possibly legislated or through negotiated agreements. For example, jurisdictions could require the ICI sector to participate in extended producer responsibility (EPR) programs. Alternatively, jurisdictions could encourage the ICI sector to recycle materials for which diversion programs already exist (e.g., printed paper and packaging, electronics, organics).
- Waste policy frameworks should require ICI waste disposal data to be reported to provincial/territorial authorities, to ensure monitoring capabilities.
- Jurisdictions could facilitate ICI organic waste diversion through implementing landfill bans, education and outreach, and infrastructure support.

Some municipalities—specifically the Regional Municipality of Durham (Durham Region), the City of Toronto, and Owen Sound—have enforced mandatory recycling bylaws targeting the ICI sector. Durham Region's Waste Management Bylaw states that any ICI establishment currently receiving Regional waste collection services must participate in the Region's recycling and organics program. The city of Toronto states that if businesses want municipal garbage pickup, they must recycle as part of the Yellow Bag program. Owen Sound distributes recycling carts to companies within the city and provides support via the city website by uploading audit guides and forms, sample recycling policies, and signs (Regional Municipality of York 2014).

A sustainable fiber study prepared for Environment Canada, on improving the recovery of paper products (Christine Burow Consulting and the Boxfish Group 2011), identified the following challenges, which could be applicable to other materials:

- **Transportation costs**—paper mills are often situated far from urban areas, and post-consumer fiber (PCF) may have to be transported over great distances for reprocessing.
- **Low tipping fees**—if the cost of landfilling is lower or the same as recycling, organizations will tend to opt for the cheap/easy solution.
- **Lack of incentives/regulation—**many provinces and municipalities have no regulations governing the disposal of PCF, particularly for the ICI sector.
- **Costs of enforcement**—enforcement of PCF disposal bans and other regulations is often prohibitively costly.
- **Sorting capacity—**existing sorting capacity can be expanded to handle more volume or a greater number of waste-paper grades, but there will usually be an increase in the capital equipment and/or operating costs required. New facilities can take advantage of new technologies and economies of scale, but will require upfront investment. Any capital investments or cost increases have to be considered against the increased revenue from waste paper sales.
- **Contamination**—the value of collected PCF is often undermined by contamination with non-recoverable paper products, leading to lower aggregate prices (and higher reject rates during sorting).
- **Lack of data**—a significant obstacle to meaningful efforts to increase the recovery of PCF in Canada is the lack of useful, granular data on current recovery rates for different paper grades. There is also a lack of standardization of the waste paper and packaging grades, which affects data aggregation as well as the ability to maximize value for the municipalities and waste industry.

Mexico

In Mexico, ICI waste—including organic waste—is regulated by state environmental authorities as Special Management Waste under the LGPGIR. The law requires waste generators to develop plans to reduce, re-use and recycle waste. While required, many generators of ICI waste have not developed these plans and state programs do not report information from the plans in a systematic manner.

As Section 2.3 shows, government programs are just beginning to promote organic waste diversion for ICI sources. To date, ICI initiatives have been driven by private companies, trade associations, and industry consortia committed to waste reduction and recycling. For example, all of Ford Motor Company's Mexico plants (located in Cuautitlan, Chihuahua and Hermosillo) have achieved zero-waste-to-landfill status. The Hermosillo plant composts 36 tonnes of cafeteria waste, to produce organic fertilizer used by farmers close to the plant (Ford Motor Company 2016). In another example, Walmart is also pursuing a zero-waste goal at its Mexican facilities and actively targeting food waste reduction. In addition to several efforts aimed at reducing food waste and recovering surplus food, Walmart is conducting food waste studies in Mexico to identify future diversion opportunities. (Walmart Stores 2017). Chapter 4 provides additional examples, in case studies from Jalisco and Aguascalientes.

United States

No comprehensive or centralized organic waste diversion data are available for the US ICI sector, though its diversion and processing efforts are known to be similar to those in the residential sector (e.g., collecting SSO for composting). ReFED estimates that 95 percent of the 19 million tonnes of food waste generated by food manufacturing and processing companies, for example, is currently diverted from disposal (mainly to animal feed or other products) (Miller and Germain 2016).

Given the lack of data, information must be drawn from voluntary programs such as the US EPA's WasteWise program or culled from individual company websites.

Table 28 provides a snapshot of ICI voluntary organic waste diversion programs.

US Voluntary Initiatives to Reduce Waste

The US EPA's WasteWise program (<www.epa.gov/smm/wastewise>) is a voluntary initiative that encourages US businesses, governments and nonprofit organizations to achieve sustainability and reduce wastes. Partners establish goals/commitments, undertake efforts and report their annual results, to demonstrate how they reduced waste, practiced environmental stewardship (<www.epa.gov/smm/additional-information-wastewise-participants#02>), and incorporated sustainable materials management (<www.epa.gov/smm>) into their waste-handling processes. WasteWise has recognized the accomplishments of more than 70 Partners in the last five years.

Table 28. Snapshot of ICI voluntary organic waste diversion programs in the United States

State	Location, Program Description	Type of Processing		Year Started
		AD	Composting	
California	Albertson's Grocery Stores: 15 regional stores—each averaging 0.22 tonnes of food scraps per day—participate in San Diego's food-scraps-for-composting program[a]		✓	2011
	Central Contra Cost Elementary Schools: food waste collected by 31 of the district's 54 elementary schools is co-digested at Oakland's East Bay Municipal Utility District Water Treatment Facility[a]	✓		N/A
	Humboldt State University: organic material is collected from the campus dining services areas for food waste diversion[b]		✓	2011
Indiana	Purdue University: dining services food waste (~18 tonnes/month) is scraped from plates, pulped and sent to the West Lafayette Wastewater Treatment Utility to fuel AD, which generates power to run the treatment process[c]	✓		
Maryland	Safeway stores: collects/sends food waste for composting[d]		✓	N/A
New York	Wegmans: collects/sends food waste for AD co-digestion at dairy farms[e]	✓		N/A

State	Location, Program Description	Type of Processing		Year Started
Pennsylvania	Weis Markets: uses a wide range of recycling programs (closed-loop recycling, re-usable bags, organics, composting, etc.) to help the chain surpass its goal of reducing GHG emissions by 20 percent by the year 2020 (achieved in 2015); as of 2013, 50 stores were composting food scraps[f]		✓	
Vermont	Green Mountain College: collects food scraps from campus kitchens/dining halls and composts at onsite farm[g]		✓	N/A

Note: This table does not describe every program in the country: rather, it provides an overview that highlights several approaches.

Sources:

[a] CalRecycle 2015a.
[b] Humboldt State University 2016.
[c] Purdue University 2013.
[d] Eilperin 2013.
[e] Wegmans 2015.
[f] Goldstein 2013.
[g] Green Mountain College n.d.

With the growing interest in voluntary diversion programs and more states and communities passing organic/food waste disposal bans, small-scale onsite organic waste processing technologies are beginning to appear in restaurants, hotels, shopping malls, sports and entertainment venues and government facilities. Onsite AD technologies can process from several kilograms up to several thousand kilograms of food waste per day. Commercial greywater systems use AD in combination with nutrients or enzymes and bacteria to reduce organic waste so it can be introduced into the sewerage system (ReFED 2016). Businesses are primarily choosing onsite processing, to save money or demonstrate sustainability initiatives or both. However, these technologies come at a high price, require added staff training and oversight, and—in the case of greywater—may not be acceptable to water resource recovery facilities (WRRFs): that is, they may require more processing or added capacity to accept the material (ReFED 2016).

Other ICI sustainability efforts with organic waste diversion and processing initiatives include the Green Sports Alliance. The Alliance works with its members (more than 300 sports teams and venues from 20 different sports leagues and 14 countries) to promote healthy, sustainable communities by advancing renewable energy, healthy food, recycling, water efficiency, species preservation, safer chemicals and other environmentally preferable practices. Teams and venues such as SafeCo Field (Seattle) have embraced food waste recovery and processing (e.g., composting) practices and communicate to the public the benefits of food waste reduction and diversion.

Concert and other event venues, such as stadiums and farmers' markets, and special events represent an opportunity to introduce the community and businesses to organic waste diversion and processing. From providing separate containers into which food waste can be deposited, to using compostable plates, cups, utensils and napkins so that all of the waste can go into a single container, events yield many organic waste management opportunities (May n.d.). Opportunities for expanding the use of compostable packaging are especially noteworthy. For example, in a case study developed by the Sustainable Packaging Coalition, a single evening concert with 6,000 attendees can divert over one tonne of organic waste, including approximately 780 pounds of food-soiled packaging (Sustainable Packaging Coalition 2017).

As well as ICI diversion and processing initiatives, companies are often establishing sustainability policies, zero-waste goals, and/or landfill diversion targets that likely include organic waste diversion, or could be furthered through more diversion.

The examples below describe successful ICI composting programs in the United States.

Industrial Composting Program: Smithfield Packing Company, Smithfield, Virginia

Virginia-based Smithfield Packing Company—a subsidiary of Smithfield Foods, a global pork products marketer and one of the largest US meat companies—has partnered with McGill Environmental Systems, a North Carolina-based compost manufacturing company, to divert organic residuals and byproducts generated in its Smithfield plant to McGill's composting facility. Since 2010, Smithfield Packing has diverted about 6,350 tonnes of residuals and byproducts from landfill disposal to be used as feedstocks in the production of premium compost products. Over the past 12 years, Smithfield companies have recycled more than 180,000 tonnes, in partnership with McGill.

In 2012, the Virginia Recycling Association gave Smithfield-McGill the "Outstanding Partnership Award for Excellence in Recycling."

Source: McGill 2012.

Commercial Composting Program: Hilton San Diego Bayfront Hotel, San Diego, California

The Hilton San Diego Bayfront Hotel, a 32-storey hotel with nearly 1,200 guest rooms, was the first San Diego hotel to initiate a food waste composting program. The hotel collects pre-consumer waste from its two main kitchens as well as two bars and a coffee shop. Post-consumer food waste is collected from the employee cafeteria and from banquet events, combined with the other food waste streams and sent to the Miramar Greenery composting facility. In the first eight months, the hotel diverted 11 percent of its waste stream—approximately 113 tonnes—and saved about US$8,000 in waste management and disposal fees.

Program highlights:

- Nearly 15 tonnes/month of food waste has been diverted from landfills.
- The hotel has saved US$1,000/month, on average.

Source: CalRecycle 2015a.

Institutional Composting Program: Green Mountain College, Poultney, Vermont

At this small liberal arts college, student volunteers collect both pre- and post-consumer food waste from the residence-hall kitchens and dining halls. Pre-consumer food includes scraps from the meal prepping and cooking process, as well as unused produce or uneaten leftovers. The post-consumer portion comprises food waste that dining hall patrons clean off their plates. Food waste is also collected from the residence halls and office building in designated bins, and then consolidated with the dining hall waste. Each day, the food waste is delivered to the college farm, where it is composted along with wood chips or dry leaves in windrows. Once the compost reaches a soil consistency, it is used as fertilizer on the farm. An existing infrastructure and using student volunteers for labor make this program relatively inexpensive and self-sustaining.

Program highlights:

- This is a low-cost program, using collection volunteers and existing site.
- Designated collection bins make it easy for stakeholders to participate.

Source: Green Mountain College n.d.

3.2.3 Key Considerations for Successful Organic Waste Diversion, Collection and Processing Programs

As demonstrated by all three countries, participation is critical to the success of residential organic waste diversion, collection and processing programs. Although less is known about ICI diversion, saving money through reduced waste management fees—as well as garnering environmental goodwill among consumers through corporate sustainability goals—likely contributes to program success. As more communities and companies embrace organic waste diversion as a means to reduce waste management costs or increase environmental benefits, North America will reap the benefits.

3.3 Technologies for Processing Organic Waste

While the North American countries might approach implementation of organic waste diversion programs differently, the collection methods (e.g., source separation into bags or bins, curbside versus drop-off) and processing technologies (i.e., rendering, AD, composting) are similar, as are the challenges encountered (e.g., lack of infrastructure; public education/participation; contamination and pre-treatment; moisture and weight issues). This section details various methods and considerations for collecting SSO and for their subsequent processing, depending on end-products desired (e.g., industrial feedstock; biogas; compost). It provides overviews of AD and composting technologies,[17] along with advantages and disadvantages of the various types of systems (e.g., wet versus dry, passive versus active aeration). Lastly, this section describes co-digestion of organic waste and the pros and cons associated with this method.

Other emerging and niche technologies for organic waste processing (e.g., gasification, pyrolysis and liquefaction) are showing promise; however, they are not yet available at a commercial scale and are therefore not within the scope of this report.

[17] Less is known (i.e., tracked/reported) about the volume of organics managed and processed into manufacturing feedstocks via rendering.

3.3.1 Methods and Considerations for SSO Waste Collection and Treatment

Generally, SSO waste is collected from residences (single- or multi-family) or from the ICI sector. SSO is typically collected alongside other trash and recycling streams, though collection services can vary drastically among different countries and even among different municipalities. Waste collection frequency can also vary: weekly collection is recommended (since it reduces odor and vectors), but costs can be a limiting factor. Because SSO is mostly composed of food waste, collection can be a challenge in terms of moisture content (35–40 percent) and weight (up to 0.17 tonnes per cart) (Miller and Germain 2016).

Collection methods can range from manual to semi-automated to fully automated, depending on the type of equipment used by the municipality or waste hauler (e.g., rear-load-packer trucks versus split-side top-load trucks); the type of trucks used will dictate the requirements for the type(s) of containers used by consumers.

Most MSW collection vehicles are not specifically designed to collect SSO. Collection vehicles for SSO require less compaction and may use augers (i.e., large internal screws that rotate and move materials toward the back of the truck) instead of compaction blades. SSO may also generate more liquid, requiring specialized containment on the vehicle. Newer vehicles may also have multiple compartments to allow for collection of multiple waste-types (e.g., SSO and MSW); this can reduce the number of vehicles and routes needed for waste collection.

Alternatively, allowing residences and businesses to use compostable bags for SSO co-collection with yard waste or MSW could eliminate the need for separate collection vehicles and allow more-frequent collection. For example, Organix Solutions developed compostable "Blue Bags" for SSO that received approval from the Minnesota Pollution Control Agency for co-collection with other waste. The bags were deemed suitable to stand up to collection and processing at material-recovery facilities, where they are extracted and managed separately (Waste360 Staff 2016).

One of the greatest challenges facing residential and ICI collection of SSO is educating residents and businesses to properly sort and manage organic waste and keep contaminants out of SSO (e.g., plates, utensils) (Miller and Germain 2016), along with ensuring high participation rates.

Cost is another challenge (though project economics are discussed at length later in this chapter). For example, the United Kingdom is known for its progressive laws, regulations, and incentives for organic waste diversion, but several studies point to the elimination of municipal programs for food waste collection, primarily due to costs (amplified by lower-than-expected participation rates), even while landfill and incineration disposal costs can be more than double the tipping fee for AD (Jones 2014). In addition, local-level data on organic waste are limited, and characterization studies are needed to understand the feedstock potential. Otherwise, collection programs or processing technologies could be over- or under-sized (Miller 2016).

The following sections discuss general collection considerations for the residential and ICI sectors, as well as contamination issues and pre-treatment methods.

Residential Organic Waste Collection Considerations

Residential organic waste (e.g., yard trimmings, food scraps) is typically collected curbside by municipal governments or individually contracted waste haulers. The municipality or hauler often provides additional bins or bags—often color-coded to help them stand out from other recyclables—to keep organic waste separate from the rest of the household refuse. Centrally located drop-off sites give residents another way to divert organics from landfills, especially in more-rural areas. Many Canadian and US cities offer drop-off sites that accept food waste for composting (e.g., Minneapolis; Napa Valley; Vancouver; Washington, DC) and/or encourage residents to compost food in their own backyards (e.g., Halifax).

One of the key considerations for a successful residential collection program is establishing an effective education campaign; another is continual monitoring and evaluation to assess program effectiveness. Introducing residential SSO can be extremely challenging, due to residents' concerns and/or perceptions that storing food waste can lead to odors and other nuisances (e.g., flies, maggots). Educating participants and/or reminding them that SSO collection merely isolates a portion of solid waste already generated and managed by households might help disarm some concerns. In some communities, SSO might be collected more often than other solid waste (e.g., weekly rather than biweekly); this should be emphasized as another way to manage odors and nuisances.

Understanding Volume- Versus Weight-based MSW Collection Pricing

A pound of food waste occupies significantly less space in a dumpster than a pound of cardboard or styrofoam packaging. Therefore, taking food waste out of the MSW container does little to reduce volume—and thus the price paid to some collection providers, leaving little incentive for some generators to divert food waste from the MSW waste stream. Small(er) quantity generators, however, might find it advantageous to combine food wastes to achieve volumes that might attract more competitive pricing.

Municipal and private-sector providers of organic waste service need to learn from other programs (successful or not) and devise effective strategies and tactics, including public education campaigns and monitoring and evaluation to measure and respond program strengths and weaknesses.

ICI Organic Waste Collection Considerations

Opportunities also exist to recover organic waste from the ICI sector, but there are challenges as well. For small and medium-sized businesses, access to collection services can be problematic. Collection service providers may be interested in the organic waste but hampered by an absence or limited number of processing facilities within a reasonable distance (i.e., transporting heavy food waste over long-distances is expensive). As well, they may not be able to make a sound business case for investment if they cannot demonstrate a secure level of feedstock (and cannot wait for infrastructure to be built to appease investors). While landfill tipping fees for MSW are typically weight-based, the pricing of commercial MSW collection is sometimes volume- rather than weight-based, which can be problematic, especially for smaller businesses with their lower generation rates, as food waste tends to be dense but low-volume (i.e., it is heavy but makes up a smaller portion of overall refuse).

One creative solution is for businesses to work through collaborative procurement: combine food waste volumes to leverage buying power, then purchase collection services from a single supplier. This results in efficiency savings for the collection provider, which in turn can be passed along to the business; it can bring down the cost of more-specialized services such as food waste collection (Parke and Baddeley 2014).

SSO can be captured or collected in plastic containers (ranging from small buckets to large, wheeled carts, depending on the establishment's anticipated volume and available space to place/store the containers), wet-strength paper bags, or compostable plastic-film liners. Grocery stores, restaurants and various institutions (e.g., colleges, hospitals, prisons, assisted living facilities, factories with dining service or cafeterias) typically provide collection containers into which employees or patrons can deposit food waste. While some large(r) grocery stores might have space to segregate food waste (e.g., keep meat and dairy products separate from produce and floral materials), most restaurants and institutions collect comingled food waste in a single container. Restaurants and cafeterias might also collect and store used cooking oil (e.g., waste vegetable oil, used fryer oil) in metal drums or dumpsters for pickup and processing into biofuels. Businesses and government have implemented office composting programs in which a third-party provider collects food scraps for composting offsite.

Specially marked or color-coded bins for food waste collection in commercial or institutional environments (e.g., restaurants, college cafeterias) can significantly encourage or increase diversion as well as re-enforce educational outreach messaging and reduce contamination (McKiernan 2015a).

Recovered food-processing waste (e.g., trimmings) composed of animal byproducts, fats and oils is processed into biofuels or biochemicals (e.g., steroids, proteins, hormones) or rendered into industrial feedstocks used to produce animal feed, paints and varnishes, health and beauty products (e.g., soap, cosmetics, toothpaste, pharmaceuticals), explosives, textiles and leather, lubricants, and other products (US EPA 2014a, 3). See Section 3.5.1 for more details.

A Tale of Two Grocers

Employees at 11 Wegmans stores in the Rochester, New York, area collect food that cannot be donated (e.g., coffee grounds, food scraps from the prepared-foods kitchen, damaged floral and produce items) in large wheeled totes. Once the totes are full, Natural Upcycling empties them onto its truck, collects from other Wegmans stores, and then heads to one of two farms that use anaerobic digesters to co-digest animal manure with the food waste. The electricity produced powers the farm and excess energy is sold to a local utility. In 2014, Wegmans diverted nearly 1,200 tonnes of food waste from landfills and converted it into energy.

More than 100 Safeway stores along the US East Coast also collect similar food waste (e.g., grounds, spoiled fruit) and ship it to Maryland, where it is deposited into an industrial compactor before transport to compost facilities in Delaware and Virginia.

Sources: Wegmans 2015; Eilperin 2013.

In addition to rendering, there are other opportunities to use food waste as valuable raw material for other products. The waste streams of fruit and vegetable processing, such as stems and leaves, skins or rinds, and spoiled produce, are often further processed to extract chemicals or substances for other products, used to produce animal feed, composted, or directly applied as a soil amendment (US EPA 2012b, 8). An example of food waste processing or "upcycling" involves processing waste citrus rinds (e.g., oranges) from juice production to extract essential oils for use in products such as cleaners or lotions (US EPA 2012b, 8). Essential oils and antioxidants are also extracted from grape seeds found in winery waste (e.g., "pomace") (USDA Agricultural Research Service 2017). Spent brewer's grain and yeast from beer brewing is typically diverted to local farms for animal feed or to fertilize crops (US EPA 2012b, 10). For these latter plant-based waste streams, examples of diversion and processing through AD or composting are provided in later sections.

OrganicWaste Pre-Treatment

Organic waste processing consists of converting the organic component of the MSW stream (e.g., yard trimmings, food waste) for use in industrial applications (e.g., rendering, pharmaceuticals), energy and digestate via AD, or soil amendments/fertilizer via composting.

Depending on the source, organic waste can contain high levels of contaminants; if so, it must be pre-treated before processing (e.g., AD). Pre-treatment may also be needed to remove plastic bags or grind organic waste into a pulp for further processing. Possible contaminants in organic waste, even SSO, include inorganic materials (e.g., glass, plastics, metals, sand), bones, soil and chemical contaminants such as disinfectants, pesticides, and antibiotics. Table 29 identifies typical food waste sources in the United States (which are likely similar in Canada and Mexico) and the associated rank of contamination (“very low” being the least contaminated; “very high” being the most contaminated).

Table 29. Food waste contamination ranks

Food Waste Source	Examples	Contamination Description	Contamination Rank
Food and beverage manufacturing	Snacks, baked goods, meat/poultry processing, dairy goods (cheese, ice cream, yogurt)	Clean-in-place chemicals used for disinfection (can be toxic to the digestion process)	Very low
Pre-consumer	College or hospital cafeteria prep, restaurant prep, grocery delis, etc.	Gloves, packaging, utensils	Low
Post-consumer	Cafeteria and restaurant waste bins	Utensils, paper goods, some glass/plastic/cans	Medium
Green bins or SSO	Municipal green collection programs	Packaging/wrappers (plastics/paper, some glass), miscellaneous “garbage”	High
Mixed MSW	Most cities in the United States	Anything and everything typically discarded from households and businesses (plastic, wood, metal, textiles, glass, chemicals, styrofoam, food scraps)	Very high

Source: McKiernan 2015b.

Compostable packaging presents a potentially valuable opportunity to mitigate contamination issues in SSO while also increasing the amount of organic material able to be diverted and reducing the need for petroleum-based plastic packaging products.[18] For more information, the Biodegradable Products Institute (BPI 2017a) is an example of a nonprofit that promotes and certifies compostable products. The BPI website contains a searchable Product Catalog of over 4600 certified compostable products available on the market—“from compostable bags and foodservice items to resins and certified packaging materials” (BPI 2017b).

Pre-treatment of organic waste is necessary in order to remove contaminants, and thus ensure process efficiency, maximize yield and reduce operational costs (Table 30). It is used to remove non-biodegradable materials and homogenize feedstock. The requirements vary depending on the feedstock. There are several pre-treatment methods:

- **Physical**—manual (i.e., removal by workers from the tipping area or sorting facility), mechanical (e.g., screening, trommels, magnets), thermal, ultrasound, electrochemical
- **Chemical**—alkali, acid, oxidative
- **Biological**—microbiological, enzymatic
- **Combined process**—extrusion, thermochemical

The feedstock is usually macerated to create the right consistency. Depending on the types of contaminants present or expected in the organic waste, chemical or biological treatment may also be

[18] Carson, S., CEO of BSI Biodegradable Solutions, in-person presentation to CEC staff, 29 September 2016.

needed. Table 30 provides an overview of the various organics feedstocks and recommended pre-treatment for each.

Table 30. Various feedstocks and pre-treatment methods

Feedstock	Pre-treatment
Separated food waste	De-packaging may be needed, depending on contamination levels
Manures/Slurries	Minimal pre-treatment needed, usually used with other feedstocks
ICI	De-packaging is needed to remove plastics and metals; often highly contaminated, so screening is also needed; effluents require minimal pre-treatment
Energy crops	Screening to remove stones; cutting or shredding; silage is usually pre-shredded

Source: US EPA 2016b.

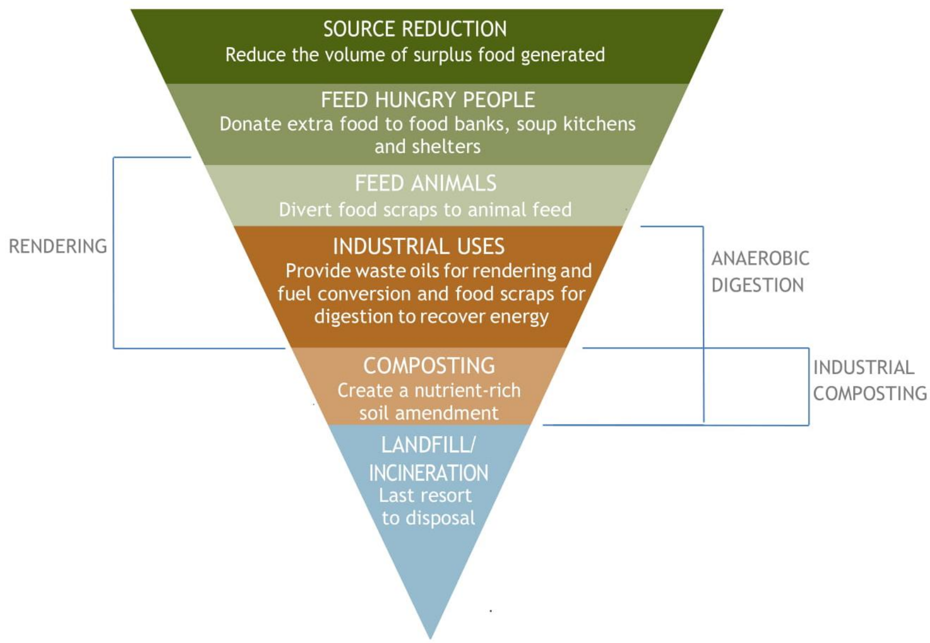
3.3.2 Industrial Uses: Animal Rendering

The animal processing industry generates byproducts (e.g., edible products such as lard, tallow or greaves, and inedible products such as meat meal and bone meal) in the course of feeding people throughout North America. Potential byproducts make up approximately 30 percent of a pig's live weight and nearly 45 percent of a cow's live weight (Marti et al. 2011, 1). These animal byproducts are usually not suitable for human consumption and would end up in landfills or incinerated, where they might contribute to public-health or environmental concerns (e.g., air or water pollution). However, many animal byproducts are recycled by rendering, which turns them into beneficial products.

Rendering is the cooking and drying process by which portions of livestock and poultry that are not intended for human consumption are converted into edible (e.g., fats such as lard, tallow) and inedible (e.g., proteins such as meat meal and bone meal) byproducts, thereby providing additional revenue for the meat industry and avoiding costly disposal. Meat meal can be used as an ingredient in animal feed and bone meal can be used as natural fertilizer (Cooper 2014). According to the National Renderers Association (NRA), which represents renderers in Canada and the United States, the process of rendering can convert 99 percent of collected meat and meat byproducts into usable products such as fertilizer, biofuel, animal feed and other industrial and consumer items (NRA 2016a). This equates to the potential for more than 26 million tonnes of material from livestock/poultry processing plants, grocery stores and restaurants to be converted into ingredients for "soaps, paints and varnishes, cosmetics, explosives, toothpaste, pharmaceuticals, leather, textiles, and lubricants" (NRA 2016b). Animal byproducts also constitute about 25 to 40 percent of premium pet foods (Marti et al. 2011, 4). Rendered fats and oils make up one-third of the feedstock used in US biofuel production (NRA 2017).

Among the organics-processing techniques, per NRA, rendering is environmentally preferable to industrial composting and anaerobic digestion. Figure 22 shows the NRA-modified food recovery hierarchy, which stands in comparison to the US EPA's food recovery hierarchy (Figure 2).

Figure 22. NRA-modified US EPA food recovery hierarchy

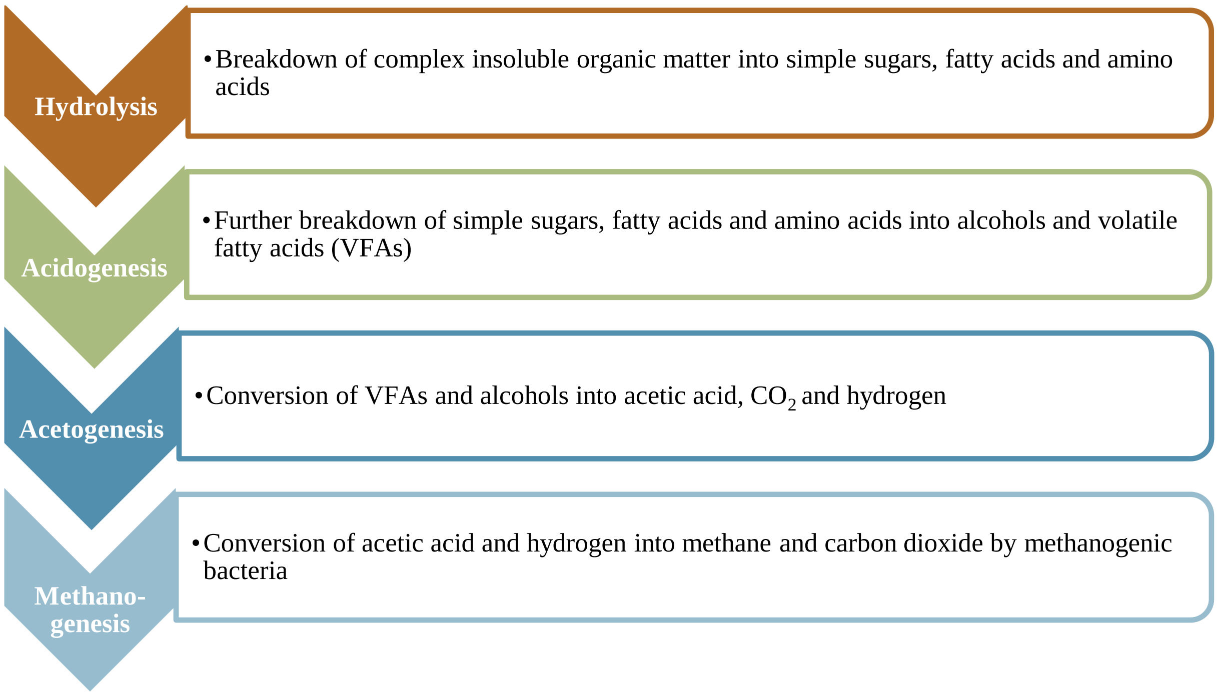


Source: NRA 2016a.

3.3.3 Industrial Uses: Anaerobic Processing

AD is the natural process that breaks down organic matter in the absence of oxygen to release a gas known as biogas, leaving an organic residue called digestate (Figure 23). Biogas—composed primarily of methane and carbon dioxide—can be captured and used to generate electricity onsite, sold to utilities as green power, converted to vehicle fuel, or treated to produce renewable natural gas (RNG). Digestate is nutrient-rich and can be directly land-applied (as fertilizer); the residual solids removed from the effluent can be converted into soil amendment (i.e., composted on- or offsite) or animal bedding (US EPA 2013a, 6). Figure 23 below shows the stages of AD.

Figure 23. Stages of anaerobic digestion



Source: US EPA 2016b.

Hydrolysis, in particular, can be used to convert lipids and carbohydrates found in food waste into biodiesel (via transesterification) and bioethanol (via fermentation), respectively (Karmee 2016).

AD technology is commonly used to treat municipal or industrial wastewater and/or sewage sludge (e.g., biosolids) and to help manage/reduce the volume of manure generated on livestock farms and/or poultry farms. In addition to biosolids and animal manure, some AD facilities supplement their inputs with other organic materials, such as food waste. Co-digesting (i.e., processing more than one biodegradable feedstock within the AD system) food can be used to adjust the solids percentage in order to improve digestion and increase biogas production by up to three times, relative to that of biosolids alone (US EPA 2013a, 6). When it comes to AD, food wastes that are minimally contaminated and/or only need a simple pre-screening also work better in wet digesters. Ideal inputs include pulped SSO from colleges' or grocery stores' prepared-foods kitchens (McKiernan 2015b). AD is particularly attractive for cities and regions that lack the space necessary for large-scale composting operations, and in states with renewable energy incentives, including renewable portfolio standards (Layzer and Shulman 2014, 15).

While AD has many demonstrated advantages, several challenges to wider adoption of organic waste AD exist. Among these challenges are:

- high capital cost;
- scaling to achieve profitability;
- securing long-term feedstocks;
- infrastructure for collection and processing equipment (e.g., collection of SSO from multi-family residences in urban areas; transfer stations; higher potential operation and maintenance cost for collection vehicles);
- complexity of operation (i.e., a need for technical knowledge);
- contamination of feedstocks;

- microbes' sensitivity to changes in feedstock composition, shock loads or changes in temperature or pH;
- markets for biogas use (off-take agreements) and digestate;
- siting (i.e., identifying and securing a location to build an AD facility);
- local, state and federal permitting requirements for air, solid waste and water (the US lists examples of permitting requirements specific to AD systems, by state, at <www.epa.gov/agstar/guidelines-and-permitting-livestock-anaerobic-digesters#permitting>); and
- lack of policies and incentives (e.g., diversion goals, lower tipping fees for food waste).

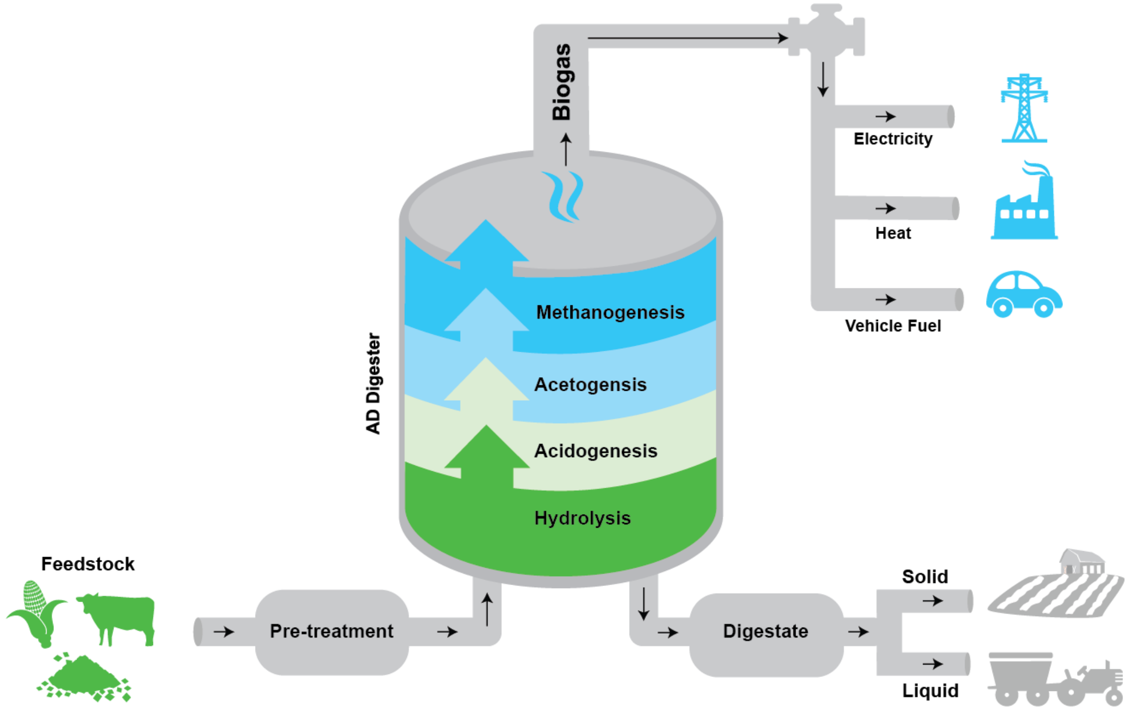
AD facilities can be classified as follows (EREF 2015, 1):

- **Stand-alone facilities** manage organic waste.
- **On-farm co-digestion systems** process agricultural materials (e.g., manure) and supplement them with offsite organic waste.
- **WRRFs with AD and other wastewater treatment systems** use co-digestion to manage waste-activated sludge (i.e., biosolids) and may accept food and other high-strength solids (e.g., spent grains from breweries).[19]

Figure 24 provides a simplified overview of the AD process, from the introduction of feedstock in the digester to the generation of biogas and digestate to beneficial uses.

[19] In the case of wastewater treatment plants /WRRFs, the facility must have existing space to receive food waste and the capacity to process that waste, and assurance the additional material will not affect its Clean Water Act nutrient discharge limits (Layzer and Shulman 2014, 15).

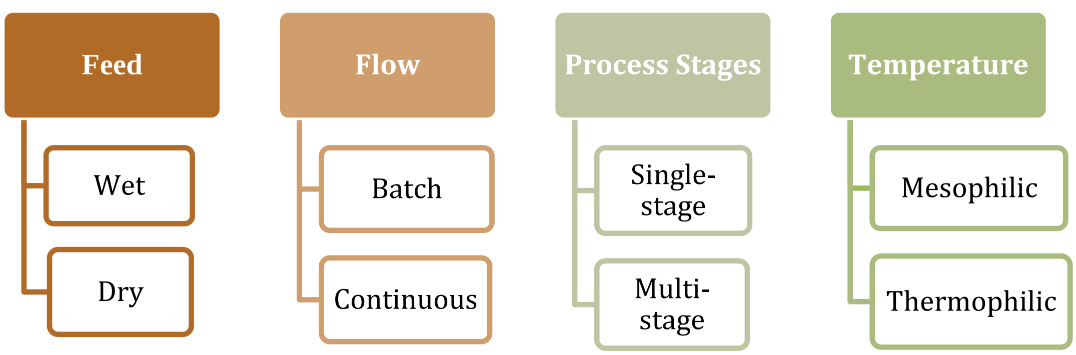
Figure 24. Typical anaerobic digestion process technology



Source: US EPA 2016b.

AD technologies are generally characterized as wet or dry, based on feedstock solids content: "wet" comprises low solids, with a moisture content greater than 85 percent; "dry" comprises high solids, with a moisture content of less than 80 percent) (EREF 2015, 1) (Figure 25). They can have a variety of configurations, in terms of flow, process stages (e.g., single or multiple), and temperature. Table 31 provides an overview of considerations for the different types of AD systems.

Figure 25. General AD technology characterization



Source: US EPA 2016b.

Table 31. Overview of AD considerations

Feed	
Wet • Low solids (moisture content greater than 85 percent) • Waste is macerated before digestion • Feedstocks include food waste, manure, slurries	Dry • High solids (moisture content less than 80 percent) • Less mechanical treatment is required • Feedstocks include green wastes and energy crops
Flow	
Batch • The digestion process is allowed to start and finish in a single vessel • Once complete, the vessel is emptied and the process is restarted with new feedstock • A series of vessels may be used to overcome peaks/valleys in feedstock and gas production flows	Continuous • Feedstock flows through the plant continuously • Eliminates the need to empty digesters and restart the process, which can be labor-intensive and time-consuming • Biogas generation tends to be more consistent, although generation rates may be lower than for batch processes
Process Stages	
Single-stage • Entire process occurs in a single vessel • Plant design is simpler, more economical • Produces less biogas • Feedstock takes longer to process	Multi-stage • Two or more vessels are used to optimize process • Helps to further degrade feedstock • Produces more biogas
Temperature	
Mesophilic • Operates at 30–40°C • Stable process • Suitable for slurries and industrial/ commercial food wastes • Popular option in developed countries	Thermophilic • Operates at 50–60°C • More complex process and less stable • Suitable for a wider range of feedstocks • More expensive due to higher energy input requirement

Sources: US EPA 2016b; EREF 2015 for moisture content in feedstock.

Digestion systems can be further classified as:

- High-solids stackable (feedstock is "stackable," or capable of being layered in reactor);
- High-solids slurry (feedstock is wet, but not necessarily liquid); and
- Wet (feedstock is essentially liquid, with low solids) (Environment Canada 2013a).

Table 32 describes some of the facility and process characteristics for AD systems.

Table 32. Characteristics of AD systems

Characteristics	High-Solids Stackable System	High-Solids Slurry System	Wet (Low-Solids) System
Facility			
Design configuration /	Concrete tunnels with	Plug-flow or continuously stirred	Continuously stirred

Characteristics	High-Solids Stackable System	High-Solids Slurry System	Wet (Low-Solids) System
operation mode	tight doors /batch	tank /continuous or batch	tank /continuous
Common supporting equipment	Front-end loader to remove digestate	Pump to extract digestate	Pump to extract digestate
Process			
Acceptable/unacceptable materials	Wastewater treatment plant residuals (sludge); yard waste (grass clippings, leaves); food scraps/fat, oils and grease; and food/beverage processing wastes (e.g., vegetable peelings, cheese whey, distillery solids) are acceptable. Unacceptable contaminants (e.g., glass, metals, plastics) should be removed before digestion.		
Typical operating capacity (tonnes per year SSO)	10,000 to 100,000	3,000 to 250,000	3,000 to 250,000
Retention time (i.e., typical active composting time)	14 to 30 days	14 to 30 days	14 to 40 days
Leachate production	Lowest	Intermediate	Highest
Net energy production (kWh/tonne SSO)	Highest (170 to 250)	Intermediate (145 to 220)	Lowest (110 to 160)

Sources: Environment Canada 2013a, 6-3, 6-4, 6-5, 6-6; EREF 2015, 7, for the list of acceptable materials.

For detailed technical descriptions of different AD systems, see these resources:

- Environment and Climate Change Canada's *Technical Document on Municipal Solid Waste Organics Processing* (Environment Canada 2013a).
- Environmental Research and Education Foundation's *Anaerobic Digestion of Municipal Solid Waste: Report on the State of Practice* (EREF 2015).
- The US Environmental Protection Agency's *Types of Anaerobic Digesters* webpage (US EPA 2017a).

As previously mentioned, biogas produced from AD processing can be used as a renewable energy source. Expected biogas generation yield from AD typically ranges from 100 to 150 cubic meters (m^3) biogas per tonne MSW (wet)[20] (IGES 2013; CIWMB 2008). Table 33 describes energy potential from various food waste sources and digestion technology, while Table 34 compares estimated electricity generation from sized AD systems.

Table 33. Food waste sources, sorted by energy potential and digestion technology

Source	Energy Potential (cubic feet of methane / tonne of material)	Digestion Technology
Food and beverage production waste	Up to 4,000+	Wet

[20] Assumes 50–70 percent methane content in biogas.

Source	Energy Potential (cubic feet of methane / tonne of material)	Digestion Technology
Pre-consumer food waste	~3,000–4,000	Wet or dry (if large bulk material)
Post-consumer food waste	~1,720–2,000	Wet
Green bin /SSO	~2,280–4,000	Wet or dry (depending on screening used)
MSW	~2,800–3,000	Dry (wet, if multistage screening used)

Sources: McKiernan 2014, 2015b.

