Biogas Utilization Feasibility Report

CAAP – Methane Recovery Feasibility Study

Completed by HDR Engineering, Inc. on behalf of the City of Iowa City, to support the Climate Action and Adaptation Plan (CAAP) and the associated Action Items 3.7 and 3.8.

Iowa City, Iowa

December 30, 2020

CITY OF IOWA CITY

VERSION: 2

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Executive Summary

In December 2019, the City of Iowa City (City) selected HDR Engineering, Inc. (HDR) to perform a Methane Recovery Feasibility Study to address two specific Action Items included in the Iowa City Climate Action and Adaptation Plan (CAAP):

> **Action Number 3.7: Take Action on a Study to Efficiently Capture and Use Methane from Wastewater Operations**
>
> *"After water is used by residents, it flows into the wastewater system and then goes to the City's Wastewater Treatment Facility. While the City currently captures methane gas from the digesters used in the wastewater treatment process, only a portion of the methane is used to offset natural gas usage for the plant. To explore other options for further management of wastewater greenhouse gas (GHG) emissions, the City should conduct a study to determine the feasibility of using all captured methane to create renewable fuel or electricity that can be used to operate the facility, and take specific actions based on the results of this study."*
>
> **Action Number 3.8: Take Action on a Feasibility Study on Energy Generation from Landfill Methane**
>
> *"The methane produced by decomposition of organic waste in the Iowa City Landfill is currently being flared to transform it into carbon dioxide, which is a less potent GHG. The City has been considering methods to use the methane as a renewable energy source, and to further explore this opportunity, the City will conduct a Feasibility Study in FY2019 and take specific actions based on the results of this study."*

This Feasibility Report incorporates a number of recently completed Technical Memorandums (TMs) that evaluated current and future biogas generation potential and identified alternatives for utilizing biogas at the Iowa City Wastewater Treatment Plant (WWTP) and/or the Landfill and Recycling Center (Landfill). HDR used its Sustainable Return on Investment (SROI) process to measure the feasibility of the objectives.

The Study objectives are to evaluate current and future methane generation, collection, processing, and reuses at the two facilities based on the following three categories for feasibility:

- Net GHG emissions, considering both incremental emission sources and direct and indirect reductions;
- Net Energy impacting, applying an Energy Return on Energy Invested (EROEI) methodology;
- Economics, using HDR's SROI framework to monetize the benefits associated with beneficial reuse of methane sourced from the Landfill and WWTP.

HDR analyzed three alternatives to beneficially reuse biogas generated at the WWTP and Landfill, as well as GHG emissions and financial impact of expanding composting operations to handle incremental food waste diverted from the Landfill. The following is a description of each alternative:

- **Alternative 1: Natural Gas Pipeline Injection**. This alternative is divided into two sub-alternatives:
  - Alternative 1a – WWTP NG Pipeline Injection.
  - Alternative 1b – Landfill NG Pipeline Injection.
- **Alternative 2: Electricity Generation**. This alternative is divided into two sub-alternatives:
  - Alternative 2a – WWTP Electricity Generation.
  - Alternative 2b – Landfill Electricity Generation.
- **Alternative 3: WWTP Natural Gas Replacement**
- **Alternative 4: Composting**

Recognizing the synergy with another Action in the City's CAAP, Item 3.2 Increase Composting of Organics, the alternatives consider impacts of diverting incremental volumes of food waste from the Landfill to the existing WWTP, a new, dedicated anaerobic digester (AD) located at the WWTP, and expanded composting operations. Each of the alternatives listed except Alternative No. 4 consider three organics diversion scenarios:

1) No incremental organics diversion (No-Diversion)
2) Additional 1,500 tons organics diverted from Landfill, which represents the available capacity at the existing WWTP AD (1,500 tons)
3) 20% of food waste diverted from landfill to a future "new" AD (Low-Diversion)

HDR developed an opinion of probable construction costs (OPCC) and opinion of operations and maintenance (O&M) costs for the No-Diversion scenario for each alternative. The No-Diversion scenario costs were then extrapolated to estimate costs for the two diversion scenarios for each alternative.

The SROI analysis considers the triple bottom line (i.e., economic, environmental, and social) benefits of methane reuse. This study focuses on the economic and environmental impacts.

The analysis took into account:

- Estimated reductions in GHG emissions and the associated social cost of carbon;
- Value of Renewable Identification Number (RIN) credits under the Renewable Fuel Standard Program;
- Value of electricity exported to the grid under net metering and buyback agreements with MidAmerican Energy Company and the Eastern Iowa Light and Power Cooperative;
- Value of avoided natural gas purchases;
- Capital investment and O&M costs of biogas reuse alternatives; and
- Energy Return on Investment (EROEI).

The results of this study are intended to help the City assess the viability of, and prioritize, alternatives with the greatest potential to reduce GHG emissions under CAAP Action Items 3.7

and 3.8. This Report details technical information on the feasibility analysis and summarizes the previous Technical Memorandums (TMs) that were completed by HDR leading up to the SROI analysis:

1. Evaluation of Existing Facilities TM
2. Wasteshed Analysis TM
3. Biogas Utilization Alternatives TM

The monetary and non-monetary results and rankings by metric are presented in Table ES-1. The evaluation of economic and environmental impacts considered a time horizon or study period, which includes project development (construction and implementation) and 30 years of operation and benefit. This extends to 2050 and aligns with the planning horizon of the City's CAAP. All monetary Costs and benefits have been converted to present value using a 3% discount factor and are compared using a benefit to cost ratio (BCR), benefits divided by costs. BCR's exceeding 1.0 indicate that the benefits from the alternative exceed the costs of the investment over a 30 year period. The non-monetary metrics include EROEI and lifecycle change in CO_2e emissions.

Table ES-1: Summary and Ranking of Monetary and Non-Monetary Results

Alternative Description	Location	Alternative	GHG Reduction	GHG Rank	EROEI	EROEI Rank	BCR	BCR Rank
Pipeline Injection	WWTP	Alt. 1a - ND	40,500	15	6.9	9	0.20	11
		Alt. 1a - 1500	77,800	12	7.9	6	0.22	9
		Alt. 1a - LD	436,200	6	7.9	4	0.39	8
	Landfill	Alt. 1b - ND	820,500	3	7.5	8	1.62	3
		Alt. 1b - 1500	844,500	2	7.6	7	1.63	2
		Alt. 1b - LD	931,800	1	7.9	5	1.69	1
Electricity Generation	WWTP	Alt. 2a - ND	19,000	16	2.0	13	0.05	16
		Alt. 2a - 1500	60,000	13	12.4	3	0.10	15
		Alt. 2a - LD	395,600	7	13.3	1	0.18	12
	Landfill	Alt. 2b - ND	459,200	5	1.5	15	0.76	6
		Alt. 2b - 1500	386,500	8	2.1	12	0.69	7
		Alt. 2b - LD	585,200	4	12.6	2	0.89	5
Natural Gas Replacement	WWTP	Alt. 3 - ND	40,900	14	4.6	10	0.11	14
		Alt. 3 - 1500	78,300	11	3.4	11	0.13	13
		Alt. 3 - LD	252,200	10	1.8	14	0.20	10
Expanded Composting	Compost	Alt. 4	365,100	9	0.0	16	0.96	4

The results show that:

- Only Alternative 1b (landfill natural gas) has benefits that exceed the costs;
- The highest BCR (1.69) is Alternative 1b – Low-Diversion. This alternative ranks highest on total lifecycle CO_2e emission reductions, and when combined with the value of RIN credits results in the greatest economic benefits;
- All of the alternatives result in a net reduction in CO_2e over the next 30 years;

- All alternatives except for composting result in an EROEI of 1.0 or greater (incremental composting of food waste does not generate energy);
- Alternative 2a (WWTP Electricity Generation) – Low-Diversion ranks highest on EROEI;
- Alternative 1b – Low-Diversion is ranked 5th on EROEI; and
- Changing the value of the SCC was found to have no effect in ranking as the value influences all of the alternatives equally.

To aid in the comparison of the monetary and non-monetary metrics and provide insight from this Feasibility Study towards actions under 3.7 and 3.8, the results have been combined into a weighted score as shown below in Table ES-2. Each result was converted to an index (1 to 0) and were then weighted equally into a total score with a maximum value of 1.

Table ES-2: Indexed and Weighted Scores for each Alternative

Alternative Description	Location	Alternative	GHG Reduction	EROEI	BCR	Total Score	Rank
Pipeline Injection	WWTP	Alt. 1a - ND	0.01	0.17	0.04	0.23	13
		Alt. 1a - 1500	0.03	0.20	0.04	0.27	11
		Alt. 1a - LD	0.16	0.20	0.08	0.43	6
	Landfill	Alt. 1b - ND	0.29	0.19	0.32	0.80	3
		Alt. 1b - 1500	0.30	0.19	0.32	0.81	2
		Alt. 1b - LD	0.33	0.20	0.33	0.86	1
Electricity Generation	WWTP	Alt. 2a - ND	0.01	0.05	0.01	0.07	16
		Alt. 2a - 1500	0.02	0.31	0.02	0.35	7
		Alt. 2a - LD	0.14	0.33	0.04	0.51	5
	Landfill	Alt. 2b - ND	0.16	0.04	0.15	0.35	8
		Alt. 2b - 1500	0.14	0.05	0.14	0.33	9
		Alt. 2b - LD	0.21	0.32	0.18	0.70	4
Natural Gas Replacement	WWTP	Alt. 3 - ND	0.01	0.12	0.02	0.15	14
		Alt. 3 - 1500	0.03	0.08	0.02	0.14	15
		Alt. 3 - LD	0.14	0.05	0.04	0.23	12
Expanded Composting	Compost	Alt. 4	0.13	0.00	0.19	0.32	10

Based on the indexing and weighting exercise:

- Alternative 1b (landfill natural gas) – Low-Diversion has the highest score (0.86).
- Alternative 1b (landfill natural gas) – 1500 ton diversion is ranked second.
- Alternative 1b (landfill natural gas) – No-Diversion is ranked third.

If the City is instead focused on reductions that will be reflected in its municipal and community-scale GHG emission inventory, then evaluation should be narrowed to focus on Alternative 2, Electricity Generation, and Alternative 3, Natural Gas Replacement. While electricity generated at the WWTP or Landfill (2a and 2b, respectively) could very well be pushed to the power grid, contractual agreements with local utilities could allow the City to retain and retire RECs for GHG accounting purposes. Specifically, RECs could be applied to the City's Scope 2 market-based GHG inventory. Using RNG to displace natural gas use at the WWTP would result in lower

Scope 1 GHG emissions. Focused on these two alternatives, Alternative 2b – Low-Diversion is ranked highest (fourth overall), followed by Alternatives 2a – Low-Diversion and 2a – 1500. These alternatives are ranked 4, 5 and 7 overall.

Finally, biogas utilization alternatives can be combined together with others, and some can be incorporated as standalone projects (as shown in Table ES-3).

Table ES-3: Potential Biogas Utilization Alternatives Combinations

Weighted and Indexed Performance Indicators Total Score, inclusive of: *GHG Reduction, EROI, and BCR*				Landfill Location						
				Do Nothing	No Diversion		1500 ton/yr Diversion		Low Diversion	
					NG Pipeline Injection	Electricity Generation	NG Pipeline Injection	Electricity Generation	NG Pipeline Injection	Electricity Generation
					Alt 1b-ND	Alt 2b-ND	Alt 1b-1500	Alt 2b-1500	Alt 1b-LD	Alt 2b-LD
WWTP Option	Do Nothing			0	0.80	0.35	0.81	0.33	0.86	0.70
WWTP Option	No Diversion	NG Pipeline Injection	Alt 1a-ND	0.23	1.02	0.58				
WWTP Option	No Diversion	Electricity Generation	Alt 2a-ND	0.07	0.87	0.42				
WWTP Option	No Diversion	NG Replacement	Alt 3-ND	0.15	0.95	0.50				
WWTP Option	1500 ton/yr Diversion	NG Pipeline Injection	Alt 1a-1500	0.27			1.08	0.60		
WWTP Option	1500 ton/yr Diversion	Electricity Generation	Alt 2a-1500	0.35			1.16	0.68		
WWTP Option	1500 ton/yr Diversion	NG Replacement	Alt 3-1500	0.14			0.95	0.47		
WWTP Option	Low Diversion	NG Pipeline Injection	Alt 1a-LD	0.43					1.30	1.13
WWTP Option	Low Diversion	Electricity Generation	Alt 2a-LD	0.51					1.37	1.21
WWTP Option	Low Diversion	NG Replacement	Alt 3-LD	0.23					1.09	0.93

There are 18 unique possible combinations of alternatives, boxes in Table ES-3 with blue numbering indicate the individual alternative scenarios at either the Landfill or at the WWTP. The individual alternatives can be combined together, but must be done so following the same waste diversion scenario from the Landfill. Specifically, an alternative from No-Diversion scenario cannot be combined with an alternative from the Low-Diversion scenario. When combining the alternatives the scores from the Landfill and WWTP alternatives can be added together to identify the optimal combination of actions under each of the waste diversion scenarios. The highest scored individual alternatives are consistently Alternative 1b – NG Pipeline Injection (landfill alternatives for each of the No-Diversion, 1500 ton diversion, and Low-Diversion scenarios).

