ARLINGTON RE-GEN

Arlington County Water Pollution Control Plant

Biogas Utilization

Executive Summary

Updated February 2022

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Introduction

Arlington County (County) is implementing new biosolids management facilities at the Arlington County Water Pollution Control Plant (Plant). Arlington Re-Gen (Program) is part of the Arlington County Water Pollution Control Bureau's commitment to protecting public health and the environment, while recovering valuable resources with innovative processes that will also reduce our carbon footprint. This comprehensive biosolids program, adopted by the County Board in 2018, includes a new thermal hydrolysis process followed by anaerobic digestion as the main treatment processes. Thermal hydrolysis treats the biosolids under high pressures and temperature to break down the solids and remove pathogens. To achieve these high pressures and temperatures, steam boilers are required. Anaerobic digestion uses microbes to digest the solids in the absence of oxygen, which stabilizes and reduces the quantity of the biosolids, while also reducing odors of the finished product. These upgrades will produce a high quality marketable biosolids product.

Biogas, comprised of approximately 60% methane and 40% carbon dioxide, is also a product of the digestion process. Beneficial use of the biogas can have a significant impact on the County's sustainability goals, as it is estimated to have an energy content of 120 billion British thermal units (Btu) per year and the capability to reduce greenhouse gas emissions by up to 3,500 metric tons per year.

The objective of this gas utilization evaluation is to look at all feasible alternatives for the beneficial use of the biogas to assist in meeting Arlington County's sustainability goals while also reliably meeting the Plant's heating (steam generation) and electrical needs. Monetary, non-monetary, and sustainability evaluations were completed to determine the recommended alternative for the County.

Overall Biogas Recommendations

Based on the analyses presented below, the Arlington County Water Pollution Control Bureau recommends proceeding with the production of renewable natural gas (RNG) as the selected biogas utilization approach. The basis for this recommendation is as follows:

- The RNG alternatives have the lowest net present value (i.e., lowest total cost to the County over the life of the equipment) for the baseline conditions using conservative capital and operating costs.
- Injecting RNG into the local utility pipeline scored the highest in the County's non-financial scoring. In particular, the County found that the RNG alternatives would be less complex to maintain and would result in fewer localized impacts

such as noise and emissions than the combined heat and power (CHP) alternatives.

- A sensitivity analysis concluded that when considering multiple variables, including RIN market volatility and changes in electrical rates, injecting RNG into the local utility pipeline had a very high likelihood of being more financially advantageous than generating electricity through CHP.
- The County has the ability to retain greenhouse credits if the biogas is used within Arlington County. With electricity for County operations projected to be 100 percent renewable by 2025, it is likely that the CHP alternatives would not result in any GHG reduction through electricity offsets.
- Benefits of on-site CHP are limited because the CHP size would not be sufficient to power the entire Plant, which is already protected with two independent power feeds and backup generators.

Biogas Utilization Alternatives

The range of feasible alternatives includes using the biogas for one or a combination of the following:

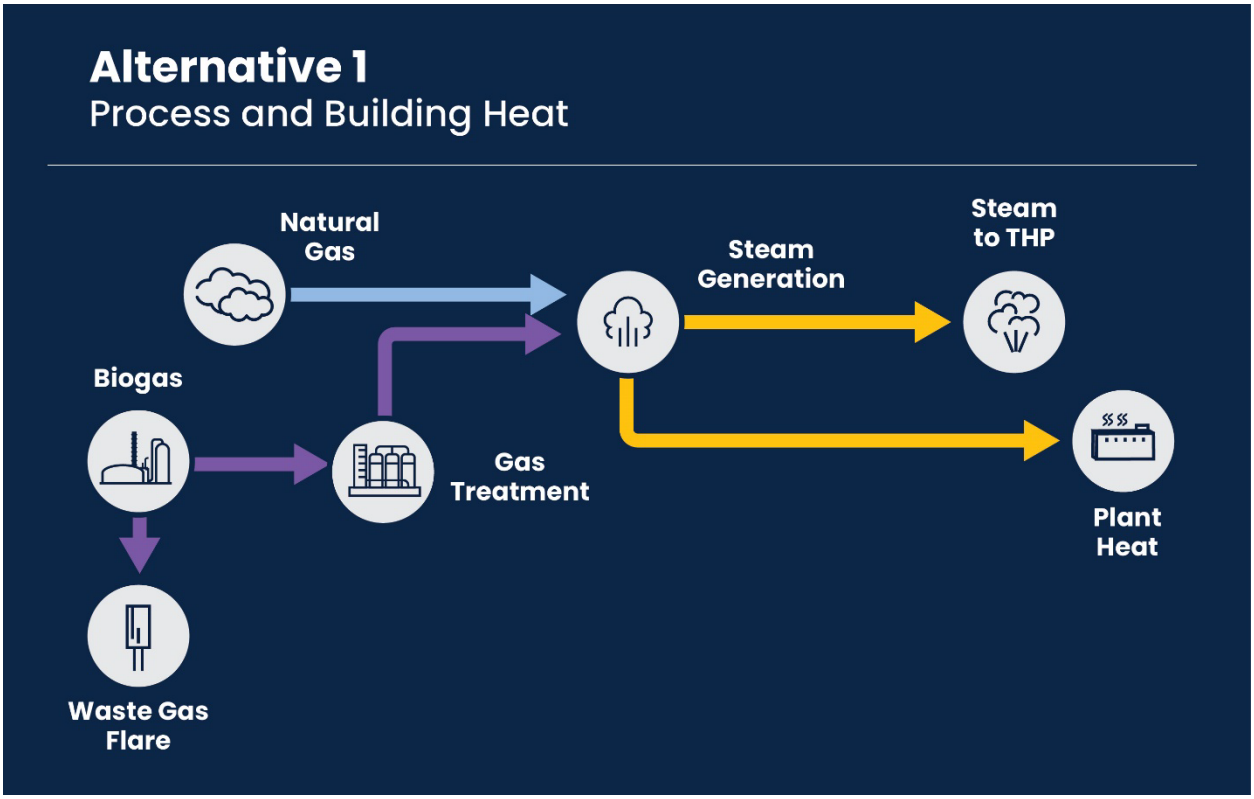
- On-site use for process and building heating
- Production of electrical power and recovery of waste heat (CHP)
- Production of RNG for use offsite through pipeline injection or as CNG for direct use as vehicle fuel.

From these potential biogas uses the following alternatives and sub-alternatives were identified for the evaluation. An energy balance was used to develop preliminary sizing of the equipment and summarize any energy production and heat recovered as well as the energy purchase requirements and biogas flared.

