



FINAL Report

City of Ames Waste-to-Energy Option Study

Report No. 507-006-01

September 2022

Prepared for
City of Ames
515 Clark Avenue
Ames, Iowa 50010

Prepared by



RRT DESIGN & CONSTRUCTION
1 Huntington Quadrangle, Suite 3S01
Melville, New York 11747-4401
631-756-1060
631-756-1064 (fax)
www.rrtenviro.com

This page intentionally blank



CITY OF AMES WASTE-TO-ENERGY OPTIONS STUDY

Report No. 507-006-01

REVISION HISTORY

Issue	Issue Date	Summary
0	03/23/2022	Final Report Draft for Owner Review
1	SEP2022	Final Report



Page ii intentionally blank



LEGAL NOTICE AND STATEMENT OF CONFIDENTIALITY

This document was prepared by RRT Design & Construction (“RRT”) solely for the benefit of the City of Ames (“Client”). Neither RRT, the City of Ames nor their parent corporations or affiliates, nor any person acting on their behalf: (a) makes any warranty, expressed or implied, with respect to the use of any information or methods disclosed in this document; or (b) assumes any liability with respect to the use of any information or methods disclosed in this document.

Any recipient of this document, by their acceptance or use of this document, releases RRT, the City of Ames, their parent corporations and affiliates from any liability for direct, indirect, consequential, or special loss or damage whether arising in contract, warranty, express or implied, tort or otherwise, and irrespective of fault, negligence, and strict liability.

The information contained in this report is intended for the exclusive use of the City of Ames. This document has been prepared pursuant to Contract for Waste-to-Energy Options Study for the City of Ames dated April 27th, 2021, therein between the City of Ames and RRT entered into effective as of April 27,2021.

To the extent that specific vendors/equipment names are used in this report, it is for the sole purpose of evaluating the City’s various options in the Study. These statements are not meant to preclude any unlisted vendors/equipment from future opportunities to propose to the City of Ames on the WTE system upgrades, nor are they meant to recommend the listed vendors/equipment as the selected system(s)/equipment for a given option. The information obtained from these vendors/suppliers was used only to develop indicative costing, conceptual layouts and designs, and to determine key performance parameters of the technical analysis.

This report does not purport to be all-inclusive or to contain all of the information that may be relevant in making any decision concerning an evaluation of the project. It is the intention of RRT to have provided services that performed in accordance with the standard of professional practice ordinarily exercised by the applicable profession at the time and within the locality where the services are performed and responsive to the contents of the City of Ames’ RFP for the project. RRT does not provide any warranty or guarantee, express or implied, including warranties or guarantees contained in any uniform commercial code.

REPORT UPDATE

RRT has no responsibility to update this report for any changes occurring subsequent to the Final Issuance of this Report



Page iv intentionally blank



Table of Contents

- 1 EXECUTIVE SUMMARY 1**
- 1.1 WTE Options Study Overview 2
 - 1.1.1 Option 1 – Resource Recovery and Power Plants As-Is (Base Case) 2
 - 1.1.2 Option 2A – Existing RRP with a New RDF Combustion Unit in the Existing PP... 2
 - 1.1.3 Option 2B – Modified RRP (20” RDF) with Two New RDF Combustion Units 2
 - 1.1.4 Options 3A-1 & 3A-2: New RRP and New RDF Combustion Unit(s)..... 3
 - 1.1.5 Options 3B-1 & 3B-2: Two New MSW Mass Burn Combustion Units..... 3
 - 1.1.6 Study Methodology 4
- 1.2 WTE Technology Considerations 4
- 1.3 Financial Analysis 5
- 1.4 Environmental Impacts..... 9
- 1.5 Summary of Evaluated Options 10
- 2 INTRODUCTION, BACKGROUND, AND STUDIED OPTIONS..... 15**
- 2.1 Objective 15
- 2.2 Background 15
- 2.3 WTE Study Options Descriptions 15
 - 2.3.1 Option 1: Resource Recovery and Power Plants As-is (Base Case)..... 15
 - 2.3.2 Option 2A: Existing RRP With New RDF Combustion Unit in the Existing PP..... 16
 - 2.3.3 Option 2B: Modified RRP (20” RDF) with Two New RDF Combustion Units 16
 - 2.3.4 Options 3A-1 & 3A-2: New RRP and New RDF Combustion Unit(s)..... 16
 - 2.3.5 Options 3B-1 & 3B-2: Two New MSW Mass Burn Combustion Units..... 17
- 3 TECHNICAL SYSTEM ANALYSIS 19**
- 3.1 Option 1 – Resource Recovery and Power Plants As-is (Base Case) 19
 - 3.1.1 MSW Storage..... 19
 - 3.1.2 RRP Plant Processing System Summary..... 19
 - 3.1.3 RDF Transport and Storage 22
 - 3.1.4 Power Plant Combustion System Summary..... 22
 - 3.1.5 RDF Co-Combustion System 23
 - 3.1.6 Steam Turbine Generators 23
 - 3.1.7 Balance of Power Plant Equipment..... 23
 - 3.1.8 Emission Control 24
 - 3.1.9 Ash Handling/Disposal 25
 - 3.1.10 Electric Energy Sales 25
 - 3.1.11 Process Flow and Mass and Heat Balance..... 27
 - 3.1.12 Building/Facility Description and Considerations 28
- 3.2 Option 2A – Existing RRP with New RDF Combustion Unit in the Existing PP 30
 - 3.2.1 MSW Storage..... 30



3.2.2 RRP Analysis and Recommended System Upgrades 30

3.2.3 RDF Transport and Storage 33

3.2.4 RDF Combustion System Options 33

3.2.5 Boiler Design..... 34

3.2.6 Power Plant System Summary 35

3.2.7 Balance of Power Plant Equipment..... 36

3.2.8 Emission Control 37

3.2.9 Ash Handling/Disposal 37

3.2.10 Electric Energy Sales 37

3.2.11 Process Flow and Mass and Heat Balance..... 38

3.2.12 Building/Facility Description and Considerations 39

3.2.13 Preliminary Conceptual Facility Layouts 39

3.3 Option 2B – Modified RRP (20” RDF) with Two New RDF Combustion Units..... 41

3.3.1 MSW Storage..... 41

3.3.2 Modified Resource Recovery Plant (RRP)..... 41

3.3.3 RDF Transport and Storage 44

3.3.4 Large RDF Combustion System 44

3.3.5 Boiler Design..... 46

3.3.6 Balance of Plant Equipment 47

3.3.7 Emission Control 48

3.3.8 Ash Handling/Disposal 48

3.3.9 Electric Energy Sales 49

3.3.10 Process Flow and Mass and Heat Balance..... 49

3.3.11 Building/Facility Description and Considerations 50

3.3.12 Preliminary Conceptual Facility Layout 50

3.4 Options 3A-1 & 3A-2 - New RRP and New RDF Combustion Unit(s) 52

3.4.1 New State-of-the-Art Resource Recovery Plant 53

3.4.2 RDF Transport and Storage 59

3.4.3 RDF Combustion System..... 60

3.4.4 Boiler Design..... 60

3.4.5 Balance of Power Plant Equipment..... 60

3.4.6 Emission Control 61

3.4.7 Ash Handling/Disposal 61

3.4.8 Electric (Option 3A-1) or Thermal (Option 3A- 2) Energy Sales 62

3.4.9 Process Flow and Mass and Heat Balance..... 62

3.4.10 Building/Facility Description and Considerations 64

3.4.11 Preliminary Conceptual Facility Layouts 64

3.5 Options 3B-1 & 3B-2 – Two New MSW Mass Burn Combustion Units 68

3.5.1 MSW Storage..... 69

3.5.2 MSW Pre-Processing System 69

3.5.3 MSW Combustion System..... 70

3.5.4 Boiler Design..... 70



3.5.5	Balance of Power Plant Equipment.....	70
3.5.6	Emission Control	71
3.5.7	Ferrous/Non-Ferrous Recovery	71
3.5.8	Ash Handling/Disposal	72
3.5.9	Electric (Option 3B-1) or Thermal (Option 3B-2) Energy Sales.....	72
3.5.10	Process Flow and Mass and Heat Balance.....	73
3.5.11	Building/Facility Description and Considerations.....	75
3.5.12	Preliminary Conceptual Facility Layouts	75
4	FINANCIAL ANALYSIS.....	79
4.1	Overview and Methodology.....	79
4.1.1	Production Information (Waste Assumptions)	79
4.1.2	Levelized Power Export.....	80
4.1.3	Revenue Modeling	80
4.1.4	Expenses Modeling, Including Debt Service	81
4.1.5	Capital Costs.....	83
4.1.6	Net Present Value	83
4.1.7	Internal Rate of Return	83
4.1.8	Impacts Not Modelled.....	83
4.2	Financial Model Results	84
4.3	Effect of Natural Gas Pricing	87
5	ENVIRONMENTAL IMPACTS.....	91
5.1	Federal and State Air Permits	91
5.1.1	Title V Operating Permits	91
5.1.2	Section 129, Section 111, and New Source Performance Standards	92
5.1.3	Iowa DNR Permitting.....	93
5.1.4	Other Permitting and Regulatory Considerations	95
5.2	Comparative Analysis of Environmental and Program Impacts	96
5.2.1	Air Emissions Summary	96
5.2.2	Greenhouse Gas (GHG) Emissions Summary.....	98
5.2.3	Water, Utilities and Processing System Requirements.....	100
5.2.4	Ash	100
5.3	Program Impacts and Considerations.....	101
5.3.1	Increased/expanded recycling program	101
5.3.2	Organics Diversion.....	102
5.3.3	Outreach and Education Programs.....	102
5.3.4	Grant Funding Opportunities	102
5.3.5	Other Impacts and Considerations.....	105
6	TIMELINE OF COMPLETION.....	107
6.1	Considerations for Construction Inside Existing Buildings.....	108
6.2	Considerations for Construction on the Coal Yard	109



6.3 Considerations for Construction of the new Facility on a “Greenfield Site” 109

6.4 Key Activities and Narrative for all Options 109

7 ADVANTAGES AND DISADVANTAGES OF PROPOSED OPTIONS 113

7.1 Option 1 – Resource Recovery and Power Plants As-is (Base Case) 113

7.2 Option 2A – Existing RRP with a New RDF Combustion Unit in the Existing PP 114

7.3 Option 2B – Modified RRP (20” RDF) with Two New RDF Combustion Units..... 114

7.4 Options 3A-1 & 3A-2: New RRP and New RDF Combustion Unit(s) 115

7.5 Options 3B-1 & 3B-2: Two New MSW Mass Burn Combustion Units 116

List of Figures

Figure 1: Average Annual 'Revenue Less Expenditures' 6

Figure 2: NPV Comparison of Net 'Revenue Less Expenditures' over Bond Period 8

Figure 3: Option 1 Overall RRP Process Flow Diagram 21

Figure 4: Renewable Generator Projected Additions Across MISO 26

Figure 5: Historic Price of Natural Gas, Henry Hub 2000-Apr 2022 (\$/dth) 27

Figure 6: Option 1 (Base Case) Overall Process Flow Diagram 28

Figure 7: Existing City of Ames Facility Layout..... 29

Figure 8: Option 2A Overall RRP Process Flow Diagram 32

Figure 9: Metso-Outotec Bubbling Fluidized Bed Combustor for <4" RDF 34

Figure 10: Typical Bubbling Fluidized Bed Combustor Boiler 35

Figure 11: Avg. PP Gas Price vs. Gas Transportation Utilization (JAN2021-MAR2021)..... 38

Figure 12: Option 2A Overall Process Flow Diagram 39

Figure 13: Option 2A Preliminary Conceptual Layout..... 40

Figure 14: Option 2B RRP Process Flow Diagram 42

Figure 15: Conveyor Transport System with Tubular Gallery..... 44

Figure 16: Martin Mass-Burn Combustion System 45

Figure 17: Ruths Inclined Reciprocation Grate Combustor 46

Figure 18: Ruths Modular Boiler Design..... 47

Figure 19: Option 2B Overall Process Diagram..... 50

Figure 20: Option 2B Preliminary Conceptual Layout..... 51

Figure 21: Process Flow Diagram for State-of-the-Art RRP 54

Figure 22: Metso USA M&J Pre-Shred 2000S 57

Figure 23: SSI Pri-MAX Shredder 58

Figure 24: Option 3A-1 Overall Process Flow Diagram 63



Figure 25: Option 3A-2 Overall Process Flow Diagram 64

Figure 26: Option 3A-1 Preliminary Conceptual Layout of New SOA RRP and RDF Storage..... 66

Figure 27: Option 3A-2 Preliminary Conceptual Layout for Industrial Site..... 67

Figure 28: General Kinematics Grizzly Deck Design 72

Figure 29: Option 3B-1 Overall Process Flow Diagram 74

Figure 30: Option 3B-2 Overall Process Flow Diagram 75

Figure 31: Option 3B-1 Preliminary Conceptual Layout at Coal Yard..... 76

Figure 32: Option 3B-2 Preliminary Conceptual Layout for Greenfield Site..... 77

Figure 33: Natural Gas Citygate Price in Iowa, U.S. EIA 82

Figure 34: Average Annual Profit for Each Option (@\$5.00/dth)..... 85

Figure 35: NPV of Each Option vs. Base Case 86

Figure 36: IRR for Alternatives to Base Case [@ \$5.00/dth]..... 87

Figure 37: Option Profit Sensitivity to Gas Prices (\$M)..... 88

Figure 38: Option NPV over Base Case for Various Gas Prices 89

Figure 39: IRR for Options at Various Gas Prices 90

Figure 40: GHG Equivalent Emission for Each Option 100

Figure 41: Estimated Timeline for Completing a Project..... 108

List of Tables

Table 1: Average Annual 'Revenue less Expenses' Sensitivity to Gas Prices [\$M] 8

