No time to "waste" Right time to act

↳ Unlocking organic waste for a greener future, sooner

Executive summary

No time to waste

For too long, ever-growing volumes of organic waste have gone to landfills, or simply ignored, returning no tangible benefit to the community from which it came. Now's the time to harness this enormous, latent energy resource to decarbonize our natural gas systems, support a circular economy and achieve ambitious emissions reduction goals on our pathway to net zero.

This series is a call to action to forward-thinking citizens, local governments, asset owners and clean energy investors everywhere to think differently about organic waste as more than a problem to be managed – but as an exciting, closed-loop energy opportunity to be unlocked.

Unlocking organic waste to get to a greener future, sooner

The urgent global need to decarbonize requires bold action and collaboration. Cities, states and whole countries have declared climate emergencies. It is now well understood that moving to a circular economy preserves our planet's precious resources, minimizes waste and reduces Greenhouse Gas emissions. A key enabler of the circular ambition is the opportunity to better leverage biogas – upgraded to Renewable Natural Gas (RNG) – to move to a cleaner future, sooner.

While large-scale renewable electricity generation and distribution is part of the long-term solution to tackle climate change, natural gas is here to stay for some time yet. That's where RNG enters the fray as a proven solution, available now, that can be harnessed to quickly green our existing (and extensive) natural gas networks.

Industry and government have started to explore RNG opportunities, but more needs to the done to encourage private and public sector action and investment. Multi-stakeholder RNG projects are already happening; the challenge now is sharing information, examples, and lessons learned to advance the biogas movement rapidly.

Everyone deserves access to clean, affordable, secure energy. Domestic, commercial, municipal and industrial end users all stand to benefit from biogas. A consumer upsurge for change is here on the back of heightened public awareness and already improved recycling habits. It's time to take the next step and band together to deliver customers and citizens the closed-loop solutions they want – and the circular economy our climate desperately needs.

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Chapter 1

Waste as a resource: going full circle

Climate change is driving global waste recovery cycles, resulting in new opportunities for organic waste producers and municipalities to recover waste as a way for communities to operate more sustainably in a circular future. However, to truly come full circle, we need full participation. The first step to project success is understanding government incentives, economics, and intrinsic motivations.

Solid waste is projected to grow 70 percent to 3.4 billion tonnes by 2050[1] due to population growth and natural human activity. A second life for waste and its role in sustainability provides new revenue streams for municipalities, agriculture, and industrial companies. Thinking about this ever-growing waste stream from the perspective of community resilience, we can design localized circular supply cycles to power vehicles, workspaces and factories and shift to renewables for heating, cooking and cooling.

Repurposing organic waste in a way that produces energy will offset our reliance on carbon-intensive energy sources like natural gas (NG). These developments include using organic waste material as feedstock to anaerobic digestion (AD) for biogas production. The nutrients produced by AD processes can close the loop by reusing these vital components in food production. With minor cleanup, biogas can be used to generate electricity and heat. Further conditioning to a higher purity standard can upgrade the biogas to pipeline-quality renewal natural gas (RNG).

As communities become more aware of the renewable nature of household waste, governments and industries must tap into more energy from waste (EfW) technologies to extend and extract value rather than accepting solutions that exacerbate environmental harm.

11%↑

Global circularity goals need to shift from 8.6 percent to 17 percent

Source: https://www.circularity-gap.world/2021

The case for waste

With the correct organic collection service, combined with an appropriate and suitable AD processing technology for feedstock, we create valuable, carbon-neutral end products communities want to support. Furthermore, this process enables municipalities to give outputs back to their communities cost-effectively and help meet environmental goals.

The opportunity to scale, drive change and create tangible benefits is growing. These projects create jobs, provide local energy security and fuel a circular, sustainable future.

Strategies, therefore, need to consider feedstock, regulatory and operational risk, economic context and infrastructure specifications to establish cost-effective connections. We then need to practically deploy solutions that complement or advance our ability to act responsibly across the EfW supply chain.

Waste to RNG has a role in shaping circular value in communities: creating a greater sense of responsibility, understanding and sustaining new value

Upgrading biogas to RNG

The current state of biogas generation and subsequent use varies geographically and within both the public and private sectors. We know biogas plays a pivotal role in circular waste strategies. It's a naturally occurring gas generated by the breakdown of organic matter such as agriculture and food waste under anaerobic conditions.

As industries adopt biogas generation and recovery systems, surplus biogas can be sold to provide renewable energy for neighboring operations. For example, historically, the biogas generated at a landfill was passively vented to the atmosphere or captured and flared without any valuable energy or revenue gained. Wherever possible, we need to look at opportunities to put this gas to better use to reduce carbon dioxide (CO_2) in the atmosphere.

Additionally, biogas can also be upgraded to RNG to provide a renewable fuel that is almost identical to NG. In Canada, it is estimated that we could work toward a level of RNG production representing about three percent of NG use. In this way, RNG displaces a portion of NG needs, and serves as a renewable fuel.

