

# **TURNING WASTE INTO VEHICLE FUEL: RENEWABLE NATURAL GAS (RNG) A STEP-BY-STEP GUIDE FOR COMMUNITIES**



**A Report by  
ENERGY VISION**

**Prepared by Joanna D. Underwood and Matthew P. Tomich**





Energy Vision is a national 501 (c) (3) organization based in New York City whose goal is to promote - through research and action - a swift transition to pollution-free renewable energy sources. Programmatically, Energy Vision informs and engages with policy, business, and environmental leaders, to support the shift of medium- and heavy-duty bus and truck fleets along the path toward a sustainable fuel, especially renewable natural gas.

This report was prepared by Energy Vision President Joanna D. Underwood and Director of Research and Outreach Matthew P. Tomich.

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# *Turning Waste into Vehicle Fuel: A Step-by-Step Guide for Communities*

## Table of Contents

<b>Foreword</b>	<b>5</b>
<b>1. Introduction: Why Write a Guide on Renewable Natural Gas (RNG) for Communities?</b>	<b>7</b>
Audiences for this Guide	8
What the Guide Contains	9
<b>2. Components of an RNG Project: Waste to Wheels</b>	<b>11</b>
Organic Wastes: The Starting Point	12
Producing Biogas from Waste: Anaerobic Digestion	12
Refining Biogas into RNG Fuel: Biogas Upgrading	15
Delivering Fuel to Vehicle Markets	16
Finding the Fleet Customers	16
<b>3. How to Target a Project Opportunity</b>	<b>17</b>
Project Leadership: Creating an “Action Group”	17
Project Planning: Getting your Goals in Sight	18
Project Siting: Landfills and Wastewater Treatment Plants That Already Produce Biogas	20
Other Sites with Large Concentrations of Organic Wastes	22
Sites for an Anaerobic Digester to Process Multiple Sources of Local Waste	24
Sites Near the Most Promising Vehicle Fuel Markets	24
<b>4. Learning About Appropriate Technologies</b>	<b>26</b>
Anaerobic Digestion and Biogas Upgrading Technologies	26

Four Anaerobic Digester Designs	27
Biogas Upgrading Systems	28
Anaerobic Digestion and Biogas Upgrading in Europe	29
The BiogasMax Project: The European Union Supports Local RNG Initiatives	31
<b>5. Building RNG Projects for Economic Success</b>	<b>33</b>
The Most Profitable Projects To Date: Closed-Loop Systems	33
The Financial Benefits of Closed-Loop Projects	34
The Diversity of Closed-Loop Projects	35
Innovations in “Closing the Loop:” Putting the Pieces Together	37
Going Beyond “Closed-Loop Systems”: The Challenges	38
Profiles: Six Pioneering RNG Projects in the U.S.	39
<b>6. RNG Projects in a Broader Context</b>	<b>46</b>
Growing Private Sector Investments in Natural Gas Fleets and Fueling Infrastructure	46
Private Sector Construction of a Nationwide Natural Gas Highway	48
U.S. Department of Energy’s “Clean Cities Program”	49
State-level Renewable Portfolio Standards (RPS) and Low-Carbon Fuel Standards	50
Federal Incentives and Potential Incentives for RNG Producers	52
Federal Tax Credits for Expanding Use of Natural Gas Vehicles and Infrastructure	54
Additional Policy and Program Approaches	54
<b>Appendices</b>	
A. Summary of Key Questions in Assessing an RNG Project	57
B. References	63
C. Resources	66

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# FOREWORD

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We are pleased to offer this new Energy Vision Guide. It aims to empower local community citizens and stakeholders and other municipal, county, and state leaders across the U.S. to take advantage of an energy resource that can contribute immeasurably to both a healthier and better quality of life for their residents and a stronger economic future for our country. That resource is what Americans have for decades considered “waste.”

Every year, U.S. households, institutions, factories, and farms throw away so much garbage, yard trimmings, crop residues, and other organic wastes that, if turned into a source of energy, it could power almost every urban truck and bus fleet in the nation. This fuel, called “renewable natural gas” (RNG) or “biomethane” is interchangeable with fossil natural gas but has distinct advantages over it. Waste-based natural gas generates close to zero greenhouse gases on a well-to-wheels basis, produces almost no health-threatening particulate emissions, and its production requires no drilling! By throwing away all manner of organic wastes, Americans have actually been destroying a vast renewable fuel feedstock while also draining public budgets.

This Guide has two overall goals: The first is to clarify the distinct and significant contribution that waste-based natural gas can make in reducing U.S. dependence on oil – primarily for transportation fuel – that puts our country’s environmental, health and economic future at risk. The second goal is to provide communities with the steps they can take to turn their residential and commercial organic wastes, and possibly the organic wastes generated locally by farms, dairies, food processing plants, restaurants and other such sources, into a clean, secure, money-saving fuel solution.

RNG can be used to generate power, to heat homes or to fuel vehicles. Perhaps most important, it can significantly reduce our country’s dangerous dependence on oil. The largest share of the oil we use goes into transportation, and while solar, wind, geothermal and other renewable energy sources are available to generate power for residential, commercial, and industrial uses, renewable as well as fossil natural gas are among the few fuels that have the commercial potential to really slash our need for foreign oil today by replacing the use of diesel in fleets of medium- and heavy-duty trucks and buses. These fleets constitute less than five percent of all road vehicles. However, they consume about 23 percent of all on-road fuel, which equates to about 13 percent of total U.S. oil consumption.

How much diesel fuel could RNG displace? Estimates vary, but all are substantial. According to a study by QSS Group, funded by the U.S. Department of Energy in 1998, the practical RNG production potential from organic wastes was about 10 billion diesel gallon equivalents – more than 25 percent of the 38 billion gallons of diesel consumed a year. Two more recent studies, a 2011 report by the American Gas Foundation and a 2012 study by the American Petroleum Council, estimated more conservatively that RNG could replace 6.4 billion gallons (16%) of today’s diesel consumption, using commercially available technologies.

Both studies, however, indicated that it will be possible to make much more RNG in the future from wood wastes and crop residues with “gasification” technology (which is under development now) –

enabling RNG to displace about 50 percent of diesel consumption – or some 17.9 billion gallons a year. But gasification technology is not yet fully commercial, and this guide focuses on technologies that are widely used today.

RNG (as does fossil natural gas) offers communities greater fuel price stability and fuel security for the indispensable “workhorse” services provided by medium- and heavy-duty truck fleets that collect garbage and recyclables, that handle emergency response, maintain roadways and deliver products, as well as bus fleets that take children to school, commuters to work, residents to airports, etc. RNG also provides a secure fuel for the trucking sector that, within cities and on long-haul routes, transports a whopping 70% of the nation’s Gross Domestic Product in the form of raw materials and products from the farthest reaches of the country to every possible locality.

While the increased domestic production of oil in the last few years has given the U.S. a more stable supply, the environmental impacts of this expanded production, including the use of “fracking” techniques for tight oil, are not fully understood. Despite these advancements, as a global commodity, the price swings of oil and the growing risk of supply disruptions – as world competition grows for shrinking global petroleum supplies – still threaten the stability of cities and communities as well as this country’s national economic strength.

RNG provides communities with a clean-burning fuel that virtually eliminates the pollutants associated with diesel exhaust, including particulates (soot) that are linked to cardio-vascular disease, cancer and childhood asthma, and smog-forming nitrogen oxides. While RNG would also produce cleaner emissions if used in power plants, when it is used in bus and truck fleets, it is safeguarding urban and suburban residents from diesel emissions that especially threaten the health of children, the elderly, and those with respiratory conditions. In June 2012, diesel fumes were labeled a “known carcinogen” by the World Health Organization.

Both RNG and fossil natural gas can help communities meet their carbon emissions reductions goals, but RNG does so even more effectively. While fossil natural gas can reduce vehicle carbon dioxide (CO<sub>2</sub>) emissions by 20 to 25 percent compared to diesel fuel, RNG can reduce the carbon footprint of diesel by 88 percent or more. It is the lowest of all low-carbon fuels available for transportation, according to the life-cycle analyses of the California Air Resources Board and Argonne National Laboratory. When considering the production, transport and use of the fuel, RNG comes close to a zero carbon footprint and can even be carbon negative when produced from food waste.

We want to express our thanks to Brookhaven National Laboratory and the U.S. Department of Energy’s Clean Cities Program, whose support made preparation of this Guide possible, and to the companies and municipal officials whose projects are discussed in the Guide. We hope the information on their initiatives will inspire others to embrace a fuel option that can help move our country toward a sustainable transportation future.



Joanna D. Underwood  
*President, Energy Vision*

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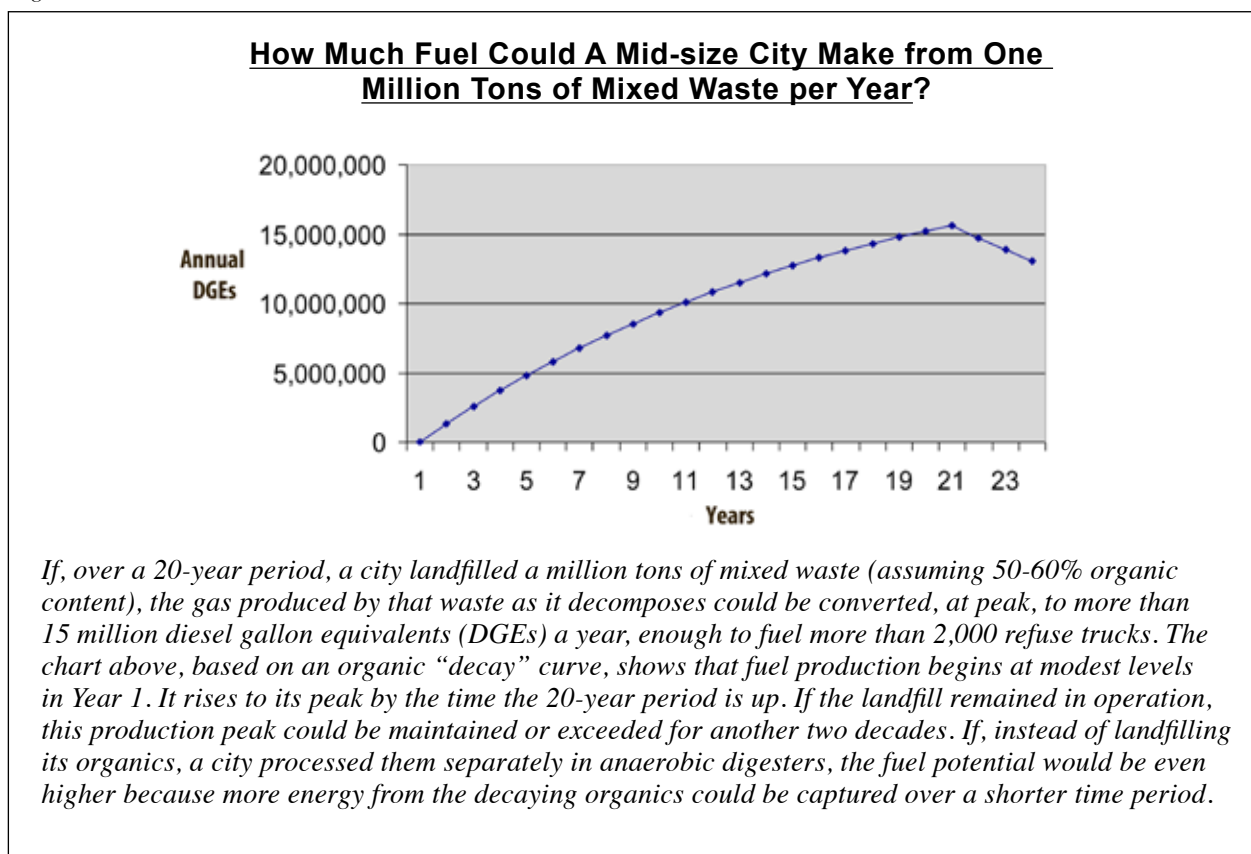
# CHAPTER 1

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## INTRODUCTION: WHY WRITE A GUIDE ON RENEWABLE NATURAL GAS FOR COMMUNITIES

Communities across the U.S. own abundant “raw materials” for making a home-grown transportation fuel supply. These largely overlooked assets are organic wastes that are daily carted to landfills, flushed down sewers, and stored on farms. To provide just one example, a typical mid-size U.S. city in the Midwest (60,000 or more) sends so much garbage and other organics to landfills that if this mass of material were deposited in the same place year after year and the gases emitted during decomposition were collected, they could be turned into enough fuel to power thousands of city trucks and buses<sup>1</sup> (See Figure 1 below).

Figure 1



The fuel produced by collecting and cleaning up gases emitted when organics decompose in airless environments is known as “renewable natural gas” (RNG) or “biomethane.” Although closely resembling



fossil natural gas and usable in all the same ways, RNG has a smaller carbon footprint – indeed, it is almost carbon neutral. Compared to diesel, it reduces carbon emissions along the path from production to consumption by 88 percent or more<sup>2</sup>, as noted in the Foreword. Other benefits that communities can realize by turning wastes into RNG fuel – especially for heavy-duty trucks and buses – include freedom from oil dependence, stable fuel prices, fuel security, lower waste-management and transportation-fuel costs, cleaner air, and improved public health, as well as economic development and job growth.<sup>3</sup>

Local elected officials, agencies, companies, institutions, and citizen groups are natural leaders in launching a potentially transformational shift of local truck and bus fleets to RNG. First, organic wastes are heavy and costly to transport, so it is most economical and efficient to convert them to fuel close to their point of generation. Second, cities, towns, and counties already own, lease, or contract with operators of trucks and buses that they can shift, or require to be shifted, to natural gas, the same technology capable of tapping into locally produced RNG. Third, centralized local fueling stations could potentially serve nearly two-thirds of all the trucks and buses in the U.S. – those that travel 50 miles or less from their home base. A large percentage of these vehicles, which number more than six million and consume about 13 billion fuel gallons a year, could eventually shift to RNG.<sup>4</sup>

This Guide aims to encourage the broad participation of communities across the U.S. to take action, as a small but growing number of cities have already done, to produce and use their own supplies of clean, renewable, low-carbon RNG fuel. The Guide’s specific objectives include the following:

- To alert towns, municipalities, and counties to their power as game-changers for sustainable transportation in their roles as managers of waste, owners of fleets, and contractors of services. Government entities need to collaborate with private sector partners to play this leadership role, but they are uniquely positioned to take crucial first steps in building local RNG projects.
- To promote and assist specific actions by community and private sector leaders to assess local RNG fuel potential, identify partnerships capable of realizing this potential, and assemble the components necessary for a successful project.
- To draw public and policy makers’ attention to a sustainable transportation solution that deserves broad support because of the many benefits it delivers to communities: lower waste management and/or transportation costs, fuel security and price stability, cleaner air, reduced public health risks, and creation of non-exportable new jobs.
- To encourage and assist in the exchange of ideas, information, and partnerships among innovative communities and companies.

## **Audiences for this Guide**

***Clean Cities Coalitions:*** A specific primary audience for this guide are the local communities and stakeholders represented by the nearly 100 Clean Cities Coalitions formed with the assistance of the U.S. Department of Energy (DOE) to deploy alternative, non-petroleum vehicle fuels and advanced propulsion technologies across the country. The Clean Cities program identified RNG as a promising fuel

option at the national workshop on renewable natural gas as a vehicle fuel, held on December 1, 2010, in Columbus, Ohio. The workshop was organized by Argonne National Laboratory, Clean Fuels Ohio and Energy Vision. Energy Vision wrote a report, *Waste to Wheels: Building for Success* based on the proceedings. This Guide follows up that introductory report on renewable natural gas, by describing a step-by-step approach for community leaders to follow in propelling RNG projects from concept to completion.

***City, Town, and County Officials:*** More generally, this Guide is written for leaders in cities, towns, and counties across the U.S. who are seeking to identify a realistic way to reduce the dependence of their fleets on high-carbon, oil-derived fuels and to move toward sustainable fuels in transportation. Local leaders can play one or more of several key roles: As *game-changers*, they have the power to turn the wastes they own into RNG fuel assets, to convert the vehicles they own into RNG consumers, or to require natural gas fuel to be used by the fleets with whom they contract. As *project partners*, they can provide one or more project components in a public-private partnership, such as shifting a public fleet to run on RNG fuel produced by a private sector company. As *advocates* they can collect and publicize information and ideas to encourage and support RNG projects undertaken by the private sector.

***State and Federal Policy Makers and Regulators:*** Both state and federal agencies regulate and monitor waste management and are key audiences for this guide. In addition, policymakers on both levels of government have broad opportunities to incentivize RNG fuel projects through grant programs as well as policies and incentives related to the shift to alternative fuels, organics recycling, greenhouse gas reduction, and other environmental practices.

***Private Sector Leaders:*** These may include officials in waste management and infrastructure development companies, in engineering and planning consulting firms, at wastewater treatment plants, food processing facilities, landfill owners/operators, biogas-related firms, and recycling and composting companies.

***Civic, Environmental, and Student Advocates:*** These are vital audiences for the guide since they can rally grassroots interest and support for community initiatives aimed at preserving the environment and contributing to a sustainable future. The research capabilities of advocates and students may help identify opportunities or contribute in other ways to local RNG projects.

## **What this Guide Contains**

***Chapter 2:*** This Guide is organized with an eye primarily to the strategic needs of municipal leaders and community groups that are seeking to mount, partner in, or assist a successful RNG fuel project. At the outset, RNG pioneers need to know what such a project looks like. What are its typical features? How many tasks, technologies, and partners may be required? Chapter 2 addresses these questions by identifying and describing the general components of RNG projects, from waste streams to vehicle markets.

***Chapter 3:*** Every RNG project is uniquely defined by local waste streams, project opportunities, regulatory frameworks, stakeholders, and incentives. A major challenge is how to target the best local

or regional project opportunity. This is the topic of Chapter 3. It is essential that communities create a broad and diverse action team to ensure consideration of multiple choices, technologies, and impacts in the search for the most attractive project opportunity.

**Chapter 4:** When it comes to choosing technologies, community leaders need not understand the complex details involved in implementing an RNG project. Instead, they can encourage and support engineers and other technical experts in their communities – including students in technical colleges – to gather and publicize some of the realistic paths to a successful local project. Here, communities can benefit from learning about the progress in both anaerobic digestion and RNG fuel development in Europe, as well as in the U.S., and tap into this knowledge for their own benefit. This is covered extensively in Chapter 4.

**Chapter 5:** Economics are the bottom line in framing and carrying out RNG fuel projects. As of the end of 2012 there were only 10 or so waste-to-vehicle fuel projects up and running in the U.S., but a careful look at six of them in Chapter 5 reveals a range of realistic pathways for building economically viable RNG projects that differ in scale, structure, waste source, and technology. The most important shared feature (for five out of the six) is a “closed-loop” business model, in which owners and managers of the waste that is turned into vehicle fuel also own or control the vehicle fleets that can consume and benefit directly from the fuel produced. This business model will likely remain dominant until RNG can be marketed “universally” (just as fossil natural gas is marketed today). This would require a major evolution involving pipeline access arrangements and, very likely, a special system of pricing RNG that rewards producers for its “green” attributes in a market where fossil natural gas may often cost less to produce than RNG.

**Chapter 6:** This chapter focuses on private sector programs and on government policies that support a shift to renewable natural gas vehicle fuel use. Although compared to diesel and gasoline RNG can provide significant savings, the current low cost of fossil natural gas makes it difficult for renewable natural gas to compete head-to-head without some level of up-front support/incentive for the inherent environmental, health, job development and waste reduction attributes of the fuel.

An **Appendix** to this guide contains organizational and published resources that may be useful in exploring local RNG initiatives.