Identifying the optimal combination of actions may be approached as follows: select the highest scored alternative from the desired waste diversion scenario (shown to be from the Alternative 1b – NG Pipeline Injection landfill alternatives) then work down the column to the corresponding green shaded boxes. Select the highest scored, or desired, combination. Corresponding capital costs for each individual alternative are also additive when combined. For example, if choosing from Alternative 1b – NG Pipeline Injection (at the Landfill, Total Score of 0.81), with 1500 ton diversion to the WWTP, work down the column (or “diversion lane”) to the desired combination scenario. In this case, combining with Alternative 2a – Electricity Generation at the WWTP, results in a combined score of 1.16. As capital costs are also additive, consideration should be given to the seemingly minor weighted score differential. In the example of combined Alt 1b-1500 with Alt 2a-1500, there is an estimated $6.2M savings to select Alt 1b-1500 with Alt 1a-1500.

Path Forward

HDR recognizes that incremental food waste diversion is not an instantaneous process, but the SROI analysis provides an assessment of the resulting impact when achieved. This Report provides decision tools to support the City’s further consideration and decision making.

Consequently, the City might consider the following path forward to further evaluate and implement the preferred alternative(s):

i. City decision on desired diversion scenario and methane utilization at the WWTP to narrow the field of alternatives. (0-6 months)
ii. Further technical analysis to develop organics management strategies to achieve a targeted diversion scenario and further evaluate life cycle costs of co-digestion (if desired) and biogas utilization to generate electricity or RNG. Consideration of impacts to planned digester rehab project. (3-6 months)
iii. Conceptual Design Development of the selected alternative(s), providing basis of design parameters and implementation planning. (3-6 months)
iv. Detailed Design Development. (TBD)
v. Bidding and Construction. (TBD)

It may be prudent for the City to complete items i) and ii) within the next 6-months for capital planning purposes.

1 Introduction

In December 2019, the City of Iowa City (City) selected HDR Engineering, Inc. (HDR) to perform a Methane Recovery Feasibility Study to address Action Items 3.7 and 3.8 included in the Iowa City Climate Action and Adaptation Plan (CAAP). The CAAP contains objectives for conducting a study that would determine the feasibility of methane generation, collection, processing, and potential re-use at the Iowa City Wastewater Treatment Plant (WWTP) and/or the Landfill and Recycling Center (Landfill). HDR used its Sustainable Return on Investment (SROI) process to measure the feasibility of the objectives.

This Feasibility Report evaluates alternatives for methane gas recovery and beneficial reuse of biogas at the City WWTP and/or Landfill as part of the City's CAAP objectives. This evaluation focuses on monetizing the benefits associated with the reuse of methane sourced from either the WWTP and/or the Landfill. The SROI analysis considers the triple bottom line (i.e., economic, environmental, and social) benefits of methane reuse. This study focuses on the economic and environmental impacts.

The analysis took into account:

- Estimated reductions in Greenhouse Gas (GHG) emissions and the associated social cost of carbon;
- Value of Renewable Identification Number (RIN) credits under the Renewable Fuel Standard Program (RFS);
- Value of electricity exported to the grid under net metering and buyback agreements with MidAmerican Energy Company and the Eastern Iowa Light and Power Cooperative;
- Value of avoided natural gas purchases;
- Capital investment and O&M costs of biogas reuse alternatives; and
- Energy Return on Investment (EROEI).

The results of this Study are intended to help the City assess the viability of alternatives with the greatest potential to reduce GHG emissions under CAAP Action Items 3.7 and 3.8. This Report details technical information on the feasibility analysis and summarizes the previous Technical Memorandums (TMs) that were completed by HDR leading up to the SROI analysis:

1. Evaluation of Existing Facilities TM
2. Wasteshed Analysis TM
3. Biogas Utilization Alternatives TM

2 Project Background

2.1 Climate Action and Adaptation Plan

In September of 2018, the City Council approved its Climate Action and Adaptation Plan. CAAP included specific actions to achieve GHG emissions targets. The plan's targets are in accordance with the Paris Agreement and include city-wide carbon emissions reductions of 25-28% over 2005 levels. On August 6th, 2019, the City passed Resolution 19-218 declaring a climate crisis and requesting accelerated action toward carbon emissions reductions in an effort to meet the Intergovernmental Panel on Climate Change (IPCC) target of limiting global warming to 1.5 Celsius.

CAAP identified 35 actions related to buildings, transportation, waste, adaptation, and sustainable lifestyle to help the City achieve its goals for reducing carbon emissions. Furthermore, these 35 actions were broken into 3 phases with phase 1 actions to be initiated by the end of 2020. Under waste actions 3.7 and 3.8 the City is looking to explore ways to recover and beneficially reuse methane from landfill and WWTP. The importance of these actions were reiterated in the Accelerating Iowa City's Climate Action Plan, published in April 2020. As noted in the CAAP:

> **Action Number 3.7: Take action on a feasibility study to efficiently capture and use methane from wastewater operations:**
>
> *"After water is used by residents, it flows into the wastewater system and then goes to the City's Wastewater Treatment Facility. While the City currently captures methane gas from the digesters used in the wastewater treatment process, only a portion of the methane is used to offset natural gas usage for the plant. To explore other options for further management of wastewater greenhouse gas (GHG) emissions, the City should conduct a study to determine the feasibility of using all captured methane to create renewable fuel or electricity that can be used to operate the facility, and take specific actions based on the results of this study."*
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> **Action Number 3.8: Take action on a feasibility study on energy generation from landfill methane.**
>
> *"The methane produced by decomposition of organic waste in the Iowa City Landfill is currently being flared to transform it into carbon dioxide, which is a less potent GHG. The City has been considering methods to use the methane as a renewable energy source, and to further explore this opportunity, the City will conduct a feasibility study in FY2019 and take specific actions based on the results of this study."*

2.2 Feasibility Study

The objective of this Feasibility Study is to evaluate alternatives developed to support actions 3.7 and 3.8. To conduct this study, HDR applied its SROI framework to evaluate alternatives. The following sections of this report detail:

- The approach used.
- The alternatives considered.
- The economic analysis methods used to evaluate alternatives.
- A summary of the economic analysis results.
- Recommendations for waste actions 3.7 and 3.8.

2.2.1 SROI Background

SROI evaluates whether the public value of a project is sufficient to justify the money required to develop the project and which alternative provides the greatest financial and societal return relative to the project cost. SROI process is an enhanced form of benefit cost analysis (BCA) that involves a systematic comparison of the benefits and costs of projects in ways that communicate a project's triple-bottom line outcomes, (i.e. its full range of environmental, social and economic impacts). SROI originated from a commitment by HDR to develop a new generation of public decision support metrics for the Clinton Global Initiative (CGI) in 2007. SROI was developed with input from Columbia University's Graduate School of International Public Affairs and launched at the 2009 CGI annual meeting. Since then, the SROI process has been used by HDR to evaluate the monetary value of numerous sustainability programs and projects for water and wastewater infrastructure utilities around the country.

2.2.2 Methodology of SROI Process

The SROI process draws from standard economic BCA methods and the best available data to systematically calculate and compare the benefits and costs of project alternatives. The process addresses sustainability goals and outcomes from a triple bottom-line perspective, meaning the range of potential environmental, social, and economic impacts (see Figure 1). In this Feasibility Study, impacts are associated with the economic and environmental benefits related to the value of RIN credits to the City as well as the social cost of carbon associated with changes in GHG emissions. In addition, the EROEI and tons of GHG emissions are estimated as non-monetary metrics.

Figure 1: SROI Triple Bottom Line Accounting

The SROI process builds on best practices in benefit-cost and financial analysis methodologies, complemented by advanced risk analysis and stakeholder elicitation. Typically, the SROI process is implemented in four steps, which include:

1. **Develop the structure and logic diagrams (S&L's)**: Structure and logic diagrams are useful to display the understanding of how key variables within an analysis interact to influence the intermediate or final outputs being measured. These diagrams provide a

transparent view of the calculations being made in the analyses for key stakeholders and subject matter experts to review and understand the process better.

2. **Assign values to inputs**: Values are assigned to inputs based on logic established in the S&L's. In some instances, ranges for inputs are established to enable the analysis to capture how an input will impact the project with the potential variability of its value essentially simulating real world conditions.
3. **Develop consensus among stakeholders to validate inputs**: The S&L's and inputs are then presented to stakeholders for validation. This is a key step in the SROI process. Stakeholders and subject matter experts are consulted regarding the values used to understand their view on these inputs. This step is critical for getting stakeholder buy-in on the process and seeking out additional knowledge that may not have been captured previously.
4. **Evaluate impact on agency goals (e.g. cost, environmental impact, public perception, etc.), including simulation if applicable**: These inputs will then be added into the model structure detailed with the structure and logic diagrams to evaluate the agency goals, specifically the costs or environmental impact. The alternative that best meets these criteria will be the one that is the most desirable alternative.

3 Renewable Natural Gas as a Resource

Renewable Natural Gas (RNG) is biogas or landfill gas that has been treated or refined to natural gas (NG) quality. The resulting RNG can be used interchangeably with NG, but is considered renewable as it doesn't rely on petroleum and can therefore provide additional environmental attributes through federal and state programs.

3.1 Renewable Natural Gas - Environmental Attributes as Vehicle Fuel

3.1.1 EPA - Renewable Fuel Standard

The United States Congress created the Renewable Fuels Standard (RFS) through the Energy Policy Act of 2005 and revised the program with the Energy Independence and Security Act in 2007. The RFS is a renewable fuels program within the Clean Air Act which mandates that large fuel producers and blenders (Obligated Parties) must include within their fuel mix a growing portion of renewable fuels. The quotas required of the Obligated Parties are referred to as Renewable Volume Obligations (RVOs) and are established and tracked by the United States Environmental Protection Agency (EPA) through the use of renewable credits, also known as, Renewable Identification Numbers (RINs). The original program was designed to increase the RVOs until 2022 and then level off beyond that point unless Congress issued another amendment. The EPA can lower or raise the RVOs up to the maximum RVO quota set for 2022, but Congressional action would be required to eliminate the RFS program. The RFS program has pressure against it from the Oil and Gas Industry, but also has a strong support from the Corn Ethanol Industry, who represent half of the RIN market.

As the EPA's RFS, RVOs are developed by categorized RIN types based on their environmental benefit and the production pathway. These categories, D3 through D7, encompass lower value biofuels like corn-based ethanol (D6) up to high value biofuels like cellulosic biodiesel or ethanol (D3) (see Figure 2).

RNG produced from landfill gas is considered D3 cellulosic biofuel in the RFS. RNG produced from wastewater biogas production from anaerobic digestion or co-digestion is considered D3 cellulosic or D5 advanced biofuel depending on the feedstocks used to production. The biogas produced from the digestion of municipal biosolids will be considered D3 cellulosic and have the highest value. However, any biogas produced by the co-digestion of municipal solids with hauled in or high strength wastes will be considered D5 advanced, unless each individual feedstock has a 75% or higher cellulosic content.

Figure 2: EPA RFS Nested RIN Categories and Volumes

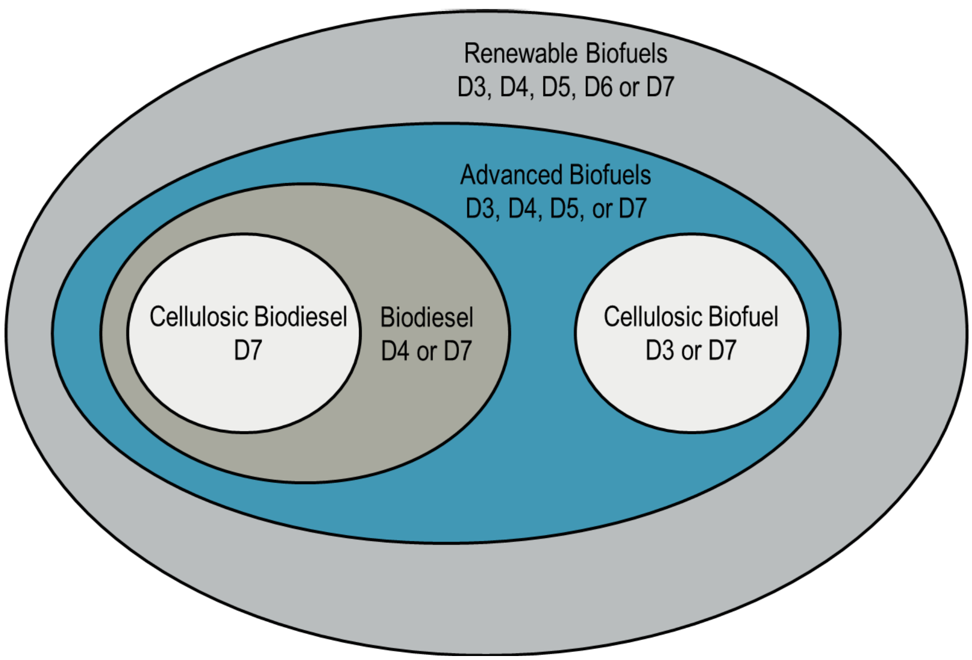
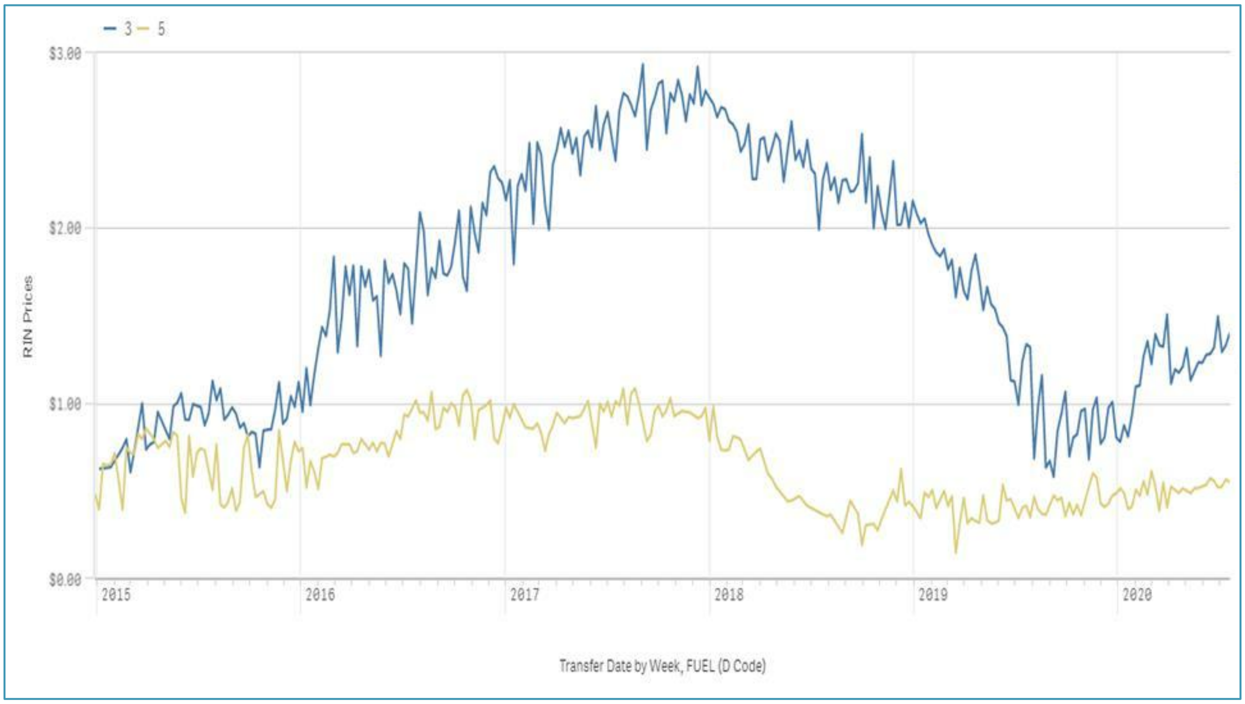