There are established technologies and systems for upgrading biogas to RNG. However, optimizing treatments and infrastructure requires close cooperation between engineers, owners and operators.

$81Ⓑ

Global biogas market to reach USD 81.3 billion by 2028

https://www.grandviewresearch.com

3-6°↑

Our current linear economy maintains a 3- to -6 degree temperature increase. If we continue business-as-usual, we will emit 65 billion tonnes of (GHGs) in 2030

https://www.circularity-gap.world/2021

Organics as a sustainable feedstock

The most significant waste category is food and green waste, representing over 40 percent of global municipal waste generated If we don't act now, solid waste-related greenhouse gas (GHG) emissions are anticipated to increase to 2.6 billion tonnes[2] of carbon dioxide equivalent by 2050.

Although today, RNG is commercially market-ready with proven technologies capable of turning all things organic into biogas and pipeline quality RNG, there is a finite availability of organics for RNG production. RNG from a range of existing sources has the potential to meet an estimated 10 percent of natural gas demand by 2040[3]; roughly equivalent to the size of the solar industry.

However, given the low carbon intensity scores (CI from 20 to -300) associated with organically derived RNG, a little goes a long way – especially when RNG is directed to sectors most challenging to decarbonize.

By capturing methane from landfills, wastewater treatment facilities and organics from industrial, commercial and institutional (IC&I) and agricultural wastes rural entities are increasingly taking charge of their environmental future by partnering with utilities and the private sector to turn waste into green energy. As municipalities enact climate emergency declarations, RNG offers an immediate and commercially viable solution for local use and to supercharge the grid.

Upgrading biogas to RNG production presents economic growth and societal quality of life improvements if the right decisions are made

Mainstream potential

Governments have already implemented, or are proposing, environmental policies for which biogas can offer solutions, including climate change, waste management and renewable energy. These policy choices have a role in overseeing waste management in the transition to a circular economy. With incentives in Canada and some US states (i.e., California) to produce RNG to "green the grid," we expect more RNG production in the years to come.

While requirements for pipeline RNG directly incentivize biogas production, two additional drivers hold the potential of indirectly increasing biogas production:

- **Organics diversion:** increased demand for alternative organic waste management and processing will drive more biogas projects. Anaerobic digestors meet waste disposal and renewable generation needs – providing a potential revenue stream from energy sales.
- **Renewable fuel standards:** aimed at fuel switching efforts, new standards to reduce the GHG emissions intensity of transportation fuels expand the need for other sources.

Attracting investment: what will it take?

① Public-private partnerships

Investors, producers and supporting sectors require certainty to bind projects into long-term contractual obligations where billions of dollars are on the line. Therefore, clear and consistent policies are necessary to support this emerging sector.

② Consistent government policy

While utilities, municipalities and the private sector are all in on the societal value of RNG in the energy transition, government policies remain inconsistent across regional jurisdictions.

Associations such as World Biogas Association, American/Canadian Biogas Associations and the Coalition for Renewable Natural Gas are tirelessly educating policymakers on the value of RNG in the overall energy mix. Their efforts impact many regions, recognizing that an energy transition to a low carbon economy requires all solutions to play harmoniously to solve a puzzle of this scale and complexity.

It's critical for all stakeholders to work collaboratively to bridge demand-supply gaps and harness incentives.

GHD helps you consider technology deployment, impacts on design and operation of infrastructure, and RNG utilization in your community. Making the right choices before you pin the blueprint to successfully build and commission RNG projects is crucial.

[1] *What a Waste 2.0 (worldbank.org)*
[2] *Trends in Solid Waste Management (worldbank.org)*
[3] *RNGSupplyandBenefits07152019.pdf (mjbradley.com)*

» What is Renewable Natural Gas?

Renewable Natural Gas (RNG) is nearly identical to natural gas but developed from renewable sources. Each local utility (geography dependent) defines RNG requirements differently. However, they have some relatively common characteristics. It is generally measured as a gas with a methane content greater than 96 percent, measured by its High Heating Value (HHV), greater than 36.5 MJ/m3. It has low concentrations of carbon dioxide, oxygen, nitrogen and (currently) hydrogen and minimal hydrogen sulphide.

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Chapter 2

Circular waste: making strides in RNG production

While the principles of a circular economy apply to many industry sectors, perhaps the broadest application of the circular model has been demonstrated by class leading municipalities enacting climate emergency declarations. The unprecedented rate of global warming has initiated society-wide mobilization to implement a circular economy for waste worldwide.

To help in the decision-making process, investors often take a triple-bottom-line approach to balance economic pressures, environmental expectations and social benefits. With the right vision, waste management streams can become income streams saving disposal costs while building social license to operate through community engagement.

Maximizing participation

Managing waste is one of the few activities that require citizens to actively participate in on a daily basis. For our waste systems to be effective, citizens are required to place different materials in different containers. How we promote and harness this interaction is critical to future sustainability. Programs that engage communities by creating vital systems to overcome waste problems and encourage participation have extended benefits by improving behavior.

