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Renewable Gas — Vision for a Sustainable Gas Network

A paper by National Grid

Executive Summary

Renewable Gas *— also known as bio-methane, is pipeline quality gas derived from biomass that is fully interchangeable with natural gas*

Renewable gas has the potential to make a significant contribution to the reduction of greenhouse gas (GHG) emissions while creating local jobs and enhancing security of supply.

This paper represents National Grid's view on this important opportunity, and provides information on the potential scope and scale, along with a view on what needs to be done in order to realize the associated benefits. In summary:

- Renewable gas is a viable option and should be considered as an alternative energy source similar to wind or solar power.
- The technology behind renewable gas exists today, but is dependent upon us to cultivate it further.
- The biggest driver of renewable gas is GHG reduction, but what makes renewable gas more compelling is that it also enhances diversity of supply while providing a solution for using local waste resources to produce renewable energy.
- Government support is critical in developing this resource and, without action now, a great opportunity could be missed.

The paper also gives an overview of renewable gas technology and clears up misconceptions about how this energy is produced and used. Finally, the paper outlines a vision of what a sustainable gas network could look like.

The content is supported by a detailed study commissioned by National Grid that indicates that, over the long term, renewable gas has the technical* potential to meet up to 25 percent of the natural gas demand in the four states served by National Grid (Massachusetts, New Hampshire, New York and Rhode Island), not including natural gas demand for power generation (see Table 1). That is enough energy to meet the annual demand of approximately 2.2 million homes that use natural gas for heating in the Northeast. It is important to mention that all of the feedstocks considered for the production of renewable gas are sustainable, and a great consideration has been given by adopting the approach of not solving one problem by creating another.

In this paper, "renewable gas" refers to pipeline quality gas derived from biomass that is injected into the natural gas distribution network for direct use in existing natural gas appliances.

* *Assumes complete utilization of all available feedstocks with process efficiencies considered (see Feedstock Assumptions section for more detail).*

Table 1 – Technical Potential Summary by State (Bcf = billion cubic feet)

STATE	TECHNICAL RENEWABLE GAS POTENTIAL (BCF/YR)	POTENTIAL AS A PERCENTAGE OF OVERALL DEMAND	POTENTIAL AS A PERCENTAGE OF DEMAND WITHOUT POWER GENERATION
MA	39	10%	18%
NY	193	17%	25%
NH	23	35%	100%
RI	13	15%	35%
Total	**268**	**16%**	**25%**

Produced mainly via anaerobic digestion (AD) or thermal gasification (TG), renewable gas represents a readily implementable and cost-effective solution to reduce GHG emissions. Renewable gas can increase the diversity of supply as well as provide a real and innovative solution for utilizing local waste resources to produce a renewable source of energy. The capital investment required to deliver the renewable gas across the four states is estimated to be approximately $7 billion, which compares well with the cost of delivering other large-scale renewable projects such as solar or wind. Construction, operation and maintenance of renewable gas production plants are estimated to create up to 9,000 new local jobs, and reduce carbon dioxide emissions by approximately 16 million tons per year (equal to annual carbon dioxide emissions of approximately 3 million cars), as well as additional GHG benefits of avoided methane that is released into the atmosphere.

Government support will be the most critical factor in delivering renewable gas.

Government support will be the most critical factor in delivering renewable gas. Currently, there is a significant disparity between government policies supporting renewable gas and renewable electricity. Public policymakers need to level the playing field by offering comparable incentives for renewable gas that are offered for renewable electricity. Further, there is an urgent need to recognize the environmental benefits of renewable gas projects. Currently, the environmental attributes of renewable gas projects are only recognized when being used for power generation.

The intent of this paper is to initiate debate and discussions with all of the stakeholders who have an interest in building a sustainable energy future and to create a practical roadmap to achieve that vision. National Grid is committed to that vision and believes that renewable gas is a viable resource to a sustainable low-carbon economy.

Background

What is Renewable Gas?

Renewable gas, also known as biomethane, is pipeline quality gas that is fully interchangeable with natural gas. To date, direct injection of renewable gas has been limited to a small number of projects in the United States. For example, the Fresh Kills landfill in Staten Island, New York has been operating for almost 30 years providing 1.8 billion cubic feet (Bcf) of pipeline quality gas annually. In addition, there are a few individual farms and waste water treatment plants that have utilized clean-up technologies to make compressed natural gas (CNG) for vehicles.