Figure 3 presents the historical RIN values as reported by the EPA from 2015 through August 2020.

Figure 3: Historical RIN values From the EPA from 2015 Through August 2020

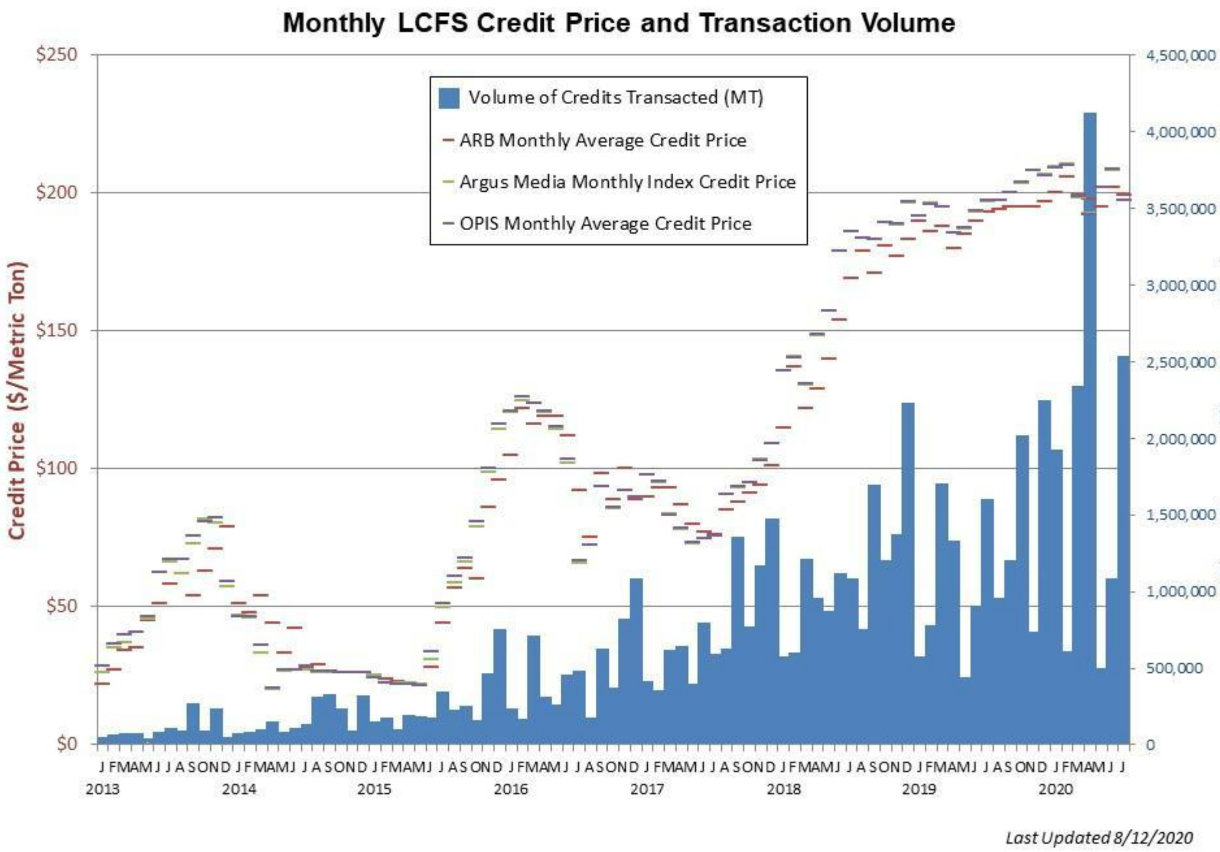


Source: https://www.epa.gov/fuels-registration-reporting-and-compliance-help/rin-trades-and-price-information

3.1.2 California Low Carbon Fuel Standard

In addition to RINs, carbon offset credits are also available through California's Low Carbon Fuel Standard (LCFS) program. The LCFS market has become a healthy market with more transactions and higher values throughout the last seven years (see Figure 4) and is not anticipated to end until 2032. LCFS credits can be obtained in addition to RIN credits as long as the renewable fuel is contracted for sale to an Obligated Party with end use in California.

Figure 4: California LCFS Market History



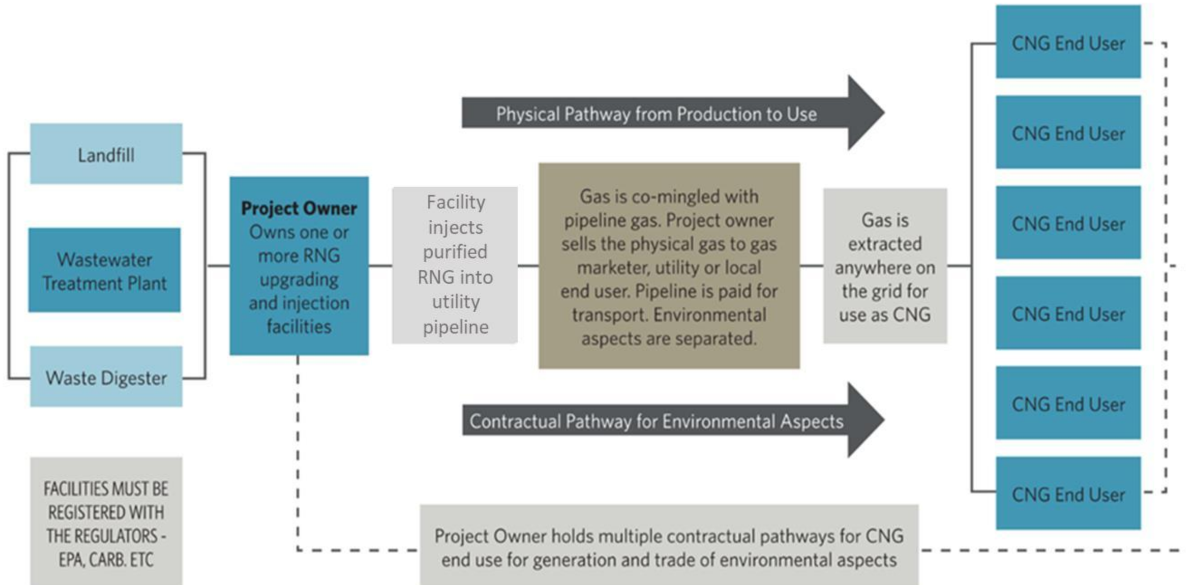
This chart tracks credit prices and transaction volumes over time. Monthly average credit prices reported by Argus Media and OPIS [used with permission] are shown along with CARB monthly average price.

3.1.3 Requirements and Pathways

A requirement to be aware of for both of these programs (RFS and LCFS) is that they are specifically renewable fuels for transportation programs. As such, the fuel must ultimately be used as a transportation fuel in order for the renewable attribute to be recognized. A renewable fuel producer is not required to explicitly find a transportation end user of the fuel it produces, however, at some point along the fuel supply pathway, it must be used as transportation fuel so that an Obligated Party can claim the RIN and/or the LCFS credit and meet its obligation with the EPA or with California.

The production and sale of RNG and environmental attributes like RINs and/or LCFS occurs in two pathways; the physical pathway and the contractual pathway for the attributes. The physical pathway is the sale of the RNG by the producer to end user of the gas via the natural gas grid. The contractual pathway for the attributes is separate and handled by third party which verifies that the RNG is truly renewable and markets the attributes to Obligated Parties. Figure 5 illustrates the two pathways of RNG and RIN/LCFS sales. It is important to note that the molecules of natural gas don't actually have to be used as vehicle fuel, but the physical pathway needs to be verified through the grid system.

Figure 5: PhysRNG Value Considerations



The value of RNG should take into account following:

1. The value of the RNG as natural gas based on the natural gas commodity market.
2. The value of environmental attributes obtained through the RFS (D3 or D5)
3. The value environmental attributes obtained through the LCFS.
4. The cost of compliance with the RFS and LCFS.
5. The cost of marketing the environmental attributes to Obligated Parties.

Items 1-3 should be considered as ranges (low, median, high) to account for the variability in future market values. The biogas revenues at the WWTP need to be divided into D3 and D5 categories. The biogas produced in the anaerobic digesters handling municipal biosolids will produce D3, but biogas produced at the co-digestion facility will be D5, but may be eligible for LCFS depending on the carbon intensity score. Items 4 and 5 are included to reflect the cost of bringing the gas to market within the environmental attribute programs. The RFS is highly regulated, so market RIN values are typically reduced by 15% and the LCFS values by 15-30% to account for the third part cost of compliance and marketing the environmental attributes to Obligated Parties. The third parties are either gas marketing companies or the Obligated Parties themselves, and are typically selected by a Request for Proposal (RFP) process. The resulting contractual arrangement specifies the City's share be based on either a fixed price or percentage of total revenue and the term of the agreement. The third party will qualify the RINs with EPA, qualify with California for LCFS credits, develop QA programs for certification, and administer the program. The City is then paid by the third party for both the natural gas commodity value and the associated renewable attributes based on a monthly or quarterly invoice.

4 Description of Project Alternatives

Three beneficial reuse alternatives were analyzed for current and future biogas generated at the WWTP and Landfill. For a complete and detailed assessment, please refer to the Biogas Utilization Alternatives Analysis Technical Memorandum previously provided by HDR, dated July 17, 2020. Recognizing synergy with another action in the City's CAAP, Action Item 3.2 Increase Composting of Organics, HDR also considered impacts of diverting incremental volumes of food waste from the Landfill to the existing WWTP, a new, dedicated anaerobic digester, and expanded composting operations. The following is a description of each alternative.

4.1 Alternative 1: Natural Gas Pipeline Injection

Biogas Utilization Alternative 1 assumes that the City purchases and operates equipment to condition the biogas to natural gas quality (RNG) for injection into the natural gas pipeline. To provide an interconnection point, the natural gas utility (MidAmerican Energy Company) would route a new pipeline from the existing natural gas distribution system to the City's property. The City would be required to reimburse the utility for the cost of the connecting pipe, and also pay an annual pipeline usage fee. This pipeline usage fee is dependent on the amount of RNG injected into the natural gas pipeline by the City. Assuming natural gas quality meets the RFS Program, the City would sell RIN credits and surrender any downstream GHG emissions reductions that would be realized by the Obligated Party purchasing the credits. Alternative 1 is applicable to both the WWTP and Landfill, presented as alternatives 1a and 1b, respectively.

4.2 Alternative 2: Electricity Generation

Biogas Utilization Alternative 2 assumes that biogas is conditioned and utilized in engine generators owned and operated by the City to produce renewable electricity. The electric power utility (MidAmerican Energy or Eastern Iowa Light & Power) would establish a connection to the grid, enabling the City to sell the renewable power. The City would be required to reimburse the electric utility for all system upgrades required to accommodate the connection. Under this alternative, HDR assumes that the City's contract with the electric power utility would allow the City to retain Renewable Energy Credits (RECs) to offset GHG emission associated with electricity use in their buildings and facilities. Alternative 2 is applicable to both the WWTP and Landfill, presented as alternatives 2a and 2b, respectively.