700K

Creating a more circular economy could create 700K additional new jobs by 2040, generating $200 billion of savings

Source: https://masdar.ae/en/about-us/useful-links/facts-and-award

The gamification of waste

As we raise our kids in the new digital age, the next generation of thinkers and the incoming workforce will continue to utilize gaming technology to accelerate social and environmental consciousness in their communities. Smart technology can motivate buy-in and achieve success through incentivization. Actions can be recorded, scored and rewarded through benefits such as free transportation, bike rental or electricity bill reduction.

If citizens feel empowered to make smarter choices about what they do with their waste and how they consume the outputs, vital collaborative relationships are formed. This could be beneficial to producing more renewable natural gas (RNG), capturing more emissions, and taking RNG to the next level.

Planning for more value

Another big step municipalities are taking to complete the circle – both economic and environmental – is by processing the source separated organics (SSO) segregated by the curbside collection program in purpose-built anaerobic digesters, producing biogas containing at least 50 percent methane. When upgraded to pipeline quality (~ 97 percent methane), biogas becomes a valuable resource in the form of RNG.

With RNG in the gas distribution pipeline, the energy molecule or rather the attached environmental attribute can notionally travel to a designated location – either connected by pipeline or delivered by truck. This completes the circular journey whereby our organic waste creates renewable energy consumed by buildings and vehicles that serve our needs, including the very process of collecting the organics with fleets running on the energy generated by the waste being collected.

Better coordination and collaboration on innovation that can generate more value for industry and citizens alike can reduce waste, pollution and costs. Interesting possibilities are available, depending on how we capture and return value.

Through smart technologies, residents are empowered to make smarter choices about what they do with their waste and how they consume it

By closing the loop, everyone takes a meaningful step toward producing carbon-neutral energy

The City of Toronto turning waste into RNG:

- The City of Toronto will start producing RNG from Green Bin organic waste late 2021. By capturing the biogas instead of flaring/burning it off, the facility will avoid more than 9,000 tonnes of carbon being released into the atmosphere annually.[4]
- Toronto's Transform TO, Net Zero Strategy is engaging individuals to become Climate Action Champions furthering support for climate outreach actions to reduce GHG in the city.
- City of Toronto Dufferin Organics Processing Facility Renewable Natural Gas Facility

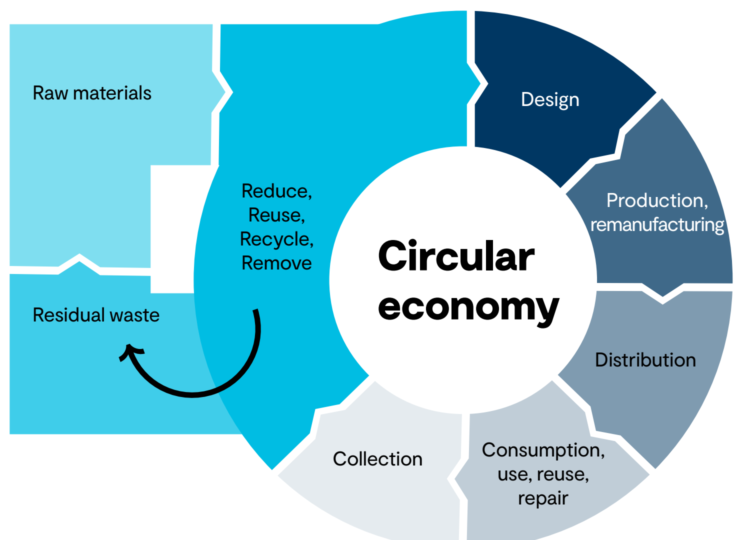
[4] *City of Toronto to start producing renewable natural gas from Green Bin organic waste – City of Toronto*

Closing the loop on organics

Recognizing that RNG is the next game-changer in vehicle fueling, the Canadian Biogas Association commissioned a paper viewing the circular economy from a "closing the loop" perspective. Specifically outlining the path for municipalities and their collection services, where the trucks collecting the organic waste run on the fuel (RNG) generated from the waste.

Furthermore, the interconnected nature of the aspirational goal of zero waste and a circular economy creates optimism benefitting both the economy and society. With incentives playing an important role in cultivating community participation, there is a lot attached to establishing a foundation for sustained collective efforts to keep up with handling growing volumes of waste. Transitioning to circular economic business models is still a hurdle. To unleash new value and link it to revenue, it needs to be based on four principles: **Reduce, Reuse, Recycle and Remove.**

- Reduce the amount of organic landfill waste
- Reuse organic waste to capture energy
- Recycle energy as products, including RNG as fuel and byproduct
- Remove the carbon by sequestering the molecule by carbon capture and storage technologies



GHD is committed to evolving actions that progress circular economy and waste management. We have played a key role in the shift towards a waste circular economy through a collaborative, connected approach, providing premium and technically robust solutions to support our clients' goals and aspirations.

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Chapter 3

Selecting waste technologies that make sense

How can we cost-effectively achieve a circular economy now?

