GOTHAM GAS GOES GREEN

ENERGY VISION

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How Upgrading the Department of Environmental Protection's Wastewater Treatment Infrastructure Can Help Build a Sustainable Future for New York

Gotham Gas Goes Green was written by Matthew P. Tomich, with significant input and assistance from Joanna D. Underwood and research support from Phil Vos.

Energy Vision is a New York-based national environmental non-profit committed to researching and promoting the clean energy strategies and solutions necessary for a sustainable future.

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FOREWORD

In November 2021, the Global Methane Pledge announced by international scientists at COP 26 gave us clear marching orders for tackling climate change. Our cities and nations must cut methane emissions 30% or more by 2030 to keep the world on track to achieve its greenhouse gas reduction targets and limit warming to 1.5° C, since methane is a greenhouse gas that is 86 times more potent in its global warming potential over 20 years than carbon dioxide. We must win this methane "sprint" if we are to meet our 2050 climate goals.

New York City, like cities across the country, faces a severe climate change challenge. The steps it takes today will determine the long term health of our residents. All those who lived through Superstorm Sandy in 2011 got a glimpse of the power of storms, of a rising ocean, and of the fragility of the infrastructure we have built, including the death of 44 citizens and the immense economic damage – $19 billion –that has not yet been totally repaired.

Can NYC meet the methane challenge? That depends on the specific practical initiatives we take now. This report highlights one critical urban strategy.

The New York City Department of Environmental Protection's Bureau of Wastewater Treatment already makes a major contribution to life in this city for its 8.8 million residents. Operating almost invisibly, it makes life livable by processing over 1.3 billion gallons of city wastewater a day. Were this imposing system of 14 water resource recovery facilities and 75 anaerobic digesters to take measures that it has now implemented at its largest facility – the Newtown Creek plant in northern Brooklyn – it could do even more for our future.

By adopting commercially viable measures to capture the methane biogases emitted by its wastewater and "co digest" 30% (350,000 tons a year) of NYC's food waste, it could cut greenhouse gases by 600,000 tons a year. That would amount to cutting 15% of the greenhouse gases emitted by all of NYC's government operations. By refining and using or selling the renewable fuel made from the system's captured methane biogases, the DEP could also generate more than $80 million dollars a year in revenue.

The amount of usable methane – in the form of renewable natural gas (RNG) – that could be produced from the DEP's operations could heat and generate electricity for NYC buildings that can't be electrified, or it could displace high-carbon polluting diesel fuel, cutting not only greenhouse gases but also 90% of lung-damaging nitrogen oxides and 60 % of particulates. This would positively impact the health of communities that live near DEP facilities as well as those disproportionately exposed to diesel truck traffic.

All these improvements are technologically viable. But how can they be funded? The 2022 Inflation Reduction Act can play a major role. This historic package of US incentives – $379 billion aimed at meeting the country's climate goals – includes support for anaerobic digestion infrastructure. Given the expressed interest of Mayor Adams in seeing New York City play a lead role in addressing our waste and climate issues, here is one critical arena for action.

Brendan Sexton, *Former DSNY Commissioner & Energy Vision Board Member*

I.INTRODUCTION

The DEP's 14 Water Resource Recovery Facilities (WRRFs)

New York City, with its 8.8 million residents, is the most populous city in the United States on a landmass of only 302 square miles. One of the great features that makes life livable – largely invisible to New Yorkers – is the extraordinary system of 14 water resource recovery facilities (WRRFs). Across the five boroughs, they collectively process a daily average of 1.3 billion gallons of wastewater and sludge generated by the city's residents and businesses.

Table 1: Capacity of NYC's 14 Water Resource Recovery Facilities (WRRFs)
Source: NYC DEP

DEP WRRF Facility	Sludge processing Capacity (gallons/day)	Borough
Newtown Creek	310,000,000	Brooklyn
Wards Island	275,000,000	Manhattan
Hunts Point	200,000,000	Bronx
North River	170,000,000	Manhattan
Bowery Bay	150,000,000	Queens
Owls Head	120,000,000	Brooklyn
Coney Island	110,000,000	Brooklyn
Jamaica	100,000,000	Queens
26th Ward	85,000,000	Brooklyn
Tallman Island	80,000,000	Queens
Port Richmond	60,000,000	Staten Island
Red Hook	60,000,000	Brooklyn
Rockaway	45,000,000	Queens
Oakwood Beach	40,000,000	Staten Island

As remarkable as the WRRF system's performance is, it has the potential to do even more. This report provides an in-depth, independent assessment of how the DEP's WRRFs could be upgraded to serve New York in new and important ways: cutting greenhouse gas emissions, helping meet the State's climate and zero waste goals, improving air quality and public health, cutting operating costs and generating revenue.

The Scope of Energy Vision's Research

This report examines the steps the DEP has taken and plans to take to upgrade its infrastructure

systemwide, to co-digest city food wastes along with its wastewater, to capture the methane biogases emitted by all this waste, and to clean up and refine these biogases into renewable natural gas (RNG) fuel.

Some biogases generated by DEP's wastewater have been used to provide heat and power to its facilities, but so far only 30% of these gases are utilized for such purposes. DEP disposes of the other 70% by flaring it – i.e. burning it before it is released into the atmosphere. Mainly to address this problem, the DEP conceived its "gas-to-grid" project at its Newtown Creek plant, NYC's largest WRRF. A decade in the planning, the project was undertaken in partnership with the local gas utility National Grid and Waste Management.

Energy Vision assessed the Newtown Creek project, particularly the innovation of diverting food scraps and other organic wastes, which would otherwise go to distant landfills, to the plant where they are combined and "co-digested" with wastewater. This has significant positive climate impacts, reducing methane emissions as biogases emitted by decomposing organics are captured, refined into RNG and injected into National Grid's local pipeline system.

Our report also considers how DEP plant processes could be further modified to maximize RNG production, including by:

- ensuring its WRRF infrastructure is in a state of good repair;
- adding gravity belt thickening technology, enabling plants to process a higher percentage of the biosolids in sludge; and
- adding food waste that the city collects to the sludge in the digesters.

We also assessed the potential impacts of current, planned, and further potential DEP upgrades across its WRRF system. These include the contributions they could make toward meeting New York City's and New York State's climate change, air quality and waste reduction goals, and how they could help implement New York State's landmark climate legislation, the Climate Leadership and Community Protection Act (CLCPA).

The report projects the potential economic benefits of these upgrades, including savings on waste disposal costs, offsetting residential and commercial natural gas purchases, and revenue the DEP can generate by selling the RNG it produces. For example, DEP could sell its RNG to high-value transportation markets, where RNG could fuel natural gas-powered buses and trucks, both in New York and in states with Low-Carbon Fuel Standards (LCFSs) discussed on page 19. DEP could also sell RNG for use in residential or commercial buildings that are difficult to electrify.

Summary of Key Findings

Across its 14 WRRFs, DEP's Bureau of Water Treatment manages and operates 75 anaerobic digesters – airless tanks commonly used to treat sewage sludge and capture biogas. But today it can do more than this. Its 14 WRRFs and 75 anaerobic digesters can help address two of the biggest environmental challenges New York faces: what to do about the City's huge stream of food and green wastes; and how to meet its ambitious air quality and climate change goals.

The DEP's 75 anaerobic digesters today capture roughly 4 billion cubic feet per year of biogas, a mix of methane, carbon dioxide, trace amounts of other compounds, and moisture. A portion of this biogas, which is emitted by organic wastes as they break down, is then burned on-site in boilers or combined heat and power (CHP) units to provide electricity and heat to the facilities. But the surplus gas—roughly 70% of the total gas produced across DEP's system – is flared with no financial or environmental benefit to the city.

The biogas captured by DEP's digesters could be put to much better use. Instead of going to waste facilities and imposing costs, they could leverage savings, generate new revenue, and help cut New York City's huge stream of food and green wastes; and meet its ambitious climate and air quality goals. Here's how:

- **Virtually all flaring of biogas from the DEP digesters could be eliminated if the gas were refined to remove carbon dioxide (CO2), impurities, and moisture, and processed into renewable natural gas (RNG)**. RNG is an ultra-low-carbon fuel chemically-similar to fossil natural gas (CH4 which consists of one carbon atom and four hydrogen atoms), and it is usable in all the same ways that fossil gas is used today. It can generate power, heat buildings or power vehicles. As a transportation fuel, it can displace petroleum (primarily diesel) in heavy-duty vehicles (buses, trucks, ferries, etc.) equipped with the sophisticated natural gas engines that have been developed over the last 30 years.

- Citywide, DEP estimates that under different operating scenarios, depending on infrastructure upgrades and the feedstocks or waste inputs, **its WRRFs could produce between 2.4 million and 3.6 million MMBTUs of RNG annually**. That's 16% to 27% of the fossil natural gas that the City currently purchases, based on data from the Department of Citywide Administrative Services (DCAS) for fiscal year 2021.