4.3 Alternative 3: WWTP Natural Gas Replacement

Biogas Utilization Alternative 3 involves conditioning biogas to natural gas quality with the intent of using the RNG in place of the natural gas at the WWTP. Biogas would be conditioned to natural gas quality by equipment owned and operated by the City to be installed at the WWTP. The WWTP RNG produced will exceed the amount of natural gas used at the plant. As such, the City would need to either: find a use for the excess RNG produced, flare the excess gas, or the City would only condition the amount of biogas needed and the excess biogas would be flared. For this analysis, it was assumed that RNG production would be capped at 62,848 standard cubic feet per day. Alternative 3 is only applicable to the WWTP as natural gas is not consumed at the landfill.

4.4 Alternative 4: Composting

Alternative 4 consists of diverting organic waste that would typically be placed in the landfill to a new or expanded composting facility. Because the existing composting operation is at capacity, this alternative assumes the City would utilize existing owned-land and purchase equipment to expand composting capacity. This alternative is only relevant for the Low-Diversion scenario, further described in the section below.

4.5 Organics Diversion Scenarios

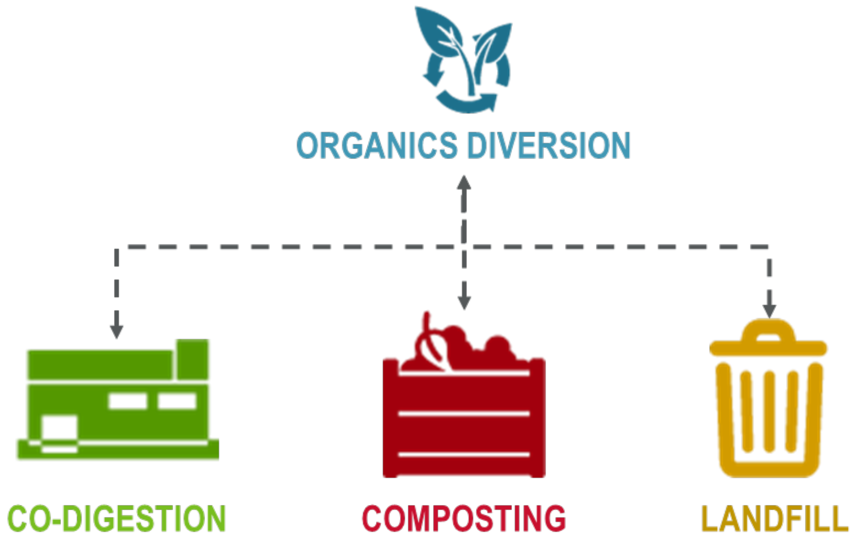
Recognizing the synergy with the City's goal to increase composting of organics, HDR evaluated the relative cost and GHG emissions impact for each of the four alternatives under three food waste diversion scenarios. HDR's previous technical analysis determined the impact on future biogas generation quantity when some of the City's organic matter is diverted from the Landfill for co-digestion or composting.

The three organics diversion scenarios include:

1) No Organics Diversion. The No Organics Diversion scenario assumes that all organics material is disposed of in the Landfill (i.e. current operation).
2) 1,500 tons. The 1,500 tons scenario assumes that an additional 1,500 tons of food waste material will be diverted from the Landfill to the existing WWTP anaerobic digester each year. This quantity represents the current available capacity in the WWTP anaerobic digester; therefore, no additional digester capacity is required for this diversion scenario. This scenario is not applicable to composting, as the existing facility is operating at capacity.
3) Low-Diversion. The Low-Diversion scenario assumes that 20% of organic material (7,960 tons/year) currently disposed of at the Landfill is diverted to new anaerobic digesters or an expanded composting facility. For GHG emissions modeling purposes, HDR assumed that the additional diverted organic material is entirely comprised of food waste. The required anaerobic digester volume required for the Low-Diversion scenario is 1.4 million gallons (MG).

For purposes of this study, HDR assumed that the new waste receiving station and standalone anaerobic digesters required to accept the additional diverted food waste would be located at the WWTP. A standalone digester facility for the diverted organic waste was assumed because the RIN credits for RNG produced in a municipal WWTP digester will have a higher value than those for RNG produced by a diverted waste digester. Additionally, the WWTP digester gas contains high levels of siloxanes. It is beneficial to keep the two sources of biogas separated until the siloxanes are removed from the WWTP biogas. Over the course of the Study development, discussion with City staff supported retaining digester capacity within the existing complex to support municipal biosolids. Therefore, for a planning level, Feasibility Study, an independent system to support new low-diversion digesters is proposed. Implementation would include independent operation, and not an expansion of the existing digester facility. However, as the plan is refined, a more detailed evaluation and conceptual design should be conducted to further determine the best approach for the City.

Figure 6: Organics Diversion



A summary of the alternatives and diversion scenarios selected for the SROI analysis are listed in Table 1.

Table 1: Summary of the Alternatives and Diversion Scenarios evaluated for Feasibility

Alternative Description		Facility Location	Scenario Name
Pipeline Injection (Alt. 1)	Sell RIN credits, & no additional organics diversion	WWTP	Alt. 1a - ND
		Landfill	Alt. 1b - ND
	Sell RIN credits, & 1,500 TPY organics diverted from landfill	WWTP	Alt. 1a - 1500 Div
		Landfill	Alt. 1b - 1500 Div
	New AD facility, sell RIN credits, & 7,960 TPY organics diverted from landfill	WWTP	Alt. 1a - LD
		Landfill	Alt. 1b - LD
Electricity Generation (Alt. 2)	No additional organics diversion	WWTP	Alt. 2a - ND
		Landfill	Alt. 2b - ND
	1,500 TPY organics diverted from landfill	WWTP	Alt. 2a - 1500 Div
		Landfill	Alt. 2b - 1500 Div
	7,960 TPY organics diverted from landfill	WWTP	Alt. 2a - LD
		Landfill	Alt. 2b - LD
Natural Gas Replacement (Alt. 3)	No additional organics diversion	WWTP	Alt. 3 - ND
	1,500 TPY organics diverted from landfill	WWTP	Alt. 3 - 1500 Div
	New AD facility, & 7,960 TPY organics diverted from landfill	WWTP	Alt. 3 - LD
Expanded Composting (Alt. 4)	7,960 TPY organics diverted from landfill	Compost	Alt. 4

Some of the alternatives listed in Table 1 can be constructed as standalone alternatives. Additionally the alternatives can be constructed together in various combinations provided the same waste diversion scenario is followed. For example, Alternative 1b – NG Pipeline Injection at the Landfill may be constructed at the Landfill with no improvements at the WWTP.

Alternatively, Alternative 1b could be selected for utilization of the biogas at the Landfill, with Alternative 2a (Electricity Generation) selected for biogas utilization at the WWTP.

A more detailed explanation and associated matrix table of possible combination scenarios is included later under Section 5.1.

4.5.1 Impacts to Existing Wastewater Treatment Plant

Implementation of anaerobic digestion for organics diversion can result in impacts to the existing WWTP. The diverted organics need to be incorporated into a mixture with a target feed total solids (TS) content of 6 percent. This requires the use of makeup water to create the mixture in a receiving station. Typically, the makeup water is a combination of digester recycle and WWTP effluent. The total water feed rate into the digester is estimated near 90,000 gallons per day, and the makeup water stream would be small.

A more important impact to the existing WWTP is the return stream from the diversion digester. After dewatering of the digested solids, some of the excess water must be returned to the plant as recycle. Digestion of organics results in the release of nutrients, nitrogen and phosphorus in the forms of ammonium and phosphate, respectively. After dewatering, the nutrients are divided between the solids and liquids residuals. A fraction of the nutrients would remain with the solids to their ultimate disposal (e.g. land application or landfilling). The remaining fraction is recycled with the liquid residuals to the WWTP. Recycled nutrients then consume part of the nitrification and nutrient removal capacities of the treatment facility. In addition, the carbon to nutrient ratio is skewed and biological nutrient removal becomes less favorable. This means that carbon addition may be needed to support biological nutrient removal. Further, liquid treatment capacity and cost must be reevaluated with potential increases to nutrient loading.

Organic waste nutrient content varies considerably. The nitrogen content can vary between 5 and 50 percent of the TS, and the phosphorus content can vary between 1 and 10 percent of the TS. This analysis used typical food waste values of roughly 10 percent for nitrogen content and 5 percent for phosphorus for the analysis. The result is an additional 150 to 200 lb-N/d nitrogen load and an additional 30 to 50 lb-P/d phosphorus load estimated for the WWTP for every ton/d of organics diversion. In all, every 1 ton/d of diverted wastes results in a recycle containing between 2 and 3 percent of the WWTP's nitrogen capacity. The Low-Diversion scenario is based on about 4 ton/d of organics diversion, which could use between 8 and 12 percent of the WWTP's TKN capacity[1].

4.6 Estimated Costs

A detailed opinion of probable costs and opinion of O&M costs was developed for the No-Diversion scenario for each alternative. The No-Diversion scenario costs (gas conditioning system and electricity generation equipment) were then extrapolated to estimate costs for the two diversion scenarios for each alternative. For the Low-Diversion scenario, costs were added for a new anaerobic digester and waste receiving station. The estimated biogas quantities for each

[1] Design TKN capacity of WWTP identified as 6,311 lb-N/d based on NPDES permit issued 05/01/2020

scenario as a basis for the extrapolation. Equipment proposals were also obtained for the No-Diversion scenario for each alternative.

Table 2 contains a summary of the capital and O&M costs for each alternative selected for the detailed SROI analysis.

Table 2: Biogas Utilization Alternatives Summary

Alternative	Scenario	Alternative Designation	Opinion of Probable Construction Costs	Opinion of Probable Annual O&M Costs
1a: WWTP NG Pipeline Injection	No Diversion	1A - ND	$8,600,000	$1,353,000
	1,500 Ton/Year	1A - 1500	$10,800,000	$1,815,000
	Low Diversion	1A - LD	$41,400,000	$3,112,000
1b: Landfill NG Pipeline Injection	No Diversion	1B - ND	$29,200,000	$2,292,000
	1,500 Ton/Year	1B - 1500	$29,000,000	$2,282,000
	Low Diversion	1B - LD	$28,000,000	$2,200,000
2a-2: WWTP Electricity Generation	No Diversion	2A - ND	$13,500,000	$1,067,000
	1,500 Ton/Year	2A - 1500	$17,000,000	$1,432,000
	Low Diversion	2A - LD	$50,000,000	$2,538,000
2b-2: Landfill Electricity Generation	No Diversion	2B - ND	$20,500,000	$1,288,000
	1,500 Ton/Year	2B - 1500	$20,300,000	$1,282,000
	Low Diversion	2B - LD	$19,600,000	$1,236,000
3: WWTP NG Replacement	No Diversion	3 - ND	$7,700,000	$867,000
	1,500 Ton/Year	3 - 1500	$9,700,000	$1,163,000
	Low Diversion	3 - LD	$39,800,000	$2,136,000
4: Composting	Low Diversion	4	$5,700,000	$495,000

4.7 Description of Impact Categories

The effect of an alternative differs across the individual impact categories (individual economic and environmental benefits and/or costs) and depends on the design of the project alternative, site conditions where the project is implemented, and characteristics in the community. Estimation of benefits and costs from a project depends on the degree to which linkages can be quantified between alternatives and a benefit or cost, and then available economic literature to value this change.

This section develops the general assumptions and inputs used in the SROI analysis framework and describes the impacts.

4.7.1 General Assumptions and Inputs

The SROI analysis measures benefits and costs throughout a 30-year period of analysis from 2021 to through the year 2050 representing the GHG emissions reduction goal year in the City's

CAAP. The methodology makes several important assumptions and seeks to avoid overestimation of benefits and underestimation of costs. Specifically:

- Input prices are inflated to 2019 dollars;
- The analysis period begins in 2021 and ends in 2050. It includes twenty-nine years of operations (2022-2050); and
- A constant 3 percent real discount rate is assumed throughout the period of analysis.

4.7.2 Impact Categories

Each of the evaluated impacts is discussed in detail in the following sections. The impacts are organized by their respective triple bottom line categorization (economic and environmental).

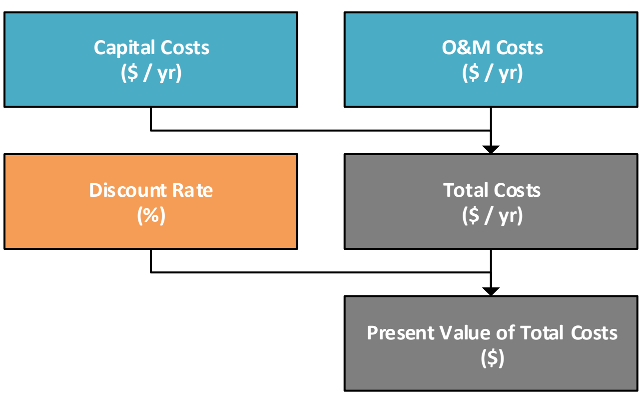
4.7.2.1 ECONOMIC IMPACTS

Economic benefits include impacts that are created by the project after deducting the cost of all inputs, including the cost of the capital expenditures (CAPEX) and annual operations and maintenance (O&M) costs (lifecycle costs of the project alternatives). Economic benefits include value of RIN credits to the City. Additionally a non-monetary measure of economic efficiency includes energy return on investment.

4.7.2.1.1 Lifecycle Costs

Lifecycle costs include CAPEX and annual O&M for each alternative. The costs are estimated as a 30 year life-cycle costs as shown below in the S&L diagram.