Alternative 1 – Process and Building Heating

In this alternative, shown schematically in Figure 1, the biogas produced during digestion would be used to fuel steam boilers to satisfy the process and building heating requirements. However, the steam demand for the Thermal Hydrolysis Process (THP) would use only about 30 percent of the biogas produced, leaving 70 percent as excess, which would be flared. **Because this alternative does not fully utilize the biogas, it is not a viable biogas utilization option, but it is included in the analysis as the minimum required to meet process needs.**

Figure 1. Alternative 1 – Process and Building Heat

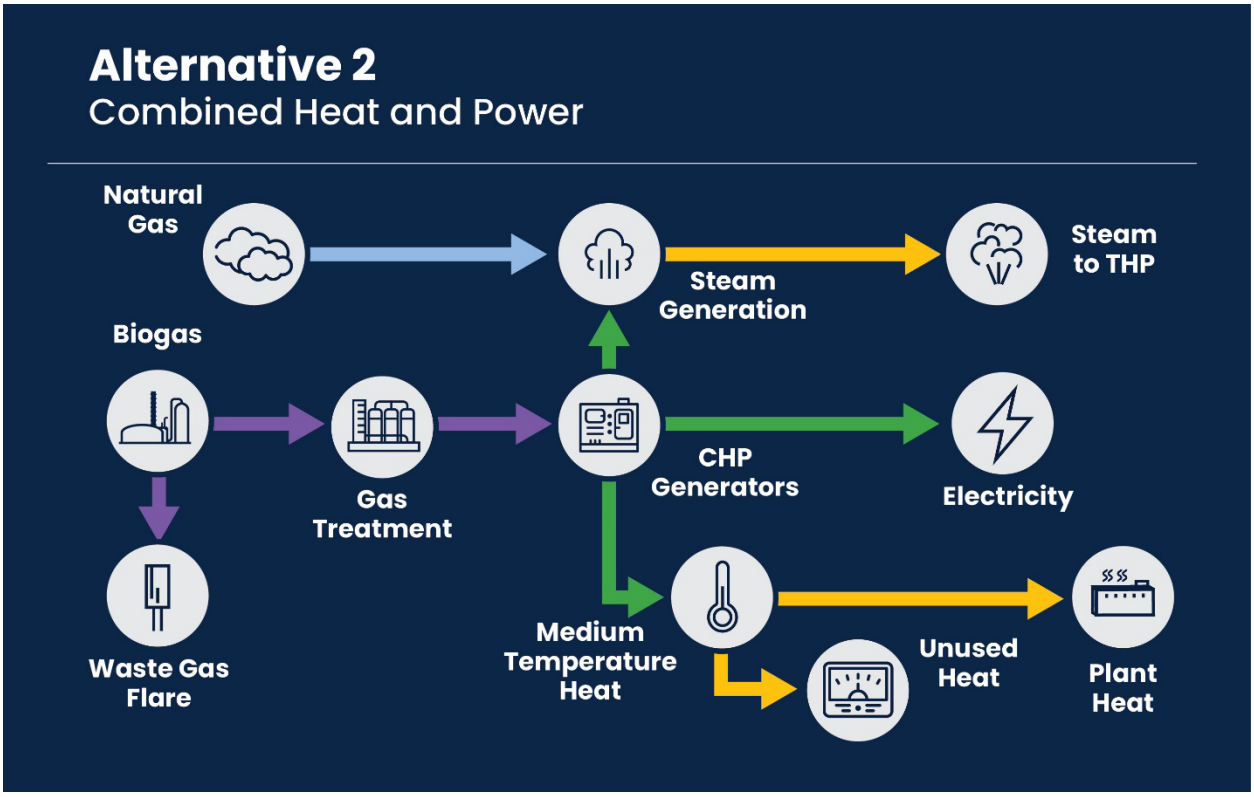


Alternative 2 – CHP

In this alternative, shown schematically in Figure 2, the biogas would be used as fuel for engines to produce electrical power. Recovered heat from the engines would be used for production of steam for process needs and building heat. Multiple types of power generation equipment are available, each with its own electrical and heat transfer efficiencies, so this alternative was divided into the following two sub-alternatives:

- **Alternative 2A – CHP with Engines:** Internal-combustion engines would produce more power at the site but would recover less heat. As supplemental heat would be required to meet process needs, some of the biogas would be bypassed around the engines to fire directly in the boiler and provide the steam for THP.
- **Alternative 2B – CHP with Gas Turbine:** A gas turbine engine would produce less power but would recover more steam. The heat recovered would satisfy process needs.

Figure 2. Alternative 2 – Combined Heat and Power

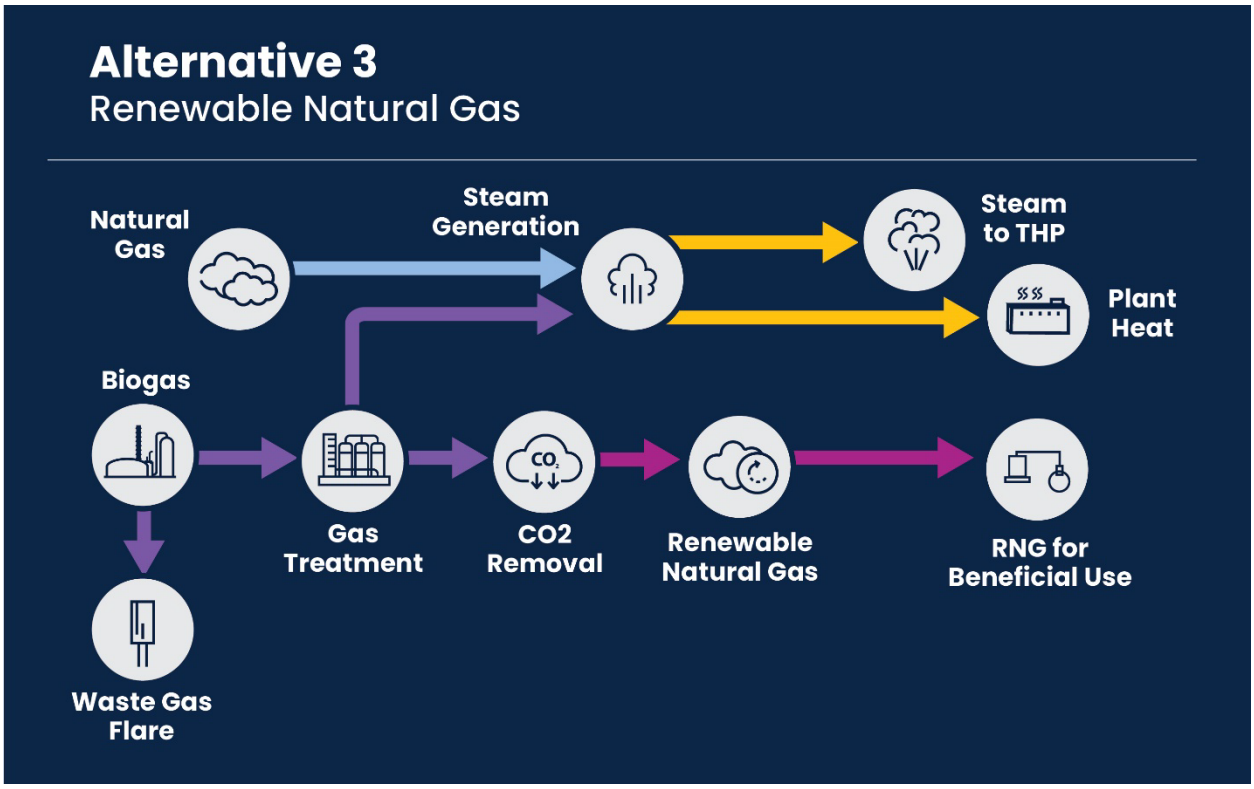


Alternative 3 – RNG

In this alternative, shown schematically in Figure 3, all of the biogas would be conditioned to RNG quality for use off site. The facility heating requirements would be met using steam boilers fueled by natural gas or from biogas onsite. There are two potential points of entry into the natural gas system so this alternative was divided into the following two sub-alternatives:

- **Alternative 3A – RNG Injected into the Natural Gas Pipeline:** In this alternative, all of the RNG would be injected into the local natural gas pipeline for off-site use as vehicle fuel.
- **Alternative 3B – RNG Used as Compressed Natural Gas (CNG):** In this alternative, the RNG would be sent to local CNG stations for use directly at those stations. This alternative is similar to Alternative 3A, but instead of injecting the RNG into the natural gas pipeline, it would be used across the road to fuel CNG buses operated by Arlington Transit and the Washington Metropolitan Area Transit Authority.