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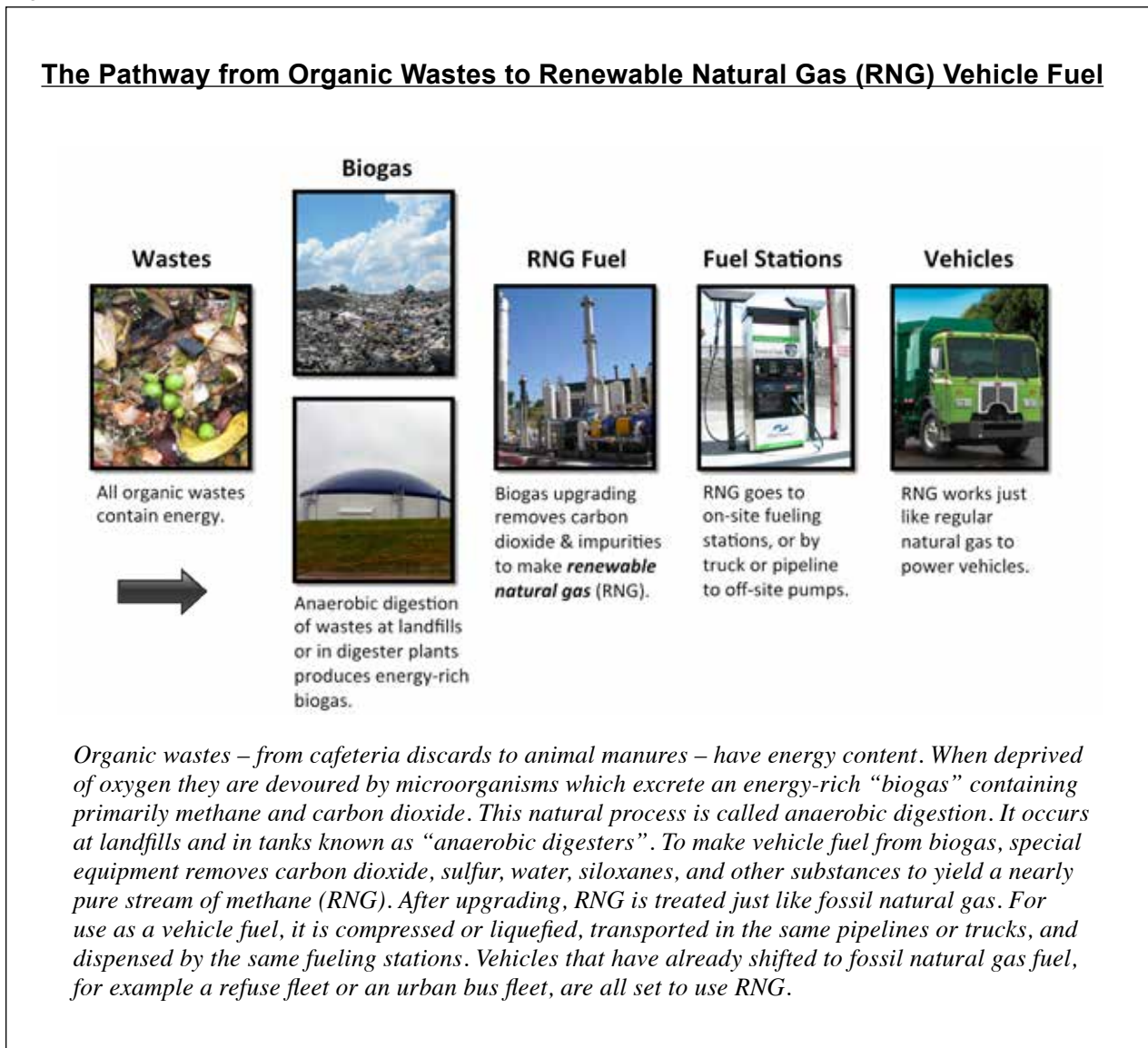
## CHAPTER 2

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# COMPONENTS OF AN RNG PROJECT: WASTE TO WHEELS

Thousands of communities across the U.S. can combine their organic wastes, other resources, and know-how to make renewable natural gas (RNG) vehicle fuel. *Figure 2* illustrates in simplified form, the basic project components along the waste-to-RNG fuel pathway.

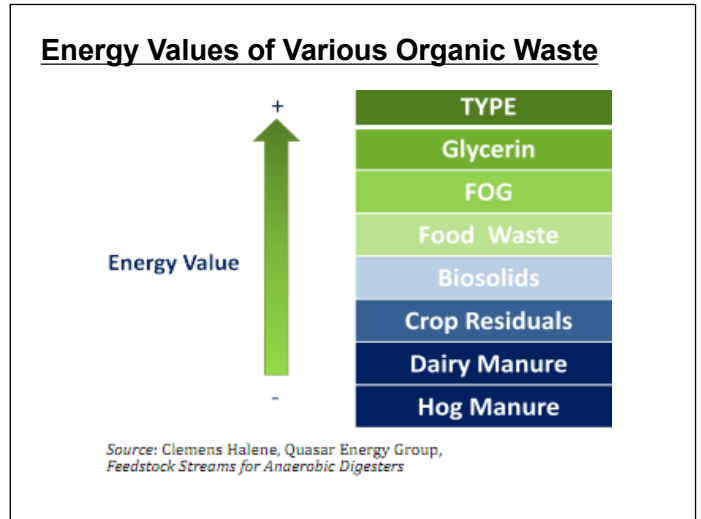
*Figure 2*



## Organic Wastes: The Starting Point

Organic wastes are numerous, diverse, and widespread in both urban and rural areas. The many organic materials that can serve as feedstocks for RNG production via anaerobic digestion include household garbage and yard clippings, human sewage and livestock manures, institutional food waste and food processing waste, numerous animal by-products including fats, oils, and grease (called FOG), and certain agricultural crops and residues. Fibrous and woody wastes are also potential feedstocks for RNG fuel production, but only when the advanced technologies needed to break them down – especially “gasification” – are commercially viable.<sup>1</sup>

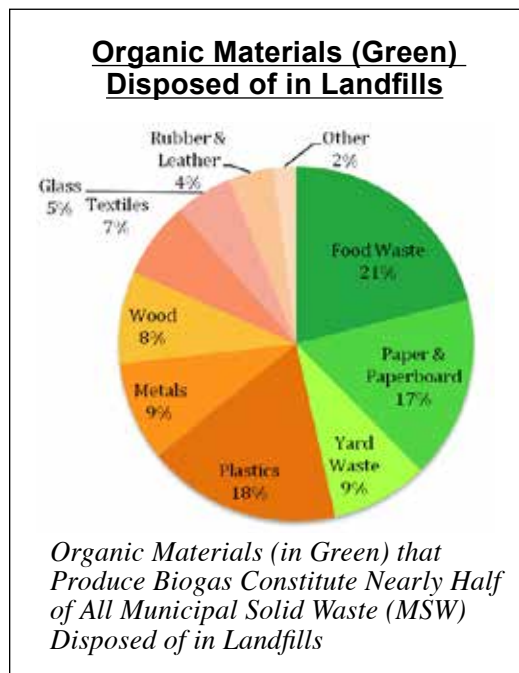
Chart 1



Each type of organic waste contains a different amount of energy, as shown in *Chart 1* above. Food wastes and FOG have high energy values whereas livestock manures and human sewage contain lower levels of usable energy. To increase biogas yield in an anaerobic digester, two or more waste types (such as high-strength food wastes and livestock manure) are often processed together.

## Producing Biogas from Waste: Anaerobic Digestion

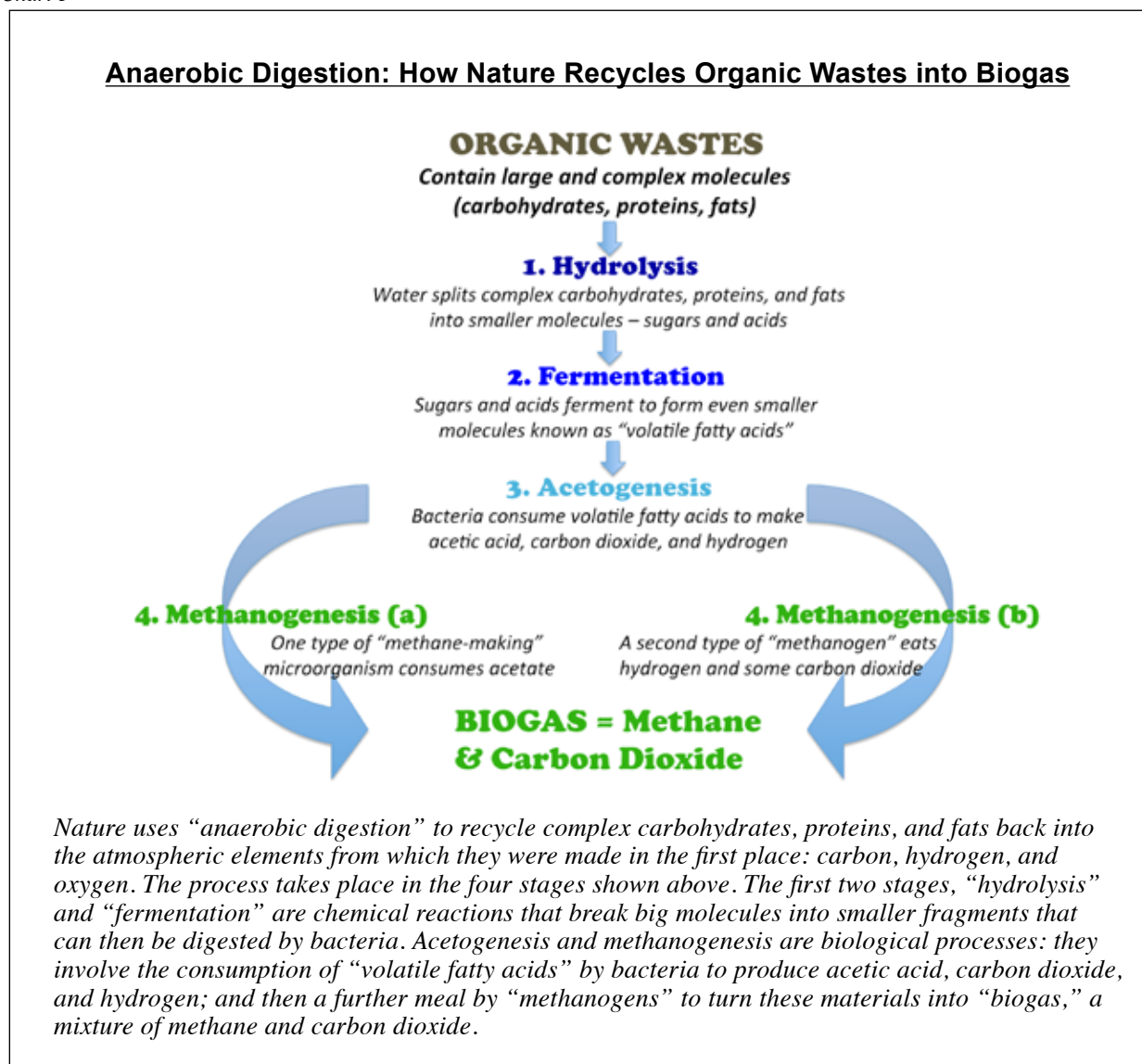
Chart 2



Anaerobic digestion is a naturally occurring process of organic decomposition that takes place when nonliving plant or animal (organic) matter is shut off from oxygen. Any site that amasses organic waste in an airless space – such as a landfill, wastewater treatment plant, or livestock manure lagoon – triggers the multiple sequential stages of anaerobic digestion, whose ultimate product is a mix of primarily methane and carbon dioxide, known as biogas, as illustrated in *Chart 3* on page 13. Moisture levels, temperature, and the nitrogen-to-carbon ratio are among the factors that determine the robustness, duration, and completeness of the process.<sup>2</sup> Sites that produce biogas by anaerobic digestion are potential locations for RNG fuel production. The large majority of existing sites are either landfills or wastewater treatment facilities, in which anaerobic digestion is occurring.

**Landfills:** No one advocates building new landfills solely as a source for RNG vehicle fuel. However, five significant

features of existing sanitary landfills – of which there are more than 1,750 across the U.S. (See *Figure 3* on page 14) – create attractive opportunities for this purpose:

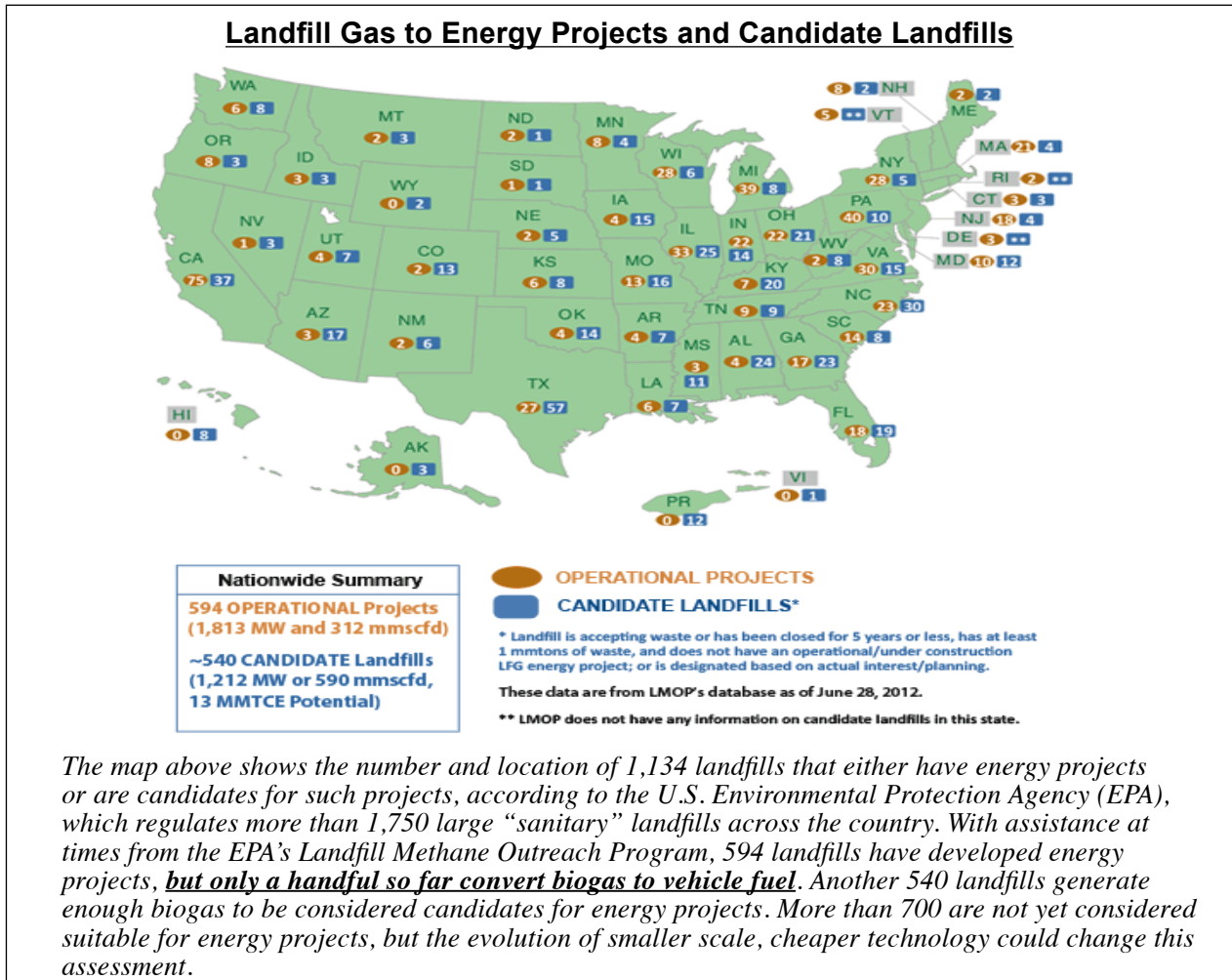


1. Biogas is produced day in and day out at landfills because between 40 to 50 percent of wastes that go into landfills consist of organic materials, especially food waste and paper (See *Chart 2* on page 12).<sup>3</sup>
2. Converting biogas to fuel prevents the wasteful process of “flaring,” or burning off the biogas to meet federal requirements prohibiting the escape of greenhouse gases. It is also a more efficient conversion of biogas to energy than making electricity using the typical on-site power generators without heat recovery.
3. Landfills come equipped with a gas collection system, storm and wastewater drains, access roads, truck scales and a security system, so the added investment needed to produce RNG is relatively small.
4. Landfills are fully permitted for waste management.
5. Landfills are the daily destination of hundreds of trucks that can refuel with this waste-based fuel.<sup>4</sup>

**Anaerobic Digesters:** Digesters are large air-tight vessels that confine organic wastes in environments where they break down to biogas, usually over about a month’s time. Of the more than 17,000



Figure 3



wastewater treatment plants across the U.S. about 1,300 have digesters, and of the thousands of farm and dairy operations, just 202 had digesters as of May 2013 (See Figure 4 on page 15), built primarily to manage biosolids and manures in a safe, odorless, and efficient manner.<sup>5</sup>



Most anaerobic digesters at wastewater treatment plants do not yet produce energy (they control odor and kill pathogens), while more than 90 percent of farm digesters use the biogas to generate electricity.<sup>6</sup> This leaves hundreds of additional wastewater plants and thousands of farms that could be digester sites in the future. Other host sites could include “transfer stations” where residential and commercial wastes are aggregated and materials can be recycled before the remainder is hauled to a landfill; and large composters that sometimes find it profitable to extract biogases from a portion of their waste stream through anaerobic digestion, without reducing the volume of soil and fertilizer products.

Much of the future potential for anaerobic digestion as a source of RNG vehicle fuel lies in the fact that a digester can be built at any location close to the generators of large quantities of organic waste. Therefore, any community or city willing to collect separate organic wastes from its residents and businesses – as feedstock for the digester – can implement an RNG vehicle fuel project.

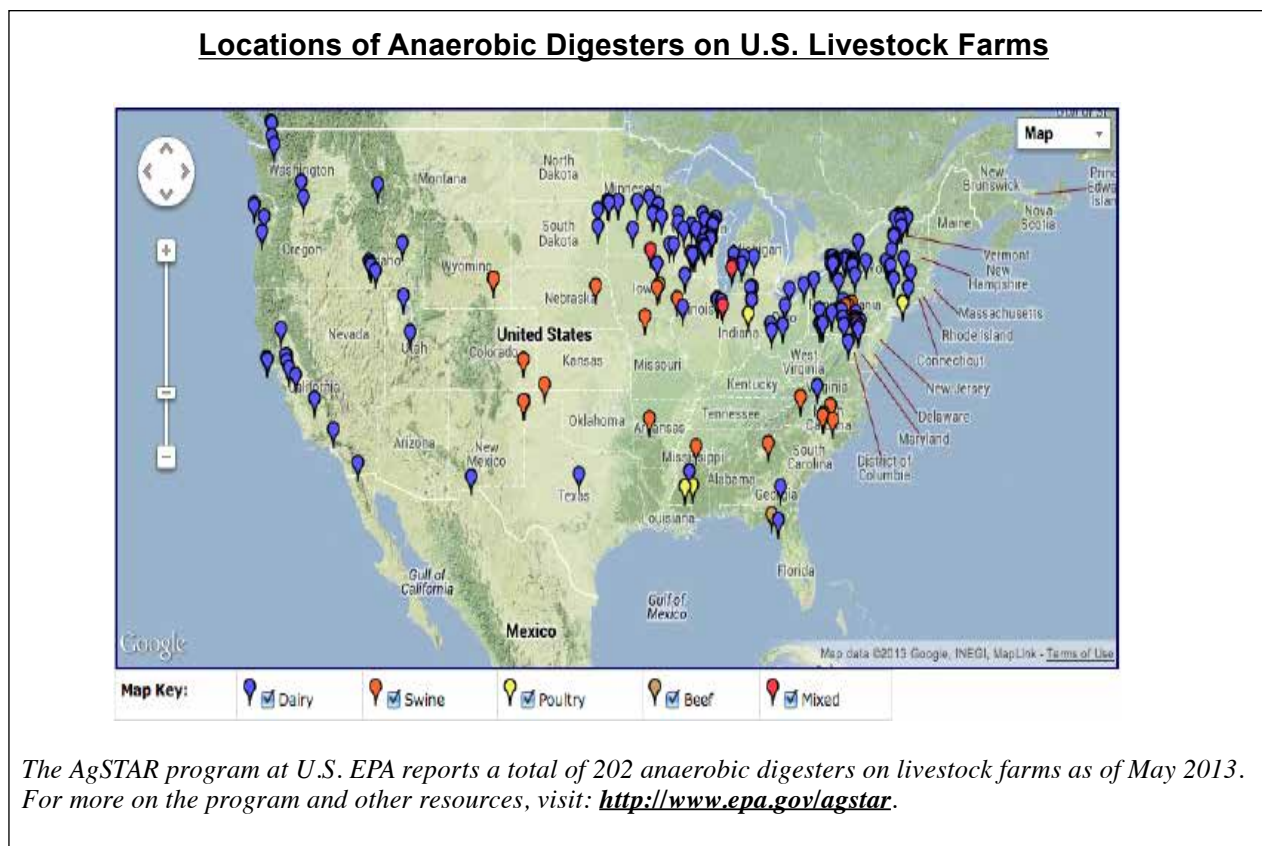


### Refining Biogas into RNG Fuel: Biogas Upgrading

The content of raw biogas collected at landfills or in digesters typically ranges from 45 to 65 percent methane, with carbon dioxide constituting most of the remainder. Raw biogas can power electricity generators or run boilers, but to make vehicle fuel the carbon dioxide, water and any trace chemicals, such as hydrogen sulfide, oxygen, ammonia, volatile organic compounds and siloxanes (depending on the composition of the waste stream) must be removed from the biogas.<sup>7</sup>

A number of proven commercial technologies can remove unwanted compounds and trace impurities, and can separate the carbon dioxide from the methane. Purified, the fuel is no longer called biogas but is known as “renewable natural gas” (RNG) or “biomethane”. It is interchangeable with fossil natural gas and can be mixed with it in any proportion.