Table 2: Option NPV Sensitivity to Base Case Gas Price [\$M] 9

Table 3: Summary Comparison of Evaluated Options (1 of 2)..... 11

Table 4: Summary Comparison of Evaluation Options (2 of 2) 13

Table 5: Typical Emissions and Permit Values for Units 7 and 8 25

Table 6: Capacity Offered and Committed for Each MISO Zone 2021/22 26

Table 7: Sensitivity of Average Annual Profit to Base Case Natural Gas Price (\$M/yr) 87

Table 8: Sensitivity of 'NPV vs. Base' Case to Gas Prices (\$M)* 88

Table 9: Sensitivity of Option IRR to Gas Prices (% IRR)* 90

Table 10: MSW Combustor Emission Limits 96

Table 11: Expected Actual Emissions - All Options 97

Table 12: Net GHG Annual CO2 Emissions Based on Avg. Annual Waste Flows..... 99



Appendices

Appendix A	Ames Process Options Summary
Appendix B	RDF/MSW Storage Analysis
Appendix C	Preliminary Conceptual Facility Layouts
Appendix D	RRP Process Flow Diagrams
Appendix E	Overall Process Flow Diagrams
Appendix F	Mass and Heat Balance Data Tables
Appendix G	Details regarding Combustor Systems
Appendix H	Details regarding Boiler Designs
Appendix I	Details regarding Emission Controls
Appendix J	Debt Service Model Methodology
Appendix K	Capital Cost Estimating Methodology and Cost Summary Table
Appendix L	Project Schedule
Appendix M	Advantages and Disadvantages Table



1 EXECUTIVE SUMMARY

The decade of the 70's brought about several changes in everyday life in America, but one factor that created numerous challenges for the United States and its citizens was the energy crisis that occurred during this period. There was both the 1973 oil crisis and the 1979 energy crisis. Another key event from the 1970's was the founding of the Environmental Protection Agency (EPA) in 1970. The concepts of environmental stewardship and conservation of resources became key focus areas for the EPA and many progressive communities. These two key factors combined to form a waste management revolution in the U.S. and a number of resource recovery facilities and waste-to-energy plants were developed as a result. A vast majority of these facilities were developed near large population centers as a way to manage their large volumes of solid waste and to create additional base load energy (electricity and thermal).

In the early 1970's the City of Ames was considering the best way to deal with solid waste disposal and made the forward-thinking decision to avoid burying all of their waste in a landfill and instead decided to build a Waste-to-Energy (WTE) system to recover valuable materials from the waste stream, convert municipal solid waste (MSW) into energy thereby reducing reliance on landfills and saving valuable farmland for growing crops. Construction of the Resource Recovery Plant (RRP) began in 1973 and it started operations in 1975 with the Refuse Derived Fuel (RDF) co-fired with coal in the existing boiler Unit 7. Shortly thereafter the construction of Unit 8 was approved in 1978, and it was similarly designed to burn RDF co-fired with coal. The combination of the Resource Recovery Plant (RRP) and construction of Unit 8 at the Power Plant paved the way for WTE production, landfill avoidance and greater environmental stewardship for the City and the surrounding communities.

The community (residents, businesses and the member agencies) has long supported the City's environmentally focused approach to waste management and as a result the City has worked to maintain the "System" (Resource Recovery Plant, RDF storage bins and the Power Plant (PP)) in good working order for the last 46 years. Factors driving a need for updating of the System include (1) the input waste stream approaches or exceeds the current power plant's capacity, requiring increasing amounts of waste to be bypassed to landfill (2) the current high variable cost of power derived from the co-firing of natural gas versus the growing abundance of renewable power at lower power prices in Iowa, (3) the operational limitations of the combustion process associated with the current fuel mix in the decades old boilers originally designed to burn primarily coal and (4) the potential of reducing environmental impacts using newer air pollution control technology. As a result, the City of Ames commissioned this WTE Options Study to consider a number of potential options to modify or replace the System and analyze the technical and financial merits of each of these options. The City of Ames will then utilize this study and accompanying financial model to consider several options to maintain the current system or to modify/replace the current system.

The electric utility for the City of Ames is a full service municipal electric utility serving approximately 27,500 metered customers. The Electric Department owns and operates four generation resources, two RDF/natural gas co-fired boilers totaling nameplate capacity of 98 MW (65 MW+33MW) and two oil-fired combustion turbines. Under the current operation, all of the net power produced from the combustion of RDF co-fired with natural gas serves the City's electricity needs first. The balance of the City's electricity needs is then purchased from the MISO Zone 3/Northern District (Ames node). The significant wind energy in the region has driven wholesale energy costs down and this further magnifies the challenge of the requirement to co-fire the RDF with significant amounts of natural gas as required under the Title V Air Permit. On January 5th, 2021, the City issued an RFP to evaluate five identified options for the disposal of MSW in a waste-to-energy (WTE) facility to meet its disposal demands for the period between 2023 through at least 2040. Through discussion with the City staff and early technical analysis, two sub-options were added (3A-2 and 3B-2) and all seven options are fully evaluated within this WTE Options Study. The seven WTE options are briefly described in **Section 1.1 - WTE Options Study Overview**.

This executive summary presents the options studied and key findings of the technical, environmental and financial analysis performed by the RRT consulting team in partnership with the City of Ames. All of the options presented would require permitting by the Iowa Department of Natural Resources (DNR) and while



a high-level overview of environmental impacts is presented in **Section 1.4**, a more detailed write-up is provided in **Section 5 - Environmental Impacts**.

1.1 WTE Options Study Overview

In order to evaluate the City's options, there was a need to establish a base case using the current operations of the existing Resource Recovery Plant (RRP) and Power Plant (PP). The technical team documented both the performance of the current System as well as the operational and maintenance costs, which were used as inputs in the financial model. The base case served as the primary case to compare all other options against. This section describes all seven evaluated options including the base case, the four¹ primary new options, and the two sub-options. A detailed side-by-side Process Options summary table is provided in **Appendix A**.

1.1.1 Option 1 – Resource Recovery and Power Plants As-Is (Base Case)

This is the base case reflecting the current operations at both the RRP and PP. The RRP continues to process Municipal Solid Waste (MSW) in the existing RRP built in 1975. The output of the RRP is a 4 inch minus sized RDF that is stored in a two-sided RDF storage bin and conveyed pneumatically to the PP. The RDF is then combusted with natural gas in existing steam boilers 7 or 8, which were commissioned in 1967 and 1982 respectively. The steam passes through the respective steam turbines to produce electricity for the City's electric utility. Under the air permit, Units 7 and 8 cannot consume RDF simultaneously, nor is the system designed to support that operation. The available waste stream currently approaches or exceeds the Power Plant physical consumption limit of 32,000 TPY by about 6%. The City of Ames projected population growth and coinciding growth in waste tonnage makes this current limitation a key issue to be addressed by whatever option is selected by the City.

1.1.2 Option 2A – Existing RRP with a New RDF Combustion Unit in the Existing PP

The existing RRP plant, RDF storage bin, and RDF conveyance system would remain mostly as-is with a few modifications to address current processing challenges in the overall WTE system. As an example, it is proposed that the City replace the existing air knife and add a new Eddy Current Separator (ECS) to improve separation and non-ferrous metal recovery from the RDF stream.

The Power Plant side of Option 2A utilizes a new boiler to exclusively burn the 4 inch minus RDF and eliminate the need to co-fire RDF with natural gas during normal operations. The RDF boiler would be installed where retired boilers 5 and 6 are located or at the adjacent former water treatment plant. Subject to inspection, Steam Turbine 5 (ST5) would be refurbished or have its steam path replaced. The associated ST5 generator would be rewound. Much of the existing power plant infrastructure including the electric utility interconnection would be re-used in this option and Unit 8 would serve as a backup to the new RDF boiler. Unit 8 would only be used a small percentage of the time as a backup to the new Unit 9, but Unit 8 would still require co-firing with natural gas. Unit 7 & 8 would be available as gas-fired (only) units for reserve capacity.

1.1.3 Option 2B – Modified RRP (20" RDF) with Two New RDF Combustion Units

This option includes modifying the existing RRP to create a rough-shred, large RDF (20" minus) for combustion. The re-designed RRP would also provide up-front (pre-combustion) metal recovery. This large size RDF requires a similar MSW boiler technology to Option 3B.

This option would utilize two new combustors, Units 9 and 10, for the large size RDF, similar to mass burn technology. The new combustors would be located in a new boiler plant building at the existing coal yard location. The study assumes the two combustion units will operate in parallel for the life of the facility and

¹ Options 3A and 3B have two sub-options (-1 & -2), depending on the location of the new facility. Sub-option 2 assumes a greenfield site not contiguous with the current operations for the intention of selling steam.



if one unit is offline (for whatever reason) the other combustor would continue to process the RDF. Due to its large size the RDF would be transported from the RRP to the boilers using a conveyor over the street in lieu of the current pneumatic lines. As a result, the existing RDF storage bin and associated pneumatic system would not be needed and thus would be abandoned or demolished. Approximately 12,000 square feet of floor space in a new storage building adjacent to the new boiler plant would be included for storing the large RDF and then loaded into the boilers using conveyors. Steam would be piped to the refurbished ST5 located at the existing steam plant. Units 7 and Unit 8 would be capacity-only resources to the Mid-continent Independent System Operator (MISO) and would no longer consume RDF.

1.1.4 Options 3A-1 & 3A-2: New RRP and New RDF Combustion Unit(s)

Option 3A-1 (Coal Yard)

A new RRP, creating 4 inch minus RDF, and a new combustion boiler (Unit 9) would be provided. The new RRP would provide state-of-the-art (S-O-A) processing equipment and would have improved throughput capability resulting in more RDF from the same incoming quantity of MSW as well as better up-front material recovery. One key aspect of higher throughput is the need for more storage space to provide the same number of days in the event the lead (larger) unit is off-line. A detailed RDF/MSW storage analysis for all of the evaluated options is discussed in **Appendix B**.

For Option 3A-1 the S-O-A RRP and one new boiler would be in a new building at the existing coal yard location. Option 3A-1 also augments the conveyance system with a new supplemental RDF storage system.

The new boiler for Option 3A-1 requires some new balance of plant support equipment since it is not contiguous to the existing power plant. The existing Unit 8 would serve as the backup boiler to consume RDF and would utilize the existing RDF conveyance system and storage bin. Steam would be piped over to the refurbished steam turbine ST5 in the existing power plant with condensate returned back to the new boiler. Unit 8 serves as a backup boiler, still co-firing RDF with natural gas. Both Units 7 and 8 are available as capacity resources for MISO when burning only natural gas.

Option 3A-2 (Greenfield)

Option 3A-2 locates the new S-O-A RRP, creating 4 inch minus RDF, and a new waste combustion facility with two new RDF boilers at a potential industrial site to provide steam to an industrial customer. Option 3A-2 requires all new power plant support infrastructure. The study assumes two new twin RDF boilers would share the load throughout the life of the facility. If one unit is offline (for whatever reason), the other unit would continue consuming RDF. The new RDF boilers would be sized to burn only RDF, using natural gas only during start-up, shutdown and for flame stabilization. A single back pressure steam turbine would generate a small amount of power (~1.5 MW) for plant use prior to exporting the steam to a nearby customer. Units 7 and 8 remain as capacity resources when burning only natural gas.

1.1.5 Options 3B-1 & 3B-2: Two New MSW Mass Burn Combustion Units

These two options provide two new dedicated MSW mass burn boilers with post combustion metal recovery located at either the existing coal yard (Option 3B-1) or an industrial site (Option 3B-2). Per the RFP, the post-combustion recovery scenario was used as input into the financial model and development of a site layout. The pre-combustion recovery of metal is discussed briefly in the technical analysis of Option 3B, and an estimated cost is provided if the City would like to pursue up-front metal recovery in lieu of post-combustion metal recovery. Units 7 and 8 remain as capacity resources for MISO when burning only natural gas.

Option 3B-1 (Coal Yard)

For Option 3B-1, two new MSW mass burn combustion boilers would be located in a new building at the existing coal yard location. Steam would be piped over to the refurbished steam turbine (ST5) in the existing power plant with condensate returned to the new boilers. Some new balance of plant supplemental infrastructure is needed to support the new boilers since they would not be contiguous to the existing power plant.



Option 3B-2 (Greenfield)

In Option 3B-2 the MSW power plant would be located at a potential industrial site outside the City to provide steam to an industrial customer. The new plant would require new power plant support infrastructure and auxiliaries. The Option would utilize two new, twin boilers to share the load throughout the life of the project. If one unit is offline the other boiler would continue to combust waste. For Option 3B-2 a single back pressure steam turbine would provide some power and all the exhaust steam would be sold to a nearby industrial customer.

1.1.6 Study Methodology

The City of Ames WTE Option Study consisted of two primary areas of technical focus and evaluation. The first phase was to technically evaluate the seven options for feasibility, performance, availability/redundancy, environmental impacts, technology options (both RRP and PP), and the capital, operating and maintenance costs. The second part of the study used the developed costs from the first phase to analyze the various options through the development of a comprehensive financial model. This model is a tool that the City will be able to use going forward and will allow adjustments to key inputs and assumptions in their overall evaluation of next steps for their waste management and power production systems.

From the two-phase process, the RRT technical team provided preliminary conceptual design layouts, process flow diagrams, mass and heat balances, analysis of various system components/options, compilation of financial data, environmental impacts and advantages and disadvantages of the studied options. RRT utilized its extensive waste and power experience to analyze, review, and compare the six new options with the City's current operations. Professional opinions, evaluations, and key considerations are discussed throughout this report, but RRT did not provide any formal recommendations in the study as this activity will be performed by City staff.

1.2 WTE Technology Considerations

Waste-to-Energy (WTE) facilities divert waste from landfills to generate energy from the combustion of municipal solid waste. Initially, waste treatment (incineration) did not have energy recovery as a primary objective. State of the art facilities now recover energy with greater efficiency and have sophisticated mechanisms that result in significantly less flue gas emissions. WTE has played a significant role in reducing the global waste problem and by maximizing energy recovery and environmental performance today, much more can be achieved. Below is a brief discussion of the various WTE technologies.