Table 34. Potential electricity generation from various AD project types

Size of AD Facility	Approximate Tonnage	Approximate Energy Production	Typical Applications
Small	Up to 7,500	25–250 kW(e)	Household or farm
Medium	7,501–30,000	250 kW–1 MW(e)	Farm or manufacturing facilities producing digestible waste
Large	30,001 or more	>1 MW(e)	Centralized, mixed feedstock sources (municipal, commercial and industrial)

Source: US EPA 2016b.

Digester effluent is often used as a liquid fertilizer or soil amendment. A valuable biofertilizer, it has many benefits:

- a source of nitrogen, phosphorous and potassium (N:P:K)
- greater availability of nutrients for crop uptake
- better soil quality and structure
- higher crop yields
- less odor
- less reliance on chemicals (i.e., financial saving)
- reduced pathogens
- potential income from sales

Digestate separation techniques include centrifuge, screw press, belt press, evaporation, bio-drying and membrane filtration (US EPA 2016b).

3.3.4 Summary of Aerobic Processing and Treatment

"Composting" refers to the decomposition of organic materials (e.g., yard trimmings, food waste, paper) by aerobic micro-organisms into humus—a usable, soil-like byproduct. Composting involves energy input and process control, but does not generate energy.[21] Like AD systems, composting systems manage the amount of moisture, amount of oxygen, and mixture of organic materials in order to achieve optimal conditions. The composting process emits heat, water vapor and biogenic carbon dioxide, reducing the raw organic materials in mass and volume (Platt and Goldstein 2014).

The composting itself takes several forms, ranging from inexpensive to capital-intensive, and composting systems have several classifications: "open vs. contained, passive vs. active, static vs. managed and onsite vs. centralized" (Platt et al. 2014, ES-2). Table 35 describes the various types of composting, as based on passively aerated or turned and actively aerated systems.

Table 35. Types of Composting Systems

Passively Aerated and Turned Composting Systems	• **Static pile:** no holding structure; material in pile allowed to decompose with little or no mixing/turning. • **Bunker:** structure (i.e., three-sided stall) typically composed of concrete, holding material pile. • **Windrow:** long row (usually multiples) of low-piled material that is regularly turned—either manually or mechanically—for aeration. • **Turned mass bed:** variation of windrow system that relies on a specialized mechanical turner. • **Passively aerated windrow (PAW):** hybrid of static pile and windrows of material, over a network of perforated pipes for aeration without manual turning.
Actively Aerated Composting Systems	• **Aerated static pile (ASP):** air forcibly pushed or pulled through compost pile, with agitation occurring only when piles are combined or moved to a different area for curing.[a] • **Enclosed ASP (i.e., tunnel):** improvement on bunker-style that uses below-floor aeration. • **Static container:** type of in-vessel system that relies on multiple containers (i.e., vessels). • **Agitated container:** operates on a continuous-flow basis through a container (i.e., vessel) with automated material-handling. • **Channel:** turned windrow piles managed indoors, with material loaded into one end of the channel and moved down length of channel (i.e., turned) mechanically. • **Agitated bed:** similar to turned mass bed system, with higher degree of automation. • **Rotating drum:** material is placed in a steel drum positioned on a slight incline and rotated to move materials from in-feed to discharge end.

[a] Compost Council of Canada n.d.-a.
Source: Environment Canada 2013a, other than as noted.

In the mix of organic materials, the proper ratio of carbon to nitrogen[22] must be maintained; as well, moisture and temperature need to be monitored. Depending on the process, composting can take a couple of weeks to several months to complete (Miller and Germain 2016). In colder climates, in

[21] There is ongoing research and demonstration projects looking at harnessing heat produced during the composting process to use to warm greenhouses, barns or homes, on a small, non-commercial scale (Gorton 2012; Smith and Aber 2014).

[22] For optimal composting (i.e., efficient material breakdown), feedstock should comprise about 25 to 30 times more carbon (C) than nitrogen (N). That is, the target ratio of carbon to nitrogen (C:N) is 25–30 to 1, expressed as 25–30:1. Food waste has a C:N ratio of 15:1; leaves have a ratio of 55:1; and woodchips have a ratio of 200:1 (EREF 2015, 3-11).

particular (e.g., northern Canada), the typical composting process might take upwards of 6 to 12 months to complete (Environment Canada 2013a, 5–8). Some experts also advise covering compost piles with an insulating layer of wood chips or completed compost to retain heat (Yee 2009).

Tables 36 and 37 provide additional characteristics associated with passively aerated or turned compost systems and actively aerated compost systems.

Table 36. Characteristics of Passively Aerated and Turned Composting Technologies

Characteristics	Static Piles	Bunkers	Windrows	Turned Mass Beds	Passively Aerated Windrows (PAWs)
Facility					
Relative space requirements (i.e., facility siting/design)	High	Medium to high	Medium to high	Medium to high	High
Relative construction costs (e.g., infrastructure)	Low	Low	Low to medium	Low to medium	Low
Common supporting equipment	Front-end loaders, skid-steers, farm tractors or excavators	Skid-steers or small front-end loaders	Front-end loaders, towed or self-propelled straddle-type windrow turners	Specialized windrow turners	Skid-steers or small front-end loaders
Electricity requirements	None	None	None	None	None
Relative operating and maintenance costs	Low	Low	Low to medium	Low to medium	Low
Process					
Acceptable/unacceptable materials	Suitable for leaf and yard waste, brush, and wood residuals; not suitable for grass trimmings or food waste	Suitable for leaf and yard waste; not suitable for food waste	Suitable for leaf and yard waste; can be used for food waste and biosolids but not recommended, due to odors	Suitable for leaf and yard waste; less suitable for food waste and biosolids	Suitable for leaf and yard waste; not suitable for grass trimmings or food waste
Typical processing capacity (tonnes per year SSO)	Less than 10,000	Less than 500	500 to 50,000	15,000 to 50,000	Up to 10,000
Retention time (i.e., typical active composting time)	2 to 3 years	2 to 6 weeks	3 to 12 months*	3 to 12 months	1 to 2 years
Level of odor control	Low	Low	Low to medium	Low to medium	Low
Leachate management (i.e., leachate quantity)	Low	Low	Low	Low	Low

* As few as 3 to 4 months during the summer or in warmer climates; as many as 6 to 12 months during the winter or in colder climates (Environment Canada 2013a, 5–8).*
Source: Environment Canada 2013a, 5-2.

Table 37. Characteristics of Actively Aerated Composting Technologies

Characteristics	Aerated Static Pile (ASP)	Enclosed ASP (Tunnels)	Containerized ASP (Static and Agitated)	Channel	Agitated Bed	Rotating Drum
Facility						
Relative space requirements	Low to medium	Low	Low to medium	Low to medium	Low	Medium to high
Relative construction costs	Medium	High	High	Medium to high	High	High
Common supporting equipment	Mechanical winders to place/remove covers	Front-end loaders	Specialized lifting system for containers	Front-end loaders, specialzed turning mechanism (e.g., conveyor, rotating drum)	Bridge crane and suspended auger turning mechanism	
Electricity requirements	Low to medium	Medium	Medium to high	Medium to high	Medium to high	High
Relative operating and maintenance costs	Low to medium	Medium to high	Medium to high	Medium	High	Medium to high
Process						
Acceptable/unacceptable materials	Leaf and yard waste, food waste, animal mortalities and manure, biosolids, industrial composting	Leaf and yard waste, food waste	Leaf and yard waste, food waste	Leaf and yard waste, food waste	Leaf and yard waste, food waste (particulrly in high proporations)	Leaf and yard waste, food waste
Typical processing capacity (tonnes per year SSO)	Less than 1,000 to more than 100,000	10,000 to more than 100,000	300 to 30,000 (static), 100 to 15,000 (agitated)	15,000 to 100,000	15,000 to more than 100,000	1,000 to more than 100,000
Retention time	2 to 8 weeks	2 to 4 weeks	2 to 4 weeks	2 to 4 weeks	3 to 4 weeks	1 to 7 days
Level of odor control	Medium to high	High	High	High	High	Medium to high
Leachate management	Low to high	Medium	Low to medium	Low	Medium to high	Low

Source: Environment Canada 2013a, 5-3.

Turned windrows (i.e., organic materials piled in rows that are turned periodically to maintain aerobic conditions and cure the product) are the most common composting systems used in North America, thanks to their low capital (e.g., site improvements, equipment) and operating costs (e.g., labor, vehicle fuel, equipment maintenance), as well as the wide variety of materials that can be accepted/processed (i.e., suitable for larger volumes of organic materials, including yard/green waste and food waste).

Challenges to wider adoption of composting organic waste include (but are not limited to) the following:

- As with AD, it can be difficult to secure long-term, reliable feedstocks.
- Incoming feedstocks can be contaminated (e.g., plastics, and products marked "biodegradable" may not be compostable).
- It can be difficult to find markets for compost products.
- Markets require high product quality, but quality is feedstock-dependent.
- Market demand or grade of compost can be verifiable and/or locally driven.
- Siting can be an issue, because composting generally requires a large footprint and increased vehicle traffic. Often, siting composting operations where infrastructure, such as a landfill, already exists can offer advantages, since neighbors may be accustomed to potential odors and traffic (Karidis 2016).
- Odors and volatile organic compounds can be problematic without proper controls such as biofilters (typically composed of a layer of mulch that exhaust gases pass through), or synthetic caps. Without proper controls, several composting operations have closed or stopped accepting food waste as a result of odor complaints (e.g., Delaware, New York City) (Karidis 2016).
- Layers of local, state and federal regulations and air-, solid waste–, or water-related permitting requirements can be complex (see the US Composting Council's map of State Compost Regulations for examples of composting permits, laws or regulations—US Composting Council 2017), and policies and incentives (e.g., diversion goals) can be lacking.

For technical descriptions of the various composting technologies, see these resources:

- *Technical Document on Municipal Solid Waste Organics Processing* (Environment Canada 2013a).
- *Composting Processing Technologies* (Compost Council of Canada n.d.-a).
- *Compost Production Manual* (*Manual de Elaboración de Composta*) (Ortiz Cuara n.d.).
- *Compost Production* (*Elaboración de Composta)* (Sagarpa n.d.).
- *Manual for Municipal Composting* (*Manual de Compostaje Municipal*) (Rodríguez Salinas and Córdova y Vázquez 2006).
- *Types of Composting and Understanding the Process* (US EPA 2017b).

3.3.5 Co-digestion of Organic Waste

Co-digestion occurs on farms or at WWTPs/WRRFs through the addition of high-strength wastes to AD to break down various types of organic waste (e.g., manure; food waste; fats, oils and grease [FOG]). Organic wastes that can be processed using co-digestion with manure include: "restaurant or cafeteria food wastes; food processing wastes or byproducts; fats, oil and grease from restaurant grease traps; energy crops; and crop residues" (AgSTAR 2016). The main benefit of co-digestion projects is that they can use existing assets and infrastructure. This makes for a more efficient use of process equipment, and costs are shared when the processing of multiple waste streams is combined in one facility. The added waste can be used to fill the capacity of anaerobic digesters or biogas utilization equipment. Other benefits of co-digestion include greater destruction of volatile solids, and higher biogas production rates (Canadian Biogas Association 2015).

Co-digestion of food waste, in particular, can increase biogas production (see Table 33 on energy potential from food waste sources). Accepting food waste for co-digestion improves biogas yields because food waste has a percentage ratio of volatile solids to total solids of over 80 (Linville et al. 2015). In addition, wastewater treatment generates biosolids (nutrient-rich organic materials) that can be used in a variety of applications: land application as fertilizer, composting, mine reclamation, alternative daily cover for landfill, and gasification for energy. A 2007 study conducted in the northeastern United States found that 55 percent of biosolids were applied to soils for agriculture and land restoration purposes, while the remaining were primarily combusted with or without energy recovery or landfilled (NEBRA 2007).

Co-digestion Assessment Tools

The US EPA created the "Waste to Biogas Mapping Tool" (<www3.epa.gov/region9/biogas/purpose.html>), an interactive map created to connect organic waste producers (e.g., grease-rendering facilities, food-processing facilities) and potential users for co-digestion with biogas recovery. The US EPA also developed the Co-Digestion Economic Analysis Tool (<https://archive.epa.gov/region9/organics/web/html/index-2.html>) to assess the initial economic feasibility of food waste co-digestion at WWTPs/WRRFs, for biogas production.

Despite its benefits for increased biogas production, co-digestion increases challenges to pre-treatment (e.g., screening for contaminants) and processing (e.g., need for additional water). Table 38 lists the pros and cons of food waste co-digestion in existing WWTP/WRRF biosolids digesters.

Table 38. Pros and cons of food waste co-digestion at WWTPs/WRRFs with AD

Pros	Cons
• Uses existing infrastructure • Can generate revenue via tipping fees and sale of biosolids (soil amendment, farm application as fertilizer) • Increases biogas production and potential revenue stream(s) or savings • Reduces facility's energy costs and carbon footprint • Is a sustainable option for organic waste management	• Requires collaboration among multiple agencies and/or services (e.g., haulers) • May require more storage (tank) and infrastructure, to accept food waste • Involves more operation and maintenance (e.g., preparation/handling, carbon:nitrogen ratio imbalance, increased ammonia emissions) • Introduces potential system disruptions from contaminants • Increases truck traffic

Sources: Fillmore 2015; Linville et al. 2015.

A definitive source on the pros and cons associated with co-digestion of food waste in on-farm digesters could not be found, but it is anticipated they are many of the same ones listed above (e.g., existing infrastructure, increased truck traffic). Research also shows that additional studies or pilot tests must be conducted to determine the compatibility of feedstock with the various types of manure (e.g., poultry, cattle, swine) to be processed.

Multiple jurisdictions in the United States, such as Los Angeles (California), Philadelphia (Pennsylvania) and Des Moines (Iowa), have implemented co-digestion projects. In Canada, co-digestion of organic waste at WWTPs/WRRFs is not common, though many municipalities across the nation are encouraging it. One example is the Organic Waste Reclamation Centre in Saint-Hyacinthe, Quebec, which uses a co-digestion stream of curbside and local dairy-industry organic wastes, and waste biosolids from a WWTP/WRRF digester to produce RNG. The municipality hopes to eventually generate enough RNG to power its entire fleet and be independent of the unpredictable fuel rates (Solid Waste & Recycling 2016).

> The recent ReFED report estimated WWTPs/WRRFs with digesters, in the US, could divert an additional 1.5 million tonnes of food waste by 2026.
>
> Source: Miller and Germain 2016.

In Mexico, municipal wastewater treatment co-digestion is not commonly used to process organic waste. The method represents untapped potential for increasing organic waste diversion to appropriate facilities (i.e., WWTPs with digesters and capacity to accept organic waste). For example, certain municipal wastewater treatment facilities may only operate at half capacity (see the Atlacomulco biodigester[23] description in Table 44). However, there are examples of organic waste processing in the ICI sector (usually at the facility level). Grupo Delta operates a co-digestion program that processes animal manure, wastewater and viscera from a local slaughterhouse and gardening waste from a strawberry farm. After harvesting, foliage is incorporated into the soil or used as a source of carbon in other composting sites within the farm. Viscera are taken to an isolated site and composted; once this process is finished, the product is analyzed for nutrient value and applied to the crops. Excess compost is sold to other local farmers. In the slaughterhouse, a covered lagoon biodigester has been installed and the resulting biogas is used in boilers for heating. In the future, Grupo Delta anticipates it can commercialize the humus and fertilizer from its composting and biodigester efforts.[24]

Co-digestion of organic waste with agricultural waste and manure is much more common in Canada. Three farm-based biogas plants are Petrocorn Inc., Kirchmeier Farms, and Maryland Farms, in Ontario. These projects together produce enough electricity to power the equivalent of 1,500 Ontario homes, and divert approximately 27,000 tonnes of organic waste from landfills. All three farms received C$400,000 of funding through the Ontario Government’s Ontario Biogas System Financial Assistance Program in 2010 (Fredericks 2010).

3.4 Organic Waste Processing and Treatment in North America: Infrastructure, Capacity, and Opportunities

As previously noted, there are similarities in how the North American countries process organic waste but each nation has unique capacities and opportunities, given geography (e.g., urban versus rural areas), infrastructure, and program/policy evolution (i.e., lessons learned). For example, the information presented in this section indicates that the United States reportedly has 25 times the number of composting facilities as Canada, which likely has two to four times as many as Mexico. Less is known about the extent to which AD is used to treat organics in all three countries (i.e., there are no centralized databases and/or volume-based studies), although US AD efforts outpace those of Canada and Mexico. This section explores the unique situations within each country (accompanied by

[23] “Biodigesters” is a term normally used to describe anaerobic digesters in Mexico.

[24] Álvarez Figueroa, M., head of Environmental Department, Grupo Delta, personal communication, January 2017.

country-specific examples or projects), as well as the shared key components/considerations for successful organic waste processing facilities in North America (e.g., quantity/quality of materials received and produced, operating costs).

3.4.1 Canada

Government agencies, associations, private companies, and others have published information on organics treatment and processing infrastructure in Canada. While less is known about industrial uses such as rendering, this section presents available information on industrial uses, AD, and composting across Canada.

Industrial Uses

The NRA estimates that there are more than 30 rendering facilities in Canada (NRA 2017). Canada produces 2.5 billion kilograms of animal byproducts annually. Rothsay, a well-known Canadian rendering company, estimated that landfill disposal of animal byproducts would fill existing landfills within four years. It was also estimated that incineration would cost the food industry C$2 billion annually if used in Canada (Rothsay 2009).

Markets for end-products of animal rendering include aquaculture, biodiesel, edible and non-edible fats, pet food ingredients, and protein meals. The aquaculture market, for example, uses feather meal (a byproduct of processing poultry feathers) in fish food. Biodiesel can be used as diesel fuel or heating oil. Edible fat and oil products include lard and shortening, used to enhance flavor of food products. Non-edible fat and oil products include animal vegetable feed, a blend of fats typically used in poultry and livestock feed (Rothsay 2009).

Indusrial Uses: Rendering Across North America

As of 2015, there were about 300 rendering facilities in Canada and the United States, which handled animal byproducts from nearly 100 million hogs, 35 million cattle and 8 million chickens annually (Cooper 2014). In 2014, Mexico raised 528 million poultry (for both meat and egg production), 33 million bovines, 16 million pigs and 17.3 million sheep and goats; some of these were processed through the roughly 100 rendering plants. The volume of recycling and/or byproducts is unknown (SIAP-Sagarpa 2015).

Anaerobic Digestion

There are more than 200 facilities processing MSW organics in Canada, of which eight are AD facilities (see Appendix A). The City of Toronto developed the first AD facility: the Dufferin Organics Processing Facility, a 25,000-tonne pilot facility built in the early 2000s. The City is currently expanding the pilot facility so that it can process up to 55,000 tonnes of SSO material annually. Next, in 2014, the City built a 75,000-tonne facility called the Disco Road Organics Processing Facility—the most advanced SSO AD facility in North America, using state-of-the-art technology (City of Toronto 2017b).

Canada has seen a growing interest in AD facilities, following Toronto's lead, with its two facilities; the private sector has developed two more facilities in Ontario and another in British Columbia. Another facility is currently under construction in Surrey, British Columbia. Drivers for these facilities have included:

- a need to deal with more contaminated feedstock from the residential and ICI sectors (plastics);
- a need to make the programs as convenient to the users as possible, to increase diversion;

- the ability to produce biogas or RNG and realize revenue from energy production and/or carbon trading;
- the ability to reduce GHGs; and
- smaller footprints for facilities, greater odor control and the ability to locate facilities closer to the feedstock in the metropolitan areas (Davis 2014).

The Surrey facility is being developed to handle 115,000 tonnes of material. The city is expected to deliver less than half of this tonnage, with the private-sector company that is building and operating the facility having to find the remaining feedstock to fill the facility. Both the Regional Municipalities of Peel and Durham are looking at developing AD facilities. Both projects are in the planning phase.

In Quebec, Quebec City is planning a new facility, which will include organics from residences, the ICI sector, and sewage sludge. The facility is planned to handle 182,600 tonnes of material annually.

Following is a snapshot of the two Toronto facilities mentioned above.

Disco Road and Dufferin Organics Processing Facilities, Toronto, Ontario

Toronto is Canada's largest city, with a population of 2.8 million. Currently, the city has a waste diversion rate of 52 percent and a target of 70 percent diversion. It has two organics processing facilities: the Disco Road Organics Processing Facility (DROPF) and the Dufferin Organics Processing Facility (DOPF).

The DROPF began operation in 2014; it can process about 83,000 tonnes of residential SSO each year.

The DOPF originally opened in 2002 as a pilot project, with the capacity to process about 25,000 tonnes of SSO annually. It is now being expanded, and will be able to process approximately 55,000 tonnes upon completion. After the expansion of the DOPF, Toronto will be able to process nearly 130,000 tonnes of SSO collected from single-family and multi-family households each year.

Source: Gorrie 2015.

Composting

The majority of composting operations in Canada started with very simple, outdoor windrow facilities for leaf and yard waste. These facilities were inexpensive, easy to operate and without significant odor issues. The introduction of other organic feedstocks (SSO, biosolids) created a need for more odor control, and technology began to change to meet this need—aerated static pile, covered systems and in-vessel systems were added.

The evolution of the organic waste industry in Canada has many drivers, and they differ from province to province. In Nova Scotia, a landfill ban on organic material in 1997 initiated the growth of the organic waste industry. In other jurisdictions, provincial policy statements outlining diversion targets of 60 percent helped grow the demand for organic waste management, and dwindling landfill disposal capacity has forced municipalities to divert more material from disposal. One of the key drivers for the larger metropolitan cities in Canada to divert organics is a combination of public opposition to disposal and a lack of available disposal capacity (Davis 2014).

The compost produced from the open-windrow and in-vessel systems is typically used in the following markets:

- horticulture

- landscaping
- agriculture
- remediation

The end-uses vary from province to province and facility to facility, depending on the local market conditions.

The growth of the organic waste industry has not happened overnight, and many lessons have been learned along the way. In the early days of SSO processing via in-vessel systems, odor issues resulted in facilities being shut down. The next-generation facilities took these issues into consideration during design.

The successful organic waste management programs in Canada use the technology that best fits the type and quantity of feedstock they are processing. Given the diversity of the country, from major metropolitan centers to small villages and rural areas, no one solution fits all. Given the number of programs across the country, there is a wealth of information available to continue to grow the amount of organics diverted.

At present, Canada has over 200 composting facilities. Of these facilities, 62 percent are municipally owned. Table 39 breaks down the composting facilities by ownership type as private, public (i.e., municipal) or private-public partnership.

Table 39. Composting facilities by ownership in Canada

Ownership	Number of Facilities (Percent of Total)
Private facilities	65 (31.6)
Municipal facilities	127 (61.6)
Public-private partnerships	14 (6.8)

Source: Green Manitoba 2013.

As Table 40 shows, Canada's composting facilities have about 4.2 million tonnes of available approved processing capacity. They currently accept 2.6 million tonnes of organic waste annually, so 62 percent of the overall capacity is currently being used.

Table 40. Organics processing capacities of composting facilities in Canada

Waste Volume	Tonnes per Year
Accepted	2,649,858
Capacity	4,242,251
Percentage	62.46

Source: Green Manitoba 2013.

The composting facilities accept four different types of feedstock material: yard waste, residential SSO, ICI organics, and biosolids from the wastewater treatment process. Many of the facilities accept more than one type of feedstock material; therefore, the percentages processed add up to more than 100 percent. Table 41 breaks down accepted feedstock material at Canadian compost facilities.

Table 41. Feedstock accepted at compost facilities in Canada

Type of Feedstock	Compost Facilities Accepting Feedstock	Percent of Total
Yard waste	166	81.4
Residential SSO	72	35.3
ICI organics	28	13.7
Biosolids	31	15.2

Source: Green Manitoba 2013.

Out of the more than 200 facilities, 166 (or 81 percent) accept leaf and yard waste as a feedstock material, 35 percent accept SSO, 14 percent accept ICI organics and 15 percent accept biosolids.

There is no central database listing all these facilities by technology used, tonnes approved or tonnes processed. Snapshots of some representative composting facilities—for which the processing system type and processing amount are known—appear below. Appendix A provides other details on key Canadian facilities.

Organic Waste Processing Facility, Guelph, Ontario

The City of Guelph opened an organic waste processing facility in 2011 at the Waste Resource Innovation Centre. The facility is designed to handle 30,000 tonnes of organic material annually. Since the City currently produces only 10,000 tonnes of organic waste annually, this facility's capacity allows for future population growth. Until then, the City receives organic waste from nearby municipalities, to reduce operating costs. The facility uses new, aerobic in-vessel composting technology, which requires less energy and generates fewer GHG emissions.

The City's Solid Waste Management Master Plan laid out the following diversion targets: 55 percent by 2011, 65 percent by 2016 and 70 percent by 2021. In 2012, Guelph had a diversion rate of 68 percent, making Guelph's the highest diversion rate in Ontario.

Source: City of Guelph 2015.

Goodwood Composting Facility, Halifax, Nova Scotia

In 1999, Halifax opened a composting plant called New Era Farms, also known as Goodwood Composting Facility. This facility (privately owned by New Era Farms) can process 25,000 tonnes of organic waste annually.

This facility has had a successful run and is said to have an estimated remaining useful life of another 10 to 15 years. As the system is aging, Halifax is looking into investing in and sustaining its organic waste management system to meet future demands. Currently, there are no plans to continue operating this facility after 2019.

In 2007, the province had a waste diversion target of reducing the amount of waste disposed of per person to 300 kilograms annually. Although progress has been made since 2007, during which time each person disposed of 430 kilograms of waste, it's estimated the rate is still over the 300-kilogram goal (i.e., that it is 380 kilograms annually). The government legislated this target in the province's 2007 Environmental Goals and Sustainable Prosperity Act.

Sources: Compost Council of Canada 2016a; Government of Canada 2015; Halifax Environment and Sustainability Standing Committee 2016; Nova Scotia Department of the Environment 1999; Ward 2016.

Low tipping fees for landfill in parts of Canada are an obstacle to implementing new waste management solutions. Landfills in Canada are owned by private companies or municipalities/regions. Tipping fees are established by the landfill owners; there are no jurisdictional policies on tipping fees (CCME 2014). These fees can be very low in Canada due in part to the competitiveness of the landfill industry. Private landfills and municipal landfills can directly compete with each other—resulting in a "race to the bottom for low tipping fees" (Alberta Government 2014).

A 2014 report by the CCME entitled *State of Waste Management in Canada* found that low tipping fees are a fact in some Canadian jurisdictions and that this promotes disposal over diversion (CCME 2014). Where tipping fees are low, municipalities and ICI generators may opt to landfill rather than divert their waste because it is the least expensive option. This is especially the case in the absence of provincial or federal direction, including funding incentives or regulatory requirements (CCME 2014).

Composting facilities compete with landfills for organic waste but are often unable to offer tipping fees as low. In Alberta, for example, landfill tipping fees have been reported as low as C$25 per tonne, whereas the cost of developing and operating a small, windrow composting plant was estimated at C$50 to C$60 per tonne (Alberta Government 2014). Not only does this discourage diversion, it is also a disincentive for private investors to establish new composting facilities. Composting facilities are costly to build and not an economically viable option if landfill tipping fees remain low (Alberta Government 2014). Further compounding the problem, the landfill industry in Alberta has long had the added advantage of infrastructure subsidies. Alberta subsidized its waste management and recycling sector for decades, providing grants for infrastructure to the tune of C$66 million from 1976 to 2006 through its Waste Management Assistance Program. A similar initiative, the Resource Recovery Grant Program, was issued for recycling projects and composting (providing C$9.5 million) but it has been defunct for many years (Alberta Government 2014). As a result of the low landfill tipping fees and lack of incentives or subsidies for organic waste diversion, private composting facilities are not common in Alberta (Alberta Government 2014).

3.4.2 Mexico

Information on the processing and treatment of organic waste capacity in Mexico is limited. According to INEGI (2016c), Mexico treated an average of 2,750 tonnes/day of residential waste, about 4 percent of all collected waste in Mexico. Table 42 shows the number of municipalities with treatment facilities for MSW and organic waste, for selected states and Ciudad de México. It also shows the percentage of organic waste treated compared to average daily collection.

Table 42. Number of municipalities with waste treatment facilities in Mexico states, 2012

State	Number of Munici-palities with MSW Treatment Facilities	Number of Munici-palities with Organic Waste Treatment Facilities	Average Daily Collection (tonnes)	Average Daily Organic Waste Sent to Treatment (tonnes)	Fraction of Organic Waste Sent to Treatment Compared to Waste Collected (%)
Aguascalientes	1	1	787	67	8
Chiapas	3	2	2,279	25	1

State	Number of Munici-palities with MSW Treatment Facilities	Number of Munici-palities with Organic Waste Treatment Facilities	Average Daily Collection (tonnes)	Average Daily Organic Waste Sent to Treatment (tonnes)	Fraction of Organic Waste Sent to Treatment Compared to Waste Collected (%)
Chihuahua	2	1	4,103	<1	0
Guanajuato	4	3	4,107	12	<1
Guerrero	1	1	2,475	<1	0
Hidalgo	1	1	1,642	<1	<1
Jalisco	14	14	7,184	21	<1
Estado de México	4	4	12,017	26	<1
Ciudad de México	16	16	17,441	2,374	14
Michoacán	8	7	3,835	19	<1
Morelos	5	5	1,300	47	4
Oaxaca	26	26	2,077	55	3
Puebla	5	3	3,623	1	<1
Querétaro	4	4	1,475	6	<1
Tabasco	1	1	1,629	82	5
Tamaulipas	1	1	3,210	2	<1
Veracruz	5	5	5,405	5	<1
Yucatán	2	2	1,154	<1	<1
Zacatecas	2	2	1,179	6	<1
National	117	99	76,923	2,749	4

Source: INEGI 2014.

Currently, at a national level, the 2009–2012 PNPGIR supports efforts to encourage greater organic waste diversion and processing:

- strengthening technical and financial institutional capacity at the three levels of government through training and professional development, to foster improved waste management capacity;
- promoting the creation of legal and economic instruments to incentivize and protect the internal markets, boost investment in infrastructure and human capital, and facilitate access to funding;
- applying waste reduction principles in all phases of waste management, to induce generation reduction, increase recycling and decrease final disposal;

- promoting financial systems to build the infrastructure needed to use all types of waste—for treatment and energy recovery—with the participation of all sectors of society and through private finance initiatives or public-private partnerships;
- integrating initiatives from civil society, private-sector companies and professional organizations with the actions of different levels of government, to create synergies and improve results;
- integrating financial strategies on waste management with those for the control of greenhouse gases from final disposal sites, using incentives in the Kyoto Protocol as a financial resource; and
- designing indicators to assess the environmental performance of integrated waste management systems at a national level.

Industrial Uses

The Secretariat of Agriculture, Livestock, Rural Development, Fisheries and Food (*Secretaría de Agricultura, Ganadería, Desarrollo Rural, Pesca y Alimentación*—Sagarpa) is the main federal agency that regulates and controls slaughterhouses, rendering plants, and animal-byproduct trading companies, which it does through the National Service of Health, Safety and Food Quality (*Servicio Nacional de Sanidad, Inocuidad y Calidad Agroalimentaria*—Senasica). As of January 2017, the Senasica registry shows 98 rendering plants—of which 93 process carcasses and five process blood and fat—and 29 trading companies that produce animal flour (Senasica 2017a, 2017b, 2017c).[25] Animal rendering operations are growing and represent a viable option for waste management, as well as increased revenue for the food processing industry. The main use of protein-related byproducts from rendering facilities is animal feed. According to the Mexican Association of Food Producers (*Asociación Mexicana de Productores de Alimentos*), in 2013, Mexico was the world's fourth-largest producer of animal feed (29 million tonnes). More than half of the feed produced was for the poultry industry, 16 percent for pigs, 27 percent for cows and 3 percent for dogs and cats (Ortiz Soto 2015).

Culinary traditions and livestock characteristics also create differences in the quantity and type of byproducts generated in Mexican slaughterhouses, compared to those in other countries. In a cattle slaughterhouse, for example, the only remaining byproducts are blood, horns and hooves, since the head and viscera—which would usually be considered byproducts in other countries—are commercialized for human consumption in Mexico (Mendizábal Acebo 1997).

Anaerobic Digestion

Mexico started investing in biodigesters (i.e., farm-based anaerobic digesters that use manure as feedstock) in the late 1990s. Between 2002 and 2005, taking advantage of the Clean Development Mechanism (CDM) under the Kyoto Protocol, the country had one of the highest numbers of methane-capture projects in the world. However, financial and technical shortcomings stalled this initial progress (IRRI México 2010).

Several other programs have emerged that provide technical and financial support to develop AD systems in different settings. The Strategic Program of Food Security (*Programa Estratégico de Seguridad Alimentaria*), launched in 2005 in collaboration with the UN Food and Agriculture Organization, is aimed at marginalized communities in Mexico and has been an important driver to advance the use of different ecological technologies, including biodigesters. The program's main

[25] Despite the number of rendering plants, records of plant capacity and/or other relevant information about market opportunities (e.g., industrial uses) were not available.

objective is to increase food security and generate income for communities and households by making use of available resources, as well as providing technical support and training. This program currently operates in 23 Mexican states (IRRI México and Tetra Tech 2015).

Sagarpa also supports AD and biogas use, through the Shared Risk Trust Fund (*Fideicomiso de Riesgo Compartido*—Firco). This fund supports agribusiness projects that use animal manure for electricity generation, via the Added Value to Agribusiness Support Project (*Proyecto de Apoyo al Valor Agregado de Agronegocios*—Provar). Provar provides 50 percent of the biodigester's cost (up to P$1 million) and 50 percent of the generator's procurement/installation costs (up to P$250,000) (Semarnat 2013a). In 2010, Firco carried out a study that involved 345 surveys at 327 swine and 18 dairy farms, to observe the biodigesters' status. All of the biodigesters had been fully built (mostly anaerobic lagoons), but only 283 were operational (the rest had not yet started operations). The main issues with the non-operational systems were oversized design, agitation system and/or burner failure, lack of frequent maintenance, and/or simply the owners' unfamiliarity with the technology. Based on these results and other official records, Firco estimated that about 367 biodigesters were operational and 354 were still in construction, for a total of 721 (Sagarpa, Semarnat, and Firco 2010).

More recently, IRRI México updated Firco's 2010 estimates. According to the IRRI 2015 study, Mexico's biodigester count had reached 2,167 as of September 2014; of these, 317 were financed through Firco (IRRI México, and Tetra Tech 2015). This is fairly consistent with Firco's most recent records, which show that 360 biodigesters and 170 motogenerators have been built through Provar or other similar programs between 2008 and 2014 (Firco 2016). It was estimated that 60 more biodigesters would be added in 2017, for a total of nearly 500 biodigesters supported by Firco. Other AD projects are supported by *Nacional Financiera* and the agriculture-related Trust Funds (*Fideicomisos Instituidos en Relación con la Agricultura*), but these are not included in current estimates.[26]

Table 43 provides information on the types of biodigesters used at different scales (i.e., size) and for different purposes.

Table 43. Digesters in Mexico

Scale (size, in cubic meters)	Location	Type	Fuel Uses	Primary Funding Source(s)	Number of Digesters
Up to 25 m^3 (Domestic)	Backyard farms in rural communities	Tubular polyethylene modular continuous flow	Heating water or cooking (displacing liquefied petroleum gas and wood consumption)	Poverty alleviation mechanisms, foundations or social initiatives	799

[26] Macías Solís, M., Firco, personal communication, 2017.

Scale (size, in cubic meters)	Location	Type	Fuel Uses	Primary Funding Source(s)	Number of Digesters
Larger than 25 m^3 but smaller than 1,000 m^3 (Productive sector)	Small to medium-size farms	Tubular polyethylene modular continuous flow (lower end, larger than 25 but smaller than 400 m^3) or covered lagoon type (between 400 and 1,000 m^3)	Mostly cooking or heating, but larger systems send the methane to a biogas burner (displacing liquefied petroleum gas)	Government programs for promotion of livestock sector	109
Larger than 1,000 m^3 (Industrial sector)	Large-scale dairy or pork farms	Covered lagoons	Most users do not use biogas other than for burning methane, although some users have invested in electricity generators[27]	Typically Firco or CDM financing mechanisms, with increasing participation of private investors seeking to sell Certificates of Emission Reduction	1,259

Source: IRRI México and Tetra Tech 2015.

In recent years, other Mexican agencies, including the Mexico City Secretariat of Science, Technology and Innovation (*Secretaría de Ciencia, Tecnología e Innovación de la Ciudad de México*—Seciti), have funded the biodigester projects described below.

Milpa Alta Biodigester

Located in the Cactus Vegetable Collection Center in Mexico City, Milpa Alta is one of the region's main cactus producers (about 400,000 tonnes/year). The Milpa Alta biodigester was launched in 2015 with funding from Seciti. The objective is to process organic waste from cactus (*nopal*) preparation and sale. The plant's installation is concluding and startup tests are underway.

Source: Delegación Milpa Alta 2016.

Pilot Biodigester

As a pilot project, the National Autonomous University of Mexico (*Universidad Nacional Autónoma de México*—UNAM) built a small biodigester with an anaerobic reactor and three dry biodigestion tanks, as well as waste conditioning and electricity generation facilities. The plant's

[27] Some generators do not deliver at their potential, due to frequent technical failures and high downtimes.

capacity was 600 kg/day of residential organic waste. It was funded by the National Science and Technology Council (*Consejo Nacional de Ciencia y Tecnología*) and Seciti, with a total budget of roughly P$36 million. A progress report (Durán Moreno n.d.) indicates the objective is to increase the plant's capacity so it can process up to 1,000 tonnes/day. However, the report also states that electricity generation has not yet been attained, because the methane content in the biogas has always been lower than the 50 percent needed for the generator to work properly.

Source: Durán Moreno n.d.

Table 44 summarizes biodigestion projects funded by the Secretariat of Environment and Natural Resources (*Secretaría de Medio Ambiente y Recursos Naturales*—Semarnat).

Table 44. Biodigestion projects funded by Semarnat in Mexico

State	Location/ Program Description	Amount of Funding (US$)	Year Started
Aguascalientes	**Municipality of Calvillo, Asientos, San Francisco de los Romo** Technology: stage III of biodigester-co-generation project Feedstock material: waste sources not identified Capacity: 50 tonnes per day[a]	1,500,000[b]	N/A
Colima	**Municipality of Colima** Technology: biodigester (construction) Feedstock material: N/A Capacity: N/A	500,000[b]	N/A
Estado de México	**Municipality of Atlacomulco** Technology: biodigester Feedstock material: originally designed to accept food waste and oil traps from markets and restaurants Design capacity: 30 tonnes per day Actual operating conditions: 12 tonnes per day; mainly waste from slaughterhouses, due to lack of operational diversion programs within the municipality; no information available on biogas or energy output[c]	1,700,000[b]	2014
Querétaro	**Municipality of Querétaro** Technology: biodigester (construction) Feedstock material: slaughterhouse waste Capacity: no further information available	308,400[b]	N/A

Sources:
[a] Gobierno del Estado de Aguascalientes 2016.
[b] Semarnat 2015b.
[c] Clemente Reyes and Estradas Romero 2015; Sema 2015.

Composting

In 2006—as part of the cooperative framework established between Mexico and Germany—Semarnat, the National Institute of Ecology (*Instituto Nacional de Ecología*) and the German Corporation for Technical Cooperation (*Deutsche Gesellschaft für Technische Zusammenarbeit*), issued the *Manual for Municipal Composting* (*Manual de Compostaje Municipal*), which provided a detailed, still-valid account of 57 facilities (36 within Mexico City and the state of Mexico alone), covering operating capacity, location and main issues—including factors contributing to failure or success (Rodríguez Salinas and Córdova y Vázquez 2006). Using that baseline information, the manual offers guidance to municipalities on the creation and sustained operation of composting plants. Table 45 provides an overview of the main issues for municipal composting plants in Mexico.

Table 45. Main issues associated with failure or success of municipal composting plants in Mexico

Type of Issue	Factors Contributing to Failure	Elements for Success
Political	• Failure by municipal authorities to prioritize and/or provide continuity for composting projects. • Perceived corruption associated with large-scale composting plants and/or among sanitary landfill operators.	• Provide assurances and/or guarantees to all the various stakeholders (e.g., generators, collectors, processors, distributors) involved in organic waste management and compost production/use.
Economic	• Perceived high(er) cost of composting compared to organic waste disposal (e.g., landfilling). • Lack of developed markets for compost (e.g., production is higher than demand).	• Cultivate a better understanding of true waste-management costs (e.g., disposal is not free). • Emphasize potential uses, especially as soil amendments in agriculture, urban orchards and landscaping applications.
Social	• Lack of awareness and/or understanding of compost's use and benefits. • Stigma on composting due to former practices that created suspicion.	• Provide education and training on beneficial uses (e.g., improving soil condition). • Emphasize process changes or enhancements to previous practices, to help overcome stigma.
Administrative	• Distance of composting plants from landfills, organic waste sources and/or compost markets. • Lack of cooperation and/or communication among waste collection service providers and composting plant workers.	• Engage experts with proven composting experience in the planning/siting stage, technical feasibility analysis, plant design, equipment procurement, and operations/personnel training. • Emphasize the need for a collaborative relationship between collection and processing services.
Technical	• Delays caused by improper equipment or machinery, inability to obtain spare parts in-country, and insufficient process monitoring (e.g., temperature control). • Inadequate estimation of potential organic waste volumes, as well as changes in their characteristics and composition in different seasons. • Poorly segregated organics that need more sorting or produce lower-quality compost.	• Ensure there is proper equipment, access to spare parts, and process-monitoring controls, to help avoid delays and ensure timely production/delivery. • Perform more thorough technical feasibility analysis to evaluate quantity and quality of feedstocks. • Implement and maintain ongoing education on effective waste separation at the source(s).

Source: Rodríguez Salinas and Córdova y Vázquez 2006.

The 2012 Baseline Diagnosis for Integrated Waste Management (*Diagnóstico Básico para la Gestión Integral de Residuos*—DBGIR) includes some data on treatment and processing facilities (INECC and Semarnat 2013). In 2012, there were 21 composting facilities in Mexico, 11 of which were in Mexico City. Most of these facilities process gardening waste; however, the Bordo Poniente compost plant (in Estado de México) processes residential organic waste, and the facilities in Quintana Roo's tourist areas compost kitchen waste (INECC and Semarnat 2013). The report also references composting plants belonging to the Secretariat of National Defense (*Secretaría de la Defensa Nacional*), but did not provide specific locations or capacity. Information reported in the DBGIR was collected from research studies, PEPGIRs and PMPGIRs; consequently, it is heterogeneous and sometimes lacking in details on design and operation capacity. Table 46 shows the location and capacity (when available) of composting plants in Mexico as of 2012.