Renewable Natural Gas production technology is evolving. RNG can be generated from various available biogas sources (landfills, wastewater treatment facilities, anaerobic digestors) with the proper pre-and-post treatment and primary (and secondary if required) upgrading technologies needed to make pipeline quality methane.

- Biogas and tailgas management
- Methane recovery
- RNG system uptime
- Major treament considerations
- Lifecycle costing

→

1 Feedstock

- process specific
- Long-term feedstock supply

2 Upgrading

- Pre-and post treatment
- CO2 and O2/N2 removal

3 Offtake

- Long-term offtake against CAPEX and OPEX
- Utility agreement

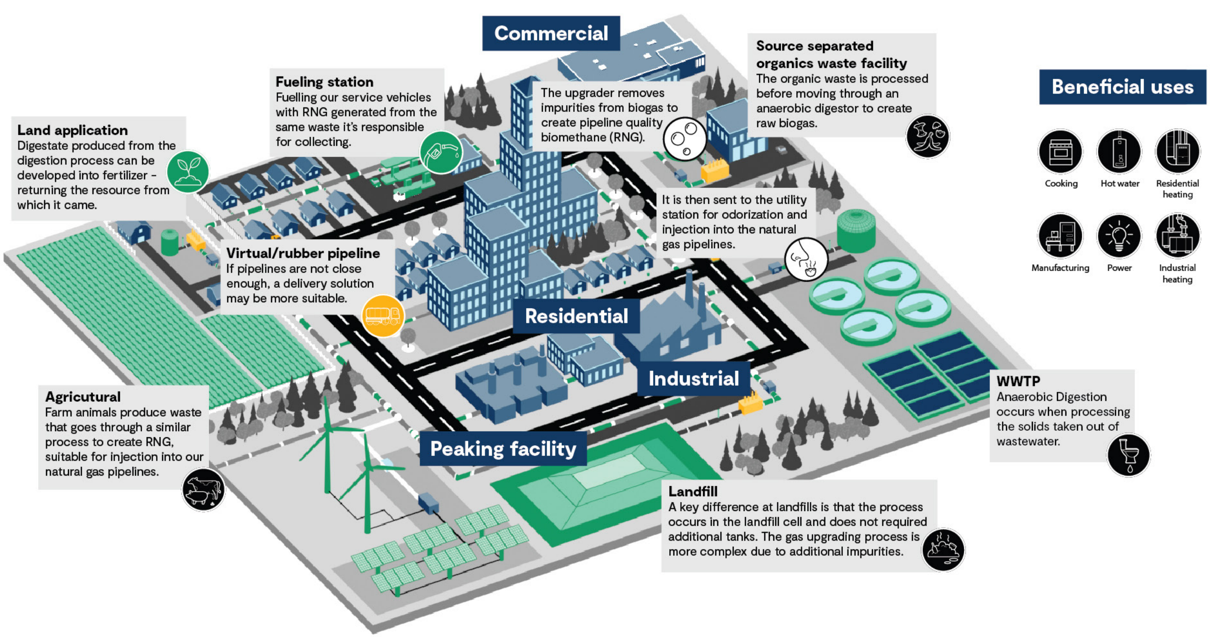
These technologies are becoming more competitive on a larger scale. We also see a trend towards more plug-and-play and standardized systems, making lower flow projects more viable. To develop a successful RNG project, we need to consider factors across the entire value chain, from biogas provision (feedstock) to long-term RNG off-take agreements.

There is no time to waste

While a wide variety of feedstock can be used to feed purpose-built anaerobic digesters, not every molecule of biogas made is created equal. Upgrading depends on feedstock characteristics, evaluating proven and emerging technology concepts and utilizing them as a future lever.

Any development strategy requires investment costs to be recovered over time. Balancing financial metrics in a circular system means the case for capital expenditure (CAPEX) and operational expenditure (OPEX) needs to be considered from a lifecycle perspective.

Balancing financial metrics means we have to understand all the financial and risk implications to establish an efficient, safe and profitable circular RNG facility. Savings can be made upfront by choosing a certain combination of technologies that suit the project. This means getting the technology design and market configuration right for a community bolstered by commercial opportunity.



Utilizing RNG to its fullest

There are many ways to monetize RNG, such as:

- Industrial settings for natural gas appliances (boilers, etc.)
- Pipeline injection into the existing natural gas grid for distribution into homes and facilities
- Pressurized into a liquid state (LNG) using cryogenic containers for remote location distribution

Ownership transfers can happen either at pipeline injection or the metering station. When ownership is maintained, the RNG producer retains the rights to the RNG (including environmental attributes) and then utilizes the notional RNG in its facilities or vehicle fleets, thereby offsetting their overall carbon footprint.

Where does biogas fit in?