Suspension Firing: Suspension firing is a common method of burning solid fuels such as pulverized coal and wood chips. RDF combustion in the U.S. was developed back in the 1970's and 1980's, when several large boiler suppliers adapted suspension fired combustor designs from other solid fuel systems to combust RDF. Several large facilities were built in the U.S., a few of which still operate today including the City of Ames. The RDF is injected into the combustor above a horizontal grate, allowing the majority of the RDF to combust before it falls to the grate surface. The RDF size requirement for suspension-fired systems is typically 6" minus, which can usually be achieved in a single shredding step. These systems were typically much larger in RDF capacity than the City of Ames, with unit capacities on the order of 1,000 TPD, as compared to current unit capacities of 80 to 150 TPD being evaluated in this study. The current City of Ames boilers employ a similar system design with suspension firing of the RDF, but the RDF is co-fired with natural gas, which improves the performance and minimizes fluctuations in the combustion caused by changes in the RDF characteristics.

Fluidized Bed: Fluidized bed combustors were adapted from biomass applications to combust RDF of a nominal size of less than 4" and 90% less than 3". A few suppliers around the world have commercialized this technology. Bubbling fluidized bed combustion systems have been successfully applied to RDF applications for many years but require a fine RDF size of 4" minus, similar to the RDF currently produced by the City of Ames. The combustion system size being evaluated for Ames is at the smaller end of the industry product line availability, leading to a higher cost per ton of waste handled compared to larger systems. The vendors also have less commercial experience with RDF created from MSW than with



biomass feedstocks. There are a number of fluidized combustion plants for RDF operating and under construction in Europe, although it is much less common than mass burn. The variability in quality of processed RDF for small RDF fluidized beds systems can result in more downtime since small systems are more susceptible to impurities such as glass and aluminum which melt in the fluidized bed and disrupt the function of the bed, requiring shutdowns to clear the fouling.

Mass Burn: The vast majority of WTE systems being installed worldwide are MSW mass-burn type combustion systems. Mass burn is the direct combustion of waste as received. There is some minimal up-front processing to remove bulk items that won't fit in the process hoppers, but 99% of the waste goes into the combustion chamber to be consumed. Reasons for the popularity of WTE mass burn systems include, the cost of pre-sorting and shredding, recyclable market price fluctuations, reliance on off-takers of recyclables, contamination/quality issues with recyclables, and the desire to have a lower volume of residual material that requires landfilling and thus saves valuable airspace. The WTE mass burn technology is well developed and has found widespread use throughout the world with over 75 units operating in the US and over 500 in Europe. A number of manufacturers provide MSW combustion systems on a “chute-to-stack” turnkey basis. The size of the WTE mass burn combustion systems evaluated in this report are also at the smaller end of the equipment design spectrum and have a resulting higher cost per ton of waste handled compared to larger systems.

The overall costs to process the MSW into small RDF and combust the RDF in these facilities in a new plant (Option 3A) are higher than mass burn systems. However, by virtue of Ames' ability to utilize existing electrical infrastructure, balance-of-plant infrastructure, existing storage, etc. the premium to continue processing MSW as RDF is substantially offset. It is notable that no new RDF facilities have been constructed in the United States to combust MSW and recover energy since the early 1980's. RDF facilities continue to be installed for processing of MSW in Europe, and for biomass-only applications worldwide to combust well processed RDF (nominal size of less than 4" and 90% less than 3").

Comparing the three types of waste combustion systems summarized above, the mass-burn systems for combusting unprocessed MSW are the most commonly used and commercially available with many reliable system providers and thousands of successful operating plants around the world. Both the suspension-fired and bubbling bed combustion systems bring less vendor options with only a few companies providing RDF from waste systems. Commercial challenges with these systems are often tied to the RDF specifications on both size and composition and difficulties meeting it on an ongoing basis.

All options evaluated (except for the base case) will utilize the same State-of-the-Art air pollution control technology (scrubber, baghouse, SCNR and PAC injection described in Appendix I). By virtue of the RDF pre-processing to remove fines and recyclables, and RDF smaller size, RDF boilers will have higher boiler efficiencies (less excess air), lower raw emissions, and therefore slightly lower pollution control system maintenance costs (e.g., consumables such as activated carbon).

The RRT team performed technical analyses on a number of key system considerations to evaluate and compare the seven total options. This includes, process flow diagrams, mass and heat balances, cost (capital, operations and maintenance, and financing), analysis of pre-and post-combustion processing systems, and various combustor technologies and power plant systems to create electricity or steam from the MSW and RDF material. The system-by-system detail and technical analysis for all evaluated options is included in **Section 3**.

1.3 Financial Analysis

To analyze the waste-to-energy options requested by the City, a financial model in MS Excel was created for each of the seven evaluated options (Option 3A and 3B have two sub-options each). In addition to each option's capital costs, the operation and maintenance costs, the Capital Improvement Plan (CIP) which includes planned major maintenance, and bond financing were developed over a 20-year operating period to determine the lifecycle costs to process the MSW using the different WTE options specified by the City in the RFP and further refined in consultation with RRT. For Option 1 (the “Base Case”) the WTE System's net power production is calculated based on the RRP and PP existing equipment functioning as designed. Similar models were then created for each of the other options using coordinated inputs and assumptions



for gross MSW available, population growth, net energy delivered to Ames, average boiler sizing, and equipment efficiencies. These inputs are listed on the “assumptions tab” in the model, which allows the user to edit the assumptions and key model inputs such as natural gas prices, escalation rates and utility prices to allow for “what-if” sensitivity analysis. City staff were trained in the basic use of the model and the underlying assumptions to allow the City to easily re-evaluate options in the future if key parameters change.

It is important to understand that the operating and maintenance costs of the RRP and PP facilities to produce the electricity generated by the two co-fired generating units are only a portion of the City’s cost to supply and deliver the required amount of electricity to its customers. City costs such as electric distribution system operation and maintenance, corporate overhead, billing, etc. are not included in this study as these costs are independent of the WTE options. Likewise, the revenue from the retail sale of electricity to customers (a mixture of residential, institutional and commercial customers) is not specifically modelled as it does not change from option to option. Since the City Electric Department operates as a non-profit, the electric revenue used for the purpose of this study is calculated from the base case such that all ‘Revenue less Expenditures’ are greater than or equal to zero for all years modelled to match the City’s approach to budgeting and keeping costs to a minimum to their customers. The revenue in all cases includes an average annual base value from the sale of electricity of \$37.9M at an average annual escalation of 1.76%. This revenue stream is kept constant across all options to provide an accurate financial comparison of the options. As further explanation, the WTE process will not impact the customers’ usage of electricity. To compare each option to the base case the power production shortfall is modeled to be purchased from the MISO Zone 3/Northern District (Ames node) electricity prices. In this way, each case provides the same amount of electricity for the City as that produced in Option 1 (base case/as-is). For the financial model the 2021 average on-peak and off-peak Ames node prices are applied and escalated 0.50% per year. A summary of the RRP and PP average annual net ‘Revenues less Expenditures’ after capital and debt service are shown in **Figure 1** for all options. The expenses reflect a \$5.00/dth gas price for the base case in year 2022 and a \$1.00/dth premium for all other cases for Citygate gas purchases. Natural gas is assumed to escalate 1% per year as directed by City personnel.

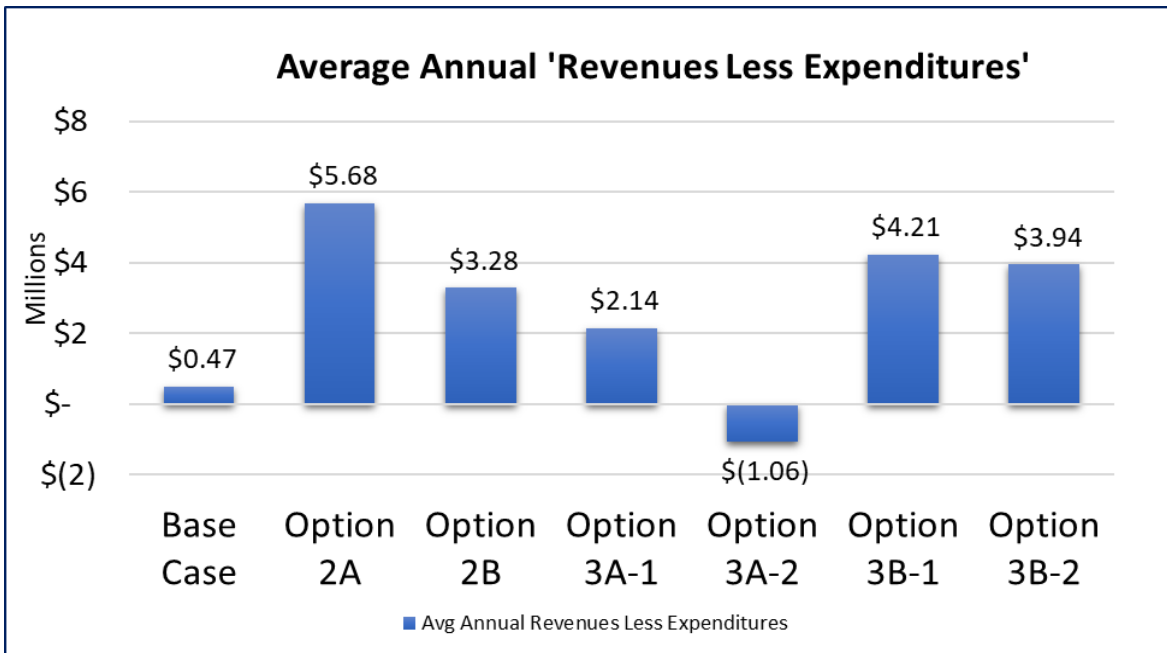


Figure 1: Average Annual 'Revenue Less Expenditures'



Other revenue streams such as metal sales and tipping fees are also included. Revenue for steam sales to a thermal user is included for Options 3A-2 and 3B-2 (only). Costs include variable costs; O&M costs for the System; landfill costs; natural gas for startup, shutdown, and flame stabilization; CIP and debt service; including maintaining and operating the capacity-only resources (Units 7 and 8) in some of the options.

In order to compare multi-year projects with different net annual cash flows and different project implementation costs, the Net Present Value (NPV) for each option is calculated to include the capital investment needed for each option and the debt service. The NPV discounts the annual net cash flow for each year during the 20-year bonding period to the first year and sums them together. If the NPV of an investment is positive, it means that the discounted present value of all future cash flows related to that project's investment will be positive as compared to the base case, and therefore attractive. The NPV is a key financial metric used to evaluate all the options over the entire 20-year bond period from 2025 to 2044. Financing is assumed to occur in early 2025 (year "one") to support construction and initial operation in late 2026. The NPV of each option is plotted in **Figure 2**, assuming \$5.00/dth gas price in the base case. **Figure 1** and **Figure 2** show that Option 2A has both the highest average annual 'Revenue less Expenses' (calculated over the period from 2025 to 2044) and the highest NPV of all the options assuming a base case gas price of \$5.00/dth. This result is driven primarily by the lower debt service (as compared to other new options), despite the need to burn natural gas when utilizing Unit 8 as backup. MSW mass burn Options, 3B-1 and 3B-2 have the next highest positive NPV values. Different assumptions, such as higher gas prices could change the magnitude, and therefore the NPV ranking. For example, the impact of the natural gas price on the Average 'Revenue less Expenses' ('Profit') and NPV for the Options is shown in **Table 1** and **2** respectively. Note that at a base case gas price of \$7.00/dth the NPV of Option 3B-2 is slightly greater than that of Option 2A. The financial model enables the City to evaluate the impact of different gas prices and other market sensitivities and assumptions. It is clear that the price of natural gas significantly impacts the operating costs of the base case. The increase in 'Profit' and NPV at higher gas prices for Options 3A-2 and 3B-2 are attributable to the increase in the steam unit sales price (which is linked to the price of natural gas). It is important to note that the change in gas price may indirectly affect other parameters such as MISO electric prices, transportation costs, consumables, etc. These impacts are not modelled as they are outside the scope of this study.