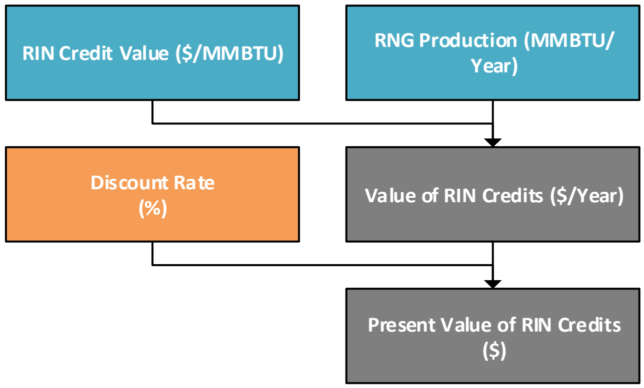
Figure 7: Lifecycle Cost Structure and Logic Diagram.



4.7.2.1.2 RIN Credit Benefits

RIN credits provide a potential unique revenue source to Alternative 1. RINs are the credits that the US Environmental Protection Agency (EPA) uses to track and enforce compliance with the renewable fuels mandates set by the federal RFS Program. The City may be able to generate and sell RIN credits to Obligated Parties by producing RNG from biogas and injecting it into the pipeline for blending with conventional, non-renewable natural gas. Figure 8 illustrates the value of RIN credits.

Figure 8: RIN Credit Value Structure and Logic Diagram.



The potential value of RIN credits beyond 2020 is shown below in Table 3. Based on this information and discussions between the City and HDR, the median D3 value ($16.18) was used in the SROI analysis for alternatives involving gas produced from the landfill. For alternatives located at the WWTP and food waste diversion scenarios the D5 value ($7.70) was used presuming the mix of a lesser quality gas.

Table 3: Value of RIN Credits

RIN and Carbon Market[2]	Units	Value			
		Most likely	Low	Median	High
Total for D3 + Commodity	$/MMBTU	$16.18	$8.20	$11.69	$25.15
Total for D5 + Commodity	$/MMBTU	$12.37	$5.71	$6.71	$9.70
Total for D5 + Commodity + LCFS	$/MMBTU	$7.70	$5.71	$11.69	$19.70

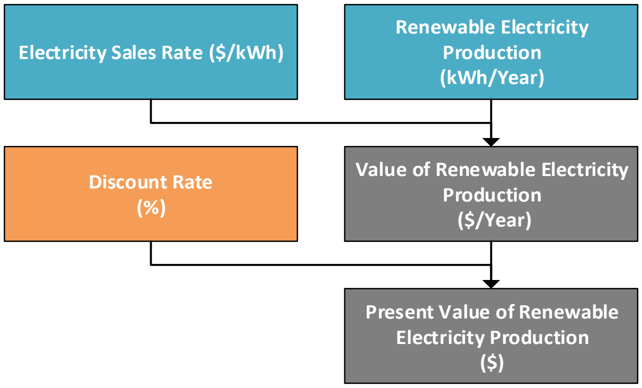
4.7.2.1.3 Renewable Electricity Production

Revenue from electricity sales are assumed to be captured from both net metering and negotiated buyback agreements with MidAmerican Energy Company and Eastern Iowa Light and Power Cooperative.

MidAmerican Energy Company (which supplies the electricity to the Iowa City Landfill) allows for net metering agreements for a facility nameplate generation capacity of up to 1 megawatt (MW) or 110% of its annual load. Credits from net metering agreements are paid out at the average locational marginal price (LMP) from the Midcontinent Independent System Operator (MISO) based on the generation profile of the resource. For energy produced beyond a nameplate capacity of 1 MW or 110% of its annual load, energy can be sold to MidAmerican Energy at a negotiated buyback rate. The Eastern Iowa Light and Power Cooperative allows for buyback agreements for facilities with a nameplate generation capacity exceeding 20 kilowatts (kW). Figure 9 illustrates the value of renewable electricity production.

[2] HDR is NOT providing a revenue projection or analysis of financial feasibility of alternatives. Such projections are highly dependent on open market commodity pricing, political volatility, and local, state, and federal programs and policies.

Figure 9: Renewable Electricity Production Value Structure and Logic Diagram



Electricity production was monetized under the assumptions shown in Table 4. The landfill is assumed to export 110% of its 2019 electricity usage at the net metered rate offered by MidAmerican Energy Company, and any excess generation is monetized at the negotiated buyback rate. The wastewater treatment plant receives the Eastern Iowa Light and Power Cooperative avoided cost rate for all of its electricity generation.

Table 4: Value of Renewable Electricity Production

Electricity Sales Assumptions	Units	Value
MidAmerican Energy Net Metering Rate	¢/kWh	2.6¢[3]
MidAmerican Energy Negotiated Buyback Rate	¢/kWh	2.6¢[4]
Eastern Iowa Light and Power Cooperative Avoided Cost Rate	¢/kWh	4.2¢[5]
2019 Iowa City Landfill Electricity Usage	kWh	278,882

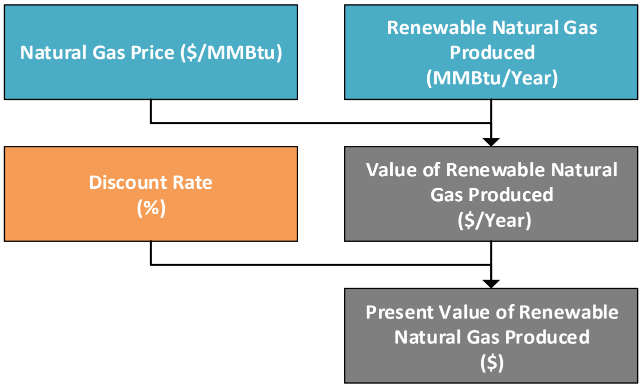
4.7.2.1.4 Value of Avoided Natural Gas Purchases

The WWTP RNG produced will exceed the amount of natural gas used at the plant. As such, the City would need to either: find a use for the excess RNG produced, flare the excess gas, or the City would only condition the amount of biogas needed and the excess biogas would be flared. Production of RNG would prevent the facility from needing to purchase natural gas. For this analysis, it was assumed that RNG production would be capped at 62,848 standard cubic feet

[3] The net metered rate is assumed to be a weighted average LMP based on 2019 hourly real-time LMP prices for the Illinois hub and the MISO load. Calculated based on data from Midcontinent Independent System Operator's market reports.
***********.misoenergy.org/markets-and-operations/real-time--market-data/market-reports/#nt=.
MISO historical load data was gathered from EnergyOnline from January 1, 2019 to December 31, 2019.
**********.energyonline.com/Data/GenericData.aspx?DataId=17.
[4] Negotiated buyback rate is assumed to be equivalent to the average LMP price calculated for the net metering rate.
[5] Weighted average calculation based on Eastern Iowa Light and Power Cooperative's posted avoided cost of generation during peak and off-peak hours.

per day and valued at the delivered cost of natural gas at the facility assumed to be **$3.16**[6] per MMBtu. The value stream is shown in Figure 10.

Figure 10: Renewable Natural Gas Value Structure and Logic Diagram



4.7.2.1.5 Energy return on energy investment

Energy return on energy investment is the ratio of the amount of usable energy delivered from a particular energy resource to the amount of energy used to obtain that energy resource as illustrated below.

$$EROEI = \frac{Eo}{E_i}$$

Where:

E_o = Energy output

E_i = Energy input

The resulting ratio demonstrates the relative energy inputs necessary to produce the energy output for each alternative. The higher the EROEI, the greater the amount of energy that is yielded for the amount of energy produced. EROEI was estimated for each alternative except for Alternative 4, because composting does not generate energy.

Energy output was based on the quantity of RNG produced or electricity generated. In addition to energy generated, HDR also factored in lifecycle energy use reduction using the USEPA Waste Reduction Model (WARM), which compares GHG emissions reductions and lifecycle energy savings from baseline and alternative waste management scenarios. HDR estimated change in lifecycle embodied energy by utilizing WARM to compare the baseline conditions to both 1,500 tons and Low-Diversion scenarios. Specifically, the output of the WARM model estimated the lifecycle energy use reduction by co-digesting or composting additional diverted food waste as compared to the baseline of landfilling this material. Because WARM is a lifecycle assessment tool, meaning impacts are estimated from cradle-to-grave, the estimated energy use reduction

[6] Calculated based on natural gas delivered and delivery charges from the wastewater treatment plant's bill for the month of October 2020.

occurs outside of the City's reporting boundary and would not be evident in annual GHG emissions inventories.

Direct energy input is based on the parasitic load of new equipment installed for the purposes of generating RNG or electricity, and does not include base load energy use required to operate the WWTP and Landfill Facilities based on current conditions. Specifically, direct energy input includes the parasitic load of the biogas conditioning equipment and electric generators. All energy output and input measures were converted into million British thermal units (MMBtu) to allow a relative comparison of alternatives. Table 5 provides details on each energy output and input value. The resulting EROEI's are presented in the results section of this report.

Table 5: Estimated Energy Inputs for Each Alternative

Alternative Description	Location	Alternative	Energy Input			Energy Output (Lifecycle Output + Lifecycle Energy Reduction)				EROEI
			kW/hr[1]	lifecycle (MMBTU)	RNG (scfm)[2]	kW-hr/day[1]	Lifecycle Output (MMBTU)	Lifecycle Energy Reduction (MMBTU)	Total Lifecycle Energy Output (MMBTU)	
Pipeline Injection	WWTP	Alt. 1a - ND	158	141,680	71	0	1,056,062	0	1,056,062	7.5
		Alt. 1a - 1500 Div	243	217,901	95	0	1,417,070	0	1,497,046	6.9
		Alt. 1a - LD	375	336,266	142	0	2,121,111	79,976	2,545,515	7.6
	Landfill	Alt. 1b - ND	1,145	1,026,733	541	0	8,096,474	424,404	8,096,474	7.9
		Alt. 1b - 1500 Div	1,145	1,026,733	536	0	8,026,070	0	8,106,045	7.9
		Alt. 1b - LD	1,145	1,026,733	515	0	7,710,000	79,976	8,134,404	7.9
Electricity Generation	WWTP	Alt. 2a - ND	305	273,497	0	10,915	407,816	424,404	407,816	1.5
		Alt. 2a - 1500 Div	353	316,539	0	14,644	547,143	0	627,118	2.0
		Alt. 2a - LD	650	582,862	0	21,921	819,033	79,976	1,243,437	2.1
	Landfill	Alt. 2b - ND	317	284,257	0	94,517	3,531,432	424,404	3,531,432	12.4
		Alt. 2b - 1500 Div	317	284,257	0	93,695	3,500,720	0	3,580,696	12.6
		Alt. 2b - LD	317	284,257	0	89,997	3,362,552	79,976	3,786,956	13.3
Natural Gas Replacement	WWTP	Alt. 3 - ND	158	141,680	71	0	653,776	424,404	653,776	4.6
		Alt. 3 - 1500 Div	243	217,901	95	0	653,776	0	733,752	3.4
		Alt. 3 - LD	650	582,862	142	0	653,776	79,976	1,078,180	1.8
Expanded Composting	Compost	Alt. 4	0	0	0	0	0	424,404	0	0.0

Notes:
1) The conversion from kw/hr to MMBTU is: kw/hr * 24 hours * 3,412.14 BTU per kW/hr * 365 days * 30 years divided by 1,000,000.
2) The conversion from scfm to MMBTU is: scfm * 1440 mins/day * 950 BTU per scfm natural gas * 365 days * 30 years divided by 1,000,000.

4.7.2.2 ENVIRONMENTAL IMPACTS

Environmental benefits include impacts that are valued based on the project's change in natural resource quality or quantity. The environmental included in this analysis include the social cost of carbon measured by changes in the emissions of carbon dioxide equivalents (CO_2e).

4.7.2.2.1 Social Cost of Carbon

GHG Emissions Impact Assessment: HDR understands that a key driver for decision-making is understanding the relative GHG emissions impact associated with each alternative and making progress towards the City's climate action goals. GHG emissions were estimated for each alternative included in the SROI analysis, and considered both direct and lifecycle impacts, as well as avoided emissions resulting from the beneficial reuse of biogas. Calculation methodologies align with best practices described in the Global Protocol for Community-Scale Greenhouse Gas Emission Inventories **(**GPC**)** and Local Government Operations Protocol (LGOP) for GHG assessment. These considerations are described below and cumulative GHG emissions impacts for each alternative are presented in Table 6.

- Direct GHG emissions were based on the incremental emissions resulting from processes required to beneficially reuse biogas. Specifically, direct GHG emissions are based on the parasitic load of new equipment installed for the purposes of generating RNG or electricity, such as energy consumed by the biogas conditioning equipment and electric generators. It is important to note that direct emissions do not include base load energy use required to operate the WWTP and Landfill Facilities based on current conditions, rather, the Feasibility Study analyzes the incremental change from current operations. At the City's direction, HDR assumed that there would not be a material change in transportation-related GHG emissions associated with diverting food waste for the 1,500 tons and Low-Diversion scenarios. Lastly, it should be noted that GHG emissions associated with combustion of biogas/RNG is considered biogenic (CO_2(b)), and per the GPC, is to be reported separately outside of Scope 1, 2, and 3 GHG emission categories. Biogenic emissions are those related to the natural carbon cycle, as well as those resulting from the combustion, harvest, digestion, fermentation, decomposition or processing of biologically based materials.
- Lifecycle GHG emissions were estimated using the EPA WARM, which compares GHG emissions reductions and lifecycle energy savings from baseline and alternative waste management scenarios. HDR estimated change in lifecycle embodied carbon by utilizing WARM to compare the baseline conditions to both 1,500 tons and Low-Diversion scenarios. Specifically, the output of the WARM model estimated the lifecycle energy use reduction by co-digesting or composting additional diverted food waste as compared to the baseline of landfilling this material. Because WARM is a lifecycle assessment tool, meaning impacts are estimated from cradle-to-grave, the estimated GHG emissions reduction occurs outside of the City's reporting boundary and would not be evident in annual GHG emissions inventories.
- Avoided GHG emissions were estimated based on the beneficial reuse of biogas, including pipeline injection, electricity generation, and natural gas displacement, assuming:
  - Biogas injected into the natural gas pipeline would be utilized to generate and sell RIN credits, ultimately being used as a renewable fuel for mobile source

combustion. RNG is a market driver for commercial fleets to transition away from conventional diesel trucks to compressed natural gas (CNG)/RNG alternate fueled-vehicles. GHG emission reductions were estimated using a diesel fuel emissions factor published by the EPA.