Figure 3. Alternative 3 – Renewable Natural Gas

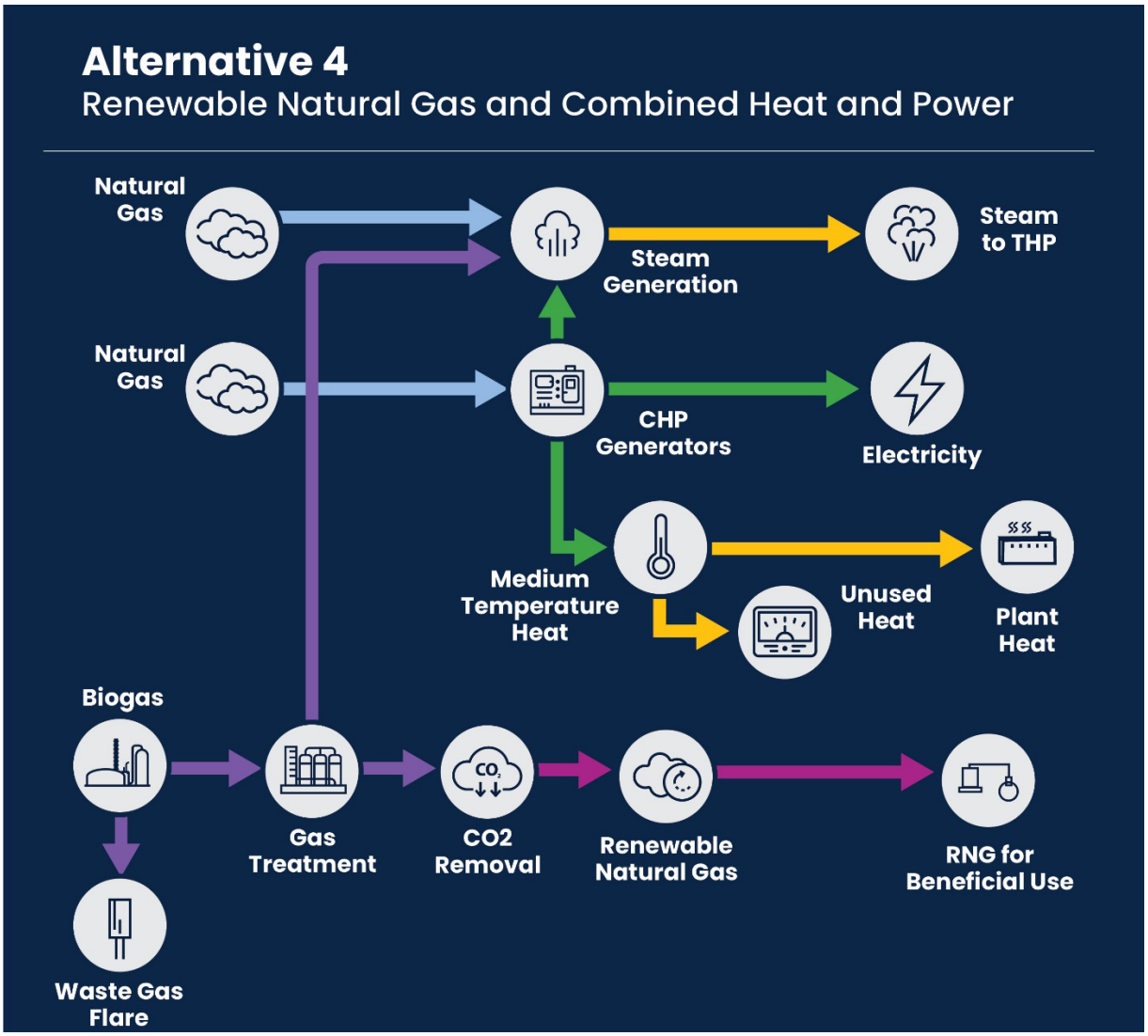


Alternative 4 – RNG and CHP

This alternative, shown schematically in Figure 4, would combine using the biogas to produce RNG as described above with using CHP fueled by natural gas for electricity and heat production. Similar to the CHP Alternative, there are two different engine options, so this alternative was divided into the following two sub-alternatives:

- **Alternative 4A – RNG and CHP with Engines:** Larger internal-combustion engines would be provided to produce all of the supplemental heat required to provide the steam for THP.
- **Alternative 4B – RNG and CHP with Gas Turbine**: Smaller gas turbine engines would produce less power but would recover more steam. The heat recovered would satisfy process needs.

Figure 4. Alternative 4 – Renewable Natural Gas and Combined Heat and Power



Alternatives Evaluations

The alternatives described above were developed and sized using the projected biogas production (approximately 120 billion Btu/year) and steam demands (approximately 35 billion Btu/year) and then evaluated using the following methods:

- **Financial analysis:** A present value of each alternative was developed from conceptual capital costs, operations and maintenance costs, energy production offsets, and RNG revenue.
- **Non-financial analysis:** A non-financial analysis was used to reflect such criteria in the overall alternatives analysis. Examples of non-financial criteria include noise production, facility aesthetics, and Plant safety.
- **Sustainability criteria:** The environmental and sustainability benefits (carbon emissions reductions) were monetized using an industry standard approach.
- **Sensitivity analysis:** To reflect future market and pricing unknowns and risks, multiple approaches were used to illustrate the sensitivity of the major assumptions.

The financial analysis considered the change in solids production and costs of electricity, natural gas, and equipment operations and maintenance over time to develop a net present value for each alternative. Based on discussions with the County, a 25-year planning period following construction was selected. With construction anticipated to finish in 2027, the planning period for this study runs from 2027 to 2052. The target year of 2052 was selected for when the design flows and loads are anticipated to be reached, resulting in a design solids production loading of approximately 40 tons per day. To illustrate the energy balance and economic analysis results presented in the subsequent sections, an evaluation year of 2037 was selected as it is close to the midpoint of the planning period and falls on one of the 5-year increments developed.

Financial Analysis

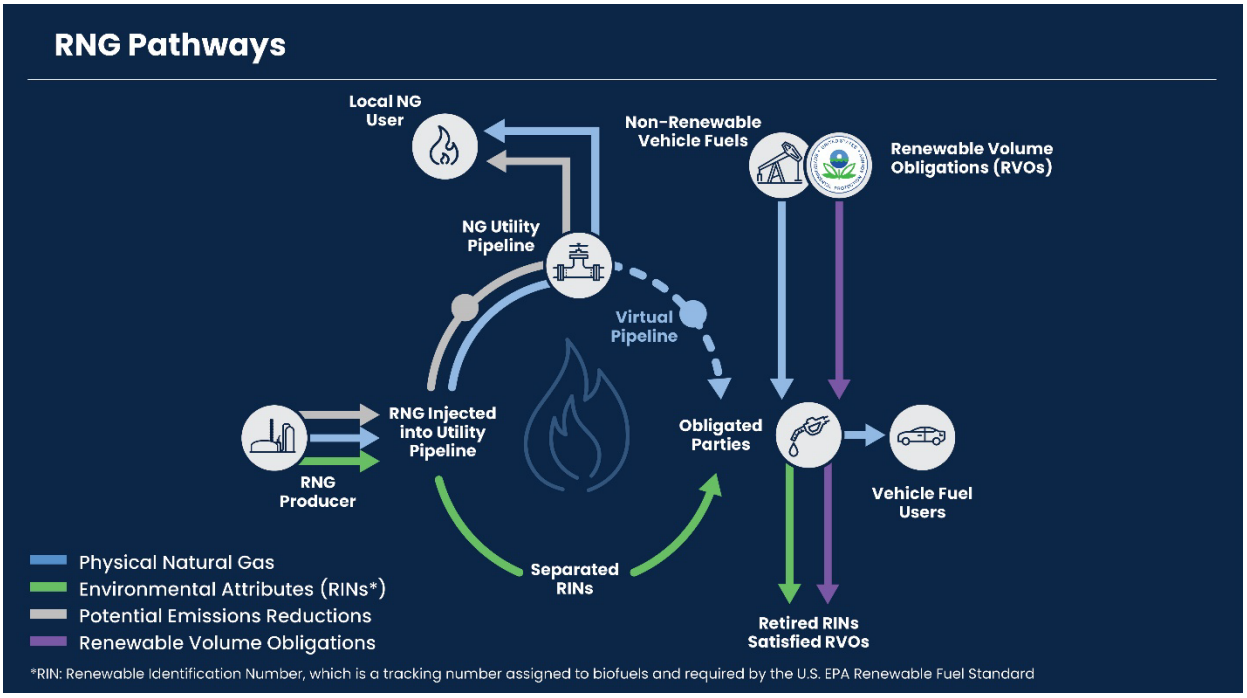
For each alternative, conceptual capital costs of the process heating, CHP, and biogas conditioning systems were developed. In addition, annual operations and maintenance costs and potential energy savings or revenues were summarized and totaled for each year of the 25-year planning period. The present value of each alternative was then developed.