Table 46. Composting plants in Mexico, 2012

State	Location	Design Capacity (tonnes/year, or cubic meters)	Operational Capacity (tonnes/year, or cubic meters)
Aguascalientes	Aguascalientes	730	N/A
Estado de México	Álvaro Obregón	1,836	1,836
	Bordo Poniente	73,000	32,120
	Centro de Educación Ambiental Ecoguardas	N/A	N/A
	Centro de Educación Ambiental de Xochimilco	N/A	N/A
	Cuajimalpa	1,200	960
	CU-UNAM	—	24 m^3/day
	Iztapalapa	1,838	1,127
	Milpa Alta	1,380	1,380
	Nicolás Romero	N/A	N/A
	Unidad Habitacional Nonoalco-Tlatelolco	N/A	N/A
	Xochimilco	1,295	446
Morelos	Cuernavaca	48 m^3/day	24 m^3/day
	Others (Tepoztlán, Yautepec and Zacatepec de Hidalgo)	N/A	N/A
Quintana Roo	Fonatur, Benito Juárez	100 m^3/day	15 m^3/day
	Others (Cooperativa Orgánica del Centro Ecol. Akumal, Querétaro and Xcaret)	N/A	N/A
Yucatán	Mérida	1,200	25 m^3/hour
Various states	55 composting plants distributed all over the country (specific locations not available)	N/A	N/A

Source: INECC and Semarnat 2013.

A 2015 report identified additional composting projects sponsored by Semarnat, via a budgetary instrument called "Ramo 16," which can be used to provide grants to state and municipality authorities, to support environmental projects (Semarnat 2015b). Between 2010 and 2014, Semarnat sponsored 45 composting projects in municipalities from seven states (exclusive of those with existing composting plants, listed in Table 46), with total funding equivalent to roughly US$3 million (P$60.5 million). Biodigesters have also been supported through these programs, with roughly US$2.5 million. Table 47 summarizes these projects. State and municipal authorities are not required to report results or to develop mechanisms to ensure proper operation and maintenance of composting projects and biodigesters.

Table 47. Composting projects funded by Semarnat in Mexico, 2010–2014

State	Year: Number of Projects per Year (Funding per Year, US$)*	Number of Projects	Total Funding per State (US$)
Campeche	**2013**: 3 (284,000); **2014**: 1 (950,000)	4	1,234,000
Colima	**2012**: 1 (32,550); **2013**: 3 (87,600)	4	120,150
Guanajuato	**2013**: 1 (230,000)	1	230,000
Jalisco	**2011**: 1 (17,500); **2012**: 2 (582,300); **2013**: 3 (148,000); **2014**: 1 (22,500)	7	770,300
Estado de México	**2013**: 1 (106,000)	1	106,000
Michoacán	**2012**: 2 (100,200); **2013**: 1 (200,000)	3	300,200
Oaxaca	**2010**: 6 (137,000); **2011**: 10 (19,530)	16	156,530
Puebla	**2012**: 5 (100,000)	5	100,000
Zacatecas	**2010**: 4 (6,500)	4	6,500
Total		**45**	**3,023,680**

* Information on the current status of these projects was not available on PEPGIR or PMPGIR websites.
Source: Semarnat 2015b.

Private companies also provide composting services (see the case study below), but there is limited publicly available information (e.g., project characteristics, capacity).

Examples of Private-Sector Composting in Mexico

With more than 40 years of combined experience, Aldea Verde (located in Querétaro) and Compostamex (located in Jalisco) have provided technical support for industrial, municipal and domestic composting projects and backyard orchards in Mexico. Specific services include project conceptualization and design, location or site selection, technical feasibility, training and assistance for operators/personnel, and process adjustment.

Aldea Verde and Compostamex have collaborated to develop more than 100 industrial and/or municipal composting plants in Mexico and Central America or Caribbean countries—as well as more than 2,000 domestic and backyard orchard projects—that collectively process approximately 3,000 to 4,000 tonnes/day of organic waste. Noteworthy projects include:

- a hybrid composting/vermicomposting plant in Mexicali, Baja California, that processes more than 19,000 tonnes/year of organic waste from an orchard packaging facility;
- a composting plant at a plantation located in the intersection of the neighboring states of Chiapas and Tabasco, which handles 16 tonnes/day of bagasse, fruits and palm residuals from palm oil production; and
- a hybrid bioreactor and vermicomposting plant in Cancun, Quintana Roo, that processes between 5 and 7 tonnes/day of food and garden waste, with plans to increase plant capacity to about 15 tonnes/day.

Experts from these companies actively participate in several composting-related organizations, routinely present at composting conferences, and have been invited by Semarnat to collaborate on guidelines for the aerobic treatment of the organic fraction of urban solid waste.

Sources: Compostamex 2017; Aldea Verde 2017; Niembro, F.A., Aldea Verde, personal communication, May 2017.

3.4.3 United States

Like Canada and Mexico, data on industrial-use facilities and on processing capacity for industrial uses is limited in the United States. As described in this section, more information is available for AD and composting.

Industrial Uses

Animal byproducts in the United States are processed into manufacturing feedstocks for a variety of "pharmaceutical, cosmetic, household, and industrial products" (Marti et al. 2011, 1). According to the USDA, "estimates of total U.S. byproduct production by species are not publicly available," particularly data for byproducts sold to a single company for production into specialty products (Marti et al. 2011, 6).[28] The supply of edible animal byproducts exceeds domestic demand; these

[28] USDA's Agricultural Marketing Service reports on large quantities of byproducts sold per month, but "only those sold for human consumption or […] to multiple companies," so once again, it is not inclusive or reflective of the industry as a whole (Marti et al. 2011, 6).

byproducts account for up to one-quarter of US beef exports and nearly one-fifth of US pork exports (Marti et al. 2011, 17, 3), and so that portion of the edible components is not processed in the United States. Cattle hides produced in the United States—which account for 75 percent of that animal's inedible byproducts—are also predominantly exported to other countries for processing into leather (Marti et al. 2011). More than half of the used cooking oil collected in the United States is exported to Europe for biodiesel production (NRA 2017).

Anaerobic Digestion

It is estimated there are about 250 AD facilities in the United States.[29] Nearly all of them are farm-based systems to manage livestock and poultry manure.

Without a centralized, comprehensive annual inventory of existing organic waste processing facilities, available processing capacity is unknown. The US EPA's AgSTAR Program maintains a database of on-farm or regional digesters, some of which co-digest food waste—but the volume of materials accepted/processed is not available (AgSTAR 2016). A separate US EPA effort to identify US facilities processing food waste and/or FOG compiled a list of roughly 100 AD facilities: 38 farms (some of which are duplicate farms listed in the AgSTAR database), 25 WWTPs/WRRFs, and 41 stand-alone, multi-source or industry-dedicated digesters (US EPA 2016g). A recent study by the Environmental Research and Education Foundation (EREF) projected that the number of stand-alone AD facilities will double in the next five to 10 years, while processing capacity will quadruple in the next five years (EREF 2015). The EREF study also estimated that more than 700,000 tonnes of MSW organics were processed using AD in 2013 (nearly 400,000 tonnes in stand-alone AD facilities, more than 100,000 tonnes on farms, more than 200,000 tonnes in WWTPs/WRRFs), but the study did not provide a breakdown or a percentage of the organic materials processed (EREF 2015, 18). Other organizations or programs (e.g., the American Biogas Council, the US EPA's Combined Heat and Power Partnership) track the number of WWTPs/WRRFs in the United States, but none indicates the number of co-digestion facilities (see Table 48). According to the American Biogas Council, however, less than 2 percent of WWTPs/WRRFs using AD in the United States are engaged in food waste co-digestion (Cernansky 2014).

Given the lack of a centralized data source, it is difficult to quantify the US organic waste diversion and processing industry. Table 48 demonstrates the diversity—and difficulty—of that task for AD, particularly as it relates to accepting/co-digesting food waste, specifically.[30]

Table 48. Estimated AD facilities in the United States

Organization	Operating Digesters	Facilities Accepting/Co-Digesting Food Waste
US EPA's AgSTAR Program (2016 data)[a]	259 on-farm/regional, of which 92 indicate co-digestion	44 (source does not indicate whether pre- or post-consumer food)
US EPA's AD data collection project[b]	102 AD facilities (38 on farms, 25 at WWTPs/WRRFs, and 41 stand-alone)	All (source does not indicate whether pre- or post-consumer food)

[29] In the absence of a centralized or comprehensive database, there is no way to discern exactly how many—and which—of these facilities might process food waste from the residential and/or ICI sectors.

[30] Yard waste (e.g., leaves, grass trimmings) is "generally not well-suited" for AD (Kraemer and Gamble 2014).

Organization	Operating Digesters	Facilities Accepting/Co-Digesting Food Waste
EREF (2015 data)[c]	181: 25 stand-alone and 129 with co-digestion (75 on-farm and 54 WWTPs/WRRFs, with an additional 27 WWTPs/WRRFs likely)	154 accepting MSW organics (unclear how much food waste)
American Biogas Council[d]	1,241 WWTPs/WRRFs	N/A
US EPA's Combined Heat and Power Partnership (2011 data)	1,455 WWTPs/WRRFs	N/A

Sources:
[a] AgSTAR 2016.
[b] US EPA 2016g.
[c] EREF 2015.
[d] ABC 2017b.
[e] US EPA 2015a.

A study by the Water Environment Research Foundation (WERF) explored co-digestion of organic wastes in an effort to respond to the questions and challenges brought by greater co-digestion implementation at municipal WWTPs/WRRFs. The study included laboratory experiments on potential feedstocks and pilot-scale tests under different operating conditions (e.g., mesophilic, thermophilic) to determine degradation levels (WERF 2014). A full-scale demonstration project showed that perceived challenges were manageable and outweighed by benefits (e.g., increased biogas production and sale), but that tipping fees would likely be required to make projects economically viable. WERF developed an economic model (available for download from the WERF website for US$175) to help decision makers evaluate economic feasibility based on criteria such as waste characteristics, energy and residuals handling.

Examples of US commercial AD facilities are described below.

Zero Waste Energy Development Company, San José, California

In 2013, "the world's largest dry fermentation AD facility and the first large-scale commercial AD facility of its kind in the United States" opened in San José. Owned and operated by Zero Waste Energy Development Company, the AD facility is the result of a joint venture between GreenWaste Recovery and Zanker Road Resource Management to divert organics from landfills and convert the materials into valuable energy. Annually, the AD facility processes about 82,000 tonnes of commercial organic waste into more than 27,000 tonnes of high-quality compost, and 1.6 megawatts of renewable biogas for onsite power and sale to local green-energy users, in compliance with the state's Renewable Portfolio Standards. This AD facility will help the city achieve its zero-waste goal by 2022. This AD facility converts commercial organic waste to high-quality compost and valuable energy and helps the municipality achieve its waste reduction goals.

Source: ZWEDC 2013.

CleanWorld/Atlas Disposal Food Waste-to-RNG Facility: Sacramento County, California

Located at the Sacramento South Area Transfer Station in Sacramento County, CleanWorld operates a biodigester that can process more than 90 tonnes of food waste a day, or more than 36,000 tonnes per year. Organic waste collected by Atlas Disposal from local restaurants, grocery stores, food-processing companies and households is converted via AD into renewable compressed natural gas (CNG), electricity and fertilizer. The CNG is used to power Atlas Disposal's waste disposal vehicles—the very trucks that collect the food waste—along with school buses and other fleet vehicles throughout the Sacramento region. Some of the biogas is used to produce electricity that powers the onsite fueling station. Once the biogases are removed from the decomposing food waste, the remaining solids constitute a high-grade compost used as soil amendment.

CleanWorld's biodigester is a thermophilic, high-solids digestion system, created through a public-private collaboration with the University of California, Davis, and the California Energy Commission. The project received US$6 million in funding by leveraging the Commission's Alternative and Renewable Fuel and Vehicle Technology Program funds, as well as private investments totaling more than US$7.3 million.

The CleanWorld biodigester annually produces more than 600,000 diesel-gallon-equivalents of RNG. Life-cycle analyses by the California Air Resources Board have determined that RNG produced from food waste and used as an alternative fuel has a net negative GHG emission impact.

Sources: California Energy Commission 2017; Energy Vision 2013.

Composting

With the passage of state laws banning the landfill disposal of yard waste (see Figure 28), the number of composting facilities and collection programs greatly expanded. The US composting experience is very similar to Canada's, starting with outdoor turned piles of yard trimmings and evolving into covered or enclosed composting facilities, with heavy equipment to move the materials. The elements of maintaining a successful composting facility are similar as well. From the commercial side, several US processors emphasized the importance of analyzing organic material content (e.g., quantity, composition) before acceptance and/or imposing pre-collection criteria on providers. Iowa-based Chamness Technology, for example, generally requires commercial food products destined for composting to be de-packaged (i.e., plastic liners/wrappers removed) to control and avoid processing costs associated with screening out packaging residuals (Emerson 2015).

BioCycle periodically surveys composting facilities, most recently in a 2014 survey performed by the Institute for Local Self-Reliance. Results indicated there were about 5,000 composting operations in the United States, which equates to one facility for about 64,000 US residents, or nearly 25,000 US households (Platt and Goldstein 2014; US Census Bureau 2017). However, only about 500—about 10 percent—of those US composting facilities accepted food waste (ReFED 2016). In 2015, EREF released a report showing 3,494 composting facilities operating in the United States. In addition, the US EPA prepares an annual report called *Advancing Sustainable Materials Management: Facts and Figures* (US EPA 2016e) that includes information on MSW generation, recycling and disposal. The most recent US EPA report was issued in 2016 and includes data through 2014. The US EPA's latest report estimated that 1.76 million tonnes of food waste were diverted through composting in 2014 (US EPA 2016e, 4). Table 49 summarizes information about the estimated number of operational composting facilities in the United States.

Table 49. Estimated composting facilities in the United States

Organization	Operating Facilities
BioCycle/ Institute for Local Self-Reliance survey (2014)[a]	5,000
Environmental Research and Education Foundation (2015)[b]	3,494

Sources:
[a] Platt and Goldstein 2014.
[b] EREF 2015.

The examples below provide a snapshot of long-running (i.e., more than a decade of operating experience) and/or largest composting operators/facilities in the United States across various sectors.

Municipal Composting Facility: Mariposa County, California

Like many local and/or regional governments, Mariposa County—home to Yosemite National Park—was facing the possibility that its landfill would run out of space within the next decade. A 1998–1999 waste characterization study determined that the county's waste stream was composed of about 69 percent compostable materials. Given these results and the alternatives (e.g., hauling waste to another regional landfill or waste-to-energy facility), MSW composting at the existing Mariposa County Landfill was considered the most economical and environmentally sound option for extending the life of the landfill. Built in 2005 on a 3-acre parcel at the landfill, the composting facility covers 4,600 square meters and was designed to accept an average of 36 tonnes of MSW per day, with upwards of 54 tonnes per day during the peak season (e.g., summer park visitors). The pre-composting process includes additional recycling opportunities to remove appropriate materials via magnets, picking or sorting stations, and screens. The remaining waste is then shredded to a more uniform size and mixed before in-vessel composting and subsequent curing. The composting facility and associated waste diversion are expected to add 20 to 30 years to the landfill's current (seven- to 10-year) life expectancy.
Project highlights:

- Composting at the existing landfill site was identified as the most economical and environmentally sound option for more than doubling landfill's capacity.
- MSW—versus SSO—composting requires additional processing (e.g., sorting, screening).

Source: Mariposa County n.d.

Commercial Composting Facility: Chamness Technology, Eddyville, Iowa

Chamness Technology, one of the largest organics recyclers in the Midwest, operates a 40-acre site in Iowa that annually receives and processes about 63,500 tonnes of organic material. Chamness' sister company, Green RU, collects about 4,500 tonnes of commercial food waste from Iowa grocery stores and other food service locations (e.g., restaurants; hospital, school and factory cafeterias) for composting at the Eddyville site. The composting operations comprise nearly a dozen windrows, about 183 meters long and 2.5 meters wide by 2.7 meters high. The Eddyville site manufactures agricultural and horticultural grades of compost that range in price from about US$7 to US$18 per tonne. Chamness operates other organic waste processing facilities that process biosolids for land application, in Nebraska, and a second organic waste composting facility, in Dodge City, Kansas.

Given its multiple locations, the company has made significant investments in collection vehicles as well as in equipment for handling and processing heavy materials—equipment such as grinders, compost turners, skid and wheel loaders, and excavators.

Project highlights:

- This composting facility processes about 63,500 tonnes/year of organic material.
- It required significant investment in equipment (e.g., trucks, grinders, turners, loaders).

Source: Emerson 2015.

Institutional Composting Facility: Ohio University

In 2009, Ohio University became home to the United States' largest in-vessel composting facility, due in part to a US$350,000 grant from the Ohio Department of Natural Resources' Division of Recycling and Litter. Total startup costs, however, approached US$800,000, with equipment purchases (i.e., a nearly 2-tonne, in-vessel composting system) and infrastructure improvements (e.g., road upgrade, cement pad, heated pole-barn). Three years later, a US$1 million American Recovery and Reinvestment Act grant allowed the composting facility to add a more than 3.6-tonne, expandable in-vessel system. The added equipment "enables the university to compost 100 percent of its pre- and post-consumer dining waste." The university's food scraps are mixed with bulking agents (e.g., landscaping wood waste) before in-vessel processing. Once the in-vessel processing is complete, the material is cured further in turned windrows, and the final compost is used on the campus' athletic fields and gardens.

Project highlights:

- Grants and university funds totaling nearly US$2.5 million were needed to establish this composting facility (does not include annual operating expenses).
- The system accommodates 100 percent of the university's dining waste and provides free, valuable soil amendment for on-campus use.

Source: OU n.d.

3.4.4 Key Components and Special Considerations for Successful Organic Waste Processing Facilities

Facilities that process organic waste face many issues with implementation (e.g., schedule delays; existing infrastructure; need for stakeholder engagement or buy-in), finances (e.g., capital and equipment costs) and performance (e.g., diversion rates achieved). Before an organic waste processing facility is established, many factors must be considered: everything from the quantities and composition of the organic waste to be received to the collection methods to be used, the number of residents or businesses to be serviced, and the amount of waste they produce.

Another major factor in the success of an organic waste processing facility is an accurate determination of the incoming waste stream's organic material content. The quality, quantity, packaging and source of the waste material play an important role in the capital and operational costs of an organic waste processing facility and in its future performance. In addition, securing long-term agreements and reliable feedstock (fewer contaminants) is critical. Other factors include location/siting, permitting, regulations, anticipated population growth, waste composition, size of facility, diversion targets and many others. Appendix C highlights examples of available tools (described in this report) to help decision makers and other stakeholders evaluate opportunities for organic waste diversion, collection and processing.

Economics (i.e., capital and operational expenses, revenues, savings) are critical to an organic waste processing facility's success or failure, but finding public financial information is a challenge (Miller and Germain 2016). AD can be capital-intensive, and financial viability can be driven by a favorable tipping fee (i.e., less than traditional disposal costs), the sales of biogas, and the markets for digestate. Several studies indicate the average AD project payback period is five to seven years or much longer (Linville et al. 2015).

Information found for this report was mostly limited to tipping fees, incentives used (e.g., grants), product pricing (e.g., sale of compost), and savings realized (e.g., using biogas to offset traditional fossil energy). Many organic waste projects are publicly owned, but cost data (i.e., capital investment, operating expenses) on them are lacking; meanwhile, privately owned projects typically do not share their financial information.

Tipping the Scales in Favor of Organic Waste

Understanding how tipping fees at organic waste processing facilities compare to the cost of traditional landfill disposal might help advance or encourage greater organics diversion. According to the National League of Cities, tipping fees at composting facilities (actual values not provided) are often lower than tipping fees at landfills (NLC 2016), which generally ranged between about US$5 (Texas) and US$130 (Washington) per tonne in 2013, for a national average of approximately US$45 per tonne (Clean Energy Projects 2013). Insight from several states is presented below.

California: Based on a recent CalRecycle study, the median MSW tipping fee for "self-haul" (i.e., for residential or private user exclusive of a contract) was nearly US$41 per tonne, with a range of US$0 to US$113 per tonne. The median green-waste tipping fee was about US$35 per tonne, with more than half of California landfills (58 percent) charging less for green waste than for MSW, and 16 percent charging more (CalRecycle 2015a).

South Carolina: Food Waste Disposal, a hauling company in Charleston, leverages the area's lower US$23 per tonne tipping fee for food and organic waste (versus US$60 per tonne for traditional waste), to attract new customers to its business.

Vermont: Green Mountain Compost collects a US$41-per-tonne tipping fee from commercial haulers who bring food scraps and other compostables to its facility (GMC 2016). Based on national landfill tipping fees data, these fees are lower than the range of US$70 to US$80 per tonne, associated with landfilling this material in Vermont (Clean Energy Projects 2013). Moreover, there is no tipping fee for residents who wish to drop off food scraps for composting; those materials are accepted free of charge.

One study (Rogoff and Clark 2014) quantified and modeled typical costs for a 4,536-tonne-per-year and a 9,071-tonne-per-year dry AD plant. For the former, the study found that capital costs were about US$2.4 million. (Included in this cost: digester components, building superstructure, engine generator, foundation, mixing platform, biofilters, food storage pad, electrical interconnect, design, permitting and fees, and contingency.) The study revealed the following modelled results (based on many assumptions) for two tonnage scenarios:

- The 4,536-tonne-per-year plant, not generating electricity, required a tipping fee of US$46–$53 per tonne.
- The 4,536-tonne-per-year plant, generating about 200 kilowatt-hours at US$0.1044 per kilowatt-hour for onsite use, required a tipping fee of US$8.76–$31.97 per tonne.
- The 9,071 tonne-per-year plant, not generating electricity, required a tipping fee of US$40–$49 per tonne.
- The 9,071-tonne-per-year plant, generating about 200 kilowatt-hours at US$0.1044 per kilowatt-hour for onsite use, required a tipping fee of US$4–$27 per tonne.

Another study, comparing capital costs to design capacity, found that the initial cost of AD projects is about US$661 per tonne capacity of annual waste throughput. The same study found operating costs can be high, in the range of US$44–$165 per tonne waste delivered. Actual operating costs, however, depend heavily on individual project specifics (CIWMB 2008).

The ReFED Roadmap cited capital costs for a larger AD plant (about 45,359 tonnes per year) around US$20 million (ReFED 2016). A study by the Compost Council of Canada (n.d.-a) gives the following estimated capital cost ranges for various types of composting compared to anaerobic digestion per throughput tonne, assuming a minimum of 50,000 throughput tonnes per year:

- composting:
  - windrows: C$40–60
  - enclosed windrows: C$100–$150
  - in-vessel aerobic composting: C$300–$500
- anaerobic digestion: C$500–$700

The study shows AD has a significantly higher capital cost than composting—particularly windrow composting—but other factors must be evaluated in determining the financial viability of various organic waste processing options. Accurately predicting their costs and revenues is challenging (as with other waste management infrastructure projects), due to a variety of considerations:

- local factors (e.g., tipping fees, labor costs, site conditions)
- predevelopment (siting, permitting, planning and design, environmental impact assessment)
- construction (infrastructure, buildings/reactors, equipment, labor)
- contracts (securing feedstock agreements, Power Purchase Agreements, gas or digestate sales agreements)
- operations (maintenance, manager training, labor, materials, water and energy, wastewater disposal, solids disposal, other fees)

Cost savings may be possible if an AD project is incorporated into existing waste management facilities (e.g., co-located at a landfill or WWTP/WRRF). Other sources of revenue include economies of scale (larger facilities with higher throughput) and maximizing all revenues (energy, tipping fees, secondary products, and incentives).

Leasing models for AD may also offer opportunities for a third-party owner or operator to maintain several digesters on a regional basis, especially for medium-sized facilities (ReFED 2016).

Although AD systems may come with higher initial capital and operating costs than some more traditional waste treatment technologies (e.g., landfills), the life-cycle cost is often difficult to calculate, due to the complexity of waste management issues and decisions:

- project life expectancy
- project siting
- environmental issues (all media)
- transportation impacts
- job creation
- social impacts
- energy commodity prices (and future prices)
- energy balance (GMI 2014)

Another important area for greater understanding is job creation from organic waste processing. The ReFED Roadmap, which focused on surplus food, found that jobs are created at the project level, as well as regionally and nationally (i.e., ancillary service jobs). The Roadmap estimated that each processing facility generates an average of five to 10 permanent employees from the onset of the project (design through construction) through operation (management, collection, processing). And every million tonnes of processed compost creates nearly 1,500 or so additional ancillary jobs (compost uses in agriculture) (ReFED 2016).

California estimated that diverting organic waste could result in generating an estimated two jobs per 907 tonnes of diverted material. By 2025, organic waste diversion could lead to 25,000 additional jobs in the waste management field (CalRecycle 2013).

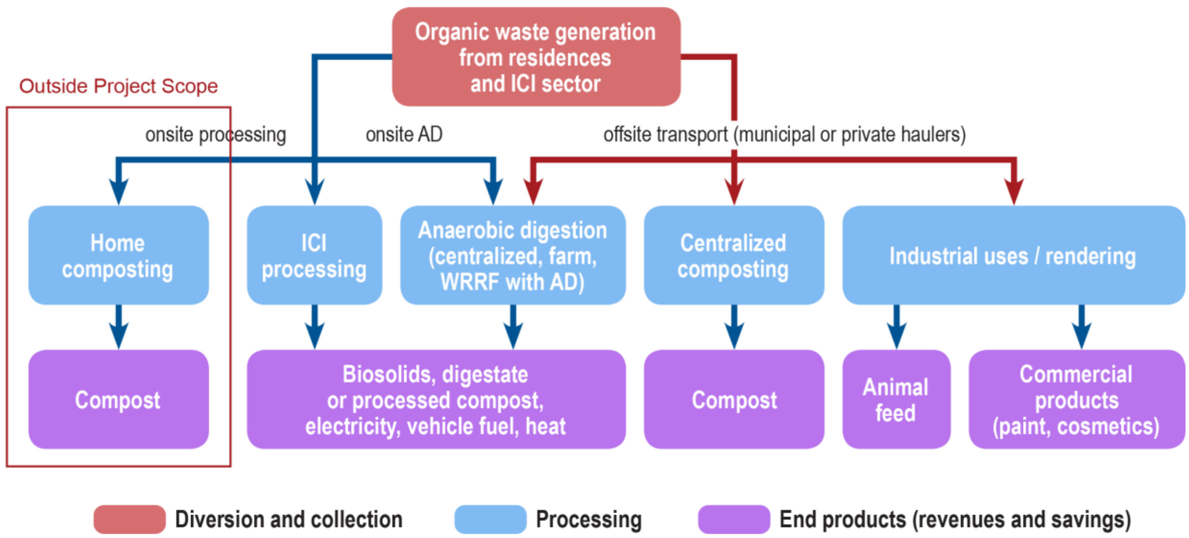
For a successful organic waste management program, waste reduction mandates (e.g., bans on yard trimmings, food waste), zero-waste goals, and disposal costs create incentives for organic waste diversion. Moreover, public convenience and education top the list of elements needed for an effective, ongoing composting program. In addition, nearby organic waste processing facilities (with available capacity) and existing yard trimmings collection programs significantly affect a city's ability to initiate and maintain a program for composting food waste (Layzer and Shulman 2014, 10). Incentives for greater public participation include shifting trash and recycling collection to a biweekly schedule and picking up compostables every week (Layzer and Shulman 2014, 10).

3.5 Markets for End-Products of Organic Waste Processing

A primary benefit of organic waste diversion and processing activities is an end-product (e.g., feedstock, biogas, compost) that can be used in other applications (e.g., manufacturing, energy generation, soil enhancement). To use these end-products to their greatest potential, the North American countries are cultivating markets for both public and private uses. This is particularly applicable for compost, which can appeal to a broad range of users, from state transportation agencies to commercial landscapers to homeowners. Section 3.5.3 mentions that quantity and quality of the end-products are also critical to the marketplace. Country-specific feed-in tariffs and renewable portfolio standards (as in Canada and the US), as well as the lack of federal composting regulations (as in Mexico and United States), also affect market development.

Figure 26 depicts organic waste diversion and processing pathways and their associated points of revenues (outputs such as power, products) or cost savings.

Figure 26. End-market destinations for processed organic waste materials and outputs



3.5.1 Markets for End-Products of Animal Rendering

As previously noted, the rendering industry yields both edible and inedible animal byproducts that can be used as ingredients or feedstock for many industrial products (e.g., paints and varnishes, explosives, lubricants), health and beauty goods (e.g., soaps, cosmetics, toothpaste, pharmaceuticals), apparel (e.g., leather, textiles) and pet food (NRA 2016b). Gelatin, derived primarily from cattle hooves, for example, can be used in a variety of products and industries: the outer soft covering on pharmaceutical capsules, an emulsifier in cosmetic lotions and foams, or a stabilizer in ice cream and other frozen desserts (Jayathilakan et al. 2011). Byproducts from the fish processing industry also have several markets: fish oils extracted for use in cosmetics (e.g., lipstick) and vitamins, or more directly, for use as biofuels in industrial burners; skeletons or “frames” dried and ground into bone meal for pet food; protein meals from livers and other visceral organs into food supplements; and everything else into fertilizers and plant food (Bechtel 2012).

Demand for byproducts from rendering is anticipated to increase as biodiesel production (i.e., hydrolysis and subsequent fermentation of carbohydrates) continues to require more raw materials, including animal fats and greases as well as vegetable oils from sustainably grown crops and/or waste oil and grease associated with food preparation.

3.5.2 Markets for Biogas, Biofuels and Digestate

Biofuels are derived from organic matter, either directly from plants (e.g., ethanol from corn) or indirectly from agriculture, commercial or industrial waste (e.g., vegetable oils, animal fats, grease). According to the California-modified Greenhouse Gases, Regulated Emissions, and Energy use in Transportation (CA-GREET) model, RNG made from food waste has a negative life-cycle carbon intensity: about -23 grams of carbon dioxide equivalent per megajoule, in comparison to more than 100 for traditional diesel or even 45 for RNG produced from landfill biogas (Tomich 2016).[31]

Biogas and digestate are produced during AD, and each has useful applications (as an energy source and as fertilizer, respectively). How the products are used, however, varies by country. Canada primarily composts its AD-generated digestate and is exploring opportunities to convert the biogas into RNG. In the United States, energy generated from AD is most often used onsite (e.g., WWTPs, farms) or sold to local utilities. AD in Mexico has been focused on farm-scale biodigesters that use manure as a feedstock to generate biogas, which in turn can generate electricity that can be sold to utilities. Dedicated organic waste AD projects are just emerging in Mexico, and details about the uses for biogas or digestate are not currently available. Specific uses and benefits—as well as existing markets—are described in greater detail below.

There are several potential ways to use biogas produced from the processing of organic waste:

- burning directly in a boiler to produce heat
- combusting to produce both heat and electricity, also known as co-generation
- upgrading to RNG, also referred to as biomethane, to displace natural gas
- upgrading to biomethane and compressing to displace CNG vehicle fuel
- flaring to destroy the methane and retire the environmental attributes of the biogas

Digestate is often used as a liquid fertilizer or soil amendment. Digestate is a valuable biofertilizer and has many benefits (see Section 3.3.3 for more-detailed benefits).

Markets in North America for biogas and digestate are discussed below.

Canada

The AD markets for digestate and biogas are still being defined in the Canadian marketplace. Digestate from Toronto facilities and Harvest Power's Richmond Compost Facility in British Columbia is being composted. Toronto is examining the potential beneficial uses of the biogas produced at its facilities. The city of Surrey intends to convert its biogas into RNG.

In Ontario, RNG is currently the only marketable energy product that is generated from biogas at a large scale. RNG can be produced and consumed for other purposes, to help reach internal GHG reduction targets, create green jobs, and/or close the loop by using the organic material collected to fuel the waste collection fleet. Since the commodity value of natural gas is very low, the highest-value municipal use of RNG in most cases is to replace diesel as a vehicle fuel.

In Quebec, RNG from Saint-Hyacinthe's Organic Waste Reclamation Centre is used to meet the municipality's energy demand by fueling its municipal vehicles and other uses. Using the biogas to supply the energy requirements of the organic waste processing facility is a plus, from a sustainability perspective.

Mexico

As in Canada and the United States, markets for biogas and digestate are still being developed in Mexico. As described in Table 43, most biogas in Mexico is used onsite for cooking, heating or electricity generation. Similarly, digestate is often used onsite as fertilizer or animal bedding.[32]

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[31] A fuel's life-cycle carbon intensity consists of the sum of GHGs emitted throughout the production and use (i.e., life-cycle) of the fuel (California Environmental Protection Agency Air Resources Board 2015).

[32] Hamdan, R., Octaform, personal communication, August 2017.

United States

In 2012, biofuels accounted for roughly 7 percent of US transportation fuel consumption; most of this was ethanol made from corn, which accounts for 94 percent of US biofuel production (USDA Economic Research Service 2017). The remaining 6 percent of produced biofuel is biodiesel made from vegetable oils (primarily from soy beans) as well as animal fats, waste oils and greases captured and recycled by the rendering industry.

In the United States, the energy generated from AD (e.g., methane) is commonly used onsite to fulfill a farm's or facility's power needs, and excess energy is frequently provided to local utilities. As mentioned above, adding food waste as another digester feedstock increases biogas production.

In October 2016, the American Biogas Council launched the Digestate Standard Testing and Certification Program, beginning with accreditation of testing laboratories and a training webinar for digestate producers. By providing information about the digestion process and digestate feedstocks and composition, this voluntary program allows biogas plants to more effectively market their digestate. The program also addresses a gap in regulations (digestate is often considered a solid waste in some states) by providing a rationale and evidence to differentiate input (solid waste) and outputs (digestate). The standard also provides composters that accept digestate with data that will allow them to determine the optimal blend for composting (Leib et al. 2016).

Exceeding Onsite Energy Needs with Biogas

East Bay Municipal Utility District operates a 60-million-gallon-per-day WWTP in Oakland, California, that was one of the first US municipal wastewater utilities to accept food processing waste. The District currently produces 135 percent of the onsite energy it needs by adding food waste to take up excess capacity in its WWTP digester and then sells excess electricity back to the power grid (Force 2014).

The Cottonwood Dairy at Gallo Farms in Merced County, California, installed an aerobic digester to process dairy manure with wastewater from its cheese processing facility. The resulting energy and waste heat are used onsite, and excess electricity is sold to Pacific Gas & Electric through a net-metering contract (US EPA 2012b).

3.5.3 Markets for Compost

There are many markets and end-uses for compost, depending on the quantity and quality of the product. For example, the CCME Guidelines for Compost Quality establish two different grades of end–compost material: Category A and Category B. Category A compost may be used in any application, such as agricultural lands, residential gardens, horticultural operations, the nursery industry and other businesses. Category B compost has sharp foreign matter or a higher

Compost Market Drivers: Quantity Versus Quality

Volume market consumers (e.g., agriculture, reclamation, sod) who purchase large volumes of compost might be unwilling to pay a higher per-unit price. Dollar market consumers (e.g., golf courses, greenhouses, landscapers) might have stringent quality requirements and therefore be willing to pay more per unit, since they are also likely purchasing smaller quantities.

Source: Compost Council of Canada n.d.-b.

trace-element content; it may only be used where human contact is less frequent (i.e., it may be used as an organic soil conditioner in a variety of non-agricultural applications such as land reclamation, mining rehabilitation and reforestation).[33] According to the Compost Council of Canada, the average reported price for compost sold in bulk ranges from C$20 to C$30 per tonne (Compost Council of Canada n.d.-c).[34]

Given the lack of organic waste diversion programs and processing facilities in Mexico, compost does not garner much attention. Most compost from municipal plants is only applied at public (i.e., city-owned) gardens and greenhouses, while products from private composting companies are sold to producers of ornamental plants and food commodities and to nurseries, gardens and others; several challenges and regulatory considerations hamper market formation. However, an assessment was conducted in Tijuana, Baja California, that considered composting markets to help inform businesses and financiers about the potential to develop composting markets. An accompanying survey revealed that backyard composting was already practiced, and recyclables segregation was taking place at the sanitary landfill by informal workers. Interviewees also expressed willingness to pay a fee to support integrated waste management efforts including composting and recycling.

A very important consideration for compost market potential is the use—and type—of fertilizers in Mexico. In 2015, for example, five out of every 10 food producers used chemical fertilizers, three out of 10 used organic fertilizers, and two out of 10 used no fertilizers. Organic fertilizers include manure, compost, vermicompost, agricultural waste, organic industrial waste, wastewater and organic sediments. This 30-percent share could represent a market opportunity for compost in Mexico. However, even though organic fertilizers have been used in Mexico for centuries, more information on nutritional content, decomposing velocity, crop requirements and potential collateral effects is needed (Sagarpa n.d.).

“Carbon Farming” in California

To help achieve its Climate Action Plan goals, West Marin County, California, embarked on a project to evaluate potential soil-carbon sequestration on the county’s rangelands as well as provide ecological and agricultural benefits for the landowners. In addition to the associated carbon sequestration following application of compost to the rangelands, the affected soil’s water-holding capacity increased by 17 to 25 percent and forage production also increased by 50 percent. Given the results, it is anticipated Marin County’s Climate Action Plan goal could be offset with compost application on approximately 6 percent of Marin’s rangelands over three years.

Source: Scolari 2016.

In the United States, as in Canada, compost is also manufactured into various grades (depending on organic inputs / level of processing) and sold for multiple purposes or uses: agricultural (e.g., crops), horticultural (e.g., gardens), land reclamation, landscaping, nurseries, recreational (e.g., sports fields, golf courses), roadside projects, sediment and

[33] If a compost product does not meet either criterion, it is likely highly contaminated and must be recycled through the composting facility again. Landfills may accept the contaminated compost (at low[er] costs) to be used as landfill cover. Land reclamation projects may accept poor-quality compost at no cost (Compost Council of Canada n.d.-c).

[34] The source did not specify whether those costs per tonne are for Category A or B compost.

erosion control, sod production, soil remediation, and wetland creation (Platt et al. 2014, ES-3). In California, in particular, compost is being used to increase soil carbon reserves (see text box).

As mentioned above, compost is processed (e.g., into grades) and marketed in accordance to the specific needs of end-users. One US compost producer, for example, sells its agricultural-grade composts (used on farms) for US$8 per tonne, whereas its horticultural-grade composts (used in landscaping) cost upward of US$20 per tonne because their consumers have higher quality demands (Emerson 2015). Several state departments of transportation—including Texas and Washington—have used compost in highway construction projects to help stabilize or revegetate roadsides, particularly on sloped surfaces (USCC 2008a, 2008b). The American Association of State Highway and Transportation Officials established erosion/sediment control specifications and advocates the use of compost-based products, such as filter berms and compost blankets. More recently, emerging markets spawned by the green infrastructure industry (e.g., green buildings) have increased demand as companies turn to compost and compost-based products to help establish green-roof media and manage storm water (Platt et al. 2014, ES-3).

For composting, one of the biggest hurdles for market expansion is competition with synthetic fertilizer manufacturers that benefit from economies of scale (large operations and customer base). Climatic factors can also be a challenge to operations and processing (winter conditions having a negative effect on compost piles). As well, food waste has a high nitrogen content, meaning that it typically needs to be mixed and balanced with carbon-rich yard waste; getting enough yard waste (at the location of the composting plant) can be challenging. These challenges are important to consider as factors that can potentially affect markets for the products.

3.5.4 Key Market Considerations in North America

Canada

The relatively low cost of landfill disposal (versus organics collection and processing) is an impediment to increased organic waste diversion in many parts of Canada. As noted in Section 3.2.2, if the cost of landfilling is lower or the same as recycling, organizations will tend to opt for the cheap/easy solution.

As previously mentioned, the Canadian markets for digestate and biogas from AD are still being defined. Plastic-film materials (i.e., contaminants such as any plastic-film bags from refuse material that must be disposed of) could be further processed into an alternative, low-carbon fuel; however, there is no established process or market for this material.

While there are many markets and end-uses for compost (e.g., agricultural lands, residential gardens, horticultural and nursery operations), many applications ultimately depend on the quantity and quality of the product, as well as Canada's compost grading (e.g., restricted versus unrestricted).

There is a strong case to be made for municipalities' generating biogas or even upgrading the biogas to RNG, from food waste and organic material. The environmental and economic benefits are compelling. In Ontario, RNG is currently the only marketable energy product that is generated from biogas at a large scale. The biogas or RNG can be used for internal facility heating; to help reach internal GHG reduction targets; to create green jobs; and/or to close the loop by using the organic material collected to fuel the waste collection fleet.

Ontario's feed-in-tariff programs provide a preferential revenue stream for electricity generation from renewable sources, such as the biogas created through the AD of organic wastes. That said, the development of on-farm AD facilities has been constrained by the uncertainty surrounding feed-in tariff programs. Energy and compost end-products have a lower market value than plastics and metals, so many municipalities and businesses focus on recycling other materials.

Ontario Regulation 452/09, "Greenhouse Gas Emissions Reporting" (from 1990), requires companies to report on their annual GHG generation, under the cap-and-trade-program. This gives industries an economic incentive to reduce their emissions so as to meet the overall environment goal. Alternatively, companies can purchase "carbon offsets": projects that reduce GHGs, such as building composting and AD facilities. However, it should be noted that regulated activities cannot qualify as carbon offsets (i.e., if regulation requires the control of biogas, the reductions are not considered additional, because they are not voluntary).

Mexico

Mexico's energy generation has concentrated primarily on fossil fuels. In 2014, non-fossil-fuel (i.e., renewable) energy sources reached only 8.7 percent, broken down into 2.3 percent nuclear and hydraulic; 4.12 percent biomass; 1.83 percent solar, geothermal and wind; and 0.02 percent biogas (Secretaría de Energía 2015).

Another important market consideration is the national deficit of natural gas in Mexico. Industrial demand for natural gas is expected to have increased by 5 percent in 2017. Increasing fuel costs in Mexico create an opportunity to use methane from AD systems. This would require purifying the resulting methane, which should not be too difficult since the technology already exists, but it would require investment.[35]

While there are experts with composting experience who may be found within various institutions and civil society groups, most of this information is not well documented or available to the public.

Several issues should be taken into account when considering the Mexican market for organic waste products:

- Composting of residential organic waste depends mainly on municipal authorities. Too often, composting facilities shut down due to lack of funding (e.g., municipal administrations do not assign enough budget to support operations, which generally cost more than waste disposal; facilities operate only as long as federal funds are available) or lack of volume (facilities do not get the anticipated amount of organic waste because municipal administrations do not encourage/enforce collection/diversion).
- The absence of government initiatives to promote compost markets is another hurdle for sustaining composting plants. Sales revenues could help pay for at least a fraction of the production costs and would help incentivize compost activities, thereby sustaining existing projects.
- There is too little information on composting activities (e.g., type/amount of organic waste generated and processed, type of equipment, processing costs per tonne, and quantity and quality of the final product).

As efforts at the national level begin to unfold in support of increasing organic waste diversion, markets for organic waste products are only beginning to emerge; more emphasis is needed on strengthening these markets both in Mexico and across North America or abroad.

Both the General Law of Ecological Equilibrium and Environmental Protection (*Ley General del Equilibrio Ecológico y la Protección al Ambiente—LGEEPA)* and LGPGIR give Semarnat the authority to issue Official Mexican Standards (*Normas Oficiales Mexicanas*), among other measures, to protect soils and prevent and control pollution, as well as to remediate soil pollution related to hazardous waste management. According to LGPGIR, integrated waste management (including

[35] Cárdenas Jimenéz, G., president, Western Oil and Protein Chamber, personal communication, 2017.

biological treatment such as composting) must consider adaptation to conditions and needs of each location. Future regulations are also an important issue to consider. The Economy Secretariat is currently developing a voluntary standard for aerobic treatment of organic waste.