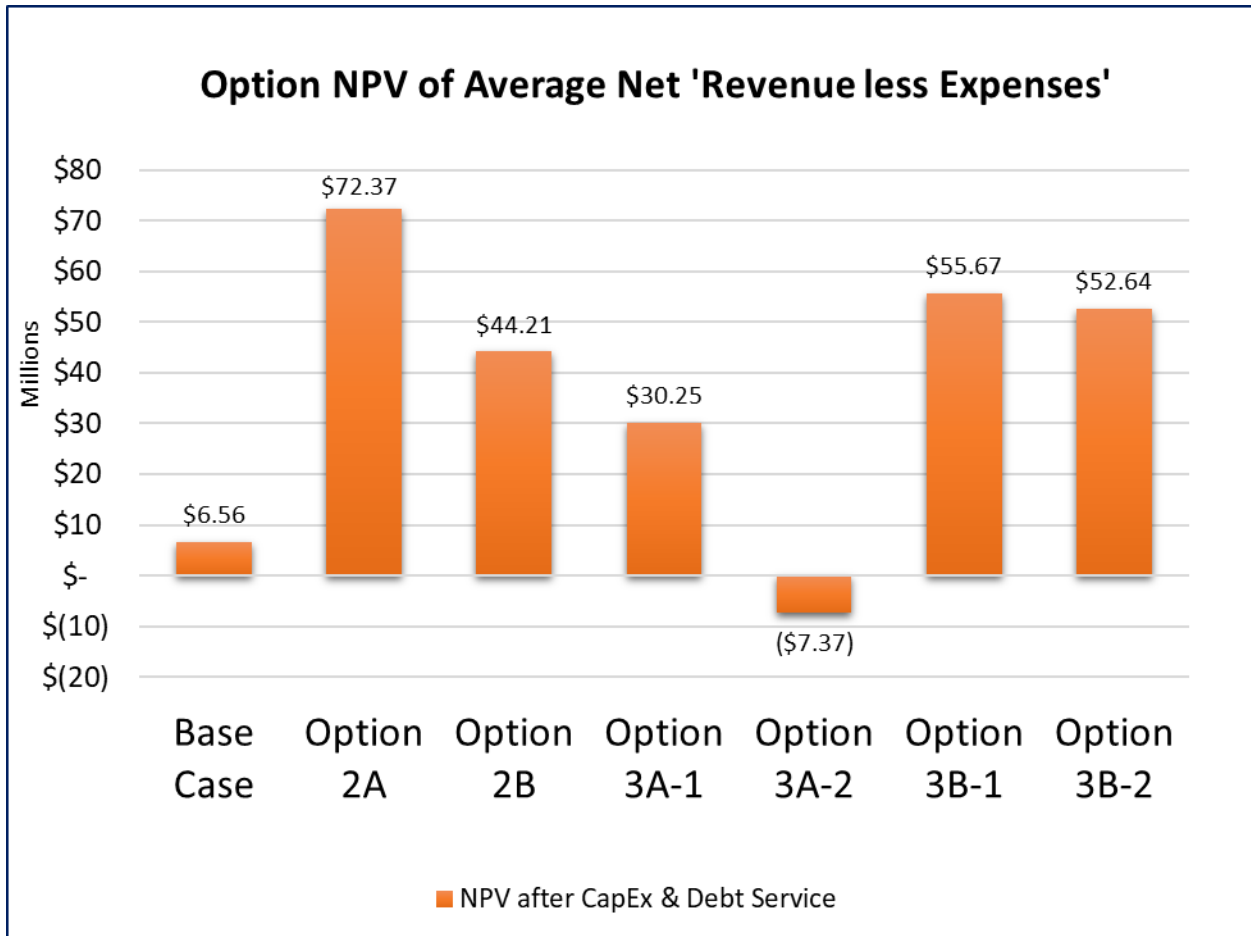


Figure 2: NPV Comparison of Net 'Revenue Less Expenditures' over Bond Period

Table 1: Average Annual 'Revenue less Expenses' Sensitivity to Gas Prices [\$M]

Base Case Gas Price	Base Case	Option 2A	Option 2B	Option 3A-1	Option 3A-2	Option 3B-1	Option 3B-2
\$4.00/dth	\$4.6	\$6.3	\$3.3	\$2.8	(\$1.6)	\$4.2	\$3.6
\$5.00/dth	\$0.5	\$5.7	\$3.3	\$2.1	(\$1.1)	\$4.2	\$3.9
\$6.00/dth	(\$3.7)	\$5.1	\$3.3	\$1.5	(\$0.6)	\$4.2	\$4.3
\$7.00/dth	(\$7.8)	\$4.5	\$3.3	\$0.9	(\$0.1)	\$4.2	\$4.7
\$8.00/dth	(\$12.0)	\$3.9	\$3.3	\$0.2	\$0.4	\$4.2	\$5.1



Table 2: Option NPV Sensitivity to Base Case Gas Price [\$M]

Base Case Gas Price	Option 2A	Option 2B	Option 3A-1	Option 3A-2	Option 3B-1	Option 3B-2
\$4.00 /dth	22.3	(13.1)	(19.3)	(70.7)	(1.6)	(9.5)
\$5.00 /dth	65.8	37.7	23.7	(13.9)	49.1	46.1
\$6.00 /dth	109.3	88.4	66.7	42.8	99.8	101.6
\$7.00 /dth	152.8	139.1	109.7	99.5	150.6	157.2
\$8.00 /dth	323.0	371.2	318.5	396.5	380.6	413.3

It is expected that the actual bonding of the project will not be performed until 2024 to support construction commencement in 2024-2025 timeframe. An average inflation index of 2.13% per year is used to estimate the cost in 2024 for the debt model. The model allows for inflation and other escalation factors to be customized. Further discussion of the financial model’s structure and methodology as well as other key findings are included in **Section 4 – Financial Analysis**.

1.4 Environmental Impacts

The environmental impacts of the seven total options are described in detail in **Section 5**. There are a number of environmental topics that are evaluated, but for the purposes of comparison, there is little variation regarding the approach to minimizing environmental impacts among the non-base case options. Municipal waste combustors (MWCs) are highly regulated by the Federal government and by the state governments, particularly regarding air emissions and this has set the benchmark for air pollution control. The designs of all of the alternatives to the base case can and will facilitate compliance with the regulations using the same S-O-A air pollution controls including baghouse, scrubber, PAC injection and SNCR. All of the alternatives to the base case will result in water consumption falling to one-tenth the current level, due to the drastic reduction in steam production requiring proportionately less makeup to the cooling tower and steam system.

The total MSW is the same for all options. Because of the large difference in density of ash vs. MSW (approximately 10:1), options that combust more material create more ash by weight and will result in less required landfill space. Since all alternatives to the base case relieve the existing system combustion tonnage limitation, they will produce more ash and also less volume to landfill. **Table 4 on Page 13** shows a landfill diversion percentage by mass and volume for all the evaluated options. All of the new options have higher diversion rates than the base case.

All of the non-base case options evaluated will require a new Title V Air Permit, as MWCs of any size require this permit. The State of Iowa will require a Construction Permit for each non-base case alternative, along with state air permits for each source or point of emissions.

The City’s has recently committed to reducing greenhouse gas (GHG) by 83% from 2018 levels by the year 2030. The GHG impact of each option was evaluated considering the following contributing components:

- CO2 from the combustion of the non-biogenic fraction of the waste
- CO2 from the combustion of natural gas (Unit 7 and Unit 8)
- Equivalent CO2 generated from the landfilling of by-passed waste
- CO2 from the production of replacement power



All of the six new considered options significantly reduce the GHG emissions by roughly half from the base case by avoiding the CO₂ generated from the constant co-fired combustion of natural gas. The electric energy produced from the consumption of natural gas in the base case would be replaced with electricity purchased from MISO Zone 3/Northern District (Ames node) which has an estimated average emissions of 611.11 lbs/MWh according to the EPA². Since this is a large component of the GHG, Ames can improve the CO₂ reduction by contracting with more renewable power contracts to further reduce the GHG footprint. A thorough GHG narrative and GHG calculations are included in **Section 5.2**.

1.5 Summary of Evaluated Options

As stated in the RFP, the City's goal of the WTE Options Study was to have a consulting team provide the detailed analysis across a number of key criteria to allow the City to then take those results and determine their path forward to selecting a preferred option for the long-term benefit of the community, the City and the environment.

The following Summary Comparison tables (**Tables 3 and 4**) show a number of key factors of each of the seven evaluated options (including the two sub-options for both 3A and 3B). These tables are intended to be used as a quick comparison tool, but do not replace the detailed evaluation found within the overall *City of Ames – WTE Options Study*.

The tables are meant to compare some of the key factors including, but not limited to the following:

- Technical performance of the selected RPP and PP systems
- Overall environmental performance
- Greenhouse Gas Performance of each option
- Financial merits and considerations of each option
- Landfill diversion estimates
- Comparative evaluation of the seven options to allow the City to narrow down or select the best option

² US EPA Egrid CO₂ output emission rate for all fuels value for Iowa, 2020 (MISO Zone 3)



Table 3: Summary Comparison of Evaluated Options (1 of 2)

Option Description	Option No.						
	1	2A	2B	3A-1	3A-2	3B-1	3B-2
	Base Case (As Is)	New RDF Unit & Nominal RRP Improvements	New 20" RDF Units & New RRP	New RDF Unit & New RRP	New RDF Units & New RRP	New MSW Combustion Units	New MSW Combustion Units
Location	Existing Buildings	Existing Buildings	Existing Buildings	New Facility @ Coal Yard	New Facilities @ Industrial Site	New Facilities @ Coal Yard	New Facilities @ Industrial Site
Feedstock RDF/MSW	<4"RDF	<4"RDF	20" RDF	<4"RDF	<4"RDF	MSW	MSW
Backup Unit	Existing Unit 7	Existing Unit 8	New Unit 10	Existing Unit 8	New Unit 10	New Unit 10	New Unit 10
Max CONTINUOUS MSW Processing Capacity of System [tons]	49,005	66,150	66,150	66,150	66,150	66,150	66,150
Net Present Value from 2026 to 2044 w/Capital Inv and Debt Service [\$Millions]	\$6.6	\$65.8	\$37.6	\$23.7	(\$13.9)	\$49.1	\$46.1
Avg. Annual (Costs)/Revenue including O&M and Capital Financing [k\$] (2026-2044)	\$473	\$5,677	\$3,279	\$2,144	(\$1,059)	\$4,211	\$3,942
Avg Annual Bypassed Waste to Landfill Over System Capacity (TPY) (2025 - 2044)	10,428	0	0	0	0	0	0
Avg MSW Process Rejects (including bulk rejects) (TPY) (2025 - 2044)	15,240	16,166	6,395	6,888	6,888	594	594
Avg Annual Ash to Landfill (TPY) (2025 2044)	2,720	3,435	6,245	4,112	4,112	11,532	11,532
Avg Total Equiv. GHG (CO2) (TPY) at Design Conditions (2025-2044) (from Table 12)	253,024	135,220	126,116	143,481	136,192	122,829	130,292

Page 12 intentionally blank



Table 4: Summary Comparison of Evaluation Options (2 of 2)

		Technical Features and Additional Considerations						
		Option No.						
		1	2A	2B	3A-1	3A-2	3B-1	3B-2
RRP Summary		Existing	Existing with small improvements	Rough Shred only	S-O-ARRP	S-O-ARRP	None	None
Primary Combustion Unit(s)		Existing Unit 8	One New 125 TPD RDF Unit 9	Dual "Large RDF" Units 9 & 10	One new RDF Unit 9	Dual RDF Units 9 & 10	Dual MSW Units 9 & 10	Dual MSW Units 9 & 10
Backup Combustion Unit		Existing Unit 7	Existing Unit 8	Unit 9/10	Existing Unit 8	Unit 9/10	Unit 9/10	Unit 9/10
Steam Turbine		Existing 7/8	Refurbished ST5	Refurbished ST5	Refurbished ST5	New ST9	Refurbished ST5	New ST9
Steam Sales		NO	NO	NO	NO	YES	NO	YES
AVERAGE AMOUNT TO LANDFILL BY MASS (2025-2044)	Excess Beyond System Capacity	17.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Bulky Rejects	2.9%	3.5%	3.5%	3.5%	3.5%	1.0%	1.0%
	RRP Process Rejects	22.6%	23.6%	7.2%	8.0%	8.0%	0.0%	0.0%
	Ash	4.6%	5.8%	10.5%	6.9%	6.9%	19.3%	19.3%
Landfill Diversion Total % [mass]		52.4%	67.1%	78.8%	81.6%	81.6%	79.7%	79.7%
Landfill Diversion Total % [volume] ¹		56.3%	72.1%	87.8%	87.5%	87.5%	96.2%	96.2%
Design Storage Mass (tons)	at RRP inlet	400+	400+	400+	400+	400+	~400 (MSW pit/floor)	~400 (MSW pit/floor)
	at RDF Bin	200	200	400	400	400	n/a see above	n/a see above
Bin Storage Duration with Lead or Single Unit Off-line in CY2044		~16	~8	~7	~7	~7	~5	~5
RRP Staffing (FTE)		17.5	17.5	8.5	9.1	16	2	2
PP staffing (FTE)		41	41	41	41	43	46	48
Total Staffing		58.5	58.5	49.5	50.1	59	48	50

¹ Based on 10 lb/cuft average density of MSW and 70 lb/cuft density of ash

Page 14 intentionally blank



2 INTRODUCTION, BACKGROUND, AND STUDIED OPTIONS

2.1 Objective

This study was prepared in response to an RFP issued by the City of Ames (“City”) on January 4, 2021 to study and assess the potential options for the City’s future waste-to-energy (“WTE”) operations including the existing Resource Recovery Plant (“RRP”) and the Ames Power Plant (“PP”) as well as potential new facility options. The following report details the associated technical and financial analysis to evaluate five primary options (and two sub-options) listed in **Section 2**. The City will then utilize this study to determine the best path forward for their waste management and power production system and continue to serve as a progressive environmental leader in the solid waste industry. The study’s overall goal is to provide the City with viable options to meet their waste management objectives, address current system limitations, enhance material recovery and diversion opportunities, address greenhouse gas (GHG) objectives, and serve the City’s energy needs into the future.

2.2 Background

The City of Ames, Iowa is located in central Iowa, approximately 30 miles north of the state’s capital, Des Moines. Ames has a population of approximately 67,000 and is the largest city in Story County. Ames is also home to Iowa State University, with over 30,000 students. The City has developed a new comprehensive plan, which is estimated to accommodate a population of 82,000 by the year 2040. Story County is estimated to reach a population of 119,500 at this same time. This WTE Options Study is intended to consider these population impacts and future growth in the area.

The Arnold O. Chantland Resource Recovery Plant (RRP) is owned and operated by the City of Ames Public Works Department. The system has been operating since 1975 and is available to process 52,000 tons of MSW annually. The MSW comes from the 12 cities within Story County, Iowa State University and parts of rural Story County. This system processes the incoming waste by removing bulky and undesirable materials and recovering ferrous and non-ferrous metals. The resulting material stream is then shredded to less than 4 inches in size and fed by a pneumatic system to a storage bin. The stored RDF is then pneumatically fed to one of two steam boilers in the Ames Power Plant (PP). The RDF is co-fired with natural gas to produce steam, which is sent to a turbine to create electricity. Rejected material from the RRP plant is taken to the Boone County Landfill. For environmental stewardship reasons the City would like to minimize the need to landfill during all operations.