Biogas – unconditioned raw gas composed of methane and CO_2

Currently, most producers either flare the raw gas or utilize it in a generator to produce electricity. This raw gas, commonly referred to as "biogas," is composed of roughly 50 to 60 percent methane and 40 to 50 percent carbon dioxide (CO_2). Flaring the gas converts methane to CO_2 thereby reducing the GHG effect by a factor of 20.

Renewable electricity incentives have led to a proliferation of power generation projects at landfills, waste water treatment plants and some farms, but using this gas to produce pipeline quality gas is a more efficient way to utilize the energy. In addition, one of the drawbacks of using biomass for power generation is the air permitting process, which can be complex and lengthy. Figure 1 (on page 4) displays the renewable gas alternative. Biomass emits methane into the atmosphere when it is decomposing, or CO_2 when it is digested and flared. By collecting, conditioning and injecting a high percentage of the available methane into the natural gas network, customers can directly use the gas in their existing natural gas appliances and other end-use applications. Further, renewable gas reduces GHG emissions by fuel substitution, essentially switching from a fossil fuel to a renewable fuel. Using renewable fuel represents the recycling of carbon already circulating in the environment, and using fossil fuel represents new emissions of carbon that was previously trapped geologically

Newtown Creek, a renewable gas demonstration project

National Grid and New York City Department of Environmental Protection are working together to deliver renewable gas from the largest waste water treatment plant in New York City. This will be one of the first projects in the United States that directly injects renewable gas into the distribution system by utilizing digester gas from a waste water treatment plant.

The project will inject enough gas to provide heat to approximately 2,500 homes and reduce CO_2 emissions by about 16,000 tons annually (equal to CO_2 emissions of approximately 3,000 cars).

Note: As of July 2010, the project is currently in the design phase, and is subject to regulatory approval.

Picture of Newtown Creek waste water treatment plant in Brooklyn, NY.
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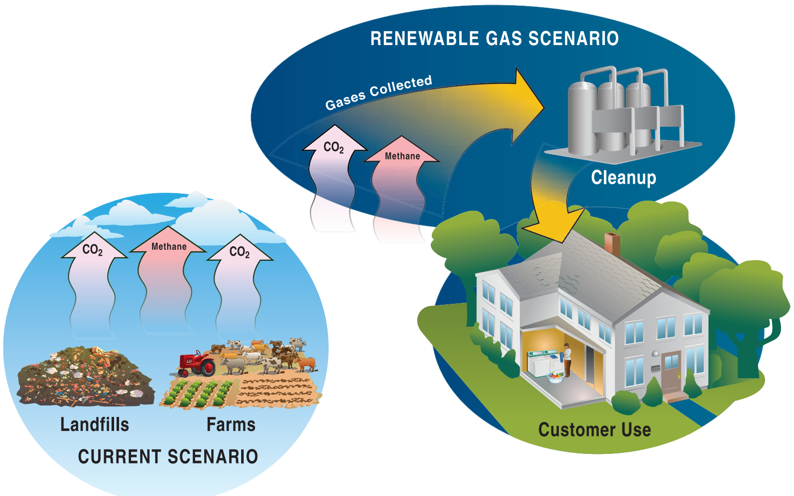
beneath the earth. The proposed scenario (see Figure 1) provides a benefit that can be gained from changing the full lifecycle of waste streams that would otherwise lead to an increase of GHG emissions.

Figure 1 – Current vs. Renewable Gas Scenario



How is Renewable Gas Produced?

Thermal Gasification (TG) – *Production of synthesis gas (syngas) through the thermal breakdown of solid biomass*

Anaerobic Digestion (AD) – *The conversion of organic matter into biogas in the absence of oxygen*

There are two principle technology platforms for producing renewable gas. One is based on thermal gasification (TG) and the other on anaerobic digestion (AD). Each platform involves the production of raw gas (biogas) that is subsequently upgraded to pipeline quality gas (renewable gas or biomethane; see Appendix for a brief technical overview). In that sense, these processes are not so different from how natural gas is produced: gas from the wellhead (produced from decomposition of organic matter) is processed into a pipeline quality fuel by removing unwanted constituents before being compressed for pipeline transmission.

Renewable gas reduces GHG emissions by fuel substitution … switching from a fossil fuel to a renewable fuel.

The two biogas production processes involve established technologies that utilize a wide range of feedstocks. AD is typically used for feedstocks with moisture content of 70 percent or higher, such as waste water, food waste and animal manures. AD has been applied at scales as small as a single farm to plants processing hundreds of millions of gallons of waste water per day. TG works best with low-moisture feedstocks such as wood chips, agricultural residues and energy crops. Gasification has been used since the mid-1800s to produce “town gas” from coal. However, with the advent of the interstate pipeline system in the 1940s and 1950s, town gas was replaced by natural gas. In that sense, renewable gas represents the utilization of existing technology in a more modern, environmentally responsible form.