Competition is driving the implementation of standardized systems, helping to drive modular solutions that can be implemented at a simplified rate, reducing costs for projects. In consideration of cleaning and purifying biogas to upgrade into RNG, we generally consider technologies in three categories:

01. **Absorption or scrubbing (Physical or Chemical)**
02. **Adsorption (Pressure Swing Adsorption)**
03. **Separation (Membrane or Cryogenics)**

Each technology presents advantages and disadvantages and is at a slightly different stage in its development and use in the market. These technologies are discussed below regarding (primary) carbon dioxide removal and (secondary) nitrogen removal. Additional deoxygenation may also be required, depending on final utility injection requirements.

Technology↓	CO_2 removal	N_2 and O_2 removal	Pre- or post treatment	Feedstock type	Feedstock suitability	Advantages	Disadvantages
Pressure Swing Adsorption	X (one-stage)	X (two-stage)	X	All	All types can be used for LFG with nitrogen as well	Can be used for primary and secondary removal	
Membrane	X (two-stage and three-stage)		X	All except LFG (unless secondary treatment)	All types except N_2, can remove some O_2	Some oxygen removal capability, high recovery in three-stage membrane	
Scrubbing (Chemical)	X		X (minor)	All except LFG (unless secondary treatment)	All types require secondary N_2 and O_2 removal can remove H_2S	Smaller footprint solution relative to other technologies , can remove H_2S as well	Requires available water source; generally more applicable at larger scales
Chemical Scrubbing	X		X (minor)	All except LFG (unless secondary treatment)	All types require secondary N_2 and O_2 removal can remove H_2S	Can remove H_2S as well	Chemical storage and supply
Cryogenics		X	X	LFG	Requires primary CO_2 removal, can remove N_2 and O_2	For N_2 removal	Require available source of liquid nitrogen

Biogas Type ↓	Wastewater Treatment Plant (WWTP)	Agricultural	Organics	Landfill
Feedstock Source	Biosolids	Agricultural waste (primarily manure)	Source separated organics (SSO) or Industrial, Commercial & Institutional (IC&I) organics	Organic material decomposition (through digestion) in solid waste
Methane content	>60 percent	>60 percent	>60 percent	~50 percent
Oxygen content (percent volume)	0 to 1 percent, generally 0, could be 1 to 2 percent if air is utilized to reduce hydrogen sulphide			Varies based on intrusion, could be 1 to 2 percent or higher (relative ratio to nitrogen)
Nitrogen content (percent volume)	0 to 1 percent, generally 0, could be 1 to 2 percent if air is utilized to reduce hydrogen sulphide			Varies based on intrusion, could be 1 to 2 percent or higher (relative ratio to oxygen)
Hydrogen sulphide content (ppm)	Without AD processing treatment: 1,500 to 3,000 ppm With AD processing treatment: less than 500 ppm			Generally less than 500 ppm, can be higher depending on type of landfill
Other Characteristics: Siloxanes, Volatile Organics Compounds, Terpenes and other compounds (treatment requirements vary based on Utility specification)				

Other critical RNG considerations

As we develop closed loop projects, we often consider multiple variables as we work through the design and integration of technologies for RNG production, such as:

01. **Biogas type** – Biogas has different characteristics depending on the organic waste source. Each RNG system must be designed and developed according to the unique biogas characteristics to ensure that the biogas is upgraded to the required specification. Across each type of biogas, there are some commonalities in types of "contaminants"; however, the amount of each varies (not only biogas type but also project-specific within those biogas types). Co-digestion and biosolids also increase methane content and biogas yield, enhancing the potential overall project performance.
02. **RNG facility requirements** – We specify minimum recovery (generally greater than 95 percent for AD applications and 90 percent for LFG applications, depending on nitrogen and oxygen levels) and up-time requirements (typically 95 percent of the total annual run time) to ensure biogas is adequately converted to RNG. Integration of the RNG facility into other facilities is also key to project success.
03. **Tail Gas management and utilization** – This tail gas management should be considered from a technical perspective (modeling, compliance, environmental) and financial (carbon intensity, capital and operation and maintenance expenditures). Tail gas is generally combusted and released into the atmosphere (primarily carbon dioxide). However, we continue to investigate and look into new technologies that utilize carbon dioxide to close the loop further.
04. **Desulfurization** – With higher hydrogen sulphide levels, bulk desulfurization can be used as an economical means for removal. However, there are additional technical considerations (waste streams, modelling) for integration and capital and operation and maintenance costs if used.
05. **Project viability** – As in all projects, security and risk minimization is key. To reduce risk and increase project success, there are two key components – feedstock and off-take. If one can bookend the project – success is much more likely. The feedstock/digestion technology is critical to generating biogas, such that it can be upgraded to RNG. Off-take ensures a suitable RNG end-user or purchaser, such that long-term demand is maintained for the project.
06. **Size and scale** –
    - **Wastewater treatment plants** may be considered too small (in biogas generation volumes) to present the proper business case to move forward. As such, wastewater treatment plants may also consider co-digestion with SSO to increase biogas generation rates, further increasing the project's financial viability.
    - Depending on the geography and type of **agriculture** (dairy, beef, pig, chicken, etc.), farms may be too small (in terms of waste volumes) to present the proper financial case to move forward. Clustering could aggregate nearby farm operations for a single manure processing and biogas production center that would also increase the project's financial viability,
    - **Landfills** represent an available methane source, considering a vast amount of landfills already maintain an existing LFG collection system (LFGCS). Adjustments may be required to optimize inlet LFG quality, but it is assumed that most maintain a LFGCS along with a flare or engines for power generation.
    - **Source Separated Organics (SSO):** Depending on the collection area, ADs for SSO are generally of adequate scale to justify the financial viability.
07. **Project financials** – As more RNG projects are developed, assuming biogas feedstock is available, a project's financial success is generally dictated by RNG upgrading costs and utility costs, including distance to the pipeline.