The City’s other waste management programs outside the RRP plant include a food diversion program, no-charge yard waste drop-off days each year (material goes to a privately operated yard waste disposal site), Rummage RAMPage, community and river cleanups, pumpkin diversion, household hazardous waste collection, and glass recovery through collection bins located throughout the County. Glass cannot be processed effectively by the RRP plant, so this diverted material is collected at drop-off centers and about 10% of the total glass in the area is received by the RRP and then sent for recycling. This broad range of material recovery is a further example of the City’s focus on environmental stewardship. The following study is meant to provide options to the City that are in line with its over five-decade approach to managing waste as a resource.

2.3 WTE Study Options Descriptions

Portable Document Format (PDFs) images of the preliminary conceptual facility layouts for each of the options discussed in this section are found in **Appendix C**.

2.3.1 Option 1: Resource Recovery and Power Plants As-is (Base Case)

As part of the study’s overall analysis and to establish a base case, the existing RRP and PP were evaluated and associated system operating, and maintenance costs were determined as part of Option 1 (Base Case). All other options in the Study were evaluated technically, operationally, and financially in comparison to the current operations.

The seven studied options are briefly described in this section and detailed analysis and further system descriptions are provided in **Section 3 - Technical System Analysis**. The following items are already on



the City's agenda to address and excluded from this analysis: (1) remediation and removal of Units 5 and 6 boilers and associated coal bunkers, (2) remediation of the coal yard and removal of two underground tanks, and (3) structural repairs to the existing storage bin.

2.3.2 Option 2A: Existing RRP With New RDF Combustion Unit in the Existing PP

Option 2A, utilizes the RRP plant in its current condition with a few proposed equipment upgrades, and provides a new dedicated boiler (labeled Unit 9) for combusting RDF. Unit 9 would be located in the existing Power Plant building where retired Units 5 and 6 boilers are currently located. Unlike the current Units 7 and 8, this new RDF combustor would be designed to only utilize natural gas for start-up, shutdown, and flame stabilization. During regular operation the new unit would burn 100% RDF. Unit 8 (boiler and turbine) would be utilized as back-up to the new RDF combustor in this option and would still require co-firing with natural gas. A new air permit will be required for Unit 9. Steam from Unit 9 would be piped over to the existing turbine hall to generate power. Power would be generated either from (a) a single new, significantly smaller, steam turbine generator (approximately 6 MW) or (b) steam turbine ST5 (7.5 MW) would be refurbished with a new steam path and generator rewind to utilize the steam from Unit 9. For this analysis the refurbishment of ST5 is assumed.

2.3.3 Option 2B: Modified RRP (20" RDF) with Two New RDF Combustion Units

Option 2B utilizes a modified RRP plant (in the existing building) to deliver a 20" nominal RDF. This RDF would be combusted in two new boilers located at the adjacent coal yard. The larger RDF would be transferred from the RRP to the new storage building using a conveyor in a tubular gallery (See **Figure 15**) over 2nd Street. The material would then be fed from the storage building with conveyors to metered feed hoppers into the boilers. Steam from Unit 9 would be piped to the existing power plant. The steam turbine and associated generator options would resemble that of Option 2A, either refurbishing steam turbine 5 (including a generator rewind), or a new steam turbine and generator. The refurbishment of ST5 is assumed. For Option 2B, the existing Units 7 and 8 would continue to be available as capacity resources burning natural gas only.

2.3.4 Options 3A-1 & 3A-2: New RRP and New RDF Combustion Unit(s)

Option 3A includes an entirely new state-of-the-art (S-O-A) RRP to produce 4 inch minus RDF (same size as currently produced) and new RDF combustor(s). The new RRP would provide enhanced processing equipment, improved throughput capability, and deliver higher metals recovery resulting in more RDF produced from the waste stream and therefore more waste diverted from the landfill. The new RDF boilers, in both Option 3A-1 and 3A-2, would only use natural gas during start-up, shutdown and flame stabilization. For both options, the existing Units 7 and 8 continue to be available as capacity resources for MISO when burning natural gas only.

Option 3A-1 (Coal Yard)

For Option 3A-1 the S-O-A RRP and a new RDF combustion boiler would be located at the existing coal yard. Option 3A-1 also augments the RDF conveyance and storage system, by adding new pneumatic conveyors and additional RDF storage and utilizing much of the existing power plant infrastructure. For Option 3A-1, only one new boiler would be installed, and Unit 8 would be kept as a backup to co-fire RDF with natural gas. The steam turbine and generator options would be the same as in Option 2A.

Option 3A-2 (Greenfield)

Option 3A-2 locates the S-O-A RRP, and a new RDF combustion building at a potential industrial site to provide steam to an industrial customer. For Option 3A-2, two new RDF combustion boilers would be provided as the installation would be on a new, non-contiguous industrial site. All steam would flow through a back pressure steam turbine and the exhaust steam would be sent to the thermal host. The back pressure steam turbine would drive a small electric generator of about 1.6 MW. A condenser would be supplied to enable the continued processing of waste should the industrial steam user's ability to accept the steam be interrupted. The City could consider an extraction steam turbine to enable the production of electricity and/or



steam, but an extraction turbine would limit the amount of steam that could be exported, since some steam (5-10%) must always flow through to the back-end and condenser.

2.3.5 Options 3B-1 & 3B-2: Two New MSW Mass Burn Combustion Units

Option 3B utilizes two mass burn waste-to-energy (WTE) units to combust unprocessed MSW. Similar to Option 3A, this option has two sub-options. Both sub-options include receiving and storage of MSW followed by direct feed into the WTE units for combustion and a planned post-combustion metal recovery system. It is assumed both units would be designed to run in parallel during normal operation, and together, capable of the expected future MSW growth. In case of a unit outage, one unit would continue to operate to process waste. Significant oversizing of the parallel boilers is not recommended to avoid both boilers operating below 70% load during normal operation. Operation below 70% can negatively impact boiler efficiency and emissions (See storage discussion in Appendix B for additional background information). For both sub-options the existing Units 7 and 8 continue to be available as capacity resources burning natural gas only.

Option 3B-1 (Coal Yard)

For Option 3B-1, two new MSW mass burn boilers would be located at the existing coal yard. Power would be generated either from (a) a single new, significantly smaller, steam turbine generator (approximately 6 MW) or (b) steam turbine generator ST5 (7.5 MW) would be refurbished with a new steam path and generator rewind to utilize the steam from Unit 9 and 10. For this analysis, the refurbishment of STG 5 is assumed.

Option 3B-2 (Greenfield)

Option 3B-2 locates the two new MSW mass burn boilers in a new power plant at a potential industrial site to provide steam to an industrial customer. The boilers would only use natural gas during start-up, shutdown and flame stabilization. All steam would flow through a back pressure steam turbine (ST9) and the exhaust steam would be sent to the thermal host. The back pressure steam turbine would drive a small electric generator of about 1.5 MW. A condenser would be supplied to enable the continued processing of waste should the industrial steam user's ability to accept the steam be interrupted. The City could consider an extraction steam turbine to enable the production of electricity and/or steam, but that would limit the amount of steam that could be exported, since some steam (5-10%) must always flow through to the condenser.



Page 18 intentionally blank



3 TECHNICAL SYSTEM ANALYSIS

The following subsections provide key details for all the studied options. For convenience and readability, the process flow diagrams for the RRP systems and the overall process flow diagrams for all of the options can be found in **Appendix D and Appendix E**, as well as being featured in the following narrative.

3.1 Option 1 – Resource Recovery and Power Plants As-is (Base Case)

3.1.1 MSW Storage

Currently the RRP facility can store approximately 400 tons of MSW on the existing tipping floor, which translates into a nominal 2 days of storage based on the RRP throughput capability. The RRP does not have any storage capabilities on the back end (exit of the RRP) as the processed RDF is immediately fed into the pneumatic system and transferred to the RDF bins.

3.1.2 RRP Plant Processing System Summary

The RRP currently accepts up to approximately 200 tons/day of MSW at its tipping floor and the current system processes about 12 to 14 TPH. As the MSW enters the facility it is first sorted to remove larger objects (mattresses, carpet, furniture, and other bulky materials) and then fed to an inclined infeed conveyor using a front-end loader. A primary shredder liberates the material and reduces the size to less than 8 inches.

A process flow diagram depicting the current RRP system is shown in **Figure 3 on page 21**. A drum magnet along with magnetic head pulleys installed throughout the process line removes ferrous metals which are sold as scrap. The remaining material is screened through a two-screen process and small fines and rejects are removed. The overs from the primary screen are shredded a second time and combined with the overs from the secondary disc screen resulting in a RDF typically less than 4 inches in size, referred to as “4-inch minus”. The RDF exits the secondary shredder and is processed through an air knife system, which separates the light fraction from the heavy fraction. The heavy fraction is processed through an eddy current separator, which removes non-ferrous metals for sale as scrap, and is then transferred via a series of conveyors and combined with the rest of the rejects. The light fraction is discharged into a pneumatic feed system. The pneumatic feeder conveys the RDF, via a single 14-inch underground pipe to storage bins located in the existing Power Plant coal yard, approximately 600 feet away. The conveyance system has a maximum throughput of 10 – 12 TPH and an average of 8 TPH.

During the technical evaluation, RRT worked with the City to determine potential RRP upgrades that would deliver better and more consistent operations. These upgrades are listed as part of Option 2A to increase both the throughput and RDF quality going into a new RDF combustor. Option 1 (Base Case) does not include these system upgrades to allow for a clear technical and financial comparison from the current operations to the other six options. If the City decides to continue with their current operations, they may still want to consider implementing the system enhancements recommended by RRT.

As further consideration of maintaining the existing RRP system versus replacing it in its entirety, the following narrative is provided and applicable for all RDF options that re-use the existing or provide a new RRP. Continuing the City’s ongoing maintenance and repairs as well as replacing parts that are beyond repair will continue extending the life of the existing RRP. These costs are included in the model and were developed from historical data at the RRP. As with all options there are risks and factors that need to be considered by the City. For the existing RRP, we assumed with reasonable certainty that the existing RRP is sufficiently funded for long-term continued service. For the options with complete replacement of the RRP, different risks emerge including the assumptions for the operating costs and system efficiency whereas the existing RRP is proven. Again, the financial analysis is sufficiently “funded” to cover the operational risks and uncertainties of new equipment. Whichever option is ultimately selected, the detailed engineering would need to include a comprehensive reliability analysis so the equipment and component selections achieve the intent of a long-service life. At that point, the financial model should be refined to reflect the more detailed information. This narrative and comments would also apply to the re-use of Unit 8 as a back-up and also other components of the overall existing WTE system to remain.



RRP Equipment and Systems

A description of the RRP equipment/systems is provided in this section as these will be referenced in other options within the study.

Shredders/Size Reducers: Equipment that processes and reduces the size of the MSW material, liberates the material by opening bags or containers and reduces the volume of unsorted waste.

Disc Screens: Equipment that separates the material by size and consists of rotating discs for separating wastes through the clearance between the discs, depending upon the size and the weight of the waste while the remaining material moves on the rotating discs.

Air Knife/ Air Classifier: Air separation systems used to separate material based on material density and on their aerodynamic properties. Separates light fraction from the heavier pre-processed MSW.

Eddy Current Separator (ECS): Equipment used to separate non-ferrous metals from the pre-processed MSW stream using high frequency magnetic field.

Magnetic Separator: Suspended magnets, magnetic pulleys, drum magnets and electro-magnets are types of equipment used to separate ferrous metals from the pre-processed MSW stream.

Pneumatic Conveyance System: Pneumatic conveying is a type of system that uses compressed air to transfer the RDF material from one process area to another. The system works by moving the material through an enclosed conveying line using a combination of pressure differential and the flow of air from a blower or fan.

Trommel Screen: A trommel screen is a mechanical screening device which separates MSW into different sizes. It consists of a perforated cylinder with different screen size openings, elevated at an angle and rotating.

Other Balance of Plant (BOP) RRP Systems: Conveyors, air compressor system for equipment and maintenance tools, fire sprinkler system, dust collection system, scales for inbound and outbound truck traffic, sorting platforms, chutes and bunkers.