- **This amount of RNG could displace over 25 million gallons of diesel fuel — more than enough to power all 6,000 heavy-duty trucks In New York City's municipal fleet**. Running these trucks on RNG instead of diesel would eliminate the more than 175,000 tons of greenhouse gas emissions, more than 90% of health-threatening nitrous oxide (NOx) emissions, and 60% of particulate (PM) emissions.

- DEP could realize significant revenue and cost savings as well as environmental gains by implementing the "gas-to-grid" and "co-digestion" model piloted at Newtown Creek across more of its plants. Conservatively estimated, **DEP could generate between $48 and $72 million dollars a year by implementing the Newtown Creek model more widely**.

- **DEP could make a significant contribution toward** meeting New York City's environmental and waste reduction (landfill diversion) goals and hitting the State's GHG emissions targets set by the CLCPA. **By replicating the Newtown Creek model at other large wastewater plants, DEP could process more than 30% of the city's food waste and reduce GHG emissions the city generates by more than 600,000 tons per year**.

- **DEP has the potential to realize significant revenue/cost-savings** by implementing co-digestion and the "gas-to-grid" model and selling RNG into compliance or voluntary markets. It also has the opportunity to contribute significantly to meeting New York City's emissions reduction goals by supplying RNG to municipal and other hard-to-decarbonize buildings. These, and other beneficial outcomes, can be achieved by upgrading the City's WRRFs and making sure the biogas they produce is actually used rather than flared.

- **The macro-level cost savings and income that upgrading WRRF infrastructure would produce are significant, but so are the upfront investments required**. Energy Vision is conducting research to specify upfront costs and possible sources of funding, including public-private partnerships.

- **The outlook on financing anaerobic digester projects is positive**. A strong, rapidly expanding industry specializing in providing anaerobic digestion system design, construction, and operational services has developed over the last decade. Meanwhile the private capital market has become increasingly interested in renewable energy generating critical infrastructure, including anaerobic digestion projects. Prioritizing public-private partnerships (P3) is an avenue worth pursuing in NYC.

- **Financial incentives in the 2022 Inflation Reduction Act make investing in WRRFs and other municipal infrastructure more attractive and compelling than ever. It provides a 30% or greater direct-pay tax credit and ongoing financial incentives for clean fuel production and use**. These incentives are a once-in-a-generation opportunity, and NYC and DEP are uniquely positioned to take advantage of them. But time is of the essence, with only a short window to qualify.

While implementing the gas-to-grid model on a city-wide scale will not happen overnight, the Newtown Creek project is a good example of what's possible. **With appropriate planning and ongoing support from DEP and City Hall, New York City is in a position to become a national leader in this exciting field**.

The NYC DEP's Newtown Creek WRRF is home to one of the most innovative municipal infrastructure projects in the country.

II. THE DEP's GROUNDBREAKING NEWTOWN CREEK PROJECT

DEP's "Gas-to-Grid" Model

The Newtown Creek WRRF in northern Brooklyn – the largest plant in NYC and one of the largest in the country – processes 310 million gallons of wastewater a day generated by a million New Yorkers in Manhattan, Brooklyn, and Queens.

It is the first WRRF in New York City to adopt the "gas-to-grid" model, where biogas produced at a WRRF is refined into RNG and injected into the existing natural gas pipeline system, so it becomes part of the energy grid. Newtown Creek is DEP's most up-to-date and most visible facility. Its eight iconic metallic digester eggs are part of the city's skyline. Inside these sealed tanks, biosolids (or "sludge") from the wastewater treatment process decompose under oxygen-free (anaerobic) conditions. Newtown Creek has also begun to accept some food waste for "co-digestion" with the wastewater sludge.

"Co-Digestion" of Food Waste

Waste Management (WM), the largest waste company in the US, is one of DEP's partners in the Newtown Creek project. WM processes food waste at its Brooklyn transfer station, turning it into a slurry. It then delivers the slurry to the WRRF, where it is fed into the digester eggs. The plant has the capacity to process up to 500 tons of city food waste a day, or 8% of the city's total food waste. Newtown Creek's capacity to process food waste is all the more important since Mayor Adams recently announced that New York will expand organics collection citywide.

The second DEP project partner is the gas utility National Grid. At the back end of the digestion process, National Grid has installed "biogas upgrading" technology to convert the raw biogas to pipeline quality RNG.

The facility employs "pressure swing adsorption" (PSA) technology which removes CO2 and other impurities, yielding 95+% pure methane, or RNG. The RNG can be used in all the same ways fossil natural gas is used, but with much lower lifecycle emissions. At present, it is being injected into existing natural gas pipelines and delivered to over 5,000 National Grid residential customers in Brooklyn. With this system online, Newtown Creek will no longer be flaring biogas, all but eliminating air pollution at the site.

One other DEP facility, Hunts Point in the Bronx, is in the early stages of upgrades that should enable it to replicate this "gas-to-grid" model. In the years ahead, it is possible that other WRRFs could adopt it as well. , For example, one proposal that deserves consideration is that if DEP were to build a state-of-the-art WRRF on Riker's Island, it could incorporate gas-to-grid capability.

As New York City expands its organics collection citywide, the DEP's WRRF infrastructure could play a critical role in the local processing of food waste, making important, beneficial use of this energy resource.

III. WRRF BIOGAS PRODUCTION POTENTIAL AND GREENHOUSE GAS REDUCTIONS

Calculating the energy value of the organic wastes processed at DEP's 14 WRRFs, Energy Vision estimates they could collectively generate 2.4 million MMBTUs. This equates to 18% of the natural gas consumed by New York City government operations in 2021.[1] Currently, however, DEP's WRRFs put only a fraction of this energy to productive use.

Note that the calculations in Table 2 below are based on the conditions of these facilities in 2019; i.e. without food waste processed in the digesters. Biogas production is largely determined by the proportion of solids present in the wastewater. In Table 2, the "thickened solids" column indicates the levels of solids present based on the plants' current processing technology.[2]

Table 2: Current DEP WRRF Biogas Production and RNG Potential
Source: NYC DEP (2019 data); Energy Vision calculations

2019 Conditions, Digestion of Biosolids Only				
WRRF	**Thickened Solids %**	**Current cubic feet (CF) biogas/day**	**Current cubic feet (CF) biogas/year**	**RNG Potential (MMBTU/year)**
Newtown Creek	6.0%	1,851,300	675,724,500	405,434.70
Wards Island	3.1%	1,559,790	569,323,350	341,594.01
North River	2.7%	1,229,070	448,610,550	269,166.33
Hunts Point	3.4%	1,012,830	369,682,950	221,809.77
Bowery Bay	3.0%	996,135	363,589,275	218,153.57
Owl's Head	2.5%	845,085	308,456,025	185,073.62
Jamaica	4.4%	809,310	295,398,150	177,238.89
Coney Island	3.9%	713,910	260,577,150	156,346.29
Tallman Island	3.3%	522,225	190,612,125	114,367.28
26th Ward	3.9%	415,800	151,767,000	91,060.20
Port Richmond	3.0%	348,210	127,096,650	76,257.99
Red Hook	3.0%	288,585	105,333,525	63,200.12

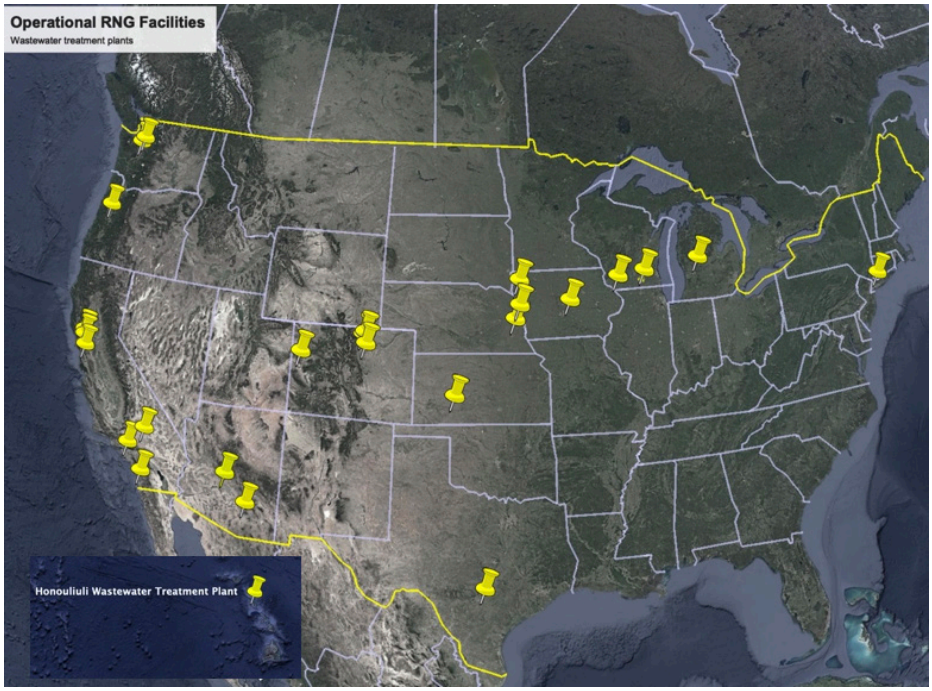
Oakwood Beach	2.8%	260,760	95,177,400	57,106.44
Rockaway	3.8%	109,725	40,049,625	24,029.78
TOTALS		10,962,735	4,001,398,275	2,400,839

The Biogas Challenge

While biogas can be used to directly heat and power WRRFs that generate it, it can't be used as-is to replace ordinary natural gas for offsite uses. It has to be refined first. This is because WRRF-derived biogas has low methane content relative to fossil gas. It contains large amounts of CO2, other chemical impurities, and moisture, making it inappropriate for standard natural gas boilers. Raw biogas is also corrosive, so it cannot readily be transported through natural gas pipelines for off-site use. This is why WRRF biogas that isn't used for onsite heating and power has generally been flared.