Figure 4





## Delivering Fuel to Vehicle Markets



To deliver renewable natural gas (RNG) to vehicle markets it must first be compressed or liquefied. It can then either be dispensed at a refueling station built on the production site or delivered to a distant fueling station by pipeline (if compressed) or by truck (if compressed or liquefied). Mature technologies for gas compression, liquefaction, storage, and transport are in widespread use throughout the fossil natural gas industry, and these same methods work identically for RNG.

The obstacles to fuel delivery are primarily logistical and economic, and largely the same as those faced when considering a shift from diesel to fossil natural gas. For example, unless local natural gas fueling infrastructure is already in place, fuel delivery will require the construction of a new refueling station. Moreover, the cost to transport or store RNG from production site to the fueling station will depend on the relative proximity of the two facilities, the amount of fuel produced and a host of other variables. The primary major difference between an RNG vehicle project and a fossil gas (CNG/LNG) project is pricing: given the low cost of pipeline (fossil) natural gas, RNG rewards its producer only if the producer can use or sell the fuel directly to displace diesel or gasoline, which cost a lot more on a gallon-equivalent basis than RNG. On-site fueling stations and direct delivery of RNG to fuel users are two ways of ensuring that RNG gets an adequate price, as shown by several of the “closed loop” projects described in Chapter 5.

## Finding The Fleet Customers



Finally, the key to a successful RNG vehicle fuel production project is securing the vehicle market (via fuel “off-take” agreements), and building this component is in many ways the most challenging task of all because of the small but growing number of natural gas vehicles currently on U.S. roads. However, any community that has already invested in natural gas fueled vehicles – urban buses or refuse trucks, for example – has therefore built refueling facilities to deliver a gas rather than a

liquid fuel, and has the wherewithal to seek and entice other vehicle/fleet customers interested in making the transition to fully-sustainable RNG.

Most communities will have to identify local public and private fleet owners that could save money by using RNG in order to catalyze this transition. This can be accomplished either through purchase of new vehicles with natural gas engines or through the retrofitting or repowering of existing (either light- or heavy-duty) vehicles. Given the slightly higher cost of these vehicles, the best early candidates are high-volume fuel users such as medium- and heavy-duty buses and trucks. In the projects profiled in this Guide, a key pattern emerging in this new fuel industry is that the fuel user is often the same entity as the waste owner/generator, either a large company or a community that both manages wastes and owns or contracts with fleets.

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## CHAPTER 3

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### HOW TO TARGET A PROJECT OPPORTUNITY

A good RNG project site combines two basic features:

- *Plentiful and secure feedstocks* – a contractually guaranteed, long-term supply of biogas from an existing biogas production site, or the assurance of sufficient organic wastes (feedstock agreements) to justify the construction of an anaerobic digester for biogas production.
- *Captive or nearby fleet markets* – vehicles that will use the fuel produced (“off-take” agreements).

Steps to take to target such a site are the topic of this chapter.

#### **Project Leadership: Creating an “Action Group”**

In-depth technical expertise is a must for the selection, design, and development of RNG projects. Such expertise can be brought together by a committed municipal leadership team, by a single motivated agency, or by a citizen-created “action group.” (The box below illustrates the successful creation of a local “action group.”)

#### **New Jersey Work Group on Renewable Natural Gas: A Flexible “Action Group” Model for Other Communities**

In January 2011, Energy Vision and the Rutgers EcoComplex jointly founded the New Jersey Work Group on Renewable Natural Gas with this goal: to promote the development of RNG vehicle fuel to displace diesel across the state with some of the nation’s highest concentrations of population, wastes, traffic, and air pollution. The 30 Work Group members represented two dozen companies and consulting firms; local, state, and federal agencies; utilities; and universities and nonprofits.

Achievements included the following:

- Identifying more than two dozen sites in New Jersey where biogas is being produced, or could be, to make vehicle fuel.
- Defining diverse business models that communities can explore to convert landfill gas, wastewater treatment gas, food processing and other food wastes, and agricultural wastes and residues into RNG vehicle fuel.
- Contributing to the State’s Energy Master Plan the recommendation for state support of biomass-based energy projects in the state’s power and transportation sectors.



*N.J. Work Group on Renewable Natural Gas members at a monthly meeting in 2011 discussing possible N.J. sites for biogas production and vehicle markets.*

## Project Planning: Getting your Goals in Sight

The entity that takes the reins of leadership will be most successful by focusing on four basic planning steps: 1) formulating a strong public rationale for the initiative; 2) defining the “wasteshed” within which to search for project opportunities; 3) recruiting the necessary public and private sector expertise, and 4) specifying objectives and deadlines.

**1. Formulating a Public Rationale:** Wherever the initial impetus lies to explore an RNG initiative, formulating its goals in the context of national, state and /or local policy priorities can strengthen its case, its public image, and its ultimate impact. Five policy goals that figure prominently on the agendas at many levels of government today and the ways in which an RNG initiative supports them are summarized in *Chart 4* below.

*Chart 4*

<b><u>Policy Goals and How RNG Initiatives Support Them</u></b>	
<i>Independence from oil-derived fuel</i>	Every vehicle that shifts to RNG displaces 100% of its dependence on gasoline or diesel with a secure local fuel supply.
<i>Climate protection through greenhouse gas reduction</i>	RNG can reduce, by 88% or more, the greenhouse gases associated with diesel and gasoline production, transport, and consumption.
<i>Cleaner air</i>	Emissions from RNG-powered vehicles contain barely a trace of health-endangering soot, low levels of nitrogen oxides, and virtually no toxic contaminants compared to pre-2009 diesel emissions.
<i>Taxpayer savings, green jobs, and economic development</i>	Producing RNG vehicle fuel transforms a costly waste burden into a local asset, reduces local budgets for waste-management and fuel-purchasing, stimulates the evolution of local businesses, and creates jobs up and down the supply chain.
<i>National Deficit</i>	Every fleet that shifts from diesel to RNG fuel, reduces the dollars that the U.S. must send abroad to buy foreign oil for diesel – a drain of more than \$110 million a day.

**2. Identifying the Relevant “Wasteshed:”** The project-search arena for a municipal team or an RNG action group is the geographic area over which local wastes are collected and managed. Wasteshed boundaries may or may not coincide with political boundaries (See *Figure 5* on page 19). For example, the fate of a city’s mixed solid waste stream may depend on one or more businesses that encompass a multi-county network of transfer stations, recycling sites, and/or landfills – not to mention the export

of local waste to distant locations. Similarly, large wastewater treatment plants typically serve more than one town or municipality, and their arrangements for sludge disposal can involve distant incinerators or landfills.

Public waste management plans and regulations may apply to a county, a metro region, a whole state, or another territorial entity. Learning which agencies and companies have responsibilities that encompass the community most closely identified with the action group is a key first step in identifying essential project advisors, consultants, and partners.

**3. Recruiting Representative Expertise:** To be effective, an action group should draw its members from an array of public and private sector entities related to the management and beneficial use of diverse organic waste streams, including representatives from the following sectors:

- Waste management companies, landfill owners and operators, and wastewater treatment plant managers
- Organics recycling and composting agencies and companies
- Environmental groups and other stakeholders that are actively pursuing renewable energy and sustainability goals
- Agricultural researchers and educators who focus on manure handling and farm nutrient management
- Natural gas utilities and local distribution companies
- Public and private fleets that are exploring alternative vehicle fuels
- University researchers and labs specializing in alternative fuels, renewable energy, organics recycling, and related fields
- Consulting and engineering firms that provide services to local waste management companies, wastewater treatment plants, and farm-based or other digester projects
- State and federal agencies that have regulatory responsibilities for the handling of wastes, the protection of natural resources, the promotion of sustainability, and the shift away from oil-derived fuels to renewable fuels.

**4. Setting Objectives and Deadlines:** An RNG-focused action group exists for one purpose – to identify and pursue an opportunity to turn local wastes into vehicle fuel. Steps identified toward this goal can include a wide array of tasks from data collection and analysis to the building of project partnerships. Each action group will need to find a path suited to its own site-specific requirements.

Figure 5



At the outset, most groups will find it helpful to look in several broad directions to target a project opportunity. These include landfills and wastewater treatment plants that already produce biogas, other sites that manage large concentrations of organic wastes, and sites where an anaerobic digester might be built to process multiple sources of waste generated locally. In exploring all of these possibilities, a crucial consideration is identifying the fleets of medium- or heavy-duty buses and trucks that might be the most promising market for the fuel to be produced. The rest of this chapter discusses these possible target areas.

## **Project Siting: Landfills and Wastewater Treatment Plants That Already Produce Biogas**

The first places to look for a promising RNG fuel production site are landfills and wastewater treatment plants that already manage large quantities of municipal solid waste or sewage and produce significant amounts of biogas. Typically, public data and expertise exist to answer these questions: How many tons of waste are deposited each year at each landfill? How many tons of sludge (bio-solids) are managed each year by the wastewater treatment plants? This tonnage data, based on standard estimates used by engineers, indicates the potential biogas production. In addition, public files usually show how much biogas is already being used on site, for example, to make electricity; and how much is being flared. Several “starter” questions to ask about each public and private operating landfill and about each wastewater treatment plant with an anaerobic digester are listed below. These indicate several directions to explore in seeking a project opportunity, but may prove to be just the beginning of a search. Local technical experts need to be involved in reviewing, refining, and amending these questions and interpreting answers to them. More detailed information about landfills and wastewater treatment facilities can be collected by means of a survey or site visits.

### ***Questions to Ask about Landfills:***

- **Does the landfill flare biogas and, if so, how much?**  
*Flaring biogas destroys its energy potential. Instead, landfill operators can decide to use it to generate electricity or clean it up and use it to fuel vehicles.*
- **How long will the landfill be in operation? Is the landfill planning to expand in size and/or collect more biogas in the future?**  
*Landfills that increase waste intake (and therefore biogas production) have an opportunity to invest in RNG fuel production, even if all currently captured biogas is used to generate electric power.*
- **Does the landfill already have an electric power plant? If so, when will the power generators be replaced or gas development and power purchase contracts be renewed?**  
*When internal combustion engines are due for replacement or when contracts for electric power production and sale come up for renewal, there may be an opportunity to explore the introduction of an RNG fuel-production unit.*

**Questions to Ask about Wastewater Treatment Plants with Digesters:**

- **Does the wastewater treatment plant flare any of its biogas?**  
*Flaring biogas destroys its energy potential. Instead, the plant operator could decide to clean up the biogas and use it to fuel vehicles.*
- **Does the wastewater treatment plant use microturbines to generate electrical power for on-site use and/or sale into the grid?**  
*Biogas fuel that has been dried out and cleaned up for use in microturbines is also nearly ready to serve as vehicle fuel – if a “missing link” can be added: the technology needed to separate the methane from the carbon dioxide.*
- **Are high-strength organic wastes generated by factories, farms, or institutions located close to the wastewater treatment plant?**  
*Wastewater sludge is relatively low in energy content. A wastewater plant can boost biogas yield by adding high-strength wastes such as fats, oils, and grease or food wastes.*

In addition to quantifying biogas production potential at each site, it is important to know or estimate what percentage of this biogas is methane. The typical range is between 45 and 65 percent, with gas coming from landfills at the lower end and gas produced in digesters at the higher end. Then it is a straightforward process to estimate how much RNG vehicle fuel (measured as diesel gallon equivalents, DGEs) can be produced from a given amount of methane, through unit conversions and arithmetic. (See *Chart 5*).

*Chart 5*

**From Cubic Feet of Methane Gas to Diesel or Gasoline Gallon Equivalents**

To convert 1,000 standard cubic feet (scf) of methane to an equivalent number of diesel or gasoline gallons:

**Step 1** Express each quantity in terms of its approximate energy content, measured in British Thermal Units (BTUs):

- 1,000 scf of methane = 1,000,000 BTUs
- 1 gallon of diesel = 135,000 BTUs
- 1 gallon of gasoline = 115,000 BTUs

**Step 2** Divide the number of BTUs in the diesel or gasoline gallon into the number of BTUs in the quantity of methane to be converted.

- 1,000 scf of methane =  $1,000,000/135,000 = 7.4$  diesel gallons
- 1,000 scf of methane =  $1,000,000/115,000 = 8.7$  gasoline gallons

*NOTE:* A gasoline gallon contains 85% of the energy of a diesel gallon.

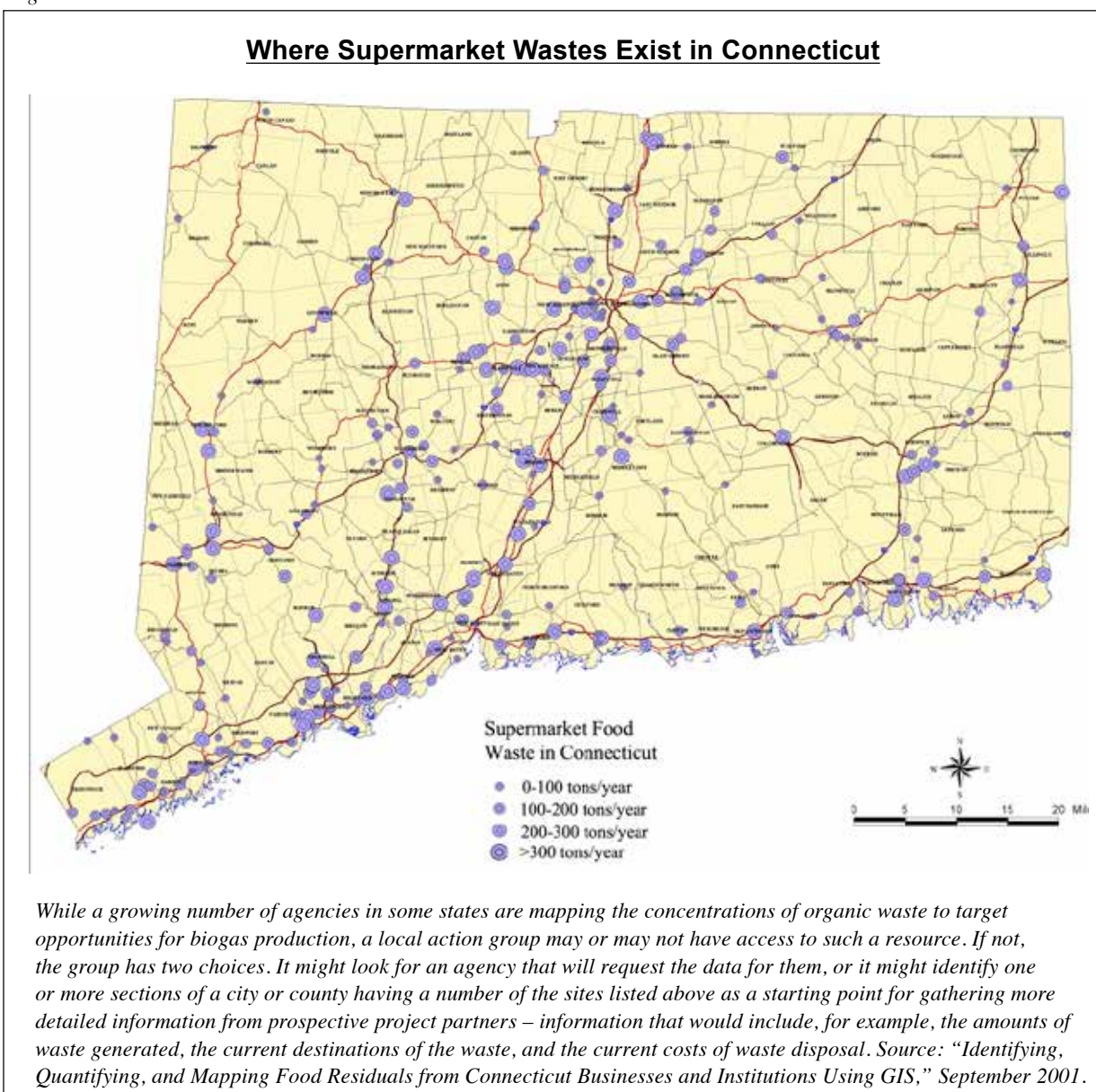


## Other Sites with Large Concentrations of Organic Waste

Landfills and wastewater treatment plants are by no means the only sources of organic waste substantial enough to justify the construction of an anaerobic digester for an RNG vehicle fuel project. Other large concentrations of organic waste may be located near sites that could accommodate a digester. How much waste is “enough” waste? There is no precise rule here, but the type of waste stream and technology to be used are more important than quantity of waste, assuming feedstock supplies meet a minimum threshold. But there really is no need for a rule. Local leaders need not evaluate every possible site. They can instead zero in on the biggest waste concentrations and consult with experts about project feasibility.

There is, however, a significant complexity for action groups committed to launching vehicle fuel projects based on building a new digester: RNG (plus CNG and LNG) vehicle markets may be too

Figure 6



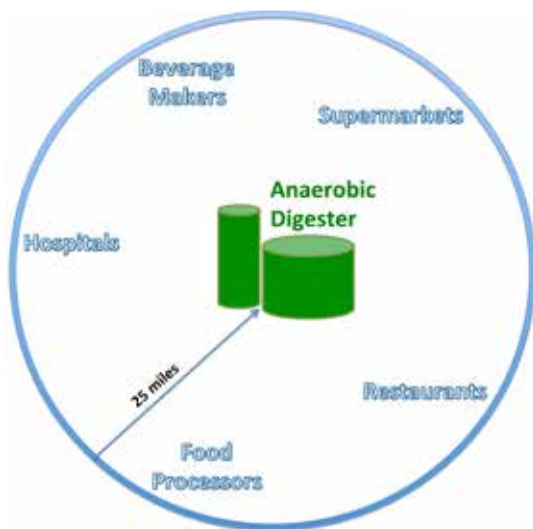
small, at least initially, to pay back the expense of the digester within a reasonable time period. Other sources of revenue will be needed until vehicle markets can be established. The most common formula here is to combine income from the generation and sale of electrical power with revenues from “tipping fees” paid by waste generators. Quantities of organic waste large enough to justify building an anaerobic digester are likely to be found at one or a combination of the following types of sites:<sup>2</sup>

- Large dairy farms and other large livestock operations
- Transfer stations, where refuse trucks deliver their loads, where recycling often occurs, and where tractor trailers pick up materials to haul to landfills
- Composting facilities, where an anaerobic digester might be added
- Food processing plants
- Public parks and open spaces that generate yard trimmings
- Terminal markets for fresh foods and large supermarkets
- Large concentrations of hotels and restaurants
- Resorts that attract large numbers of conventioners and tourists
- Universities, hospitals, and other institutions providing food services

A valuable tool for identifying significant sources of organic wastes in a given region is the mapping function of the Geographic Information Systems (GIS). See *Figure 6* (previous page) for an example of the kind of information this can produce.

### Sites for an Anaerobic Digester to Process Multiple Sources of Local Waste

*Figure 7*



A good rule of thumb in seeking a promising location for a digester project that depends on combining wastes from several sources is to locate a digester within a 25-mile radius of multiple waste producers. Hauling wastes to a digester from distances greater than this is unlikely to be economically viable. *Figure 7* to the left illustrates this strategy.

In general, sites located in states and regions having high “tipping fees” – disposal charges at landfills – will be the most promising for anaerobic digester RNG projects. Rates for landfill disposal establish a ceiling for the amount that an anaerobic digester project can charge the producers of organic waste for hauling away their residues. (See *Chart*

*6* on page 24). The higher these rates, the greater the potential revenue for project developers who are, in effect, in the business of turning what was considered waste into a saleable clean fuel.



Chart 6

<b>Examples of The Wide Variation of Landfilling Costs by State<sup>2</sup></b>	
States Reported on in <i>The State of Garbage in America</i> , 2010	Average cost per ton (“tipping fee” or “gate fee”) to place municipal solid waste (MSW) in a landfill
<b><u>Lowest Landfill Fees</u></b>	
Oklahoma	\$15-22
Alabama	\$25
Mississippi	\$25
Texas	27.8
New Mexico	\$28
<b><u>Highest Landfill Fees</u></b>	
Vermont	\$96
New Hampshire	\$77
Massachusetts	\$72
New Jersey	\$68
Iowa	\$64
<b><u>U.S. Average</u></b>	<b>\$44</b>

*Source: Rob van Haaren, Nickolas Themelis, Nora Goldstein, “The State of Garbage in America: 17th Nationwide Survey of MSW Management in the U.S. Biocycle Magazine, October 2010, p. 20. Only the lower 48 states are included in the survey.*

Projects that depend on multiple independent sources of organic wastes and that do not actually control waste generation or disposal (unlike landfills, wastewater treatment plants and livestock farms), confront a unique challenge: how to ensure the steady provision of waste to the digester once it is built. The planners for digester projects have two basic choices: getting a contract up front with waste generators that secures the wastes to be delivered to them, which can be difficult to do but greatly enhances a project’s attractiveness; or, if the economics permit, building the digester in an area rich in organic waste sources and counting on the risky *Field of Dreams* principal, “if you build it they will come,” although the latter approach will likely limit a project’s access to funding.