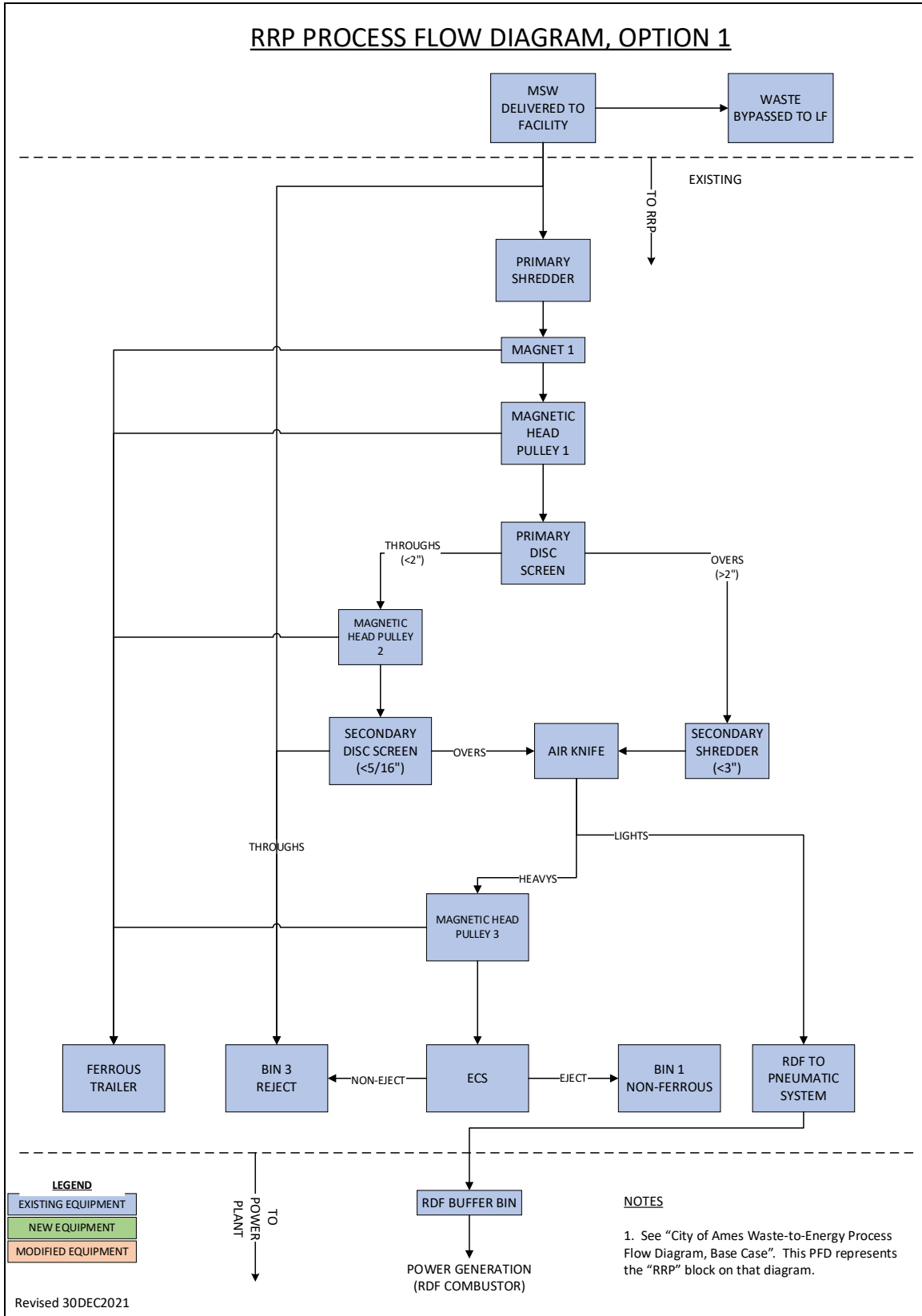


Figure 3: Option 1 Overall RRP Process Flow Diagram



3.1.3 RDF Transport and Storage

The RDF is stored in an approximately 5,600 ft² rectangular storage bin containing two sides separated by a dividing wall. Each side is capable of storing a theoretical amount of 100 tons, for a total of 200 tons, which can support 2 days of storage when the power plant is not operating or nearly 16 days of storage when lead Unit 8 is offline. Refer to **Appendix B** for a detailed RDF/MSW Storage Analysis for all options.

The bin provides storage for the RDF to balance the operation of the RRP as needed, Sunday through Friday, as opposed to the power plant which must be fully staffed 24 hours per day, 7 days per week.

The bins are alternately filled and emptied in order to burn older RDF first. Having two bins also provides the option to perform maintenance on one bin, while processing into and out of the other bin. The RDF bin is normally unmanned and feeds the material automatically through a series of conveyance systems made up of augers, drag conveyors, and rotary feeders to eventually drop the RDF into a pneumatic conveyance system going from the RDF storage bins via two (2) 8" diameter underground pipes. The original RDF storage bin was designed by Atlas as a single round shaped bin. The original bin was replaced with two side-by-side bins from Clarke Industries, which are a trapezoid shaped type of design with independent augers for each bin. These bins were designed for a storage height of 25 feet of RDF, but this resulted in high levels of compaction at the base and makes the RDF very hard to extract. Therefore, the RDF storage height is currently limited to 15 ft, which equates to 100 tons per side. The compaction is also increased by higher moisture content at times.

From the RDF bin, the RDF is transported pneumatically to the power plant boilers using two 8" pipes with a max feed rate of 6 TPH and an average operating rate of 3.6 TPH (32,000/8,760). A total of four lines go to the power plant, however only two are being used for RDF conveyance. One remaining line is used for cables, while the other is currently not in use.

3.1.4 Power Plant Combustion System Summary

The Power Plant (PP) is located at 200 East 5th Street. It consists of two (2) operating steam boilers, Units 7 and 8. Units 5 and 6 are retired but are still in place, along with their respective steam turbines and generators, which gives the power plant a total of four (4) steam turbine generators (ST).

Boiler Unit 7 is a Combustion Engineering tangentially fired boiler that was constructed in 1967. It was designed to generate 360,000 lb/hr of superheated steam using pulverized coal with startup and shutdown on fuel oil. The boiler includes an electrostatic precipitator to remove fly ash. The steam drives Steam Turbine No 7 (ST7), a non-reheat, GE turbine generator with a nameplate rating of 33 MW. The steam produced by Unit 7 is 900 psig and 850F.

In conjunction with the construction of the RRP in 1975, Unit 7 was retrofitted to co-fire RDF with coal.

In 1982, the PP added Unit 8, a Babcock and Wilcox wall-fired boiler designed to co-fire RDF with coal and produce 620,000 lbs/hr of high pressure, high temperature steam. The boiler included two (2) parallel hot side electrostatic precipitators and steam turbine 8 (ST8), a 65 MW GE non-reheat steam turbine generator. The steam exits Unit 8 at 1,250 psig and 955F.

In the current combustion process, the RDF is directed into either Unit 8 (primary) or Unit 7 (backup) for co-firing with natural gas. Under the Title V operating permit, both units are not allowed to be co-fired with RDF simultaneously.

In 1986, Unit 5 and Unit 6 boilers and steam turbine generators were decommissioned. The Utility intends to remove boilers 5 and 6 in 2022. Steam turbine generator 6, which is rated at 12.65 MW, is slated to remain until its re-use is ruled out. ST5 and ST6 are of similar vintage, and ST5 will be retained as it is much closer in size to that needed for all of the non-base case options considered. ST5's refurbishment and its generator rewind would also be less expensive than refurbishing ST6. Note there is a shared overhead crane with ST5, ST6 and ST7.

In 2016, both boilers were converted from coal/RDF (with fuel oil for startup/shutdown) to natural gas/RDF fuel mix. Under the power plant's Title V permit, the boilers are permitted to consume no more than 30%



RDF by weight. Therefore, approximately 10% of the electricity comes from the energy released from RDF consumed in the boiler. The remaining 90% of the electricity is from the co-fired combustion of natural gas. Only one boiler at a time can consume RDF per the Title V permit. Unit 7 can consume up to ~85 tons of RDF per day and Unit 8 can consume up to ~120 tons/day. This RDF limit requires 70% or more of natural gas to be burned while co-firing RDF.

Fly ash and bottom ash from the boilers are sluiced to an ash pond northeast of the PP where it is eventually mounded and dried. The ash generated is solely a result of combusting RDF (i.e., there is no ash generated from the combustion of natural gas). The ash storage site is located approximately 0.5 mile northeast of the PP. It is operated as a “zero discharge” basin (no outflow) and is periodically emptied of accumulated ash and hauled to a landfill.

A Continuous Emissions Monitoring System (CEMS) monitors SO₂, NO_x, CO₂ and flow within the stack. Opacity is also monitored with a Continuous Opacity Monitoring System (COMS) as required under the air permit.

3.1.5 RDF Co-Combustion System

In 1975, the power plant added the ability to co-fire RDF provided by the RRP with coal. In 1982, a new boiler, Unit 8, was designed as a co-fired (coal/RDF) unit. In order to continue to qualify as an Electric Generation Facility under Title V of the EPA, the RDF co-firing is limited under the Power Plant’s Air Permit to 30% of the total fuel consumption by weight and limited to 10% of total boiler energy consumption per calendar quarter.

In 2016, Unit 7 and Unit 8 were converted to enable operation on natural gas only and to also co-fire RDF with natural gas in lieu of coal. Boiler start-up is done using only natural gas.

It has been observed that the combustion characteristics of the natural gas with RDF, compared to coal with RDF, has resulted in increased corrosion rates in the equipment that comes in contact with the combustion gases, namely the boiler tubes and stack breeching. The co-firing with natural gas has required on-going operation and maintenance costs to the PP operation and negatively impacted the throughput due to downtime needed for repairs, in particular with Unit 8, which is the larger of the two boilers. The City has worked to remedy this issue by undertaking a recent Inconel cladding of the boiler tubes in the super-heat section of the boiler. The PP has now installed corrosion resistant coating on the tubes located in the high corrosion areas of Unit 8. This remedy is expected to slow the tube corrosion to a more manageable rate. The City may also want to continue to evaluate the possible injection of hydrated lime into the furnaces of Units 7 and 8 to reduce the potential of corrosion from the flue gas. This technique may negatively impact the rate of boiler fouling, so a planned testing and evaluation approach should be followed to quantify any potential negative impacts.

3.1.6 Steam Turbine Generators

The steam throttle conditions for steam turbines 7 and 8 are unique to each boiler and cannot be cross connected to each other. Unit 7 steam conditions are 900 psig and 850 F while Unit 8 steam conditions are 1250 psig and 950 F. While higher steam temperatures improve steam turbine performance, the higher temperature also results in accelerated corrosion of the boiler tubes. For waste-to-energy systems the boiler design conditions are generally below 775 F to minimize corrosion. Retired steam turbine generators 5 and 6 of 7.5 MW and 12.5 MW rated capacity have not operated since the 1980’s. Due to its robust design, it is highly likely that ST5 can be refurbished, and the generator rewound for re-use. The same overhead 50-ton crane services ST5, ST6 and ST7.

3.1.7 Balance of Power Plant Equipment

The balance of power plant (BOP) equipment/systems that support the boiler(s) and steam turbine generator(s) are listed below. A description of the plant equipment/systems is provided in this section as these will be referenced in other options within the study.

Fresh air supply fans: These provide combustion air needed for the boilers.



Boiler feed pumps: These pumps raise the pressure of the condensate return water to the boiler operating pressure.

Water Treatment: Using reverse osmosis and de-ionization, city-water is treated to remove minerals and other contaminants to meet the boiler and steam turbine water quality specifications. A monitoring system and periodic testing of the water are included.

Steam Condenser(s): The condensers are heat exchanges used to condense the steam exiting the steam turbine (condenser shell side) using water from the cooling tower (condenser tube side).

Cooling Water System (Cooling Tower(s)): Cooling water is circulated through the steam condensers to the cooling towers where the heat removed from the condenser is rejected to the atmosphere. Other heat rejection may also be rejected to the system such as from lube oil coolers, HVAC systems or auxiliary systems.

Electrostatic Precipitator(s): Devices in the exhaust of the boiler used to collect and remove particulate matter from the exhaust air using an electrostatic charge and periodic rapping of the plates that collect the aggregated particles.

Continuous Emission Monitoring (CEMS): Continuous sampling of the exhaust gas and measurement of the products of combustion being monitored. For Ames the CEMS is required under permit to monitor opacity, SO₂, NO_x, CO₂ or O₂ and flow.

Continuous Opacity Monitoring System (COMS): System that continuously monitors the exhaust gas opacity as a measurement of particulate matter being released.

Generator Step up Transformer(s) (GSU): Transformers used to step up the generation voltage to the electric voltage of the utility interconnection.

High Voltage Interconnection: A system of relays, switches, breakers, metering and detection devices assembled to safely interconnect, meter, monitor and control the interconnection to the electric utility.

Auxiliary Cooling Systems: Closed loop cooling water circulating system that removes residual heat from auxiliary power equipment (e.g. boiler feed pumps, compressors) and rejects the heat to the atmosphere using fin-fan coolers (radiators).

Auxiliary Power Transformers: Transformers to reduce the voltage from the generation voltage to the voltage needed for the power plant auxiliary equipment (4160V and/or 480V).

Power distribution system (4160/480/120): Breakers, cables, wires and trays and conduit and protection devices used to distribute power to the electric auxiliary equipment within the PP.

Poker Picker: Provision added to equipment to collect and remove long items (pokers) such as cables, sticks, rods from the waste stream to prevent damage of downstream equipment.

Distributed Control System (DCS): An electronic control and monitoring system for the plant.

Uninterrupted Power System (UPS): A battery backup system for ensuring critical controls and services (emergency lighting) is powered for the safe shutdown of the facility or until permanent power is restored.

Fire Protection: A fire alarm system monitors smoke and temperature conditions with detectors throughout the facility and automatically alarms and activates fire water pumps that distribute water through a hydrant and sprinkler piping system to suppress the fire.

3.1.8 Emission Control

Both Units 7 and 8 utilize electrostatic precipitators (ESPs) to remove fly ash particulate from the flue gas prior to the stack. The fly ash is then conveyed and mixed with the bottom ash and sluiced to the ash disposal area. Neither of the units employ scrubbers to control the SO₂ and HCl emissions that are generated from the combustion of the RDF. SO₂ stack emissions are monitored for both units using a



continuous Emissions Monitoring System (CEMS). HCl stack emissions are not monitored from either Units 7 or 8.

It should be noted that ESPs are commonly used in fossil fuel combustion applications for particulate control. Baghouses, also known as fabric filters, are the best technology to control particulates, mercury, and dioxins in waste-to-energy applications, as well as improve the control of SO2 and HCl.

Combustion related emissions of CO and NOx are controlled by the combustion control system of the boilers. Typical stack emissions from plant data reports along with the Title V Air Permit values for Units 7 and 8 are listed in **Table 5**. Note the production of SO2 is significantly below the permit limits.

Table 5: Typical Emissions and Permit Values for Units 7 and 8

Unit		Typical	Title V Permit	Units of Measure	Typical	Title V Permit	Units of Measure
7	CO	0.004	0.20	lb/MMBTU	1.55	95.2	lb/hr
	NOx	0.174	0.40	lb/MMBTU	58.9	n/a	lb/hr
	SO2	<0.02	2.5	lb/MMBTU	<8.5	520	lb/hr
	Opacity	<2%	40%	n.d.			
8	CO	0.0003	0.20	lb./MMBTU	0.23	155	lb./hr.
	NOx	0.122	0.46	lb./MMBTU	57.4	538.1	lb./hr.
	SO2	<0.01	5	lb./MMBTU	<8	923	lb./hr.
	Opacity	<2%	20%	n.d.			