Various clean-up or upgrading technologies, including the kind used at Newtown Creek, can purify and refine waste-derived biogas into RNG. The process removes CO2, moisture, and other impurities, resulting in pipeline-quality RNG fuel that can then be transported offsite and substituted for fossil gas across multiple applications, making it accessible to multiple potential markets.

Many urban and suburban WRRFs across the country have the potential to adopt this "gas-to-grid" model and reap the benefits. But despite the anaerobic digestion industry growing especially rapidly in the last five years, WRRF adoption has lagged. To date only 26 WRRFs nationwide are producing RNG (see map below), and few of those projects are as large as Newtown Creek.[3] Yet conservative projections from both government and industry sources estimate there are hundreds of WRRF sites large enough to consider adopting the gas-to-grid approach and producing RNG.



The 26 Operational WRRF RNG Facilities in the US (2022 Data)

WWT Facility	Facility City	State
91st Avenue, Phoenix	Phoenix	AZ
Tres Rios Wastewater Reclamation Facility	Tucson	AZ
City of San Mateo Wastewater Treatment Plant	San Mateo	CA
Ellis Creek Water Recycling Facility	Petaluma	CA
Las Gallinas Valley Sanitary District	San Rafael	CA
Los Angeles County Sanitation Districts Joint Water Pollution Control Plant	Carson	CA
Point Loma Wastewater Treatment Plant	San Diego	CA
Victor Valley Wastewater Reclamation Authority	Victorville	CA
Longmont Wastewater Treatment Plant	Longmont	CO
Persigo Wastewater Treatment Plant	Grand Junction	CO
City of Boulder WRRF	Boulder	CO
South Platte Water Renewal Partners	Englewood	CO
Honouliuli Wastewater Treatment Plant	Ewa Beach	HI
Des Moines WWTP	Des Moines	IA
Dubuque Water and Resource Recovery Center	Dubuque	IA
Sioux City WWTP	Sioux City	IA
Warrior Biogas Reuse Project	Dodge City	KS
Grand Rapids WRRF.	Grand Rapids	MI
Fremont WWTP	Fremont	NE
Lincoln, Nebraska Theresa Street WWTP	Lincoln	NE
Newtown Creek Wastewater Treatment Plant	Brooklyn	NY
Metropolitan Wastewater Management Commission, Eugene / Springfield	Eugene	OR
Dos Rios Water Recycling Center	San Antonio	TX
South Wastewater Treatment Plant (King County)	Renton	WA
Tacoma Central Wastewater Treatment Plant (Tideflats)	Tacoma	WA
Janesville Wastewater Treatment Plant	Janesville	WI

The Value of Converting Biogas into Renewable Natural Gas (RNG)

RNG is chemically similar to fossil natural gas, but it has much lower greenhouse gas (GHG) emissions than fossil natural gas on a lifecycle basis, i.e. including production, transportation, and end use. Understanding the difference in the two sources is critical. Fossil natural gas is extracted from geologic sources underground, which is itself a carbon-intensive process. Fossil natural gas is largely methane produced by anaerobic decomposition of ancient organic material – a remnant of the carbon cycle from millions of years ago. Left in the ground, this methane would do no harm to Earth's climate or ecosystems. But bringing it to the surface and burning it generates CO2 and other GHGs, adding carbon to the atmosphere that was previously sequestered, throwing off the planet's fragile "carbon balance."[4]

The methane biogases from which RNG is derived relate to the atmosphere and Earth's ecosystems in the opposite way. They are captured from above-ground sources of decomposing organic wastes such as food waste, "green" waste, agricultural manures or wastewater. This methane requires no extraction. If these sources of methane are ignored, instead of being trapped and contained, they would escape into the air, warming the climate. And methane is an especially powerful warming agent, with a global warming potential (GWP) over a 20-year timeframe 84-86 times higher than that of CO2.

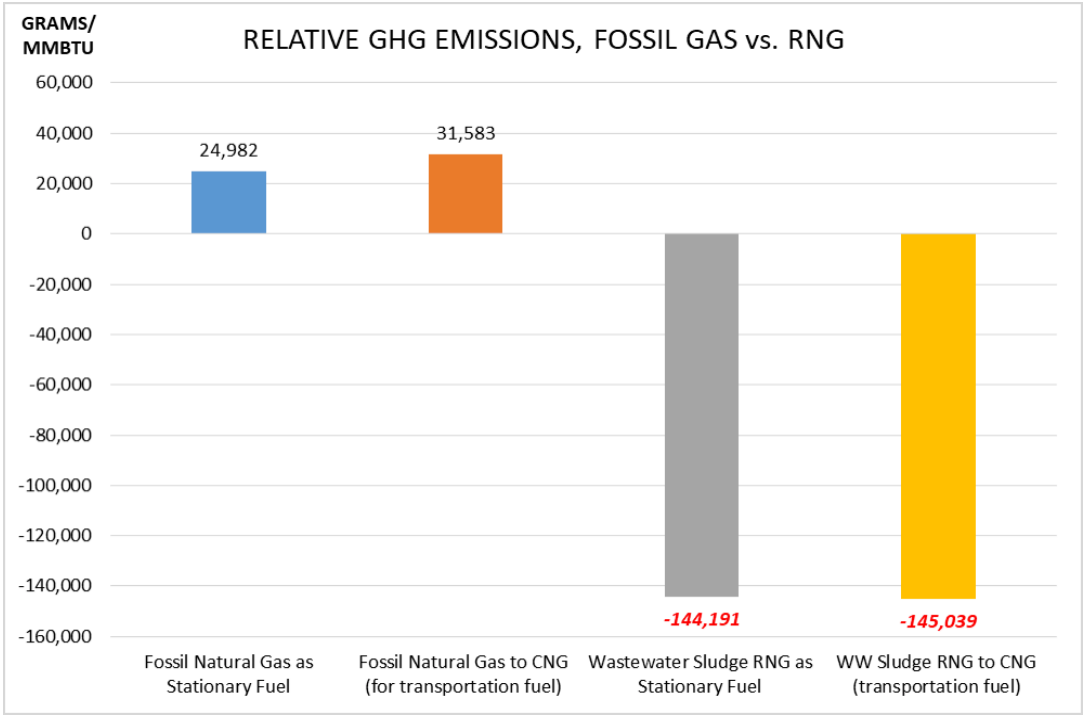
But if methane biogases are captured, they can be used in ways that not only don't harm the climate, but can actually benefit it. RNG made from wastewater sludge is often classified as "net carbon-negative," because producing the fuel captures more GHG (in this case methane) than using it emits (combusting the methane converts it to CO2 which has a far lower warming effect). This is a big net gain for the climate.

Lifecycle Greenhouse Gas Emissions from Fossil Fuel vs. RNG

"Lifecycle carbon accounting" is the one method of evaluating the impact of an energy source that considers its whole impact, from the point of production all the way through end use. Recognizing this, the Inflation Reduction Act of 2022 (IRA) mandates that all fuels/technologies be assessed on a lifecycle basis using the US Department of Energy's Argonne National Laboratory "GREET" (Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation) model.[5] Only fuels achieving a 50% or greater lifecycle GHG reduction compared to a petroleum baseline are eligible for the full suite of tax credits and other incentives in the IRA.