- Biogas used to generate electricity would ultimately offset electricity generated by local electric power utilities (MidAmerican Energy or Eastern Iowa Light & Power). Emission factors were provided by the City. While MidAmerican Energy does have a public goal related to 100% of retail sales being served by renewable energy, this is not equivalent to a net zero carbon production goal. Absent of either electric utility having a publicly stated carbon emissions reduction goal, GHG emission reductions were estimated using the emission factor provided by the City, held constant for the study period.
- Biogas used as onsite fuel at the WWTP would displace natural gas on a 1:1 unit basis. GHG emission reductions were estimated using a natural gas emissions factor published by the EPA.

Table 6: Estimated GHG Emissions

Alternative Description	Location	Alternative	Change in Landfill GHG Inventory	Parasitic energy load	Change in biological treatment inventory	Beneficial reuse GHG benefit	Change in Net Embodied Carbon (EPA WARM)	Total Annual Change in CO_2e Metric Tons
Pipeline Injection	WWTP	Alt. 1a - ND	0	666	0	-2,017	0	-1,351
		Alt. 1a - 1500 Div	1,027	0	27	-2,707	-941	-2,594
		Alt. 1a - LD	1,585	0	144	-4,052	-4,996	-7,318
	Landfill	Alt. 1b - ND	0	4,840	0	-32,190	0	-27,350
		Alt. 1b - 1500 Div	0	4,840	0	-32,047	-941	-28,148
		Alt. 1b - LD	0	4,840	0	-30,903	-4,996	-31,059
Electricity Generation	WWTP	Alt. 2a - ND	0	1,289	0	-1,922	0	-633
		Alt. 2a - 1500 Div	1,492	0	27	-2,579	-941	-2,001
		Alt. 2a - LD	2,748	0	144	-3,861	-4,996	-5,965
	Landfill	Alt. 2b - ND	0	1,340	0	-16,647	0	-15,307
		Alt. 2b - 1500 Div	0	1,340	0	-13,282	-941	-12,884
		Alt. 2b - LD	0	1,340	0	-15,851	-4,996	-19,507
Natural Gas Replacement	WWTP	Alt. 3 - ND	0	666	0	-2,030	0	-1,363
		Alt. 3 - 1500 Div	0	1,027	27	-4,076	-941	-3,963
		Alt. 3 - LD	-7,221	144	2,748	-4,076	-4,996	-13,401
Expanded Composting	Compost	Alt. 4	-7,221	0	0	722	-5,670	-12,169

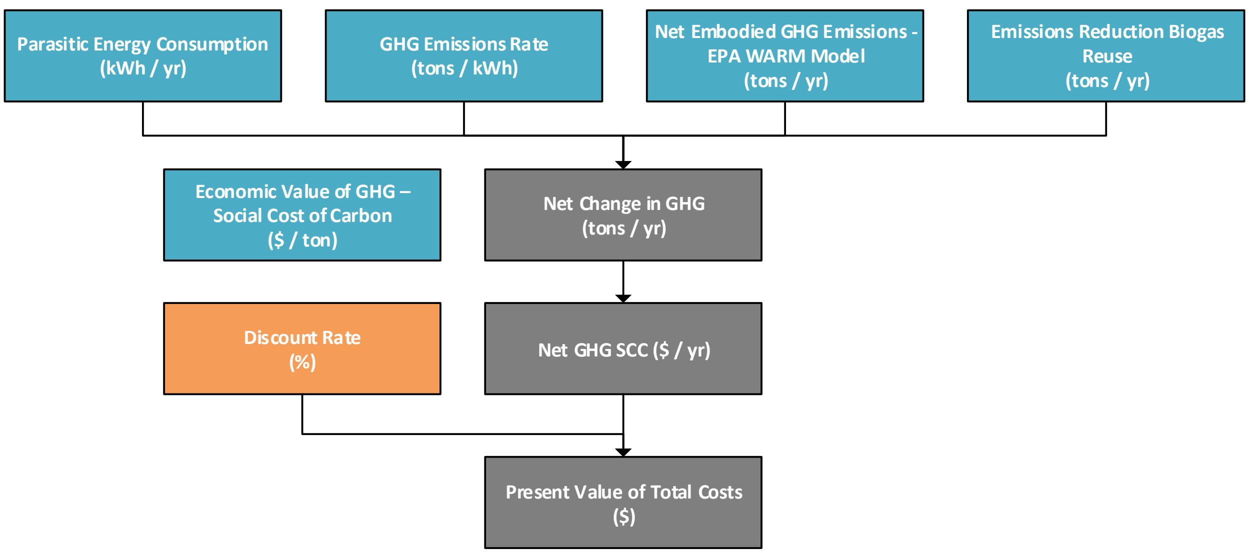
Value of GHG Emissions: Scientific studies in the United States and internationally have widely concluded that GHG emissions are closely linked with climate change, a condition that has been determined to lead to future economic impacts from more extreme weather events and damaging conditions on coasts. The impact is estimated from the change in energy production and net embodied carbon in each of the waste diversion scenarios. In alternatives of 1A and 1B (pipeline injection), RIN credits are counted as an economic benefit and the environmental attributes would therefore be sold to Obligated party who purchases the RIN credits. As such, the value of the social cost of carbon (SCC) is not counted for the associated changes in GHG emissions to avoid double counting.

GHG impacts were estimated using:

- EPA WARM model for the change in metric tons of CO_2e from embodied carbon in the waste stream;
- an electricity conversion factor (converts megawatt hours to tons of pollution for each emission type); and
- a cost of emission (monetizes the impact).

The logic for the estimating impacts of changes in GHG emissions is illustrated in Figure 11.

Figure 11: GHG Emissions Structure and Logic Diagram.



For CO_2e; the value from the Interagency Working Group on the Social Cost of Carbon (IWGSCC) was used in the analysis. This value is then escalated annually at 2% using rates derived from the Federal Interagency Working Group on Social Cost of Carbon. All values are in 2019 US dollars per ton.

Table 7: Social Costs of GHG Emissions

GHG Emissions	Unit	Value	Source
CO_2e	$/Ton	$46	IWGSCC (2013)

5 Summary Economic, and Environmental Impacts of Alternatives

The evaluation of economic and environmental impacts considered a time horizon or study period, which includes project development (construction and implementation) and 29 years of operation and benefit. This extends to 2050 and aligns with the planning horizon of the City's CAAP. Costs and benefits have been converted to present value using a 3% discount factor. Total benefits and costs are compared using a benefit to cost ratio (BCR), benefits divided by costs. BCR's exceeding 1.0 indicate that the benefits from the alternative exceed the costs of the investment over a 30 year period. Results are shown below in Table 8.

Consideration should be given to the implementation schedule of alternatives and potential for a phased approach. Revising the economic framework to account for a phasing of projects over 5-10 years would affect all of the alternatives equally and would not change the overall ranking or comparison of the alternatives. Furthermore, there is limited impact to the capital and O&M cost considerations as long as the period of study remains over 30-years. The more significant cost impacts are observed with a minimum delay of 8-10 years out of the study period. A number of implementation scenarios are possible, but the CIP planning impact is often similar from a planning perspective.

Table 8: Summary of Monetary Benefits and Costs ($ Millions, 2019)

Alternative Description	Location	Alternative	Total Cost	Total Social Cost of Carbon	Total Value for RIN Credit and Energy Revenues	Total Benefit	Benefit -Cost Ratio
Pipeline Injection	WWTP	Alt. 1a - ND	$35.92	$1.67	$5.48	$7.15	0.20
		Alt. 1a - 1500	$47.44	$3.21	$7.35	$10.56	0.22
		Alt. 1a - LD	$104.23	$18.01	$23.09	$41.10	0.39
	Landfill	Alt. 1b - ND	$75.47	$33.87	$88.14	$122.01	1.62
		Alt. 1b - 1500	$75.07	$34.86	$87.37	$122.23	1.63
		Alt. 1b - LD	$72.42	$38.46	$83.93	$122.39	1.69
Electricity Generation	WWTP	Alt. 2a - ND	$35.04	$0.78	$1.58	$1.91	0.05
		Alt. 2a - 1500	$45.91	$2.48	$2.71	$4.41	0.10
		Alt. 2a - LD	$101.24	$16.33	$2.77	$18.31	0.18
	Landfill	Alt. 2b - ND	$46.50	$18.96	$27.16	$35.23	0.76
		Alt. 2b - 1500	$46.18	$15.95	$26.91	$32.08	0.69
		Alt. 2b - LD	$44.55	$24.16	$25.75	$39.58	0.89
Natural Gas Replacement	WWTP	Alt. 3 - ND	$25.20	$1.69	$1.09	$2.78	0.11
		Alt. 3 - 1500	$33.18	$3.23	$0.93	$4.16	0.13
		Alt. 3 - LD	$82.92	$16.60	$0.15	$16.75	0.20
Expanded Composting	Compost	Alt. 4	$15.69	$15.07	$0.00	$15.07	0.96

The results show that only Alternative 1b (landfill natural gas) has benefits that exceed the costs. The highest BCR is Alternative 1b – Low-Diversion. This alternative ranks highest on total lifecycle CO_2e emission reductions, and when combined with the value of RIN credits results in the greatest economic benefits. However, the City should be aware that the CO_2e emission reduction when RINs are sold to an Obligated Party will occur outside of the City's municipal and community-scale GHG inventories. This alternative has the sixth highest cost of the 15 alternatives presented. The net result, of Alternative 1b, is a BCR of 1.69 dollars of benefit per dollar of cost invested.

A sensitivity test was conducted to test the impact of key monetary values (RIN credits and SCC values) on the ranking of the alternatives. Changing the value of the SCC was found to have no effect in ranking as the value influences all of the alternatives equally. Conversely, the RIN credit value only affects the BCR of pipeline injection alternative (Alternative 1) and would have an impact on alternative ranking. The sensitivity analysis showed that the realized RIN credit value would need to be below $6.00 per MMBTU, or 5% greater than the low value of D5 RIN credits shown Table 3 for the BCR ranking of alternatives to change.

Perhaps as important for consideration in CAAP are non-monetary considerations. The non-monetary metrics (EROEI and lifecycle change in CO_2e emissions) are shown in Table 9. Perhaps the most important measure related to CAAP action objectives is CO_2e reductions. All of the alternatives result in a net reduction in CO_2e over the next 30 years. Alternative 1b – Low-Diversion results in the greatest net reduction.

Table 9: Summary of Non-Monetary Impacts

Alternative Description	Location	Alternative	Lifecycle Change in CO_2e Emissions	Lifecycle EROEI
Pipeline Injection	WWTP	Alt. 1a - ND	40,500	6.9
		Alt. 1a - 1500	77,800	7.9
		Alt. 1a – LD	436,200	7.9
	Landfill	Alt. 1b - ND	820,500	7.5
		Alt. 1b - 1500	844,500	7.6
		Alt. 1b - LD	931,800	7.9
Electricity Generation	WWTP	Alt. 2a - ND	19,000	2.0
		Alt. 2a - 1500	60,000	12.4
		Alt. 2a - LD	395,600	13.3
	Landfill	Alt. 2b - ND	459,200	1.5
		Alt. 2b - 1500	386,500	2.1
		Alt. 2b - LD	585,200	12.6
Natural Gas Replacement	WWTP	Alt. 3 - ND	40,900	4.6
		Alt. 3 - 1500	78,300	3.4
		Alt. 3 - LD	252,200	1.8
Expanded Composting	Compost	Alt. 4	365,100	0.0

Finally, all alternatives, except for composting, result in an EROEI of 1.0 or greater. Incremental composting of food waste does not generate energy. Opposite of the economic and GHG measures, Alternative 2a (WWTP Electricity Generation) – Low-Diversion ranks highest on EROEI. Meanwhile Alt 1b – Low-Diversion is ranked 5th on EROEI.

The overall ranking of the alternatives for the monetary (BCR) and the two non-monetary results are shown below in Table 10.