For the alternatives that include the off-site sale of RNG, the RNG revenues were developed from the commodity value of natural gas and the historical and anticipated values of the environmental attributes of the RNG in the U.S. Environmental Protection Agency (EPA) Renewable Fuel Standard (RFS). This program is specifically for renewable fuels for transportation programs. Therefore, the fuel must ultimately be used

as a transportation fuel for the renewable attribute to be recognized. In addition to the EPA's RFS, similar state programs exist such as the California Low Carbon Fuel Standard (LCFS). These state programs could be pursued by Arlington County but are not currently included in the financial metrics.

The production and sale of RNG and environmental attributes like Renewable Identification Numbers (RINs) through the RFS occurs via two pathways: the physical pathway for the commodity value and the contractual pathway for the attributes. The physical pathway is the sale of the RNG by the producer to an end user of the actual gas via the natural gas grid. The gas can be sold either to the current gas supplier or to another party directly. The contractual pathway for the environmental attributes (RINs) is separate and handled by a third party that verifies that the RNG produced complies with the RFS and markets the attributes to Obligated Parties (any refiner or importer of gasoline or diesel fuel in the United States). Note that these two pathways are independent of carbon credit programs. The County will be able to take credit for the reduction of greenhouse gases (GHGs) in its internal accounting independently of the sale of RINs as long as the gas is used within Arlington County. The valuation of RINs and GHG credits are treated separately in this report. The various physical, contractual, and greenhouse gas pathways are shown schematically on Figure 5.

Figure 5. RNG Pathways



In the RFS, RINs include a "D code" that identifies the type of biofuel based on the feedstock used. Each D code has a different market value in the RFS program. RNG generated from wastewater biosolids qualifies as a D3 RIN (cellulosic biofuel), which

have historically traded at the highest value. Historical RIN values are provided in Figure 6. The base RIN value used in the financial analysis was $1.15/RIN or $15 per 1 million British thermal units (MMBtu). This value is also represented on Figure 6. The October 2021 D3 RIN value was approximately $38/MMBtu[1]. The value of the RNG environmental attributes greatly impacts the results of the financial analysis, which is why a sensitivity analysis was performed to further characterize the financial risks associated with RNG. The results of the sensitivity analysis are summarized later in this section.

Figure 6. Historical RIN Pricing

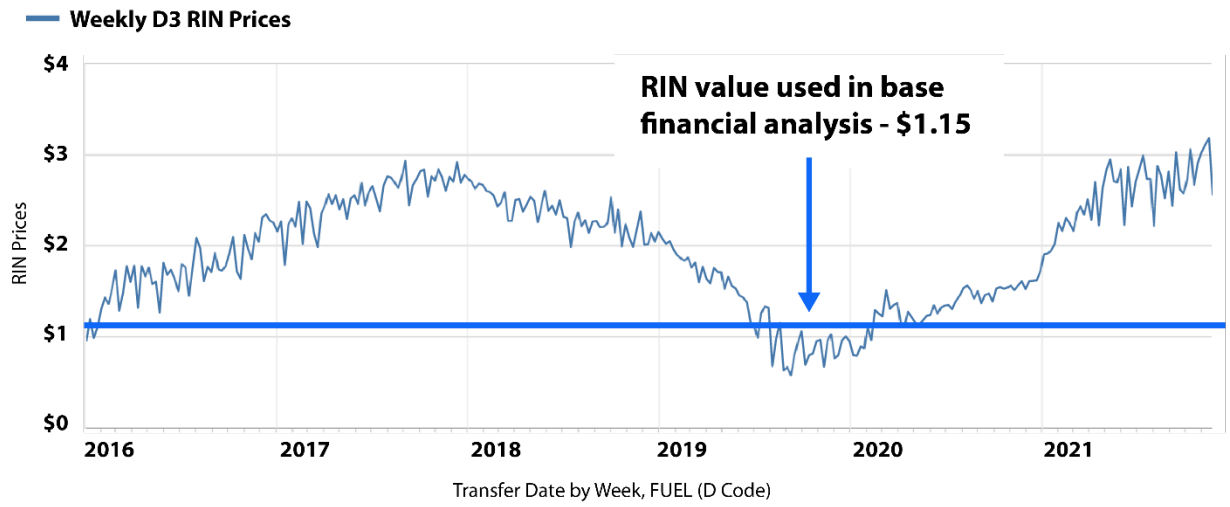
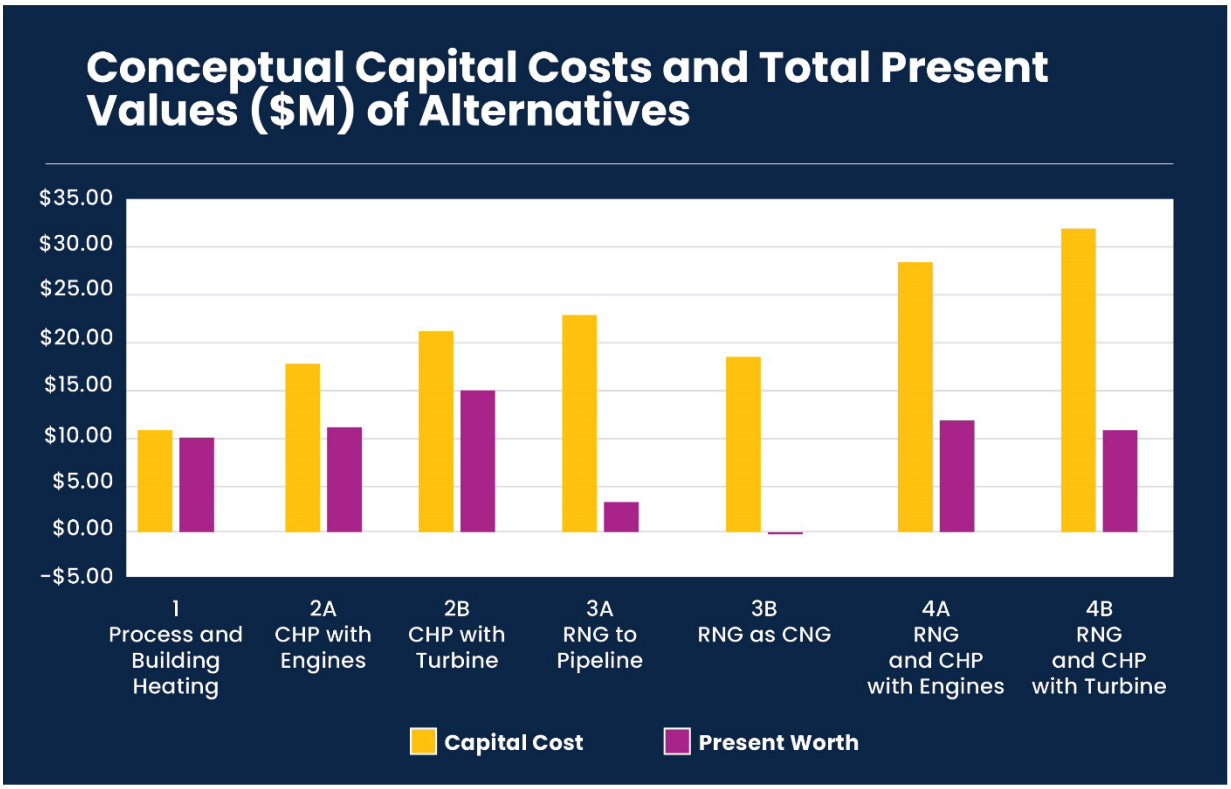