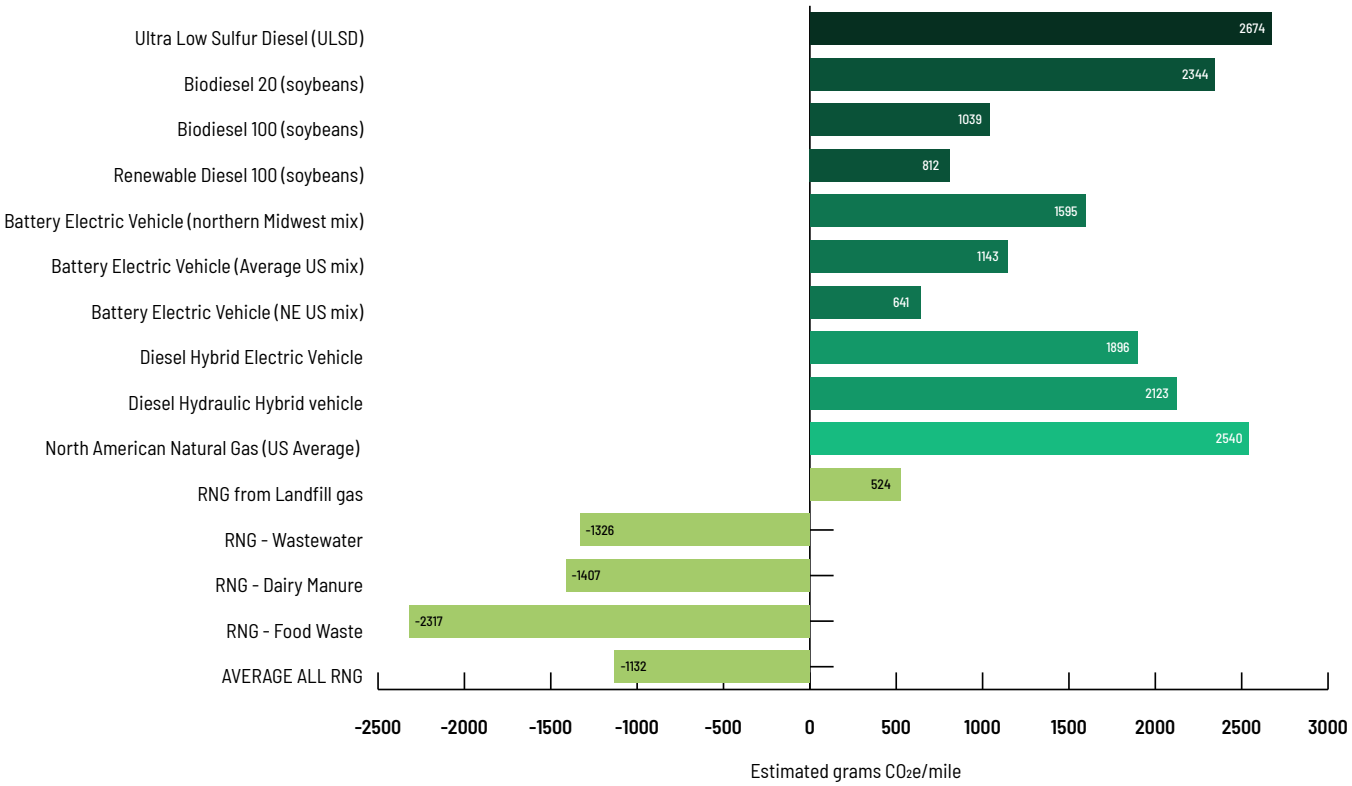
The chart below uses the GREET model to calculate and compare the relative lifecycle emissions of fossil natural gas and RNG made from wastewater sludge, considering two different applications: using it onsite as a stationary fuel vs. using it as a transportation fuel.

Comparative "Lifecycle" Greenhouse Gas Emissions – WRRF RNG vs. Fossil Gas
Source: Argonne GREET (2022)



The following chart compares lifecycle greenhouse gas emissions (also using the GREET model) of petroleum-based and alternative fuels used in the transportation sector. RNG is the lowest carbon commercially available option, since it can both reduce methane emissions at their source and displace fossil fuel consumption downstream.

Comparative Lifecycle GHG Emissions of Various Transportation Fuels
Source: Derived from Argonne GREET (2022)



IV. FIVE RENEWABLE NATURAL GAS PRODUCTION SCENARIOS

DEP is considering implementing the Newtown Creek "gas-to-grid" model across its WRRF system. Extensive renovation and expansion are underway at DEP's Hunts Point facility in the South Bronx, and DEP anticipates it could be the next WRRF to co-digest food waste, convert biogas to RNG, and inject it into gas pipelines to eliminate flaring of excess biogas. All DEP's WRRFs require upgrades to varying degrees. DEP is working with National Grid and Con Edison to identify which ones would be the best candidates for adopting the gas-to-grid model.

How much RNG a WRRF can produce depends on various factors, including the overall state of repair of the plant; whether food waste is being co-digested; and whether planned upgrades to solids handling equipment have been made.

The 26th Ward WRRF in Brooklyn

DEP laid out five different scenarios (A through E, below) that represent different combinations of these factors. Scenario A estimates RNG production potential of DEP's WRRFs under 2019 conditions, assuming digestion of wastewater (biosolids) only. This is the baseline to which other scenarios are compared.

Scenarios B through E estimate future potential RNG production, varying according to what upgrade investments are made, what technology enhancements are installed, and whether food waste is co-digested:

- **B**: production from **biosolids only** under a state of good repair for all facilities
- **C**: production from **biosolids only** under a state of good repair that includes new thickening technology (gravity belt thickeners) raising total solids content to 6%
- **D**: production from **co-digestion of biosolids and food waste** under a state of good repair
- **E**: production from **co-digestion of biosolids and food waste** under a state of good repair that includes gravity belt thickeners raising solids content to 6%

Scenario A: 2019 Conditions, Biosolids Only (Baseline)

Under baseline Scenario A, RNG is produced from biosolids only. Assuming a state of good repair for all facilities, total RNG output would be equal to 16.2% of the fossil natural gas purchased for NYC government

operations in FY 2021, and worth roughly $17.5 million in annual cost savings via fossil fuel displacement (commodity only) excluding sale or monetization of "environmental attributes."[6]

Table 3: RNG Production Based on 2019 Biogas Levels ("Scenario A")
Source: NYC DEP data; Energy Vision calculations

Based on 2019 Conditions, Using Biosolids Only			
WRRF	**Total Solids %**	**Total Annual Biogas MMBTU @600 BTU/CF**	**RNG MMBTU (Assumes 10% CH4 loss)**
Newtown Creek	6.0%	405,435	364,891
Wards Island	3.1%	341,594	307,435
North River	2.7%	269,166	242,250
Hunts Point	3.4%	221,810	199,629
Bowery Bay	3.0%	218,154	196,338
Owl's Head	2.5%	185,074	166,566
Jamaica	4.4%	177,239	159,515
Coney Island	3.9%	156,346	140,712
Tallman Island	3.3%	114,367	102,931
26th Ward	3.9%	91,060	81,954
Port Richmond	3.0%	76,258	68,632
Red Hook	3.0%	63,200	56,880
Oakwood Beach	2.8%	57,106	51,396
Rockaway	3.8%	24,030	21,627
TOTALS		2,400,839	2,160,755

Scenario B: 2050 State of Good Repair, Biosolids Only

In Scenario B, RNG is produced from biosolids only. All facilities are assumed to be in a state of good repair, and new thickening facilities and basic infrastructure upgrades are installed, resulting in energy production increases ranging from 1% (Oakwood Beach) to 30% (Red Hook). Energy production across the system would increase 10%, and total output would be equal to nearly 18% of the fossil natural gas purchased for NYC government operations in FY 2021, and worth $24.4 million in annual cost savings via fossil fuel displacement.

Table 4: Gas Production "Scenario B"
Source: NYC DEP data; Energy Vision calculations

2050 Conditions – Average Flow, Biosolids Only				
Plant	**Total Solids %**	**RNG MMBTU (Assumes 10% CH4 loss)**	**2019 RNG MMBTU**	**Change vs. 2019**
NC+BB	6.0%	668,084	561,229	19%
Wards Island	3.1%	345,981	307,435	13%

North River	2.7%	251,965	242,250	4%
Hunts Point	3.4%	230,071	199,629	15%
Owl's Head	2.5%	179,589	166,566	8%
Jamaica	4.4%	138,786	159,515	-13%
Coney Island	3.9%	149,016	140,712	6%
Tallman Island	3.3%	105,532	102,931	3%
26th Ward	3.9%	90,299	81,954	10%
Port Richmond	3.0%	74,116	68,632	8%
Red Hook	3.0%	74,116	56,880	30%
Oakwood Beach	2.8%	51,709	51,396	1%
Rockaway	3.8%	22,277	21,627	3%
TOTALS		2,381,543	2,160,755	10%

Scenario C: 2050 State of Good Repair, 6% Total Solids, Biosolids Only

Scenario C assumes overall good repair across all facilities, plus installation of thickening technology (gravity belt thickeners) that increase solids content to 6%. This would raise energy production relative to Scenario A anywhere from 3% (Rockaway and Tallman Island) to 35% (Red Hook), with a 12% gain in output systemwide, and total output equal to slightly more than 18% of the fossil natural gas purchased for NYC government operations for FY 2021. Savings would be roughly $24.8 million based on 2022 commodity pricing.[7]

Table 5: Gas Production "Scenario C"
Source: NYC DEP Data; Energy Vision calculations

2050 Conditions – Average Flow, Gravity Belt Thickeners, Biosolids Only				
Plant	**Total Solids %**	**RNG MMBTU (Assumes 10% CH4 loss)**	**2019 RNG MMBTU**	**Change vs. 2019**
NC+BB	6.0%	668,084	561,229	19%
Wards Island	6.0%	355,171	307,435	16%
North River	6.0%	261,583	242,250	8%
Hunts Point	6.0%	230,071	199,629	15%
Owl's Head	6.0%	186,366	166,566	12%
Jamaica	6.0%	144,023	159,515	-10%
Coney Island	6.0%	148,527	140,712	6%
Tallman Island	6.0%	105,532	102,931	3%
26th Ward	6.0%	90,299	81,954	10%
Port Richmond	6.0%	76,838	68,632	12%
Red Hook	6.0%	76,991	56,880	35%