Table 10: Summary and Ranking of Monetary and Non-Monetary Results

Alternative Description	Location	Alternative	GHG Reduction	GHG Rank	EROEI	EROEI Rank	BCR	BCR Rank
Pipeline Injection	WWTP	Alt. 1a - ND	40500	15	6.9	9	0.20	11
		Alt. 1a - 1500	77800	12	7.9	6	0.22	9
		Alt. 1a - LD	436200	6	7.9	4	0.39	8
	Landfill	Alt. 1b - ND	820500	3	7.5	8	1.62	3
		Alt. 1b - 1500	844500	2	7.6	7	1.63	2
		Alt. 1b - LD	931800	1	7.9	5	1.69	1
Electricity Generation	WWTP	Alt. 2a - ND	19000	16	2.0	13	0.05	16
		Alt. 2a - 1500	60000	13	12.4	3	0.10	15
		Alt. 2a - LD	395600	8	13.3	1	0.18	12
	Landfill	Alt. 2b - ND	459200	5	1.5	15	0.76	6
		Alt. 2b - 1500	386500	9	2.1	12	0.69	7
		Alt. 2b - LD	585200	4	12.6	2	0.89	5
Natural Gas Replacement	WWTP	Alt. 3 - ND	40900	14	4.6	10	0.11	14
		Alt. 3 - 1500	78300	11	3.4	11	0.13	13
		Alt. 3 - LD	402000	7	1.8	14	0.20	10
Expanded Composting	Compost	Alt. 4	365100	10	0.0	16	0.96	4

5.1 Findings and Insights

To make recommendations for actions under 3.7 and 3.8, the monetary and non-monetary results are combined into a weighted score as shown below in Table 11. Each result was converted to an index (1 to 0). The indexed results were then weighted equally into a total score with a maximum value of 1.

Table 11: Indexed and Weighted Scores for each Alternative

Alternative Description	Location	Alternative	GHG Reduction	EROEI	BCR	Total Score	Rank
Pipeline Injection	WWTP	Alt. 1a - ND	0.01	0.17	0.04	0.23	13
		Alt. 1a - 1500	0.03	0.20	0.04	0.27	11
		Alt. 1a - LD	0.16	0.20	0.08	0.43	6
	Landfill	Alt. 1b - ND	0.29	0.19	0.32	0.80	3
		Alt. 1b - 1500	0.30	0.19	0.32	0.81	2
		Alt. 1b - LD	0.33	0.20	0.33	0.86	1
Electricity Generation	WWTP	Alt. 2a - ND	0.01	0.05	0.01	0.07	16
		Alt. 2a - 1500	0.02	0.31	0.02	0.35	7
		Alt. 2a - LD	0.14	0.33	0.04	0.51	5
	Landfill	Alt. 2b - ND	0.16	0.04	0.15	0.35	8
		Alt. 2b - 1500	0.14	0.05	0.14	0.33	9
		Alt. 2b - LD	0.21	0.32	0.18	0.70	4
Natural Gas Replacement	WWTP	Alt. 3 - ND	0.01	0.12	0.02	0.15	14
		Alt. 3 - 1500	0.03	0.08	0.02	0.14	15
		Alt. 3 - LD	0.14	0.05	0.04	0.23	12
Expanded Composting	Compost	Alt. 4	0.13	0.00	0.19	0.32	10

As noted previously, the Alternative 1b-LD (Landfill RNG Pipeline Injection) – Low-Diversion has the highest BCR. It also has the highest GHG reduction over 30 years. This is driven by the assumption that biogas injected into the natural gas pipeline would be utilized to generate and sell RIN credits, ultimately being used as a renewable fuel for mobile source combustion. Further, RNG is a market driver for commercial fleets to transition away from conventional diesel trucks to compressed natural gas (CNG)/RNG alternate fueled-vehicles. However, the City should be aware that when RINs are sold to an Obligated Party, the CO_2e emission reduction will occur outside of the City's municipal and community-scale GHG inventories. Opposite of the economic and GHG impacts, Alternative 2a (WWTP Electricity Generation) – Low-Diversion ranks highest on EROEI. Meanwhile Alternative 1b – Low-Diversion is ranked 5th on EROEI.

Based on the indexing and weighting exercise, Alternative 1b (Landfill Natural Gas) – Low-Diversion has the highest score (0.86). Alternative 1b (landfill natural gas) – 1500 ton diversion is ranked second. Alternative 1b (landfill natural gas) – No-Diversion is ranked third. Again, CO_2e emission reduction associated with pipeline injection and used as a renewable fuel will occur outside of the City's municipal and community-scale GHG inventories.

If the City is instead focused on reductions that will be reflected in its municipal and community-scale GHG emission inventory, then evaluation should be narrowed to focus on Alternatives 2 (Electricity Generation) and 3 (Natural Gas Replacement). While electricity generated at the WWTP or Landfill (2a and 2b, respectively) could very well be pushed to the power grid, contractual agreements with local utilities could allow the City to retain and retire RECs for GHG accounting purposes. Specifically, RECs could be applied to the City's Scope 2 market-based GHG inventory. Using RNG to displace natural gas use at the WWTP would result in lower Scope 1 GHG emissions. Focused on these two alternatives, Alternative 2b – Low-Diversion is ranked highest (fourth overall), followed by Alternatives 2a – Low-Diversion and 2a – 1500. These alternatives are ranked 4, 5 and 7 overall.

If total GHG emissions reduction is the ultimately priority, Alternatives 1b (Landfill Pipeline Injection) offers the greatest potential, simply due to the volume of biogas generation and associated potential for renewable electricity generation.

Finally, biogas utilization alternatives can be combined together with others, and some can be incorporated as standalone projects (as shown in Table 12).

Table 12: Potential Biogas Utilization Alternatives Combinations

Weighted and Indexed Performance Indicators **Total Score, inclusive of:** ***GHG Reduction, EROI, and BCR***				**Landfill Location**						
				Do Nothing	No Diversion		1500 ton/yr Diversion		Low Diversion	
					NG Pipeline Injection	Electricity Generation	NG Pipeline Injection	Electricity Generation	NG Pipeline Injection	Electricity Generation
					Alt 1b-ND	Alt 2b-ND	Alt 1b-1500	Alt 2b-1500	Alt 1b-LD	Alt 2b-LD
WWTP Location	Do Nothing			0	0.80	0.35	0.81	0.33	0.86	0.70
	No Diversion	NG Pipeline Injection	Alt 1a-ND	0.23	1.02	0.58				
		Electricity Generation	Alt 2a-ND	0.07	0.87	0.42				
		NG Replacement	Alt 3-ND	0.15	0.95	0.50				
	1500 ton/yr Diversion	NG Pipeline Injection	Alt 1a-1500	0.27			1.08	0.60		
		Electricity Generation	Alt 2a-1500	0.35			1.16	0.68		
		NG Replacement	Alt 3-1500	0.14			0.95	0.47		
	Low Diversion	NG Pipeline Injection	Alt 1a-LD	0.43					1.30	1.13
		Electricity Generation	Alt 2a-LD	0.51					1.37	1.21
		NG Replacement	Alt 3-LD	0.23					1.09	0.93

There are 18 unique possible combinations of alternatives, Table 12 has been developed to more appropriately showcase combinations and the "diversion lanes" in which decisions would need to be maintained with a decision. Boxes with blue numbering indicate individual alternative scenarios at either the Landfill or at the WWTP. The boxes are also color coded in a “heat map” format, to show the overall ranking of the individual scenarios.

The individual alternatives can be combined together, but must be done so following the same waste diversion scenario from the Landfill. When combining the alternatives the scores from the Landfill and WWTP alternatives can be added together to identify the best combination of actions under each of the waste diversion scenarios. From Table 11 above, the higher the score the better the alternative. The highest scored alternatives are: Alternative 1b – NG Pipeline Injection landfill alternatives for each of the No-Diversion, 1500 ton diversion, and Low-Diversion scenarios. Identifying the best combination of actions works as follows: select the highest scored alternative from the desired waste diversion scenario (shown to be from the Alternative 1b – NG Pipeline Injection landfill alternatives) then work down the column (or “diversion lane”) to the desired combination scenario. In the case of combining with Alternative 2a – Electricity Generation at the WWTP, a resulting combined score of 1.16. As capital costs are also additive, consideration should be given to the seemingly minor weighted score differential. In the example of combined Alt 1b-1500 with Alt 2a-1500, there is an estimated $6.2M savings to select Alt 1b-1500 with Alt 1a-1500.

5.1.1 Path Forward

HDR recognizes that incremental food waste diversion is not an instantaneous process, but the SROI analysis provides an assessment of the resulting impact when achieved. This Report provides decision tools to support the City’s further consideration and decision making.

Consequently, the City might consider the following path forward to further evaluate and implement the preferred alternative(s):

i. City decision on desired diversion scenario and methane utilization at the WWTP to narrow the field of alternatives. (0-6 months)
ii. Further technical analysis to develop organics management strategies to achieve a targeted diversion scenario and further evaluate life cycle costs of co-digestion (if desired) and biogas utilization to generate electricity or RNG. Consideration of impacts to planned digester rehab project. (3-6 months)
iii. Conceptual Design Development of the selected alternative(s), providing basis of design parameters and implementation planning. (3-6 months)
iv. Detailed Design Development. (TBD)
v. Bidding and Construction. (TBD)

It may be prudent for the City to complete items i) and ii) within the next 6-months for capital planning purposes.

6 References:

City of Iowa City (2018), Climate Action and Adaptation Plan, https://www.icgov.org/project/climate-action.

City of Iowa City (2019), City Resolution 19-218, https://www.icgov.org/project/climate-action.

City of Iowa City, (2020), Accelerating Iowa City's Climate Action Plan, https://www.icgov.org/project/climate-action.

Clinton Global Initiative, (2007), https://www.clintonfoundation.org/clinton-global-initiative/commitments/creating-sustainable-return-investment-sroi-tool.

Interagency Working Group on Social Cost of Carbon (IWGSCC), United States Government. (2010). Technical Support Document: Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866.

U.S. Environmental Protection Agency (2019). Environmental Protection Agency Waste Reduction Model (WARM) version 15. https://www.epa.gov/warm/versions-waste-reduction-model-warm#15.

A

Appendix A

Low-Diversion Scenario Digester Costs

OPINION OF PROBABLE CONSTRUCTION COSTS

Low Diversion Scenario (20% Diversion) - New Anaerobic Digester Complex			
			Costs
Capital Cost	**Hauled Waste Receiving Station**		$2,960,000
	Anaerobic Digester (1.4 MG)		$18,325,000
	Sludge Dewatering and Storage		$4,990,000
	Total Adjusted Base Bid with Installation		**$26,300,000**
Annual O&M Cost	**General O&M - Parts, Labor, Electricity**	1.5% of capital subtotal	$394,500
	Annual O&M Costs		**$394,500**

B

Appendix B

Financial Proforma – Breakeven Analysis

Appendix B - Memo

Date:	Wednesday, December 23, 2020
Project:	CAAP Methane Recovery Feasibility Study (HDR #10203725)
To:	City of Iowa City (PM – Joseph Welter)
From:	HDR (PM – Morgan Mays; Marcella Thompson; Serguei Kouznetsov; Jeremy Cook)
Subject:	Financial Proforma - Breakeven Analysis

Building on the Sustainable Return on Investment (SROI) and the Energy Return on Energy Invested (EROEI) analysis performed by HDR, a high-level breakeven financial analysis was performed for each of the options identified in the Final Feasibility Report. The financial analysis examines the impact of cash flows to Iowa City (the City) to compare the revenues (inflows) and costs (outflows). The purpose of the analysis was to identify the length of time for each alternative to break-even. This memorandum outlines the cash flows evaluated, key assumptions, and the results of the analysis.

Key Assumptions

The financial analysis examined revenue streams for the various alternatives. For the pipeline injection alternatives, the revenue is derived from the Renewable Identification Number (RIN) credits under the Renewable Fuel Standard Program. For the electricity generation alternatives, the revenue is derived from electricity sales through an agreement with the utilities and Renewable Energy Credits (RECs). For natural gas replacement alternatives, revenue or rather savings are derived from avoided natural gas purchases.

Revenue from electricity sales are assumed to be captured from both net metering and negotiated buyback agreements with MidAmerican Energy Company and Eastern Iowa Light and Power Cooperative.