Figure 7 shows the conceptual capital costs and total present value for all alternatives. In this analysis, the cost of electricity was assumed to be $0.06 per kilowatt-hour (kWh) as this is the current average rate paid by Arlington County and energy prices are projected to remain stable.

The base cost analysis indicates that although the RNG alternatives (Alternatives 3A and 3B) do not have the lowest capital cost, they do have the lowest cost when taking into account the entire life cycle of the gas handling equipment to develop a total present-value cost, primarily because the value of the RINs offsets the initial capital investment. In comparison, the RNG and CHP alternatives (Alternatives 4A and 4B) would entail larger capital costs and comparable present-value costs to CHP alternatives (Alternatives 2A and 2B).

[1] https://www.epa.gov/fuels-registration-reporting-and-compliance-help/rin-trades-and-price-information#regulatory-categories

Figure 7. Conceptual Capital Costs and Total Present Values ($M) of Alternatives



The initial present-value analysis supported eliminating Alternatives 4A and 4B (RNG and CHP alternatives) from further consideration because of high capital costs, high overall complexity, significant use of natural gas to run the engines, and comparable present financial values to Alternatives 2A and 2B (CHP alternatives). The remaining alternatives were further analyzed for risk and non-financial factors, sustainability, and sensitivity to changing market conditions.

Non-Financial Analysis

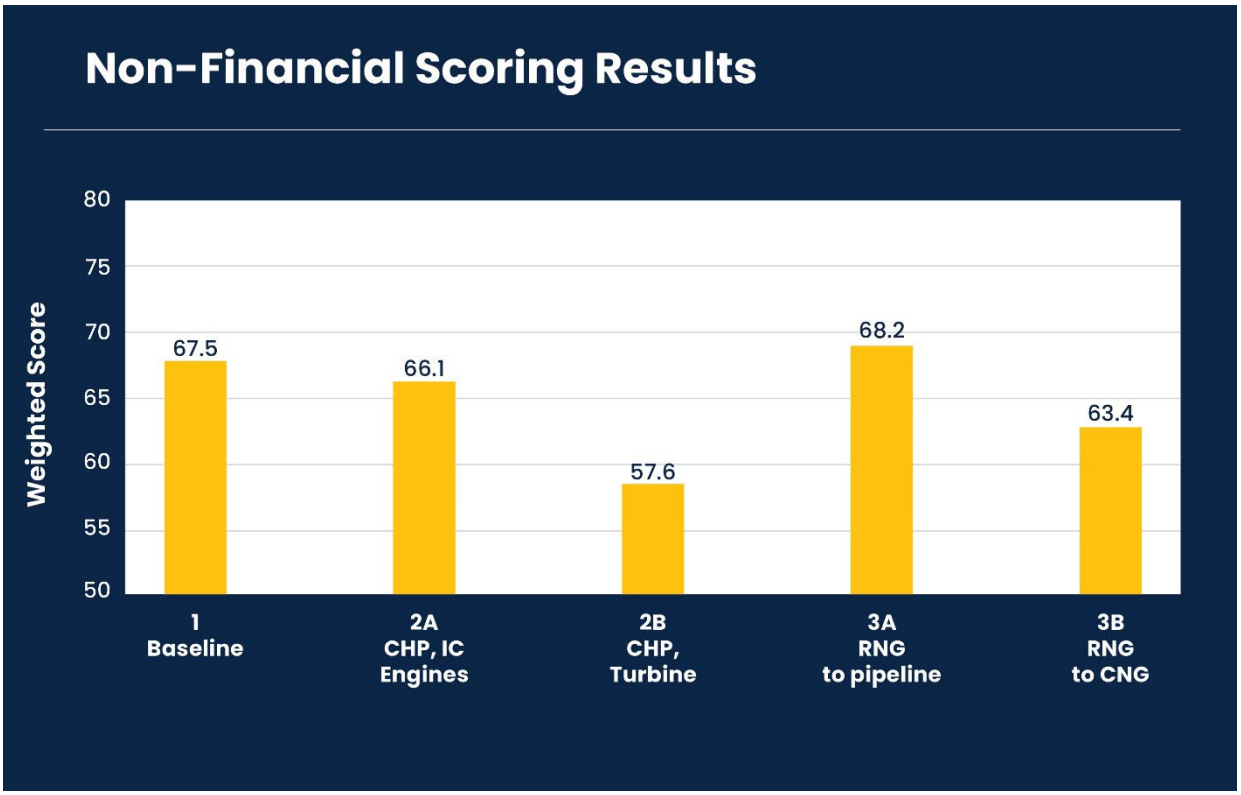
Non-financial criteria were developed and weighted using input from County stakeholders. A description of the non-financial criteria and the weights established by the County for those criteria are presented in Table 1.

Table 1. Non-Financial Criteria

Criterion	Description	Weight
Localized emissions	Produces emissions at Plant site that may negatively impact air permitting requirements, cause neighborhood issues, or result in poor air quality in immediate area	8.0%
Noise	Generates excess noise that may impact neighbors or result in costly noise reduction measures	8.4%
Visual aesthetics	Is acceptable to the neighbors and general Arlington County community from a visual aesthetics standpoint	4.1%
Footprint	Sufficient space for operations and maintenance; does not take land space from current needs or potential future add-ons	6.9%
Potential for flaring	Provides multiple outlets for use of biogas or redundancy options to minimize the amount of biogas sent to the waste flare	8.4%
Operational complexity	Complexity of equipment and facilities in operation	11.8%
Maintenance complexity and reliability	Reliability of equipment and facilities, ongoing maintenance requirements, annual downtime for maintenance, and number of components that could fail, resulting in failure of system	11.8%
Safety	Risks for operation of system, including leaks, pressures, number of components, etc.	22.5%
Resilience	Provides for additional resilience benefits for the Plant and solids handling systems	8.8%
Future opportunities	Maintains flexibility for modifying approach should market conditions change	9.3%

The remaining alternatives (excluding Alternatives 4A/4B – RNG and CHP) were then scored based on this criteria to develop a non-financial score. With this methodology higher scores are better. Figure 8 presents the average scores for each alternative carried forward. Alternative 3A (RNG into pipeline) had the highest average non-financial score at 68.2, followed by Alternative 1 (Process and Building Heat) at 67.5. As stated previously, Alternative 1 is not a viable biogas utilization option, but it is included in the analysis as the minimum required to meet process needs. Alternative 1 scored well in the non-financial analysis as it is generally less complex than the other alternatives. Alternative 2B (CHP with Turbines) had the lowest non-financial score of 57.6.