Oakwood Beach	6.0%	54,636	51,396	6%
Rockaway	6.0%	22,277	21,627	3%
TOTALS		2,420,398	2,160,755	12%

Scenario D: 2050 State Of Good Repair, Biosolids And Food Waste "Co-Digestion"

In Scenario D, co-digestion is added at the facilities highlighted below, which would result in energy production increases ranging from 79% (Newtown Creek, also processing Bowery Bay's sludge) to 178% (26th Ward). Systemwide gain in output would be 38%, and the total output would be equal to 22.5% of the fossil natural gas purchased for NYC government operations in FY 2021, with baseline annual savings of $30.6 million.[8]

Table 6: Gas Production "Scenario D"
Source: NYC DEP Data; Energy Vision calculations

2050 Conditions - Average Flow, Codigestion of Biosolids and Food Waste				
Plant	**Total Solids %**	**RNG MMBTU (Assumes 10% CH_4 loss)**	**2019 RNG MMBTU**	**Change vs. 2019**
NC+BB	6.0%	1,005,256	561,229	79%
Wards Island	3.1%	345,981	307,435	13%
North River	2.7%	251,965	242,250	4%
Hunts Point	3.4%	364,188	199,629	82%
Owl's Head	2.5%	179,589	166,566	8%
Jamaica	4.4%	138,786	159,515	-13%
Coney Island	3.9%	149,016	140,712	6%
Tallman Island	3.3%	105,532	102,931	3%
26th Ward	3.9%	228,008	81,954	178%
Port Richmond	3.0%	74,116	68,632	8%
Red Hook	3.0%	74,116	56,880	30%
Oakwood Beach	2.8%	51,709	51,396	1%
Rockaway	3.8%	22,277	21,627	3%
TOTALS		**2,990,541**	**2,160,755**	**38%**

Scenario E: 2050 State of Good Repair, 6% Total Solids, Biosolids And Food Waste

In Scenario E, facilities implementing co-digestion highlighted below also install technologies to raise their solids content to 6%, resulting in improvements in energy production relative to Scenario A ranging from 34% (26th Ward) to 288% (Hunts Point). Systemwide gain in output would be 65%, and total output would be equal to nearly 27% of the fossil natural gas purchased for NYC government operations in FY 2021, representing savings of $36.6 million.[9]

Table 7: Gas Production "Scenario E"
Source: NYC DEP Data; Energy Vision calculations

2050 Conditions - Average Flow, Gravity Belt Thickeners, Biosolids and Food Waste				
Plant	**Total Solids %**	**RNG MMBTU (Assumes 10% CH_4 loss)**	**2019 RNG MMBTU**	**Change vs. 2019**
NC+BB	6.0%	1,005,256	561,229	79%
Wards Island	6.0%	355,171	307,435	16%
North River	6.0%	261,583	242,250	8%
Hunts Point	6.0%	775,376	199,629	288%
Owl's Head	6.0%	186,366	166,566	12%
Jamaica	6.0%	144,023	159,515	-10%
Coney Island	6.0%	148,527	140,712	6%
Tallman Island	6.0%	105,532	102,931	3%
26th Ward	6.0%	362,951	81,954	343%
Port Richmond	6.0%	76,838	68,632	12%
Red Hook	6.0%	76,991	56,880	35%
Oakwood Beach	6.0%	54,636	51,396	6%
Rockaway	6.0%	22,277	21,627	3%
TOTALS		**3,575,528**	**2,160,755**	**65%**

Summary of Scenarios A through E

There is great potential at DEP to upgrade the biogas produced at WRRFs across its system to carbon-negative renewable natural gas (RNG), allowing surplus biogas to be made available for other uses and achieve environmental and economic benefits, rather than being flared. Reducing GHG emissions from DEP's WRRFs is a strategy aligned with New York City's own citywide and government-specific emissions reductions goals, as well as the goals of the 2019 Climate Leadership and Community Protection Act, now New York State's landmark climate law.

DEP's "gas to grid" model, co-digesting sludge with food wastes and upgrading the collected biogases into RNG fuel, has multiple potential benefits including:

- WRRFs can stop flaring surplus biogas, eliminating greenhouse gases and health-damaging criteria air pollutants. The latter is especially important since 12 of DEP's 14 WRRFs are located in or bordering on what the New York State Department of Environmental Conservation has designated as "potential environmental justice areas."

- WRRFs become a local option for processing New York City's abundant supply of food waste, helping the city move toward its target of zero waste to landfills by 2030 ("0x30"). In the case of Hunts Point, taking food waste from the neighboring Hunts Point Terminal Market would have the additional benefit of reducing pollution from refuse trucks servicing the market.

- The RNG generated will be carbon negative on a lifecycle basis, meaning that producing it prevents more emissions than come from using it, largely due to avoided landfill methane emissions.

- The City will receive revenue for its sale of pipeline-quality RNG to gas utilities, likely for both the commodity (molecules) and "environmental attributes" (e.g. compliance based and voluntary instruments valuing the carbon benefits) – see below.

- In addition to furthering high-priority City and State landfill diversion goals, leveraging existing WRRF infrastructure to "co-digest" food waste at WRRFs may also enable DEP to cover the operational and maintenance costs of the projects.

A table summarizing energy production across the various scenarios is shown below. Relative to the 2019 baseline, energy production increases anywhere from 10% when all WRRFs are in a state of good repair, to 65% when all facilities have received solids handling upgrades and take in food waste for co-digestion.

Table 8: Gas Production Scenario Summary
Source: NYC DEP Data; Energy Vision calculations

Summary of Scenario Energy Production			
Scenario	**RNG MMBTU (Assumes 10% CH4 loss)**	**2019 RNG MMBTU**	**Change vs. 2019**
Scenario A (2019 conditions)	2,160,755	N/A	N/A
Scenario B (2050 GR, only biosolids)	2,381,543	2,160,755	10%
Scenario C (2050 GBT, only biosolids)	2,420,398	2,160,755	12%
Scenario D (2050 GR, Biosolids + food waste)	2,990,541	2,160,755	38%
Scenario E (2050 GBT, Biolids + food waste)	3,575,528	2,160,755	65%

V. ADVANCING TOWARD NEW YORK'S CLIMATE CHANGE AND WASTE REDUCTION GOALS

New York City and State have set ambitious climate and clean energy goals over the past decade. They include:

- Reducing emissions from City Government operations 40% by 2025 and 50% by 2030, against a 2005 (FY 2006) baseline (3.87 MMT CO2e);[10]

- Reducing citywide emissions 40% by 2025, 50% by 2030 and achieving carbon neutrality by 2050, against a 2005 baseline (65 MMT CO2e).[11]

Towards achieving these goals, the City passed Local Law 97 (2019), mandating carbon emission reductions from residential and commercial buildings over 25,000 square feet in area. The City is also seeking to divert its waste from landfills in alignment with Mayor de Blasio's Zero by Thirty (zero waste to landfill by 2030) initiative.

In addition to these emissions reduction goals, NYC must also comply with the 2019 **Climate Leadership and Community Protection Act (CLCPA)** New York State's flagship climate legislation which now mandates an economy-wide 85% reduction in GHG emissions from a 1990 baseline by 2050. More broadly, EPA has set a national goal of cutting methane emissions, one of the most potent greenhouse gases, 30% by 2030.

The Role of RNG in Achieving NYC's Emissions Reduction Goals

Capturing methane-rich biogas from New York City's WRRF's and co-digesting food waste at some of these facilities can have a meaningful impact in achieving the City's climate goals. Table 9 below summarizes the contribution of the different RNG production scenarios to the emissions reduction goals for City Government operations.[12] It shows emissions that would be produced by getting the energy from RNG versus fossil natural gas. Under the most ambitious scenario whereby NYC's WRRF infrastructure is fully utilized to process food scraps and other organic waste, the RNG produced would reduce GHG emissions by more than 600,000 tons a year and take NYC almost totally to its short-term climate goal. It would also align with the federal EPA goal of cutting methane emissions 30% by 2030.

Table 9: The RNG Scenarios and City Government Emissions Reduction Goals
Source: NYC DEP Data; Energy Vision Calculations

	SCENARIOS, EMISSIONS REDUCTIONS & CONTRIBUTION TO CITY GOVERNMENT GOALS				
	A: 2019 Conditions	**B: 2050 GR, Biosolids**	**C: 2050 6% Solids, Biosolids Only**	**D: 2050 GR, Biosolids + Food Waste**	**E: 2050 6% Solids, Biosolids + Food Waste**
RNG Potential (mmbtu)	2,160,755	2,381,543	2,420,398	2,990,541	3,575,528
Fossil Gas Emissions	53,980	59,496	60,466	74,710	89,324
RNG Emissions	-311,561	-343,397	-349,000	-431,209	-515,559
Emissions Reduction	365,541	402,893	409,466	505,919	604,883
Contribution Toward 2050 NYC Gov't Target	9.5%	10.4%	10.6%	13.1%	15.6%

VI. MARKETING RNG GENERATED AT DEP FACILITIES

Overall, Energy Vision's research has found that DEP is well positioned to capitalize on the environmental and economic value of its WRRF infrastructure – given the necessary planning and investments – by tapping its substantial biogas resource.