Potential for Renewable Gas (in MA, NH, NY & RI)

National Grid recently commissioned the Gas Technology Institute (GTI) to conduct a market assessment, and the following explains the results of the study. The study included a comprehensive review of all the potential feedstocks statewide in the states where National Grid operates: Massachusetts, New Hampshire, New York and Rhode Island. The results of the analysis are summarized in Table 2.

Table 2 — Summary of Results by Feedstock and State

		ENERGY PRODUCTION POTENTIAL* (BCF/YR)				
FEEDSTOCK	PRODUCTION TECHNOLOGY (TG OR AD)	NEW YORK	MASSACHUSETTS	NEW HAMPSHIRE	RHODE ISLAND	TOTAL
Municipal Solid Waste	TG / AD	88.2	22.3	5.5	9.9	**125.9**
Wood Residues	TG	40.7	10.2	14.2	1.5	**66.6**
Livestock Manure	AD	27.7	1.0	0.8	0.1	**29.6**
Energy Crops and Agricultural Residues	TG	18.4	1.5	0.6	0.2	**20.7**
Landfill Gas	AD	11.4	3.5	1.7	0.6	**17.2**
Waste Water Treatment Plants	AD	5.4	0.5	0.05	0.2	**6.2**
Other**	AD	0.9	0.2	-	0.03	**1.1**
Total		**192.7**	**39.2**	**22.9**	**12.5**	**267.3**

** Represents technical potential; assumes complete utilization of all feedstocks.*
*** Other category includes mainly fish waste and specific waste from other industrial processes such as potato waste water and cheese whey.*

Although New York state represents the greatest technical potential, the appropriate way to assess the opportunity is to compare this potential relative to the state's demand for natural gas, as captured in Table 1. Principally, the potential for renewable gas is directly linked to population and size of the state.

Approximately 20 percent of the overall technical potential would be produced by utilizing AD technology. This number could increase if the organic fraction of municipal solid waste (MSW) (i.e., food waste) is added to this category as well. AD is a commercially viable technology, and there are many commercial injection facilities around the world. In addition, with recent clean-up technology advancements, feedstock sources such as waste water treatment plants, landfills and livestock manure represent the initial commercial targets for immediate renewable gas production.

The majority of the potential will require gasification technology. Gasification is a proven technology; however, it is not currently commercially viable for biomass. That said, there are a number of demonstration projects in the U.S. and Europe, and National Grid expects that the technology will be commercially available over the next few years.

Delivering the technical potential to market will require approximately $7 billion of capital investment by potential investors. Estimated state-by-state investment and associated GHG reduction and new job creation benefits are summarized in Table 3.

Table 3 — Capital Investment and Potential Benefits

STATE	CAPITAL INVESTMENT (MILLIONS $)	CO_2 REDUCTION (MILLION TONS/YR)	JOBS CREATED*
MA	$1,100	2.3	400 - 1,300
NY	$4,600	11.3	1,800 - 6,400
NH	$650	1.3	200 - 800
RI	$400	0.7	100 - 400
Total	**$6,750**	**15.6**	**2,500 - 8,900**

**Jobs created is a high-level estimate based on number of jobs created from utilization of biomass to produce power. These are levelized over a 25-year project life accounting for manufacturing, construction, maintenance and operation.*

The figures above are based on the overall technical potential, which assume that all of the feedstocks are captured and utilized for the production of renewable gas. Clearly, this would be a significant challenge; however, it is important to highlight the major benefits of renewable gas. In light of this, National Grid has also developed two additional scenarios to provide a practical framework for developing this opportunity over the next 20 years; these scenarios are discussed in more detail in the "Roadmap to Success" section.

Feedstock Assumptions

- **Municipal Solid Waste (MSW)** — This category excludes any waste that is currently being recycled or used for other waste-to-energy projects. Any waste that is being exported from the state is included in the analysis; however, the analysis excludes any waste that is being imported to any of the states. The main reason that both AD and TG are being utilized to produce renewable gas from MSW is that there is a gaining momentum in the waste industry towards a "zero waste" concept, which National Grid supports. The vision of zero waste includes capturing food waste from the current waste stream, similar to the current processes of separating yard waste, paper and plastics. In that case, AD would be a viable technology for the production of renewable gas from this particular feedstock. TG could be used for the remaining waste, which is preferable to incineration from an emissions and efficiency perspective.