3.1.9 Ash Handling/Disposal

For both Units 7 and 8, the fly ash, which has no end markets, is conveyed and mixed with the bottom ash collected at the bottom of the combustors, and then sluiced to an ash disposal area northeast of the PP. The ash generated is solely a result of combusting RDF. Note that the RDF will contain heavy metals that were present in the MSW at trace, parts per million levels. These heavy metals are not recovered in the RRP, which only recovers ferrous and non-ferrous metals for recycling.

The ash storage site is located approximately 0.5 miles northeast of the PP. It is operated as a “zero discharge” basin (no outflow) and is periodically emptied of accumulated ash and sent to a landfill.

3.1.10 Electric Energy Sales

Electricity generated by the Plant is delivered to the City of Ames Electric Utility, which distributes and sells it to its retail customers. Since power from waste-to-energy is continuous (i.e., the PP does not cycle the RDF consumption up and down in response to the City’s electric load) the PP is essentially a “must-run” generation resource for the Utility. Iowa has continued to see an increase in electricity provided by renewable energy. In 2020, 57% of Iowa’s electricity was generated from wind³ and 53% of the state’s *electric usage* was provided by wind energy. As a result, wind energy is increasingly the source of power “on the margin”. This drives the average wholesale price of electricity down as more wind generation comes on-line. As of 2019, approximately 3,750 MW of additional wind generation installed capacity was queued to be added in MISO Zone 3 (Iowa), and 31,121 MW in the MISO territory (see **Figure 4**). For the 2021/22 MISO UCAP (unforced capacity) auction results, the Planning Reserve Margin Requirement (PRMR) and the UCAP capacity offered in the auction for each MISO zone is shown in **Table 6**. It should be noted that the wind *installed* capacity is significantly discounted when converted to UCAP. A new wind resource will

³ US Energy Information Administration, Iowa State Energy Profile, *Updated June 17, 2021*

first have the class average wind capacity credit of 16.3% applied to its rated capacity to arrive at its UCAP value.⁴

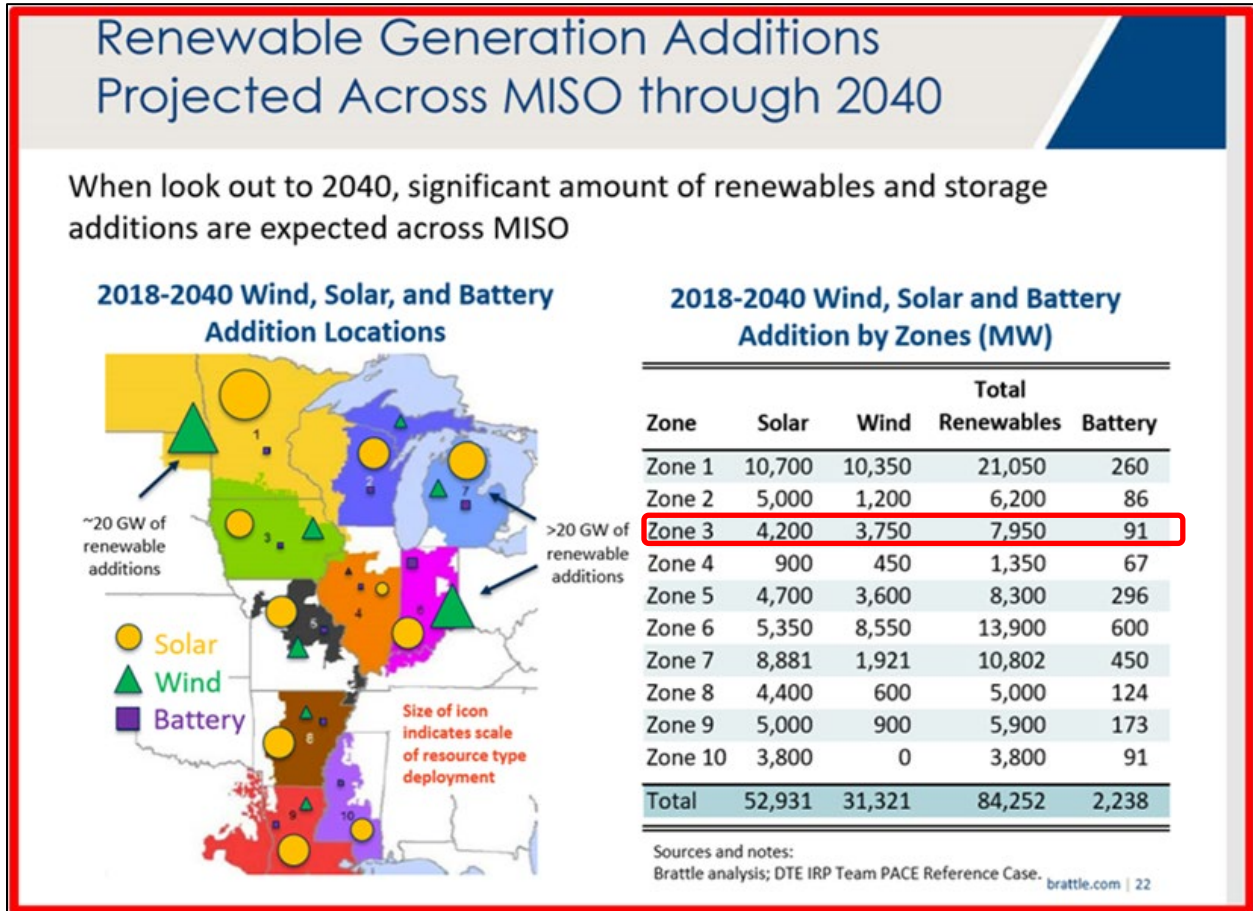


Figure 4: Renewable Generator Projected Additions Across MISO⁵

Table 6: Capacity Offered and Committed for Each MISO Zone 2021/22

	Z 1	Z 2	Z 3	Z 4	Z 5	Z 6	Z 7	Z 8	Z 9	Z 10	ERZ ⁶	System
MW PRMR	18,359	13,617	10,280	9,853	8,247	18,146	21,459	7,828	21,283	4,833	n/a	133,903
MW Offered	20,289	13,980	10,827	9,506	7,811	15,832	21,666	10,642	23,017	5,354	1,639	140,565

⁴ Planning Year 2021-2022 MISO Wind & Solar Capacity Credit, Draft Report PY 21-22, January 2021

⁵ "Battery Storage in MISO-How Might Batteries Change the MISO Landscape and Affect Operations" December 11, 2019, The Brattle Group (presentation at the MISO Advisory Group Committee Meeting)

⁶ ERZ=External Resource



For 2021 the average off-peak price for wholesale electricity was \$17 MWh and for on-peak electricity it was \$30/MWh at the Ames interconnection node. As a point of reference, a gas fired plant with an average heat rate plant of 11,500 btu/kWh and average burner tip (all-in) cost of gas of \$5.00/dth, the breakeven cost of producing power to cover just the fuel expenses would be \$57.5/MWh ($4 \times 11,500 / 1000$). Historically, the average “all-in” gas price (commodity plus transportation) for the power plant during 2020/21 was \$3.48/dth assuming a 95% transportation contract utilization rate. This excludes any value received from the resale of unused gas. The gross heat rates of Unit 7 and 8 when co-firing with natural gas is historically 11,552 and 11,161 BTU/kWh respectively as measured by the power plant. The price of natural gas has been on the rise as of this writing. A 12-year history of the price of natural gas at Henry Hub (Texas) is shown in **Figure 5**.

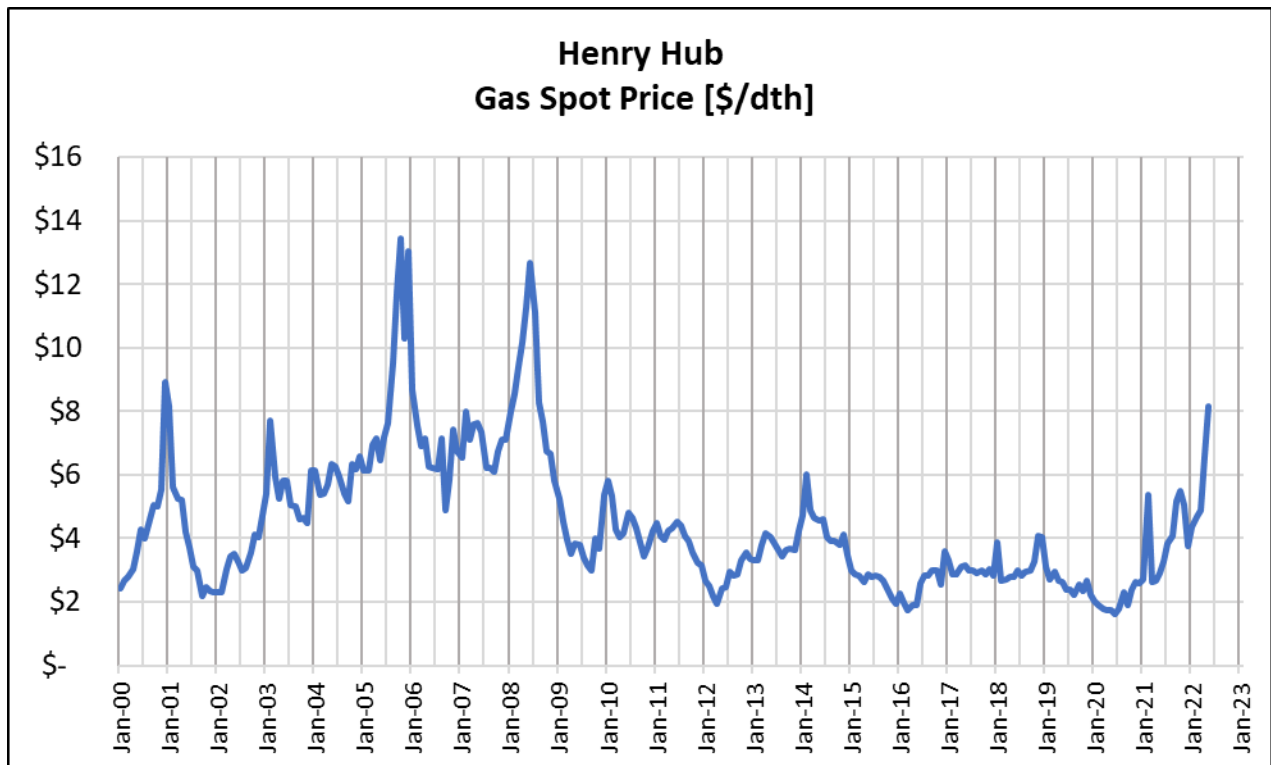


Figure 5: Historic Price of Natural Gas, Henry Hub 2000-Apr 2022 (\$/dth)

3.1.11 Process Flow and Mass and Heat Balance

An overall process flow diagram depicting the existing system in Option 1 is shown below in **Figure 6**. Mass and heat balance data can be found in **Appendix F**.

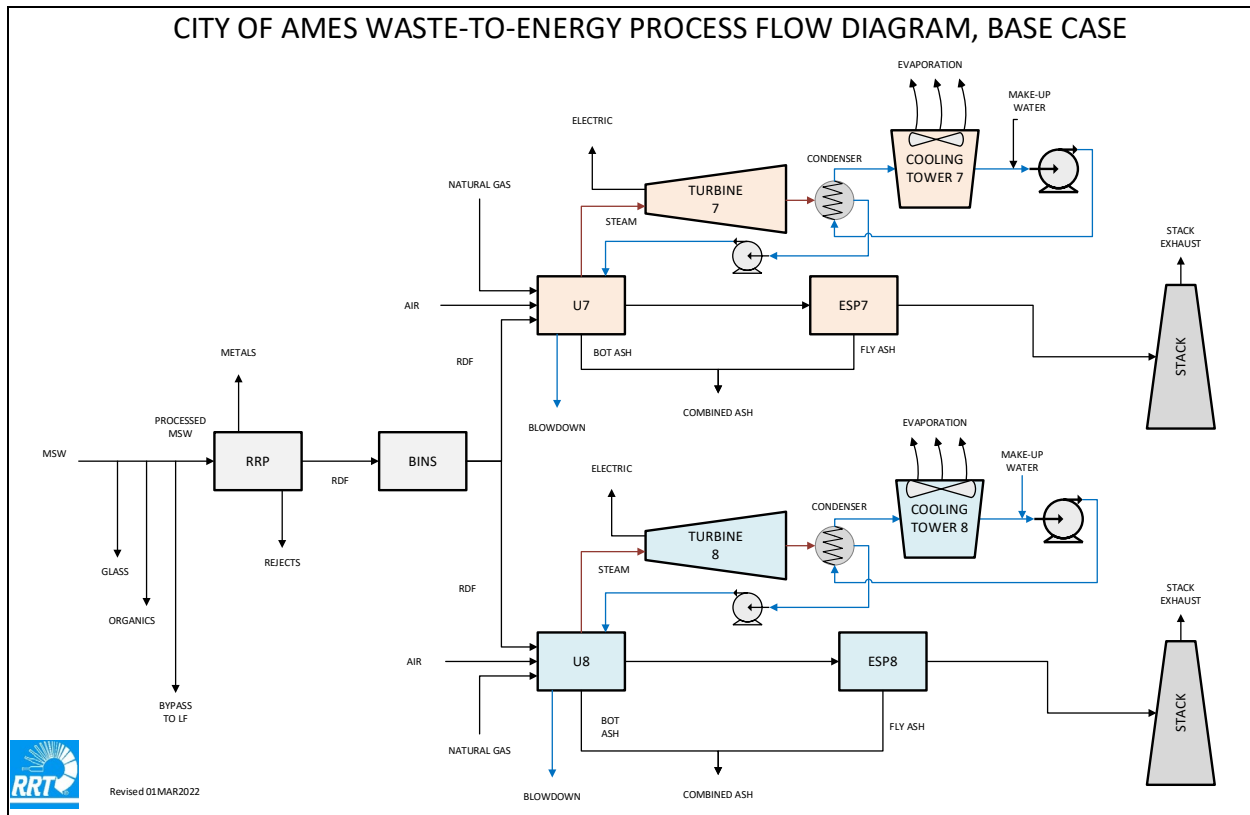


Figure 6: Option 1 (Base Case) Overall Process Flow Diagram

3.1.12 Building/Facility Description and Considerations

A facility description is not provided for Option 1, as the existing facility and system narrative is already provided in both the RRP and PP System Summary Sections and nothing is being changed in this option.