By co-digesting food waste and producing RNG, DEP has the opportunity to reduce its own emissions by eliminating on-site combustion and flaring, as well as to divert food waste from landfills. It can reduce the associated methane emissions and beneficially reuse them to produce energy in the form of RNG. The DEP can sell that RNG into a range of local and national end-use markets to generate a valuable revenue stream while advancing toward achieving ambitious climate goals.

The flares at Newtown Creek (seen here) will no longer burn off unused biogas with the implementation of the innovative "gas-to-grid" model.

In addition to cost-recovery from co-digestion and revenue from RNG sales, the City could also generate revenue in the form of "saleable credits" if it chooses to sell its RNG in one of the following ways:

- DEP could sell this RNG into the transportation-focused "compliance" markets that were created by US EPA through its Renewable Fuel Standard (RFS), which requires petroleum producers and refiners to produce or purchase increasing volumes of renewable, low-carbon transportation fuel(s).

- DEP could also sell its RNG to fleets in the states that have created "Low Carbon Fuel Standards" (Oregon, Washington, and California), where fuel producers and vehicle fleets have a strong economic incentive to make or use non-petroleum transportation fuels, including RNG. (New York is considering its own Clean Fuel Standard which would create a major incentive to utilize this fuel locally.)

- DEP could consider selling its RNG into "voluntary" (non-transportation) markets where displacing fossil natural gas or other higher-carbon fossil fuels for thermal (stationary) applications is a growing challenge and priority. A number of major corporate and government entities have begun procuring RNG to help meet ambitious climate and sustainability targets (see p. 21).

- Finally, with enabling policy and regulation, DEP could sell into the local gas distribution market for use by residential and commercial natural gas customers. An example: in February (2022), California's Public Utility Commission (CPUC) voted unanimously to approve a renewable gas standard (effectively a Renewable Portfolio Standard for RNG), setting by far the most ambitious RNG procurement program in the country, equating to as much as 12% of California's residential and commercial natural gas de-

mand to be met by RNG by 2030. The pros, cons, mechanics, and potential revenues of participation in these markets are complex and are discussed further below. They both represent substantial economic upsides (see table below for indicative RNG value).

Table 10. Indicative DEP Revenue Potential Based on RNG Scenarios A-E

Scenario	Biogas Production (cubic feet/yr)	RNG Potential (MMBTU)	Transportation Market RNG Value	"Voluntary" RNG Value
Scenario A (2019 conditions)	4,001,398,275	2,160,755	$48,812,536	$38,893,590
Scenario B (2050 GR, only biosolids)	4,410,264,012	2,381,543	$53,800,237	$42,867,766
Scenario C (2050 GBT, only biosolids)	4,482,219,220	2,420,398	$54,678,010	$43,567,171
Scenario D (2050 GR, Biosolids + food waste)	5,538,038,894	2,990,541	$67,557,817	$53,829,738
Scenario E (2050 GBT, Biolids + food waste)	6,621,348,037	3,575,528	$80,772,964	$64,359,503

An additional RNG market may also develop in New York City. Under Local Law 97 of 2019, NYC buildings over 25,000 square feet will be regulated beginning in 2024 and will be fined for each ton of carbon dioxide equivalent (CO2e) emissions in excess of their limit. Buildings that are "difficult to electrify" are potential buyers of the RNG DEP produces, as well as a potential market for credits generated by DEP for its RNG production, purchase of which could be used as an alternative form of compliance with LL97 emissions limits. Based on available benchmarking data, there are nearly 3,100 residential, commercial, and municipal buildings that have not achieved the emissions thresholds that will apply from 2024 to 2029, and over 14,000 that have not achieved the 2030 to 2034 thresholds.

High-Value Transportation Markets

The *Renewable Fuel Standard*, administered by the US EPA, has been the primary driver for RNG project development. The credits generated under this program (called RINs) create significant value for producers of RNG, but participation requires that RNG be delivered – directly or via pipeline – to vehicles equipped with advanced natural gas engines.

Use of RNG in natural gas vehicles — including the MTA's more than 700 natural gas buses — is an eligible use under the federal RFS program

Relying on these credits comes with both legislative and market risk. If the RFS program were to be abolished or appreciably amended by Congress, it would create significant negative financial impacts. RINs' value has fluctuated significantly over the past eight years. Given these risks, it is difficult to secure long-term contracts to sell RNG (called "offtake" agreements) into the high-value transportation market. However, those that have gotten comfortable enough with these risks to do so have done very well financially. The most common approach to hedge against these risks is to sell only a portion of RNG from a given project or portfolio into the transportation market (e.g. 30%), and to lock in the balance of the volume in lower-value, long-term/fixed price offtake arrangements.

A *Low-Carbon Fuel Standard (LCFS)* is a state-level, technology-agnostic market-based program, to date implemented by California, Oregon and Washington. It pegs all transportation fuels sold in the state for transportation use to a "carbon intensity" target benchmark. All fuels that come in below that target (containing less carbon) are net-generators of credits; all fuels that are above the benchmark (containing more carbon) – namely petroleum-derived gasoline, diesel and kerosene – are net generators of deficits. The value (or cost, as is the case with petroleum fuels) ascribed to a particular fuel is related directly to its lifecycle carbon intensity and the volume of fuel being consumed in the transportation market in that jurisdiction. One LCFS credit is generated for each metric ton of carbon dioxide equivalent (CO_2e) reduced.

Unlike the RFS, where each qualified fuel producer generates a certain type of RIN credit with inherent value, under an LCFS, each facility/project has its own unique CI score that determines the number and value of credits generated. For RNG, landfills generally have the highest CI score (~50). Anaerobic digesters processing wastewater, food waste or livestock manure are all net-carbon-negative, per Argonne GREET (see chart, pg. 11), so they have very low CI scores. As such, digester RNG projects can generate significant value under an LCFS program beyond RINs and the physical commodity itself. This can help offset the high initial capital costs.

California, Oregon and Washington are currently the only states with LCFS programs, but projects anywhere

in the continental US can sell low-carbon fuel(s) into these markets. Much like the RFS, doing so requires registration and third-party validation/auditing. It's very important to note that selling into an out-of-state LCFS market will almost certainly preclude the seller from claiming carbon reduction benefits, because the fleet end-user in the LCFS state would be entitled to claim them.

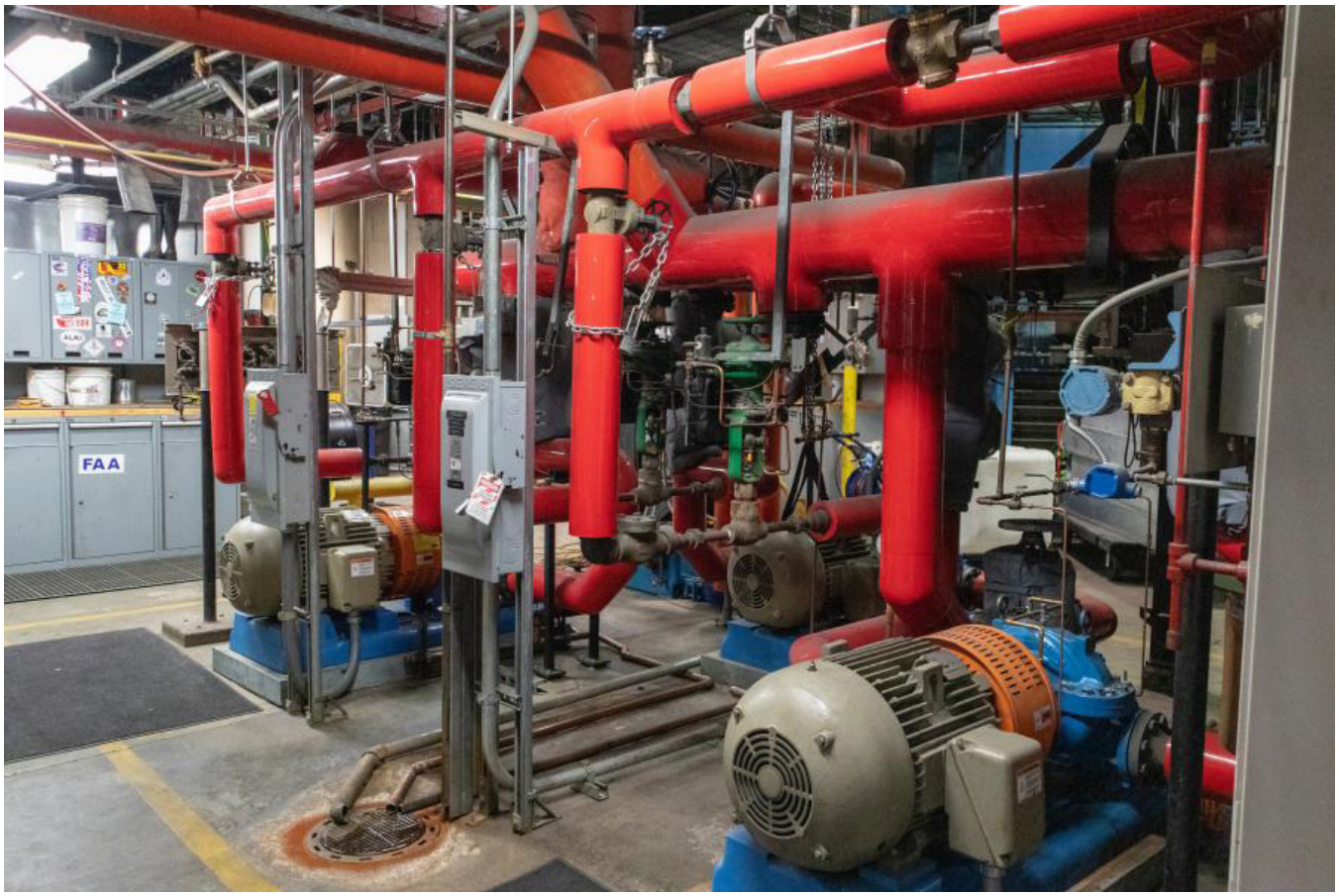
For some entities, the additional economic value is the major driving force that tips the scales in favor of participating in an LCFS market. It seems unlikely this will be the case for DEP. With impending compliance issues around Local Law 97 and the CLCPA, and a strong desire to realize RNG's benefits locally, selling to LCFS markets is likely only an option for DEP if New York adopts its own LCFS program.