- **Wood Residues** — It is important to mention that this category does not include or suggest any deforestation. The wood residues for this study include forest residues, which are basically the unused portion of cut trees, wood waste from manufacturing, construction and utility tree trimmings.
- **Livestock Manure** — This category uses the data on animals (cows, horses, pigs, chickens, etc.) that is provided by the United State Department of Agriculture. The majority of this category in all of the four states is represented by cow manure from either the dairy or beef industry.
- **Energy Crops** — There are several candidates that could be used for energy production. Switchgrass was the selected crop to calculate the yield, and the potential is based on utilization of idle cropland.
- **Landfill Gas** — In an effort to support zero waste, the analysis was based on the assumption that deposition of waste ends in 2010 for all of the active landfills. This category does not include any landfill projects that are currently using biogas to generate electricity.
- **Waste Water Treatment Plants** — Study results do not include any waste water treatment plants that are currently utilizing biogas (or digester gas) to generate electricity. The potential captures the remaining waste water treatment plants that process 17 million gallons per day (MGD) or more. Our analysis has shown that 17 MGD is needed before the upgrading is economically feasible. This figure is likely to change as technology advances.

What are potential sources of Renewable Gas?

Renewable Gas is produced from biomass, also referred to as “feedstock” in this paper. The sources of feedstock are waste water treatment plants, landfills, municipal solid waste (including organic fraction of waste, i.e., food waste), wood residues, agricultural residues and energy crops. There are other non-traditional sources that can be utilized as well, mainly from specific industrial processes; a brewery is a good example.

Gas Quality – Myth vs. Reality

Pipeline natural gas is one of the most popular fuel choices today. It is called "natural gas" because it is found in the earth as a natural material produced as a result of decaying organic matter. Most pipeline natural gas is also called "associated gas" because it is a co-product associated with the oil recovery process. However, other sources of supply include coal bed methane, shale gas, landfill methane, digester gas, non-associated gas directly recovered from gas drilling operations, imported re-gasified liquefied natural gas (LNG) and refinery gases.

The biggest misconception about renewable gas is that it is somehow different or inferior to conventional natural gas.

"Natural gas quality" is a term typically used to describe the physical and chemical properties associated with a particular gas stream. Much like biogas streams, pipeline natural gas may contain a range of constituent concentrations based on the supply source and the level of processing of the gas stream prior to delivery into the local distribution system. National Grid does not distinguish between renewable gas vs. pipeline natural gas; all gas entering Natural Grid's distribution system is considered compatible with pipeline natural gas or else it is not permitted to enter the system. Table 4 summarizes the anticipated gas composition associated with processed raw gas producing renewable gas.

Table 4 — Anticipated Renewable Gas Composition

ANTICIPATED RENEWABLE GAS COMPOSITION	
Methane	95 to 97 percent
Carbon Dioxide	Less than 2 percent
Oxygen	Less than 0.2 percent
Hydrogen Sulfide	Less than 4 parts per million
Moisture	Less than 7 lbs/million cubic feet
Nitrogen	Less than 2.75 percent
"Commercially Free" of objectionable matter (polychlorinated biphenyl, dust, gums, tars, other liquids, chemical constituents or particulate matter that may interfere with the merchantability of flowing gas)	

The biggest misconception about renewable gas is that it is somehow different or inferior to conventional natural gas. Most pipeline natural gas supplied by utilities is composed of 80 to 95 percent methane. Methane is the same substance that results from decay of organic matter in some swamps, sewage treatment plants and landfills. However, unlike most gas recovered from these sources, pipeline natural gas contains other hydrocarbon and non-hydrocarbon constituents, including ethane, propane, butane, pentane, hundreds of other trace hydrocarbon constituents, carbon dioxide, nitrogen, trace sulfur compounds and moisture. In summary, pipeline natural gas is a complex mixture of the above mentioned constituents, while processed biogas, or biomethane, is simply methane with little or no trace constituent issues of concern.

Another misconception is that gas quality is directly related to “heat content.” Gross Heating Value (also called the “higher heating value” or “heat content”) is simply the amount of energy per standard cubic foot of gas transferred as heat from the complete ideal combustion of the gas with air at standard temperature and pressure. Heating value is not “gas quality,” rather an indicator of composition and associated energy content.

Gas quality considerations are not a barrier for introducing renewable gas into the North American pipeline grid.