### **Sites Near the Most Promising Vehicle Fuel Markets**

A crucial step in selecting any biogas-to-fuel site is to choose a location convenient for fuel customers, especially trucks and buses that consume large quantities of fuel and therefore contribute more to project economics on a per-vehicle basis than passenger vehicles. In some cases, as with a landfill, wastewater treatment plant, dairy farm, transfer station, or compost facility, the site may already be a hub for trucks hauling wastes or products or both. Such fleets are a natural market for RNG producers because they can fuel up during their regular trips to and from the fuel production site.

Even sites having captive fleets, however, may need to find additional fuel users. Once built, a biogas facility produces a steady stream of biogas, 24/7. To the degree that it is destined for a vehicle market, RNG fuel must be sold on site, stored, transported by truck or pipeline, or diverted to other uses, non-stop.

Therefore, fuel production sites located close to major roads and highways have the best opportunities to attract customers using natural gas vehicles already in the area – as well as to encourage additional fleets to make the shift.

As noted in Chapter 2, communities that have already invested in shifting their own truck or bus fleets to natural gas technology or have mandated the use of natural gas by fleets providing services to them have taken a big step toward creating markets for RNG vehicle fuel. Since natural gas fuel distribution systems and refueling facilities are already in place, the location of these fleets and the opportunities for also fueling them from a particular possible production site are key to consider when selecting the sites.

It will be very important for an action group to reach out to local public and private fleets at the early stages of project exploration. Often fleet owners or managers remain unaware of the opportunities for an economically viable shift to natural gas technology, much less the potential of RNG fuel to displace fossil fuel altogether. Fleet owners should be represented in the action group and should be sought out in a number of sectors including public work fleets, private delivery fleets, buses, and other fleets headquartered near a potential fuel production site or using routes that pass close to it.

### **Community Concerns About New RNG Projects: Will They Approve?**

How can community leaders best address public concerns about a new RNG project? Remember: Any project that impacts the community (a shopping mall, road construction, new traffic lights, etc.) will likely generate some form of opposition from various stakeholder groups. Their concerns are often valid.

Some of the potential roadblocks to public approval for RNG development are:

1. Zoning restrictions, permitting and surveying
2. Concerns about increased noise and traffic
3. Fear of contamination from any new waste-related development
4. Public cost of project: new roads, water/sewer connections, other construction
5. Costs of required studies (environmental impact, feasibility, etc.) and consultants to oversee them
6. Costs of community outreach (mailings, canvassing, etc.) to educate about the facts and benefits
7. Organized and vocal opposition to project development
8. NIMBY

Some of the tools and techniques that can be useful for winning public support include:

1. Visit your local waste facilities! Talk with officials who may be involved in implementing a project.
2. Organize tours of existing digesters or landfill RNG facilities to help people understand these processes.
3. Set up meetings to present project proposals and especially to listen to public questions and concerns.
4. Use online media to educate (fact sheets and success stories), engage and create a forum for discussions.
5. Be proactive! The more people know ahead of time, the better.

If public requests for facts and transparency are met, the likelihood of public support for a project will be greatly increased. Be prepared!

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## CHAPTER 4

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### LEARN ABOUT APPROPRIATE TECHNOLOGIES

After targeting a promising RNG fuel production site, the next step for community leaders is to learn about the technologies that are available for biogas production and cleanup that might work at this site. They can recruit local engineers, researchers, and other experts to gather information and give visibility to various fuel-plant options. They can encourage local leaders and experts to travel to sites where RNG fuel is being produced to gain insight about multiple facets of project development that shape technology choices.

There are a variety of basic technologies available for making biogas in digesters and then upgrading it to vehicle fuel quality. Digesters for farms that convert manures into fuels that can generate electricity, heat buildings and/or power vehicles are well understood in the U.S., as are digester models that can be used at wastewater treatment plants. However, when it comes to digesters that process food wastes along with manures, biosolids, and/or other wastes, European countries greatly outpace the U.S. But a growing number of U.S. experts and vendors are working with European technologies and expertise, including several involved in the six U.S. profiles that form the basis of Chapter 5. Therefore it is important to consider European technologies and methodologies for converting wastes to fuel.

#### **Anaerobic Digestion and Biogas Upgrading Technologies**

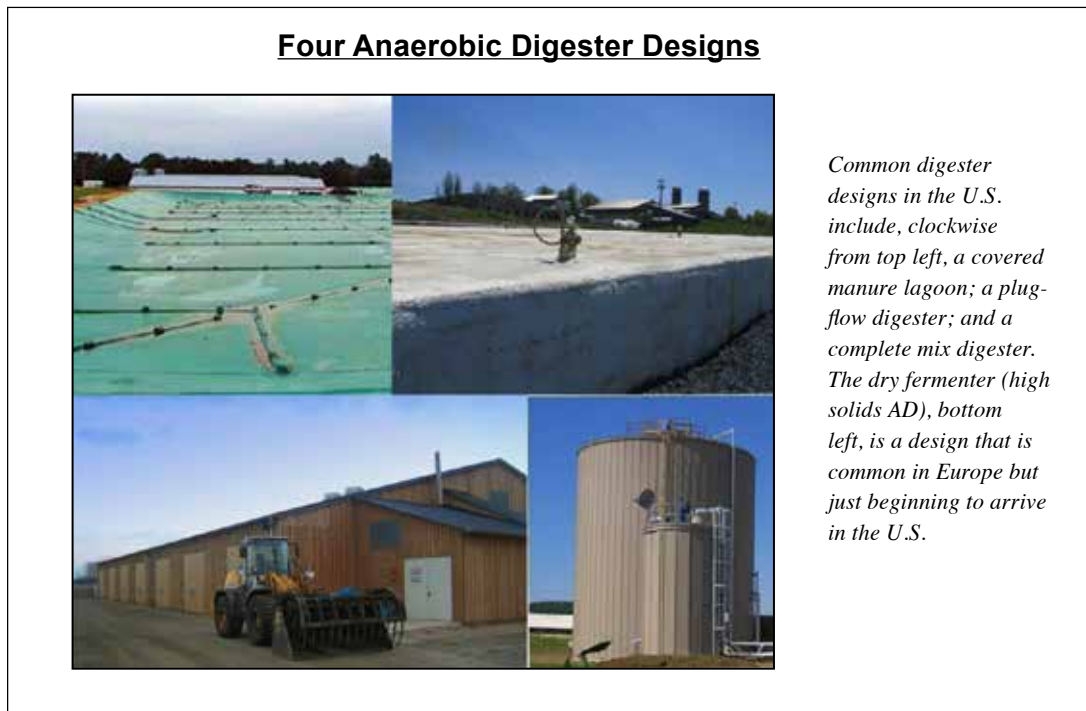
RNG vehicle fuel production projects depend on two “families” of commercial industrial technology: anaerobic digestion and biogas upgrading. As noted in the previous chapter, in the U.S. the simplest route to building a vehicle fuel production facility is to locate it where a landfill or a digester is already producing biogas. Otherwise, an “in-vessel” digester must be built specifically to process the type and quantity of waste available. No matter how the biogas is produced, the defining feature of an RNG vehicle fuel project is the choice of an “upgrading” technology to remove water, small amounts of unwanted gases, and impurities from raw biogas, and to separate the methane from carbon dioxide to achieve a nearly pure stream of methane.

#### **Four Anaerobic Digester Designs**

“Reactors” – large vessels in which organic materials break down and produce biogas – come in four basic designs, each of which is best suited for particular types of waste (liquid versus solid manure, wet versus dry food waste, etc). Each design has variations, and there are multiple vendors and engineering firms that can provide details about both reactors and related operational

components, such as the pre-treatment of waste. The four basic designs prevalent in the U.S. and Europe today are shown in *Figure 8* and discussed below:

*Figure 8*



**1. Anaerobic lagoon digesters for liquid manure waste on U.S. farms:** These are lined and covered earthen basins into which a farmer flushes manure waste and spray water and from which methane gas can be extracted as it collects under the lagoon cover. Lagoon wastes are not heated or mixed, so this technology is most effective in warmer climates where temperatures average above 59 degrees F (15 degrees C). Lagoon digesters have the advantages of low cost and ease of maintenance, but their large land requirements are one drawback.

**2. Plug-flow digesters for “high-solids” manure and other wastes:** Plug-flow digesters are typically built below the soil surface and process wastes that often contain 15 to 20 percent solids. Waste is fed in batches into the digester at one end of the tank, and each load travels for about three weeks’ through the digester like a “plug” – impelled by the injection of more batches of waste at the front end – to the exit. This simple design does not require the use of mechanical pumps to move the material. A modification of this design incorporates a mixer in a “two-stage process”. These systems typically operate at 95 to 105 degrees F (35 to 40 degrees C).

**3. Complete mix tank digesters for semi-liquid waste, or slurry of manures, sewage sludge, and other wastes including food waste:** Complete mix systems, common in both the U.S. and Europe, consist of a large insulated tank, or less commonly of two or three tanks in which one or more wastes are processed in a slurry state. Solids usually comprise three to six percent of the mix. The tank is heated, and the wastes are stirred to promote microbial action. Stirring can be

carried out by a rotating vertical shaft with attached blades, or by “impeller agitators” that move from top to bottom of the tank. Through this process, gas collects in a space at the top of the tank from which it is withdrawn. Complete mix digesters can operate effectively at two temperature ranges: a “medium” range (95 to 105 degrees F or 35 to 40 degrees C) and a “high” range (about 130 degrees F or 54 degrees C). The higher temperature reactors are used primarily to eliminate pathogens, such as those found in sewage sludge.

**4. Dry fermentation anaerobic digesters (or “fermenters”) for the organic fraction of municipal solid waste and other “dry” organics:** These digesters, also known as high solids anaerobic digesters, often resemble long garages that can process the organic fraction of municipal solid waste, which is typically comprised of 20 to 40 percent solid material. The decomposing waste moves through the system via “plug flow” but much less water is needed than for “wet” systems with the result that handling, mixing, and pre-treatment methods differ significantly. Because of the density of the mix and the proportion of inorganic to organic materials, the waste is “inoculated” with microbes to achieve sufficient decomposition as it travels through the digester.

## Biogas Upgrading Systems

The upgrading process for raw biogas begins with the removal of carbon dioxide (CO<sub>2</sub>), which is the main diluter of the biogas’s energy content. The goal of removing the CO<sub>2</sub> is to produce a biogas that is 90 to 99 percent pure methane. A number of road-tested commercial processes are available for this job, for use singly or, at times, in combination. Each method is also used to remove water, hydrogen sulfide, nitrogen, and/or siloxanes – which vary across biogas sources. There are four main approaches to biogas upgrading<sup>1</sup> (See *Figure 9* on page 29):

**1. Absorption** dissolves the carbon dioxide out of the raw biogas as it passes through a solvent-filled column under pressure. The solvent can be water, polyethylene glycol, or an amine solution, and the tank containing it is familiarly known as a “scrubber”.

**2. Pressure Swing Adsorption** uses activated carbon or a similar material that bonds with carbon dioxide molecules (but not with methane molecules) and removes them from the raw biogas.

**3. Membranes**, which are microscopic meshes, make use of the fact that carbon dioxide molecules are smaller than methane molecules, and as the biogases travel through the membranes the carbon dioxide and methane molecules are separated into two distinct streams.

**4. Cryogenic** upgrading lowers the temperature of the biogas stream to the point where the carbon dioxide condenses and can be separated out as a liquid stream.

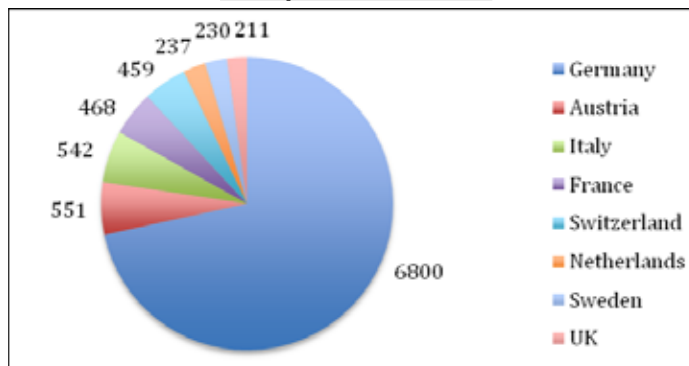
Figure 9



## Anaerobic Digestion and Biogas Upgrading in Europe

Figure 10

### Biogas-Energy-Production Sites in Eight European Countries



Source: International Energy Agency, Individual Country Reports on Task 37, 2011

According to the International Energy Agency, Task 37 studies, in the eight European countries with at least 200 organic waste processing facilities, there are nearly 9,500 sites that utilize biogas for electrical power generation.<sup>2</sup> This is approximately ten times the number of biogas-to-energy facilities in the U.S., for a nearly identical population (300 million plus), and a significantly smaller land mass.

Landfills account for less than half the biogas-to-energy production in the European Union as a whole, and far less than that in the eight countries shown in *Figure 10* on page 29, compared to the dominant role of landfills as biogas-to-energy sites in the U.S.

The most common biogas production sites in Europe consists of small farm digesters, such as those in Germany where farmers are well-compensated for producing small amounts of electricity. The development of larger-scale urban digesters is a newer trend promoted in the framework of European Union directives to member nations: 1) to divert 65 percent of organic wastes from landfills by 2016; 2) to raise the renewable content of energy consumption to 20 percent by 2020; and 3) to raise the renewable content of transport fuel to 10 percent by the same year. According to the European Union, upgraded biogas made from “biowaste” (especially organics separated from the municipal waste stream) could meet about one-third of the EU’s renewable fuels target in transportation.<sup>3</sup>

Biogas upgrading plants in Europe have recently soared in number from a handful at the turn of the 21st century to 159 sites in ten countries inventoried in 2011 by the International Energy Agency, Task 37. Just five countries account for 150 of these sites – Austria, Germany, The Netherlands, Sweden and Switzerland – as shown in *Figure 11* below. Feedstocks for these sites are shown in *Chart 7*. These plants include multiple examples of three of the four cleanup technologies described above, on different scales and under different operating conditions, a valuable source of information for U.S. communities. Only “cryogenic” technology (reducing the temperature of the biogas to liquefy it so it can be transported by trucks) that was developed more recently and has had more vigorous development in the U.S. is not broadly represented in Europe.

Figure 11

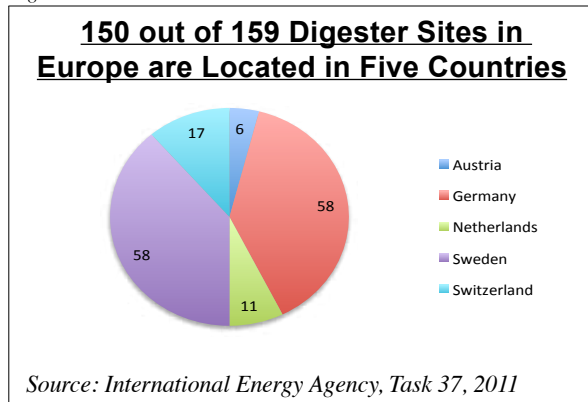
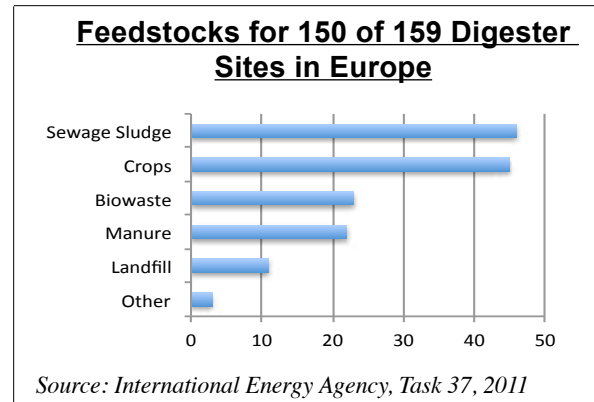


Chart 7



At 87 of the 150 European sites shown in *Figure 11* where biogas is upgraded, it is subsequently injected into the gas pipeline (for various end uses), while at 50 locations it is used on-site as a vehicle fuel.<sup>4</sup> (The end-use information for the other 12 sites is not provided.) Sweden has by far the most vehicle fuel projects in Europe and has carried local participation in developing partnerships furthest. Sweden also played a very significant role in a project called the “BiogasMax” project. It focused attention on the crucial role of local cities and regions in promoting biomethane technologies.



## The BiogasMax Project: The European Union Supports Local RNG Initiatives

To promote public awareness of the merits of RNG as a vehicle fuel and to support local RNG production initiatives, the European Union funded the BiogasMax project from 2006 to 2010. This project put a spotlight on the importance of local initiatives in the framework of European policy – especially the broad European commitment to a shift in transportation to low-carbon fuels, a shift aimed at replacing 20 percent of petroleum-based fuels in transportation with 5 to 8 percent biofuels, 10 percent natural gas, and 2 percent hydrogen.

Through BiogasMax, project funding, which ultimately totaled about 7.5 million euros or 9.2 million dollars, and technical assistance flowed from the “federal” to the “local” level for projects involving problem solving and project building. The projects that it supported had these major objectives:

- To demonstrate large-scale digestion and biogas upgrading initiatives to produce vehicle fuel from urban wastes and nearby rural waste.
- To expand natural gas-fueled public and private vehicle fleets, with emphasis on refuse trucks and buses.
- To prove the reliability, cost-effectiveness, and environmental and social benefits of RNG, more frequently referred to in Europe as “biomethane”, and
- To spread the knowledge gained to other European cities.

Localities participating in BiogasMax included: Bern, Switzerland; the Region of Goteberg and Stockholm, Sweden; the Lille metropolitan area in France, and Rome and the Lombardy region in Italy. The initiatives carried out under BiogasMax included a wide array of measures such as the examples sites below:



*In Bern*, a wastewater treatment plant was upgraded; spent methanol from a pharmaceutical company and other wastes were co-digested to increase biogas production. Seven new filling stations were built to dispense the RNG. A local energy company (ewb) campaigned extensively to persuade local public and private entities to shift 1,000 vehicles to use natural gas, not necessarily RNG. Bernmobil replaced 72 diesel buses (more than half of its bus fleet) with buses

fueled with the RNG. (Beginning in 2007, natural gas was no longer subject to government fuel taxes in Switzerland, while gasoline and diesel taxes were increased.)



*In Rome*, a biogas upgrading and collection facility was built at a regional landfill, producing RNG fuel to partially power 18 refuse trucks. In addition, a source-separated organic waste collection program involving 420,000 citizens was implemented, and plans were laid for building a new anaerobic digester and shifting the public buses to this new fuel.



*In Göteborg, Sweden*, with BiogasMax support, a regional RNG project was developed, and production of biomethane increased by 90 percent over a



three-year period. Nearby Falköping, a town with only 30,000 inhabitants, developed a small-scale biogas system using a combination of local waste streams. This system now provides the fuel for all the city’s buses as well as for a large number of municipal and company cars. This community produced a local “decision-making guide” that is available on the web at: <http://bit.ly/zkOEmt>.

BiogasMax facilitated outreach, information exchange and networking on RNG vehicle fuel projects across European cities and regions. Community leaders in the U.S. can use these European models to create their own integrated transportation, waste management, and sustainable energy systems.