Emerging Non-Transportation Markets

High value transportation markets have been the major driving force in the exponential growth of US RNG production over the past decade. However, there is growing interest – especially among institutionally-based RNG producers – in pursuing longer-term, fixed-price off-take arrangements. To date, most of these contracts have been done on a bilateral basis, which is to say there isn't yet a robust voluntary market for RNG.

Nonetheless, more and more corporate and public entities are exploring this option as a means of reducing demand for fossil natural gas without disrupting operations or retrofitting infrastructure. Natural gas utilities are similarly pursuing long-term (opt-in) voluntary procurement options for RNG, creating diverse end-use market options and associated premium pricing with reduced market or legislative risk.

While relatively few and far between to date, there are public and private entities that have entered or are willing to enter into long-term RNG off-take agreements for non-transportation (primarily thermal) applications. Some recent examples include cosmetics giant L'Oreal, the University of California, Middlebury College in Vermont, and the Port of Seattle, all of which have committed to long-term RNG procurement contracts between 10 and 25 years.



At Seattle Tacoma International Airport, RNG used in boilers provides more than 50% of the heat for its terminals

In addition to voluntary RNG procurement, a growing number of gas utilities are starting to develop voluntary "green gas" tariffs where commercial or residential customers have the option to pay a premium for RNG. The first to gain regulatory approval was Vermont Gas in 2016, and others have since followed suit. The largest and most successful to date is SoCalGas, which filed a petition with the California Public Utilities Commission (CPUC) requesting authority to offer RNG to residential and commercial (non-fleet) customers. In February, the CPUC unanimously approved the program which gives SoCalGas and the other investor-owned gas utilities regulatory approval to procure up to 12% of total utility natural gas from in-state biogas sources by 2030 and anticipated pricing in the $17-27/MMBT range. Utilities in other jurisdictions, including CenterPoint in Minnesota, Xcel in Colorado, and National Grid (NY/MA) are exploring/pursuing similar programs.

RNG Project Case Studies

On-road compliance-based transportation markets (RFS + LCFS) continue to drive investments and growth in RNG demand as much or more than any other factor. There are now hundreds of public and private fleets procuring and using RNG in natural gas vehicles. Outside California, fleet owners/operators can generally expect to retain or obtain a share of the RIN revenue, depending on volumes and contract term(s). For reference, D3 RINs were trading near $3.50 in 2022; there are 11.7 RINs per MMBTU; there are ~7 diesel gallon equivalents per MMBTU. By giving fleets a small portion of RIN revenue, RNG producers allow fleet end users to enjoy a healthy fuel discount on the order of $0.35/gallon.

On the supply side, there are numerous RNG producers making their fuel from a range of feedstocks, bought from a variety of entities (public or private) large or small. Table 11 below shows 2021 RNG projects by feedstock type in comparison to 2020 totals. Landfill gas and agricultural (dairy/swine manure) projects still dominate

the RNG market, both in terms of total facilities and volume of gas produced. Even so, the number of WRRF RNG projects has grown considerably since 2016 when Energy Vision first began tracking this data.

Table 11. RNG Projects by Feedstock (2021) & Production vs. 2020 Totals
Energy Vision Research

RNG Source	Number of Operating Projects	RNG Production (MMBTU)
Food Waste	13	3,872,391
Landfills	76	53,394,825
Livestock, agriculture	115	14,457,908
WRRFs	26	2,125,823
2021 Totals	**230**	**73,850,947**
2020 Totals	**157**	**59,488,530**
% Increase (2021 vs. 2020)	**46.50%**	**24.14%**

On-road transportation end-use still dominates, with 80+% of all RNG producers sending at least a portion of their fuel to a combination of the RFS and LCFS markets. However, outside of agricultural digester RNG producers, there appears to be a growing trend to seek lower risk, longer term off-take arrangements, especially among landfill gas developers. For example, Archaea Energy, a large developer of landfill RNG projects, publicly stated – prior to its IPO and subsequent sale to BP – its goal of selling 70% of the RNG it produces to gas utilities or voluntary customers.

Here are some high-profile examples of fleets using RNG today:

Table 12. Prominent Fleets Using RNG
(Energy Vision Compilation)

FLEET	# of RNG buses/trucks	Source
MTA/NYCT	749	https://new.mta.info/system_modernization/sustainabletransit
UPS	6100	https://www.greenbiz.com/article/ups-buy-huge-amount-renewable-natural-gas-power-its-truck-fleet
LA Metro	2,250	https://www.socalgas.com/for-your-business/natural-gas-vehicles/Metro
Amazon	1,700	https://www.reuters.com/article/us-amazon-engines-natural-gas-exclusive/exclusive-amazon-orders-hundreds-of-trucks-that-run-on-natural-gas-idUSKBN2A52ML
Waste Management	11,000	https://sustainability.wm.com/downloads/WM_2022_SR.pdf
Republic Services	2,500	https://www.republicservices.com/blog/republic-services-keeping-it-clean-on-america-s-roads
Manhattan Beer	200	https://www.manhattanbeer.com/environmental-initiatives
Anheuser Busch	180	https://www.transportdive.com/news/anheuser-busch-renewable-natural-gas/583476/
PepsiCo/Frito Lay	700	https://www.pepsico.com/our-impact/esg-topics-a-z/fleet-efficiency

In addition to the transportation market, potential voluntary buyers of RNG (public or private entities) wanting

to decarbonize their buildings or operations and cut their greenhouse gas emissions are a quickly growing market. Examples include the University of California, The Port of Seattle, and numerous gas utilities.

The University of California, under the leadership of the Office of the President (UCOP), really paved the way for voluntary RNG procurement as a cost-effective way to reduce its own emissions. The University began purchasing landfill-derived RNG from a facility in Louisiana in 2013 and later acquired the project. By using its balance sheet, creditworthiness and willingness to commit to long-term (15-25 year) contracts, the University has steadily increased its RNG supply (from a number of suppliers) over the past decade. Today, it is certainly the largest buyer of "voluntary" RNG. Its efforts have been driven largely by an internal mandate that all UC schools be carbon neutral by 2025.[13]

The Port of Seattle (POS), following the University of California's lead, embarked on a similar journey in 2017. The Port approached Energy Vision to ascertain whether RNG supplies would be available, and if so, at what price, if it chose to procure "voluntary" RNG under a long-term, fixed-price contract. Our assessment clearly concluded that yes, there would be ample RNG supply, most likely available in the $12-15/MMBTU range. These findings combined with the Port's staff and board leadership led to a 2019 Request for Proposals (RFP), which resulted in a signed RNG off-take arrangement in 2020.

Unlike the University of California, the Port of Seattle actually had demand for natural gas as a transportation fuel from its roughly 30 natural gas-powered airport shuttle buses, which accounted for about 10% of the Port's total natural gas consumption. As a result, 10% of the RNG procured from third-party supplier US Gain has qualified for valuable D3 RIN credits. These credits mean that the fuel used in the airport shuttle vehicles is effectively free, or at times, even comes at a negative cost; i.e. the fleet operator is getting paid to consume RNG. The monetization of RINs for that portion of the gas also effectively brings down the cost for the other 90% directed to voluntary thermal applications.

Today, many **gas utilities** are seeking to use RNG. Their goal is to pursue regulations or government policies enabling them to deliver RNG to customers large and small. Vermont Gas Systems was the first utility in the country to implement a "green gas tariff," enabling customers who are willing to pay a premium to purchase RNG in different blends of (from 10% to 100%). As of 2022, there were 17 states with mandated or voluntary utility RNG procurement programs, and more states are considering adopting them.