In short, gas quality considerations are not a barrier for introducing renewable gas into the North American pipeline grid. Various technologies exist today to process raw biogas effectively to yield a product indistinguishable from a constituent perspective to natural gas. Biogas can be treated to remove trace constituents to comparable levels in traditional pipeline supplies. However, continuous monitoring of critical variables is necessary to ensure the treatment process remains effective. Development of gas quality monitoring plans is an important component in an overall strategy to maximize introduction of this valuable resource. It should be noted that each evaluation is unique, and that pre-treatment testing and historical evaluation of raw biogas are necessary to ensure treatment systems are optimized. A “one size fits all” solution is not the optimum solution to the issue of gas treatment; rather, a combination of treatment and blending schemes may be necessary to optimize and fully integrate renewable supplies into a market area. National Grid has established a standardized approach to determine system impacts and a process to integrate renewable gas into its distribution network.

Roadmap to Success

The move towards a low-carbon economy is picking up momentum. Policymakers are grappling with formulating a comprehensive U.S. energy policy that addresses climate change, security of supply and affordability within a framework that supports the transition to a low-carbon future. Business leaders are considering sustainable growth strategies and integrating sustainability in the way they manage their businesses. While these discussions continue, it is also clear that there is no single fuel or technology of choice. The future of energy will include a mix of renewable technologies and other emerging technologies, such as large-scale carbon capture and storage (CCS), and a new fleet of nuclear generation. National Grid believes that renewable gas can play a significant role in the future of energy. As stated earlier, while the biggest driver of renewable gas is GHG reduction, what makes renewable gas more compelling is that it also provides the following:

> The future of energy will include a mix of renewable technologies and other emerging technologies … renewable gas can play a significant role.

- Enhances diversity of supply
- Stimulates local economy and creates green jobs
- Provides a real and innovative solution for using local waste resources to produce renewable energy
- Creates a more efficient use for the fuel
- Leverages the existing gas network to deliver a renewable fuel

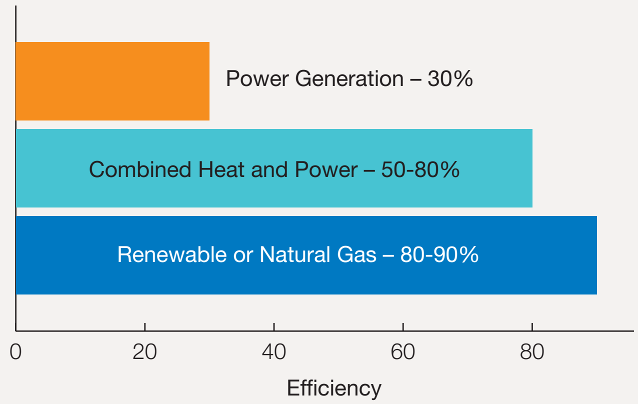
Efficiency Consideration

Power generation is about 30 percent efficient.

Capturing waste heat from the process will increase the efficiency to a range of 50-80 percent, depending on the application.

Direct use of renewable or natural gas in existing natural gas appliances — for example, heating homes — is approximately 80-90 percent efficient.

When renewable gas is used for heating, it results in greenhouse gas emission reduction benefits, but currently there is no recognition for renewable gas.