United States

Given the negative carbon intensity of RNG made from food waste and the currently low market-penetration of biofuels (7 percent of US transportation fuel consumption), there appears to be room for market development. The US RNG industry was expected to double over the course of 2017, from 2016 volumes (Tomich 2016). The technologies to process food waste into RNG are proven and commercially available (see the Sacramento case study in Section 3.4.3), but challenges to greater market development include logistics and funding.

A key consideration in the US compost market is a lack of federal regulations or quality standards. In the absence of a federal standard, many states such as California, Massachusetts and Washington have regulations and/or programs (e.g., loans or grants) in place to support or encourage composting operations (ILSR 2010). To help compost producers and purchasers determine a compost's suitability for intended use(s) and/or compare compost products, the US Composting Council created its Seal of Testing Assurance (STA) Program—based on consensus among leading compost research scientists—for testing, labeling and disclosing information about compost products (USCC 2016). The science and tests behind the STA Program are derived from *Test Methods for the Examination of Composting and Compost*, which provides "detailed protocols for the composting industry to verify the physical, chemical, and biological condition of composting feedstocks, material in process and compost products at the point of sale" (USCC 2016). STA Program manufacturers or marketers regularly sample and test their compost in accordance with STA protocols and pay an annual application fee per certified product in order to display the STA Program logo, which is nationally recognized by industry and other stakeholders.

A more comprehensive (i.e., nationwide) standard might spur greater compost use, particularly among those segments of the marketplace that might be concerned about compost's content (e.g., nurseries, home owners). The federal government (e.g., the US EPA) and state agencies also have developed procurement requirements for compost and fertilizers made from organic waste (e.g., use in landscaping around federal and state buildings and parks). Thirteen states mandate the use of Certified Compost (STA-approved), which promotes compost markets (Miller and Germain 2016).

About half the states have enacted yard- and/or food-waste disposal bans and a handful of states—California, Connecticut, Delaware, Florida, Massachusetts, Michigan and New York—have also set landfill diversion targets, which organics exclusion will likely help them reach (EREF 2015, 27–28). But current policies in some states impede greater composting and/or use of AD (e.g., a strict definition of composting as "aerobic biological decomposition" excludes AD opportunities) to handle these diverted organics, so it is unknown how much impact these bans and/or targets might truly have (EREF 2015, 29). Digesters, in particular, are subject to solid-waste and air- and water-quality permitting that varies from state to state, meaning that project developers who work in multiple states must know how each permit system might affect specific projects. Detailed information on policies, regulations and best practices can be found in Chapter 4.

3.5.5 Opportunities for Collaboration in the North American Market for Organic Waste

As demonstrated throughout this chapter, the three countries approach organic waste management quite differently. While each country has similar policies, each faces persistent challenges to greater organic waste diversion (e.g., low landfill tipping fees in Canada, lack of compliance/enforcement in Mexico, lack of federal regulations in the United States). One of most common themes is a lack of consistent or sufficient generation and collection of data—particularly in the ICI sector—that could help inform and design future programs and thereby secure processing capacity and ensure markets for end-products (e.g., biofuels, biogas, compost).

Collaboration among the countries (e.g., capacity-building or trainings in Mexico by Canadian or US experts) as well as information-sharing by organic-waste-related organizations (e.g., Compost Council of Canada, US Composting Council) could go a long way toward advancing Mexico's organic waste markets. Lessons learned from existing programs and best practices in a North American country could also be shared with communities in the other countries, especially if they are similar in population and infrastructure (e.g., "sister cities"), to help those governments know in advance what issues they might encounter and how they might address those issues. See Chapter 6 for more-detailed cross-border cooperation ideas.

3.6 Conclusion

Diverting the organic waste component of the MSW stream not only conserves valuable—and diminishing—landfill space, but it also provides several economic and environmental benefits, such as renewable energy, reduced GHG emissions, and improved water and soil conditions.

Residential organic waste diversion (i.e., collection and processing) is underway in hundreds of Canadian and US communities, many of which have implemented ordinances limiting the types or volume of organics that can be landfilled, set zero-waste goals, and/or established unit-based pricing programs (e.g., PAYT) to encourage AD or composting of these materials. Diversion programs for residential organic waste are less prevalent in Mexico, but the legislative framework is there for municipal officials to build upon. Regardless of country, early and ongoing communication with participants is key to the success of any residential program.

Because less is known about the North American ICI sector's organic waste practices (i.e., generation, diversion potential), it is difficult to understand how that sector's volume might affect processing (i.e., capacity) and markets (e.g., byproducts, biofuels, biogas, digestate, compost). More accessible or consistent ICI data would help communities plan for organic waste diversion and processing if they could be assured of sufficient quantities of organic waste to sustain AD or composting programs for the long term.

Use of AD to process food waste—particularly through co-digestion on farms, at WWTPs/WRRFs or in stand-alone facilities—is still in its infancy, but gaining traction throughout North America. Studies and models such as those produced by WERF will hopefully encourage more municipal WWTPs/WRRFs to include food waste as a possible digester feedstock. Better communicating the benefits of using the biogas produced for energy production or RNG as vehicle fuel might also convince more communities to explore this under-utilized market.

Despite the number of composting technologies available, windrowing remains a clear favorite in all three North American countries, which is understandable, given its relatively low capital costs. SSO in separate bags or color-coded containers is the preferred collection method, due to its low contamination rate and need for little-to-no pre-treatment before processing. As discussed above, Canada and the United States have well-established composting programs, many of which accept food waste. While Mexico lags behind in implementation, its potential for robust composting of organic waste is clear. All three countries, however, could benefit from more-secure markets.

4 Policies, Programs, Regulations and Best Practices

> "Food-waste recycling is where traditional recycling was 25 years ago. There is a lack of necessary infrastructure, a wide variety of approaches, a patchwork of state/local regulations, and a common misperception that recycling should be 'free' […] Now, commercial and residential recycling is widespread, and most communities can't imagine going back."
> —Steven Finn, Casella Organics and Waste360

As North America embarks on new or additional initiatives to increase diversion and processing of organic waste (e.g., grant funding for new projects, landfill disposal bans), it is important to review and examine the policies, programs, regulations and best practices already in place. Some of these initiatives are outgrowths of national policy, such as Mexico's General Law on the Prevention and Comprehensive Management of Waste (*Ley General para la Prevención y Gestión Integral de los Residuos*—LGPGIR). Others—in the absence of federal policy, as is the Canadian and US cases—have been developed and implemented at the provincial, territorial, state or municipal level. Presently, these country-specific efforts occur in somewhat of a vacuum (i.e., without impact/influence from the other North American countries), but there might be opportunities to better share or leverage expertise and experiences in order to increase diversion and processing of organic waste across the continent.

The following sections provide an overview of successful efforts (e.g., policies/regulations), including steps for program implementation (e.g., timeframe) and case studies highlighting best practices.

4.1 Overview of Successful Policies, Programs, Regulations and Best Practices

Provinces, states, counties and municipalities within the North American countries have all undertaken efforts to divert or process organic wastes. In Canada, for example, some provinces (e.g., Prince Edward Island, Nova Scotia) and municipalities (e.g., the Regional District of Nanaimo and the City of Vancouver, in British Columbia) have banned organics from landfills. Many Canadian municipalities are phasing in various types of wastes and collection methods to allow for (better) transition and also learn from communities that have gone before them. Mexico's waste management—including management of organics—is regulated under a country-wide waste prevention and management mechanism that requires state authorities to issue regulations to comply with the comprehensive scheme. While the United States has no federal organic waste policy, individual states have established their own, differing policies (e.g., organics are prohibited from landfills in 24 state-wide bans).

This section provides an overview of the more successful policies and regulations (e.g., waste bans, renewable portfolio standards, carbon offset markets), programs (e.g., pay-as-you-throw [PAYT], zero-waste or sustainability goals), and best practices (e.g., pilot testing, early and ongoing participant involvement) within each of the countries, as well as notable gaps or challenges to greater organic waste diversion and processing.

4.1.1 Canada

With no federal law governing management of solid waste, Canadian municipalities, provinces and territories set the policies, regulations and guidelines for managing it. Most provinces and territories began by implementing residential "blue box" recycling (e.g., glass, plastics, metals, paper), followed by leaf and yard waste diversion and composting, then source-separated organics (SSO) composting. The blue box programs in Canada typically receive some funding through stewardship programs and/or extended producer responsibility (EPR) programs. The municipal tax base funds organics programs, with limited provincial or federal funding available to support them.

Organic Waste Landfill Bans and Other Policy Initiatives

Canada established a National Zero Waste Council in 2013, to bring together governments, businesses and nongovernmental organizations to advance waste prevention in Canada. In March 2017, the Council put forth the National Food Waste Reduction Strategy, which aims to cut the amount of food waste disposed of in landfills by suggesting a national target of 50-percent food-waste reduction by 2030, aligning with the US target (National Zero Waste Council 2017).

In 1998, Prince Edward Island and Nova Scotia were the first provinces to ban organic waste from landfills. To date, they remain the only provinces with a fully-implemented province-wide ban; Quebec is currently implementing a ban in phases, with a 2020 goal to eliminate the disposal of organic waste in both the residential and the industrial, commercial and institutional (ICI) sectors (Taillefer 2014). Municipalities in British Columbia have recently banned organic waste from landfills. For example, the Regional District of Nanaimo banned commercial and institutional organic waste from its landfill in 2005. After this initiative, the District began collecting residential curbside organic waste in 2007. The Metro Vancouver Regional District, home to two-thirds of British Columbia's residents, banned residents and businesses from disposing of organic waste in landfills, in 2015 (Gorrie 2012). With bans comes the development of organic waste management programs. Table 50 provides an overview of provinces and municipalities that have banned (or plan to ban) disposal of organic waste in landfills.

Table 50. Organics-to-landfill bans in Canada

Ban Features	**Province**				
	British Columbia		**Nova Scotia**[a]	**Prince Edward Island**[b]	**Quebec**[c]
Area(s)	Regional District of Nanaimo[d]	Metro Vancouver Regional District / City of Vancouver[e]	Province-wide	Province-wide	Province-wide
Sectors Covered	"Commercial and institutional facilities such as restaurants, grocery stores, and school and hospital cafeterias"	Businesses: Every business-license holder Residential: Every owner/occupier of a residential property where food waste is produced	All generators (i.e., nearly 1,000,000 citizens)	Every household and business	"All stakeholders"
Applicability/ Threshold	2005: Commercial food waste disposal ban 2011: Region-wide green-bin residential food	"All food scraps—raw and cooked food, plate scrapings, leftovers, expired food, meat, bones, and dairy products" banned, effective 1 January	"Compostable organic material [including] food waste" banned, effective 1998	"Province-wide mandatory composting program for all residents and the ICI sector,"	2015: 60% recycling target for organics 2016–2019: Gradual implementation of complete

Ban Features	Province				
	British Columbia		Nova Scotia[a]	Prince Edward Island[b]	Quebec[c]
	waste collection	2015		since 1999	organics-to-landfill ban 2020: Ban to eliminate organics from disposal

Sources:
[a] Government of Nova Scotia n.d.
[b] Giroux Environmental Consulting 2015.
[c] Taillefer 2014.
[d] Regional District of Nanaimo 2013.
[e] City of Vancouver n.d.

Some municipalities have decided to roll out programs over time and steadily increase the types and methods of waste collected for processing. This type of transition allows residents, businesses and the municipalities to learn from their experiences and the experiences of other communities. For example, Quebec started by banning simple recyclable materials such as cardboard and eventually worked its way to banning organics—learning from Nova Scotia's years of success and failures. For maximum effect, a landfill ban should target both residential and ICI sectors, as well as organics, paper fiber, and construction and demolition waste (Werf and Cant 2012). Table 51 summarizes the policy approaches taken by each province and territory.

Table 51. Summary of provincial and territorial organic waste programs in Canada

Province or Territories	Program in Place	Percent of Households
Prince Edward Island	All residential and ICI organic waste diverted	96
Nova Scotia	Multiple municipal organic waste diversion programs	94
Ontario	Multiple municipal organic waste diversion programs	75
British Colombia	Multiple municipal organic waste diversion programs	64
New Brunswick	Multiple municipal organic waste diversion programs	58
Alberta	Multiple municipal organic waste diversion programs	56
Manitoba	Multiple municipal organic waste diversion programs	56
Saskatchewan	Multiple municipal organic waste diversion programs	43
Newfoundland and Labrador	Some municipal organic waste diversion programs	42
Quebec	Multiple municipal organic waste diversion programs	42
Territories*	Multiple municipal organic waste diversion programs	—
Federal	Guidance	—

* *Yukon:* organic waste separation at some waste facilities; City of *Whitehorse:* curbside program, multi-residential pilot; *Dawson City:* pilot project.
Northwest Territories: composting at one waste facility; City of *Yellowknife:* pilot project.
Nunavut: no current composting activities.
Source: Giroux Environmental Consulting 2015.

Snapshots of some of Canada's policy initiatives are shown below.

Solid Waste Action Plan: City of Whitehorse, Yukon Territory

This program is part of Whitehorse's Solid Waste Action Plan, adopted in August 2013. Whitehorse planned to achieve 50-percent waste diversion by 2015, to be in line with its zero-waste plan by 2040. On 1 June 2015, the first phase of the organics waste management bylaw passed, banning organic waste from disposal as garbage, in the local food service businesses. As of July 2015, the city collected separated organic waste from over 60 businesses, equivalent to 12 tonnes of waste being diverted from the landfill each month. The bylaw requires participation by all food service businesses and was intended to be enforceable by September 2016; as of 31 January 2017, however, no updates were found on the status of this enforcement. Currently, all single-family to multi-family (four units or less) homes in the area have a biweekly curbside collection program. This is an effort to separate organics from the waste stream.

Sources: City of Whitehorse 2013, 2015a, 2015b.

Capital Regional District Organics Ban: City of Victoria, British Columbia

This ban went into effect on 1 January 2015, and was two to four years in the making. It bans landfill organics from being disposed of at the Hartland (main) landfill, for waste delivered by collectors and residents. A waste load containing excessive amounts of kitchen scraps may be charged a fine or ticket and surcharges. A C$20/tonne incentive was offered for loads of kitchen scraps delivered to a District-approved transfer station or composting facility in 2013 and 2014 as part of the transition period. Thus, the District aimed for 70-percent diversion by 2015, and 80-percent by 2020. As of 2015, the waste diversion rate was 63 percent.

Sources: Government of British Columbia n.d.; Metro Vancouver 2016.

Pay-As-You-Throw: Regional Authority of Carlton Trail Waste Management District, Saskatchewan

The District has achieved a 55-percent diversion rate, in part through implementation of a PAYT program. Residents must purchase a tag for each bag of garbage, but they can drop off yard waste, clean wood and compost for free at 17 transfer stations and two landfills.

Source: Federation of Canadian Municipalities 2009.

Regional District of Nanaimo Organics Ban: City of Nanaimo, British Columbia

The Regional District of Nanaimo Organics Ban went into effect in 2007, and took two to three years to implement. It essentially bans the disposal of organics at District facilities for commercial waste only. A surcharge is applied to a waste load containing food waste, in addition to the standard tipping fee. Any person delivering waste containing organics to a regional facility pays a fine that is double the current tipping fee for municipal solid waste (MSW), C$115 per tonne in 2012.

Source: Regional District of Nanaimo 2013.

4.1.2 Mexico

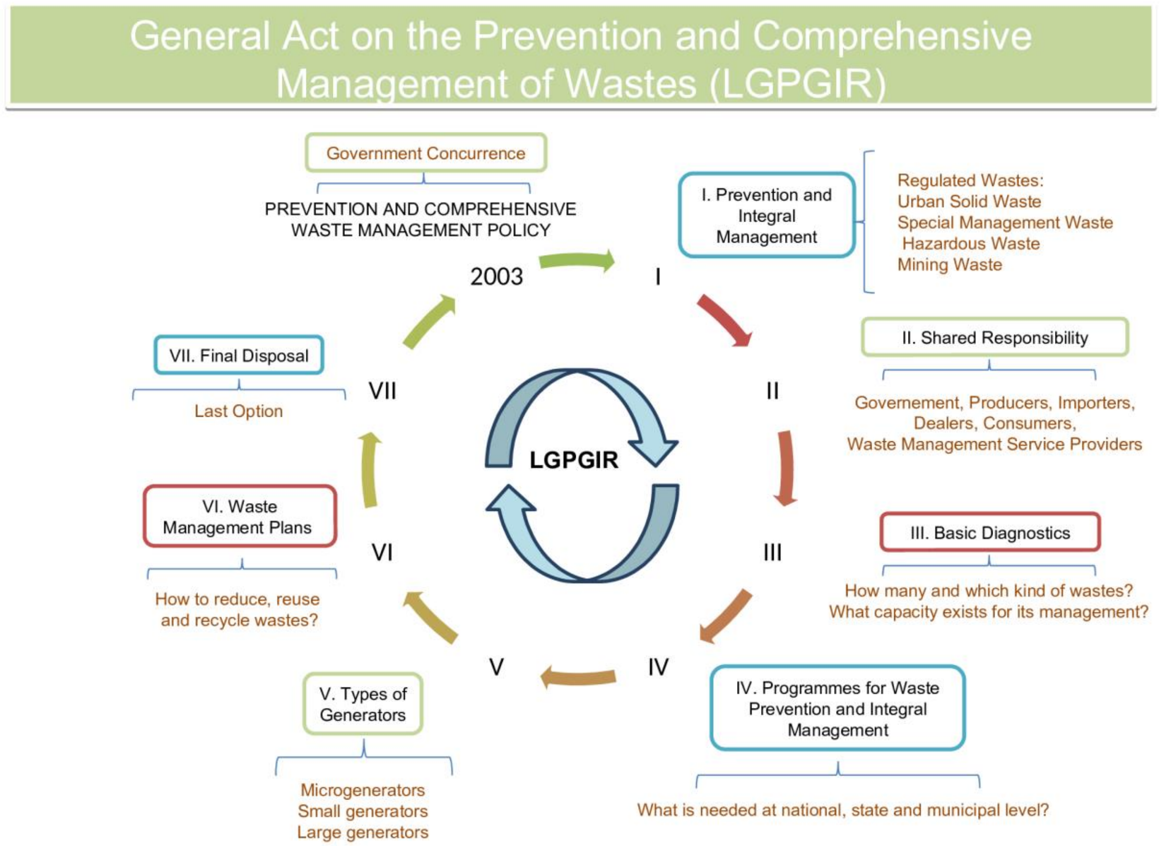
At the federal, state and municipal levels, integrated waste management (i.e., waste reduction, segregation, selective recovery, re-use, recycling) is regulated under LGPGIR, which came into effect in 2004. This law was issued after Mexico's accession to the Organisation for Economic Co-operation and Development, following the OECD's recommended strategies for waste prevention and minimization (DOF 2004; OECD 2000). To achieve the law's objectives, federal, state and municipal authorities are responsible for determining the volume and composition of solid waste and the infrastructure and capacity for processing it. They must also identify needs, and design and implement programs to meet these needs. One of LGPGIR's core principles is that producers, importers, exporters, dealers, consumers, companies or waste-management service providers, and authorities from the three levels of government are all accountable for waste management. The main objectives of the law are as follows (Semarnat 2008):

- Prevent and minimize wastes through legal and economic instruments.
- Achieve participation from all sectors, with gender perspective[36] and emphasis on reduced generation, source separation, and environmental management of wastes, by using training and environmental education instruments.
- Reduce the amount of wastes for final disposal, by using reduction, re-use and recycling schemes.
- Ensure an adequate infrastructure for collection, re-use, recycling or treatment, as well as for the final disposal of wastes that cannot be recycled or used as an energy source.
- Develop a national information subsystem on integrated waste management, as part of the National Environmental Information System *(Sistema Nacional de Información Ambiental).*
- Comply with international conventions related to waste prevention, management and transboundary movement.
- Prevent and mitigate environmental and occupational health risks associated with waste management.
- Promote scientific and technological research, to achieve efficient, environmentally sound and economically viable waste management systems.
- Reduce or avoid greenhouse emissions associated with waste treatment and final disposal.
- Reduce environmental impacts of wastes from natural disasters.

Figure 27 shows LGPGIR's different elements and stakeholders, as well as the policy mechanisms available to implement its major sections.

[36] Gender differences and inequalities have an effect on various aspects of waste disposal. These differences are especially notable with respect to the management of household waste, given the primary role of women in the household. In addition, although women may be willing to spend scarce household resources on waste disposal, they may not have adequate access to the family finances. Women also have reduced participation in community decision-making about waste disposal (OECD 1998).

Figure 27. LGPGIR sections (I–VII) and basic elements



Source: Cortinas n.d.

Under the law, the Secretariat of Environment and Natural Resources (*Secretaría de Medio Ambiente y Recursos Naturales*—Semarnat) is responsible for the following:

- **Developing a national solid-waste program.** In 2008, Mexico published the 2009–2012 National Program for the Prevention and Comprehensive Management of Waste (*Programa Nacional para la Prevención y Gestión Integral de los Residuos*—PNPGIR) (Semarnat, 2008), which describes the program's objectives, waste management strategies, cross-cutting issues, financing, and program evaluation. Table 52 describes waste-related strategies oulined in the document.
- **Creating a national solid-waste inventory.** In 2012, Semarnat issued the Baseline Diagnosis for Integrated Waste Management (*Diagnóstico Básico para la Gestión Integral de Residuos*—DBGIR), which includes inventories (amounts and composition) and a description of waste management infrastructure, capacities and needs, for all waste types.
- **Developing a solid-waste information management system.** Semarnat is in the process of creating the National Information System for Integrated Waste Management (*Sistema de Información Nacional para la Gestión Integral de los Residuos*—SINGIR).
- **Issuing federal mandatory standards and guidelines.** Standards known as Official Mexican Standards (*Normas Oficiales Mexicanas*—NOM) and guidelines known as Mexican Norms (*Normas Mexicanas*—NMX) establish requirements or technical specifications for monitoring, sampling and documenting during the waste management process. For example, several technical environmental standards (e.g., NTEA-006-SMA-RS-2006) establish

requirements for soil enhancers from organic waste and specifications for source separation, sorted waste storage and MSW collection.

Table 52. 2009–2012 PNPGIR waste-related elements

Waste Management Objectives	• Change the focus of the traditional solid-waste management practice of final disposal to waste collection, use transfer stations, construct and operate regional sanitary landfills with LFG recovery, and establish sorting plants for recycling associated with the regional landfills. • Encourage LFG recovery and use. • Promote technologies that can reduce the volume of waste sent to landfills and incineration. • Recover energy from anaerobic treatment of organic waste. • Minimize the amount of waste sent to landfills by promoting recycling under shared responsibility schemes along the entire value chain.
Organic Waste Treatment Goals	• Encourage the use of organic waste in energy generation or composting (large volumes). • Develop a national inventory of composting facilities and others that use organic waste. • Encourage industrial processing of at least 5 percent of national organic waste generation. • Reduce the amount of organic waste sent to landfills through composting or energy use, to reduce greenhouse gas (GHG) emissions. • Establish one operational composting plant in every state. • Promote aerobic composting as an adequate and affordable alternative for organic waste, without limiting other alternative uses that are economically and environmentally acceptable.
Climate Actions	• Implement a national strategy for mitigating GHG emissions from waste. • Design a national strategy for monitoring, combustion and use of GHGs from waste disposal sites. • Reduce the amount of solid waste disposed of in landfills, through re-use, recycling, composting, recovery and energy recovery—under the “three Rs” philosophy. • Use fiscal and market mechanisms, as well as resources from carbon funds, to support the implementation of systems to reduce the amount of organic waste disposed of in landfills and prevent GHG emissions. • Promote the use of the Clean Development Mechanism (CDM) of the Kyoto Protocol, to make projects more financially viable. • Promote the use of the CDM by creating composting plants, strengthening the market for compost or treatment of organic waste for use as organic fertilizer or soil improver by the government and agriculture sectors. • Draw on resources and expertise from international mechanisms such as Methane to Markets (now the Global Methane Initiative), to carry out sanitation projects and closure of final disposal sites.

Source: Semarnat 2008.

State and municipal authorities are required to assess wastes in their jurisdictions and develop programs to manage them, while following the methods and guidelines established by Semarnat. States report this information in documents called State Programs for the Prevention and Comprehensive Management of Waste (*Programas Estatales para la Prevención y Gestión Integral de Residuos*—PEPGIRs). Municipalities submit this information in Municipality Programs for the Prevention and Comprehensive Management of Waste (*Programas Municipales para la Prevención y Gestión Integral de Residuos*—PMPGIRs).

Regulatory authority, management responsibility, recordkeeping requirements, data management and market opportunities all vary depending on the type of waste. States regulate ICI waste, including special-management wastes (*residuos de manejo especial*—RME). These wastes include non-hazardous waste generated in production processes of the primary (extractive industries, agriculture, livestock, forestry and fisheries), secondary (manufacturing) and tertiary (services) sectors. RME also includes large quantities of urban solid waste (10 tonnes per year or more) generated by single sources, defined as "large generators" (*grandes generadores*).

Large municipalities manage urban solid waste (*residuos sólidos urbanos*—RSU), which includes residential waste and waste from small ICI sources. Table 53 explores the types of solid waste (within the scope of this report) as defined in LGPGIR.[37]

Table 53. Types of waste under LGPGIR, and their corresponding regulatory authorities

Regulated Wastes	Regulatory Authorities
Urban solid waste from ICI sources (*servicios*) and large generators (at or above 10 tonnes/year) considered RME (special-management wastes)	State environmental authorities (regulate and control)
RME from productive processes	State environmental authorities (regulate and control)
Household RSU (urban solid waste)	Municipalities (regulate and control)

Source: DOF 2004.

According to LGPGIR, ICI waste generators are legally responsible and accountable for reducing and re-using their wastes, as well as supporting recycling activities to ensure environmentally sound management of waste. RME generators are responsible for comprehensively managing these wastes by processing them in their own facilities, contracting authorized waste management companies or using public services provided by municipalities.

Large generators are required to implement waste management plans to reduce, re-use and recycle waste. These plans should aim to (DOF 2004):

- promote waste prevention, valorization, and integrated management;
- establish management modalities that respond to the particularities of waste;
- ensure that constituent materials meet the specific needs of certain generators that have peculiar characteristics;
- establish management schemes in which the shared-responsibility principle applies; and
- encourage innovative processes, methods and technologies to achieve integrated waste management that is economically feasible.

Large generators are also allowed to sell, exchange and donate waste to other manufacturing processes without authorization, as long as the wastes are used as inputs to other productive processes and are not transferred to waste management companies. All organic waste from ICI sources is included in the RME category, but little information is available to understand how large generators manage organic waste.

[37] LGPGIR also defines hazardous, mining sector–, and petroleum sector–related wastes, which primarily fall under federal jurisdiction.

4.1.3 United States

In the United States, the US Environmental Protection Agency (EPA) regulates household, industrial, manufacturing and commercial solid and hazardous wastes under the Resource Conservation and Recovery Act, which serves as the national framework for a solid-waste control system. Under Subtitle D (the portion of the Act that relates to solid waste), the US EPA's Solid Waste Program codifies the following objectives:

- Encourage states to develop comprehensive state-wide plans to manage MSW and nonhazardous industrial solid waste.
- Set criteria for MSW landfills and other solid waste disposal facilities.
- Prohibit open dumping of solid waste.

The US EPA and the US Department of Agriculture (USDA) released the nation's first-ever goal for reducing food waste, in September 2015. The goal—a 50-percent reduction in food loss and waste by 2030—will be achieved through a combination of preventing food losses through better management; recovering surplus food to feed needy people and animals; and industrial use, anaerobic digestion (AD) and composting.

States have their own differing policies and regulations for organic waste. Many states and municipalities have regulations or permitting requirements that may cover organic waste diversion and processing (e.g., organic waste landfill bans, AD, composting), as well as other relevant local ordinances (e.g., odor, noise). For example, see the US Compost Council's interactive map of state composting regulations (US Composting Council 2017).

Many communities have announced reduction or diversion goals (e.g., zero waste) in recent years, with targeted deadlines set several years to decades in the future. So only time will tell how truly successful most of these policies, regulations and best practices might be (see Section 4.1.4 for a discussion of the challenges of organic waste programs or projects). However, due to growing interest and support for sustainability efforts at the municipal and ICI level, organic waste management is expected to continue to increase.

Policies related to residential organic waste become increasingly diverse among the more than 3,000 US counties/ county equivalents, and nearly 20,000 incorporated areas (i.e., cities and towns). Of all these jurisdictions, about 200—only 1 percent—have curbside collection for food waste (see Section 3.2.1). Even fewer have actual policies and/or regulations to accompany or mandate organic waste diversion or establish zero-waste goals (see Table 54 below); these represent about 6 percent of the current US population (Bodamer 2015; American Fact Finder 2016).

Table 54. Major US cities with ambitious waste reduction targets and/or zero-waste goals

City, State (2015 Population)	Goals (e.g., Targets) for Progress toward Zero Waste
New York City, NY (8,550,405)	90-percent diversion, relative to 2005 levels, by 2030
Los Angeles, CA (3,971,883)	Zero waste by 2025
San Diego, CA (1,394,928)	75-percent diversion by 2020, 90 percent in 2035 and 100 percent in 25 years
Dallas, TX (1,300,092)	40-percent diversion by 2020, 60 percent by 2030, and zero waste by 2040
Austin, TX (931,830)	Zero waste by 2040
San Francisco, CA (864,816)	Zero waste by 2020
Seattle, WA (684,451)	70-percent diversion by 2025
Washington, DC (672,228)	Styrofoam food-service products banned effective 2016; zero-waste plan

City, State (2015 Population)	Goals (e.g., Targets) for Progress toward Zero Waste
	to move toward 80-percent waste diversion (no date given)
Oakland, CA (419,267)	Zero waste by 2020
Minneapolis, MN (410,939)	50-percent diversion by 2020 and 80 percent by 2030

Sources: Bodamer 2015; American Fact Finder 2016.

PAYT Encourages Organic Waste Collection

In 2012, Vermont passed the Universal Recycling Law (Act 148), requiring municipalities and waste haulers to establish PAYT programs for materials collection, based on volume or weight (i.e., the less you toss and more you recycle, the less you pay).

One result was Brattleboro's program, developed in 2015. (The PAYT requirement became mandatory on 1 July 2015.) The town offers residents two bag sizes: a yellow 49-liter for US$2.00/bag, and a purple 125-liter for US$3.00/bag. Despite some wrinkles at the outset of the program, after the first four weeks in July the town reduced its total tonnage of collected garbage by 50 percent, compared to 2014, and SSO more than doubled during the same timeframe. It was estimated that the revenue from the sale of the bags covered collection and disposal costs, but months of data are needed before any conclusions can be drawn.

Source: Spencer 2015.

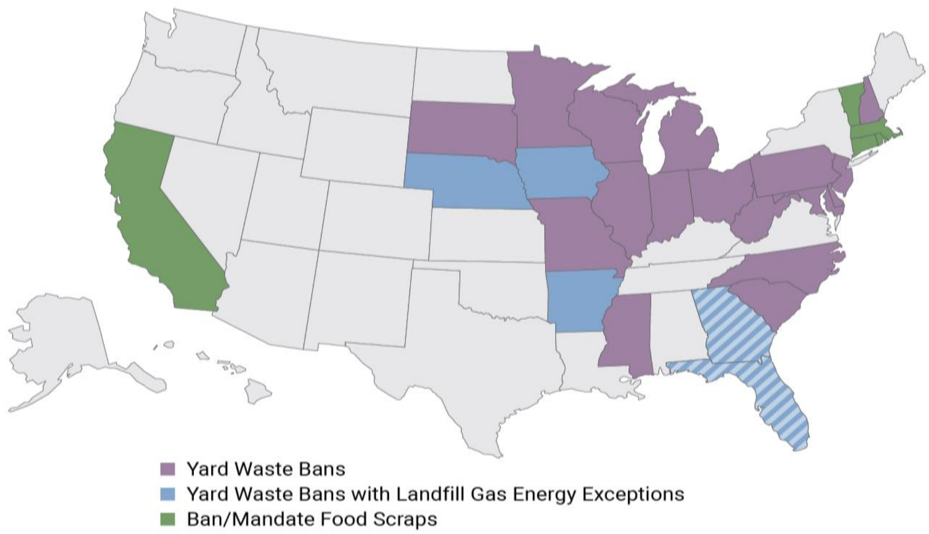
In the organic waste diversion programs featured in Chapter 3, convenience, education and cost appear to be the biggest drivers. From a cost perspective, in particular, communities are more likely to succeed in implementing their policies if they have existing PAYT programs that allow residents to reduce their refuse disposal costs by diverting materials to recycling and/or composting programs. States such as Vermont and cities such as San Francisco have successfully implemented PAYT to encourage residents and businesses to separate organic waste for collection and treatment.

From a processing perspective, using existing infrastructure (e.g., adding food waste collection to an existing yard waste collection program; using existing capacity or available space at a waste processing facility) helps negate many of the costs that can derail new organic waste management policies or programs.

Bans on Organic Waste in Landfill

Figure 28 shows the twenty-four states that have mandated organic waste diversion and/or banned disposal of yard waste or other organics in landfills. As the figure shows, only five of these states have enacted legislation for organics disposal specific to food waste.

Figure 28. States that have enacted yard and organic waste diversion, or landfill bans



Note: The bans in Florida and Georgia were repealed. Several other states may be considering repealing yard waste disposal bans, but there is limited information on their status.
Source: Adapted from Gardner 2016.

The five states with food waste disposal bans primarily target the ICI sector. Table 55 provides an overview of those states' organic waste disposal bans.

Table 55. State organic waste disposal bans in the United States

Ban Features	State				
	California	**Connecticut**	**Massachusetts**	**Rhode Island[a]**	**Vermont**
Sectors Covered	Commercial or public entity such as firms, partnerships, corporations, and associations (for-profit or not) Multi-family dwellings exempt except for more than five units with landscaping	Commercial food wholesalers or distributers, industrial food manufacturers or processors, supermarkets, resorts, and conference centers	Any individual, partnership, association, firm, company, corporation, department, agency, group or public body (governmental)	Commercial food wholesalers or distributers; industrial food manufacturers or processors; supermarkets; resorts or conference centers; banquet halls; restaurants; institutions,[b] corporations or casinos	Individual partnerships; companies; corporations; associations; joint ventures; trusts; municipal, state and federal entities; and any other legal or commercial entity

Ban Features	State				
	California	Connecticut	Massachusetts	Rhode Island[a]	Vermont
	services				
Applicability Threshold	Businesses: 2016: 6 m^3 per week 2017: 3 m^3 per week 2020: 1.5 m^3 per week[c] Multi-family: > 10 tonnes per week	2014: 94 tonnes per year 2020: 47 tonnes per year	0.9 tonnes per week	2016: 94 tonnes per year 2018: 47 tonnes per year for covered educational facilities	2014: 94 tonnes per year 2015: 47 tonnes per year 2016: 24 tonnes per year 2017: 16 tonnes per year 2020: all food scraps banned from landfill
Distance (km) to Organic Waste Processor	None[d]	32	None	24	32

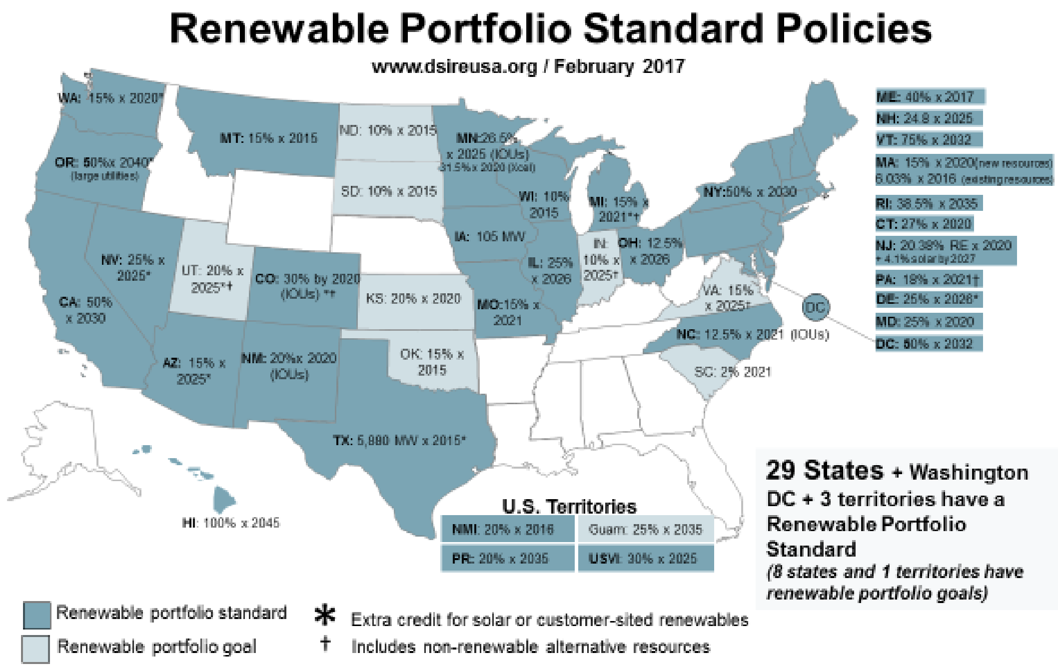
[a] Certain waivers exist.
[b] Includes religious, military, prison, hospital or other medical care institution, covered educational facility.
[c] If state-wide organic waste disposal has not been reduced to 50 percent of 2014 level.
[d] Exemptions for rural jurisdictions.
Source: Leib et al. 2016.

At the time of writing, New Jersey lawmakers were debating a bill that, beginning on 1 January 2019, would require the largest food-waste generators in the state (e.g., supermarkets, universities, food processors) to start shipping their organic waste to authorized energy conversion facilities within 40 kilometers of their locations. Smaller food-waste generators would be exempt until 2022 (Flammia 2016). In addition, California and Oregon passed legislation in 2016 that focused in part on organic waste diversion and processing, from a climate change mitigation approach.

Other Policies and Incentives

According to the US Department of Energy's (DOE's) Database of State Incentives for Renewables & Efficiency, the United States has more than 523 biomass-related regulatory policies and/or financial incentives—of which 227 relate specifically to AD technologies (NC Clean Energy Technology Center 2016). However, it is unclear how many (if any) of these initiatives are specific to organic waste and/or include composting efforts. More than three-quarters of the states have renewable portfolio standards (RPSs) or renewable energy portfolio policies that could be met if there were a greater emphasis on organic waste diversion and processing. A 2014 presentation on behalf of the Environmental and Energy Study Institute indicated that only 4 percent of US RPS capacity is composed of biomass (Stolark 2014). Figure 29 below summarizes US renewable energy portfolio policies and/or goals by state.

Figure 29. Policies/goals of renewable portfolio standards in the United States



Source: NC Clean Energy Technology Center 2017.

As Figure 29, above, shows, 29 states plus the District of Columbia and three territories have either RPSs or goals that require or support the use of renewable energy, but there is little information specifically on the use of biogas from AD. States have a patchwork of definitions for "renewables," and how AD or other types of organic waste conversion technologies are defined affects whether a project qualifies for any incentive.

In addition to state RPSs, incentives such as DOE's Qualified Energy Conservation Bonds (US DOE 2017) and USDA's Advanced Biofuel Payment Program (USDA 2017a) are available to AD projects. The American Biogas Council lists 25 state profiles (ABC 2017a) that link to such areas as incentives or green policies for AD. Other assistance includes the following:

- The federal Renewable Fuel Standard (US EPA 2017e) includes biogas as a cellulosic and advanced fuel, to meet renewable volume obligations. Qualifying biogas used in transportation generates Renewable Identification Numbers that help to facilitate markets for biogas sales from AD. In addition, Congress recently passed a $300 billion transportation bill, helping haulers to expand the use of compressed natural gas (CNG) in the public and private sector by continuing a limited truck weight waiver for natural gas vehicles (Gil 2016).
- USDA's Rural Energy for America Program (REAP) (USDA 2017b) can help agricultural producers and rural small businesses install renewable energy systems, including AD. Two types of funding assistance are available. The Renewable Energy Systems and Energy Efficiency Program provides grants and loan guarantees to agricultural producers and rural small businesses, to install renewable energy systems and make energy efficiency improvements. Other policies include voluntary markets for the reduction of GHG emissions, often referred to as "carbon offset markets." Voluntary markets, including the Climate Action Reserve, Voluntary Carbon Standard, and American Carbon Registry, are leading the way in terms of waste protocols and registered projects (methodologies, creating carbon credits). Many of the historically registered projects include organic waste (landfill gas [LFG]

recovery, agriculture methane recovery, composting); presently, though, persistent low carbon prices, low energy prices and other externalities have weakened investment in such projects. With their more consistent carbon pricing, regulated carbon markets like those in California or Quebec may alleviate some of the uncertainty, but issues such as what constitutes an eligible project are being debated (e.g., whether a regulated waste management project is eligible for carbon offset credits) (Boss 2016).

These state initiatives restrict or reduce GHG emissions:

- California Senate Bill 1383, "Short-lived climate pollutants: methane emissions: dairy and livestock: organic waste: landfills," was signed into law on 19 September 2016, establishing tough restrictions on short-lived climate pollutants, including methane, black carbon, and other "super-pollutants" that are potent GHGs. The law is intended to support the adoption of policies that improve organics recycling and innovative, environmentally beneficial uses of biomethane derived from solid-waste facilities. The legislation also specifies steep reduction targets for organic waste disposal in state landfills: a 50-percent reduction from the 2014 level by year 2020, and a 75-percent reduction from the 2014 level by year 2025 (LMOP 2016).
- Washington's Clean Air Rule caps and reduces carbon pollution. Starting in 2017, businesses that generate 100,000 or more tonnes of carbon pollution annually will be required to cap and then generally reduce their emissions by an average of 1.7 percent per year (State of Washington 2017). Businesses may purchase carbon offsets or purchase allowances under approved protocols, including the Climate Action Reserve's Organic Waste Composting Project Protocol (Climate Action Reserve 2017a), Organic Waste Digestion Project Protocol (Climate Action Reserve 2017b), or US Landfill Project Protocol (Climate Action Reserve 2017c).

ICI Policies and Initiatives

Various US companies have adopted sustainability goals and/or practices, but most of the endeavors focus on production and product life-cycle (e.g., EPR take-back programs), not organic waste diversion and processing. In November 2016, the USDA and the US EPA announced the formation of the US Food Loss and Waste 2030 Champions program, composed of businesses and organizations that have committed to cutting their US operations' food waste generation and disposal in half by 2030 (US EPA 2017c). To date, 20 companies have committed to achieving the 50-percent reduction commitments by 2030. In 2016, more than 950 businesses and organizations—including "grocers, educational institutions, restaurants, faith organizations, sports and entertainment venues, and hospitality businesses"—have joined the US EPA's Food Recovery Challenge to prevent and divert over 670,000 tonnes of food waste in their operations, in accordance with the Food Recovery Hierarchy (i.e., prevention, donation, composting, AD) (US EPA 2017d).