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## CHAPTER 5

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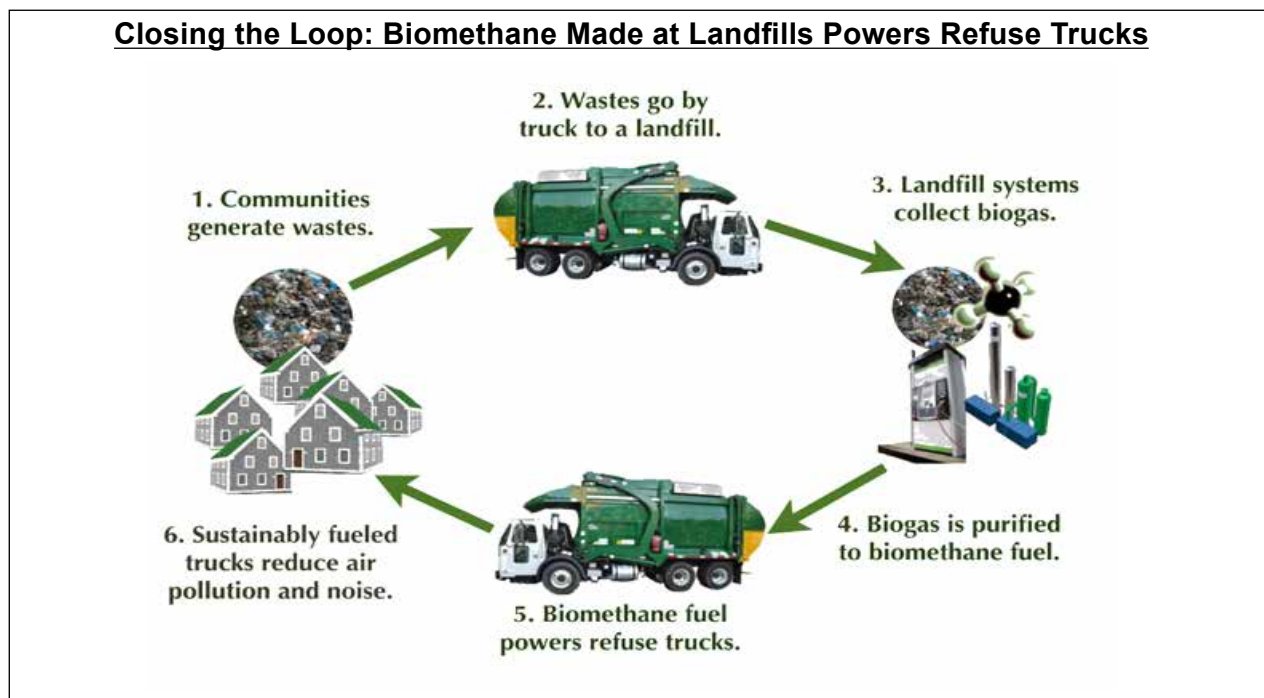
# DESIGNING RENEWABLE NATURAL GAS PROJECTS FOR ECONOMIC SUCCESS

No technical obstacles impede the broad development of vehicle fuel from organic wastes. The challenge for every waste-to-fuel project is to assemble the pieces economically and logistically to achieve direct financial, job-creation, clean energy, and environmental benefits. Examples of success in the U.S. are now beginning to emerge. As a group, they reveal a diversity of players, technologies, plant sizes, motivations and funding strategies. The experience of six of these pioneering initiatives, discussed in this chapter, suggests the wide range of projects a local community might undertake in partnership with the private sector.

### The Most Profitable Projects To Date: Closed-Loop Projects

Waste disposal costs can be significantly reduced by using a community's wastes as feedstock to produce fuel for its refuse trucks and other municipal vehicles. This "closed loop" system is ideal for managing landfill waste. As shown in *Figure 12\** an RNG-fueled truck delivers waste to a landfill, where it then

*Figure 12*



\* The best known example of this in North America is detailed in a recent EV Report: *The City of Surrey: Setting the Pace for Sustainable Transportation*. [http://www.energy-vision.org/pdf/ev\\_SR12\\_FINAL.pdf](http://www.energy-vision.org/pdf/ev_SR12_FINAL.pdf)

refuels using RNG collected at the same landfill. This process can be adapted for use at wastewater treatment plants, farms, and freestanding digesters as well. A community that maintains or has access to any of these facilities may be capable of developing its own closed-loop system.

### The Financial Benefits of Closed-Loop Fuel Projects

A project’s financial benefits largely depend on the ability to produce and/or sell RNG for significantly less than the retail price of traditional petroleum-based fuels. For example, in Dane County, Wisconsin, the publicly-owned Rodefild Landfill collaborated with public and private partners to expand a successful “closed-loop” RNG demonstration project. The county purchases the fuel from the landfill, at a significant discount to the local retail cost of diesel or gasoline, which it uses to power its small but growing municipal fleet of CNG vehicles.

As shown in *Chart 8* below, a gasoline gallon equivalent (GGE) of RNG is projected to cost \$2.37. Assuming that gasoline sells for \$3.27 per gallon, the RNG savings would be \$.90 per GGE. Including anticipated environmental credits, the project estimates that it can undersell gasoline by \$1.50-\$1.82 a gallon. If RNG displaces 70,000-90,000 gallons of gasoline per year, local officials anticipate a payback period of approximately four years.

Chart 8

<b>Production Cost of RNG at a Small-Scale Plant at Rodefild Landfill, Dane County, Wisconsin</b>	
<b>RNG Production/ Cost Areas</b>	<b>RNG Cost Per GGE*</b>
Acquisition of raw biogas	0
Operation and maintenance of RNG plant and fueling station	0.99
Finance charge	1.16
Subtotal (during finance period)	2.19
Federal excise tax	0.18
State excise tax	0
<b>Total</b>	<b>\$2.37</b>
<i>Value of potential carbon credits and tax credits**</i>	<i>(\$0.55-\$0.87)</i>
<i>Cost after credits, if applicable***</i>	<i>\$1.50 – \$1.82</i>

\* Cost of the RNG equivalent of one gallon of gasoline (GGE)

\*\* These include RIN credits that RNG can earn as an “advanced biofuel” under the EPA’s Renewable Fuel Standard (RFS2), as well as energy production tax credits (PTCs) and investment tax credits (ITCs) under the American Taxpayer Relief Act of 2012 (ATRA), for closed and open-loop biomass facilities and landfill gas facilities that have begun construction before January 1, 2014. Credits are available for biogas-to-CNG vehicle refueling (Sec. 402) and the Alternative Fuels Tax Credit (Sec. 412).

\*\*\*After the finance period, estimated to be four to five years, the cost could drop to well under \$1 per gallon equivalent, depending on the availability of credits and subsidies.

## Diversity of Closed-Loop Projects

Chart 9 (page 36) summarizes key information about a wide variety of “closed-loop” projects. Major differences among these projects include:

**Scale:** Economic successes are emerging at different scales. The production capacity of the largest of these RNG projects (at the Sauk Trail Hills Landfill, which produces six million diesel gallon equivalents annually) is approximately 80 times greater than that of the smallest (Janesville Wastewater Treatment Plant, which produces 63,750 diesel gallon equivalents).

**Production Sites and Feedstocks:** Four different production sites are included – landfill, farm, wastewater treatment plant, and ‘freestanding’ digester; feedstocks include organic materials buried in landfills, animal manures, human sewage, food processing wastes, and fats, oils and grease (FOG).

**Upgrading Technologies:** Five different biogas upgrading systems are in use by the six projects. The quasar, Linde, and Clean Energy projects have been designed “in house” using commercially available components. The system in use at the Sacramento Biodigester and Janesville Wastewater Plant (and Rodefeld) is from BioCNG, LLC, and is available as a turnkey “skid”. The fifth upgrading system is made by Greenlane Biogas, a popular design at European sites; but UTS, a U.S. engineering firm, has modified the system to include some additional features such as a fuel delivery system.

**Fuel Delivery Systems:** Four of the six sites on the list rely either entirely or mostly on on-site fueling. One of these sites, Fair Oaks Farm, also injects some of the RNG into the natural gas pipeline as a transport and storage system. The two largest sites, Altamont and Sauk Trail Hills Landfills, move the RNG to distant markets. Waste Management transports liquefied RNG from their Altamont facility to fueling stations hundreds of miles away; Clean Energy injects RNG from Sauk Trail Hills into the interstate pipeline to be sold as vehicle fuel and for other uses.

**Business Models and the Role of Fuel-Cost Savings (Revenues) in Paying Off the Initial Capital Investments:** Dane County’s Rodefeld project, the Waste Management-Linde plant at Altamont, and Fair Oaks Dairy, explicitly included fuel-cost savings in their business models (these projects all incorporate the “closed-loop” model as well – they control/own waste feedstocks and vehicle fleets). quasar energy group’s Columbus project and the Clean Energy-Republic Services project at Sauk Trail Hills are expected to include RNG fuel sales in the future, but anticipated revenues or savings from vehicle fuel sales did not influence their initial financing. One project, at the Janesville Wastewater Treatment Plant, found a way to introduce vehicle fuel production at low cost as part of a plant upgrade, but the vehicle component was secondary to power production.

Together, these six projects demonstrate that RNG vehicle projects come in many different shapes and sizes. But regardless of scale, location or feedstock, technical expertise will be essential in assessing the complexities surrounding a project’s feasibility and economic viability. By choosing the appropriate technology/model for a given community’s needs, RNG can reduce fuel expenses and generate additional revenue through the sale of excess RNG to nearby commercial and private fleets.

**Six “Closed-Loop” Success Stories of RNG Fuel Production**

<b>Site &amp; Feedstock</b>	<b>Site Owner = Fleet Owner / Contractor</b>	<b>Fuel Production (GGEs or DGEs / Year)</b>	<b>Vehicles Fueled</b>	<b>Plant Cost &amp; Fuel Savings / Year</b>	<b>Fuel-Cost Savings in Financial Plan?</b>	<b>Fuel Delivery Type</b>
<b>Janesville, WI</b> <i>Wastewater Plant</i> <ul style="list-style-type: none"> <li>• Sludge, food waste</li> </ul>	City of Janesville BioCNG, LLC	< 63,750 GGEs	40 municipal pickups and cars phased in over a decade	NA/ \$50,000/year <i>within a decade</i>	As “icing”	On-site
<b>Sacramento, CA</b> <i>Sacramento Biodigester</i> <ul style="list-style-type: none"> <li>• Food Waste</li> </ul>	CleanWorld Partners Atlas Disposal	700,000 DGEs	17 Atlas Disposal refuse trucks and several other municipal vehicles	\$13 million <i>(including a grant of \$6 million)</i> \$1.1 million/year	Yes	On-site
<b>Columbus, OH</b> <i>Central Digester</i> <ul style="list-style-type: none"> <li>• Sewage sludge</li> <li>• Food proc. waste</li> <li>• Fats, oil, grease</li> </ul>	quasar energy group	1.5 million DGEs	quasar vehicles & other local fleets	NA/NA	In the future	On-site
<b>Fair Oaks, IN</b> <i>Dairy Farm Digester</i> <ul style="list-style-type: none"> <li>• Manure</li> <li>• Ethanol thin stillage</li> </ul>	Fair Oaks, Inc. AMP Americas	1.5 million DGEs	42 long-haul milk delivery vehicles	\$18.5 million/NA \$2 million/year	Yes	On-site and pipeline
<b>Altamont, CA</b> <i>Private Landfill</i> <ul style="list-style-type: none"> <li>• Landfill gas</li> </ul>	Waste Management	2.5 million DGEs	300-400 WM refuse trucks	\$15.5 million/NA	Yes	Tanker truck
<b>Sauk Trail Hills, MI</b> <i>Private Landfill</i> <ul style="list-style-type: none"> <li>• Landfill gas</li> </ul>	Republic Services Clean Energy Fuels	6 million DGEs	Republic has an option on a percentage for truck fuel	NA/NA	In the future	Pipeline

The developers of the six projects profiled in this Guide have reported that they have another 90 projects “in the works.” BioCNG, LLC is in talks with a variety of waste owners/generators/ haulers across the country. Waste Management and Linde have been assessing the viability of another large-scale landfill-based RNG production site in Simi Valley, California. quasar energy group is building additional digesters in Ohio and New York and has several more in the conversation stage in other states. Clean Energy, as a developer of RNG projects that also produces and sells fossil natural gas, is moving away from a “closed-loop” model and toward a pipeline-distribution model, as described below. In short, a new industry is quickly emerging.

## **Innovations in “Closing the Loop:” Putting the Pieces Together**

Each of the six projects listed in *Chart 9* is innovative. These examples, discussed below, demonstrate that each RNG production plan will differ depending on waste source, fuel use, financing, site availability and project partners. To that end, each project has been tailored to address local needs and challenges, and users of this Guide may find these examples helpful.

***Janesville Wastewater Plant*** has demonstrated that RNG fuel production can be included on a small scale as an economically viable component of the expansion and improvement of a publicly-owned wastewater treatment plant. As was the case at Janesville, if sludge is already being digested for biogas production and utilized for power generation, additional upgrading and compression to achieve vehicle quality fuel can be inexpensive and straightforward. The facility now has the capacity to produce upwards of 60,000 GGE’s of RNG annually.

***Sacramento Biodigester*** has demonstrated the first municipal “closed-loop” RNG project in which residential and commercial food waste is hauled by a local waste company (Atlas Disposal), converted into RNG via anaerobic digestion, and then used to fuel those same vehicles that transport the organic waste. The digester facility, built and operated by CleanWorld Partners, has the capacity to handle up to 100 tons of organic waste per day, which will produce close to 700,000 DGE’s annually. This kind of municipal “closed-loop” model has the potential to be replicated in almost any mid-size city in the country.

***quasar energy group*** has successfully adapted European anaerobic digestion technology to extract biogas from sewage, food processing wastes, and fats, oil and grease (FOG). After capturing raw biogas for heating and power, and upgraded biogas (RNG) for vehicle fuel, the digested residual material is used for soil amendments, liquid fertilizer and livestock drinking water. (Greenhouse products may be added in the near future.) quasar has identified vehicle fuel as the most profitable long-term energy product and has built a fueling station on-site to begin dispensing fuel to company vehicles and other local fleet vehicles. For stand-alone digesters, “tipping fees” paid for waste disposal, like those paid at landfills, are a primary revenue source and are crucial to the financial success of any such project.

***Fair Oaks Dairy***, in partnership with Chicago-based AMP Americas, has completed its switch from diesel to RNG made from cow manure. This waste-based fuel is powering 42 long-haul milk delivery trucks that have been retrofitted with additional storage capacity for compressed RNG (R-CNG) fuel. These trucks haul 53 loads of raw milk daily from Northwestern Indiana to processing plants in Kentucky, Michigan and Tennessee. To supply the trucks, a European-designed upgrading plant feeds 1.8 million gallon equivalents of RNG per year to an on-site fueling station built by Clean Energy, and into the pipeline, so that RNG and CNG are used interchangeably at two separate fueling sites. Fuel savings on the trucks' combined daily travel of 30,000 miles, according to the company, are substantial.

***Waste Management and Linde*** formed a joint venture that demonstrates how a large-scale project at a major landfill can benefit both parties: the landfill owner (Waste Management) and RNG technology provider (Linde NA). This business model is also innovative in that it is crucially integrated with the commitment of Waste Management to shift a significant number of its trucks each year to run on fossil natural gas, so it was prepared in advance, especially in the State of California, to benefit from the RNG produced at Altamont. Linde processes enough of Altamont's landfill gas to fuel the majority of WM's refuse vehicles in 20 California communities.

***Clean Energy and Republic Services***, two other publicly traded companies, entered into an RNG recovery agreement that also taps in the energy riches of a large landfill in Michigan. Most of the processed landfill gas generated at Sauk Trail Hills is injected directly into the interstate natural gas pipeline, from which it is eventually withdrawn for home-heating, power generation and vehicle fuel use. Under the terms of the agreement, Republic Services, the landfill owner, has the option to withdraw a portion of the RNG for its refuse and recycling trucks at remote Clean Energy-built refueling stations.

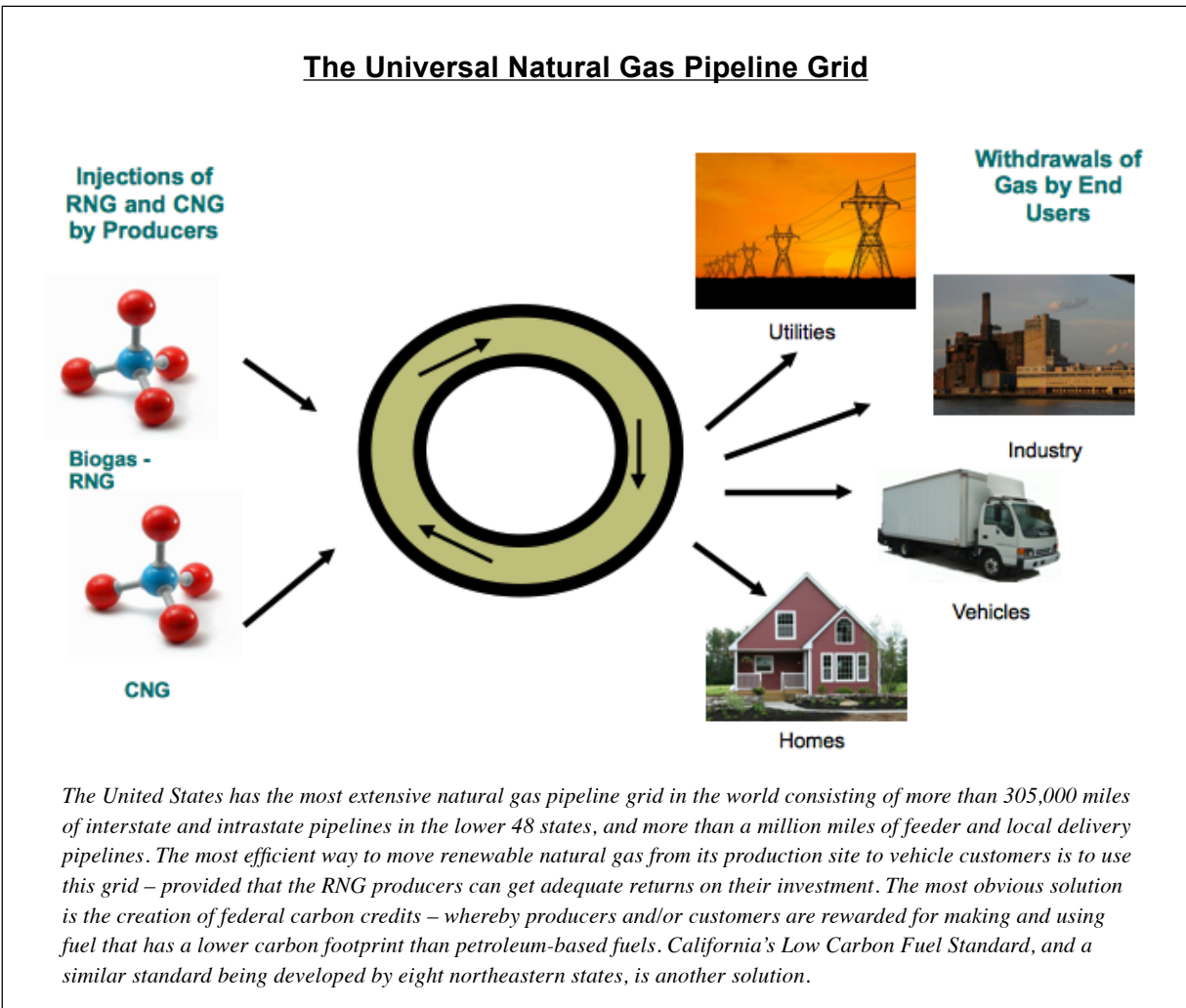
### **Going Beyond “Closed-Loop” Systems: The Challenges**

In the Clean Energy and Republic Services project at the Sauk Trail Hills Landfill, the closed-loop model plays a much smaller role than in any of the other projects profiled. Here, the primary strategy is to transport RNG through the existing pipeline grid (see *Figure 13* on page 39) to sites in many parts of the country. (The landfill owner, Republic Services, has a purchase option for the future.) The conundrum for Clean Energy and any other company that seeks to market RNG through the pipeline is this: since the market price of conventional pipeline gas is currently lower than the market cost of RNG, its renewable, carbon-free equivalent, some method must be found to capture greater value while still competitively pricing RNG.

Clean Energy's solution has been to create an “RNG 10” blend – 90 percent fossil natural gas and 10 percent RNG. The additional cost of the renewable portion of this blend is estimated at 10 cents per diesel gallon equivalent compared to the cost of pipeline gas. The customer will still realize a large savings of between \$0.90 and \$1.90 per gallon. Moreover, the blend proportions can be adjusted according to the carbon-reduction goals of the fleet customer.



Figure 13



## **Profiles: Six Pioneering Renewable Natural Gas Projects in the U.S.**

***In California, the world’s largest renewable liquefied natural gas (R-LNG) plant uses landfill gas to fuel 300-400 refuse trucks a day.***

**Altamont Landfill, Livermore, California:** Every day Waste Management (WM), the largest waste management company in North America, fuels 300 to 400 refuse and recycling trucks serving dozens of California communities with renewable natural gas (RNG) fuel made at its own Altamont Landfill near Oakland. There, WM has teamed up with Linde NA, an international industrial gas supplier, to build the world’s largest plant for turning biogas into a liquid form of RNG (R-LNG). The plant, which opened in 2009, produces 2.5 million diesel gallon equivalents (DGE) of R-LNG a year. The liquefied fuel goes by tanker truck to eight WM fueling stations in different parts of California to be dispensed along with





conventional natural gas (the two forms of the fuel are interchangeable). Using climate-friendly R-LNG, WM's trucks reduce annual carbon emissions by 30,000 tons.

Having already shifted hundreds of its California-based refuse and recycling trucks to natural gas technology, WM provides its own "market" for cost-effective RNG made at Altamont, where high levels of RNG production should continue for at least 30 years. This is a classic case of "closing the loop", where the owner of a valuable waste asset is a transportation-intensive company able to use the waste-based fuel. WM trucks using RNG from Altamont include one-third of those serving Alameda County where the landfill is located. WM plans to convert the remainder of the Alameda fleet to natural gas in coming years.