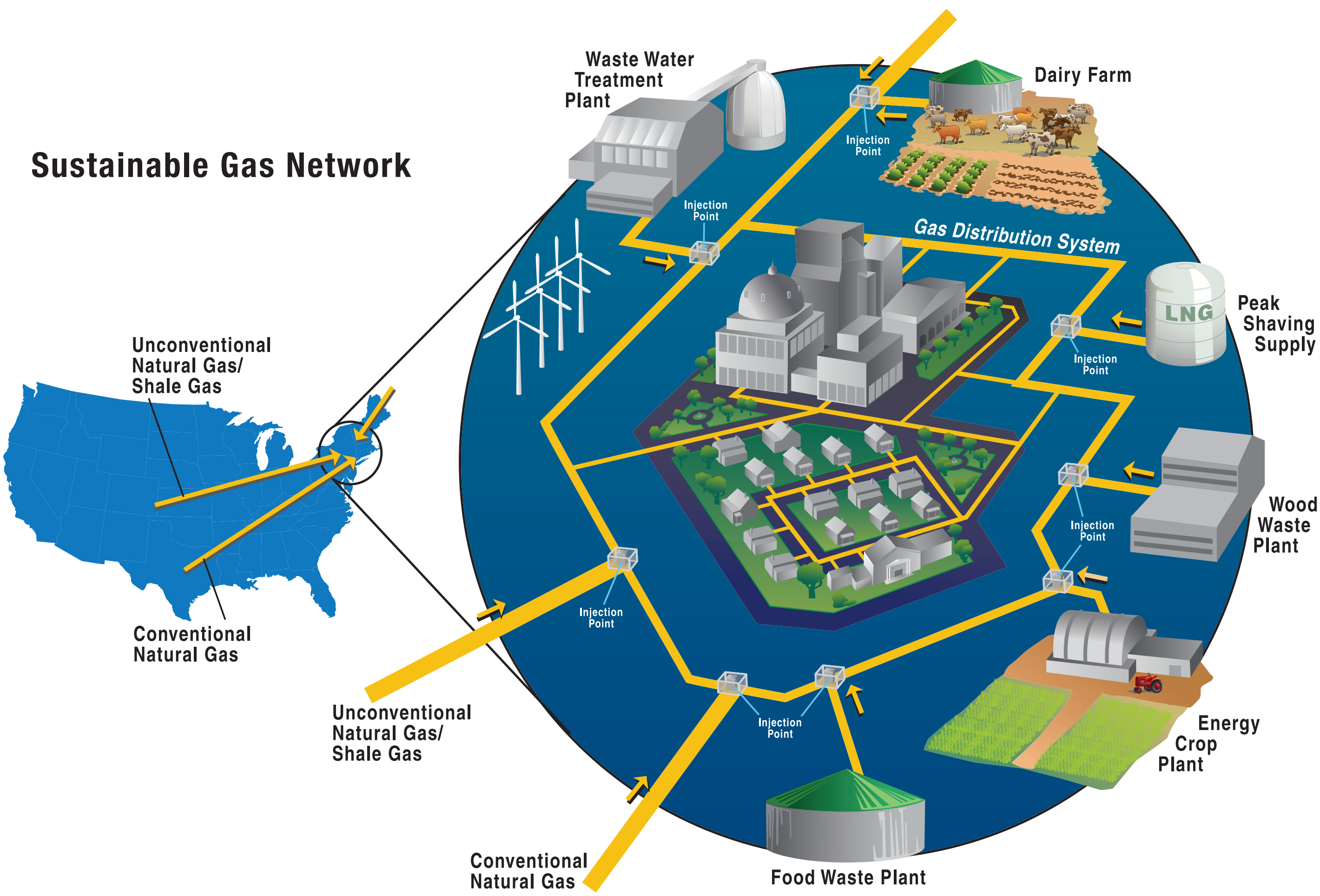


Building the Vision

The ability to imagine the future and work back to the present to make policies that pave the road forward is a vital part of the process. Figure 2 depicts a vision for renewable gas that includes a natural gas network supplied by conventional sources as well as unconventional sources such as shale gas. The recent discoveries of shale gas have significantly changed the U.S. energy outlook, and shale gas will play an increasing role in domestic supply as associated gas quality and delivery infrastructure issues are addressed. The vision also includes utilizing liquefied natural gas (LNG) for peak shaving or incremental supply as well as baseload integration of LNG imports. The future natural gas network will also carry renewable gas from dairy farms, waste water treatment plants, landfills, wood waste and food waste plants.

Peak Shaving – *Storage utilized during peak demand*

Figure 2 – National Grid's Vision for a Sustainable Gas Network



In an effort to build a practical framework to deliver this vision, two scenarios were developed. Major assumptions of these scenarios are highlighted in Table 5. Both cases have a 20-year horizon, starting in 2010. Each scenario uses a different utilization of feedstock between the first and second decade. The model incorporates an adoption phase from 2010 to 2020, with greater adoption from 2020 to 2030. The utilization of each feedstock is different as well. The majority of renewable gas production from 2010 to 2020 is from feedstocks that require AD technology (landfills, waste water treatment plants and livestock manure). Both scenarios depend on government policy support, mainly offering the same incentives and credits equivalent to renewable electricity. The major difference between the two cases is that Scenario A assumes that there is no obligation to purchase renewable gas, while Scenario B assumes that there is an obligation, probably at the state level, to purchase renewable gas similar to renewable portfolio standards (RPS) established for the power sector.

Table 5 – Two 20-Year Scenarios (potential for MA, NY, NH & RI)

SCENARIO	MAJOR ASSUMPTIONS	TOTAL RENEWABLE GAS POTENTIAL (BCF/YR)	POTENTIAL AS A PERCENTAGE OF OVERALL DEMAND	POTENTIAL AS A PERCENTAGE OF DEMAND WITHOUT POWER GENERATION
Technical Potential	◆ Complete utilization of all feedstocks, process efficiencies considered	268	16%	25%
A	◆ Production/investment tax credit or other incentives for renewable gas, similar to renewable electricity ◆ Recognition of environmental attributes similar to Renewable Energy Certificates (RECs) ◆ Moderate national GHG reduction targets ◆ Gasification has been accelerated by government support of demonstrations	50	3%	5%
B	◆ Same incentives as Scenario A, with the addition of renewable portfolio standards (RPS) for renewable gas ◆ Aggressive national GHG reduction targets ◆ Strong government support for low-carbon technology ◆ Feedstocks are set aside for renewable gas production	119	7%	11%