Figure 8. Non-Financial Scoring Results



The main differentiators between the RNG alternatives (Alternatives 3A/3B) and CHP alternatives (Alternatives 2A/2B) were that the RNG alternatives had:

- Lower localized emissions
- Reduced noise
- More outlets for beneficial use of the biogas and ability to reduce flaring
- Lower maintenance complexity and reliability
- Ease of adaptability to other gas utilization alternatives in the future

Sustainability Criteria

Table 2 presents net change in GHG (namely carbon dioxide [CO_2]) emissions for each of the sources of energy for 2037. The net GHG change presented in Table 2 is solely for the gas utilization equipment, not the entire biosolids upgrade program. Alternatives 2A and 2B (CHP alternatives) result in emissions reductions from the offset of purchased power, while Alternatives 3A and 3B (RNG alternatives) result in emissions reductions because of the reduction in use of petroleum-based natural gas. Overall, Alternatives 2A (CHP with Engines) and 3A/B (RNG =alternatives) have greater GHG reductions than Alternative 1 (Process and Building Heating) and Alternative 2B (CHP with Turbines).

GHG reductions for Alternatives 2A and 2B (CHP alternatives) are based on the current Dominion Energy CO_2 emission profile, which includes a combination of fossil-fuel and renewable energy sources. Electricity for Arlington County operations is projected to be 100 percent renewable by 2025 through separate power purchase agreements, in which case the GHG reduction for net electricity production would be zero. However, the generation of renewable power at the Plant may allow for currently forecasted renewable sources to be used elsewhere.

Table 2. Total Change in Net CO_2 Emissions (Metric Tons) in Year 2037

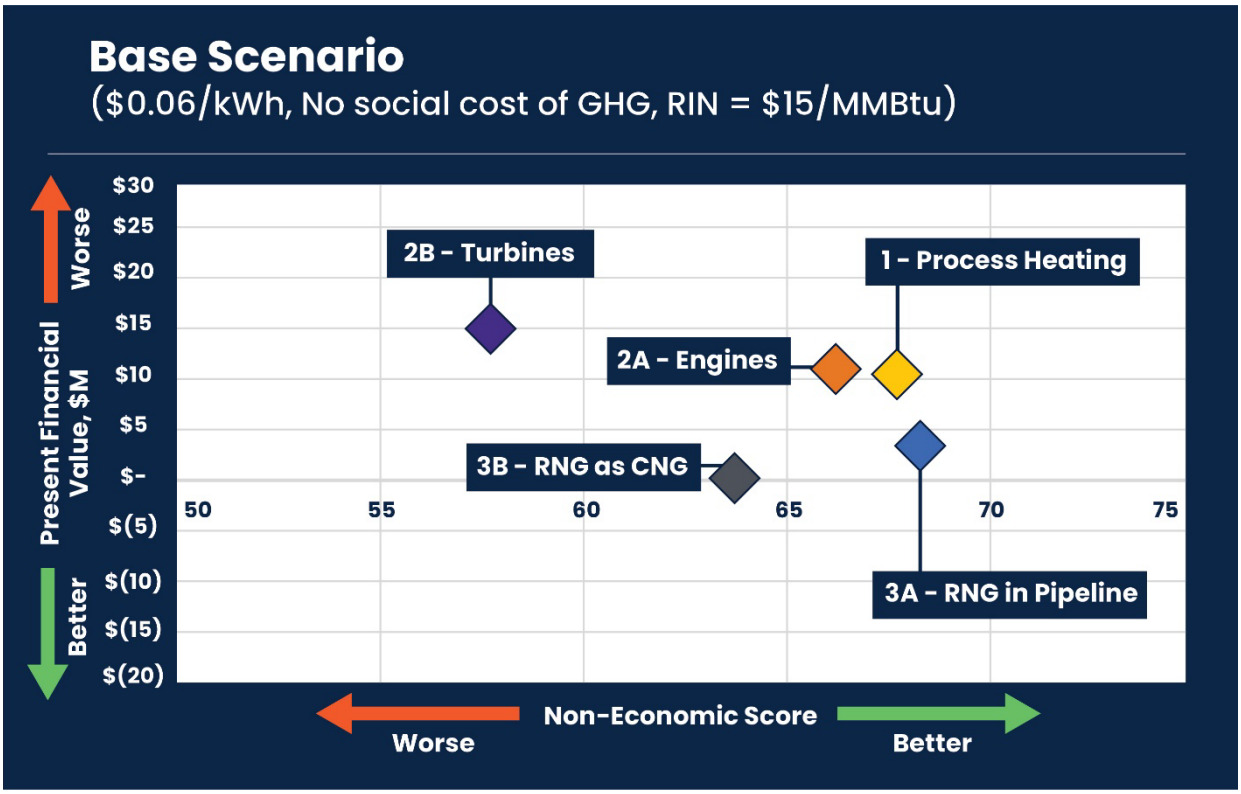
Alternative	Net Electricity Use of Biogas Utilization	Biogas Production (Offsets Natural Gas Purchases)	Natural Gas Purchased	Total Change in Emissions
1: Process and Building Heat	80	-40	0	40
2A: CHP with Engines	-3,330	-40	0	-3,370
2B: CHP with Turbines	-2,310	-40	0	-2,350
3A: RNG to Pipeline	770	-6,240	1,970	-3,500
3B: RNG Used as CNG	770	-6,240	1,970	-3,500

Note: Negative values are emissions reductions and positive values are emissions increases.

Composite Results

Figure 9 presents a composite result of the financial and non-financial scores using the base financial conditions (namely current electrical price of $0.06/kWh and average RIN market value of $15/MMBtu). The non-financial score is presented on the x-axis, the present financial value is presented on the y-axis, and the size of the bubble represents the conceptual capital cost. For this base condition, without considering the social cost of GHG, Alternative 3A (RNG to Pipeline) had the highest non-financial score and the second-lowest present financial value.

Figure 9. Base Scenario ($0.06/kWh, No social cost of GHG, RIN = $15/MMBtu)



Several alternative scenarios were run to test the sensitivity to key parameters. Figure 10 provides the same analysis including the social cost of GHG and the average RIN value for the past six years of $23.35/MMBtu. This RIN value furthers the financial advantage of the RNG alternatives.