Meanwhile, some US companies have zero-waste-to-landfill or landfill-free status—which means they have taken the needed steps to reduce or eliminate waste (including organic materials) along the way. In particular, Subaru of Indiana Automotive has maintained zero-waste-to-landfill status for more than a decade (see text box).

More Than a Decade of Zero Landfill Status

The Subaru of Indiana Automotive (SIA) plant in Lafayette, Indiana, was the first North American automobile manufacturing plant to achieve zero landfill status (i.e., "nothing from the plant enters a landfill").

In 2002, Subaru's parent company challenged SIA to strive for zero landfill status by 2006. This seemed like an unrealistic goal: no other automotive plant had achieved that status, and four years did not seem like enough time for the necessary steps.

But SIA began to examine—and then reduce—the amount of waste it produced. For example, it reworked its process for stamping steel parts; this saved more than 45 kilograms of steel per vehicle, reducing the overall amount of steel it used by about 425 coils per year. This effort also saved other resources, including enough energy to power more than 2,000 homes. SIA also reduced or saved more than 2.3 million liters of oil by automating its parts' lubricating process.

For material that could not be eliminated or reduced, SIA sought ways to re-use it. Packaging that was previously landfilled after the first use is now re-used for engine shipments between SIA and Japan.

By 2004, SIA achieved its zero landfill goal—two years early. The plant recently celebrated more than a decade of zero landfill status and now works with other companies to share its experience and promote zero landfill practices.

Source: Haden 2015.

Table 56 highlights company efforts that have been verified by NSF International or GreenCircle Certified LLC, as well as Underwriters Laboratories or the US Zero Waste Business Council.

Table 56. Examples of US companies that have third-party-certified or -validated zero-waste-to-landfill or landfill-free status

Company	Commercial Sector (Plant/Facilities Affected)	Certification		Additional Comments
		NSF International	GreenCircle Certified LLC	
Bridgestone Americas, Inc.	Tire manufacturer (plant in Wilson, North Carolina)			Validated by Underwriters Laboratories

Company	Commercial Sector (Plant/Facilities Affected)	Certification		Additional Comments
		NSF International	GreenCircle Certified LLC	
Cargill	Meat-products producer (plant in Hazelton, Pennsylvania)	✓		Produces more than 4,500 tonnes a month, but sends nothing to landfills.
J+J Flooring Group	Commercial-flooring maker (US facilities)		✓	First US commercial-flooring manufacturer to achieve landfill-free status.
Superior Essex	Communications-cable manufacturing (facility in Hoisington, Kansas)		✓	First zero-waste-to-landfill effort achieved by a communications-cable manufacturer.
West Liberty Foods	Food producer (two facilities in Iowa; one in Utah)	✓		From just one facility, diverts 900 tonnes of waste annually from the local landfill.
Whole Foods Markets	Grocery stores (three in California)			Certified by US Zero Waste Business Council

Sources: Gerlat 2015; Whole Foods information from WFM 2013.

4.1.4 Notable Gaps in Current Approaches

As with most efforts, there are obstacles (e.g., lack of existing infrastructure and facilities, little to no ICI data/engagement) that—if not overcome—might lead to gaps in North America's approach to organics waste management (i.e., ability to boost national diversion) until resolved. Organic waste policies, programs and regulations also differ among Canada, Mexico and the United States—and within the countries themselves (e.g., from province to province or state to state)—which further impedes greater organic waste diversion and processing.

Mexico faces the most country-specific gaps, while Canada and the United States generally share gaps, due to similar circumstances. It is worth noting that many of the shared gaps apply to all of the countries and represent opportunities for cooperation (e.g., sharing best practices) to address the gaps (see Chapter 6 for recommendations and strategies for overcoming the gaps).

Two especially notable and consistent gaps in current approaches to diversion and processing of organic waste, among the three countries, are discussed below:

- Engagement with the ICI sector must be emphasized. The North American ICI sector has much greater diversion potential (e.g., grocery stores, restaurants) but diversion/processing data are lacking, and Mexico's programs to divert organic waste from ICI are just emerging. Canada only diverted 8.4 million out of a total 33 million tonnes of organic waste, making the national average a mere 25 percent. To fill this engagement gap, targeting the ICI sector is viewed as a potential opportunity for a number of jurisdictions. A lack of policies or programs focusing on ICI organic waste diversion and processing is compounded by limited ICI data available for policy-makers. Governments face challenges to designing effective and transparent policies or programs without reliable data.

- There is a need for ongoing, consistent outreach to inform residents of pending plans to develop an organic waste processing site, address their potential concerns (see the "Lessons Learned: California Dreamin'" text box), explain how to properly separate organics to minimize contamination, and advertise the benefits of composting and AD. Communication goes a long way to addressing other issues that might arise (see the "Legal Battles" text box).

Lessons Learned: California Dreamin'

Two planned AD projects are under fire from residents over odors and other concerns (Waste Today Staff 2016):

- Residents are concerned about possible odor from a proposed US$70 million, 330-square-meter AD project in Anaheim. They have responded to the proposal with concerns over odor and a drop in property value. "It's a dump," Anaheim Hills' Judy Morton said in the report. "Because it is so close to home, I do not feel comfortable with my health. When you put a place like this near homes your property (value) dumps quickly. They cannot equivocally say this is not going to stink" (Waste Today Staff 2016).
- Residents from San Luis Obispo are challenging the city's plan to open a digester on Waste Connections' San Luis Garbage property. The city has already approved the plans, but some residents living near the planned AD project are concerned about odors, increased truck traffic and loud noises. They are even more concerned that they only heard about the project three weeks before a public meeting and that the city was not addressing their concerns.

Involving residents as early as possible in the planning stage is crucial: it ensures transparency and allows the airing of concerns and proposed solutions.

Organic Waste Management Is Not Without Its Legal Battles

In 2015, a Waste Management unit sued the city of San Francisco for its exclusivity contract with Recology Inc., stating that the city's Department of the Environment had betrayed the competitive procurement process (Gerlat 2015).

The same year, six months after the city of Seattle*'s curbside composting became law and waste haulers were encouraged to examine homeowners' refuse for errant compostable items, a group of residents filed suit against the city, claiming their constitutional rights could be directly violated by haulers' actions without a warrant (Hickman 2015).

4.2 Implementation of Selected Policies, Programs, Regulations and Best Practices

Provincial/state and municipal governments throughout North America have undertaken efforts to implement policies, programs, regulations or best practices targeting organic waste. These efforts range from unit-pricing programs (e.g., PAYT), which help waste generators reduce disposal costs by diverting a portion of their waste (thereby reducing the overall volume of waste they pay to dispose of) or other financial incentives aimed at encouraging voluntary diversion (e.g., lowering tipping fees for organics at drop-off facilities), to mandatory recycling laws requiring generators to divert organic waste to composting or AD. Curbside collection of SSO in the public or private sector is gaining traction as one of the best ways to increase diversion volumes, by providing customers with flexibility—like the size and availability of containers, and collection frequency—making it easy to customize or adjust for the population.

All-out bans on organic waste in landfills are challenging to implement. Successful enforcement, penalties and transition strategies must be in place, and individual jurisdictions often must take the initiative and introduce bylaws, larger penalties, and tipping fees, to discourage disposal of recyclable materials.

Highlights from Canadian provinces or territories, Mexican states and US cities that have successfully implemented organic waste management efforts are provided below.

4.2.1 Canada

The provinces of Ontario, Nova Scotia, British Columbia and Quebec have demonstrated the most success over the years in terms of organic waste management policies, programs, regulations and best practices, and are therefore the main focus of this section. These provinces have implemented innovative policies, programs or incentives and serve as models for the country.

Best Practice in Canada: Composting Standards

Several standards and guidelines help ensure the quality of compost in Canada:

- Standard CAN/BNQ 0413-200, "Organic Soil Conditioners—Composts" <www.bnq.qc.ca/en/standardization/environment/composts.html>
- CCME Guidelines for Compost Quality <www.ccme.ca/files/Resources/waste/compost_quality/compostgdlns_1340_e.pdf>
- Ontario's Compost Quality Standards <www.ontario.ca/page/ontario-compost-quality-standards>
- Quebec's Guidelines for the Beneficial Use of Fertilizing Residuals <www.mddelcc.gouv.qc.ca/matieres/mat_res/fertilisantes/critere/guide-mrf.pdf>

Ontario

Municipalities across Ontario have handled organic waste diversion in evolving ways, over time. As mentioned earlier in this chapter, the individual municipalities are responsible for managing residential waste and the resulting programs have evolved within the circumstances of each municipality.

Regulation 101/94 sets the requirements for collecting and processing residential organic waste in Ontario. Any municipality with a population over 50,000 must implement a leaf and yard waste collection and composting program; any municipality with a population over 5,000 must provide home composters to all residents. In some cases, municipalities distribute composters free of charge;

in others, they charge a fee. This regulation began the establishment of leaf- and yard-waste composting programs in the province in the mid-1990s.

Another driver for organic waste diversion in the residential sector has been a shortage of landfill disposal capacity. For some time, Ontario made up for this shortage by shipping waste to Michigan landfills (which have a cheaper tipping fee). In 2006, though, Michigan passed legislation to ban the disposal of Canadian waste in its landfills. The Ontario government stepped in and negotiated an agreement with Michigan that would reduce and ultimately end the shipment of residential waste to Michigan landfills by 2010. This created pressure on municipalities to develop diversion programs, including those for organic waste. Added to the landfill capacity shortage, the province announced a diversion target of 60 percent in June 2004 (MOECC 2004). In order for municipalities to achieve the 60-percent diversion from landfills, organic waste became a required part of every diversion program.

Other policies and standards that have contributed to successful organic waste diversion in Ontario include:

- The General Waste Management Regulation 347 of the Environmental Protection Act of 1990 regulates waste management activities, including the receiving and processing of organic waste by compost facilities, as well as the application and use of compost (Government of Ontario 2016).
- Ontario Regulation 267/03 of the Nutrient Management Act of 2002 regulates the application and storage of nutrients, including compost, on agricultural lands. As more AD facilities are developed, the use of digestate on agricultural land becomes a more viable option (Government of Ontario 2015).
- Ontario Compost Quality Standards of 2012, referred to in Regulation 347, set a framework that allows a greater range of feedstocks to be composted (MOECC 2012).

The above-mentioned policies and standards help divert waste from disposal by increasing residential and ICI composting rates. By 2014, 63 percent of residential households in Ontario were involved in curbside collection of yard waste and 58 percent were involved in curbside SSO collection. Notably, most of the eligible households were single-family homes. This resulted in over 1 million tonnes of material being diverted to composting facilities in 2014 (WDO 2016).

Diversion of organic waste from the ICI sector has not been as successful in Ontario. This is, in part, because the United States has relatively cheap disposal capacity available. Thus, Ontario has been exporting between 2.5 and 3 million tonnes of waste to the United States for the past 10 years, most of it ICI and construction, remodeling and demolition waste.

Ontario has a feed-in tariff (FIT) in place, developed by the Independent Electricity System Operator. Its aim is to encourage and support greater use of renewable energy sources by providing an incentive for the production of biogas from facilities sourced by renewable energy. The former Ontario Biogas Systems Financial Assistance Program, along with the FIT program, has helped fund many biogas projects that are either under construction or already operational. The FIT program offers price guarantees for electricity generated using a renewable energy technology. These prices vary based on the type of project, and they are designed to allow for cost recovery and a reasonable return on investment. Based on the price schedule from 21 June 2016, biogas facilities less than 500 kilowatts in size are to receive a contract price of 16.8 cents per kilowatt-hour (Ontario Ministry of Agriculture, Food, and Rural Affairs 2016).

In 2015, a document titled *Strategy for a Waste Free Ontario: Building the Circular Economy* was released by Ontario's Ministry of the Environment and Climate Change (MOECC 2015). Its vision focuses on waste as a resource with a variety of beneficial uses and a role in achieving a circular economy. The strategy has two stated goals:

- zero waste in the province
- zero GHG emissions from the waste sector

Both of these goals are long-term aspirations, though the second will guide priority-setting for resource recovery and waste reduction.

The strategy recognizes that organics make up about one-third of the waste stream, and that reducing the amounts of organics that go to landfill would reduce GHG emissions. It states that an organics action plan—which should drive more organic waste diversion—will be developed for the province in 2017.

Nova Scotia

Nova Scotia is one of two provinces (the other being Prince Edward Island) that have implemented landfill bans for organic materials such as food (as of 1 June 1997) and leaf and yard waste (1 April 1996) for both the residential and ICI sectors (Municipality of Colchester 2016). The province will continue to add materials to the ban list (particularly from ICI, an expanding area) as its waste diversion infrastructure improves. Its program of landfill bans is one major reason why the province has the country's highest diversion rates for organic materials (Giroux Environmental Consulting 2015).

More generally, Nova Scotia's solid waste is regulated under the Solid Waste Resource Management (SWRM) Regulations, in Section 102 of the Environment Act of 1996. These regulations approve a series of programs: municipal waste diversion programs, including source reduction, re-use, recycling and composting programs; municipal household hazardous waste programs; municipal waste management education programs; and market development, manufacturing and processing of recycled materials (Government of Nova Scotia 2009).

Best Practice in Nova Scotia: Clear Bags for Organic Waste

Municipalities in the province began using clear garbage bags, rather than the traditional black opaque bags. This practice was first adopted in Cumberland County and the town of Oxford in 2001; more recently, municipalities along the southern shore of Nova Scotia adopted it in 2014 and 2015. The contents of clear bags are easier for collection vehicle operators to inspect, which in turn makes it easier for them to leave non-compliant bags at the curb. As of 2014, 45 of the 54 municipalities use clear bags for residential and ICI waste management, which equals 48 percent of the overall population. (The Halifax Regional Municipality, which makes up 40 percent of the remaining population, has yet to adopt the clear-bag program.) This practice has increased organics and recyclables diversion by 20 to 40 percent.

Source: Compost Council of Canada 2014.

Alongside the SWRM regulations, in 2009 Nova Scotia renewed its SWRM strategy from 1995. The strategy was based on the following goals: environmental protection, ecological value, wise and efficient use of renewable and non-renewable resources, and promotion of economic opportunities through the development of a vibrant environmental industries sector (Government of Nova Scotia 1995).

British Columbia

British Columbia follows the Environmental Management Act of 2003 and the Public Health Act of 2008. Accompanying these Acts is the Organic Matter Recycling Regulation, created in 2002 and last amended in July 2016. This regulation oversees the production, quality and land application of organic matter in solid waste. It serves as a guidance document for local governments and compost and biosolids producers, explaining how to use organic material, as well as how to protect soil quality and drinking water sources (Government of British Columbia 2016b).

Best Practice in British Columbia: Surcharge on Tipping Fee

On 1 January 2017, Metro Vancouver Board's Bylaw No. 302 (published in October 2016) took effect. The bylaw establishes a tipping fee and solid-waste disposal regulation; Table 4 in its Schedule B lists the applicable surcharges on hauled waste. For example, until 30 June, 2017, a 50-percent surcharge applies to any load disposed of at a disposal site, if food waste makes up more than 25 percent of its total weight or its total volume. A C$50 surcharge per load is applied to SSO containing more than 0.05 percent of other refuse material. The purpose of this bylaw is to reinforce Metro Vancouver's landfill disposal ban of organic waste of 2015.

Source: GVS&DD 2016.

The Regional District of Nanaimo, Capital Regional District, and Metro Vancouver Regional District have developed and implemented a disposal ban on organic municipal waste. Nanaimo banned the disposal of organic waste in landfills in 2007, through its Solid Waste Management Regulation Bylaw. The Capital Regional District started with a C$20/tonne incentive for delivering SSO to an approved transfer station within the district in 2012, and then in 2014 included a 20-percent surcharge on sending garbage containing organics to local landfills; the full ban was implemented in 2015. Metro Vancouver started with an organic waste disposal ban from single-family homes in 2012, then included a surcharge on tipping fees for businesses and multifamily residences; the full ban was implemented in 2015 (Government of British Columbia 2016a).

Quebec

Quebec is following in the footsteps of Nova Scotia and Prince Edward Island's landfill bans on many recyclable materials, including organic waste for both the residential and the ICI sectors. The Quebec Residual Materials Management Policy sets forth planning to implement a similar organics ban in 2020. To help achieve this goal, Recyc-Québec issued a mandated Organic Recycling Issue Table (i.e., roundtable) in 2012 to invite and encourage stakeholders who play a major role in the development of organic waste to work together and adopt an integrated recycling approach. There are 30 roundtable members, some of whom represent environmental and government organizations, stores and institutions (MDDELCC n.d.).

Best Practice in Quebec: Biogas Strategy

Quebec has a timetable for producing biogas from organics digestion, under its program of biomethanization and composting. The province includes criteria for energy recovery from waste in its energy strategies.

For further information, see:

<https://politiqueenergetique.gouv.qc.ca/wp-content/uploads/Energy-Policy-2030.pdf>.

In another effort to achieve the 2020 goal of eliminating all organic waste, the importance of recycling residual fertilizing materials (RFM) through land application was noted. In May 2011, however, the Quebec Court of Appeal released a municipal bylaw prohibiting the importation, storage and spreading of RFM under the Municipal Powers Act. According to Section 52 of the Act, municipalities have the right to prohibit the application of RFM (Recyc-Québec 2017a).

The *Guidelines for the Beneficial Use of Fertilizing Residuals* was revised in December 2015 to include recommendations made by the Organic Recycling Issue Table. One of these included tightening certain criteria, particularly with regard to odors from RFM storage (Recyc-Québec 2017b).

4.2.2 Mexico

Mexico has forged ahead on waste management issues, through the creation of federal policies and programs to promote diversion and processing of organic waste. At the state and municipal level, waste management initiatives have also begun to spring up. Despite this, policies are often not enforced or followed (at least not adequately) and primarily focus on garden and landscaping waste (i.e., few policies or programs directed at food waste). The implementation framework for Mexico's national waste management policies and programs are described below, followed by state/municipal examples of best practices and implementation challenges unique to Mexico.

National Policies and Programs

Although waste management issues are not first-level goals for Mexico's current administration, they are nonetheless included in the 2013–2018 National Development Plan (*Plan Nacional de Desarrollo*—PND). The PND is a roadmap for all federal government agencies; it outlines general objectives and establishes strategies to meet them.

Objective 4.4 of the PND encompasses waste management activities through its goal "to promote and guide an inclusive green growth that preserves our natural heritage and, at the same time, generates wealth, competitiveness and jobs" (Secretaría de Hacienda y Crédito Público 2013). Born out of Objective 4.4 is Strategy 4.4.3, which mandates the creation of environmental and climate change policies aimed at achieving "a competitive, sustainable, resilient and low-carbon economy" (Secretaría de Hacienda y Crédito Público 2013). One line of action under Strategy 4.4.3 is the achievement of an integrated management of solid waste, special-management waste and hazardous waste in a manner that minimizes risks to the population and the environment (Secretaría de Hacienda y Crédito Público 2013)..

Semarnat and other federal environmental agencies are legally accountable for achieving the goals set out in the PND through the creation of relevant programs. In response to Strategy 4.4.3, Semarnat created the 2013–2018 Environment and Natural Resources Sector Program (*Programa Sectorial de Medio Ambiente y Recursos Naturales*—Promarnat).

Like the PND, Promarnat contains stated objectives, strategies and lines of action intended to meet them. Objective 1 of the current Promarnat ("To promote and facilitate a sustained and sustainable low carbon growth that is equitable and socially inclusive") includes a line of action to "design and promote schemes that allow access to resources for contaminated site remediation and waste treatment activities."

Objective 5 ("Stop and reverse the loss of natural capital as well as water, air and soil pollution") contains waste management strategies to meet its stated goal. Strategy 5.4, in particular, seeks to "encourage valorization and maximum utilization of wastes" and is further supported by 10 lines of action (see text box).

Promarnat Actions to Minimize Waste

The following lines of action stem form Promarnat strategy and are related to solid-waste prevention and management:

“5.4.1 Publish the 2013–2018 National Programme on Waste Prevention and Comprehensive Management (PNPGIR).

“5.4.2 Encourage increase in infrastructure coverage for integrated management of urban solid wastes, special-management wastes and hazardous wastes.

“5.4.5 Boost recycling activities.

“5.4.6 Incentivize implementation of National Waste Management Plans for priority wastes.

“5.4.7 [Achieve] Zero open dumping. Encourage sanitation and closure of existing open dumps and abandoned sites.

“5.4.8 Promote design and implementation of economic incentives for waste recovery and reuse.

“5.4.9 Promote research on and technology development for waste management.

“5.4.10 Optimize use and integrated management of wastes from the primary sector.”

Source: Semarnat 2013a.

Achievement of these objectives has been limited. To date, the 2013–2018 PNPGIR has not yet been issued; the most recent PNPGIR is the 2009–2012 version, which includes waste management objectives, organic waste treatment goals, and climate actions (Semarnat 2008)—similar to the new Promarnat lines of actions. Table 57 provides an overview of the 2009–2012 PNPGIR elements relative to waste.

Table 57. PNPGIR waste-related elements, 2009–2012

Waste management objectives	• Change the focus of the traditional solid-waste management practice of final disposal to waste collection, use transfer stations, construct and operate regional sanitary landfills with LFG recovery, and establish sorting plants for recycling associated with the regional landfills. • Encourage LFG recovery and use. • Promote technologies that can reduce the volume of waste sent to landfills and incineration. • Recover energy from anaerobic treatment of organic waste. • Minimize the amount of waste sent to landfills by promoting recycling under shared responsibility schemes along the entire value chain.
Organic waste treatment goals	• Encourage the use of organic waste in energy generation or composting (large volumes). • Develop a national inventory of composting facilities and others that use organic waste. • Encourage industrial processing of at least 5 percent of national organic waste generation. • Reduce the amount of organic waste sent to landfills through composting or energy use, to reduce GHG emissions.

	• Establish one operational composting plant in every state. • Promote aerobic composting as an adequate and affordable alternative for organic waste without limiting other alternative uses that are economically and environmentally acceptable.
Climate actions	• Implement a national strategy for mitigating GHG emissions from waste. • Design a national strategy for monitoring, combustion and use of GHGs from waste disposal sites. • Reduce the amount of SW disposed of in landfills through re-use, recycling, composting, recovery and energy recovery, under the "three Rs" philosophy. • Use fiscal and market mechanisms, as well as resources from carbon funds, to support the implementation of systems to reduce the amount of organic waste disposed of in landfills and prevent GHG emissions. • Promote the use of the Clean Development Mechanism (CDM) of the Kyoto Protocol, to make projects more financially viable. • Promote the use of the CDM by creating composting plants, strengthening the market for compost or treatment of organic waste for use as organic fertilizer or soil improver by the government and agriculture sectors. • Draw on resources and expertise from international mechanisms such as Methane to Markets (now the Global Methane Initiative) to carry out sanitation projects and closure of final disposal sites.

Source: Semarnat 2008.

States and Municipalities

As described in Section 3.4.2, all Mexican states have assessed solid-waste management and developed strategies for reducing waste. All but six of Mexico's 31 states have established at least one strategy related to improved organic waste management. Many of these plans focus on garden and landscaping waste. Few policies or programs have been directed at food waste. State Programs for the Prevention and Comprehensive Management of Waste (*Programas Estatales para la Prevención y Gestión Integral de Residuos*—PEPGIRs) have been issued in all 31 states and Mexico City. Most programs focus primarily on residential waste and very few include estimates of organic waste from ICI sources. Estimates in these programs are not harmonized and are very scarce, depending on the economic activity developed in each state. Table 58 shows years of publication for all PEPGIRs.

Best Practice in Mexico: Regional Collaboration

Municipalities in Mexico have also started implementing their own waste management programs. To date, 37 municipalities out of a total of 2,454 have issued PMPGIRs. Four programs have been created by groups of municipalities within the same region as a result of PMGIRs submitted by municipalities. These programs have proved to be very effective in bringing different regional stakeholders to agree on waste management opportunities. Regional collaboration is a scheme worth exploring for future projects.

Table 58. PEPGIR publication dates

Year Published	States
2008	Michoacán
2009	Guerrero, México, Morelos, Nayarit, Oaxaca, Quintana Roo
2010	Aguascalientes, Campeche, Distrito Federal, Yucatán
2011	Baja California, Baja California Sur, Chiapas, Colima, Durango, Hidalgo, Puebla, Querétaro, Sonora
2012	Chihuahua, Nuevo León, Sinaloa
2013	Coahuila, San Luis Potosí, Veracruz
2014	Guanajuato, Tabasco, Tamaulipas, Zacatecas

Obligatory (NOM) and voluntary (NMX) standards relevant to organic waste management include those that provide technical environmental guidance to develop RME waste management plans (e.g., NOM-161-SEMARNAT-2011), waste quantification and characterization, and final waste disposal (e.g., NOM-083-SEMARNAT-2003). Several technical environmental standards (e.g., NTEA-006-SMA-RS-2006) establish requirements for soil enhancers from organic waste and specifications for source separation, sorted-waste storage and MSW collection. Jalisco and Mexico City both have local standards for the separation of organic waste (yard and municipal green waste) for composting and for managing slaughterhouse waste.

Querétaro has also demonstrated leadership in regulations development. In 2011, Querétaro adopted waste management regulations that give municipalities a legal basis to:

- define organic waste(s) appropriate for production of quality compost;
- identify potential compost demand/consumption by public and private sectors, including commercialization plans;
- develop guidelines for organic waste separation, collection and transport, as well as compost production and use (e.g., criteria for soil amendments or fertilizers);
- secure resources (e.g., material, labor, financial) to operate composting plants; and
- provide education and training to ensure public participation in organic waste collection and compost use efforts.

The regulations also set forth provisions for segregating organic waste from wastes unsuitable for composting, to take place at solid-waste selection plants. In locations where it is not economically feasible to implement or install municipal composting programs/plants, the state will promote domestic (e.g., backyard) or private composting. Lastly, the regulations oblige agricultural, industrial and/or agro-industrial companies to capture biodegradable wastes generated from their production processes for further processing into energy sources (e.g., biogas), compost or other products. (Poder Legislativo del Estado de Querétaro, 2004)

Implementation Challenges

Mexico has promulgated a far-reaching solid-waste law, but it has faced implementation problems, in both the residential and ICI sectors. Some of the difficulties encountered are the following:

- **Changes in municipal administrations.** Municipal administrations change every three years and sometimes momentum for organic waste management programs is lost. While such changes also affect municipalities in Canada and the United States, the impact is more pronounced in Mexico, as programs there are less developed.

- **Perception that waste separation is not worthwhile.** An annual survey by the National Institute for Statistics and Geography (*Instituto Nacional de Estadística y Geografía*—INEGI) shows that 47 percent of households do not segregate waste because they believe it will be mixed again when it is collected (INEGI 2016d).
- **Disconnection between environmental authorities and localities.** Some organic processing facilities, such as the AD system in Atlacomulco (described in Table 44), are operating at half capacity because local authorities do not enforce diversion programs within the population. This is often the case because environmental authorities overseeing these projects are seldom associated with the actual day-to-day waste collection schemes, which are mostly operated by public services for municipal waste management.
- **States' unreadiness to issue waste regulations, even though the national law made them responsible for doing so.** Although state laws included provisions for waste management (see the Querétaro example below), some state environmental institutions were not prepared for the responsibilities. Instead, state authorities promoted voluntary programs to adopt cleaner technologies, environmental management systems, and industrial synergies to share secondary materials as inputs to productive processes. This process is ongoing; some states still have not issued their own regulations, and many PEPGIRs do not include ICI data.
- **Lack of guidance on preparing planning documents for ICI waste management.** There are no guidelines or uniform methodologies available to assist generators in estimating and reporting ICI waste generation and handling.
- **Lack of compliance with planning requirements for ICI waste management.** Although large ICI generators are required to register and submit waste management plans at the state level (i.e., environmental secretariats or equivalent), there is a lack of compliance. Due to limited resources (e.g., personnel, budgetary), the Attorneys for the Protection of the Environment have very few inspectors and enforcement officers. Moreover, they are usually dealing with other matters and do not have the time to prosecute environmental non-compliance. Waste management plans represent main sources of data that could be used to develop waste inventories (e.g., composition, types of management), as well as final destination.

4.2.3 United States

The US EPA helps guide state, regional and local decision makers on best practices in solid-waste management, such as ordinances, programs, outreach and technical assistance, and infrastructure. The Managing and Transforming Waste Streams Tool features 100 measures (e.g., zero-waste goals for organics; PAYT; source-separation incentives; procurement policies) that communities can take to reduce waste and recover specific materials (US EPA 2017f). By using the tool's interactive functions to sort, search and/or filter the various measures, local planners can create a list of waste management strategies tailored to their community's needs and capabilities.

The tool also features over 300 implementation examples from US and Canadian communities, including links to local ordinances and program websites. The measures and accompanying examples help demonstrate the type(s) of solid-waste management approaches local governments—as well as state or regional agencies—can take, and identify opportunities to implement more-stringent practices over time.

States

As previously mentioned, the US EPA *encourages* states to develop solid-waste management plans (SWMPs) to assist and guide development and implementation of solid-waste management programs within the state (i.e., how the state will reduce, manage, and/or dispose of its solid waste), by outlining what actions need to be taken and by establishing criteria for decision making (e.g., reduction targets). SWMPs are not required, however; roughly 30 percent of the states do not have comprehensive plans guiding program development and implementation for solid-waste management. (See Appendix B for a list of state SWMPs.) Several states—California, Nevada, Utah—require counties to submit SWMPs to guide actions at a more regional or local level.

Some states' policies have an even greater impact on local communities. Minnesota's Metropolitan Solid Waste Management Policy Plan, for example, sets forth actions for managing the Twin Cities Metropolitan Area's (TCMA's) solid waste through 2036. The seven metropolitan counties within the TCMA—Anoka, Carver, Dakota, Hennepin, Ramsey, Scott and Washington—participated in the plan's development, along with the Minnesota Pollution Control Agency (MPCA). A Minnesota statute (Minn. Stat. 473.149) provides legislative mandate and requires that the Plan be followed in the TCMA and that all stakeholders—including the MPCA—be accountable for implementation (MPCA 2016). The state legislature established a 75-percent combined recycling and organics goal[38] for the TCMA; to meet this objective by 31 December 2030, the TCMA will need to make region-wide changes. The Plan also specifies that by 2020, every county should require that all licensed waste haulers offer curbside organics collection. By 2022, cities of the first and second class (as defined in Minn. Stat. 410.01) should provide a residential organics collection program. Lastly, all residents in the TCMA should have access to organized curbside collection of organics by 2025 (MPCA 2016, 29). Minnesota's legislative charge to the local municipalities provides a definitive path forward.

Technical Assistance and Funding from States

Some states have gone beyond SWMPs and developed state-wide programs to help other organizations interested in solid-waste management issues. RecyclingWorks in Massachusetts is one such assistance program, designed to help businesses and institutions start a recycling or composting program or maximize reuse opportunities. RecyclingWorks provides information (e.g., materials guidance) and tools (e.g., a searchable database of recycling haulers/processors), as well as expert technical assistance and opportunities to connect with and learn from other organizations (e.g., events and workshops). The program is funded by the Massachusetts Department of Environmental Protection (MassDEP) and supported by the Center for EcoTechnology (Recycling Works Massachusetts 2017).

The California Department of Resources Recycling and Recovery (CalRecycle) provides funding for public and private solid-waste management projects such as composting and AD, through its Organics Grant Program. The purpose of this competitive grant program is to lower overall GHG emissions by expanding existing capacity or establishing new organics processing facilities in California, to reduce the amount of organic materials (e.g., yard trimmings, food waste) or alternative daily cover sent to landfills. Table 59 lists Organics Grant Program awards for fiscal year (FY) 2014–2015; each of those awarded received roughly US$3 million, for a total disbursement of US$14.5 million (CalRecycle 2015c).

[38] The combined goal includes traditional recycling of 60 percent and organics equaling 15 percent (MPCA 2016). Organics may include "food to people, food to animals, and composting of source-separated compostable materials" (MPCA 2016, 15).

Table 59. CalRecycle Organics Grant Program awards, Fiscal Years 2014–2105

Grantee	Project Summary
Burrtec Waste Industries	Build covered, aerated, static-pile composting operation
Colony Energy Partners–Tulare, LLC	Build high-solids AD facility
CR&R Incorporated	Expand existing AD facility to double processing capacity
Mid Valley Disposal, Inc.	Construct covered, aerated, static-pile composting operation
Recology East Bay Organics	Buy equipment for processing system, to extract organics from mixed solid waste for AD

Source: CalRecycle 2015c.

For the FY2016–2017 grant cycle, US$24,000,000 will be distributed equally between composting and digesting projects (CalRecycle 2017).

Local Government

Local governments play a key role in solid-waste management, and are often responsible for setting policy that affects particular components of the waste stream (e.g., organic waste diversion) and/or how these wastes are managed (e.g., public versus private collection). Municipalities can also adopt approaches for preferred solid-waste treatment (e.g., composting, waste-to-energy) and establish how those programs might be funded (e.g., levies).

In some instances, municipalities use their local powers (e.g., ordinances) to expand on state mandates. After San Francisco reached its State of California–mandated 50-percent landfill diversion by 2000, the city extended its own landfill diversion commitment and set additional goals of 75-percent diversion by 2010 and zero waste by 2020 (SF Environment 2016). The city adopted various policies, including a Mandatory Recycling and Composting Ordinance that went into effect in October 2009. This ordinance requires San Francisco residents and businesses to sort recyclables (e.g., plastic, glass) from organic material (e.g., food scraps) and deposit them into specified collection containers. In San Francisco's case, the city's zero-waste program is entirely funded by revenue generated through customers' refuse rates.

4.3 Case Studies of Selected Policies, Programs and Best Practices

Development and implementation of organic waste management options typically comprises several steps and/or occurs in phases over years—or decades. This section focuses on country-specific case studies in Canada, Mexico and the United States that emphasize the timeframes involved in selected policies and programs, as well as some of the best practices (e.g., community and stakeholder engagement/input; diagnostics/decision-making tools) that have helped to ensure success. It also gives an overview of organic waste management experience around the world, and features regions and/or cities that could serve as international leaders to emulate.

4.3.1 Canada

Many successful diversion and processing programs operate in Canada. However, case studies on Toronto, Halifax, Saint-Hyacinthe and Surrey showcase some of the most effective and innovative approaches to organic materials diversion policies and implementation in Canada:

- Toronto is one of the largest cities in North America and shows how residential organic waste diversion can be successful in a major urban center.
- Halifax's organics program was one of the first developed in Canada and includes both the residential and ICI sectors.
- Saint-Hyacinthe developed Quebec's—and one of North America's—first organic waste reclamation centers, whereby sludge produced by the city's wastewater treatment plant (WWTP), along with municipal green waste, is turned into biogas.
- Surrey is developing a major organics processing facility to service both the residential and ICI sectors.

Each program shows the evolution of organic waste management in Canada.

Best Practice: Customer Flexibility in Toronto, Ontario

The city's SSO program is noteworthy as it allows residents to place material in plastic bags. It also allows pet waste, diapers and sanitary products to be placed in the specially colored bins. By making the program as easy to use as possible, the city hopes for greater diversion of organic waste. To accommodate the plastic waste, the city has developed wet AD as the preferred processing technology.

City of Toronto

Toronto has a long history of managing residential leaf and yard waste and SSO. Two programs were implemented in 2002 and have grown since then (see Table 60). The city collected about 70,000 tonnes of leaf and yard waste and 3,000 tonnes of SSO in 2002, and about 133,000 tonnes of leaf and yard waste and 125,000 tonnes of SSO from residential sources in 2014.

Table 60. Timeline of organic waste diversion in Toronto

Date	Event
1980s	The leaf and yard waste program was introduced.
2002	The Dufferin Organics Processing Facility (DOPF) was commissioned, making Toronto the only city in North America to use AD technology for processing collected green-bin organics. The facility was originally designed as a pilot project, with a capacity of 25,000 tonnes/year. Green-bin organics collection was rolled out to 70,000 single-family households in Etobicoke.
2003–2004	Green-bin organics collection for single-family residences was rolled out in Scarborough in June 2003; Toronto, York and East York followed in 2004.
2005	Green-bin organics collection was rolled out to single-family residences in North York.
2006	Development guidelines for multi-residential buildings were revised to accommodate organics collection.
2007	City council approved the Target 70 plan, which outlined the proposed initiatives to get to 70-percent waste diversion by 2010.
2009	A pilot program for green-bin organics was rolled out to multi-residential buildings.
2011	Construction began on the anaerobic digester for organics processing, at the Disco Road Organics Processing Facility.
2012	The first stage of the DOPF's expansion was completed with the addition of a second digester.
2013	The city started approaching all multi-residential buildings to participate in the green-bin organics program.
2014	The DOPF discontinued operations in March 2014 to allow decommissioning/shutdown activities in

Date	Event
	preparation for an expansion to 55,000 tonnes/year. The Disco Road Organic Processing Facility began operations in July 2014, for 75,000 tonnes/year.
2016	Construction of the DOPF expansion began, and is to be completed by 2018.

Organic waste processing and digestion is done onsite. The digestate is sent offsite to private facilities for composting. The city is investigating options for using biogas produced at its AD facilities.

In 2014, the city provided SSO curbside collection to 460,000 single-family homes and collected about 112,000 tonnes, or 240 kg/household, of material. Another 13,000 tonnes were collected from multi-family residences, schools, agencies and corporations (City of Toronto 2017a).

City of Halifax

In 1998, Halifax became the first city in Canada to implement an SSO program. The city processed 53,000 tonnes of SSO organics in 2015: 37,000 tonnes from the residential sector and 16,000 from the ICI sector. It has two in-vessel composting facilities (operated by private contractors until 2019); these began operations in 1999 and have now reached their processing capacity limits.

The city is working toward increasing its organics processing capacity from 50,000 tonnes to 60,000 tonnes per year, with the option to increase to 75,000 tonnes per year in the future (Halifax Environment and Sustainability Standing Committee 2016).

In 1994, while the local landfill was reaching capacity, the city government gathered the public to help change traditional waste solutions. About 300 residents participated in the public meetings, which led to the creation of the Community Stakeholder Committee. In 1995, the Committee developed an SWRM strategy to put forth a new solid-waste system. The city closed the local landfill, and implemented the SWRM strategy by opening two composting plants, as well as a waste stabilization and disposal facility (Tools of Change 2016).

Best Practice: Community Engagement in Halifax, Nova Scotia

The city of Halifax has always encouraged community involvement when developing a waste management strategy. Based on a planning process led by a citizen's committee in 1996, an implementation plan with a goal of 60-percent waste diversion was established. The city has a diversion rate of 59 percent as of 2012, with all residential, commercial and institutional solid waste included.

Source: Federation of Canadian Municipalities 2009.

Halifax's source reduction programs include backyard composting, grasscycling and a precycling campaign that encourages consumers to contemplate potential waste before making an unnecessary purchase. A pilot project is also underway in which green bins are collected each week between 2 July and 31 August 2016 (Federation of Canadian Municipalities 2009).

Saint-Hyacinthe, Quebec

In 2014, an organic waste reclamation center was opened in Saint-Hyacinthe. The project was developed in two phases. Phase 1 involves treating sludge from the WWTP by AD. Phase 2 involves installing biogas plants and digestate maturation to produce biogas, which will be sold and injected into the gas network. The facility has an annual waste processing capacity of 205,000 tonnes, and an estimated capital cost of C$106 million. The project was supported by provincial and local business, and received about C$50 million in grants and funding, including from Canada's Green Infrastructure Fund and Quebec's program for processing organic matter using biomethanization and composting

(*Le Programme de Traitement des Matières Organiques par Biométhanisation et Compostage*). It has a biogas generation capacity of 16.8 million cubic meters of methane per year, which is equivalent to approximately 49,000 tonnes of GHG emission reductions. This is the first facility in Quebec and one of the first in North America to produce biogas from waste. The province's waste management policy has identified a 60-percent recycling target for organics for the year 2015 and a ban in 2020. As of 2012, only 25 percent of the organic waste was recycled, making it highly unlikely for the 2015 target of 60 percent to be met. Thus, a Metropolitan Waste Management Plan 2015–2020 was proposed to support the principles set forth in the 2011–2015 Action Plan by extending the 60-percent organic waste target to 2025 (Government of Canada 2015; Garon and Paquet 2015; Lemonde 2015; Solid Waste & Recycling 2016; Compost Council of Canada 2016a).

City of Surrey

In 2012, Surrey launched a new waste collection initiative called Surrey's Rethink Waste Program, designed to maximize the diversion of organic and recyclable waste while reducing the waste sent to landfills. The program introduced a cart-based, curbside waste collection system that collects three streams of residential waste: garbage, recyclables and organics. It services the city's roughly 510,000 residents, who live in 100,000 residential dwellings. Source separation, along with the switch to biweekly collection of garbage and weekly collection of organic waste, doubled the city's yearly collection of organic waste (City of Surrey 2015b).

Best Practice: Using Biogas to Reduce GHG Emissions in Surrey

The city of Surrey pledged to reduce GHG emissions by 20 percent by 2020. After considering options, the city decided to switch its waste transport fleet to run on biogas (CNG) from the planned AD facility. (The fleet makes up 40 percent of total GHG emissions, and waste collection makes up half of that.) Including organic waste diverted from the landfill, GHG emissions will be reduced by 40,000 tonnes a year. By looking beyond business as usual, the city forged a path that combines the benefits of diverting organic waste and producing CNG to reduce emissions from its waste fleet.

Source: Renewable Waste Intelligence 2016.

Within the first three months, the program achieved a 40-percent drop in the city's residential garbage tonnage, along with an increase in waste diversion of 50–70 percent. This allowed the city to meet its waste diversion goal well in advance of its 2015 target. From an economic point of view, the program saved C$4.5 million each year in collection and waste disposal costs (City of Surrey 2015b).

The city is now constructing an organic waste biofuel processing facility, which is the second phase of the Rethink Waste Program. The biofuel facility is being developed as a public-private partnership with Orgaworld Canada Ltd. Surrey's organic waste will go through a pre-treatment process, followed by AD, then in-vessel composting. The biogas captured from the AD process will be refined before its injection into the FortisBC grid, and the renewable natural gas will be used to fuel the city's waste-collection trucks. At the site's peak capacity, about 20 waste trucks will be fueled with CNG. The digestate from the composting process will be processed into nutrient-rich compost. It is estimated that the facility will produce about 35,000 tonnes of compost annually (Fletcher 2015).

The facility is set to begin operations in early 2018. It has an estimated cost of C$67.6 million, though the Canadian government will award the project up to C$16.9 million (the P3 Canada Fund will contribute up to 25 percent of the capital cost of the project), lowering the overall cost to C$45.9 million. Implementation of this facility is projected to save the city C$3 million each year in waste collection costs. From an environmental point of view, 115,000 tonnes of organic waste will be diverted from landfills annually (City of Surrey 2015a).

4.3.2 Mexico

The case studies described below, from Mexico City and the state of Aguascalientes, illustrate both progress and limitations in implementing comprehensive organic waste programs and policies in Mexico. Mexico City is a good example of how organic materials from households can be successfully diverted and processed to produce compost and reduce the amount of waste disposed of in landfills. Aguascalientes is one of the few states (others are Jalisco, Puebla, Querétaro, and Quintana Roo) that include organic RME waste from the ICI sector in their PEPGIRs. Despite the scarcity of data, some PEPGIRs are effectively promoting the practice of developing a baseline of solid-waste management amounts and characteristics and local waste management capacity, which is a useful tool for decision making. The most recent PEPGIR from the state of Jalisco, for example, describes two cases of organic waste diversion from agriculture (e.g., sugarcane) and manufacturing (i.e., tequila). This section also provides case studies of bi-national agreements and associated projects between Mexico and the United States, as well as and case studies of diversion efforts in Jalisco.