Linde and Waste Management financed \$14 million of the \$15.6 million dollar plant. Funding from three state agencies – California Air Resources Board, CalRecycle, and South Coast Air Quality Management District – filled the gap. The WM-Linde partnership reports economic success at Altamont. (These partners in a joint venture, called High Mountain Fuels, LLC, are exploring the opportunity for a second similar plant at the Simi Valley Landfill in Ventura County, CA.) Fuel-cost savings achieved by turning waste into RNG are further enhanced by the sale of "RINs" – a form of carbon-reduction credit that the Altamont facility earns as a producer of "advanced biofuel" under the U.S. EPA's Renewable Fuel Standard (RFS2).

*In Columbus, Ohio, the first in a new generation of anaerobic digesters converts municipal and commercial waste into electricity, vehicle fuel, and usable organic material.*

**Central Ohio Bioenergy Digester, Columbus, Ohio:** A fuel pump dispensing renewable compressed natural gas (R-CNG) at quasar energy group's Columbus digester has been fueling a dozen quasar vehicles since December 2011, along with 40 "drop-in" refuse trucks. The R-CNG,



marketed as "qng," is enough to fuel dozens more vehicles moving forward, especially as word spreads among local fleets that it sells for 25% less than diesel or gasoline. But Columbus is not quasar's only RNG fueling site: Its digesters in Wooster and Zanesville opened their own pumps in 2012. Moreover, a vehicle fueling component is planned for four more Ohio digesters currently under construction by quasar, one of a family of trucking-intensive businesses owned by the

Kurtz Brothers of Akron, Ohio, including landscaping, composting, and other “green” services. In total, company fleets consume five million gallons of fuel a year at a cost of more than \$16 million. These fleets can greatly reduce their operating costs and their carbon footprint by shifting as fully as possible over time to RNG produced at quasar digesters.

The Columbus digester extracts biogas from 50,000 wet tons per year of mixed municipal sewage sludge (in a partnership with the Solid Waste Authority of Central Ohio), food processing waste, and FOG (fats, oils, and grease). Like all digesters being designed and built by quasar in Ohio and other states, this one uses a “complete mix” system adapted from European technology. quasar supplied an in-house-designed biogas upgrading unit (using commercially available components) and built the fueling station. In addition to qng vehicle fuel, the plant produces electricity and pipeline quality gas. The digestate and liquids that remain are extracted and applied to farm fields.

“Tipping fees” – charges paid by waste generators for quasar’s “disposal” services – and the sale of electrical power are the plant’s two major sources of revenue. The anticipated payback period is four years. Going forward, however, quasar views the vehicle fuel market as top-priority for expansion because the value of RNG, when directly sold to displace retail diesel or gasoline, is higher than can be earned through the sale of biogas-based electricity or the injection of RNG into the pipeline. The plant benefited financially from a rebate given to private developers of renewable energy facilities, under the American Reinvestment and Recovery Act of 2009.

***The first long-haul fleet in the U.S. to be powered by renewable compressed natural gas (R-CNG) transports milk from Indiana to Kentucky, Michigan and Tennessee.***

**Fair Oaks Dairy, Fair Oaks, Indiana:** In late 2012, at one of the nation’s largest farms and a popular tourist destination, RNG made from cow manure began to power some of the heaviest trucks on the road. Daily, 42 “semis” equipped with Cummins Westport ISL G 8.9 liter and ISX12



G 11.9 liter natural gas engines – operated by Ruan Transportation Systems, one of the largest privately-held trucking companies in the U.S. – fuel up with farm-produced RNG to carry 53 truckloads of bulk milk, a total of 300,000 gallons, from northwestern Indiana to processing plants in Kentucky, Michigan and Tennessee. The trucks will travel 11 million miles a year. By displacing more than 1.8 million gallons of diesel with nearly

carbon-neutral R-CNG, they will greatly reduce both their direct emissions and their carbon footprint.

To make the RNG, Fair Oaks first produces biogas from the manure of 11,500 cows, and

“stillage” left-over from making ethanol in a “mixed plug-flow” anaerobic digester manufactured by the American company GHD (now DVO). The biogas then undergoes “water scrubbing” using Greenlane Biogas technology, which is employed in at least 30 operating systems in 13 countries. The upgraded biogas emerges from the scrubber as pipeline quality RNG ready for compression and vehicle fueling. Additional biogas powers a microturbine that supplies electricity to the farm.

One of the Fair Oaks project’s exciting innovations is the design of a fuel delivery system that has its on-site fueling next to a gas pipeline (running through the farm at a three-mile distance from the digester), with the use of the pipeline itself. When the digester produces more gas than the fueling station is dispensing to trucks, the excess can be “stored” in the pipeline. When fuel demand outpaces R-CNG supply, fossil natural gas from the pipeline can make up the difference. Before injection into the pipeline, the R-CNG is tested and any gas that does not meet pipeline standards is flared off. Clean Energy built the two fueling facilities which are owned by Renewable Dairy Fuels (AMP Americas).

The private financial partners in this project are Fair Oaks Dairy and AMP Americas. A \$750,000 grant for the fueling stations was provided under the federal American Recovery & Reinvestment Act of 2009 and administered through Clean Cities of Greater Indiana. A \$2 million grant from Indiana’s State Energy Program covered the cost of equipping 42 natural gas trucks with extra fuel storage capacity. The total all-in project cost was \$18.5 million. For a more detailed project summary, including more on the economics, the Innovation Center for U.S. Dairy profiled the project in a case study available on its website: <http://bit.ly/13QEBgX>.

*At a Wisconsin wastewater treatment plant, anaerobic digestion produces biogas used to generate electricity; some is refined into renewable natural gas (RNG) for vehicles.*

**Janesville Wastewater Treatment Plant, Janesville, Wisconsin:** A municipal facility serving a population of 30,000 is the first community-scale wastewater plant in the U.S.



to fuel public fleet vehicles with R-CNG made on-site. The plant began operations in June 2012 by fueling ten sedans and pickup trucks, with a planned future phase-in of more than 40 vehicles.

At the plant, digesters originally built in 1970 and upgraded twice since then (with parts from Envirex and other manufacturers) process

“biosolids” from two sources: those that settle out of the incoming sewage stream (during “primary treatment”) and those that are removed with the help of microorganisms (during “secondary treatment”). The plant has the capacity to process 20 million gallons per day

in both primary and secondary treatment, eventually returning a flow of clean water into the nearby Rock River. After leaving the sludge digesters, biogas travels through a “conditioning” process to clean it up and prepare it for feeding into microturbines that generate electricity for sale into the grid. The facility gets a feed-in price for its renewable energy that is more than double what the plant must pay for the energy it withdraws from the grid.

After its conditioning for the power plant, biogas is only one step away from being vehicle fuel: the carbon dioxide must be removed to raise the methane concentration to 90% or more. This is achieved through the use of small-scale technology successfully demonstrated at Rodefild Landfill in Dane County, Wisconsin by BioCNG, LLC, a subsidiary of Cornerstone Environmental Group, a national engineering firm, and Unison Solutions, an Iowa-based manufacturer.

Clever economic strategies made this project a “no-brainer” for Janesville. First, the RNG upgrading equipment and fueling station were included in a \$350,000 quote to be spent primarily for a 200 kilowatt microturbine to double the plant’s electricity production. Second, a new organic waste feed-in facility to process industrial organic wastes was purchased at the same time as the new microturbine to increase biogas production for making power and fuel, and to earn “tipping fees” paid to the plant by waste generators.

The City anticipates a short, two-year payback period for its overall \$750,000 investment in the microturbine, RNG plant and fueling station, feed-in equipment, and kits for retrofitting vehicles to use natural gas fuel. This is due to the extra \$300,000 per year it will earn from increased combined electricity sales and tipping fees. Further, the RNG fuel facility will displace increasing amounts of petroleum-based fuel, a benefit that will result in annual fuel-cost savings beginning at about \$8,000 and rising to more \$60,000 as the City acquires more and more natural gas vehicles.

***The first “closed loop” municipal project in which residential and commercial food waste is converted to R-CNG to power public and private refuse vehicles***



**Sacramento Biodigester, Sacramento, California:** Two Sacramento-area companies, CleanWorld and Atlas Disposal, have partnered to: 1) capture the energy content in more than 100 tons of pre- and post-consumer food waste per day from local restaurants, supermarkets, food processing companies and households; and 2) refuel 17 of Atlas Disposal’s Autocar CNG refuse trucks powered by Cummins Wesport ISL G 8.9 liter engines – in

addition to other natural gas vehicles at the public access refueling station built by California-based Clean Energy Fuels. This **carbon neutral renewable natural gas** is produced from raw biogas at the facility using BioCNG, LLC's patented biogas upgrading technology.\* The modular design of CleanWorld's digester as well as BioCNG, LLC's upgrading skid will enable the opportunity for future plant expansion as more food waste is collected and more vehicles convert to natural gas.

At present, the facility converts 25 tons of food waste from local food processors, restaurants and supermarkets into raw biogas, but expects to be at full capacity (100 tons/day) by the end of 2013. To achieve its green fleet goals, Atlas Disposal plans to replace its conventional diesel trucks with compressed natural gas models as older vehicles are retired. In doing so, the new trucks will be able to run on either pipeline gas or waste-derived fuel. Similar to other "stand alone" digesters, the remaining biosolids will be marketed and sold as organic soil co-products.

The project's environmental and economic benefits include the following:

- Diversion of nearly 40,000 tons of food waste from landfills annually
- Greenhouse gas reductions of 5,800 tons per year
- Yearly diesel displacement of more than 700,000 gallons
- The creation of 16 long-term green jobs
- Annual combined municipal tax revenue of more than \$1.1 million
- The sale of high value organic soil amendment co-products

The \$13 million project received more than \$6 million in grant funding from the California Energy Commission. Synergex, Five Star Bank, Central Valley Community Bank, CalRecycle and the California Office of the State Treasurer provided the additional financing.

*In Michigan, the first interstate pipeline transports renewable natural gas (RNG) for use as a vehicle fuel across the U.S.*



**Sauk Trail Hills Landfill, Canton, Michigan:** Clean Energy, the nation's largest supplier of natural gas to transportation, has built a biogas upgrading plant at the Sauk Trail Hills landfill to produce the equivalent of six million diesel gallons' worth of RNG annually. The RNG will be injected into the national pipeline grid for distribution to multiple customers, including natural gas utilities, power plants, and truck fleets.

\* A June 2012 life-cycle analysis by the California Air Resources Board (CARB) suggests that net-negative carbon emissions can be achieved by converting food waste to renewable natural gas through high solids digestion.

Sauk Trail Hills is owned by Republic Services/Allied, the country's second largest waste management company. As a project partner, Republic has the option of withdrawing a portion of the RNG when it uses Clean Energy stations to refuel its refuse and recycling trucks. This innovative model puts the "closed-loop" concept to work in a broad national framework, demonstrating how partnerships for producing and marketing RNG at private landfills can benefit from using the pipeline grid for distribution.

A key element of this new model is that Clean Energy can sell RNG from Sauk Trail Hills into the most attractive energy markets of the day. One good market is to sell it at a premium price to electric power generators seeking to meet the requirements of state-level Renewable Portfolio Standards. Another crucial feature is that RNG can be mixed flexibly with fossil natural gas to meet carbon reduction targets. Incentives identified by Clean Energy that will spur the marketing of RNG as a vehicle fuel include carbon credits established by California's Low Carbon Fuel Standard, and the "RIN" credits that can be earned by renewable vehicle fuel producers under the U.S. EPA's Renewable Fuel Standard. Clean Energy has also developed another large landfill-based RNG project at McCommas Bluff Landfill in Dallas, TX, which is due for expansion. From that site Clean Energy also ships RNG by pipeline for interstate sales.

Equity funding for the Sauk Trail Hills plant is provided by the Clean Energy Fuels Corporation, which is using a combination of European and American technologies in the plant itself. A \$12 million bond inducement resolution passed by Michigan's Strategic Fund will open the door to a tax-exempt bond offering to help finance the project. The project has also received a five-year property tax exemption for the Township of Canton, where the landfill is located; and it is exempt from Michigan sales tax.



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## CHAPTER 6

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### **RNG PROJECTS IN A BROADER CONTEXT: PRIVATE SECTOR PROGRAMS AND PUBLIC POLICIES THAT SUPPORT A SHIFT TO RENEWABLE NATURAL GAS VEHICLE FUEL**

RNG vehicle fuel projects are designed for municipalities, cities, or counties to achieve greenhouse gas emission reductions, oil independence, fuel cost savings, and a clean sustainable fuel supply on the local level. However, these projects can add momentum to – and benefit from – broader private sector initiatives and state and national policies that also support the shift of heavy-duty vehicles from diesel to low-carbon fuel alternatives.

Five examples are briefly outlined in this chapter: (1) the rapidly expanding private sector investments in natural gas-powered fleets and in natural gas fueling infrastructure, especially in the waste management industry; (2) the U.S. Department of Energy’s nationwide network of Clean Cities coalitions that are helping communities deploy non-petroleum vehicle fuels and technologies; (3) State-level Renewable Portfolio Standards (RPS) and Low Carbon Fuel Standards (LCFS); (4) Federal tax credits and carbon credits rewarding the producers of low-carbon and renewable fuels; and (5) Federal grants and tax incentives promoting the use of alternative fuel vehicles and construction of natural gas fueling infrastructure, as well as giving an added cost advantage to already low-cost natural gas fuel.

#### **1) Growing Private Sector Investments in Natural Gas Fleets and Fueling Infrastructure**

The use of natural gas as a vehicle fuel nearly doubled between 2003 and 2009, according to the Natural Gas Vehicle Association, from 175 to 300 million GGE’s. And although urban transit buses presently account for more than half of current natural gas consumption by vehicles, the fastest growing natural gas-powered fleets are those belonging to waste collection, recycling, and waste transfer companies.<sup>1</sup>

#### ***The Shift of Refuse and Recycling Fleets to Natural Gas***

Waste Management, the largest waste company in North America, is the industry leader in the use of natural gas waste collection and recycling trucks, with more than 1,400



out of its national fleet of 21,000 trucks powered by this cleaner fuel. WM is also a leader in the purchase of new natural gas trucks as well as in natural gas vehicle conversions.

WM unveiled its 1,000th natural gas truck in June 2011 in Carson, CA and estimated that these natural gas trucks were displacing eight million gallons of petroleum a year and eliminating 45,100

metric tons of greenhouse gas emissions.

Over the next decade or so, WM plans to shift most of its commercial diesel-fueled vehicles to natural gas through a “normal replacement schedule”. Right now, eight out of every 10 new trucks purchased by WM run on natural gas.

More than half of WM’s natural gas trucks are located in the State of California, where stringent vehicle emission control regulations have propelled the transition to natural gas fuel by bus and truck fleets that contract with public agencies, whether public or private owned. In addition, WM, in order to support the expansion of its burgeoning natural gas fleet, is having fueling stations built, which numbered close to 50 by mid-2013.

WM is also a leader, as noted in the Altamont project profile on pages 39-40, in the use of renewable natural gas, which it uses to power close to 400 of its refuse trucks. In a partnership agreement with Linde North America, an affiliate of the international gas processor, Linde AG, a biogas refining plant was built at WM’s Altamont Landfill in Livermore, CA, and the refined RNG fuel is transported in liquified form by tanker trucks to fueling stations used by WM trucks servicing 20 communities. A second landfill gas project may be developed at WM’s Simi Valley Landfill in Ventura County, CA.

Republic Services, another leading waste management company in the U.S., based in Phoenix, AZ is also embracing natural gas technology. Five hundred and fifty of its 16,000 refuse trucks are powered by natural gas. Republic has an agreement with Clean Energy, which is producing RNG from the biogases emitted at Republic’s Sauk Trail Hills Landfill in Michigan (See page 40), under which Republic will be able to use a portion of this fuel to power trucks in its fleet. Republic announced that it will convert all 140 of its refuse trucks serving Denver, CO to natural gas by the end of 2013.

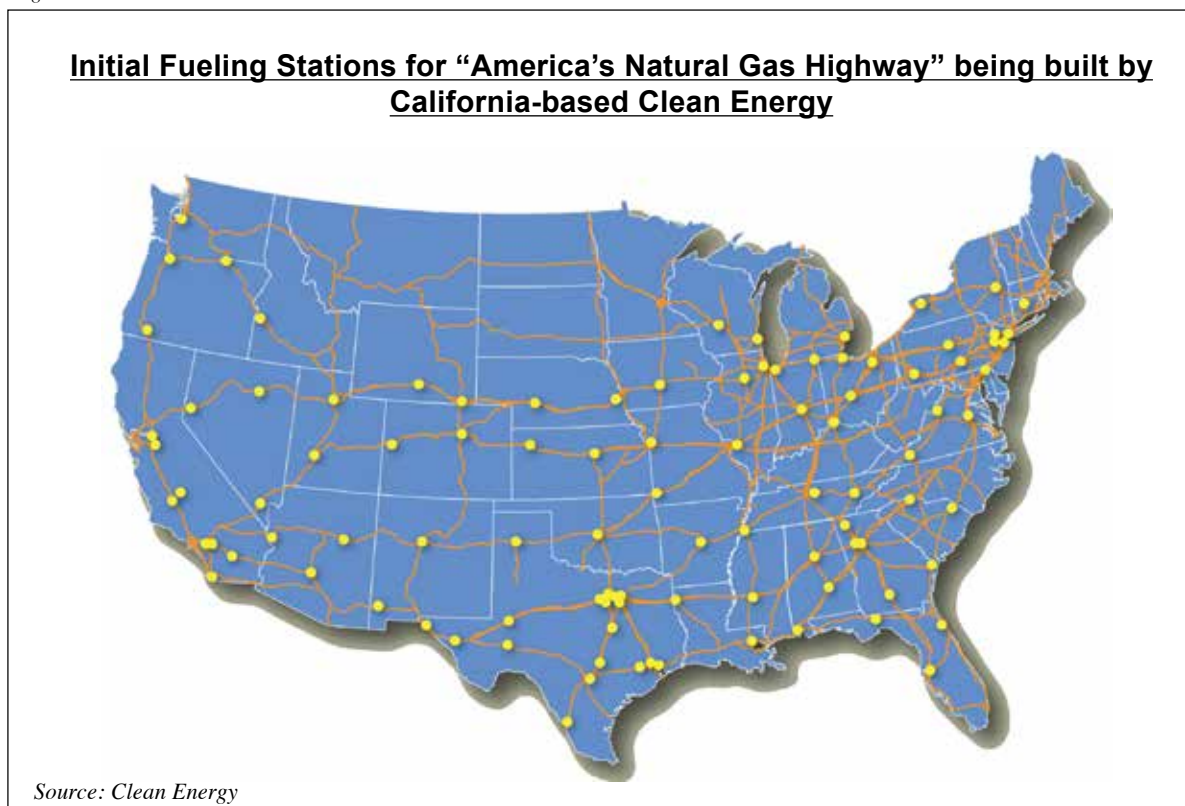


Many smaller private waste management and recycling companies across the U.S., are investing in natural gas trucks and infrastructure, contributing to the accelerating trend toward NGVs in the waste management sector. Some examples on the East Coast include Metropolitan Paper Recycling in NYC, Garofolo and Sons on Long Island, South Jersey Waste and Blue Diamond in New Jersey, Casella Waste Systems in Vermont, EnviroExpress in Connecticut, and Choice Environmental Services in Florida. Simultaneously, more and more truck manufacturers – including AutocarTruck, McNeilus, Mack, Freightliner, and Navistar are offering natural gas models. Thus, any community developing an RNG supply can do well, searching in this dynamically evolving industry for supporters and partners, especially for potential consumers of RNG fuel.

### ***Private Sector Construction of a Nationwide Natural Gas Highway***

Each community and each company that shifts its medium and heavy-duty trucks and buses to CNG, LNG, or RNG relies on new local refueling infrastructure. These natural gas fueling “islands” may soon be able to connect to “America’s Natural Gas Highway” (See *Figure 14*) being built by California-based Clean Energy, with a \$150 million investment by Chesapeake Power, to supply liquefied natural gas (LNG) fuel to tractor trailers that haul goods “coast-to-coast and border-to-border”.<sup>2</sup>

Figure 14



The first phase in developing the fueling infrastructure for cross-country trucking involves the construction of 150 fueling stations. Some of their locations are shown on *Figure 14*. Seventy of these were due to open in 33 states by the end of 2012, and the remainder are to be completed by the end of 2013. Many will be co-located at Pilot-Flying J Travel Centers that already serve “goods movement” trucking. Trucks using LNG can save up to \$1.50 per gallon, or even more, based on market conditions, to achieve a stunning one-year payback period for the added cost of a natural gas truck compared to its diesel counterpart. Several other companies have entered the CNG/LNG refueling infrastructure space, including giants like Shell.