Figure 10. Average RIN Scenario ($0.06/kWh, Includes social cost of GHG, RIN = $23.35/MMBtu)

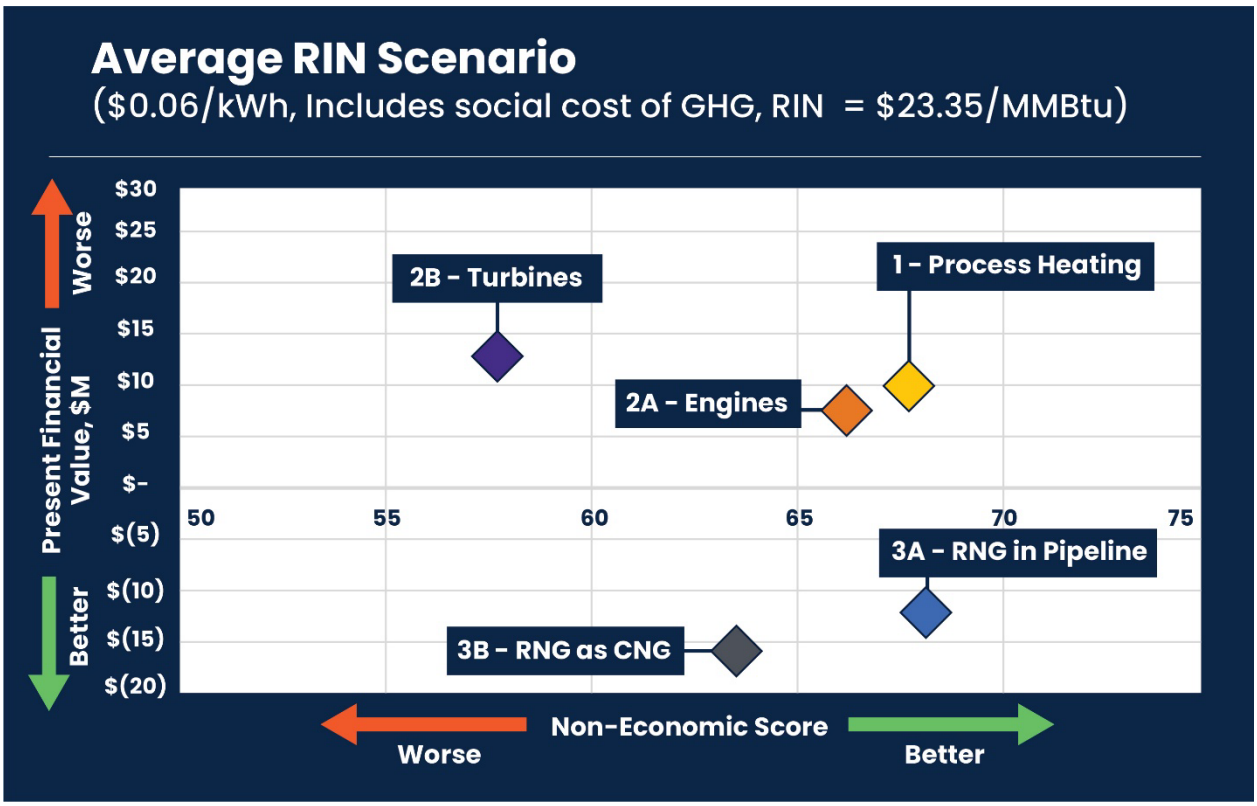


Figure 11 provides the same analysis including the social cost of GHG and the lowest weekly RIN value over the last six years of $6.38/MMBtu. In this scenario, Alternative 2A (CHP with Engines) becomes more financially advantageous.

Figure 11. Lowest RIN Scenario ($0.06/kWh, Includes social cost of GHG, RIN = $6.38/MMBtu)

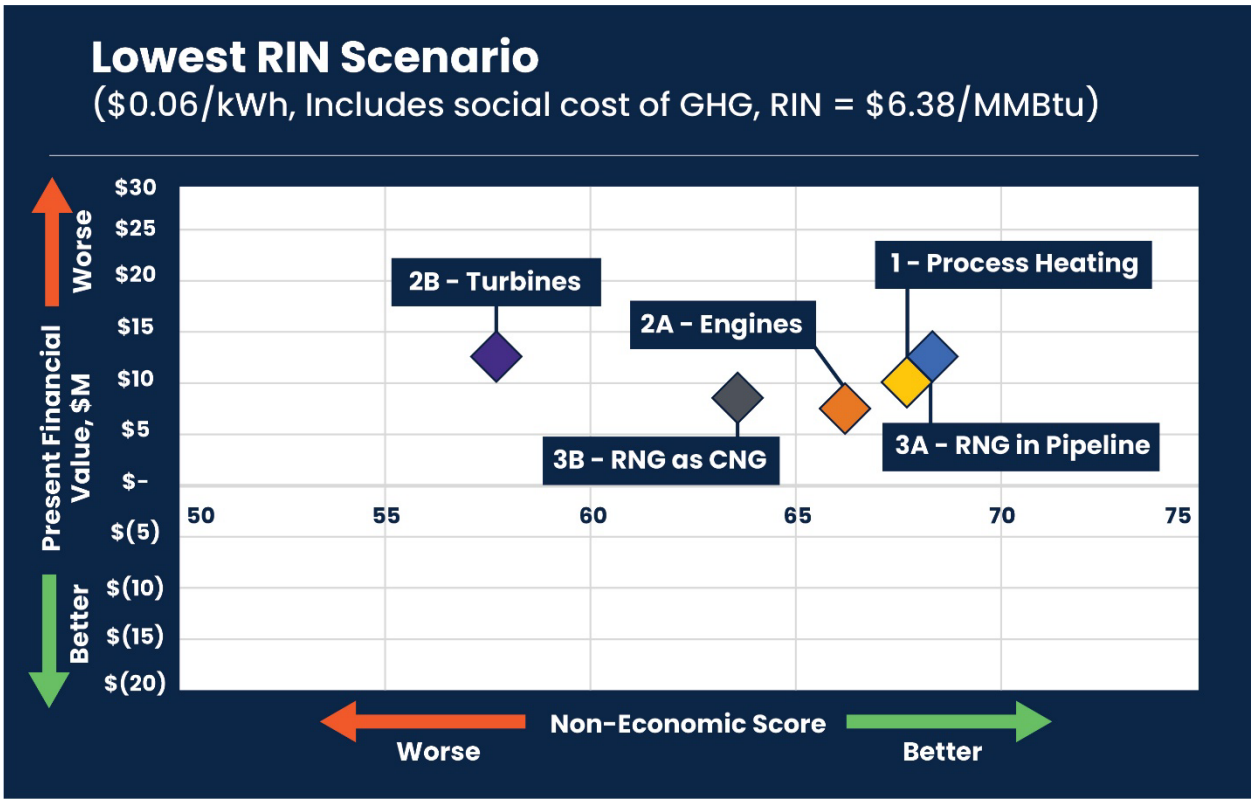
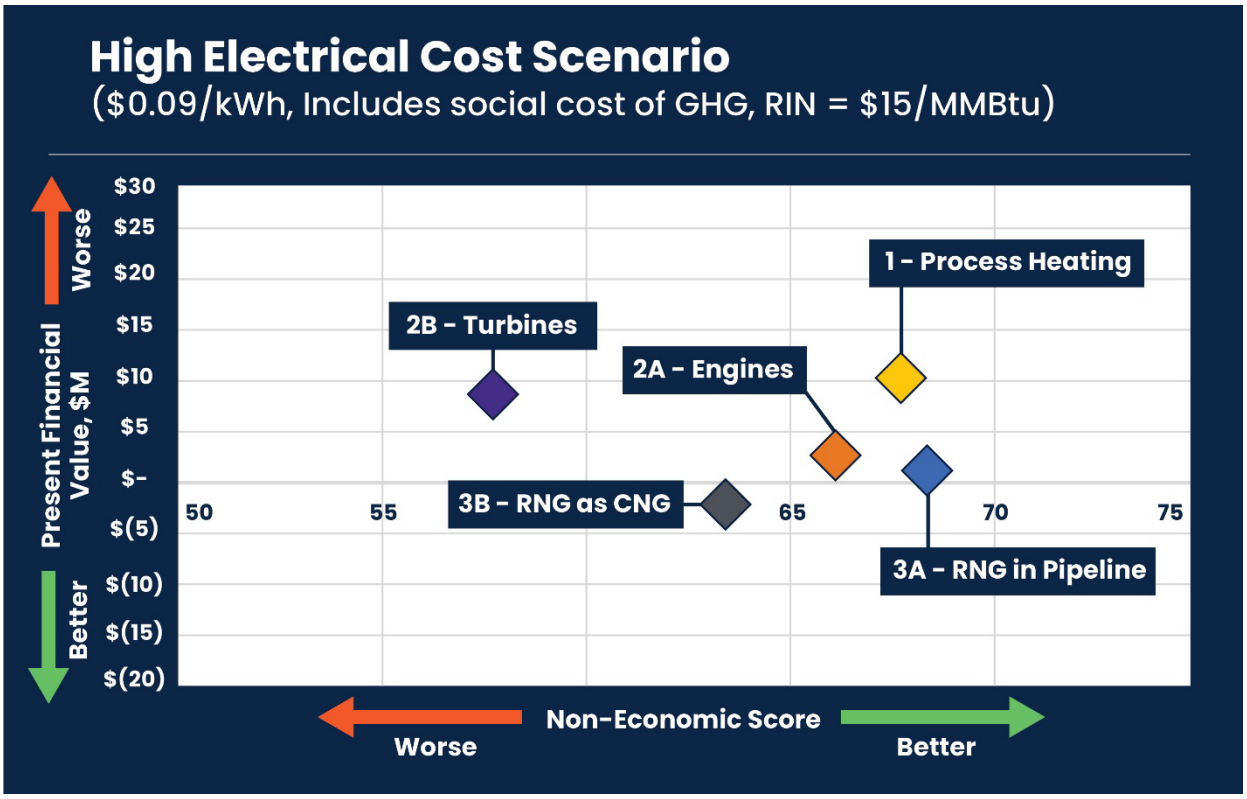