Mexico City

Organic waste processing started with a small composting plant operated by the Mexico City government in 1998. This facility started processing gardening residues from Mexico City and was later expanded to include 100 tonnes/day of organic waste (e.g., stems, flowers and vegetables) from the central market (*central de abasto*). It was then relocated to a site adjacent to the Bordo Poniente Landfill. In 2001, the facility's capacity was increased to 200 tonnes/day (mostly gardening residues, organic waste from different markets, and the segregated organic waste from residential sources). During that period, the compost produced was used in the median strips and green areas of Mexico City's primary road network (*Jefatura de Gobierno del Distrito Federal* 2004).

Best Practice: Quality Assurance in Mexico City

For the first time in Mexico's history, a large composting plant has been operating under stable conditions and rendering a product with acceptable quality—particularly after a quality assurance laboratory was installed at the compost plant.

The plant's composting procedures were optimized based on the type and mixture of waste received, (e.g., gardening debris, market waste, residential organic waste) to maximize efficiency. Universities, including the Metropolitan Autonomous University, undertook several research studies on the microorganisms present in different stages of the composting process, which can be used as process indicators. Control standards were also established for processing parameters (e.g., pile turning frequency). The costs of composting (wages, energy, fuel, and equipment maintenance) were about P$180–270 per tonne of processed waste, which compared favorably with landfill disposal costs. The calculated cost, however, did not include the amortization of machinery and equipment. It also did not include payment for the use of the land for the composting plant, since this land was provided by the federal government to the Department of the Federal District (now the Government of Mexico City) without cost, through an agreement for the treatment and final disposal of waste (López Jardines, Judith. Personal communication. 2017).

In 2003, an organic and inorganic waste separation program was established in Mexico City, shortly after the Solid Waste Law of the Federal District (*Ley de Residuos Sólidos del Distrito Federal*) was published. After an effective communications campaign, most households started waste separation; however, collection workers were reluctant to change their practices to maintain segregated waste. In 2010, Bordo Poniente Landfill reached the end of its useful life. It became evident that Mexico City would need to reduce waste disposal, since the nearest disposal site was 40 kilometers away and privately owned (which increased disposal costs dramatically). Mexico City's government negotiated with collection workers and established an economic incentive for waste separation (P$40/tonne of separated waste), which increased separation supervised by collection workers. Consequently, the amount of source-separated waste increased from 1,502 tonnes/day in 2011 to 2,009 tonnes/day in 2012, which is almost 70 percent of the organic waste generated in Mexico City (*Jefatura de Gobierno de la Ciudad de México* 2016).

For a period, the amount of available organic waste exceeded the composting plant's capacity. Mexico City's authorities began investigating the possibility of increasing the plant's processing capacity to accommodate all the organic waste received from the city. Organic waste quantities have since decreased, however, to 1,569 tonnes in 2013 and 1,349 tonnes in 2014 (Idem.). With declining volumes, it is unclear if the plant's capacity will be expanded.

State of Aguascalientes

Aguascalientes is an example of a state that reports RSU and RME and urban solid-waste generation.[39] Table 61 provides summary statistics.

Table 61. Summary of statistics for Aguascalientes

Number of municipalities	11
Total population (2015)	1.3 million
Year environmental regulation published	2010
Total RSU generation	791 tonnes/day; 29 percent food waste, 10 percent paper and paperboard, 15 percent garden waste
Total RME generation	2,207 tonnes/day from agriculture, livestock (manure), slaughterhouses, construction, manufacturing, tourism, transport, education, health and government

Sources: Gobierno del Estado de Aguascalientes, Insituto del Medio Ambiente, and Universidad Autonoma de Aguascalientes 2010; INEGI 2015a.

Aguascalientes' PEPGIR includes a 2025 forecast that projects ICI will make up 76.34 percent of total waste (about 3,703.5 tonnes/day, or 23 percent more than in 2010). This expected increase is a challenge for current and future environmental authorities because of the lack of infrastructure for ICI waste, including organic waste. Recognizing these challenges, PEPGIR includes policy measures to improve waste minimization, increase the use of waste to generate electricity or new recycled products, lower waste environmental risks, reduce the consumption of raw materials, increase the generation of biofuels, decrease landfilling, and mitigate the contribution of waste to climate change by reducing methane emissions.

[39] As more states begin to report RME and RSU data, additional organic waste analyses can be conducted to benchmark data and trends.

Binational Agreements

The 1983 US–Mexico Agreement on Cooperation for the Protection and Improvement of the Environment in the Border Area (La Paz Agreement), and subsequent cooperative programs, were developed to protect human health and the environment along the US–Mexico border. The Border 2020 Program (and its predecessor Border 2012 Environmental Program), implemented under the agreement, emphasizes regional, bottom-up approaches for decision making, priority setting and project implementation, to address the environmental and public health problems in the border region. It encourages meaningful participation from communities and local stakeholders.

The 1992 North American Free Trade Agreement created the North American Development Bank and its sister institution, the Border Environment Cooperation Commission (BECC), governed by the Mexican and US governments in a joint effort to work with communities and project sponsors to develop, finance and build affordable and self-sustaining projects with broad community support. The following projects were developed under the past border programs and funded through the BECC:

- **Management Guidelines for Special Waste in the Northern Sonoran Border (CEDES/BECC 2010)**. An inventory of special waste streams in three Sonoran border cities, among them San Luis Río Colorado, estimated a variety of “special waste streams,” as defined in state law. San Luis Río Colorado has a large agriculture industry, estimated to generate approximately 5,000 tonnes of organic waste per year; 25 percent of this waste is composted directly by the generators and the rest disposed of in open dumps. The study advises composting the remaining 75 percent of organics currently being disposed of, particularly given the good quality of the organic materials being generated.
- **Urban Solid Waste Assessment in Tijuana, Baja California** (Colegio de la Frontera Norte AC 2010). This assessment provided an overview of the Tijuana region’s organic wastes to help inform government, businesses, and financiers about the types and volumes of organics generated and promote composting markets (see the “Critical Compost Market Indicators” sidebar for recent developments).[40] The assessment found organics were some of the principal wastes—food waste 30 percent and garden waste nearly six percent—in all economic categories of households, and paper made up more than 15 percent of wastes in higher-income households. An accompanying survey revealed that backyard composting was already practiced, and informal workers (*pepenadores*—i.e., scavengers) were segregating recyclables at the sanitary landfill. Interviewees also expressed willingness to pay a fee to support integrated waste management efforts, including composting and recycling.
- **Urban Compost Center in Tijuana, Baja California** (Tijuana Calidad de Vida 2010). This center created 150 tons of compost from landscape cuttings provided by the municipality of Tijuana. San Diego’s Miramar Greenery shared firsthand knowledge on compost practices with Tijuana Calidad de Vida. In its two years of operation, the center trained 170 people from various institutions on how to compost, using diverse organic streams. A follow-up effort in 2015 assessed compost service and product markets, as part of developing a business plan for the center. The survey assessment found that there is interest for services among the Tijuana food industry, in trying to meet customer and corporate sustainability demands, and that landscape gardeners and regional farmers are interested in certified compost products.

[40] The US EPA also provided funding for projects related to waste management to Mexican border cities, such as a project to assess composting markets in Tijuana, Baja California (McCarthy et al. 2016).

Critical Compost Market Indicators

Five critical market indicators signal good timing for entry into Tijuana's compost products and services market:

1. willingness to implement policy and legislation to promote best practices (see below)
2. waste management projects in strategic plans
3. availability of government funding and subsidies
4. GHG reduction targets
5. growing volumes of organic waste

Efforts at the federal, state and municipal levels demonstrate increased interest in implementing policy and legislation for waste management—and more specifically, composting:

- Mexico promulgated the federal waste management law, administered by Semarnat, which directs municipalities to create solid-waste management plans.
- Baja California promulgated its own state waste management law, which established bylaws for municipal compliance.
- Tijuana's local government agencies provided in-kind support for the local nonprofit, Tijuana Calidad de Vida, to undertake a pilot composting project.

- **Eco-Parque Food Composting** (Colegio de la Frontera Norte 2015). A neighborhood of 118 households in Tijuana participated in a food-scrap composting demonstration. Under the project, the people collected 10,067 kilograms of household organic food scraps over 24 weeks. The food scraps were composted at Eco-Parque, part of the university's urban sustainability initiative. The compost was designed to meet Mexico City's compost standard for use as soil amendments. As a token of appreciation, 107 sacks of compost were distributed to households participating in the pilot program. Throughout the project, the participants were fully committed, demonstrating their willingness to conform to the procedural, quality and schedule demands of the compost practices.

Diversion: Sugarcane and Agave in Jalisco

These examples showcase successful programs to divert large quantities of organic waste; other states may be doing similar work, but the documentation is not yet available.

Turning Sugarcane Residuals into Biofuel and Compost: State of Jalisco

Sugarcane is produced in 15 Mexican states and processed in 54 sugar mills. In Jalisco, six mills process sugarcane to obtain 871,000 tonnes of sugar annually and generate the following wastes: molasses, cane bagasse (fibrous matter), ashes from burned bagasse, cachaza obtained from sludge filtering, sludge filters and vinasse. The cane bagasse, as well as other sugarcane agricultural residues, is used as a biofuel for energy production.

In the municipality of Ameca, the San Francisco de Ameca sugar mill has three centers which together process about 18,000 tonnes per year of the mill's own organic waste, generating compost used to improve soils where sugarcane is cultivated. Additionally, a group of women from a nearby neighborhood, with support from the University Center of Exact Sciences and Engineering (*Centro Universitario de Ciencias Exactas e Ingenierías*—CUCEI) at Guadalajara University, is developing a project to produce—and commercialize—paper and paper-decorated products from sugarcane residues.

Source: Secretaría de Medio Ambiente y Desarrollo Territorial del Estado de Jalisco unpublished.

Turning Agave Residuals into Biofuel and Compost: State of Jalisco

Tequila is a traditional Jalisco product, obtained from the heads of the blue agave plant. It is produced in 150 factories, from an estimated 318 million agaves in Mexico's tequila plantations. In 2010, Jalisco produced 239 million liters of tequila from 944,000 tonnes of agave heads. Waste generation totaled 974 million liters of vinasse, of which almost half was used for agricultural irrigation and 18 percent for composting (Snell Castro 2016). Tequila production also yields bagasse equivalent to 40 percent of the weight of ground agave heads. In 2002, for example, 414,000 tonnes of ground agave heads generated roughly 166,000 tonnes of bagasse (Cedeño 1995). Based on this proportion, in 2010 agave heads produced roughly 378,000 tonnes of waste.

Mexico's Law on Renewable Energy and Energy Transition (*Ley para el Aprovechamiento de las Energías Renovables y el Financiamiento de la Transición Energética*) states that non-fossil-fuel sources must contribute 35 percent of electricity production by 2024. To achieve this goal, the Secretariat of Energy and the National Council of Science and Technology established a Sector Fund for Sustainable Energy, which supports the creation of National Centers for Energy Innovation. CUCEI is part of the "Gaseous Biofuels Cluster" supported by this fund and is currently carrying out research on anaerobic treatment of tequila vinasses and bagasse to produce hydrogen and methane for its use as biofuel (Snell Castro 2016).

4.3.3 United States

The following case studies showcase some of the most effective and innovative approaches to organic materials diversion policies and implementation in the United States.

City of San Antonio, Texas

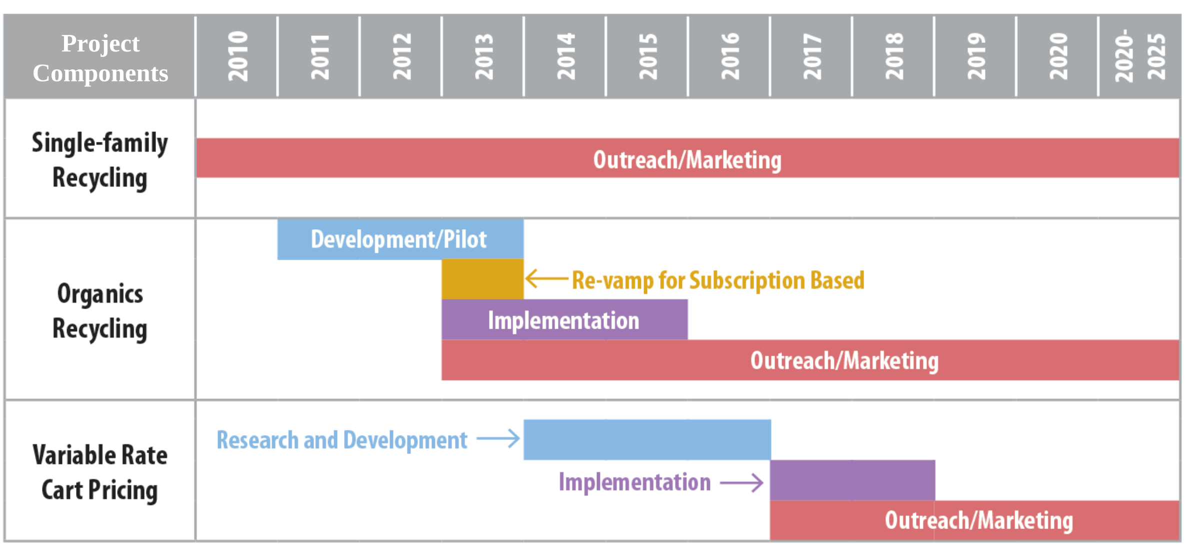
In June 2010, the City of San Antonio adopted a 10-year plan to achieve a 60-percent recycling rate for single-family households by 2020, ensure access to recycling programs for multi-family households, and improve recycling opportunities for commercial establishments (McCary 2011). For single-family households, the City developed a project timeline composed of ongoing outreach and marketing for each of the three components (i.e., residential recycling, organics materials collection, and PAYT pricing system), as well as pilot and research and development phases before implementation of organic materials recycling and PAYT (see Figure 30).

Best Practice: Phased Approach in San Antonio

When San Antonio adopted its 10-year plan to enhance recycling efforts and began implementing PAYT, the city initiated a pilot program with 28,000 households. After the initial phase, the program was expanded to 190,000 households. In 2017 (the final phase), PAYT will be expanded to all households.

Sources: Sculley 2016; Hagney 2016.

Figure 30. San Antonio's 10-year recycling and resource recovery plan timeline



Source: City of San Antonio n.d.

During the first quarter of FY2016 (about halfway into the pilot phase), an additional 700 tonnes of material were being collected, which equates to an increase of roughly 60 percent from the previous year (Sculley 2016). The city is ramping up its organics recycling program; following successful pilots, the PAYT program will be available to all San Antonio households (Hagney 2016).

State of Massachusetts

MassDEP introduced its first landfill ban on recyclable materials in 1990 (Government of Massachusetts 2016). Since then, the state's municipalities and businesses—with support from MassDEP grants and technical assistance—have worked to develop an extensive collection infrastructure to divert additional items from disposal. In 2014, the state issued a new ban that requires commercial entities disposing of "at least one ton of organic material per week to donate or re-purpose useable food" and requires that any remaining food waste be sent for composting, animal feeding operations, or AD (Government of Massachusetts 2016). Based on decades of food waste industry–related input and support, many of the affected businesses were ready when the ban took effect.

Best Practice: Leveraging Voluntary Industry Efforts in Massachusetts

The structure of Massachusetts' food waste ban was developed over several decades of experience and key stakeholder input from a voluntary supermarket recycling certification program that operated in partnership with the Massachusetts Food Association from the early 1990s to April 2016 (Jackson 2015). Thanks to ongoing work by the Association, the grocery industry, and MassDEP to divert organics from the waste stream, Massachusetts grocery stores were well prepared for the ban and already diverting edible organics through food bank donations and/or composting, feed lots, and AD (Spero n.d.).

Massachusetts' RecyclingWorks program also helps other businesses and institutions comply with the food waste ban, by providing free Web-based resources and guidance (e.g., searchable service-provider database, direct technical assistance). The Massachusetts example demonstrates the need to have stakeholder input—based on ongoing cooperative experience between the state and industry—as well as to provide additional resources and guidance to implement the ban.

Hennepin County, Minnesota

Hennepin County is a regional and national leader in environmental protection, particularly as the latter relates to recycling and diverting waste from landfills. The County's Solid Waste Management Master Plan, adopted in 2012, was developed by the Department of Environmental Services, following extensive public engagement and input. The Master Plan was intended to guide the county's waste management through 2030; most of its strategies focused on meeting the state's objective of 45-percent recycling by 2015.

In developing the Master Plan, the County went above and beyond state requirements for public input by hosting comprehensive public outreach that reached significantly more people. The county gathered feedback from nearly 2,000 participants (e.g., residents, business representatives, school and education staff, waste haulers, recycling coordinators) at public meetings, community events and forums, and via online and in-person surveys. Based on this feedback, several strategies were widely supported:

- "Standardize materials collected and education materials.
- Provide more technical assistance/support to improve recycling.

- Expand organics recycling programs and plastic recycling opportunities.
- Improve education efforts."

In 2010, 42 percent of the waste generated in Hennepin County was managed through recycling (38 percent) and organics recovery (4 percent). By 2015, the County had achieved 43-percent recycling—2 percent shy of state goals—and organics recovery had dropped to 3 percent, which does meet the state goal but is short of the county's 6-percent goal (Hennepin County 2016, 5). Despite these shortcomings, the county increased resource recovery from 27 to 36 percent and reduced land disposal from 32 to 18 percent (Hennepin County 2016, 5), for a total diversion rate of 82 percent.

Going forward, Hennepin County—as part of the TCMA, featured in Section 4.2.3—will work toward the region-wide, long-range policies set forth in Minnesota's Metropolitan Solid Waste Management Policy Plan (MPCA 2016).

Source: HCES 2012, unless otherwise noted.

Seattle, Washington

Seattle has a long history of recycling and waste diversion and has implemented many efforts over the years:

- 1988: Prohibited yard waste in refuse.
- 2005: Prohibited recyclables in refuse and began curbside food waste collection.
- 2009: Required residential properties to either: 1) subscribe to food and yard waste collection or 2) participate in backyard composting.
- 2011: Required multi-family buildings to provide compost collection service for residents.
- 2015: Prohibited food waste in refuse.

Seattle currently recycles about 60 percent of its MSW, up from 58 percent in 2015; this is its 12th straight year of continuous growth in recycling rate since 2003 (Seattle Public Utilities 2016). The city now seeks to recycle 70 percent by 2025.

To help enforce its recyclables and food waste bans and increase waste diversion, Seattle Public Utilities required garbage collectors to perform a "visual inspection" to determine if more than 10 percent of a container's contents were recyclable items or food waste. If so, the hauler places a warning tag on the container, for non-compliance. After two warnings, non-compliant single-family homes might receive a charge of US$1 per can ($50 for multi-family residences) on their waste bill, for recyclables and/or food waste found in their garbage. In April 2016, however, a judge ruled this inspection unconstitutional without a warrant—so it remains to be seen how further non-compliance will be determined and addressed (Richardson 2016).

Source: City of Seattle 2016, unless otherwise noted.

4.3.4 International Policies

Europe is a world leader in solid-waste management practices and diversion of waste from landfills. By 2014, the 27 states in the European Union (EU) as a whole had reduced total solid waste going to landfills (66 million tonnes) by 54 percent, from the amount landfilled in 1995 (144 million tonnes) (Eurostat 2016). One contributing factor to this success has been the 1999 EU landfill directive, which set targets for European countries to reduce the amount of organic waste disposed of in landfills to "35 percent of 1995 levels by 2016" for most member countries and by 2020 for some countries (EEA 2009). The European Environment Agency (EEA) credits the landfill directive's success to two factors: 1) its combination of long-term and intermediate targets, and 2) its flexibility. According to EEA, the targets have helped governments and the European Commission measure progress and focus attention on the core issues. The directive's flexibility has allowed members to try alternative policies, adjust measures to meet local conditions, and adapt policies based on this experience.

Success Story: AD in the UK

In the United Kingdom, anaerobic digestion has increased over 600 percent (outside of the water sector) in the last five years, with about 100 new AD plants opening. The UK has over 388 plants, generating over 447 megawatts of electrical equivalent (electricity or biomethane). Much of the growth can be attributed to stable government policies and incentives to encourage organic waste recovery and treatment. However, the political landscape has recently shifted and there is uncertainty about how organic waste will be supported or not under the new government. The Anaerobic Digestion and Bioresources Association believes there is tremendous potential for further growth. UK AD currently generates around 7 terawatt-hours, but the uptapped potential is for 40 terawatt-hours, or about 30 percent of the UK's gas demand.

Source: Morton 2015.

More recently, in 2015, the EU passed the Household Food Waste and Bio-waste Regulations, which ban discarding food waste in residual waste bins (for non-recyclable refuse) or changing the waste in any way, such as shredding (Hornig 2016). EU residents can now choose to divert food waste by:

- separating at source, for collection (collection must be provided);
- composting at home; or
- self-hauling to a treatment facility (e.g., AD).

ICI sectors must either separate at source their food waste, for collection, or treat it onsite, or self-haul it to a treatment facility.

According to a 2000 European Commission report on composting and separate-collection success stories, six featured countries—France, Ireland, Italy, Portugal, Spain and the United Kingdom—annually collected nearly 400,000 tonnes of biodegradable waste and produced more than 80,000 tonnes of compost, making them some of Europe's leaders in organic waste diversion and processing (European Commission 2000).

Asia has no regulation comparable to Europe's landfill directive, and landfilling of organic waste is still regarded as an appropriate treatment method, due in part to the potential Clean Development Mechanism revenue[41] and to lack of waste-separation collection or operations (especially for food waste). Many developing countries rely on informal recycling (i.e., waste pickers sift through garbage at the curb or at the landfill to recover recyclables such as glass, plastics, metals and cardboard), which means most of the remaining waste is organic. Legislation and policies are shifting gradually, however. For example, China's 12th five-year plan (2011–2015) specifies the development of a circular economy—one of the included seven requirements is exploiting kitchen waste resources (NPC 2011). As a result, over 100 kitchen-waste pilot projects are now underway, to collect, process and treat primarily restaurant waste; several also include residential SSO. (China's MSW is primarily composed of organic waste.) However, many challenges remain, as local infrastructure is lagging (e.g., separate trucks and routes still used to collect the material, inadequate transfer stations, lack of processing) and public education is proving inadequate for the separation of kitchen waste (i.e., no incentive for households to separate food scraps).

ZWIA Principles/ Practical Steps toward Zero Waste

1. Adopt ZWIA's definition of zero waste.
2. Establish goals/timeline.
3. Engage the entire community.
4. Manage resources, not waste.
5. Identify program funding (e.g., fees).
6. Conduct education and outreach.
7. Perform waste assessments.
8. Link residual-separation and research facilities.
9. Establish new rules and incentives to reduce waste.
10. Encourage businesses to adapt (e.g., extended product responsibility).
11. End subsidies for wasting (e.g., incinerators).
12. Encourage "green" purchasing/ procurement.
13. Invest in infrastructure.
14. Promote "green" businesses.

Source: Liss and Christopher 2012.

The Zero Waste International Alliance (ZWIA), a worldwide leader in zero-waste promotion and outreach, was established in 2002 "to promote positive alternatives to landfill and incineration" and increase community awareness and regard for waste as a resource for opportunity (ZWIA 2016). ZWIA operates at every level (e.g., international, national, local) and seeks to involve all sectors in working toward a zero-waste world, through its principles and practical steps (see the text box). Going forward, ZWIA will be a good source of information on cities and businesses around the world that are striving for zero waste.

The following regions and/or cities are leading examples of organic waste diversion and processing in the world.

[41] For industrialized countries with emission-reduction or emission-limitation commitments under the Kyoto Protocol of the UN Framework Convention on Climate Change, the CDM provides the flexibility to implement emission-reduction projects (e.g., capture/use of landfill methane) in developing countries, in order to meet reduction or limitation targets.

European Leader: Flanders, Belgium

Flanders—the Flemish region of Belgium—has one of Europe's highest waste diversion rates, with almost three-quarters of the residential waste produced being re-used, recycled and composted. Much of its success is credited to far-reaching policies established by the regional Flanders Public Waste Agency (*Openbare Vlaamse Afvalstoffenmaatschappij*), which coordinate well with local waste management programs. Flanders' regional waste management policies date back to the early 1980s and the first Waste Decree; since then, new plans (including per-capita waste reduction targets/goals) have been developed every four to five years.

The initial organic waste plan was developed from 1991 to 1995, and inspired the creation of the Flemish compost organization (Vlaco), which "encourages organic waste prevention, promotes composting […], certifies compost" and serves as a reference and a resource for assistance (Allen 2012). Organic materials in Flanders are processed via either composting or AD. From one subpar composting plant in the early 1990s, the number of sites grew to include 35 composting plants and 29 AD plants by 2010, which processed nearly 1.8 million tonnes of organic materials and sold more than 270,000 tonnes of compost that same year.

Flemish government–mandated source-separated collection—complemented with policies to restrict landfilling and incineration—has led to increased recovery of recyclable and compostable materials in the region. The Public Waste Agency also uses financial incentives (e.g., environmental taxes) to further "discourage burying and burning" and provides subsidies to build drop-off centers and compost plants, as well as implement PAYT programs. Municipalities perform extensive outreach and provide technical or financial assistance to help citizens reduce waste. Home composting is essential to the region's solid-waste management strategy, with about 34 percent of the Flemish population composting at home, in 2010.

Source: Allen 2012.

Asia: South Korea

Since the mid-90s, the South Korean government has embarked on comprehensive and successful policies that target food waste. Over the years, the government launched various programs and/or initiatives (built upon the previous action) aimed at raising awareness of food waste and increasing food waste reduction:

- 1996: Released Food Waste Reduction Masterplan.
- 1998: Established recycling program to collect "food waste in residential areas and from food wasters such as restaurants."
- 2004: Revamped recycling program to meet current needs.
- 2005: Banned food waste from being sent to landfills.
- 2010: Signed food waste reduction agreements with different sectors (e.g., restaurants, hotels, schools), for voluntary cooperation, and also "introduced a volume-based food waste fee system" (i.e., PAYT).

This 2010 initiative allows municipalities to choose from three PAYT options: prepaid standard plastic bags for pickup, prepaid stickers for food-waste bins (which are not emptied without the stickers), and higher-tech bins that use magnetic card-readers to display the weight of the food waste. Monthly fees are based on the volume collected. As a result of increased awareness, the food waste diversion rate increased from 2 percent in 1995 to 95 percent by 2009, and food waste that was previously disposed of in landfills is now being composted or turned into livestock feed or biomass/biofuels. To further promote food waste diversion/processing, the government has financed expansion of public recycling facilities that transform food wastes into these commodities, as well as invested "782.3 billion Korean Won to build 17 biogas facilities and four sewage sludge drying fuel facilities" that will annually convert nearly 200,000 tonnes of organic waste into biofuels.

South Korea's food waste reduction policies are deemed to be among the world's most advanced in promoting sustainable practices, and the mix of policies (e.g., regulations/standards, voluntary measures) has proven highly successful.

Source: Innovation Seeds n.d.

4.4 Conclusion

Organic waste–related policy/regulation and programs do not happen overnight. Canada, Mexico and the United States have worked individually over recent years on efforts targeting organic waste diversion and processing, with some success. Echoing information from Chapter 3, early and ongoing public participation and education proves critical in advancing organic waste diversion policies and best practices. But as this chapter also illustrates, there are still gaps to fill (e.g., lacking ICI data), challenges to overcome (e.g., political, administrative, technical obstacles), and lessons to be learned/shared—particularly from other international waste management leaders—to divert and process greater volumes of organic waste in North America.

5 Climate Pollutants and Other Environmental Impacts

5.1 Links Between Organic Waste and Greenhouse Gas Emissions

In April 2015, the Intergovernmental Panel on Climate Change (IPCC) released a report (IPCC 2015) showing that global emissions of greenhouse gases (GHGs) have risen to unprecedented levels despite a growing number of policies to reduce climate change. Emissions grew more quickly between 2000 and 2010 than in each of the three previous decades. The US Environmental Protection Agency (EPA) estimates the waste sector is the third-largest source of non-carbon-dioxide (CO_2) GHG emissions globally, accounting for 13 percent of total non-CO_2 GHG emissions (US EPA 2012c).

After carbon dioxide, methane is the second most important human-made GHG, and is responsible for more than a third of total anthropogenic climate forcing. It is also the second most abundant GHG, accounting for 14 percent of global GHG emissions. Methane is considered a short-lived climate pollutant (SLCP), meaning that it has a relatively short lifespan in the atmosphere—about 12 years. Although it stays in the atmosphere for less time and is emitted in smaller quantities than CO_2, its ability to trap heat in the atmosphere (its "global warming potential") is 25 times greater. As a result, methane emissions contributed to about one-third of today's anthropogenic GHG warming (GMI 2015).

As the organic fraction of municipal solid waste (MSW) decomposes under anaerobic conditions, such as those in landfills, landfill gas (LFG) is produced. It contains roughly 50 percent CO_2 and 50 percent methane, along with small amounts of non-methane organic compounds. (The exact content depends on waste and landfill conditions.) Without a collection and control system, LFG escapes to the atmosphere, where it acts as a heat-trapping GHG and contributes to other local air-quality and public health impacts (i.e., smog, premature deaths). Globally, landfills are the third-largest anthropogenic source of methane, accounting for about 11 percent of estimated global methane emissions, or nearly 799 million tonnes of carbon dioxide equivalent ($MTCO_2e$), in 2010 (GMI 2015).

Even landfills with LFG collection and control systems cannot capture 100 percent of landfill gas. Since it is the organic fraction of MSW that generates LFG during decomposition in a landfill, diverting that organic waste away from landfills to other management options such as anaerobic digestion (AD) and/or composting could significantly reduce the landfill emissions of methane that contribute to climate change. Organic waste, especially food waste, decomposes rapidly in the landfill environment; this presents opportunities for reducing methane emissions during landfills' early years of operation (before LFG collection) by diverting organic waste to other, more controlled treatment/mitigation (AD) or to landfill avoidance (compost). Organic waste diversion has other benefits as well, including positive impacts on human health, the economy and crop production.

Emissions of methane and other GHGs due to human activities have increased dramatically since pre-industrial times. The global atmospheric concentration of methane has grown from a pre-industrial value of about 715 parts per billion (ppb) to a value of 1,782 ppb in 2007—more than doubling during that period and now far exceeding the natural range in the last 650,000 years. The US EPA estimates that global anthropogenic methane emissions could increase by an additional 20 percent by 2030, to 8,522 million tonnes of $MTCO_2e$ (GMI n.d.).

This chapter explores the methodologies and estimates of SLCP generation from organic waste in Canada, Mexico and the United States, along with the potential emission reductions associated with diverting organic waste from landfills to other forms of organic waste treatment.

5.2 Methodologies and Estimates of GHG Emissions in Canada

5.2.1 Estimated GHG Emissions

Environment and Climate Change Canada (ECCC) reports national emissions (including those from the waste sector) via the National GHG Inventory. This inventory has been updated annually since 1990, in accordance with Canada's commitments to the Kyoto Protocol and subsequent Paris Agreements, and submitted Intended Nationally Determined Contributions (UNFCCC 2016). The annual update is called the National Inventory Report (NIR), and includes operations in Canada that emit more than 50,000 MTCO$_2$e annually. The most recent NIR was completed in 2016, and included emissions and trends from 1990 through 2014. It notes that the waste sector in Canada includes emissions from the treatment and disposal of wastes, including solid-waste disposal on land (landfills), wastewater handling, and waste incineration. Methane produced from the decomposition of waste in landfills is calculated using the Scholl Canyon model, a first-order decay model that reflects the fact that waste degrades in a landfill over many years. N_2O emissions are associated with the wastewater treatment facilities that operate anaerobically (ECCC 2016).

In May 2016, the Ontario Waste Management Association (OWMA) published a study titled *Cap-and-Trade Research for Ontario's Waste Management Sector* (GHD 2016). Table 62—excerpted from the OWMA report—lists available protocols for landfills and AD projects.

Table 62. Available protocols for landfills and AD projects

Available Protocols	Registry	Number of Registered Projects/Precedence
Landfill		
Landfill Gas Capture and Combustion (protocol under review)	ACOS	2
Landfill Methane Collection and Combustion	ACR	12
US Landfill Project Protocol	CAR	119
Landfill methane recovery	CDM-AMS-III.G.	42
Flaring or use of landfill gas	CDM-ACM0001	235
Flaring or use of landfill gas	VCS-ACM0001	38
Avoidance of landfill gas emissions by in-situ aeration of landfills	CDM-AM0083	1
Avoidance of landfill gas emissions by passive aeration of landfills	CDM-AM0093	0
Protocol 2—Landfill Sites—CH_4 Destruction	QC	4
Anaerobic Digestion		
Methane recovery through controlled anaerobic digestion	CDM-AMS-III.AO.	6
Alternative waste treatment processes	CDM-ACM0022	9
Organic Waste Digestion Project Protocol	CAR	3

Source: GHD 2016.

The OWMA report also calls for the development of a GHG calculation tool, designed to help OWMA members make decisions about their projects. The calculation tool will allow entities such as municipalities to enter site-specific information and waste management data to determine opportunities for potential offsets. The OWMA report reviews regulatory and other basic additionality requirements for known waste-sector projects, and compares the results against baseline landfilling operations to determine how projects such as AD will actually affect the Ontario GHG footprint. This study is expandable to the wider Canadian context.

The OWMA report concludes that Ontario has 2,382 approved landfills, of which 805 are active and 1,577 are either closed or inactive. There are roughly 37 open landfill sites with an approved-in-design capacity greater than 1.5 million cubic meters (GHD 2016). It is difficult to verify the accuracy of these numbers, as over two-thirds of these landfills do not have electronically accessible Ministry of Environment and Climate Change compliance approvals. Within Ontario, large landfill sites are regulated under O. Reg. 232/98, which requires them to have LFG collection systems. Similar regulations mandating LFG collection and control exist in Quebec and British Columbia.

Emissions from landfills are difficult to estimate. Many factors can contribute to overall emissions, including the types of waste, amount of waste in place, and annual amounts of waste being disposed of in the landfill. Also, these emissions are released over time, whereas most other facilities' emissions happen at particular points. Canada's 2016 NIR (ECCC 2016a) estimated that in 2014, the Canadian waste sector produced a total of 26 million $MTCO_2e$ of GHG emissions. This number includes solid-waste disposal on land (i.e., landfills) and excludes wastewater handling and waste incineration. Table 63 breaks down this total, by province.

Table 63. Landfill GHG emissions, by province, as reported in the NIR

Province	NIR Emissions from Landfills ($MTCO_2e$)
Alberta	2,300,000
British Columbia	5,300,000
Manitoba	1,100,000
New Brunswick	690,000
Newfoundland and Labrador	770,000
Northwest Territories	3,400
Nova Scotia	540,000
Nunavut	2,800
Ontario	8,500,000
Prince Edward Island	100,000
Quebec	5,700,000
Saskatchewan	940,000
Yukon	1,900
Total	**25,948,100**

Note: NIR emissions from landfills are limited to operations in Canada that emit more than 50,000 $MTCO_2e$ annually.

Source: ECCC 2016.

The NIR states the following on waste-sector emissions in Canada (ECCC 2016):

> "The primary source of emissions in the Waste Sector is CH_4 [methane] from Solid Waste Disposal, which accounts for about 91% of emissions for this sector. The CH_4 emissions from publicly and privately owned municipal solid waste landfills (MSW) make up the bulk of emissions from Solid Waste Disposal (approximately 84%). The remainder (approximately 16%) originates from onsite industrial landfills of wood residues; such landfills are declining in number as markets for wood residues grow.
>
> "Since 1990, overall emissions from the Waste Sector have grown by 10%, mostly from increases in emissions from landfill operations. Emission releases in this sector are significantly mitigated by the growing volumes of landfill gas (LFG) captured and combusted at the landfill sites. While the CH_4 emissions generated by all MSW landfills increased by 37% to 33 million $MTCO_2e$, the amount of CH_4 captured increased by 134% to 11 million $MTCO_2e$ in 2014. Of the overall CH_4 captured, 49% was combusted for energy recovery applications and the remainder was flared. The number of landfill sites with LFG capture systems is rapidly rising in Canada, with 81 such systems operating in 2014."

5.2.2 Potential GHG Emission Reductions

The methodologies employed by OWMA and NIR to estimate GHG emissions from landfills use a first-order decay model which is very prescriptive (i.e., has only a few basic inputs) and is useful for estimating emissions from a single landfill site. For comparing emissions from different waste management scenarios to estimate potential emission reductions, however, it is useful to apply a life-cycle analysis (LCA).

There are several LCA tools, based on the US EPA's Waste Reduction Model (WaRM) with necessary updates for the Canadian context. Two examples are:

- Environment Canada's "GHG Calculator for Waste Management" tool (Environment Canada 2013b), an adaptation of WaRM that uses Canada-specific emission factors and includes GHG emissions-modeling from waste management activities, including transportation and facility operation; and
- S&T Consultants' "GHGenius" tool (S&T Consultants 2014).

These life-cycle GHG emissions calculators are designed to compare the differences in GHG emissions between waste management scenarios. Inputs to an LCA model may vary, depending on the boundaries set for the investigation, and can consider the emissions from a single site as well as the impacts of collecting the waste in the municipality and transfer-station operations. Essentially, LCA models provide as narrow or as wide a look at emissions as the user wishes to produce. This also makes it difficult to compare baseline emissions on a national level, such as those provided in the NIR, which has elected to use only the first-order decay model approach.

To apply these models and generate an estimate of potential emission reductions resulting from organic waste diversion, it is necessary to make assumptions on how diverted organic waste would be treated. As mentioned above, the LCA model does not provide a standard basis; offset protocols such as those in Alberta use first-order decay models as a basis for modeling the effects of the absence of organics in the landfill. Essentially, the offset protocols model the organics as if they were processed in the landfill and produced methane, but discount those emissions as offsets as a result of the waste sector project (AD or composting, respectively).

For the purposes this report, estimates were generated for two primary waste processing methods: AD and aerobic composting. In Alberta, the offset methodology for aerobic composting equates to about 0.9 $MTCO_2e$ offsets per tonne of organic material processed (Government of Alberta 2017). This value is obtained through a high-level assessment of the first-order decay model and represents the available potential for offsets. In reality, the offsets may vary, depending on other factors such as operational parameters and weather conditions. In Ontario, the OWMA report used a more conservative approach that resulted in a factor of 0.44 to 0.47 $MTCO_2e$ offsets per tonne of organic material processed, depending on the composting method (GHD 2016).

For AD in Ontario, OWMA uses a factor 0.48 $MTCO_2e$ offsets per tonne of organic material processed (GHD 2016). Note that this factor includes the benefit of electricity production: the AD process generates biogas that can be used to generate electricity or cleaned and upgraded to be used as RNG in either a natural gas pipeline or natural-gas-powered vehicles.

In 2012, given an offset factor of 0.45 $MTCO_2e$ per tonne and the amount of organic waste diverted that year, as shown in Table 7, a total of about 1.1 million $MTCO_2e$ were avoided through existing compost programs in Canada. This is a high-level estimate where an emission offset factor of 0.45 $MTCO_2e$ per tonne of organics (conservative average of offset factors reported in OWMA report) is simply multiplied by the tonnage of organics remaining in the waste stream. Table 7 shows that in 2012, 24 percent of the food, yard and wood waste was diverted from disposal in Canada. Below are the results possible at greater levels of diversion:

- At 100 percent diversion, all 7 million tonnes of organic waste would be diverted from disposal, resulting in an emission reduction of about 3.4 million $MTCO_2e$.
- At 75 percent diversion, about 5 million tonnes of organic waste would be diverted from disposal, resulting in an emission reduction of about 2.5 million $MTCO_2e$.
- At 50 percent diversion, about 3.8 million tonnes of organic waste would be diverted from disposal, resulting in an emission reduction of about 1.7 million $MTCO_2e$.

As noted above, based on the amount of organic material generated, Canada has the potential to reduce an additional 3.4 million $MTCO_2e$ through organic waste diversion programs and processing. That being said, existing diversion policies and programs in Canada may not be sufficient to address such high levels of diversion. An increase in diversion would require additional organic waste diversion policies, programs and processing capacity. A new offset protocol for AD facilities is being developed as part of the Climate Change Mitigation and Low-Carbon Economy Act, passed by the Ontario government in May 2016.

5.3 Methodologies and Estimates of GHG Emissions in Mexico

5.3.1 Estimated GHG Emissions

Mexico has been a non–Annex I party to the UN Framework Convention on Climate Change[42] since 1994 and has issued five National Communications to IPCC, the most recent one published in 2012 (INE-Semarnat 2012). National Communications include emission inventories—estimates of methane emissions from all sectors, including waste. The Fifth National Communication included emissions from sources in five categories associated with organic waste (UNFCCC 2017):

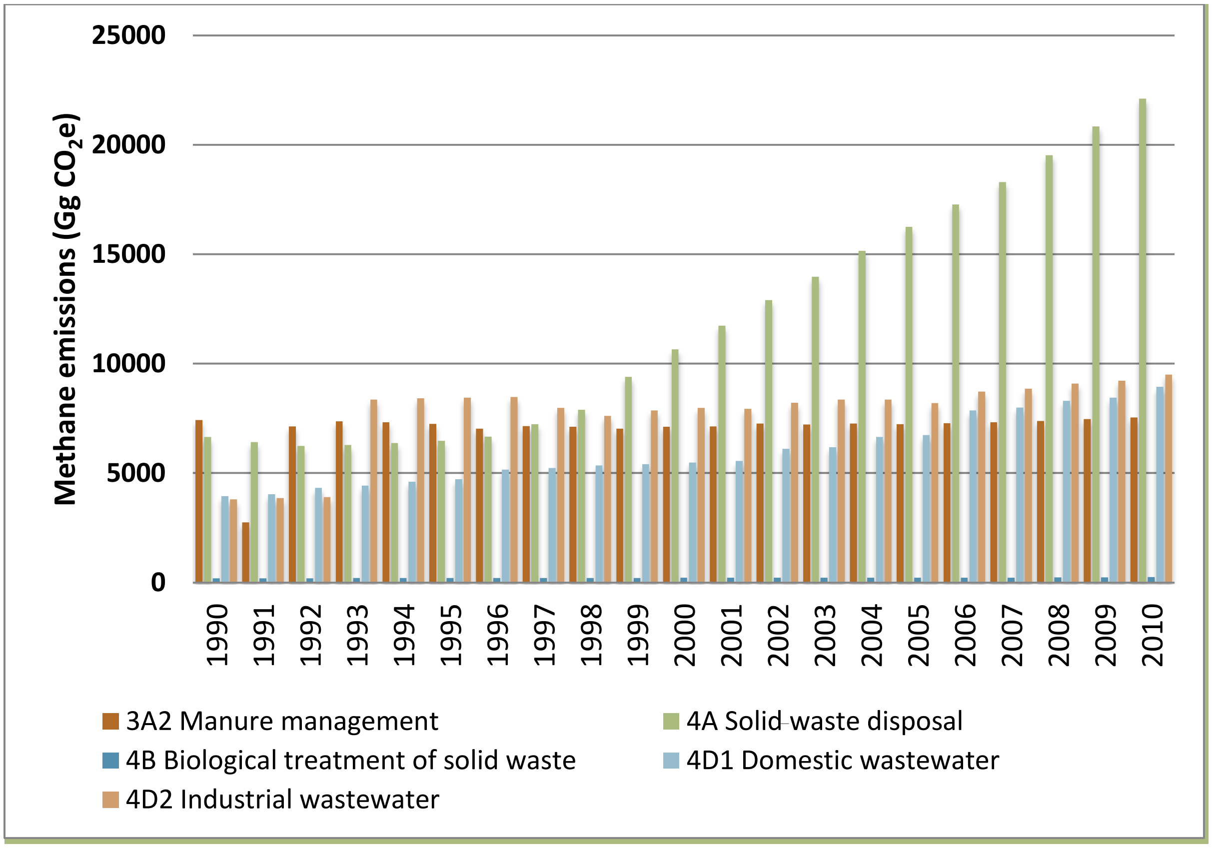
- manure management (3A2)
- solid waste disposal (4A)
- biological treatment of solid waste (4B)
- domestic wastewater treatment and disposal (4D1)

[42] Non–Annex I parties are typically developing countries. They are encouraged to reduce GHG emissions but are not bound by the same obligations as Annex I and Annex II parties.