A model based on the assumptions above was developed and the results are summarized in Table 5. Please note that the results in Table 5 represent all of the four states and vary state-by-state. Under Scenario A, renewable gas can provide five percent of the overall natural gas demand, not including the demand for power generation; Scenario B yields 11 percent respectively. With appropriate policy support, the potentials for both scenarios, which are significantly lower than technical potential as discussed earlier, are achievable over the next 20 years. Therefore, it is not unreasonable to propose a RPS for renewable gas, and a three percent target (as a percentage of the entire natural gas demand of the four states combined) by 2030 would be a modest target. To put this into perspective, according to the National Renewable Energy Laboratory, in 2008, approximately three percent of the power generated in the U.S. came from renewable sources (excluding hydropower), driven by a dramatic growth in investment over the past decade that reached more than $23 billion in 2008.

Renewable Gas around the World

As renewable gas becomes more relevant in the United States, it is also important to highlight the status of the industry in the rest of the world, particularly in Europe. Grid injection of renewable gas is increasing in Europe, driven mainly by feed-in-tariffs for power generation. Germany is the market leader with approximately 20 plants injecting into the gas grid and approximately 40 additional plants under development or construction, and a national target of six percent of gas demand to be provided by renewable gas by 2020. The Netherlands, Austria and Switzerland also utilize renewable gas grid injection. Sweden mainly uses renewable gas to fuel vehicles. Starting in April 2011, the United Kingdom will introduce a renewable heat incentive to encourage the development of renewable gas, and a number of demonstration projects are currently being planned or constructed.

Summary

In summary, renewable gas represents a great opportunity to reduce GHG emissions, create jobs and enhance security of supply. It is a unique solution that utilizes existing waste streams from a variety of resources. The technology is advancing rapidly, and there are no insurmountable technical or safety barriers in delivering this resource. It is one of the few options that can deliver a renewable fuel within a relatively short period of time by utilizing existing infrastructure. The success of delivering this resource depends on the actions of regulators and policymakers.

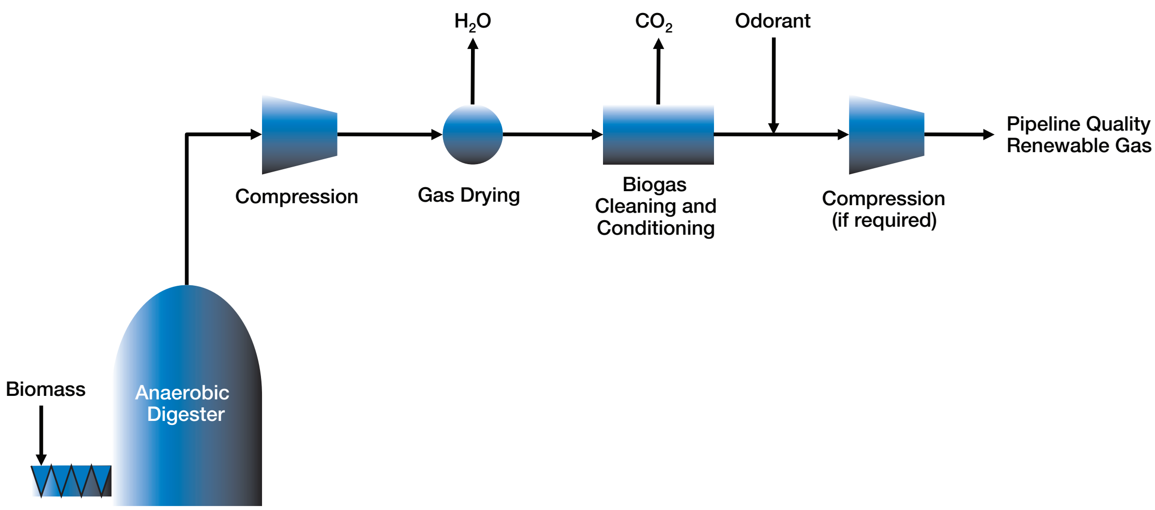
The time to act is now, and National Grid is committed to collaborating with all stakeholders to deliver a low-carbon, sustainable energy future.

Appendix – Technology Overview

Anaerobic Digestion (AD)

In AD (Figure A), microorganisms (typically bacteria), in the absence of oxygen, convert organic matter into biogas. The principle trace constituent is hydrogen sulfide (H_2S). Creating pipeline quality renewable gas involves drying the gas, removing trace constituents and removing CO_2 down to levels of approximately two percent or less.