RNG upgrading costs are optimized based on biogas upgrading requirements (this can be ensured through proper biogas/ feedstock characterization). Project financials should be considered on a capital, operation, and maintenance basis (labour, consumables, utilities, etc.) to ensure that costs are accounted for over the project lifespan.

The utility costs are usually defined as injection or interconnection station costs as well as pipeline connection costs. Depending on the total biogas flow, distance to pipeline can be a limiting factor for project financial success. Alternative solutions, such as clustering (combined feedstocks) or virtual pipelines (CNG transportation) could also be considered.

No two projects are exactly alike – identifying and managing the complexities of technology integration for high quality RNG production is critical to success. As we develop RNG projects, we consider methane recovery and up-time as major system considerations, as these correlate directly against the amount of biogas converted to RNG and available for injection or use.

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Chapter 4

RNG developments: managing risk and navigating obstacles

Policies diverting landfills are already leading municipalities to design circular programs preventing organics from entering energy sinks (e.g. landfills) and turning the waste into valuable resources, such as digestate and bioenergy.

More recently, pledges and policies to displace and offset gaseous and liquid fuels with carbon-neutral, and often carbon-negative renewable alternatives, such as renewable gas (RNG), are creating a powerful portfolio opportunity for investors.

Common to both the public and private sectors is the influence of government energy and environmental policy and regulation on project development. These policies and regulations typically drive most public sector agencies to adopt RNG and other types of projects that generate renewable energy from waste. These projects help reduce their greenhouse gas (GHG) emissions to meet regulatory climate targets and serve as an additional revenue stream to offset costs to achieve other policies such as food waste diversion targets.

Projects developed in the private sector take advantage of the economic opportunities created by government policies for developing markets for RNG as green energy and ultimately creating a market for the purchase and sale of environmental attributes such as carbon offsets.

The key to full monetization of RNG requires a producer or developer to understand the intricacies and tradeoffs associated with various RNG-related regulatory programs

The confluence of private-sector ESG goals and government policies to promote renewable projects has resulted in an influx of new projects and concepts into the market, with RNG being the cornerstone of many.

Public sector drivers

- Federal, state/provincial, and municipal climate change policies, as well as declared climate change emergencies, are resulting in a circular economy approach
- Public pressure for federal and state/provincial regulatory agencies to hold municipal facilities to the same emissions standards as private facilities
- Pending Provincial / Municipal Organics Ban to restrict food waste disposal
- Evolving Public Environmental Ideology – public pressure for municipalities to adopt environmental sustainability goals

Private sector drivers

- Increased regulation on conventional energy and stricter compliance requirements
- Carbon neutrality targets, internal and external (regulatory vs. ESG)
- Ability to create a "premium" low- or -negative-carbon natural gas molecule, which can be worth significantly more than fossil-derived natural gas
- Carbon credit/RIN/LCFS generation
- Voluntary purchase of offsets for social license as the consumer market is driving demand for carbon-neutral products and services

RNG project pathways

Although RNG incentives and drivers are typically mutually exclusive based on the organization and sector, we are also starting to see the convergence between the public and private sectors and utilities. Current initiatives have seen both an increase in the provision of salable renewable energy to end-use markets and the use of renewable content in their day-to-day consumption by producers.

Current initiatives have seen both an increase in the provision of salable renewable energy to end-use markets as well as the use of renewable content in their day-to-day consumption by producers

Understanding barriers

The full economic picture of RNG is often viewed starting at the endpoint, where a molecule of RNG can be worth multiples more than that of traditional natural gas. However, understanding the project's full revenue and cost picture, overlain with compliance and/or ESG requirements, and technology considerations can create complex decision criteria for each project. Given the bespoke nature of each project, some examples of key factors that drive project costs include:

- Upfront capital costs and pipeline interconnection costs, both of which are relatively high compared to traditional natural gas
- Feedstock terms and other contractual obligations
- The size and scale of the project. Are economies of scale possible?
- Is the project brownfield or greenfield?
- Which technologies are being deployed and are they the right fit for the project?

Project-specific criteria and the uniqueness of each opportunity results in RNG projects that can range from the tens of millions of dollars up to and exceeding USD 100 million. However, the low-carbon RNG molecules produced from these projects are often sold at a significant premium to traditional natural gas.