- industrial wastewater treatment and disposal (4D2)

Methane emissions were estimated for 2012 and recalculated for 1990–2010, using the 2006 IPCC guidelines and the latest emission factors and activity data available. Total methane emissions in 2010 were 7.9 million tonnes, having shown a steady increase each year. Figure 31 shows that solid-waste disposal accounts for the largest change in emissions (a 200-percent increase), followed by domestic wastewater treatment (127-percent increase) and industrial wastewater treatment (150-percent increase). These changes can be attributed to an increase in the amount of wastewater being sent to treatment plants and a larger amount of waste being sent to disposal sites (INE-Semarnat 2012, 221).

Figure 31. Estimated methane emissions (in Gg CO_2e) from sources in FCCC categories 3A2, 4A, 4B and 4D (Mexico)



Source: INE-Semarnat 2012, 221.

Another source of data on methane emission estimates is the SNAP (Supporting National Action and Planning on SLCP) report (Molina Center for Energy and the Environment and INECC 2013). As part of the Climate and Clean Air Coalition (CCAC), Mexico developed a baseline inventory for 2010, baseline projections to 2030, and two mitigation scenarios, leading CCAC's SNAP initiative. This was part of a pilot study in four countries (Bangladesh, Colombia, Ghana, Mexico) to develop a "fast-start national planning for SLCP" to start work on mitigation options (Molina Center for Energy and the Environment and INECC 2013, 8). The pilot study also supported the development and testing of what would later become the Long-range Energy Alternatives Planning System (LEAP) Integrated Benefits Calculator Toolkit, developed by the Stockholm Environment Institute (Stockholm Environment Institute 2015).

Black carbon and methane emissions were estimated for the sectors that, according to Mexico's Fifth National Communication, contributed the most to emissions of both pollutants. Methane emissions were calculated for livestock (enteric fermentation), water resource recovery facilities (WRRFs), solid-waste disposal sites, manure management, and industrial oil and gas processes. For this report, the toolkit was implemented when feasible and additional bottom-up calculations were performed when available information allowed. This included reviewing the most recent sources of information and adapting emission factors and activity data where possible.

Results from the LEAP toolkit for organic waste sources show that total methane emissions in 2010 were 4.2 million tonnes. Solid-waste disposal was the second-largest source of methane, at 23 percent; manure management contributed the least, at 1 percent (Stockholm Environment Institute 2015, 44). Updated emissions estimates of fugitive emissions[43] from oil and gas production account for most of the total emission difference between SNAP and Fifth National Communication estimates.

Mexico issued its first Biennial Update Report (BUR) in 2015, which includes updated estimates of all GHGs (INECC and Semarnat 2015). The report includes the latest emission factors and activity data compiled from recent country-specific research on manure management, solid-waste disposal, domestic wastewater treatment and discharge. Total estimated methane emissions in 2012 were 127.6 million $MTCO_2e$ (5.1 million tonnes of methane), 48 percent larger than those estimated for 1990. Solid-waste disposal and wastewater treatment and disposal were the third-largest source of total methane emissions.

Table 64 summarizes the data from of the three main sources described above.

[43] Fugitive emissions are pollutants in the form of gases or vapors that have escaped from pressurized equipment. They are usually the result of leaks and other unintended releases resulting from industrial activities.

Table 64. Estimates of methane emissions from organic waste–related sectors in Mexico, 2010

Sector	Methane Emissions (1000 $MTCO_2e$)			% Contribution			Methods		
	Estimate in 5th National Communication[a]	Estimate in SNAP[b]	Estimate in BUR[c] (2012)	Estimate in 5th National Communication[a]	Estimate in SNAP[b]	Estimate in BUR[c] (2012)	Estimate in 5th National Communication[a]	Estimate in SNAP[b]	Estimate in BUR[c] (2012)
Manure management (3A2)	7,552	1,100	2,122	3.8	1.1	1.7	(IPCC 1997) Tier 1 (sheep, goats, mules/donkeys, horses, poultry) Tier 2 (cattle, buffaloes, pigs and other)	(IPCC 1997) Tier 1 (sheep, goats, mules/donkeys, horses, poultry) Tier 2 (cattle, buffaloes, pigs and other)	(IPCC 1997) (Ramírez 2010)
Solid-waste disposal (4A)	22,120	24,400	18,240	11.1	23.4	14.3	(IPCC 2006b) Tier 2 (FOD)[d]	(IPCC 2006b) Tier 2 (FOD)[d]	(IPCC 2006b) (US EPA 2009)
Biological treatment of solid waste (4B)	250	Not estimated	1,200	0.1	Not estimated	0.1	(IPCC 2006c) Tier 1	Not estimated	(IPCC 2006c)
Domestic wastewater treatment and discharge (4D1)	8,950	10,700	5,428	4.5	10.3	4.3	(IPCC 2006a) Tier 1	(IPCC 2006a) Box 2 Tier 2 (IIE 2012)	(IPCC 2006a) (Noyola et al. 2013)
Industrial wastewater treatment and discharge (4D2)	9,508	Not estimated	10,960	4.8	Not estimated	8.6	(IPCC 2006a) Tier 1	Not estimated	(IPCC 2006a)

Sources:
[a] INE-Semarnat 2012, 223.
[b] Molina Center for Energy and the Environment and INECC 2013.
[c] INECC and Semarnat 2015.
[d] IIE 2012.

5.3.2 Potential GHG Emission Reductions

The Fifth National Communication to the United Nations Framework Convention on Climate Change (UNFCCC) describes the updated mitigation potential for GHG in different sectors. Detailed data are mostly available for the energy and industrial sectors—unlike the waste sector, for which information is often aggregated. Several mitigation opportunities involving waste management have been identified in the Fifth National Communication, as well as in a study by the National Institute of Ecology (INE) to calculate the mitigation potential and the costs associated with different measures in all sectors (INE and Semarnat 2010).

Table 65 shows the data reported in the 2010 INE study. Table 66 shows the potential opportunities for reducing emissions identified for the waste sector in the Fifth National Communication. (The document does not specify the source of these calculations.)

Table 65. Mitigation opportunities identified in the 2010 INE study

Mitigation Opportunity	2020 (million $MTCO_2e$)	2030 (million $MTCO_2e$)	Assumptions
Use biogas from landfills	20	41	20% of gas generated is burned
Recycling and composting	2	38	82–85% of recyclable and compostable waste is processed

Source: INE and Semarnat 2010.

Table 66. Mitigation opportunities identified in the Fifth National Communication to the UNFCCC

<table>
<tr><th>Opportunities</th><th>Potential Reduction ($MTCO_2e$)</th></tr>
<tr><td>Improve manure management</td><td>3.5 million</td></tr>
<tr><td>Increase private-sector participation in recycling, segregation, re-use, and final disposal of waste</td><td rowspan="3">26 million (2020)</td></tr>
<tr><td>Improve collection and treatment fees, so that re-investing in better technologies and waste management practices is feasible</td></tr>
<tr><td>Inform and train the population on the importance of waste reduction at source</td></tr>
<tr><td>Wastewater treatment—use emitted methane to operate wastewater treatment facilities (three projects, unspecified)</td><td>1.02 million (2020)</td></tr>
</table>

Source: INE-Semarnat 2012.

Though it is older, the 2010 INE study describes calculations and assumptions and is a more reliable source of information.

Another source of data on mitigation potential is the Special Climate Change Program (*Programa Especial de Cambio Climático*). This program includes several country-specific mitigation goals for all sectors, including waste (Gobierno de la República 2016). The Fifth National Communication reported progress on several projects related to these goals to 2012, 2013 and 2014 where available, giving an idea of the mitigation potential (Table 67).

Table 67. Mitigation goals and projects (waste sector) included in Mexico's Special Climate Change Program

Goal/Project	Status	Mitigation Goal
Promote adequate management of solid waste; close open dumps; build landfills, biodigesters	Planning phase	500,000 $MTCO_2e$ (annual in 2018)
Increase residential wastewater treatment	Planning phase	2.87 million $MTCO_2e$ (annual in 2018)
Ecatepec biogas project	In operation	210,000 $MTCO_2e$ (reported in 2014)
Tutlitlán biogas project	In operation	42,528 $MTCO_2e$ (reported in 2014)
Tecámac waste-to-energy project	In operation	57,196 $MTCO_2e$ (reported in 2014)
Rincón Verde waste-to-energy project	In operation	270,000 $MTCO_2e$ (reported in 2014)
Tlalnepantla biogas project	In operation	79,921 $MTCO_2e$ (reported in 2014)

Source: INE-Semarnat 2012.

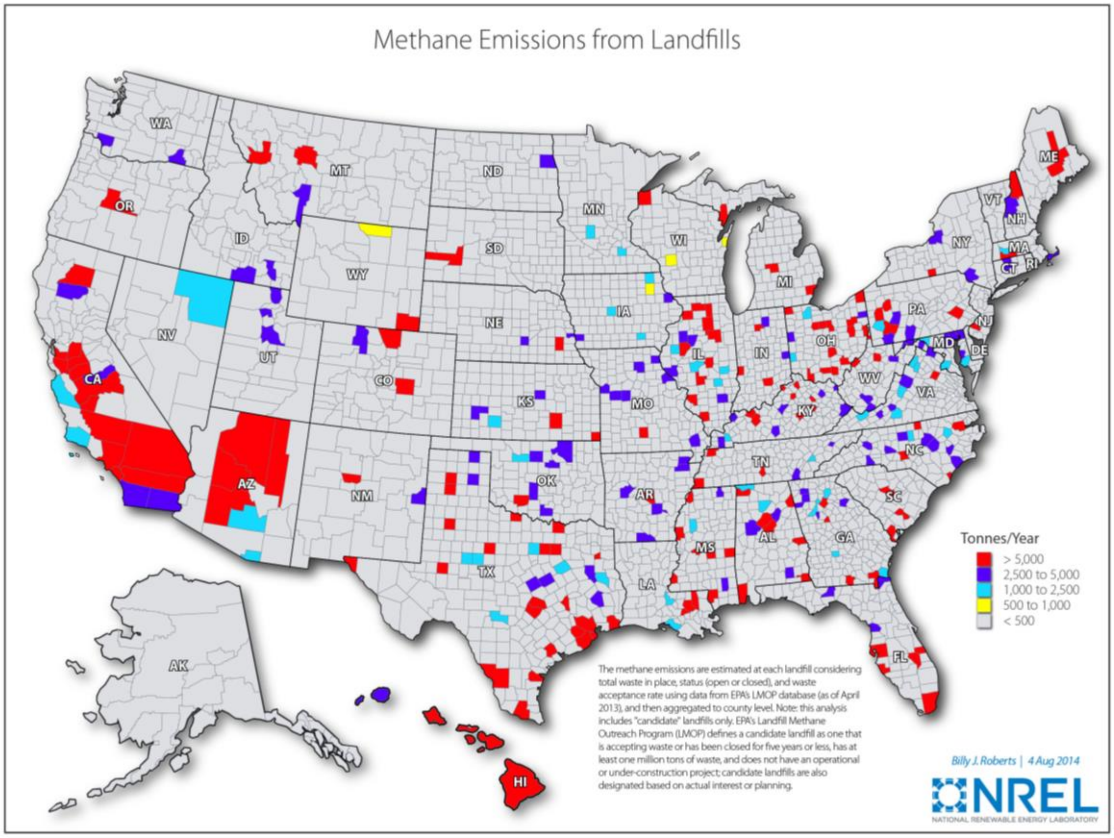
The available information on mitigation potential is evidently limited and not harmonized. Although the 2010 study shows more detail, it likely needs to be updated. Sector-based or state-level projects and estimates should be included in the analysis to improve the description of the potential emission reductions in this sector.

5.4 Methodologies and Estimates of GHG Emissions in the United States

5.4.1 Estimated GHG Emissions

The US EPA estimates that landfills accounted for about 20 percent of all anthropogenic methane emissions in 2014—148 million $MTCO_2e$—making landfills the third-largest source of methane emissions in the United States. It is notable that while this estimate has increased from 142 million $MTCO_2e$ in 2010, it is down significantly from 179.6 million $MTCO_2e$ in 1990 (US EPA 2016c). The vast majority of these emissions come from MSW landfills, where the amount of organic waste disposed of (and thus contributing to methane emissions) is higher. Since 1990, the number of MSW landfills has decreased, from over 6,000 to about 2,000, while the average size of landfills has increased (US EPA 2016c). These changes have resulted in a more dispersed profile of methane emissions from landfills, as shown in Figure 32, which was created by the National Renewable Energy Laboratory for the US Department of Energy.

Figure 32. Methane emissions from landfills in the United States, by county



Source: NREL 2014.

As discussed in Chapter 2, waste disposal rates in the United States are increasing, so the decrease in emissions from landfills can largely be attributed to the development of more-regulated "sanitary" landfills and better collection and control of LFG, as well as a reduction in disposal of organic waste. Thus, according to the US EPA, the amount of methane emissions from landfills has increased steadily since 1990, while the amount of methane recovered from landfills has also increased, as shown in Table 68.

Table 68. Methane emissions and recovery from landfills in US (million $MTCO_2e$)

Source/Activity	Methane Emissions (in million $MTCO_2e$)						
	1990	**2005**	**2010**	**2011**	**2012**	**2013**	**2014**
MSW landfills	205.3	287	321	325.2	328.6	332	335.4
Industrial landfills	12.1	15.9	16.4	16.4	16.5	16.5	16.6
Recovered	-17.9	-131.8	-179.5	-181.2	-187	-188.2	-187.7
Oxidized	-20	-17.1	-15.8	-16	-15.8	-16	-16.4
Total	**179.5**	**154**	**142.1**	**144.4**	**142.3**	**144.3**	**147.9**

Notes: Negative numbers indicate methane emission reductions. "Oxidized" refers to methane emission reductions due to oxidation at municipal and industrial landfills.
Source: US EPA 2016c.

The US EPA's estimates are based on the first-order decay model described by the 2006 IPCC Guidelines.

Until 2011, The US Energy Information Administration (EIA) also produced an inventory of US GHG emissions, based on the methodology of the 2006 IPCC Guidelines. In its final 2011 update on 2009 GHG emissions, EIA estimated 179.6 million $MTCO_2e$ from MSW landfills (EIA 2011). The EIA estimate is a net estimate (i.e., it accounts for recovered LFG), but it does not include industrial landfill emissions. EIA's methodology also does not appear to account for oxidized emission reductions that are part of the US EPA's analysis.[44] Applying these parameters to the US EPA data for 2009 (315.9 million $MTCO_2e$ gross emissions from MSW landfills minus 160.6 million $MTCO_2e$ from recovered LFG) gives 155.3 million $MTCO_2e$ net emissions from MSW landfills, which is slightly lower than EIA's estimate.

5.4.2 Potential GHG Emission Reductions

Food waste diversion represents both the largest and the most immediate potential impact on methane emission reductions.

Although recovery of organic wastes in the United States is near an all-time high (see Chapter 2), there is still potential for significant increases in organic waste diversion, particularly for food waste. While about 75 percent of paper and paperboard was recovered in 2013 and about 60 percent of yard trimmings was recovered, only about 5 percent of food waste was recovered (US EPA 2016c). Yet, as discussed in Chapter 2, food waste still accounts for over 22 percent of waste disposed of in the MSW stream, compared to about 14 percent of paper and 8 percent each of yard trimmings and wood. Since food waste also decomposes faster than yard trimmings, food waste diversion represents both the largest and the most immediate potential impact to methane emission reductions.

The US EPA's Waste Reduction Model (WARM) provides a robust methodology for estimating GHG emission reductions from waste, including very specific considerations for organic waste (food waste and yard trimmings). The WARM methodology is a "streamlined life cycle GHG analysis" focusing "on the waste generation point, or moment a material is discarded, as the reference point and only considers upstream GHG emissions when the production of new materials is affected by materials management decisions" (US EPA 2016a). The WaRM methodology accounts for impacts of organic waste diversion—such as changes in a process's energy requirements; transportation emissions; indirect emissions benefits from avoided electricity production; and the effect of carbon storage in landfills—to produce emission factors that can be used to estimate the net impact of organic waste diversion on GHG emissions.

To estimate potential nationwide GHG emissions reduction from organic waste diversion in the residential sector of the United States, this analysis applied the factors from WaRM to the estimates of disposed-of organic waste (Table 21) to get the landfill emission for each type of organic waste. These factors account for the multiple types of landfill operations found across the United States (e.g., landfills with/without LFG recovery, with/without energy recovery). Note that WaRM's emission factors for landfilling yard trimmings and wood are negative—indicating a net carbon savings for those waste types due to the effect of less-rapid decomposition rates and carbon storage within the landfill.

[44] A fraction of the methane in LFG is oxidized to carbon dioxide by microbes as it permeates through the landfill cover. For further information, see "Emissions of Greenhouse Gases in the U.S.," EIA, accessed 30 June 2017, <www.eia.gov/environment/emissions/ghg_report/notes_sources.php>.

Next, the emission factors for alternative waste management options within WaRM were applied to the available organic waste estimates from Table 21 (residential waste) and Table 22 (ICI waste) to calculate the net effect of diverting a year's worth of organic waste from landfills to a different management option. This report assumes AD as that alternative. Some diverted organic waste would likely be composted, but space limits make it unlikely that all of it could be composted. For the purposes of estimating a net emission reduction potential, and without knowing how much diverted waste would be composted versus anaerobically digested, this analysis assumes the waste would all go to AD. Due to the energy input requirements for AD, the emissions benefit of AD is lower than that of composting; thus, the assumption of diverting all waste to AD also provides a more conservative estimate of potential climate benefits, as shown in Table 69. Note that negative numbers in this table represent a net emission reduction, while positive numbers represent an emission increase.

Table 69. Potential GHG emission reductions in US from 100-percent diversion of organic waste from landfills to anaerobic digestion (AD)

Organic Waste Material	Emissions from Landfilling ($MTCO_2e$)	Emissions from Anaerobic Digestion (Dry AD with Digestate Curing) ($MTCO_2e$)	Total Net Emissions after 100% Diversion to AD ($MTCO_2e$)
Food waste	56,917,000	-5,017,000	-61,934,000
Yard trimmings	- 2,412,000	-1,220,000	1,192,000
Paper and paperboard	3,062,000	N/A	-3,062,000
Wood	-6,887,000	-3,070,000	3,817,000
Total	**50,680,000**	**-9,307,000**	**-59,987,000**

Note: Negative numbers indicate a net emission reduction. For example, there is a small net positive emissions increase from diverting yard trimmings from the landfill to anaerobic digestion, while there is a large net decrease in emissions from diverting food waste from the landfill to anaerobic digestion.
Source: Organic waste disposal data from Tables 21 and 22, this report, using WaRM v.14 emission factors.

Overall, the analysis shows a potential GHG emission reduction, for diverting a year's worth of available organic waste from landfills to AD, of nearly 60 million $MTCO_2e$ in the United States. This amount represents a total net life-cycle impact, based on the 2014 data presented in Chapter 2. The life-cycle component is important because decomposition of organic waste in landfills (and thus GHG emissions) takes decades to complete; the AD process can be completed in a matter of weeks.

Note that the vastly greater part of the estimated potential reduction in net emissions comes from the diversion of food waste. Note also that the net emissions of diverting yard trimmings and wood are positive (indicating an increase in emissions); as discussed above, this is due primarily to the benefit of carbon storage that these materials provide when buried (as in landfills). Also, WaRM does not allow for modeling the diversion of paper and paperboard to AD (or composting for that matter). The emission reduction associated with diverting paper and paperboard away from landfills is included here under the assumption that it would be recycled and not anaerobically digested.

To show the maximum potential emission reduction for organic waste diversion in the United States, this analysis also assumes that 100 percent of annual available organic waste could be diverted from landfills. However, 100-percent diversion is a lofty goal that would likely take decades of progress to achieve. A more likely near-term scenario would be compliance with the UN's Sustainable Development Goal 12.3 (UN 2015) of 50-percent diversion of food waste. Applying this 50-percent diversion goal to all types of organic waste would result in the scenario shown in Table 70.

Table 70. Potential GHG emission reductions in US from 50-percent diversion of organic waste from landfills to anaerobic digestion (AD)

Organic Waste Material	Emissions from Landfilling (MTCO2e)	Emissions from Anaerobic Digestion (Dry AD with Digestate Curing) (MTCO2e)	Total Net Emissions after 50% Diversion to AD ($MTCO_2e$)
Food waste	28,458,000	-2,508,000	-30,966,000
Yard trimmings	-1,206,000	-610,000	596,000
Paper and paperboard	1,531,000	NA	-1,531,000
Wood	-3,444,000	-1,535,000	1,909,000
Total	**25,339,000**	**-4,653,000**	**-29,992,000**

Note: Negative numbers indicate a net emission reduction.
Source: Organic waste disposal data from Tables 21 and 22, this report, using WaRM v.14 emission factors.

Finally, note that this analysis also focuses only on organic waste that is not currently landfilled. Organic waste that is already in landfills will continue to produce GHG emissions for many years regardless of future diversion, in accordance with first-order decay equations for waste in place.

5.5 Summary of GHG Emissions and Potential Emission Reductions in North America

GHG (primarily methane) emissions from solid-waste disposal depend on two primary factors: the amount of organic waste sent to landfills, and the collection and control of LFG at landfills in each country. The previous sections present methodologies for estimating emissions from waste in each country; the estimates themselves are summarized in Table 71.

Table 71. Estimated annual GHG emissions from solid- waste disposal in Canada, Mexico and US

Canada	Mexico*	United States
26 million $MTCO_2e$[a] (0.73 $MTCO_2e$ per capita)	18–25 million $MTCO_2e$[b] (0.15 to 0.21 $MTCO_2e$ per capita)	148 million $MTCO_2e$[c] (0.46 $MTCO_2e$ per capita)

* Emissions from organic waste management in Mexico are likely much higher than Table 71 shows. Obtaining reliable estimates of emissions, however, is complicated by the lack of consistent and reliable data and the higher number of uncontrolled landfills and open dumps in Mexico.

Sources:
[a] Table 63, this report.
[b] Table 64, this report (Gg methane converted to $MTCO_2e$ using a global warming potential of 25).
[c] Table 68, this report.

Differences in population is one of the key factors contributing to these estimates of GHG emissions. The US population is nearly three times greater than Mexico's and almost 10 times greater than Canada's, but the United States has well-established LFG collection and control that reduces overall emissions from waste. Emissions from waste management in Mexico are likely much higher than the table shows, based on the amounts of waste produced in Mexico and discussed in Chapter 2. Obtaining reliable estimates of emissions, however, is hampered by the lack of consistent and reliable data, and by the higher number of uncontrolled landfills and open dumps in Mexico.

Estimates of residential organic waste and associated GHG emissions in North America are the most reliable, since this waste stream is tracked. However, ICI-sector comparisons are more difficult, due to differing definitions and data collection efforts.

Large data gaps exist in both Canada and Mexico for ICI-sector organic waste generation and diversion, while the United States has limited data on the industrial sector.

Furthermore, the US and Canadian ICI estimates do not include organic waste from sewage treatment plants, animal excrement and manure, and animal carcasses, yet these sources contribute to increased opportunities for diversion and processing.

The ultimate potential emission reduction is the total estimated emissions, though such a reduction would require eliminating waste generation or diverting all waste to a management option that does not produce emissions. Since neither of those scenarios is realistic in the near term, models such as the US EPA's WaRM are used to estimate emission reductions through diversion from landfills to options such as composting or AD. Differences in the types of models, assumptions within models, and assumptions of waste diversion rates and alternative management all affect how potential reductions can be quantified and achieved over time.

Based on the assumptions and methodologies available for each country and presented in this chapter, the estimated potential emission reduction in each country is presented in Table 72.

Table 72. Estimated annual potential GHG emissions reduction in Canada, Mexico, and US

Canada	Mexico	United States
3.4 million $MTCO_2e$[a] (0.09 $MTCO_2e$ per capita)	2–38 million $MTCO_2e$[b] (0.02 to 0.32 $MTCO_2e$ per capita)	60 million $MTCO_2e$[c] (0.19 $MTCO_2e$ per capita)

Sources:

[a] Section 5.2.2, this report. (Based on current organic waste generation and disposal rates.)
[b] Table 65, this report. (38 million $MTCO_2e$ is an estimate of future potential reductions in 2030.)
[c] Table 69, this report. (Based on current organic waste generation and disposal rates.)

These estimated potential emission reductions are in line with the estimated emissions from each country, as presented in Table 71, above. Emission reduction potential in the United States is highest because GHG emissions from landfills are the highest and because GHG emissions from landfills represent a higher percentage of overall GHG emissions in the United States. The wide range in potential emission reductions in Mexico is due to uncertainty stemming from the availability and completeness of data, as well as variations in methodologies used to make the estimates.

5.6 Other Environmental and Socioeconomic Benefits of Organic Waste Diversion

Diverting organic waste from landfills has many benefits besides reducing climate pollutants, as discussed in this chapter. One benefit from the composting process is the production of a stable, mature, pathogen-free finished compost product. This dark, friable, earthy-smelling material resembles soil and is high in humus and valuable plant nutrients. Compost is extremely beneficial in a variety of applications, including use as a soil amendment for agriculture, landscaping, and horticulture. It can also be used to decrease the need for fertilizer use; for erosion control; or to prevent loss of topsoil. Also, over the past decade, research has proven that compost can suppress soil-borne disease organisms (Environment Canada 2013a).

Another benefit of diverting organic waste from landfills to the AD process is the ability to produce either electricity, heat or renewable natural gas from the biogas produced by AD systems, without the need for a costly LFG collection system. Producing energy using biogas offsets the use of fossil fuels at traditional power plants, resulting in additional environmental benefits due to the additional reduction in GHG and other pollutant emissions. Financial benefits are also possible, since the biogas byproduct of AD can be collected from the enclosed systems at much higher efficiencies than those obtained in collecting LFG.

Other environmental and social benefits of organic waste diversion and GHG reduction include the following:

- Reducing GHG and other pollutant emissions (e.g., particulates and air pollutants) helps protect human health and prevent degradation of natural ecosystems.
- Reducing the quantity of organics in landfills helps reduce the amount of landfill gas generated and the associated safety risks.
- Extended landfill life contributes to land preservation; diverting organics from landfills preserves space for those wastes that cannot be diverted or re-used.
- Removing organics from landfills reduces leachate management issues, potential soil and groundwater contamination, and odor nuisances, thereby decreasing the risks and negative impacts on surrounding communities and society.
- ICI byproducts (e.g., rendering scraps, citrus rinds) help conserve virgin materials by using organic waste as feedstock in new products (e.g., animal feed, essential oils in cleaners).
- Biogas is a renewable natural gas that can be used to produce electricity or heat, thereby offsetting use of fossil fuels and providing a local source of renewable energy.
- Digestate can be used as soil amendment, animal bedding or fertilizer.
- Use of compost decreases the need for synthetic fertilizers (as well as the intense energy use and the emissions associated with their manufacture), increases erosion control, prevents topsoil loss, and further protects the climate by capturing carbon (i.e., sequestration).

In terms of regional economic benefits, the Conference Board of Canada estimates that increasing Ontario's overall waste diversion rate to 60 percent could create 13,000 new jobs, which is equal to an increase in the gross domestic product of C$1.5 billion (OWMA et al. 2015). A study commissioned by OWMA and the Regional Public Works Commissioners of Ontario estimated that direct employment by organics processing facilities in Ontario averages 0.15 direct labours/operators employed for every 1,000 tonnes of organic waste produced (van der Werf 2013).

In the United States, a University of California at Berkeley report (Goldman and Ogishi 2001) estimated average impacts to the State of California of solid-waste disposal versus diversion. The report used US currency at its 1999 value, and showed as follows:

- a positive total income impact of US$111 per tonne of waste diverted;
- a positive value-added impact of US$161 per tonne of waste diverted; and
- a positive jobs impact of 2.5 jobs per 1,000 tonnes of waste diverted.

Assuming a 100-percent organic waste diversion scenario for the 142.3 million tonnes of organic waste (residential and ICI) disposed of in the United States in 2014 (as presented in Chapter 2), these factors equate to a potential positive economic impact of up to US$14 billion and over 320,000 jobs (calculation based on factors from Goldman and Ogishi 2001, using US currency at its 1999 value).

As explained in Section 5.4.2, 100-percent diversion of organic waste is a lofty, long-term goal.

A more realistic, near-term goal is 50-percent diversion of organic waste (in accordance with UN Sustainable Development Goal 12.3; see UN 2015). A 50-percent diversion rate would result in a potential positive economic impact of up to US$7 billion and over 160,000 jobs (calculation based on factors from Goldman and Ogishi 2001, using US currency at its 1999 value).

A realistic near-term goal is 50-percent diversion of organic waste. This would have a potential positive economic impact of up to US$7 billion and over 160,000 jobs.

Source: Goldman and Ogishi 2001.

6 Key Challenges, Gaps and Recommendations

Drawing on a review of published organic waste research, government and industry statistics, and case study data and interviews with stakeholders, the North American Initiative on Organic Waste Diversion and Processing identified persistent challenges to and gaps in greater organic waste diversion and processing across North America. This chapter highlights these cross-cutting challenges and gaps across North America, as well as country-specific challenges, and makes recommendations for policy or decision makers.

6.1 Cross-cutting Challenges, Best Practices and Recommendations

This section describes a series of challenges, best practices and recommendations that apply to multiple stakeholder groups across all three North American countries.

6.1.1 Providing Data Clarity: Recommendations for Policy Makers

Up-to-date and accurate data are critical for developing baselines, metrics, policies, programs, incentives, markets and regulations. Because the requirements and standards for measuring, monitoring and reporting organic waste vary among the countries (as well as across states, provinces and municipalities), data availability and consistency also vary. This represents a challenge in designing national, state/provincial or local actions to expand organic waste diversion and processing, and makes it more difficult to assess progress. Recommendations for government policy makers are described below.

Create a North American Organic Waste Database

While the definition of organic waste differs across the countries, combining or linking national databases and/or establishing a comprehensive database for Canada, Mexico and the United States would allow for the recording, tracking and maintenance of organic waste data and other statistics for the public (e.g., allow benchmarking, data comparison, policy analysis). For example, estimates of residential organic waste in North America are the most reliable, since this waste stream is tracked. However, ICI-sector comparisons are more difficult, due to differing definitions and data collection efforts. Large data gaps exist in both Canada and Mexico for ICI-sector organic waste generation and diversion, while the United States has limited data on the industrial sector. Furthermore, the US and Canadian ICI estimates do not include organic waste from sewage treatment plants, animal excrement and manure, and animal carcasses, yet these sources contribute to increased opportunities for diversion and processing. A North American organic waste database could be hosted by an industry trade group (as one example) and promoted to stakeholders in Canada, Mexico, the United States and other countries worldwide.

Create a Knowledge Portal

This project highlighted a demonstrated need to collect, track and maintain centralized information about North American and international programs, policies, incentives, case studies, best practices, and other technical materials and tools. Creating a centralized organic waste knowledge portal (i.e., website) of available information would facilitate the exchange of information across North America and other countries. A knowledge portal could also host or link to a North American organic waste database.

Improve Data Tracking at the Municipal, State, and Provincial Levels

Better data tracking and reporting at the municipal, state and provincial levels would enhance development of a North American organic waste database. For example, Canadian national waste composition data are not available to generate national solid-waste data. Waste composition data are still gathered at the local level through characterization studies and not easily obtained for extrapolation to the national level.

Engage the ICI Sector

Data about the use of organic waste in the production of end-products were quite limited and represent a large gap in understanding the types of products or how these products are produced or sold. The North American ICI sector has much greater diversion potential (e.g., grocery stores, restaurants), but data are lacking, and Mexico's organic waste diversion programs from the ICI sector are just emerging. To fill this engagement gap, targeting the ICI sector is viewed as a potential opportunity for a number of jurisdictions. Policy makers have limited data, which contributes to limited or no policies or programs focusing on ICI. Governments face challenges designing effective and transparent policies or programs without reliable data.

Coordinate with Sustainable Business Organizations to Gather Data

Efforts to coordinate with sustainable business organizations (e.g., the World Business Council for Sustainable Development) and the ICI sector should be encouraged, to gather data that can be made available to the public, inform policy and ensure transparency.

6.1.2 Focusing on Economic Considerations: Recommendations for Local, State and Provincial Government

Organic waste infrastructure typically has higher capital and operational costs than other solid waste management practices such as landfilling and combustion, and the cost difference between organic waste diversion and processing and disposal inhibits the growth of the organic waste industry, particularly in the ICI sector. Recommendations for local, state and provincial government policy makers are described below.

Level the Playing Field

Governing bodies must evaluate how much priority will be placed on organic waste diversion and processing. Supporting more organic waste diversion may require higher landfill or waste-to-energy tipping fees. It may be necessary to levy landfill taxes or other taxes that organic waste processors can use to help level the playing field. In the United States, at least 20 states have implemented landfill taxes that support grants, infrastructure or education (ReFED 2016).

In addition, economic incentives such as grants, low-interest loans, feed-in tariffs, renewable portfolio standards (such as those in Canada and the United States) or carbon credit opportunities to allow trading or purchasing offsets (by reducing or avoiding methane) from organic waste processing could be expanded across North America.

Consider Implementing Unit-based Pricing Programs

Provincial/state and municipal governments throughout North America have successfully implemented unit-pricing programs (e.g., pay-as-you-throw [PAYT]) that help waste generators reduce disposal costs by diverting a portion of their waste—thereby reducing the overall volume of waste they pay to dispose of—or other financial incentives aimed at encouraging voluntary diversion (e.g., lowering tipping fees for organics at drop-off facilities).

Consider Banning Organics from Landfills

Mandatory recycling laws, or bans on organic waste in landfills require generators to divert organic waste to composting or anaerobic digestion (AD). In Canada, for example, some provinces (e.g., Prince Edward Island, Nova Scotia) and municipalities (e.g., the Regional District of Nanaimo and the Metro Vancouver Regional District, in British Columbia) have banned organics from landfills. Similar bans exist at the state level in the US (e.g., Massachusetts, California) and at the municipal level (e.g., Seattle). Despite those initiatives, complete bans on organic waste in landfills are challenging to implement. Successful enforcement, penalties, and transition strategies must be in place, and individual jurisdictions often must take the initiative to introduce bylaws, larger penalties, and tipping fees, to discourage disposal of recyclable materials.

Focus on Regions with Existing Support for Organic Waste

Waste diversion projects continue to be viewed as high-risk/low-reward. Focusing efforts in states, provinces or cities with landfill disposal bans, higher waste tipping fees, and existing infrastructure can minimize investor concerns (e.g., established infrastructure, markets, knowledge and support for organic waste diversion).

Consider Job Creation Benefits

Consider other economic benefits due to job creation from organic waste diversion and processing. The ReFED Roadmap (ReFED 2016), which focused on food waste, found that processing jobs are created at the project level, as well as regionally and nationally (i.e., ancillary service jobs). A similar job creation analysis could be done to consider the entire organic waste life-cycle (from collection services to educational initiatives to selling end-products).

6.1.3 Overcoming Operational Issues: Recommendations for Project Developers and Municipal Program Managers

Operational factors, including the consistency of organic feedstock, the capabilities of municipal collection fleets, organic waste characteristics, implementation strategies (e.g., use of color-coded bags), and community acceptance, influence the success of organic waste diversion and processing efforts. Recommendations for project developers and municipal program managers are described below.

Have a Financial Plan

Before initiating a project, rigorously analyze all potential sources of revenue or cost savings. Consider questions such as whether to consume power or heat onsite or to sell them to the grid or natural gas pipeline or end-user(s). Identify and secure markets for end-products (through agreements) before developing organic waste processing facilities.

Other revenue-generating considerations include economies of scale (larger facilities with higher throughput) and revenue maximization (energy, tipping fees, secondary products and incentives). Lease models for AD may also offer opportunities for a third-party owner or operator to maintain several regional digesters, especially for medium-sized facilities (ReFED 2016).

Failing to secure sustainable sources of revenue or cost savings will harm the project's bottom line. Contracts and off-take agreements for end-products must be identified (markets), negotiated (adding cost) and secured (preferably long-term, to lock in pricing). Since some market participants might be reluctant to enter a long-term contract, consider including variable pricing. For example, a contract that adjusts for the prices of energy over a 10-year power purchase agreement or gas sale agreement could significantly affect project finances, considering factors like low energy prices, a rebound in natural gas prices, or availability of renewable identification numbers.

Accurately Assess Feedstock Consistency

Accurately determining the feedstock content and quantity of the incoming waste stream is crucial to the success of any organic waste diversion and processing program. The quality (e.g., waste composition), quantity (e.g., anticipated population growth), packaging and source of the waste material play important roles in the collection, treatment, capital and operational costs, and operations of an organic waste processing facility and its future performance. In addition, securing long-term agreements and reliable feedstock with fewer contaminants is critical for addressing investor or lender concerns about long-term project viability.

Depending on the source, organic waste can contain high levels of contaminants such as glass, plastics, metals and sand; if so, it must be pre-treated before processing. Pre-treatment may also be needed to remove plastic bags or grind organic waste into a pulp for further processing, to ensure process efficiency, maximize yield and reduce operational costs (US EPA 2016b).

Evaluate Collection Fleet Capabilities

Analyze the current collection fleet to determine if the vehicles are adequate to collect and transport organic waste or whether specialized vehicles are needed. Collection vehicles for organic waste require less compaction, may use augers instead of compaction blades, and have specialized containment for liquids. Newer vehicles may also have multiple compartments to allow for the collection of multiple waste streams, such as source-separated organics (SSO) or municipal solid waste (MSW); this can reduce the number of vehicles and routes needed for waste collection. However, a cost-benefit analysis for procuring specialized collection vehicles should be determined.

Pilot Test Projects Prior to Implementation

Start out with a pilot project before investing in large-scale infrastructure projects. Pilot projects allow managers to identify issues that could occur at full scale (e.g., feedstock composition, contamination, collection routes, participation rate) and allow project leaders to make necessary adjustments while the investment is still relatively small. Toronto, Ontario, for example, pilot-tested using AD technology for processing organics before going full-scale. The Dufferin Organics Processing Facility was constructed as a 25,000-tonne pilot facility in 2002 and subsequently expanded over time to full-scale operation (City of Toronto 2017b). In another example, Sunnyvale, California, embarked on a nine-month food-scrap recovery pilot program from March to December 2015. Roughly 500 households were provided with 64-gallon carts, with 32-gallon capacity on each side. Results of the pilot indicated that 90 percent of the residents participated and 75 percent of food scraps were placed on the proper side of the cart (Gertman 2016).

Expand Yard Waste Collection Programs

In many cases, municipalities fund organics programs, with limited provincial, state or federal funding available to support them. Expanding existing yard waste collection programs to gradually include food waste may reduce the need for separate collection and use existing infrastructure to keep costs manageable without increasing taxes on residents or business.

Consider Opportunities to Improve Source Separation of Organic Waste

Opportunities to improve source separation of organic waste include providing more bins or bags, preferably color-coded, to help distinguish them from other recyclables that might be collected, and providing compostable bags for co-mingled organics. In San Francisco, California, for example, the use of a color-coded bin system, policies (including financial incentives) and extensive public outreach have helped the city divert about 80 percent of its waste from landfills (SF Environment 2016)—the highest diversion rate of any major North American city (SF Environment 2016). Municipalities in Nova Scotia (including Cumberland and Oxford) use clear plastic bags for organics, which allows for easier inspection by collection crews. Allowing residences and businesses to use compostable bags for organic waste co-collection with yard waste or MSW could eliminate the need for separate collection vehicles and allow more frequent collection (since a regular hauling vehicle could co-collect the material without increasing collection frequency).

Ease Siting and Community Concerns

The public, especially in larger municipalities, can be resistant to certain technologies and programs in their neighborhoods (the "not-in-my-backyard" [NIMBY] phenomenon). With composting facilities, for example, procuring a site can pose difficulties, as odor and increased vehicle traffic can be concerns for nearby residents (Hay 2013). Modifying existing waste infrastructure, such as by adding composting or AD to a landfill or waste-to-energy facility, is less likely to cause as many concerns as siting on a greenfield site. Moreover, adding or modifying existing centrally located drop-off sites gives residents another way to divert organics, especially in more-rural areas. Many Canadian and US cities offer drop-off sites that accept food waste for processing.

In addition, municipalities should consider flexibility and support for expanded or new collection and processing infrastructure (creative solutions may be needed that might fall outside current policies or regulations). For example, consider adding new or upgraded infrastructure like transfer stations or materials recovery facilities as centralized collection points that can also pre-treat organic waste.

6.1.4 Improving ICI Data: Recommendations for Government and ICI Collaboration

The North American Initiative on Organic Waste Diversion and Processing found that most local governments do not mandate diversion of organic waste from the ICI sector. Instead, most rely on voluntary efforts. One major hurdle identified in this report is a lack of data on ICI activities and successes. A recommendation for improving ICI data is described below.

Encourage Waste Reduction Activities and Reporting

Through outreach efforts or voluntary partnership programs, municipalities or states/provinces could encourage the ICI sector to implement waste-prevention activities, such as bulk purchasing, paper use reduction, initiatives to limit purchases of single-use or disposable products (e.g., plastic bags, disposable cutlery), and re-use programs. Jurisdictions could encourage the ICI sector to recycle materials that already have diversion programs (e.g., printed paper and packaging, electronics, organics). Rebates and incentives could help persuade ICI businesses to participate in select waste prevention activities by providing financial motivation.

In addition, companies are increasingly establishing sustainability policies or zero-waste goals and/or landfill diversion targets that likely include—or could be achieved with greater—organic waste diversion. It would be useful to have communication among governments and the stakeholders in the ICI sector, and documentation of the achieving of these policies, goals or initiatives through organic waste diversion.

Waste policy frameworks need to have more direct engagement with and requirements for the ICI sector—possibly legislated (e.g., landfill bans) or through negotiated agreements. Waste policy frameworks could also require that ICI waste disposal data be reported to municipal or state/provincial authorities.