Figure 12 provides the analysis including the social cost of GHG and higher electricity cost of $0.09/kWh. In this scenario, the RNG alternatives retain their advantage over Alternative 2A (CHP with Engines), even with the higher electricity cost.

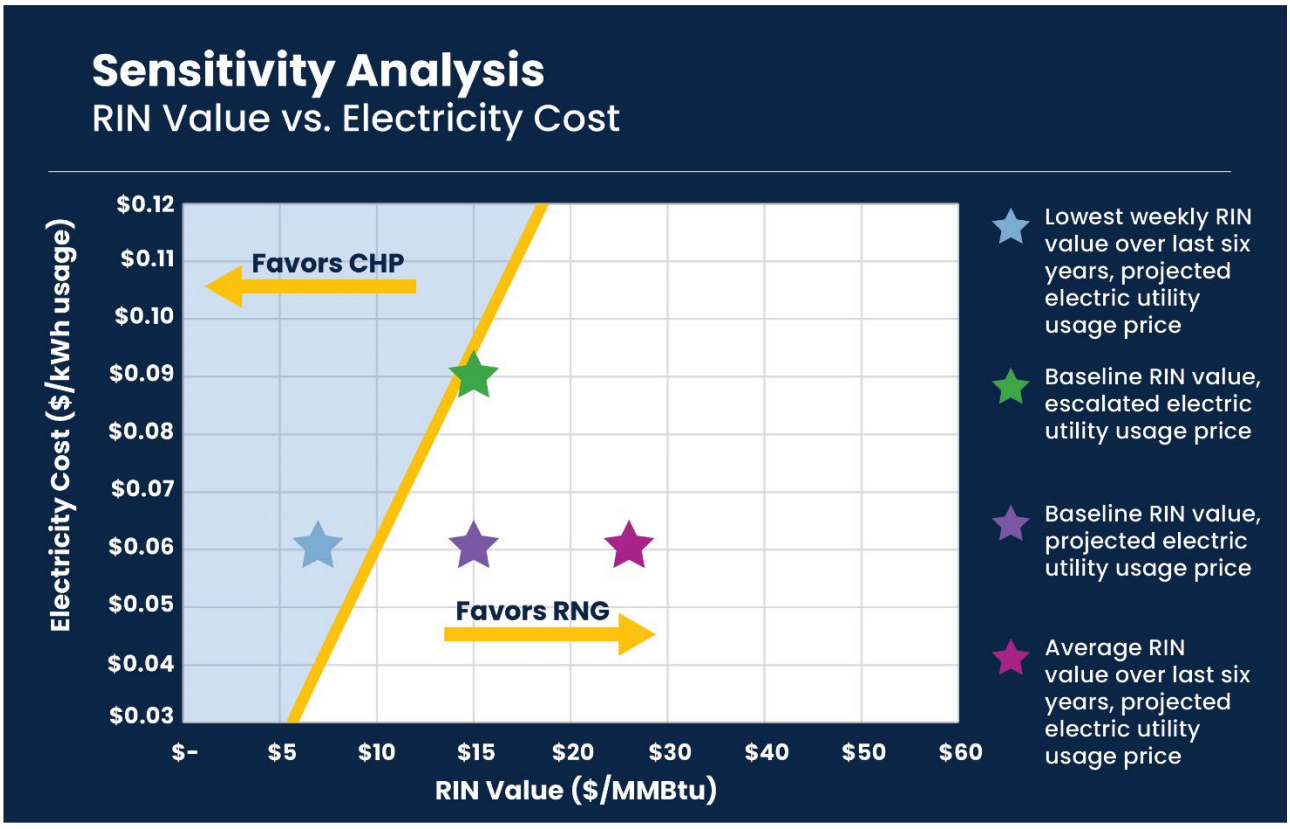
Figure 12. High Electrical Cost Scenario ($0.09/kWh, Includes social cost of GHG, RIN = $15/MMBtu)



Sensitivity Analysis

The financial analysis makes it clear that the main drivers in the comparison are the cost of electricity and the value of the RIN market. A break-even analysis was completed to identify the point at which Alternative 2A (CHP with Engines) is financially equal to Alternative 3A (RNG into Pipeline). This break-even analysis is shown on Figure 13, with the scenarios completed above identified.

Figure 13. Sensitivity Analysis of RIN Value vs. Electricity Cost



Additional detailed computer simulations were completed and these simulations confirmed the very high likelihood (greater than 95%) that the RNG alternatives will be more financially advantageous to Arlington County than the CHP alternatives.

Biogas Utilization Conclusion

Based on the analyses presented, the Arlington County Water Pollution Control Bureau recommends proceeding with Alternative 3 (RNG) as the selected biogas utilization approach. The basis for this recommendation is as follows:

- Alternative 3 (RNG) has the lowest net present value (i.e., lowest total cost to the County over the life of the equipment) for the baseline conditions using conservative capital and operating costs.
- Alternative 3A (RNG into Pipeline) scored the highest in the County's non-financial scoring. In particular, the County found that the RNG alternatives would be less complex to maintain and would result in fewer localized impacts such as noise and emissions than the CHP alternatives.
- A sensitivity analysis concluded that when considering multiple variables, including RIN volatility and changes in electrical rates, Alternative 3A (RNG into Pipeline) had a very high likelihood of being more financially advantageous than Alternative 2A.
- The County has the ability to retain GHG credits if the biogas is used within Arlington County. With electricity for County operations projected to be 100 percent renewable by 2025, it is likely that the CHP alternatives would not result in any GHG reduction through electricity offsets.
- Benefits of on-site CHP are limited because the CHP size would not be sufficient to power the entire Plant, which is already protected with two independent power feeds and backup generators.

The County's current preference is for Alternative 3A (RNG into Pipeline) over Alternative 3B (RNG as CNG) due to the uncertain future of Arlington Transit and Washington Metropolitan Area Transit Authority fueling stations and the lack of a match between fueling times and gas production times (resulting in the need for additional storage). However, the final decision to inject RNG into the natural gas utility pipeline or to use CNG will be made in the future as more discussions with the stakeholders are conducted.