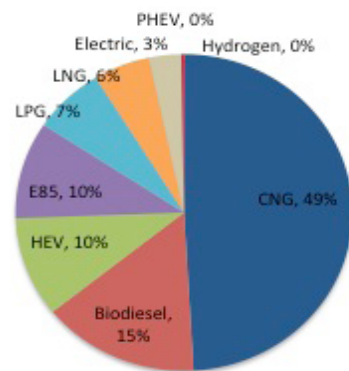
## 2) U.S. Department of Energy’s “Clean Cities Program:” A Network of Local Clean Cities Coalitions which Promote Reduced Petroleum Consumption in Transportation

Among the most effective players in assisting communities to make the transition to cleaner domestic transportation fuels are the Clean Cities coalitions, which are part of a program created in 1993 by the U.S. Department of Energy (DOE) to “accelerate [the] adoption of alternative fuels, advanced vehicle technologies, and smarter driving practices”. Clean Cities coalitions are public/private sector groups that must apply and be accepted as members in the DOE program. There are nearly 100 such coalitions at present located in 46 states and the District of Columbia. The DOE offers them technical assistance, training, and other support.<sup>3</sup>

Alternative fuels and technologies that are included in the Clean Cities portfolio are biofuels (including E85 ethanol, biodiesel, and renewable natural gas), electric vehicles, hybrids (and plug-in hybrids), propane, and natural gas, as well as idle reduction and other fuel economy initiatives that help to curb petroleum use. The shift of heavy-duty vehicles to

**Percentage and Volume of Petroleum Displaced by Alternative Fuels**  
Preliminary Data from US Dep’t of Energy Clean Cities Projects in 2012

Clean Cities Petroleum Reduction by Fuel/Technology	
Fuel	GGEs Reduced
CNG	190,570,476
Biodiesel	58,707,929
HEV	39,651,795
E85	38,418,388
LPG	26,729,781
LNG	21,181,139
Electric	11,922,263
PHEV	861,548
Hydrogen	138,140
<b>Total</b>	<b>388,181,458</b>



natural gas has been a significant focus of Clean Cities' initiatives. In 2012, (See *Chart 10* on page 49) Clean Cities coalition efforts helped to displace more than 385 million gasoline gallon equivalents (GGEs) of petroleum. Natural gas vehicles (CNG and LNG), many of them medium- and heavy-duty, accounted for 55 percent of the total petroleum displacement—more than 210 million GGEs. Stimulus funding committed under the American Recovery and Reinvestment Act of 2009 alone will put more than 3,500 more natural gas vehicles in service, through projects administered by Clean Cities coalitions. More than 59,000 natural gas vehicles are in operation today that were deployed as a direct result of Clean Cities efforts.

In 2010, Clean Cities, in collaboration with Argonne National Laboratory and Clean Fuels Ohio, convened a workshop which was attended by representatives of 29 Clean Cities coalitions. Energy Vision, part of the workshop planning group, then published a report, based on the workshop's proceedings, *Waste to Wheels: Building For Success*. This report is available via the Clean Cities and Energy Vision websites. Clean Cities: ([http://www1.eere.energy.gov/cleancities/waste\\_to\\_wheels.html](http://www1.eere.energy.gov/cleancities/waste_to_wheels.html)) Energy Vision: (<http://www.energy-vision.org/pdf/Waste2Wheels110608.pdf>)

### **3) State-Level Renewable Portfolio Standards (RPS) and Low-Carbon Fuel Standards**

“Renewable energy” is a term that almost always refers to the generation of electricity from sources like solar and wind. Yet even if the entire electric power sector were weaned from fossil fuels tomorrow, U.S. dependence on oil would be virtually unchanged, because only 1% of all electricity in the U.S. comes from oil-fired plants.<sup>4</sup> In the absence of mandatory federal standards for shifting to renewable power sources, 30 states have established their own requirements in the form of Renewable Portfolio Standards. (See *Figure 15* on page 51).

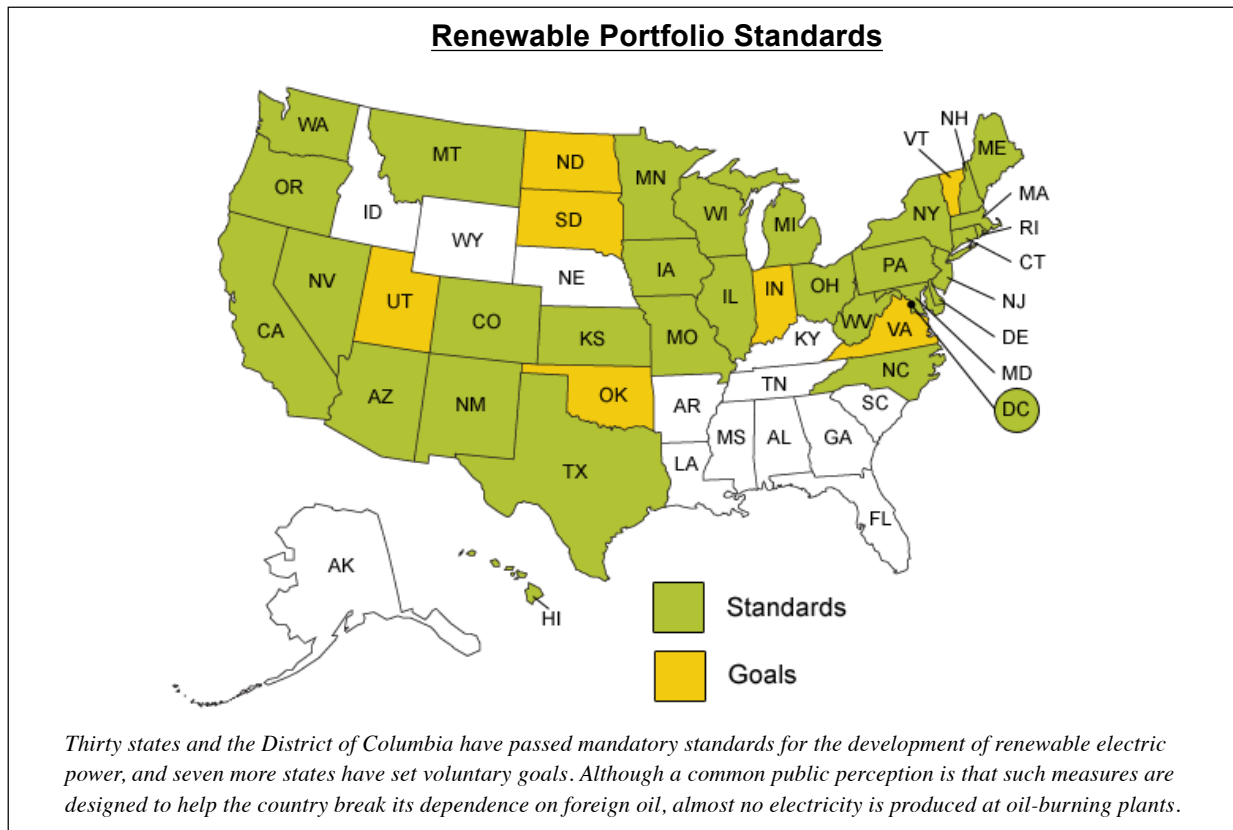
#### ***Renewable Portfolio Standards***

The RPS standards focus entirely on electric power generation. It might be possible to modify the standards to include targets for shifting to renewable transportation fuels, but this has not happened to date. The standards vary widely. For example, a 2011 California law requires utilities to obtain at least 33% of their electricity from clean, renewable sources by 2020; Ohio legislation requires electric distribution utilities and electric services companies to secure 12.5% of their energy from renewable sources by 2024 (and another 12.5% from “advanced” energy sources including nuclear, clean coal, and certain types of fuel cells by 2025). Each state's preferences and resource base — rather than general criteria such as measurable GHG reductions or production efficiency — determine which renewable power sources are encouraged and to what degree.

Since transportation fuels are not covered by state RPS programs, only biogas-based heat/power is rewarded, disadvantaging the use of biogas for vehicle fuel. One way to “level the playing field” would be to expand the definition of qualifying end uses for biogas-based energy to ensure that producers of biogas-based renewable vehicle fuel receive the same incentives



Figure 15



as producers of biogas-based renewable electricity under a state RPS. A bill to do just that was introduced in the State of Ohio, (SB 242 of 2011) and although it was not passed into law, this strategy could hold promise for communities in some states seeking to encourage RNG production from the processing of organic wastes at landfills or in anaerobic digesters.

### **Low Carbon Fuel Standards**

Perhaps a more promising approach to ratcheting down a state's dependence on high-carbon depletable diesel and gasoline fuels is to follow the leadership of California in developing a "low-carbon fuel standard" specifically for highway transportation. California adopted the first low-carbon fuel standard in the U.S. in 2009. This regulation focuses on refiners, importers, and blenders of petroleum-based fuels. It assigned each one a maximum level of GHG emissions per unit of energy sold and required a 10 percent reduction in these emissions by the year 2020. To meet this carbon-reduction goal (and interim benchmarks) regulated parties could either sell low-carbon fuels themselves or purchase credits from producers of low-carbon fuels such as RNG.

A similar standard is now under development for potential adoption by 11 states in the Northeast/Mid-Atlantic Region: Connecticut, Delaware, Maine, Maryland, Massachusetts, Pennsylvania, New Hampshire, New Jersey, New York, Rhode Island, and Vermont. If adopted, state by state, this standard would operate in a similar way to that in California to achieve a 5 to 15 percent reduction in the carbon intensity of fuels used for transportation in the region over the next 10 to 15 years.<sup>5</sup>



Low-carbon fuel standards depend on what is known as a “life-cycle analysis” of all fuels on the market. This provides comparable measures of the total amount of carbon emitted during all stages of each available fuel’s production, transportation, and combustion. A 2011 court case brought against the California standard by oil refiners and out-of-state corn growers claimed that the carbon values assigned to out-of-state fuels are unfair and violates the interstate commerce clause due to the extra transportation costs involved in getting their fuel to the State. Ultimately, a low-carbon fuel standard would make most sense at the federal level to avoid the confusion of inconsistent state regulations of the carbon intensity of vehicle fuels.

### ***Federal Tax Credits for Expanding Use of Natural Gas Vehicles and Infrastructure***

Under the Energy Policy Act of 2005, federal tax credits were provided that helped stimulate the shift of trucks and buses from diesel to natural gas fuel by covering up to 80 percent of the incremental costs of these new vehicles. A portion of the costs of new refueling infrastructure was also covered. (These incentives are scheduled to expire at the end of 2013.) Under the Transportation Equity Act that same year, an excise tax credit making alternative fuels cheaper than petroleum-derived fuels for retailers and non-profit fuel purchasers further encouraged the fuel shift. These credits, summarized in *Chart 11*, have made the shift to RNG possible in some communities, but their future existence remains uncertain given budget concerns.

## **4) Federal Incentives and Potential Incentives for RNG Producers**




In striking contrast to state-level low-carbon fuel standards, the federal approach for shifting the transportation sector to non-petroleum fuel is the U.S. EPA’s “renewable fuel standard” (RFS2) which went into effect in 2007 under the Energy Independence and Security Act.

### ***Federal Renewable Fuel Standard***

The RFS2 increased the volume of renewable fuels that had to be used in transportation in the U.S. from nine billion gallons a year in 2008 to 36 billion by 2022. The EPA, in order to monitor this mandated increase in renewable fuel production, required that every gallon of renewable fuel that was produced have a serial number attached to it. These “Renewable Identification Numbers, called “RINs,” had to be submitted to the EPA each year by petroleum producers/refiners (obligated parties) to prove that they have blended renewable fuel in the required amount. In the event that blending is not an option, obligated parties are also able to buy excess RINs — from refiners who used more renewable fuel than was required or “producers” of qualified renewable fuels — to comply with the Standard. The Altamont Landfill RNG project was the first to take advantage of this financial incentive, but other RNG producers have begun to benefit as well, including the Fair Oaks Dairy project. (The value of RINs tends to fluctuate between \$.70 and \$1.20.) The 36 billion gallons of “biofuels” to be sold annually by 2022 is to consist of at least 21 billion gallons of “advanced” biofuels which reduce GHG emissions by 50 percent or more, and up to 15 billion gallons of corn ethanol which is exempt from this requirement.<sup>6</sup>

One current Federal disconnect/barrier for producers of RNG vehicle fuel is that a production tax credit now exists under Section 45 of the U.S. Tax Code for producers of renewable electric power, including those that produce landfill gas for this purpose—but only for the production of electricity—not for vehicle use.<sup>7</sup> Expanding the credit of 1.5 cents per kwh to include producers of vehicle fuel from biogas would create a powerful incentive to develop RNG at both landfills and digesters.

Chart 11

<b><u>Federal Tax Credits that Can Support the Shift of Trucks and Buses to Natural Gas Fuel and RNG</u></b>		
<b><u>Vehicle Purchase (expired)</u></b>	<b><u>Fuel Station Installation</u></b>	<b><u>Alternative Fuel Excise Tax Credit</u></b>
		
<b>What Do the Credits Achieve?</b>		
They help to cover the incremental cost of a new natural gas vehicle, compared to a diesel or gasoline vehicle.	They help to cover the cost of installing a fueling station.	They incentivize the sale and use of non-petroleum vehicle fuel, including CNG and RNG.
<b>Who Gets the Benefits?</b>		
Tax-paying buyers: OR tax-liable sellers to Non-taxable buyers; OR a nontaxable buyer “claims” the credit from the tax-liable seller and this becomes part of the price negotiation.	The entity that puts a fueling property in service gets the credit. If this is a tax-exempt entity, the seller gets the credit and can sell at a lower price.	Retailers get the credit (reflected in the fuel price), except when buyers are tax exempt, in which case the buyer (e.g., a school district) gets a cash rebate.

In 2010, 2011 and 2012, both the House and the Senate introduced “nat gas” bills to extend these credit programs into 2013 and beyond, but they were not passed. Similar bills will likely be reintroduced, and communities pursuing a shift to CNG, LNG or RNG vehicle fuel have a great interest in supporting them.

### **Looking Toward the Future: Additional Policy and Program Approaches**

Revisiting and reformulating federal and state policies and programs to see how they can work best singly or together to facilitate market entry for new clean low-carbon renewable fuels -- of which renewable natural gas is currently the leading contender for the medium- and heavy-duty transportation sector -- is vital as this country charts its course into the 21<sup>st</sup> century.

There are several other ways in which tax codes and federal or state guidelines could promote the production and use of renewable natural gas that deserve consideration:

- Modification of the U.S. tax code (IRS Investment Tax Credit) to include vehicle fuel. It currently only provides an incentive for producing biogas for power generation.
- Setting uniform federal or state specifications for gas acceptance, and of a national quality standard for RNG injected into the pipeline system would make it easier for RNG project developers to negotiate agreements with gas utilities, saving considerable time and cost.
- Creating state-level mechanisms (such as “feed-in tariffs” established in Canada and Germany), that provide an assured price for RNG. Without these market incentives, suppliers of RNG, having higher fuel production costs than those for CNG or LNG, find it uneconomic to put their product into a pipeline for vehicle fuel use where it is sold at the low CNG rate.
- Instituting uniform federal permitting, regulations, and tax exempt status for RNG would greatly enhance the success and speed at which projects are built. The tax classification and permitting processes for biomethane production now vary by state. When combined with these regulatory hurdles, access to gas pipelines, a crucial component of more widespread adoption of biomethane as a vehicle fuel, can be difficult and/or prohibitively expensive.
- Developing state and federal programs or various market mechanisms that incorporate a fuel’s carbon intensity in its price would incentivize the production and use of biomethane. Cheap and abundant natural gas has made it difficult for RNG and other renewable technologies to compete. The current glut of fossil natural gas, and the near all-time low price of this fuel, mean that the economics of RNG (and renewables in general) are less attractive without accounting for its inherent environmental and health attributes.

## Project Team

Joanna D. Underwood is the founder and President of Energy Vision, a New York-based, national non-profit organization, founded in 2006, to conduct research and outreach promoting a swift transition in this country to a sustainable transportation future. Energy Vision's focus has been on educating public and private sector leaders about the alternative fuels and vehicle technologies that can best reduce this country's reliance on oil-derived fuels and pave the way to use of renewable, and pollution- and carbon-free fuels. Ms. Underwood, in launching Energy Vision, drew on research that she guided for over a decade examining alternative vehicle fuels. This research produced nine alternative fuel-related studies which became widely used references in the U.S. and elsewhere. It included three reports, entitled *Bus Futures* (2000) and *Greening Garbage Trucks* (2003 and 2006), which were the first analyses published of fuel options for these sectors.

Working with government officials and private sector experts, EV has sponsored training workshops for municipal leaders and refuse and recycling fleet operators in New York and New Jersey, and EV's outreach played a major catalytic role in inspiring the first municipal and private conversions of refuse fleets on the East Coast from diesel to natural gas. EV's research since 2009 has explored the potential of biomethane fuel, the renewable and carbon-neutral "twin" of fossil natural gas, for heavy-duty fleets, and EV participated in the planning of the Department of Energy's Clean Cities workshop (held in Columbus Ohio in 2010) introducing Clean Cities affiliates to renewable natural gas (RNG). Ms. Underwood has overseen the publication of four RNG reports, including the follow-up report, *Waste to Wheels*, summarizing the workshop content and providing a broader introduction to this fuel.

Research lead by Ms. Underwood has received numerous leadership awards, including one from the US Environmental Protection Agency and two from EPA Region 2. She has participated in many business and government leadership forums, served on advisory boards for the US Department of Energy, participated during the Clinton Administration in the President's Council on Sustainable Development, served as a board member of The Rocky Mountain Institute and was a member of the New York State Energy Research and Development Authority Board from 1979 to 1999. Ms. Underwood currently serves on the Boards of the Robert Sterling Clark Foundation in New York City and the Clean Vehicle Education Foundation in Washington DC. In 2000 and 2002, Ms. Underwood was chosen by The Earth Times as one of the world's 100 most influential voices in the global environmental movement.

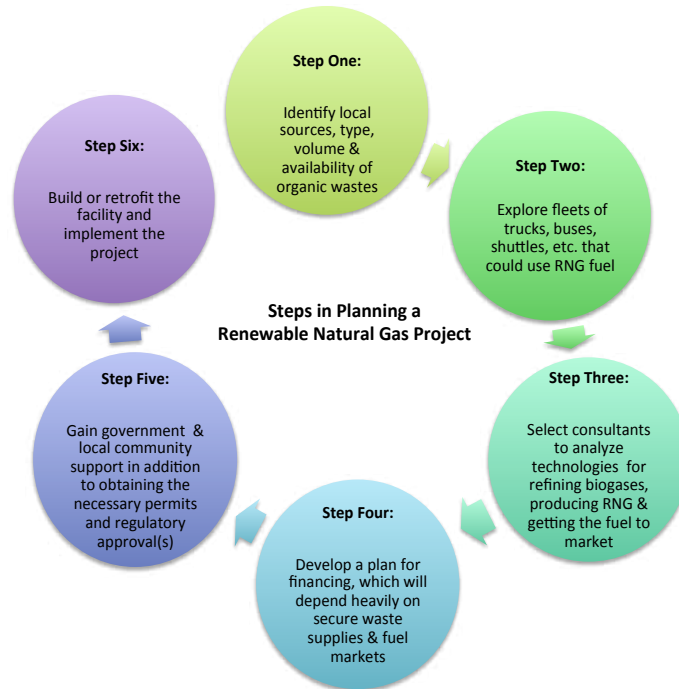
Matthew P. Tomich joined Energy Vision in January 2012 as Research and Outreach Associate. His focus has been on the advancement of renewable natural gas (also known as RNG or biomethane) as a vehicle fuel. His work has included research on major RNG initiatives in the U.S. in the dairy, landfill gas, wastewater treatment plant, residential and commercial waste sectors – research published on Energy Vision's website and various other media outlets. Tomich has also co-authored three Energy Vision reports: *Renewable Natural Gas: The Solution to a Major Transportation Challenge* (2012); *Tomorrow's Trucks: Leaving the Era of Oil Behind* (2013); and *Turning Waste into Vehicle Fuel: A Step-by-Step Guide for Communities* (2013).

Tomich has been instrumental in coordinating Energy Vision's various regional and national education and outreach initiatives, and he has appeared as a speaker at multiple venues across the country. He earned a B.A. in Geology from Haverford College, where he focused on Soil Geochemistry, and an M.B.A. from Kansas State University with an emphasis on Technology Commercialization and Entrepreneurship.



# APPENDIX A - SUMMARY OF QUESTIONS

## Exploring an RNG Initiative: Key Questions to be Addressed by Communities



Every RNG project is uniquely defined by local waste streams, project opportunities, regulatory frameworks, stakeholders, costs and incentives. But what follows is a summary of the key lines of exploration that will help clarify options for communities:

### Organics Profile of an Individual Community and in the Region

What is the community's organic waste generation profile?