01. Regulatory

Understanding the market dynamics around monetization pathways of RNG is key to making project cash flow as predictable as possible. The fungibility of the product means that RNG can be used just like traditional natural gas: to produce electricity, for heating homes and businesses, and to fuel vehicles via Compressed or Liquefied Natural Gas. Despite the variety of applications, not all end uses of RNG lead to the same economic outcomes.

For example, when sold and used as a natural gas vehicle fuel in the US, an RNG molecule is worth the summation of a traditional natural gas molecule, plus (potentially) a certain Renewable Identification Number ("RIN") value, which is driven by the federal Renewable Fuel Standard in the US. When sold as a vehicle fuel in certain states, a further state/province-level regulatory incentive is also available to increase the value of the RNG molecule. The stacking of these various revenue streams means that an RNG molecule can be worth a significant amount. However, these regulatory-driven revenue streams come with a substantial amount of uncertainty. This cash flow variability results in projects that often struggle to become bankable, which is a key barrier to further RNG production.

Alternatively, utilities and other larger corporations are beginning to offer attractive off-take terms to RNG producers to "green-up" their grids and existing infrastructure to meet certain ESG goals. These "voluntary" markets for RNG are gradually beginning to take shape and should help drive further development in the industry.

02. Feedstock

There are various types of feedstocks for RNG projects, creating a long runway for industry expansion. However, competition for strategic feedstock sources, product consistency, and seasonality are just a few of the barriers to consider for an RNG project. The highest value projects are often those with significant amounts of feedstock closest to an existing natural gas pipeline with the takeaway capacity, though the competition to secure projects with these characteristics is very high among developers. Feedstock volumes and characteristics are typically held in confidence by feedstock owners/generators and their contracted haulers. Limited access to this information can make it difficult to assess feedstock costs when developing business cases for RNG facilities.

03. Energy Transition Mindset

Despite enhanced GHG regulations and global accords such as the Paris Agreement, fossil fuels remain the cheapest and most accessible form of energy for both first world and developing countries, employing thousands of workers worldwide and attracting billions of dollars in infrastructure investment. Renewable sources of energy such as RNG are often perceived as a threat to this traditional economy and have the potential to force the abandonment of costly infrastructure before the end of intended lifecycles.

This mindset can be potentially changed through the following:

- Further public education on RNG's cost and benefits
- Highlighting job creation opportunities and transferrable skills that RNG and other renewables will require from an already skilled energy workforce
- Highlighting current fossil fuel infrastructure may also be used within the renewable industry with little to no modifications.
- Providing federal incentives to lower the costs of connections to main pipelines and/or federal support to reduce the regulatory and market risk that may make RNG projects prohibitive

If you are thinking about a biogas or RNG project, we encourage you to reach out. GHD is playing an instrumental role in evolving energy from waste solutions to expedite the global energy transition.

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Limited access to feedstock volumes and characteristics can make it difficult to assess feedstock costs when developing business cases for RNG facilities

Conclusion

The next era for RNG and beyond

Organic waste often comes with a large environmental footprint because of a lack of adequate infrastructure to process it into a valuable resource. Organic waste is being recognized as a valuable resource. Waste conversion processes offer opportunities to reduce methane generation and support circular economy sustainably. With urban populations growing worldwide, there is increased pressure to evolve waste into a major pillar of circularity by turning it into energy and organic matter to be returned to the land. Opportunities exist to develop or upgrade waste operations to produce RNG through technology, provided the viability and bankability of projects finding revenue streams. There is enormous potential.

Accelerating the circular approach of organics management involves some key drivers:

- Availability of reliable, consistent feedstock quantities – organics diversion programs in municipalities and the industrial, commercial and institutional sectors have been growing across North America to respond to the demand for higher diversion rates or lack of disposal capacity. With government policies banning organic wastes from landfill disposal, we can accelerate this process. Countries implementing restrictions have seen a significant increase in organic feedstocks available for processing.
- Standardization of materials and equipment is necessary to increase efficiencies in the construction and operation of infrastructure.
- Continue to enhance the value of RNG through off-take agreements and carbon pricing.
- Given the technical complexity of the solutions to process the organic wastes, produce biogas, and ultimately RNG, public and private sector partnerships are required to develop and deliver projects of appropriate scale. Contract and delivery for these projects can be improved to remove development roadblocks.
- Review potential for modifying currently built and operating infrastructure (e.g. wastewater treatment plants or on-farm digesters) using anaerobic digestion to generate biogas, increase feedstocks (SSO), increase biogas, and ultimately, increase biogas RNG production.

The most significant driver in accelerating the circular approach of organics management is demonstrating that each of us can contribute to decarbonizing through our everyday choices of what we do with a banana peel and apple core. If we create systems enabling everyone to participate and educate the population of the environmental benefits of that participation, it becomes a societal goal. And, we can support future generations by leveraging gamification to support this goal.