Figure A – Anaerobic Digestion



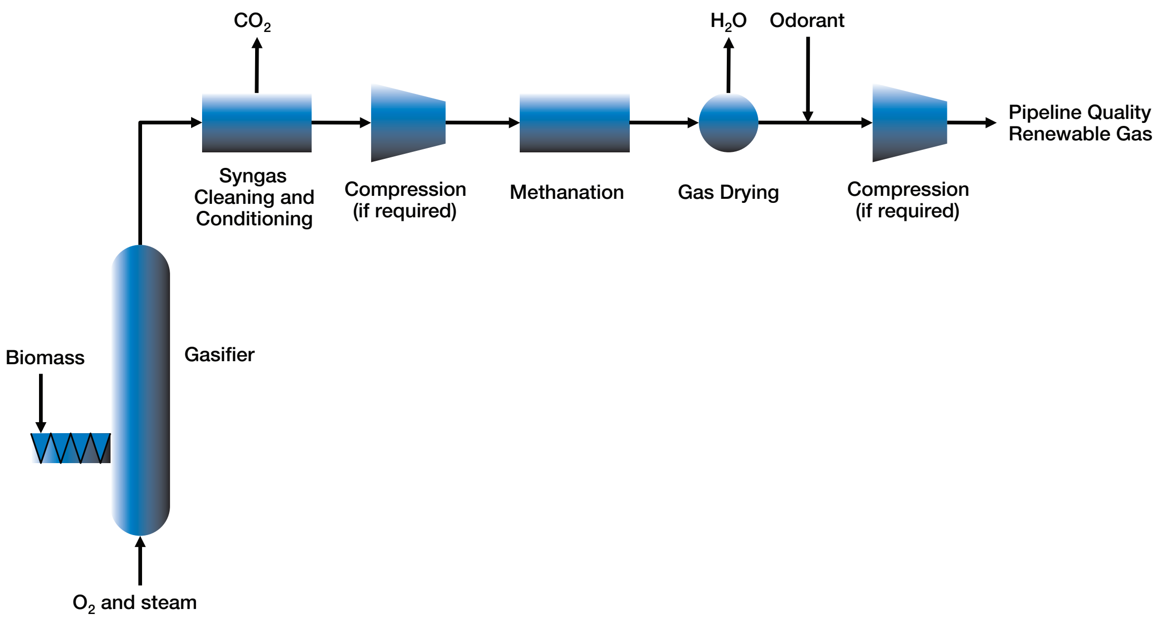
Although almost any organic material can be processed in AD, it is typically used for feedstocks with moisture content of 70 percent or higher, such as waste water, food waste and certain animal manures. Digesters vary in design, from simple covered lagoons on dairy farms, to large, carefully controlled above-ground vessels characteristic of large waste water treatment plants.

Landfill gas (LFG) is also produced via AD. In this case, the AD process occurs over an extended period of time in the landfill as microorganisms break down the organic fraction of the waste into LFG. The raw LFG is collected via a network of perforated pipes and then processed in a similar manner as the biogas produced in digesters.

Thermal Gasification (TG)

Thermal gasification (Figure B) involves the production of a synthesis gas ("syngas") in a gasifier through the thermal breakdown of solid biomass into non-condensable gases. There are numerous chemical reactions in TG; steam and oxygen are often added to promote the desired reactions.

Figure B – Thermal Gasification



Methanation – *The process by which H_2 and CO are converted to methane*

The raw syngas is a mixture composed mostly of hydrogen (H_2), carbon monoxide (CO), carbon dioxide (CO_2), water vapor (H_2O), and methane (CH_4), as well as smaller amounts of hydrogen sulfide (H_2S) and light hydrocarbons such as ethane. Syngas cleaning involves removing the particulates, tars, H_2S and any other trace constituents. To produce renewable gas, H_2 and CO are converted to methane via a process known as "methanation." The CO_2 is then removed. Unlike AD, TG works best with low-moisture feedstocks, such as wood chips and woody biomass residues, crop residues (e.g., corn stover) and energy crops such as perennial grasses. Since some of these feedstocks have high moisture content when harvested, they may require drying before gasification.

Regardless of the process used to produce the raw gas, the conditioning step is a key element for creating renewable gas. CO_2 and other trace constituents can be removed using numerous commercially available adsorption or separation systems. These processes can recover up to 98 percent of the methane from the biogas and are the same ones used in traditional natural gas production processing.

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