Improving data collection and transparency could help inform and design future programs, thereby securing processing capacity and ensuring markets for end-products (e.g., biofuels, biogas, compost).

6.1.5 Establishing ICI Best Practices: Recommendations for ICI Managers

Some of the lessons learned from municipal collection (e.g., use of color-coded bags) apply to the ICI sector; however, other issues are not applicable, since ICI leaders are collecting materials from fewer individual locations than municipalities. Recommendations for ICI managers are described below.

Explore Collaborative Procurement

For small and medium-sized businesses, access to collection services can be problematic. For example, haulers face difficulties making a sound business case for investment if they cannot demonstrate a secure level of feedstock, and they cannot wait for infrastructure to be built to appease investors. Businesses could pull their collective resources and work through collaborative procurement: combine food waste volumes to leverage buying power, and then purchase collection services from a single supplier.

Demonstrate Organic Waste Diversion through Events or Initiatives

Concert and other event venues, such as stadiums, and special events represent an opportunity to introduce the community and businesses to organic waste diversion and processing. An example of this in practice is the provision of separate containers for food waste, and compostable plates, cups, utensils and napkins go into a single container (May n.d.). Municipalities or haulers could encourage the use of compostable plates, cups and cutlery, to introduce the materials to the public. They could also offer separate bins or compostable bags to residents and businesses (free of charge or with coupons offering discounts).

In addition, events offer opportunities for expanding the use of compostable packaging. For example, in a case study developed by the Sustainable Packaging Coalition, a single evening concert with 6,000 attendees can divert over one tonne of organic waste, including approximately 350 kg of food-soiled packaging (Sustainable Packaging Coalition 2017).

Sustainability efforts—including organic waste diversion initiatives like the Green Sports Alliance, which represents members from teams, venues and leagues in Canada and the United States—could be further expanded in North America. Large venues are ideal locations to get the word out about a team’s support for sustainability efforts, while encouraging fans to recycle organic waste.

Supply Marked or Color-coded Bins for Food Waste Collection

Specially marked or color-coded bins for food waste collection in commercial or institutional environments (e.g., restaurants, college cafeterias) can significantly encourage employees or customers to properly discard food waste in the appropriate bins, as well as re-enforce outreach messaging and reduce contamination (McKiernan 2015).

Encourage Use of Compostable Packing and Materials

Compostable packaging presents a potentially valuable opportunity to mitigate contamination issues in SSO while also increasing the amount of organic material that can be diverted and reducing the need for petroleum-based plastic packaging products.

Expand Onsite Processing Capabilities

Businesses are increasingly interested in onsite processing, in order to save money or demonstrate sustainability initiatives or both. Small-scale onsite, organic-waste processing technologies are beginning to appear in restaurants, hotels, shopping malls, sports and entertainment venues, and government facilities. Onsite AD technologies can process from several kilograms up to several thousand kilograms of food waste per day. Commercial greywater systems use AD in combination with nutrients or enzymes and bacteria to reduce organic waste so it can be introduced into the sewerage system (ReFED 2016).

However, these technologies come at a high price, require added staff training and oversight, and—in the case of greywater—may not be acceptable to wastewater treatment plants (WWTPs) and water resource recovery facilities (WRRFs) (because accepting the material may require more processing or added capacity) (ReFED 2016).

6.1.6 Enhancing Markets for End-Use Products: Recommendations for Government Policy Makers

A primary benefit of organic waste diversion and processing activities is the resulting end-products that can be used in other applications (e.g., manufacturing, energy generation, soil enhancement). To maximize the potential of these end-products, the North American countries are cultivating markets for both public and private uses—particularly for compost, which appeals to users ranging from state transportation agencies to commercial landscapers and homeowners. In addition, rendering organic waste materials from the ICI sector results in commercial products, which include soaps, paints and varnishes, cosmetics, explosives, toothpaste, pharmaceuticals, leather, textiles and lubricants (NRA 2016b). Organic waste end-products from Canada, Mexico and the United States mainly find markets in North America, though some are sent overseas (Marti et al. 2011; NRA 2017). Furthermore, market drivers are primarily steered by project economics—proximity to markets affects revenues and expenses (e.g., fuel to transport product).

One recommendation for government policy makers is described below.

Promote Buy-Local Efforts

Because markets may be limited or distant from organic waste processing, organic waste end-products are usually less expensive if the markets to sell their products exist locally (i.e., “buy local”). States, provinces and municipalities should encourage the use of local organic waste end-products through the procurement process (e.g., procurement of compost for public landscaping) and promote the products to consumers via media campaigns.

To maximize the potential of end-products, markets for both public and private uses should be cultivated. This is particularly applicable for compost, which appeals to a broad range of users, including state transportation agencies, commercial landscapers and homeowners.

6.1.7 Promoting Greater Outreach and Education: Recommendations for Government Policy Makers

There is a need for ongoing and consistent outreach and education to inform residents and businesses of pending plans to develop an organic waste processing site, addressing their potential concerns (e.g., concerns about odor or other nuisances, such as flies), explaining how to properly separate organics to minimize contamination, and advertising the benefits of composting and AD. In addition, there is a need to address perceptions that some residents have—e.g., that organics collection should be free because recycling is free or that landfill disposal is still typically the least expensive waste management option. States, provinces and municipalities must better convey the realities of organic waste diversion. Developing infrastructure and markets will require community investment and acceptance. Communication will go a long way to address several other issues and concerns that might arise. Recommendations for government policy makers include the following:

- Develop a well-conceived educational initiative that focuses on reducing contamination and encouraging high levels of participation. This should be done as an initial step prior to moving ahead with an organic waste program.
- Support concerted, long-term educational campaigns and events to promote local benefits from organic waste diversion and end-products. After an educational initiative has been established, municipalities and private-sector companies can shift their focus to long-term strategies intended to instruct the public. Educating participants and/or reminding them that SSO collection merely isolates a portion of solid waste they already generate and manage might help alleviate some concerns.
- Host public forums and outreach at public events; provide handouts and other communications explaining the community's critical role in making the program a success. For example, if taxes will rise for residents or businesses because of the program, be sure to emphasize the program's benefits (e.g., chance to increase jobs in the community, potential cost savings). Involving the community early in the program may increase interest.
- Consider combining outreach with penalties for nonparticipation to achieve behavior change (ReFED 2016).
- Monitor and evaluate educational initiatives routinely to determine what is working, what is not, and what can be done about it; adjust programs as needed.

6.2 Country-specific Challenges and Recommendations

The three North American countries approach organic waste management quite differently. While each country has similar policies, each faces persistent challenges to greater organic waste diversion. For example, low landfill tipping fees in areas of Canada compete with organic waste diversion and processing initiatives; lack of compliance and enforcement in Mexico limits markets for organic waste due to end-product quality concerns; and lack of federal regulations in the United States causes a patchwork of state and local policies, programs, initiatives and regulations. One of the most common themes is a lack of consistent or sufficient generation and collection of data—particularly in the ICI sector—that could help inform and design future programs and thereby secure processing capacity and ensure markets for end-products (e.g., biofuels, biogas, compost).

6.2.1 Canada

The North American Initiative on Organic Waste Diversion and Processing identified the following challenges and recommendations for increasing organics waste diversion and processing in Canada.

Conduct More Research on Co-digestion

While many municipalities in Canada are encouraging co-digestion of organic waste at WWTPs/WRRFs, the practice is not common; thus far it has not been widely adopted. Co-digestion of organic waste with agricultural waste and manure is much more common. More guidance and research on successful co-digestion facilities, practices, policies and incentives should be developed. Lessons can be learned from other countries that are promoting opportunities for co-digestion, such as the United States. For example, the US EPA published a report that discusses opportunities for enhancing biogas generation in WRRFs through the addition of organic waste (food, fat, oils and grease) (US EPA 2014b).

Assess Additional Sources of Organic Waste

There is no separate data collection to inventory organic waste from septage, sewage, biosolids, animal excrement and manure, and animal carcasses, in Canada. Opportunities may exist to expand Statistics Canada's national survey to track this information.

Investigate Opportunities to More Fully Use Available Processing Capacity for Organic Waste

Canada's composting facilities have about 4.2 million tonnes of available, approved processing capacity and currently accept 2.6 million tonnes of organic waste annually, leaving 38 percent of existing capacity unused. Canada should investigate opportunities to expand organic waste acceptance using existing composting infrastructure.

Improve ICI Organic Waste Diversion and Processing

In 2012, the Canadian Council of Ministers of the Environment completed work with major retailers, the restaurant and food sector, brand owners, and the packaging industry that led to an industry-driven approach to reduce waste in Canada (CCME 2014). Resulting recommendations for the ICI sector are summarized as follows:

- Jurisdictions could encourage the ICI sector to implement waste prevention policies such as bulk purchasing, paper-use reduction, initiatives to limit purchases of single-use or disposable products (e.g., plastic bags, disposable cutlery), and re-use programs.
- Waste policy frameworks need to have more direct engagement with and requirements for the ICI sector—possibly legislated or through negotiated agreements. For example, jurisdictions could require the ICI sector to participate in extended producer responsibility (EPR) programs. Alternatively, jurisdictions could encourage the ICI sector to recycle materials that already have diversion programs (e.g., printed paper and packaging, electronics, organics).
- Waste policy frameworks should require ICI waste disposal data to be reported to provincial/territorial authorities to ensure monitoring capabilities with respect to organic waste.
- Jurisdictions could facilitate ICI organic waste diversion by implementing landfill bans, education and outreach, and infrastructure support.

The *Rethink Organic Waste: A Circular Strategy for Organics* report made a series of recommendations on how to drive organic waste management forward in Ontario (OWMA et al. 2015). Although these recommendations were written for Ontario, they could serve as a template of what would be useful to advance organic waste diversion and processing across Canada.

National Recommendations Based on Ontario's Experience

- Develop a long-term comprehensive strategy for reducing food waste and capturing and processing organic waste, based on the waste hierarchy's prioritizing reduction and re-use, recovery, and recycling. The strategy should include economic, social and environmental elements; policies based on the strategy should incorporate these longer-term objectives.
- Support broader public and business understanding of the need to reduce food waste and of diversion and processing of organic waste, by creating a public awareness campaign.
- Provide tax incentives and develop government procurement policies to reduce food waste, through mechanisms like food donation programs.
- Identify incentives to increase organic residual management programs at all government agencies and institutions and establish preferred purchasing programs for organic residual products (i.e., feedstocks for new products) to encourage procurement.
- Provide incentives to encourage markets for renewable energy generated from organic waste.
- Establish disposal bans, disposal levies and/or extended producer responsibility (EPR) programs, to encourage organic waste reduction and diversion.
- Restructure the approvals and service-delivery processes, to reduce complexity and strengthen enforcement while ensuring environmental protection.
- Establish a system to better capture and publish data on organic-waste generation, type, collection, processing and end-markets, by working with the organic waste sector.
- Establish ongoing investment and funding for research and development to keep standards up to date.
- Require businesses and organizations to collect and manage organic materials in a manner that reduces contamination and ensures high-quality outputs.

6.2.2 Mexico

Like Canada and the United States, Mexico has organic waste policies, laws and projects. However, the North American Initiative on Organic Waste Diversion and Processing found that compliance and enforcement related to these laws and policies are often inconsistent or lacking. While many state and municipal authorities acknowledge the relevance of diversion programs, maximizing potential requires political will and coordination among different entities (i.e., agencies, service providers, processors). Further, when local regulations are passed that include provisions for waste diversion and processing, they often lack enforcement, understanding and promotional markets, policies and incentives, and public education initiatives. While facing a multitude of challenges, Mexico shows tremendous opportunity for significant expansion of organic waste diversion and processing. The market is in essence untapped: adopting effective strategies and recommendations should enable Mexico to achieve organic waste diversion and processing growth and success. Recommendations for Mexico are described below.

Increase Support for National and Local Initiatives

Mexico could establish more national, state and municipal programs to: develop specific standards and guidance; promulgate technical information; and offer outreach, education, training and technical assistance. The 2013–2018 National Program for the Prevention and Comprehensive Management of Waste (*Programa Nacional para la Prevención y Gestión Integral de los Residuos*) has not yet been issued (Semarnat 2017). Upon its launch, it will support a framework for formulating or updating state and municipal programs, but a robust enforcement, compliance and education initiative is needed for the program to succeed.

Partner with Trade Associations to Promote ICI Diversion and Processing

To accelerate the involvement of large generators of organic waste in diversion and processing, the Secretariat of Environment and Natural Resources (*Secretaría de Medio Ambiente y Recursos Naturales*—Semarnat) (in coordination with state and municipal authorities) could promote a program for implementing waste management plans in food generation, production and distribution, slaughterhouses, hotels, restaurants, markets, supermarkets, and other sources, through the relevant trade associations.

Support End-Product, Market, and Investment Opportunities

To increase support for scientific and technological research to improve organic waste end-product, market and investment opportunities, Semarnat could explore implementing a strategy and convene a working group consisting of the National Council of Science and Technology (*Consejo Nacional de Ciencia y Tecnología*); other secretariats, such as the Secretariat of Agriculture, Livestock, Rural Development, Fisheries and Food (*Secretaría de Agricultura, Ganadería, Desarrollo Rural, Pesca y Alimentación*—Sagarpa); and key universities and research centers across the country.

Develop a Public Registry of Composting and AD Service Providers

A growing number of companies that specialize in composting and vermicomposting offer technical assistance, compost products, and machinery to produce compost. In some cases they develop projects for the creation, operation and supervision of composting and vermicomposting plants. Currently, there is no survey or directory of such companies. Companies that offer proven composting and AD services related to organic waste processing for industry, educational institutions and households—in urban and rural areas—should be identified and listed in a public registry, and involved in activities to strengthen Mexico’s capacity to process organic waste.

Develop Standards and Guidance to Promote Beneficial Re-use

Projects that use organic waste to produce biofuels or compost for crop fields will rely on support from the Secretariat of Energy (*Secretaría de Energía*), as well as the Secretariat of Health (*Secretaría de Salud*), Sagarpa and Semarnat, to develop standards and guidance to promote beneficial uses for organic waste.

Form Partnerships across Government Agencies

Under its 2030 Agenda for Sustainable Development for Mexico, Mexico could establish programs or policies that are consistent with the United Nations’17 Sustainable Development Goals (UN 2015) in supporting organic waste diversion and processing. These programs or policies could be supported and promoted by different secretariats, such as the Secretariat of Health (healthy communities), Sagarpa (rural sustainable development), Semarnat (self-sustaining housing), and civic and educational organizations involved in sustainability initiatives. The secretariats of Treasury and Economy should also be involved, to ensure that there are economic incentives in place along with other incentives for the sustainable production and consumption of biofuels, compost or other products from organic waste processing.

Tap into University Expertise

Clusters of universities involved in related education and research—as well as networks of experts and associations working to strengthen Mexico’s capacity to reduce, re-use and recycle wastes—are a source of experience and social will that can be useful in designing and implementing strategies for organic waste diversion and processing.

Create a Centralized Database of Waste Statistics and Information and a Directory of Stakeholders

Mexico should consider developing the National Information System for Integrated Waste Management (*Sistema de Información Nacional para la Gestión Integral de los Residuos*—SINGIR) to create a centralized database of key waste statistics and information sharing. These data could become part of a comprehensive North American organic waste database. Mexico should also consider creating an electronic directory of institutions, groups, businesses and government agencies involved in organic waste diversion and processing.

Provide More Information on End-Use Products

An important consideration for compost market potential is fertilizer use. Many food producers continue to use chemical fertilizers (with their large operations and customer base, synthetic fertilizer manufacturers benefit from economies of scale); 30 percent use organic fertilizer (Sagarpa n.d.). This 30 percent could represent a market opportunity for compost containing organic waste. However, more information is needed on organic compost products (e.g., nutritional content, collateral effects) before their wider adoption as fertilizer.

Document and Share Information

Mexico should increase efforts to document and share information on composting activities (e.g., type/amount of organic waste generated and processed, type of equipment, processing costs per ton, quantity and quality of the final product).

6.2.3 United States

While there are many examples of successful policies, programs, incentives and best practices from all levels of government, communities and businesses, challenges persist that limit opportunities for greater organic waste diversion and processing in the United States. States have their own differing policies and regulations for organic waste. About half of all states have enacted yard and/or food waste disposal bans, and a handful of states have also set landfill diversion targets. Current policies in some states impede greater composting and/or use of AD to handle these diverted organics, though, so it is unknown how much impact these bans and/or targets might truly have. Composting operations and digesters, in particular, are subject to solid-waste and air- and water-quality permitting that varies from state to state, thereby requiring project developers that work in multiple states to know how each permit or local ordinance might affect specific projects (finances, technology selection, end-products).

States have a patchwork of definitions for organic waste and renewables, and how AD or other types of organic waste conversion technologies are defined affects whether a project qualifies for any incentive. Achieving agreement on common definitions will facilitate growth of the biogas industry. Many federal and state incentives are available to support the adoption of cleaner technologies, but their applicability to organic waste can be uncertain. For example, the United States has more than 523 biomass-related regulatory policies and/or financial incentives. Of these, 227 relate specifically to AD technologies—but it is unclear how many (if any) of these initiatives are specific to organics and/or include composting efforts. In addition, more than three-quarters of the states have renewable portfolio standards or renewable energy portfolio policies that they could meet if there were more emphasis on organic waste diversion and processing. As with incentives, there is little information specifically on the use of biogas from AD.

Initiate a National Organic Waste Working Group

To tackle the challenges stated above, state and federal government representatives, along with representatives from the organic waste industry and nongovernmental organizations, including trade associations and academia, should establish a working group to evaluate these disparities and develop a set of norms to streamline the expansion of organic waste diversion and processing. The working group would identify and analyze the key challenges and opportunities at the federal, state and local levels and provide a set of recommendations. The recommendations would form the basis for a series of solutions that could be considered for agreement by government or industry.

Increase Federal Cooperation on Organic Waste

Federal agencies and departments including the US EPA, US Department of Energy and USDA, are involved in organic waste diversion and processing at various levels (i.e., creating policies, programs, incentives, regulations). Opportunities for greater cooperation between and within these agencies and departments should be considered. Another option includes involving other agencies and departments such as the Department of Labor to evaluate and recommend improvements for markets for end-products or for providing technical and outreach support to the ICI sector (e.g., encourage greater data transparency, developing national ICI metrics). Federal agencies and departments should consider establishing an inter-agency task force to coordinate organic waste efforts. Federal experts could analyze many of the challenges described in this report to provide recommendations for harmonizing efforts to expand organic waste diversion and processing in the United States. For example, the AgSTAR program has historically focused on farm-based digesters. Given the volume of non-farm organic waste, the US EPA or USDA or both should consider expanding the program to include more resources on co-digestion and facilitate partnerships between food processors and farms and/or wastewater treatment plants to increase co-digestion.

Promote Lessons Learned from State and Local Government

Opportunities exist for local governments to enter into partnerships with other cities or organizations to help further environmental goals. More than 100 local governments participate in the US EPA’s WasteWise program. Others could look to state programs or offices, such as RecyclingWorks or CalRecycle, for guidance or lessons learned.

In 2005, the City of Austin, Texas, signed onto the San Francisco Environment’s Urban Environmental Accords, which comprise a set of objectives “for an urban future that would be ecologically sustainable, economically dynamic, and socially equitable” (SF Environment 2017).[45] In doing so, Austin committed to achieving zero waste to landfills by 2040 (City of Austin 2005). In 2009, Austin established Texas’ first local Zero Waste Strategic Plan (City of Austin 2009). To help implement that plan, it adopted the Resource Recovery Master Plan in December 2011 (City of Austin 2011).

6.2.4 Opportunities for Trilateral Collaboration

Collaboration among North American countries, as well as information-sharing among organic-waste-related organizations, could go a long way toward advancing organic waste markets and practices. Lessons learned from existing programs and best practices in each North American country could also be shared with communities in the other countries, especially if they are similar in population and

[45] San Francisco hosted a United Nations World Environment Day in 2005, during which mayors from around the world were invited to sign the Urban Environmental Accords, which were based on existing best practices in areas such as “energy, waste reduction, urban nature, transportation, and water” (SF Environment 2017). To date, more than 100 mayors have signed and begun applying the Accords within their own cities.

infrastructure (e.g., "sister cities"), to give those governments advance knowledge of what issues they might encounter and how they might address those issues. Opportunities for trilateral collaboration are described below.

Examine Cross-Border Market Opportunities

There may be opportunities for cross-border cooperation, especially along the Canada–US and Mexico –US borders. For example, establishing a composting or AD plant in these border regions could draw on a larger waste shed (feedstock) to supply the plant. Border requirements would need to be examined to determine how national and state/provincial laws would affect such cross-border exchange (e.g., sending waste collection vehicles across the border). The North American Initiative on Organic Waste Diversion and Processing identified minimal information about cross-border markets for organic waste, and recommends additional research to evaluate the challenges and opportunities.

Expand Collaborative Efforts to Establish Sustainability Goals

A growing number of communities and businesses are establishing sustainability goals that include zero-waste initiatives, but there are considerable opportunities for expansion. Federal, state, provincial and municipal governments and businesses should work together to support continued expansion of sustainability goals, including organic waste diversion and processing. Examples of potential collaboration include promoting and rewarding achievements, sharing best practices, and educating the public/customers.

To help establish or achieve zero-waste goals, localities should consider legislative approaches—as well as working with generators—to develop programs and incentives to encourage expansion of organic waste diversion and processing as part of corporate or municipal sustainability plans.

Collaborate to Identify End-Markets for Products Derived from Organic Waste Processing

The organic waste industry, including trade associations (American Biogas Council, US and Canadian compost councils), could collaborate with government to invest and develop joint initiatives to research and document markets for end-products (benefits, cost) and conduct outreach to potential end-user business or manufacturing trade associations to make this information available (several trade associations have already developed some materials to promote their end-products and -markets, but there is no unified effort).

Improve Data Collection and Transparency

Improving data collection and transparency—particularly in the ICI sector—could help inform and design future programs, thereby securing processing capacity and ensuring markets for end-products (e.g., biofuels, biogas, compost).

Conduct Capacity Building Efforts and Training in Mexico

Mexican authorities (national, state, municipal) could work with Canadian, US and international industry and public leaders to pursue capacity-building and training. Many of Mexico's challenges are technical and involve limited organic waste expertise in the commercial sector. Most of Mexico's efforts focus on composting, and there have been repeated problems—ranging from operations and maintenance to collection and separation. Regional training workshops would facilitate an exchange of knowledge from North American experts, including field operations expertise. In addition, several training workshops could be hosted in Canadian and US processing facilities. Attendees would have a chance to learn about all aspects of the process, including designing and maintaining an effective diversion program, establishing policies (e.g., PAYT), and exchanging best practices (e.g., hands-on experience in pre-treatment and processing). The training workshops would align attendees with similarly sized municipalities. Lessons learned from programs and best practices in other cities—especially cities similar in population and infrastructure (e.g., “sister cities”)—would help the Mexican government (federal, state, local) understand potential problems and generate ideas to overcome them.

Mexico could explore convening international experts to help identify the elements, strategies and actions to include in a proposed new national program on organic waste diversion and processing. This could involve a planning workshop to which Canadian and US experts would be invited to share their experiences and best practices and discuss lessons from the foundational report. The experience of the experts could facilitate dialogue to help Mexico advance organic waste diversion and processing initiatives. Using digital technology (e.g., social media) to inform interested parties about the purpose of the program and desired outcomes could be an effective, inexpensive and immediate way to catalyze the process and attract attention.

7 Limitations of Analysis

The greatest limitation of this report is the lack of organic quantity and composition data that are consistent in their coverage and availability across countries, provinces, states and municipalities. Without sound data, it is difficult to develop strategies, policies or programs, or metrics around the management of organic wastes across North America. Gaps in data about industrial, commercial and institutional organic waste generation and post-generation handling or treatment were frequently found during the research phase, as well as about industrial uses that should be considered for further evaluation. Some of the gaps could be filled through agreed-upon terms and definitions, and parameters needed in data collection, monitoring, reporting and verification. See Section 6.1.1 for a more detailed discussion of the recommendations for improving data quality and quantity.

Additional limitations included differing methodologies used to estimate GHG emissions from organic waste disposal and potential emission reductions to be gained from diverting organic waste to beneficial uses. There is no single methodology or model to estimate landfill GHG emissions versus life-cycle GHG emissions for the three countries, and a robust country-specific or regional (or both) tool to estimate life-cycle GHG emissions would be useful.

The CEC companion report, *Characterization and Management of Food Loss and Waste in North America*, found similar limitations in identifying country-specific data on environmental and socio-economic impacts from food loss and waste for the three countries. Given that, an approach that could be considered would be to build on existing environmental and socio-economic impact quantification models, using proxy data to customize by country.

Appendix A Key Organic Waste Processing Facilities in Canada

Province	Location/ Program Description	Type of Processing: AD	Type of Processing: Composting	Year Started
Alberta	**Calgary, City of** Technology: in-vessel composting Feedstock material: SSO, leaf and yard Quantities processed: 125,000 tonnes/year		✓	Under construction[a]
Alberta	**Edmonton, City of** Technology: aerated bays Feedstock material: SSO, leaf and yard, biosolids Quantities processed: 160,000 tonnes/year[b]		✓	2000[b]
British Columbia	**Coast Environmental (Cowichan Valley)** Technology: in-vessel composting Feedstock material: biosolids, SSO, leaf and yard, fish waste, dairy waste Quantities processed: 14,000 tonnes/year[c]		✓	2009[c]
British Columbia	**Earth Renu Energy Corp (Metro Vancouver)** Technology: AD Feedstock material: fats, oils and grease Quantities processed: 66,000 tonnes/year[d]	✓		2014–present (ongoing)[e]
British Columbia	**Enterra (Metro Vancouver)** Technology: soldier fly larvae digestion Feedstock material: SSO Quantities processed: 32,658 tonnes/year[f]	✓		2014[g]
British Columbia	**Enviro-Smart Organics (Metro Vancouver)** Technology: covered aerated static pile Feedstock material: SSO, leaf and yard Quantities processed: 200,000 tonnes/year[h]		✓	2007, upgrade in 2014[i]
British Columbia	**Harvest Power Richmond (Vancouver)** Technology: windrow composting and AD Feedstock material: SSO, leaf and yard Quantities processed: 40,000 tonnes/year	✓	✓	2014[j]
British Columbia	**ICC Composting Group (Nanaimo)** Technology: rotating drum in-vessel composting Feedstock material: SSO, leaf and yard Quantities processed: 36,500 tonnes/year[k]		✓	2004, upgrade in 2012[k]
British Columbia	**Northwest Organics (Thompson-Nicola)** Technology: windrow composting Feedstock material: SSO, leaf and yard, wood Quantities processed: 19,000 tonnes/year[l]		✓	2011[l]
British Columbia	**Orgaworld Surrey—under construction (Vancouver)** Technology: dry AD and composting Feedstock material: SSO, leaf and yard, ICI Quantities to be processed: 115,000 tonnes/year[m]	✓	✓	2018[m]
British Columbia	**Resort Municipality of Whistler (Squamish-Lilloet)** Technology: in-vessel composting Feedstock material: SSO, sewage biosolids, wood waste		✓	2004[o]

Province	Location/ Program Description	Type of Processing: AD	Type of Processing: Composting	Year Started
	Quantities processed: 13,000 tonnes/year[n]			
Manitoba	**Manitoba** 53 municipal and commercial facilities in province Technology: windrow composting Feedstock material: SSO, leaf and yard, others Quantities processed: 35,000 tonnes/year[p]		✓	Various[p]
New Brunswick	**Envirem Organics Inc.** Technology: 6 composting facilities, 1 AD facility Feedstock material: forestry and industrial residuals Quantities processed: 500,000 tonnes/year	✓	✓	Multiple [q]
Newfoundland and Labrador	**Argentia Access Road Industrial Composting Facility** Technology: composting Feedstock material: mink farm offal, spent hens, dead birds, poultry feathers, slaughterhouse offal and carcasses, fish processing waste Quantities processed: 900 tonnes/year[r]		✓	Construction summer 2016[r]
Nova Scotia	**Goodwood Composting Facility** Technology: composting Feedstock material: SSO Quantities processed: 25,000 tonnes/year[s]		✓	1999[s]
	Town of Yarmouth Composting Facility Technology: composting Feedstock material: ICI and residential food and yard waste, paper products Quantities processed: 9,000 tonnes/year[t]		✓	Approval stage[t]
Ontario	**All Treat Farms** Technology: GORE and windrow composting Feedstock material: SSO (residential and commercial), non-recyclable paper, paper plates and cups, leaf and yard waste, approved clay and filter cakes, AD digestate Quantities processed: 120,000 tonnes/year[u]		✓	N/A
	Disco Road Processing Facility Technology: AD Feedstock material: SSO (residential and commercial collected by Toronto) Quantities processed: 75,000 tonnes/year	✓		2013
	Dufferin Organics Processing Facility—Toronto Technology: AD Feedstock material: SSO (residential and commercial collected by Toronto) Quantities processed: 55,000 tonnes/year	✓		2002
	Eastern Ontario Waste Handling Facility Inc. Technology: composting Feedstock material: non-hazardous domestic and ICI organic waste, SRM and biosolids Quantities processed: 40,000 tonnes/year		✓	2015
	Guelph, City of Technology: in-vessel composting		✓	2011

Province	Location/ Program Description	Type of Processing		Year Started
		AD	Composting	
	Feedstock material: SSO (residential) ICI, leaf and yard waste Quantities processed: 30,000 tonnes/year			
	The Miller Group Technology: outdoor windrows and indoor Ebara technologies Feedstock material: SSO, leaf and yard waste Quantities processed: 130,000 tonnes/year[u]		✓	~ 1990[u]
	Niagara Waste Systems Technology: GORE composting Feedstock material: leaf and yard, residential and ICI SSO, solid non-hazardous and liquid industrial wastes, off-spec alcohol, wood Quantities processed: 65,000 tonnes/year		✓	2001
	Ottawa Valley Waste Recovery Centre Technology: container composting Feedstock material: household, leaf and yard, ICI food processing from commercial/retail and restaurants Quantities processed: 6,000 tonnes/year		✓	2002
Prince Edward Island	**Central Composting Facility** Technology: composting Feedstock material: MSW, industrial organic wastes Quantities processed: 30,000 tonnes/year		✓	2001[w]
Quebec	**Les Composts du Québec (a subsidiary of Englobe)** Technology: composting Feedstock materials: N/A Quantities processed: ~100,000 tonnes/year[x]		✓	Multiple[x]
	Organic Waste Reclamation Centre[w] Technology: AD, co-digestion Feedstock material: food and yard waste, paper products Quantities processed: 205,000 tonnes/year	✓		2014
Saskatchewan	**Yorkton** Technology: windrow composting Feedstock material: SSO, leaf and yard, others Quantities processed: 30,874 cubic yards[x]		✓	2008[x]

Sources:
[a] Compost Council of Canada 2016b.
[b] City of Edmonton 2016b.
[c] Coast Environmental 2016.
[d] Ministry of Energy and Mines 2012.
[e] Harpur 2013.
[f] Griffin 2015.
[g] Enterra 2014.
[h] Westcoast Lawns 2015.
[i] Barker 2015.
[j] Harvest Power 2014.
[k] ICC Group 2016.

[l] Bridge River Lillooet News 2011.
[m] Fletcher 2015.
[n] Squamish-Lillooet Regional District 2013.
[o] Piech 2008.
[p] AMM 2014.
[q] Envirem Organics 2010.
[r] Newfoundland Labrador 2016.
[s] Niagara-Hamilton Waste Plan 2006.
[t] Government of Nova Scotia 2016.
[u] Miller Group 2017.
[v] Englobe 2017.
[w] Governments Going Circular 2016.
[x] Briere 2015.

Appendix B Examples of Residential Organic Waste Diversion Programs in the United States

State	Location/ Program Description	Type of Processing: AD	Type of Processing: Composting	Year Started
California	**Alameda County** Technology: composting Program/materials: curbside residential “food scraps, food soiled paper and plant debris” collection Population served: 420,000 single-family households[b]		✓	~2002
	Central Contra Costa Solid Waste Authority Technology: composting Program/materials: allows food scraps in yard trimmings cart Population served: 62,500 households		✓	N/A
	Los Angeles City Technology: composting Program/materials: limited food scraps collection pilot Population served: 8,700 households[c]		✓	2008
	Palo Alto and Santa Clara County Technology: composting Program/materials: three-cart curbside residential food scraps collection Population served: 18,000 single-family households		✓	2004
	San Mateo County Technology: composting Program/materials: curbside residential food scraps collection Population served: 93,000 single-family households		✓	2009
	San Francisco Program/materials: mandatory residential organics collection Population served: 7,900 apartment buildings plus unknown number of single-family households		✓	1997 (revised October 2009)
Colorado	**Boulder** Technology: composting Program/materials: city-wide food scraps collection Population served: all single-family households		✓	2009
	Boulder County Technology: composting Program/materials: residential food scraps collection Population served: unknown		✓	2014
	Denver Technology: composting Program/materials: residential food scraps, yard trimmings and soiled paper collection Population served: ~7,000 homes		✓	2007

State	Location/ Program Description	Type of Processing		Year Started
Connecticut	**Bridgewater** Technology: composting Program/materials: curbside food scrap/soiled paper sign-up service Population served: offered to 1,100 households; 140 had signed up in 2015		✓	2014
Delaware[d]	**Five coastal communities** Technology: composting Program/materials: existing curbside yard waste collection service expanded to curbside SSO food waste pilot Population served: unknown		✓	N/A
Illinois	**Oak Park** Technology: composting Program/materials: pay-as-you-throw residential food scraps collection Population served: 740 households plus six multifamily buildings		✓	2012
Iowa	**Cedar Rapids** Technology: composting Program/materials: residential food scraps and yard trimmings collection Population served: 39,400 households		✓	2001
	Dubuque Technology: composting Program/materials: seasonal residential food scraps and yard trimmings collection Population served: unknown		✓	N/A
	North Liberty Technology: composting Program/materials: residential food scraps and soiled paper collection; yard trimmings collected separately in US$1.65 bag Population served: unknown		✓	2014
Kentucky	**Lexington** Technology: composting Program/materials: residential food scraps, yard trimmings and soiled paper collection Population served: unknown		✓	2011
	Louisville Technology: composting Program/materials: food scraps and soiled paper collection for businesses and residents[e] Population served: unknown		✓	2014
Maine	**Unnamed municipalities** Technology: AD and composting Program/materials: food scraps drop-off and several companies offer subscription food waste collection[f] Population served: unknown	✓	✓	N/A
Maryland	**Howard County** Technology: composting Program/materials: residential food scraps, yard trimmings and soiled paper collection Population served: 15,000 households eligible; 5,900 signed up		✓	2010

State	Location/ Program Description	Type of Processing		Year Started
	Takoma Park Technology: composting Program/materials: residential food scraps collection Population served: available to 3,200 households; 1,300 signed up		✓	2013
	University Park Technology: composting Program/materials: residential food scraps collection Population served: 150 households in 2013		✓	2011
Massachusetts	**Cambridge** Technology: composting Program/materials: residential food scraps collection Population served: 800 homes		✓	2013
	Hamilton/Wenham Technology: composting Program/materials: residential food scraps and soiled paper collection Population served: 3,600 households		✓	2009
	Ipswich Technology: composting Program/materials: residential food scraps, yard trimmings and soiled paper collection Population served: offered to 5,000 households; 432 signed up		✓	2011
	Manchester by the Sea Technology: composting Program/materials: residential organics and soiled paper collection; drop-off program for yard debris Population served: 2,400 households		✓	2014
	Salem Technology: composting Program/materials: residential food scraps and soiled paper collection Population served: offered to 1,250 households; 950 signed up—service is free, but several-step process		✓	2014
Michigan	**Ann Arbor** Technology: composting Program/materials: residential food scraps and yard trimmings collection Population served: 11,000 “subscribers” out of 43,000 households[g]		✓	2006
	Mackinac Island Technology: composting Program/materials: residential food scraps collection by horse-drawn trailers Population served: unknown		✓	1992
Minnesota	**Hennepin County** Technology: composting Program/materials: citywide residential food scraps collection Population served: 106,000 households		✓	2005
	Hutchinson Technology: composting		✓	N/A

State	Location/ Program Description	Type of Processing		Year Started
	Program/materials: residential food scraps and soiled paper collection Population served: 6,000 households			
New Jersey	**Lamberkardistville** Technology: composting Program/materials: residential food scraps and soiled paper collection Population served: 100 homes		✓	2014
	Princeton Technology: composting Program/materials: residential food scraps, yard trimmings and soiled paper collection Population served: 9,500 households[h]		✓	2010
New Mexico[d]	**Albuquerque** Technology: composting Program/materials: drop-off sites at local farmers' markets, but no residential collection Population served: unknown		✓	N/A
New York	**New York City** Technology: composting Program/materials: residential food scraps collection; residents can also take food scraps to drop-off sites Population served: 100,000 households plus 151 apartment buildings[i]		✓	2013
	Tompkins County Technology: composting Program/materials: residential food scraps collection Population served: 1,236 households, in addition to five drop-off sites		✓	2013
Oklahoma[d]	**Oklahoma City** Technology: composting Program/materials: drop-off for residential food scraps at local community garden, but no curbside collection Population served: unknown		✓	N/A
Oregon	**Bend/Redmond** Technology: composting Program/materials: residential yard trimmings plus fruits and vegetables collection Population served: 2,639 households		✓	2010
	Marion County Technology: composting Program/materials: residential organics collection with the exception of compostable bags and packaging Population served: 48,000 single-family households		✓	2010
	Newport Technology: composting Program/materials: residential yard trimmings and food scraps collection Population served: 2,400 households[j]		✓	2014
	Portland Technology: composting Program/materials: mandatory food diversion for the largest commercial generators; citywide residential food		✓	2010 (revised August 2014)

State	Location/ Program Description	Type of Processing		Year Started
	scraps collection Population served: 147,000 households plus 50,000 multi-family units			
Pennsylvania	**State College** Technology: composting Program/materials: residential food scraps, yard trimmings and soiled paper collection Population served: 3,400 households[k]		✓	2010
Texas	**Austin** Technology: composting Program/materials: residential food scraps, yard trimmings and soiled paper collection Population served: 6,500 households		✓	2012
	San Antonio Technology: composting Program/materials: residential food scraps, yard trimmings collection Population served: 19,000 households are subscribed, with a goal of 344,000 by 2017		✓	2011
Vermont	**Brattleboro** Technology: composting Program/materials: residential food scraps and soiled paper collection, with minimal yard trimmings Population: 900 households		✓	2012
Washington	**King County** Technology: composting Program/materials: residential food scraps and soiled paper collection Population served: reaches 319,500 single-family homes and 225,500 homes are signed up[l]		✓	2004
	Seattle Technology: composting Program/materials: ordinance prohibits the disposal of food by businesses and institutions that dispose of 1 ton or more of organic waste per week Population served: unknown		✓	January 1, 2015
Wisconsin[d]	**Unnamed cities** Technology: composting Program/materials: Two small residential pilots; working to build food waste composting infrastructure Population served: unknown		✓	N/A

Sources:

Yepsen 2015 (unless otherwise noted).
[a] StopWaste 2016.
[b] Helou 2014.
[c] Yepsen 2014.
[e] City of Louisville 2016.
[f] Burns 2016.
[g] City of Ann Arbor 2016.
[h] Princeton, New Jersey 2016.
[i] New York Department of Sanitation 2016.
[j] City of Newport 2014.
[k] State College, Pennsylvania 2016.
[l] King County 2016.

Appendix C Example Organic Waste Management Tools

Resource	Description
Managing and Transforming Waste Streams Tool <www.epa.gov/transforming-waste-tool>	Features 100 measures (e.g., zero-waste goals for organics, PAYT, source-separation incentives, procurement policies) that communities can employ to reduce waste and recover specific materials. The tool also features over 300 implementation examples from US and Canadian communities, including links to local ordinances and program websites.
Waste to Biogas Mapping Tool <www3.epa.gov/region9/biogas/purpose.html>	An interactive map created to connect organic waste producers (e.g., grease-rendering facilities, food-processing facilities) and potential users for co-digestion with biogas recovery.
Co-digestion Economic Analysis Tool (CoEAT) <https://archive.epa.gov/region9/organics/web/html/index-2.html>	Assesses the initial economic feasibility of food waste co-digestion at WRRFs for biogas production.
Waste Reduction Model (WARM) <www.epa.gov/warm>	Helps solid-waste planners and organizations track and voluntarily report GHG emissions reductions from several different waste management practices. WaRM calculates and totals GHG emissions of baseline and alternative waste management practices—source reduction, recycling, anaerobic digestion, combustion, composting and landfilling.
Municipal Solid Waste Decision Support Tool <https://mswdst.rti.org/>	Used to identify and evaluate cost and environmental aspects associated with specific waste management strategies or existing systems. Can also be used to identify costs and environmental aspects of proposed strategies such as those designed to meet recycling and waste diversion goals; quantify potential environmental benefits associated with recycling; identify strategies for optimizing energy recovery from MSW; and evaluate options for reducing greenhouse gases, air pollutants, and environmental releases to water-bodies or ecosystems.
Greenhouse Gases (GHG) Calculator for Waste Management <www.ec.gc.ca/gdd-mw/default.asp?lang=En&n=D6A8B05A-1>	Used to help municipalities and other users estimate GHG emission reductions from different waste management practices, including recycling, composting, anaerobic digestion, combustion and landfilling.
GHGenius <www.ghgenius.ca/>	Primarily focuses on the life-cycle assessment of current and future fuels for transportation applications for specific regions (east, central or west) of Canada, the United States and Mexico. Also considers a few circumstances where the fuels could be used in stationary applications rather than for transportation. Can be used to predict emissions for past, present and future years through to 2050.

Appendix D Interview List

Position	Country	Type of Stakeholder
President	Canada	Consultant
Manager of Waste Planning and Technical Services	Canada	Government
Director, Sustainable Waste Processing	Canada	Government
Director of Policy	Canada	Industry Association
Vice-President Operations	Canada	Organics Processor
Manager Solid Waste Utility	Canada	Government
Senior Advisor	Canada	Developer
Consultant	Mexico	Government
Researcher	Mexico	Government
Under-Director of Bioenergetics and Alternative Energy	Mexico	Government
General Director, Climate Change	Mexico	Government
Forestry Regulation Director	Mexico	Government
Consultant	Mexico	Consultant
Researcher and Professor	Mexico	Academia
Director of Research on the Sustainable Management of Chemical Products, Substances and Wastes	Mexico	Government
Human Resources Manager	Mexico	Nonprofit Organization
General Manager	Mexico	Industry Association
Under-director of Recycling, Department of Urban Services	Mexico	Government
Consultant	Mexico	Consultant
Chief of Department, Special Projects and Climate Change	Mexico	Academia
Consultant	Mexico	Consultant
Consultant	Mexico	Consultant
Environmental Protection Specialist	US	Government
Team Lead	US	Government
Sales Manager	US	Consultant
Project Coordinator	US	Vendor
Director of Public and Governmental Affairs	US	Industry Association
Sustainability Specialist	US	Hauler
Investment Professional	US	Investor

Position	Country	Type of Stakeholder
Manager of Environmental Engineering	US	Vendor
Director of Marketing and Business Development	US	Vendor
Principal	US	Consultant
Market Director	US	Vendor
Assistant Professor	US	Academia
Executive Director	US	Industry Association

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