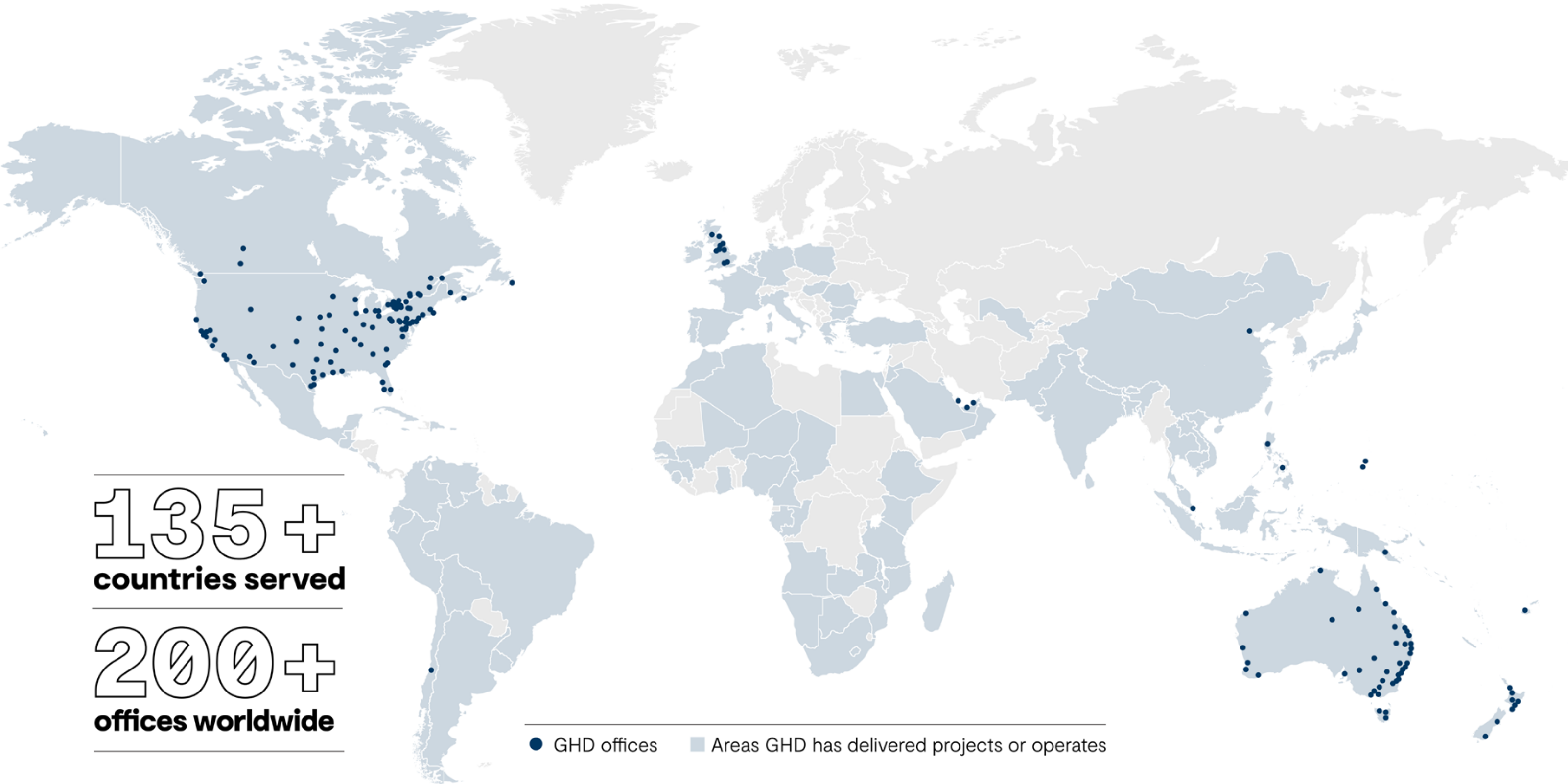
Suppose we harness all these potential RNG sources - 10 percent of the existing natural gas used in North America could be replaced– a significant achievement we can all contribute to and feel good about.

Beyond RNG - The new horizon

Hydrogen is seen as the future fuel to provide further decarbonization of the natural gas supply. Blending hydrogen into natural gas and replacing natural gas usage with 100 percent hydrogen in certain applications (e.g., hard to decarbonize industrial operations) will provide further decarbonization of the natural gas supply.

With the race to decarbonize happening worldwide, there is "no time to waste."

RNG technology from organic waste is available now. To get these projects off the ground, all stakeholders need to understand how we can leverage biogas – upgraded to Renewable Natural Gas – to move to a cleaner future, sooner.



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We are a global professional services company that leads through engineering, construction and architectural expertise. Our forward-looking, innovative approaches connect and sustain communities around the world. Delivering extraordinary social and economic outcomes, we are focused on building lasting relationships with our partners and clients.

Established in 1928, we remain wholly owned by our people. We are 10,000+ diverse and skilled individuals connected by over 200 offices, across five continents – Asia, Australia, Europe, North and South America, the Middle East and the Pacific region.

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