In February (2022), the California Public Utility Commission (PUC) voted unanimously to approve **California's renewable gas standard**, setting by far the most ambitious mandated RNG purchasing program in the country. Under this initiative, California's investor-owned gas utilities will collectively procure up to 72.6 billion cubic feet (~72 million MMBTU) of RNG produced in the state by 2030. To put this in perspective, total national RNG production across all feedstocks and project types – as of 2022 – was just shy of 75 million MMBTU; in other words, California's RNG program is expected to nearly double national RNG production.

The program prioritizes RNG produced via anaerobic digestion using the 8 million tons of food scraps and green wastes generated in California that would otherwise be sent to landfills. By providing a stable, high-value market for this kind of RNG, California's renewable gas standard aims to stimulate significant investments of private capital in critical sustainable infrastructure projects. To meet its landfill diversion/organics recycling requirements, the State anticipates the need for up to 50 additional AD facilities – either stand-alone operations or involving WRRF co-digestion.[14]

A Growing Opportunity for Public Private Partnerships

Public-private partnerships (P3s) are collaborations between government agencies and private-sector companies that are used to finance, build, and operate public projects, including infrastructure. Financing a project through a P3 can allow for quicker project completion, or make a project possible that otherwise

could not have been built. Depending on how they are structured, P3s can require the government partner to make concessions to the private sector partner involving revenues, liability, or ownership rights.[15]

While P3s can be useful instruments for accelerating public works projects, they should be entered into carefully, with a thorough understanding of capabilities, expectations and terms on both sides.

VII. MOVING NEW YORK TOWARD A SUSTAINABLE FUTURE

There has never been a better time for municipalities, including New York City, to pursue urban infrastructure projects that help fight climate change and generate renewable energy. That's largely due to the passage of the 2022 Inflation Reduction Act (IRA) last August. The IRA is by far the largest investment by the federal government in clean energy, with $379 Billion allocated for climate-related infrastructure projects. That includes upgrades and expansions to WRRFs, such that most WRRF RNG projects will qualify for a 30% (minimum) investment tax credit applicable toward total capital costs.

Unlike previous federal clean energy incentives, the IRA includes a "direct-pay" option for tax-exempt entities including municipal governments. NYC would be eligible for direct reimbursement of significant capital costs via the federal government. This incredibly attractive and lucrative Investment Tax Credit (ITC) incentive is available through December 31, 2024 (and beyond, provided certain progress milestones are met). Time is of the essence, especially given the complex nature and slow pace of infrastructure projects in NYC.

In New York private entities are expressing interest in partnerships that involve a much longer-term funding approach than in the past. This is an additional factor in favor of a P3 approach. Time horizons for P3 projects have grown from a decade or less to 20 or 30 years. That's long enough to commit to capital repayment over the entire lifespan of a WRRF RNG project .

A recent example of a P3 involving a WRRF producing RNG is the agreement between five Arizona cities, (Phoenix, Glendale, Mesa, Scottsdale and Tempe) known as the "sub-regional operating group," and private sector infrastructure company Ameresco on a renewable natural gas project at the 91st Avenue wastewater treatment plant in Phoenix. Under the agreement, Ameresco is responsible for designing, building, owning, operating and maintaining (DBOOM) the project, bringing its financial, technical and marketing/sales expertise to implement a large RNG project that will provide environmental and economic benefits to the five cities. Ameresco handles all of the gas upgrading, pipeline injection and RNG sales and marketing while the cities use their core competencies to operate the large WRRF.

The size, technical capabilities, and access to capital of a given municipality will determine the most appropriate P3 structure. For example, smaller municipalities are typically more suited for P3s where an Energy Services Company (ESCO) will handle all aspects of a project, including financing. For larger municipalities with greater in-house capabilities and access to inexpensive capital, there may be hybrid partnership models to consider that best leverage the public and private entities' greatest strengths.

Implementing the "gas to grid" model across DEP's WRRF system will involve numerous decisions about technology options to produce RNG, which attribute markets to enter, how to administer that participation, etc. With RNG operations under way at Newtown Creek and one under development at Hunts Point, DEP needs to determine which of its remaining WRRFs are the best candidates for moving forward with the gas-to-grid model. This involves evaluating the condition and potential capacity of each facility, the potential food waste resource that could be directed to them, and the cost of the necessary capital investment, including digester upgrades, necessary food waste processing and input, biogas upgrading equipment, and pipeline interconnection.

DEP is well-positioned to become a significant producer of RNG. The core infrastructure required – 75

anaerobic digesters fed by New York City's more than eight million residents – is already in place, though various equipment upgrades are required. Implementing "gas-to-grid" (RNG) projects at water resource recovery facilities is complex and requires many steps and considerations. But the complexities are much better understood now than they were a decade ago, when the Newtown Creek project was conceived. 26 WRRF RNG projects are operational nationwide today.

The most likely route for achieving upgrades across the system may rely on a well-crafted, public private partnership (P3) agreement with companies that can provide design/build/operate (DBO) services as well as access to the private capital markets. While there are multiple paths to realizing the potential of DEP's WRRF infrastructure, the passage of the IRA and expanding private sector expertise make this a uniquely opportune time to pursue this strategy in NYC. Doing so will maximize the utility and positive impacts – economic and environmental – of this critical urban infrastructure while also advancing ambitious City and State climate goals.

REFERENCES

[1] NYC DCAS, "Core Report Citywide Total from Heat/Light/Power Expenditures: Energy Cost, Usage, and CO2e Emissions," February 2022, https://www1.nyc.gov/assets/dcas/downloads/pdf/energy/ reportsandpublication/energycorerereport_2021.pdf

[2] *Historic DEP sampling and other research indicate that biogas produced at NYC WRRFs is "about 65% methane." To be conservative, we have assumed 60% methane content, meaning that a cubic foot of biogas contains 600 BTUs of energy. (In common shorthand, a cubic foot of fossil natural gas is considered to represent 1000 BTUs of energy.)*

[3] Derived from the Energy Vision-Argonne National Lab RNG Database (2021); https://www.anl.gov/esia/reference/renewable-natural-gas-database

[4] "Nature tends to keep carbon levels balanced, meaning that the amount of carbon naturally released from reservoirs [living organisms, the atmosphere, oceans, rocks, minerals] is equal to the amount that is naturally absorbed by [those] reservoirs. Maintaining this carbon balance allows the planet to remain hospitable for life. Scientists believe that humans have upset this balance by burning fossil fuels, which has added more carbon to the atmosphere than usual and led to climate change and global warming." National Geographic Society, "The Carbon Cycle," https://www.nationalgeographic.org/encyclopedia/carbon-cycle/

[5] Argonne National Laboratory GREET tool (Greenhouse gases, Regulated Emissions, and Energy use in Technologies), 2021 release, "RNG" tab, Table 3, using 20-year GWP; "NG" tab, Table 4, using 20 year GWP. The GREET Excel-based tool can be found at https://greet.es.anl.gov/. Transportation emissions shown for RNG are an average of on-site fueling and off-site fueling. The NG and RNG tabs do not have the same usage scenarios; personal communication with members of the ANL GREET team confirmed that the RNG tab's "as intermediate fuel" option was an appropriate proxy for the NG tab's "as stationary fuels" column.

[6] Ibid, based on averaged DCAS cost per MMBTU for fossil natural gas in FY 2021 and the first half of FY 2022 (July to December 2021).

7 Ibid.

8 Ibid.

9 Ibid.

10 Based on FY 2006 data downloaded from Mayor's Office of Sustainability, "Inventory of New York City Greenhouse Gas Emissions," https://nyc-ghg-inventory.cusp.nyu.edu/#about

11 2005 baseline of 65MMT CO2e, "Pathways to Carbon-Neutral NYC," page iv, note a. The "Pathways" report defines "carbon neutral" as "reducing emissions as much as possible and offsetting any unavoidable emissions with high-quality carbon offsets to bring net emissions to zero. Carbon offset projects should meet specific environmental integrity principles: unambiguously owned and independently auditable projects should result in real, additional, permanent, transparent, and measurable emissions reductions." Mayor's Office of Sustainability, ICF et al., "Pathways to Carbon Neutral NYC," April 2021, https://www1.nyc.gov/assets/sustainability/downloads/pdf/publications/Carbon-Neutral-NYC.pdf

12 Emissions values are in metric tons CO2e, based on Argonne National Laboratory lifecycle emissions coefficients shown in Figure 3, above, for stationary applications. "GR" = Good Repair

13 UCOP and most corporate buyers use WRI's GHG Protocol for carbon accounting. Under this rather archaic methodology, lifecycle carbon emissions are not included. Instead, any "biogenic" source of carbon or fuel classifies as "net-zero" emissions. In the case of RNG, this means landfill gas is treated the same as dairy or WRRF gas.

14 "CPUC Sets Biomethane Target for Utilities", Feb 24, 2022. https://www.cpuc.ca.gov/news-and-updates/all-news/cpuc-sets-biomethane-targets-for-utilities

15 Investopedia, "Public Private Partnerships," April 2022, https://www.investopedia.com/terms/p/public-private-partnerships.asp