How much organic waste is generated by the community, where is it disposed of at present, what costs are paid for disposal, and what contracts define current commitments?

What other communities, major businesses and institutions within a 20 mile radius are generating organic wastes? Where are these wastes disposed of at present, what costs are paid for disposal, and what contracts define current commitments? These wastes might come from:

- dairies
- farms
- food processors
- hospitals
- universities
- hotels or conference centers

Where is the closest landfill, and what are the total organic wastes (pounds and types) deposited there by the community, by other communities, and by haulers for commercial and institutional establishments? What are the landfill "tipping fees" paid to deposit municipal waste in local/ regional landfills? On what bases might the generators be able to make their organics available for centralized processing in a conveniently placed anaerobic digester?



Are the biogases from the local landfill being collected? How much gas is being produced? What happens to these gases now? Are they flared? If not, how much biogas is used to generate electricity, heat homes, or power vehicles?

How much sewage goes to a local wastewater treatment plant? How much biogas is being (or could be) collected from these wastes? If there is biogas collection, how is the biogas being dispatched or used: to generate electricity, heat homes, or power vehicles?

### **Environmental Benefits of Collecting and Refining Biogases for Vehicle Fuel**

What are the air quality benefits? Reducing particulates, nitrogen oxides, non-methane hydrocarbons?

What are the greenhouse gas reductions (meeting or exceeding regulatory requirements)?

### **Environmental Benefits of Source Separated Organics**

What quantity of biosolids might be available after gas collection for use as fertilizers or soil amendments?

### **Fuel Security**

How much diesel/gasoline vehicle fuel might be displaced?

### **Economic Benefits**

What would be the economic gains of turning the biogases collected into saleable products: Sold to a utility to generate electric power? Sold for home heating? Or sold as vehicle fuel? These benefits must be weighed against the up-front costs of putting the processing systems in place for the various uses of the biogases.

What economic value could be captured through the sale of the soil enhancement biosolids that remain after the biogases have been extracted through anaerobic digestion?

What would be the avoided costs of disposal; and What income from tipping fees might result if organic waste generators near the anaerobic digester dump their loads there?

What fuel savings and price stability can be expected by switching to RNG, thus avoiding the volatile and unpredictable costs of diesel/gasoline?

What environmental credits – that reward low-carbon, non-petroleum fuels – might the project qualify for and how much will these credits be worth? (See Chapter 6.)

### **Job Creation**

What permanent local green jobs in RNG production and related industries might be created?

## **Technology and Consulting Support**

In finding the technologies and systems that may best suit the community's needs, local leaders do not need to become technical experts. However, leaders can benefit from gaining an overview of the status of anaerobic digestion and RNG fuel developments in Europe and of the projects underway in the U.S. Those who can help identify the best sources of expertise on technologies include:

Companies in the new Renewable Natural Gas Production Industry, Trade Associations, or Government/Civic Programs involving RNG\*

Energy Vision

Local engineers

Other technical experts in the communities or general region including professors or students in technical colleges

The growing number of consultants and natural gas refueling station builders

## **Potential Costs of Equipping the Community to Produce and Use RNG**

If the community's organics are disposed of with other wastes in local landfills; and if its sewage goes to a local wastewater treatment plant:

What will be the costs of installing the equipment for capturing biogases from these facilities and for refining them for their intended uses?

What will be the costs of getting the RNG to the site where a refueling station will be built? The options include:

Building a refueling station at the production site; or

Transporting the fuel by tanker truck (as LNG) to refueling stations away from the production site; or

Transporting the fuel away from the production site by pipeline to fueling stations elsewhere.

If the community wants to make the maximum beneficial use of organic wastes, which means collecting these wastes separately:

What will be the cost of setting up a program for separate collection of residential/commercial organics?

What will be the costs of finding and establishing contracts for any additional feedstock(s) that will be needed for organics coming from other generators?

What will be the costs of building an anaerobic digester to process the separated organic wastes; and What will be the cost of equipment for refining the biogases into RNG? (See Chapter 4.)

\*Leads to Industry experts may be found through Energy Vision, (New York City) The American Biogas Council (Washington D.C.), The Coalition for Renewable Natural Gas (California), The Landfill Methane Outreach Project at the U.S. Environmental Protection Agency, and the U.S. Department of Energy's Clean Cities Program (Washington D.C.)

## **RNG Market Potential: Local Vehicle Fleets**

If the community plans to purchase natural gas vehicles for its own fleet(s), what will they cost compared to comparable diesel/gasoline powered vehicles?

What other costs are needed for the shift to natural gas trucks in worker training, modification of the vehicle depot for adequate ventilation, other?

If the community plans to mandate use of CNG or RNG trucks in its next contract with private haulers, how much higher will the bids be?

## **Potential Income/Savings**

If the community owns the fleet, what will its savings be from using less expensive natural gas fuel and for vehicle operation and maintenance?

What will be the increased tipping fees from other organics generators that are bringing their wastes to the community's anaerobic digester?

What will be the number of years to recoup up front costs?

## **How to Target a Project Opportunity**

Every RNG project is uniquely defined by local waste streams, project opportunities, regulatory frameworks, stakeholders, and incentives. Thus a major fundamental challenge is how to target the best local or regional project opportunity from an array of choices. (See Chapter 3.)

*A good RNG project site combines two basic features:*

- 1) Plentiful and secure feedstocks – a contractually guaranteed, long-term supply of biogas from an existing biogas production site, or the assurance of sufficient organic wastes to justify the construction of an anaerobic digester for biogas production (feedstock agreements).
- 2) Captive or nearby fleet markets – vehicles that will use the fuel produced (off-take agreements).

A key step here for some communities will be to form a broad and diverse action team to consider multiple choices, technologies, and impacts in the search for the most attractive project opportunity.

## **Selecting Appropriate Technologies/Vendors**

Again, when it comes to choosing technologies, community leaders need not understand the complex details involved in implementing an RNG project. However, there are a variety of proven commercially available technologies for the anaerobic digestion of organic waste as well as biogas upgrading.

The project's size/location, primary waste feedstock(s) and desired end use all play a role in choosing the best option.

***Which of the four Anaerobic Digestion Technology Options will be Best for the Community?***

- 1) Anaerobic lagoon digesters for liquid manure waste on U.S. farms: These are lined and covered earthen basins into which a farmer flushes manure waste and spray water and from which methane gas can be extracted as it collects under the lagoon cover.
- 2) Plug-flow digesters for “high-solids” manure and other wastes: Plug-flow digesters are typically built below the soil surface and process wastes that often contain 15 to 20 percent solids.
- 3) Complete mix tank digesters for semi-liquid waste, or slurry of manures, sewage sludge, and other wastes including food waste: Complete mix systems, common in both the U.S. and Europe, consist of a large insulated tank, or less commonly of two or three tanks in which one or more wastes are processed in a slurry state. Solids usually comprise three to six percent of the mix. The tank is heated, and the wastes are stirred to promote microbial action.
- 4) Dry fermentation anaerobic digesters (or “fermenters”) for the organic fraction of municipal solid waste and other “dry” organics: These digesters, also known as high solids anaerobic digesters, often resemble long garages that can process the organic fraction of municipal solid waste, which is typically comprised of 20 to 40 percent solid material.

***Which of the Biogas Upgrading Options will be Best for the Community?***

- 1) Absorption dissolves the carbon dioxide out of the raw biogas as it passes through a solvent-filled column under pressure. The solvent can be water, polyethylene glycol, or an amine solution, and the tank containing it is familiarly known as a “scrubber”.
- 2) Pressure Swing Adsorption uses activated carbon or a similar material that bonds with carbon dioxide molecules (but not with methane molecules) and removes them from the raw biogas.
- 3) Membranes, which are microscopic meshes, make use of the fact that carbon dioxide molecules are smaller than methane molecules, and as the biogases travel through the membranes the carbon dioxide and methane molecules are separated into two distinct streams.
- 4) Cryogenic upgrading lowers the temperature of the biogas stream to the point where the carbon dioxide condenses and can be separated out as a liquid stream.

With multiple companies potentially bidding to plan and install such systems, technical experts/consultants for the community will be vital in deciding the best, most cost-effective technology options for a given project.

**Designing Projects for Economic Success**

No technical obstacles impede the broad production of vehicle fuel from organic wastes. The challenge for every waste-to-fuel project is: How can all the pieces be assembled economically and logistically to achieve the greatest direct financial, job-creation, clean energy, and environmental benefits?

The most important shared feature of most existing U.S. renewable natural gas vehicle fuel projects is a “closed-loop” business model, in which owners and managers of the waste that is turned into vehicle fuel also own or control the vehicle fleets that can consume and benefit directly from the fuel produced. This business model will likely remain dominant until RNG can be marketed “universally” (just as fossil natural gas is marketed today) via pipeline injection into the extensive natural gas grid.

A project’s financial benefits largely depend on the ability to produce and/or sell RNG for significantly less than the retail price of traditional petroleum-based fuels (e.g. can the fuel cost savings be significant enough to justify the expenditure of up-front capital?). For example, in Dane County, Wisconsin, the publicly owned Rodefild Landfill collaborated with public and private partners to expand a successful “closed-loop” RNG demonstration project. The county purchases the fuel from the landfill, at a significant discount to the local retail cost of diesel or gasoline, which it uses to power its small but growing municipal fleet of CNG vehicles (see Chapter 5 for more on this and other successful U.S. projects).

### **Diversity of Closed-Loop Projects**

The existing successful U.S. RNG projects demonstrate many different shapes and sizes. But regardless of scale, location or feedstock, technical expertise will be essential in assessing the complexities surrounding a project’s feasibility and economic viability. By choosing the appropriate technology/ model for a given community’s needs, RNG can reduce fuel expenses and generate additional revenue through the sale of excess RNG to nearby commercial and private fleets.

Each project is uniquely defined by a broad set of variables such that there is no universal formula for successful project development. But regardless of size, location and feedstock, it’s important to understand these myriad variables and options to best determine the economic viability and technical feasibility of a local RNG project.

### **Understanding Renewable Fuel Policy Drivers, Incentives and Resources**

What local, state and federal grants, incentives, and other assistance programs exist to help offset the upfront costs of converting vehicles to run on renewable natural gas and of implementing a renewable natural gas production initiative?

What resources exist to aid in identifying sources of support, in addition to Energy Vision, the regional Department of Energy’s Clean Cities affiliates, and private consultants?

For more detailed information on these incentives, programs and resources, Chapter 6 of the Guide and Appendix A provide a thorough overview of these topics and more.

## APPENDIX B - REFERENCES

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### **Chapter 3**

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3. European Biomass Association: “A Biogas Road Map for Europe.” [http://www.aebiom.org/IMG/pdf/Brochure\\_BiogasRoadmap\\_WEB.pdf](http://www.aebiom.org/IMG/pdf/Brochure_BiogasRoadmap_WEB.pdf)
4. International Energy Agency Task 37 Reports, Biogas Upgrading. [http://www.iea-biogas.net/\\_download/Up-grading\\_Plant\\_List.pdf](http://www.iea-biogas.net/_download/Up-grading_Plant_List.pdf)
5. “BIOGASMAX: 2006/2010 the synthesis.” European Union Directive on Trans-European transport networks & Smart transport. [http://www.biogasmax.co.uk/media/synthesis\\_report\\_biogasmax\\_web\\_\\_036599500\\_1239\\_23122010.pdf](http://www.biogasmax.co.uk/media/synthesis_report_biogasmax_web__036599500_1239_23122010.pdf)

### **Chapter 5**

1. California Air Resources Board: Low Carbon Fuel Standard Program. <http://www.arb.ca.gov/fuels/lcfs/lcfs.htm>
2. U.S. EPA: Renewable Fuels Standard Program. <http://www.epa.gov/oms/fuels/renewablefuels/regulations.htm>

### **Chapter 6**

1. Natural Gas Vehicles for America (NGVAmerica): For Fleets. <http://www.ngvc.org/forfleets/index.html>
2. Clean Energy Fuels Corporation: “America’s Natural Gas Highway: The Clean Energy Solution.” <http://www.cleanenergyfuels.com/pdf/CE-OS.ANGH.012412.pdf>

3. U.S. DOE: Energy Efficiency and Renewable Energy: Clean Cities. <http://www1.eere.energy.gov/cleancities/>
4. U.S. DOE: Alternative Fuels and Advanced Vehicles Data Center: Electricity Production and Distribution. [http://www.afdc.energy.gov/afdc/fuels/electricity\\_production.html](http://www.afdc.energy.gov/afdc/fuels/electricity_production.html)
5. Northeast States for Coordinated Air Use Management (NESCAUM): Proposed Clean Fuel Standard. <http://www.nescaum.org/topics/clean-fuels-standard/>
6. U.S. EPA: Fuels and Fuel Additives (RFS2). <http://epa.gov/oms/fuels/renewablefuels/compliancehelp/rfs2-aq.htm#7>
7. Novogradac and Company: Renewable Energy Tax Credit Resource Center. [http://www.novoco.com/energy/resource\\_files/irs\\_guidance/irc/section\\_45.pdf](http://www.novoco.com/energy/resource_files/irs_guidance/irc/section_45.pdf)

## **APPENDIX C - RESOURCES**

### **These Websites and Organizations are Sources of Further Information on RNG**

#### **General**

Clean Cities Website

[www.cleancities.energy.gov](http://www.cleancities.energy.gov)

Clean Cities Coordinator Toolbox

[www.cleancities.energy.gov/toolbox](http://www.cleancities.energy.gov/toolbox)

Alternative Fuels & Advanced Vehicles Data Center – Federal and State Incentives

[www.AFDC.energy.gov](http://www.AFDC.energy.gov)

Energy Efficiency and Renewable Energy (EERE) Information Center

[www.eere.energy.gov/afdc/informationcenter.html](http://www.eere.energy.gov/afdc/informationcenter.html)

EERE State Activities & Partnerships – Renewable Portfolio Standards

[www.csrees.usda.gov/qlinks/partners/state\\_partners.html](http://www.csrees.usda.gov/qlinks/partners/state_partners.html)

Energy Vision

[www.energy-vision.org](http://www.energy-vision.org)

#### **Anaerobic Digestion**

Midwest Rural Energy Council

[www.mrec.org/anaerobicdigestion.html](http://www.mrec.org/anaerobicdigestion.html)

American Biogas Council

[www.americanbiogascouncil.org](http://www.americanbiogascouncil.org)

#### **Natural Gas Vehicle Technology**

Natural Gas Vehicle Coalition

[www.ngvc.org](http://www.ngvc.org)

American Gas Association

<http://www.aga.org>

CNG Now

<http://www.cngnow.com>

NYSERDA: CNG for Delivery Trucks and Refuse Haulers

<http://www.nyserra.ny.gov/BusinessAreas/Energy-Innovation-and-Business-Development/Research-and-Development/Transportation/Alternative-Fuel-Vehicles/CNG-for-Delivery-Trucks-and-Refuse-Haulers.aspx>

## **Farm and Dairy Projects**

U.S. EPA: AgStar Program  
<http://www.epa.gov/agstar>

Argonne National Lab  
Energy Systems Division: Waste-to-Wheel Analysis of Anaerobic-Digestion-Based Renewable Natural Gas Pathways with the GREET Model  
<http://www.greet.es.anl.gov/files/waste-to-wheel-analysis>

U.S. Department of Agriculture  
<http://www.usda.gov/wps/portal/usda/usdahome>

Cooperative Extension  
[www.csrees.usda.gov/Extension/](http://www.csrees.usda.gov/Extension/)

Land Grant Universities  
[www.csrees.usda.gov/qlinks/partners/state\\_partners.html](http://www.csrees.usda.gov/qlinks/partners/state_partners.html)

Rural Development Energy Programs  
[www.rurdev.usda.gov/Energy.html](http://www.rurdev.usda.gov/Energy.html)

Innovation Center for U.S. Dairy  
<http://www.usdairy.com/Pages/Home.aspx>

## **Landfill Projects**

U.S. EPA: Landfill Methane Outreach Program  
<http://www.epa.gov/lmop>

U.S. EPA: Division of Solid Waste Management State Programs  
[www.epa.gov/osw/wyl/stateprograms.htm](http://www.epa.gov/osw/wyl/stateprograms.htm)

Solid Waste Management Association of North America  
[www.swana.org](http://www.swana.org)

Solid Waste Associations (with State Chapters)  
[http://swana.org/\\_Membership/MemberBenefits/SWANACHapters/tabid/123/Default.aspx](http://swana.org/_Membership/MemberBenefits/SWANACHapters/tabid/123/Default.aspx)

National Solid Waste Management Association  
[www.nswma.org](http://www.nswma.org)

## **Wastewater Treatment Plant Projects**

EPA Wastewater Programs: Sewage Sludge (Biosolids)  
<http://water.epa.gov/polwaste/wastewater/treatment/biosolids/index.cfm>

Municipalities and Wastewater Treatment Plants  
[www.epa.gov/chp/markets/wastewater.html](http://www.epa.gov/chp/markets/wastewater.html)

### **State Policies (Low Carbon Fuel Standard etc.)**

California  
[www.energy.ca.gov/low\\_carbon\\_fuel\\_standard](http://www.energy.ca.gov/low_carbon_fuel_standard)

Northeast States for Coordinated Air Use Management  
[www.nescaum.org/topics/clean-fuels-standard](http://www.nescaum.org/topics/clean-fuels-standard)

Regional Greenhouse Gas Initiative (RGGI)  
[www.rggi.org](http://www.rggi.org)

National Conference of State Legislatures  
[www.ncsl.org](http://www.ncsl.org)

The United States Conference of Mayors  
[www.usmayors.org](http://www.usmayors.org)

### **European Experience**

Biogasmax  
[www.biogasmax.eu](http://www.biogasmax.eu)

European Biomass Industry Association  
<http://www.eubia.org/285.0.html>

International Energy Agency (IEA) Biogas Task 37  
[www.iea-biogas.net](http://www.iea-biogas.net)

Natural and bio-Gas Vehicle Association Europe  
[www.ngvaeurope.eu](http://www.ngvaeurope.eu)

Swedish Gas Center  
<http://www.sgc.se/en/>



For more information on ordering this or other Energy Vision transportation reports, see below.

*Turning Waste into Vehicle Fuel: Renewable Natural Gas; A Step-by-Step Guide for Communities (2013)\**

*Tomorrow's Trucks: Leaving the Era of Oil Behind (2013)\**

*Renewable Natural Gas: The Solution to a Major Transportation Problem (2012)\*\**

*Waste to Wheels: Building for Success (2010)\**

*Fueling a Greener Future: NYC Metropolitan Area Garbage Fleets Commit to Alternative Fuels (2008)\**

\*Price per copy: \$30 plus \$3.50 postage and handling

\*\*Price per copy: \$15 plus \$3.50 postage and handling

Bulk orders of 10 or more: 20% discount

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EV is a national non-profit organization that analyzes and promotes ways to make a swift transition to pollution-free renewable energy sources and to the clean, petroleum-free transportation fuels of the future.

138 East 13th Street  
New York, New York 10003





## Comments on *Turning Waste Into Vehicle Fuel*

*Energy Vision's latest publication "Turning Waste into Vehicle Fuel" is a highly comprehensive resource for the development of renewable natural gas for transportation. Using this guide, communities will be able to chart the critical path towards harnessing a local, diversified, and environmentally friendly transportation fuel. In doing so they can generate meaningful economic growth, while dramatically reducing the greenhouse gas emissions of transportation. We applaud Energy Vision's sustained efforts in spreading this information.*

*Scott DeWees, Project Manager, Western Washington Clean Cities Coalition*

*I just read through Energy Vision's new Community Guide. It is awesome work. The guide is comprehensive, very easy to read (and use) and it includes all the critical elements/key areas of information needed to advance development of renewable natural gas projects. Congratulations!*

*Nora Goldstein, Editor, BioCycle Magazine*

*"Turning Waste Into Vehicle Fuel" is a great primer on Renewable Natural Gas (RNG) and a practical instruction guide for those considering this ultra-low carbon fuel. Communities will learn how to ensure productive and profitable use of products once discarded as waste. Business owners will discover how to transition their vehicle fleets to clean, renewable, and affordable RNG. Policy leaders will identify the steps they can take to make RNG production and use a reality in their communities."*

*David Cox, Director of Operations, The Coalition for Renewable Natural Gas*

*"Turning Waste into Vehicle Fuel" will be a valuable resource to municipal leaders, sustainability managers, and more. Beyond the myriad environmental benefits, our company is actively engaged in a number of RNG initiatives because they meet three simple criteria: 1) RNG is a fully sustainable fuel 2) The technology is commercial 3) RNG as a vehicle fuel is financially viable.*

*Mark Maloney, Co-Founder, AMP Americas*

138 East 13th Street  
New York, New York 10003