MidAmerican Energy Company (which supplies the electricity to the Iowa City Landfill) allows for net metering agreements for a facility nameplate generation capacity of up to 1 megawatt (MW). Credits from net metering agreements are paid out at the average locational marginal price (LMP) from the Midcontinent Independent System Operator (MISO) based on the generation profile of the resource. For energy produced beyond a nameplate capacity of 1 MW, energy can be sold to MidAmerican Energy at a negotiated buyback rate. The Eastern Iowa Light and Power Cooperative allows for buyback agreements for facilities with a nameplate generation capacity exceeding 20 kilowatts (kW). RECs are earned for each megawatt-hour (MWh) of electricity generated. For the purposes of this analysis, an average LMP of **2.6¢**[1] per kilowatt-hour (kWh) was calculated based on the 2019 LMP prices for the Illinois hub and the 2019

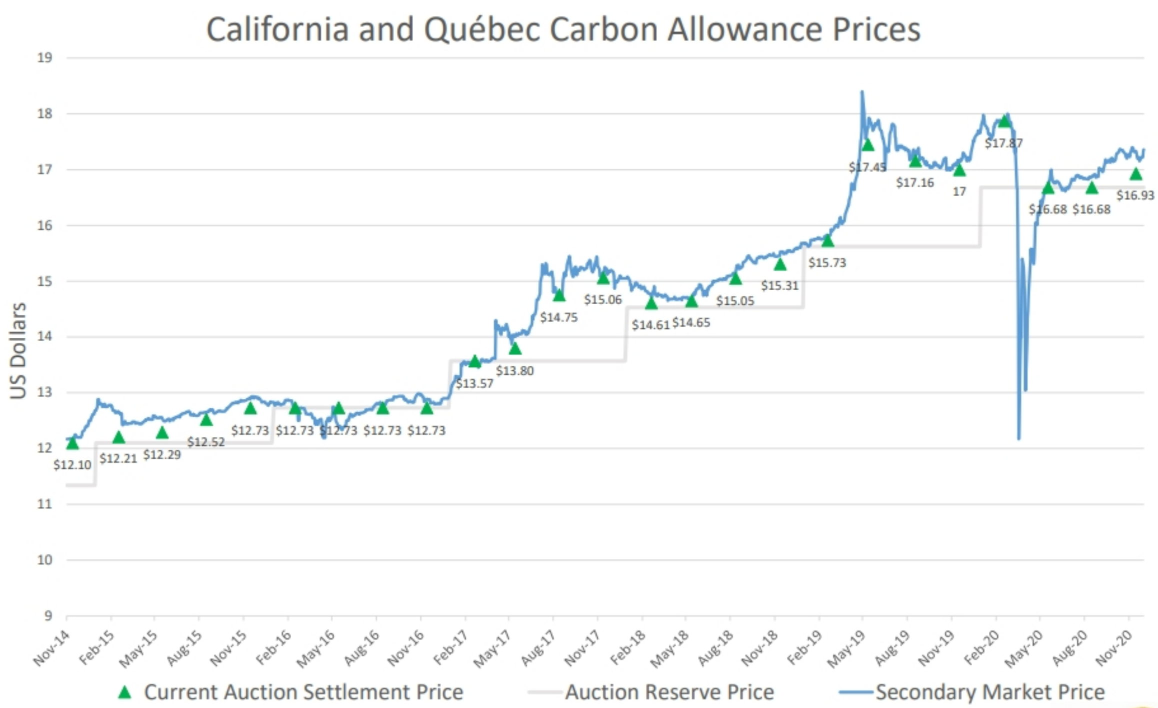
[1] Real time LMP prices gathered from Midcontinent Independent System Operator (MISO)'s historical LMPs for real-time markets from January 1, 2019 to December 31, 2019.
***********.misoenergy.org/markets-and-operations/real-time--market-data/market-reports/#nt=.
MISO historical load data was gathered from EnergyOnline from January 1, 2019 to December 31, 2019.
**********.energyonline.com/Data/GenericData.aspx?DataId=17.

MISO load. This was assumed to be the price paid per kWh for MidAmerican Energy's net metering agreements. It was also assumed that the negotiated buyback rate for electricity generation in excess of 1 MW was equivalent to the average LMP price of **2.6¢** per kWh. Eastern Iowa Light and Power Cooperative posts its avoided cost of generation during peak and off-peak hours online from which a weighted average rate of **4.2¢** per kWh was calculated for energy sales from the wastewater treatment plant.

Renewable energy credits were monetized at an average rate of **$17** per MWh based on the latest auction prices of $16.93 per MWh in and the approximate band of prices over the past couple of years (see figure below). The analysis assumed that prices would remain at that price for the full 30 years of the analysis.

Figure 1: Historical Auction Prices for Renewable Energy Credits[2]

Posted December 4, 2020



Notes:

1. California and Québec held their first joint auction in November 2014.
2. Current Auction Settlement Price is the price at which current vintage allowances sold at auction.
3. Auction Reserve Price is the minimum price at which allowances can be sold at auction.
4. Secondary Market Prices are a composite of commodity exchange futures contract prices for near month delivery and a survey of OTC brokered transactions for California Carbon Allowances. Secondary market prices are provided with permission of Argus Media Inc.
5. Secondary Market Price data drawn on December 4, 2020.

As mentioned in the main report, the WWTP RNG produced will exceed the amount of natural gas used at the plant. As such, the City would need to either: find a use for the excess RNG produced, flare the excess gas, or the City would only condition the amount of biogas needed

[2] California Air Resources Board. California and Quebec Carbon Allowance Prices, December 4, 2020. ********ww2.arb.ca.gov/sites/default/files/2020-09/carbonallowanceprices_0.pdf.

and the excess biogas would be flared. For this analysis, it was assumed that RNG production would be capped at 62,848 standard cubic feet per day and valued at the delivered cost of natural gas at the facility assumed to be **$3.16** per MMBtu.

Results

High level results of the financial analysis are presented in the tables below. Projects were assumed to be bonded at a 3% interest rate and the breakeven term represents the minimum financing term that would be needed for the project to break even financially. Many alternatives have a payback term that is longer than 30 years, making them infeasible without grant funding support.

Table 1: Lifecycle Financial Breakeven Analysis Results, Millions of 2019$

Alternative Description	Location	Alternative	Total Cost	Total Financial Benefit	Project NPV (3% bond rate)	Financial Breakeven Term
Pipeline Injection	WWTP	Alt. 1a - ND	$35.92	$5.48	-$30.44	N/A
		Alt. 1a - 1500 Div	$47.44	$7.35	-$40.10	N/A
		Alt. 1a - LD	$104.23	$23.09	-$81.14	N/A
	Landfill	Alt. 1b - ND	$75.47	$88.14	$12.67	17.9 years
		Alt. 1b - 1500 Div	$75.07	$87.37	$12.30	18.0 years
		Alt. 1b - LD	$72.42	$83.93	$11.52	18.2 years
Electricity Generation	WWTP	Alt. 2a - ND	$35.04	$1.58	-$33.47	N/A
		Alt. 2a - 1500 Div	$45.91	$2.71	-$43.21	N/A
		Alt. 2a - LD	$101.24	$2.77	-$98.47	N/A
	Landfill	Alt. 2b - ND	$46.50	$27.16	-$19.34	N/A
		Alt. 2b - 1500 Div	$46.18	$26.91	-$19.28	N/A
		Alt. 2b - LD	$44.55	$25.75	-$18.81	N/A
Natural Gas Replacement	WWTP	Alt. 3 - ND	$25.20	$1.09	-$24.11	N/A
		Alt. 3 - 1500 Div	$33.18	$0.93	-$32.25	N/A
		Alt. 3 - LD	$82.92	$0.15	-$82.77	N/A
Expanded Composting	Compost	Alt. 4	$15.69	$0.00	-$15.69	N/A

Table 2: Annual Financial Breakeven Analysis Results

Alternative Description	Location	Alternative	Annual Debt Service on Capital Costs	Annual Operating Costs	Annual Revenues/ Savings	Net Annual Financial Impact
Pipeline Injection	WWTP	Alt. 1a - ND	$0.44	$1.35	$0.27	-$1.52
		Alt. 1a - 1500 Div	$0.55	$1.82	$0.36	-$2.00
		Alt. 1a - LD	$2.11	$3.11	$1.14	-$4.08
	Landfill	Alt. 1b - ND	$1.49	$2.29	$4.37	$0.58
		Alt. 1b - 1500 Div	$1.48	$2.28	$4.33	$0.57
		Alt. 1b - LD	$1.43	$2.20	$4.16	$0.53
	WWTP	Alt. 2a - ND	$0.69	$1.07	$0.08	-$1.68

Alternative Description	Location	Alternative	Annual Debt Service on Capital Costs	Annual Operating Costs	Annual Revenues/ Savings	Net Annual Financial Impact
Electricity Generation		Alt. 2a - 1500 Div	$0.87	$1.43	$0.13	-$2.17
		Alt. 2a - LD	$2.55	$2.54	$0.14	-$4.95
	Landfill	Alt. 2b - ND	$1.05	$1.29	$1.35	-$0.99
		Alt. 2b - 1500 Div	$1.04	$1.04	$1.33	-$0.74
		Alt. 2b - LD	$1.00	$1.24	$1.28	-$0.96
Natural Gas Replacement	WWTP	Alt. 3 - ND	$0.39	$0.87	$0.05	-$1.21
		Alt. 3 - 1500 Div	$0.49	$1.16	$0.05	-$1.61
		Alt. 3 - LD	$2.03	$2.14	$0.01	-$4.16
Expanded Composting	Compost	Alt. 4	$0.29	$0.50	$0.00	-$0.79

Given that many of the alternatives do not generate enough financial benefits to break even in a reasonable time frame, the HDR team considered whether grant funding support could make the project feasible. The table below presents the minimum amount of grant funding required for each project to break even within specific time frames. Since grant funding is used to support up-front project capital costs, amounts above the initial capital costs are highlighted in red as not feasible. Amounts in green are feasible with the specified amount of grant funding.

Table 3: Grant Funding Support Necessary for Projects to Break Even

Alternative Description	Location	Alternative	Initial Project Capital Cost	Baseline Financial Breakeven Term	Grant Funding Support to Break Even within 30 Years
Pipeline Injection	WWTP	Alt. 1a - ND	$8.60	N/A	$30.44
		Alt. 1a - 1500 Div	$10.80	N/A	$40.10
		Alt. 1a - LD	$41.40	N/A	$81.14
	Landfill	Alt. 1b - ND	$29.20	17.9 years	$0
		Alt. 1b - 1500 Div	$29.00	18.0 years	$0
		Alt. 1b - LD	$28.00	18.2 years	$0
Electricity Generation	WWTP	Alt. 2a - ND	$13.50	N/A	$33.47
		Alt. 2a - 1500 Div	$17.00	N/A	$43.21
		Alt. 2a - LD	$50.00	N/A	$98.47
	Landfill	Alt. 2b - ND	$20.50	N/A	$19.34
		Alt. 2b - 1500 Div	$20.30	N/A	$19.28
		Alt. 2b - LD	$19.60	N/A	$18.81
Natural Gas Replacement	WWTP	Alt. 3 - ND	$7.70	N/A	$24.11
		Alt. 3 - 1500 Div	$9.70	N/A	$32.25
		Alt. 3 - LD	$39.80	N/A	$82.77
Expanded Composting	Compost	Alt. 4	$5.70	N/A	$15.69

In general, pipeline injection and electricity generation at the landfill are the only options that generate enough revenues to pay for the operating costs on an ongoing basis. Pipeline injection is feasible with bonding terms of about 18 years, while electricity generation would require around $19 million in grant funding support to be financially viable within 30 years. That said, the electricity generation revenues are currently limited by the net metering and buyback agreements in place. This analysis has assumed that MidAmerican Energy Company (which provides electricity to the Iowa City Landfill) will negotiate a buyback agreement similar to the LMP-based rates they offer under their net metering agreement. However, if the City were able to negotiate a higher rate, it could make the alternatives financially viable. Specifically, an electricity sales rate of **5.7¢** per kWh would make all three of the alternatives financially viable within the 30-year time frame.

Grant Funding

A few federal and state grant programs could potentially be leveraged to reduce the City's financial contribution and make the alternatives financially viable. The table below summarizes a few options based on literature review of the biggest programs which have had funding cycles within the past year.

Table 4: Grant Funding Opportunities

Program Administrator	Funding Program	Eligible Applicants	Eligibility Requirements	Funding
Federal Programs				
US Department of Energy Office of Energy Efficiency and Renewable Energy	Bioenergy Technologies Multi-Topic FOA	Individuals, entities, state or local governments, corporations, etc.	Varies based on year. FY2020 included area of Waste to Energy Strategies for the Bioeconomy, focusing on projects addressing topics such as advanced preprocessing of feedstocks, conversion of wet wastes to energy and products, and synergistic integration of algal biomass technologies with municipal wastewater treatment for greater energy efficiencies and lower costs. 20% cost share required.	Varies based on topic. Based on the FY20 grant application documentation, minimum award was $1,000,000 and maximum award for most topics was between $2,000,000 and $4,000,000.
US Department of Agriculture	Biorefinery, Renewable Chemical, and Biobased Product Manufacturing Assistance Program	Individuals, entities, state or local governments, corporations, institutions, public power entities, etc.	Must be for development and construction or retrofitting of a commercial scale biorefinery using an eligible technology for the production of advanced biofuels and biobased products. Majority of production must be an advanced biofuel.	Maximum loan guarantee of 80% of project costs or $250 million. Term length of the lesser of 20 years or the useful life of the project.
State Programs				
Iowa Energy Center	Iowa Energy Center Grant	Iowa businesses, colleges and universities, and private nonprofit agencies and foundations	Projects must provide benefit to Iowa ratepayers and aid in one of the key focus areas of the Iowa Energy Plan: 1) technology-based research and development, 2) energy workforce development, 3) support for rural and underserved areas, 4) biomass conversion, 5) natural gas expansion in underserved areas, 6) electric grid	Minimum award of $10,000, maximum award of $1,000,000.

Program Administrator	Funding Program	Eligible Applicants	Eligibility Requirements	Funding
			modernization, 7) alternative fuel vehicles.	
Iowa Energy Center	Alternate Energy Revolving Loan Program	Businesses, individuals, water and wastewater utilities, rural water districts and sanitary districts	Eligible technologies and resources include solar, wind, waste management, resource recovery, refuse-derived fuel, agricultural crops and residue, and wood burning, hydroelectric facility at a dam, energy storage, anerobic digestion, biogas, combined heat and power, wind repower. Facility must be in Iowa and be wholly owned by the borrower.	Minimum loan of $25,000, up to 50% of eligible project costs. Maximum loan of $1,000,000 per project. Loans offered at 0% interest.
Iowa Department of Natural Resources	Solid Waste Alternatives Program	Any unit of local government, public or private group, or individual	Projects to reduce the amount of solid waste generated and landfilled in Iowa. Funds can be used for waste reduction equipment and installation, recycling, collection, processing or hauling equipment, purchase and installation of recycled content products. 25% cash match required.	First $10,000 is eligible as a forgivable loan, next $50,000 is eligible as a zero-interest loan, and 3% loan on the remainder.