Existing City of Ames Facility Layout

The City’s existing RRP, storage bins and power plant are shown in **Figure 7**. The RRP building is located along the north side of Lincoln Way east of Duff Avenue. The second-generation rectangular storage bin is located just south of the railroad on the western side of the former coal yard. The power plant is located to the North of the rail line with its main entrance on 5th Street. See **Figure 7** below for further details.

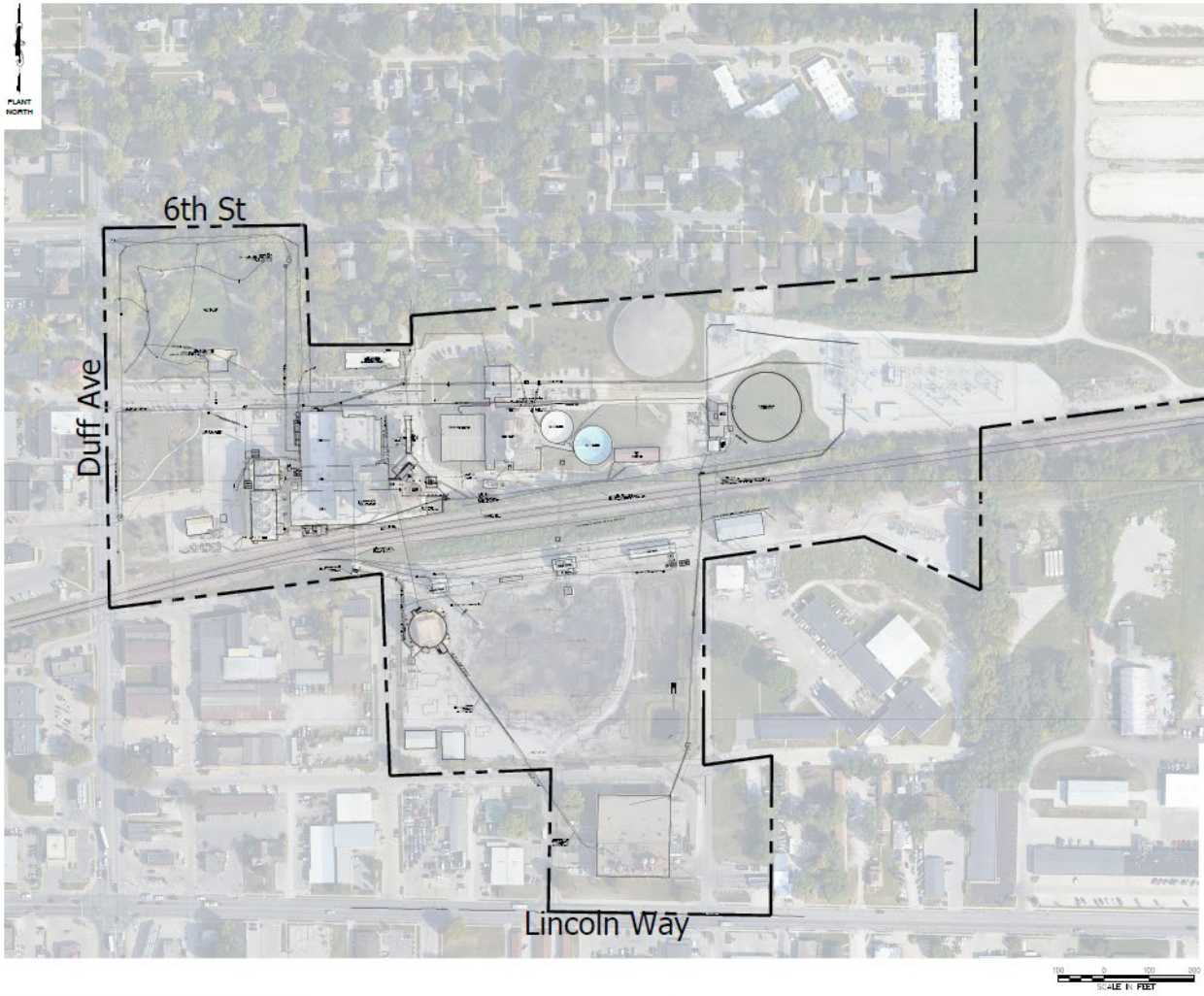


Figure 7: Existing City of Ames Facility Layout



3.2 Option 2A – Existing RRP with New RDF Combustion Unit in the Existing PP

The following items characterize the key elements of Option 2A

- Processing MSW into 4 inch minus RDF using the existing RRP
- RRP enhancements to improve processing capability to handle increased throughput
- Unit 5 and 6 boilers and associated equipment would be remediated and dismantled. Select equipment may be reusable depending on its condition (e.g., surface condenser, boiler feed-pumps) subject to inspection. This expense is currently budgeted for by the City and this report assumes it will be completed before any project engineering to enable a complete investigation of the as-left condition.
- One new, state-of-the-art RDF-only combustion boiler (Unit 9) would be installed where retired boilers 5 and 6 are currently located or in the adjacent water treatment plant area. Natural gas will be used only for startup, shutdown, and flame stability of the boiler.
- As a backup, maintain and operate Unit 8 as currently designed when Unit 9 is unavailable. Note: While Unit 7 could also be used as a backup, Unit 7 is smaller than Unit 8 and therefore would not be able to handle the full amount of incoming RDF.
- Unit 7 and 8 would be maintained by the City as capacity resources for the MISO burning natural gas only. They would be bid into the electric market based on Citygate gas prices. It is estimated that they would be selected to operate less than 5% of the time.
- The contract for well head gas and firm transportation could be cancelled and only Citygate gas purchases made as needed, since annual quantities would be small (startups and shutdowns) and timing unpredictable, including for the operation of Unit 8 as the backup boiler.
- Power would be generated from refurbished steam turbine 5 (ST5) and updated to utilize the steam from Unit 9. A new electronic control system, new steam condenser and an electric generator rewind are also assumed. An internal inspection would be conducted to confirm the feasibility and cost of the steam path refurbishment and generator rewind. A cost-benefit analysis would compare the expected performance and cost of the refurbishments vs. installing a new steam turbine and generator of comparable size. Power would be delivered to the grid via the existing electrical infrastructure.
- Steam turbines 7 and 8 will not be able to accept the new RDF boiler steam conditions and will remain as capacity only resources.
- New Balance of (Power) Plant (BOP) equipment and systems would be installed to support the installation and operation of Unit 9.

3.2.1 MSW Storage

Option 2A involves using the existing RRP equipment in its current condition along with a few recommended upgrades further described in the next section. The front-end storage capabilities at the facility are not expected to change from the base case Option 1. The same storage capacity available on the RRP tipping floor is expected to be sufficient for dealing with downtimes and maintenance issues in the facility.

3.2.2 RRP Analysis and Recommended System Upgrades

- As part of the existing RRP technical analysis, RRT and the City discussed some potential upgrades for the waste processing and transfer systems. Option 2A proposes to address the



following items summarized below, and includes a cost allowance for upgrade and/or replacement. RRT proposes to upgrade the existing pneumatic conveyance system by adding capabilities for metering the RDF inbound and outbound to the existing bin as well as providing new airlock feeder systems and material handling blowers.

- Upgrades to the existing air knife system to increase separation efficiency
- Improvements to the existing data collection, instrumentation and information management system, and CCTV system.
- A new Eddy Current Separator (ECS) will be added to the overs fraction from the primary disc screen, after the secondary shredder, to increase non-ferrous recovery. The upgrade will include necessary conveyors and a poker picker to capture rods or wires that come through the screen and might be blown over by the air knife into the light fraction, the latter leading to plugs or jams in the pneumatic conveyance line.
- A new scale for outbound traffic is also proposed, given the existing inbound scale is not suitable for walking floor trailers currently used for outbound rejects.

Figure 8 shows the RRP Process Flow Diagram for Option 2A.

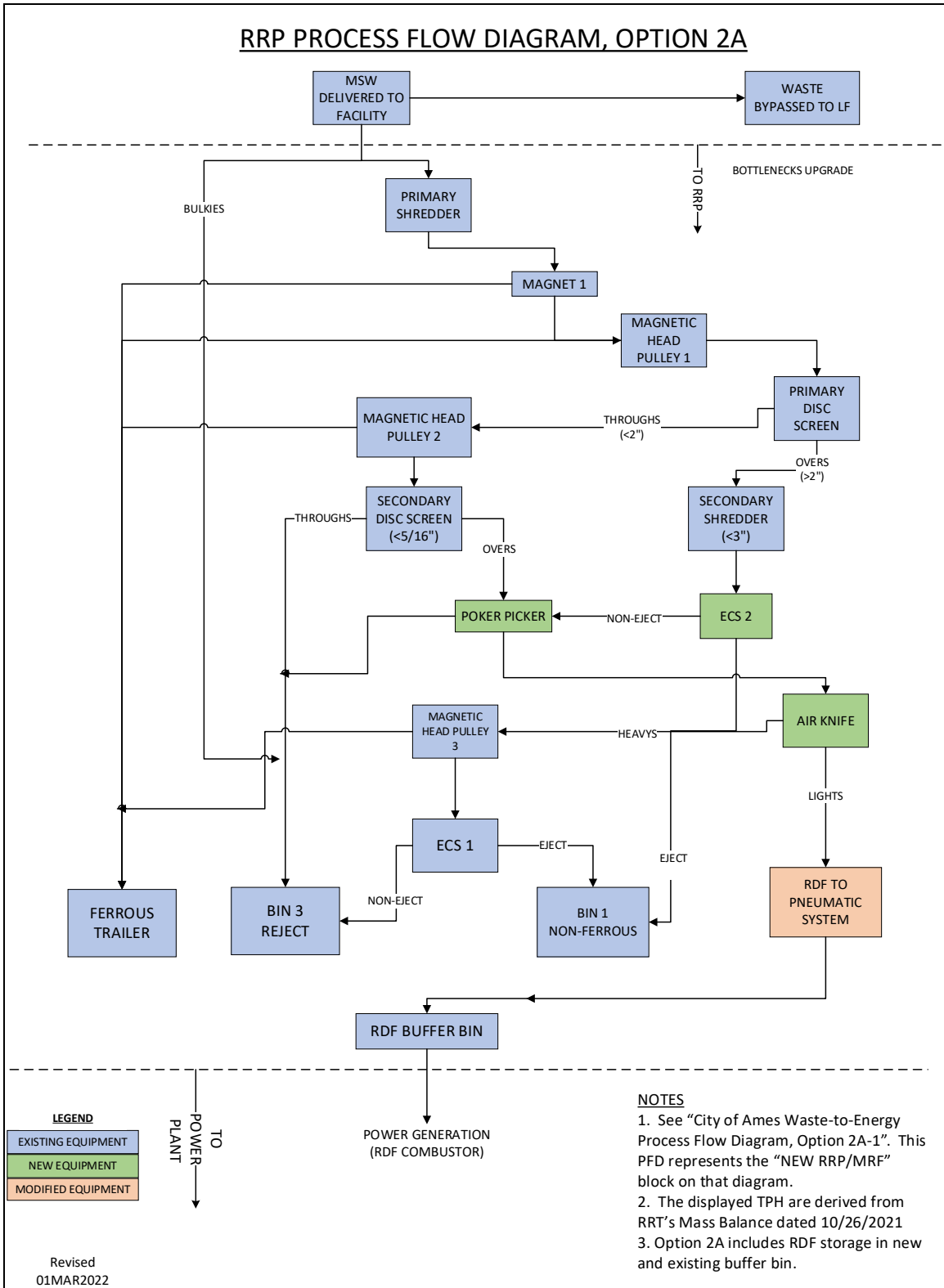


Figure 8: Option 2A Overall RRP Process Flow Diagram



3.2.3 RDF Transport and Storage

The RDF is conveyed pneumatically to the RDF storage bin for interim storage, via a single 14" pipe, which limits the throughput to a maximum of 12 – 14 TPH, with an average of 8 TPH. The bin provides storage for the RDF to balance the operation of the RRP (~80 hours per week) and the power plant (24 hours/day). The bin is divided into 2 sides, allowing one side to be emptied while the other is being filled and also enables performing maintenance on one side while the other is in operation. Each side holds approximately 100 tons of RDF. From the bin, the RDF is transported pneumatically to the power plant using two 8" pipes. As further detailed in the RDF/MSW Storage Analysis found in **Appendix B**, additional storage for Option 2A is not necessary. In this case, the 200 tons of existing storage, along with Unit 8 back-up capacity, yields approximately 12 days of storage at the end of the 20-year evaluation period when one unit is off-line.

Of the total four existing pneumatic lines to the boiler, only two are currently being used to convey RDF from the existing bin to the PP. One line is used as a cable conduit. As part of 2A upgrades, we recommend restoring the remaining non-operational line to improve fuel delivery reliability and redundancy to the boiler in light of the increase in RDF consumption of the new boiler.

3.2.4 RDF Combustion System Options

A variety of combustor design options could be used for the combustion of 4" RDF, including bubbling fluidized beds, suspension-fired traveling grates, and inclined reciprocating grates. Details on all of these combustor types were introduced in Section 1.2 and are provided in **Appendix G**.

Historically, the most common combustor design for RDF utilizes suspension firing, with a horizontal traveling grate to combust larger materials that are not completely burned in suspension and fall to the grate. The RDF size requirement for suspension-fired systems is typically 6" minus, which can usually be achieved in a single shredding step. Back in the 1970's and 1980's, several large boiler suppliers adapted designs from other solid fuel systems to combust RDF, and a number of large facilities were built in the U.S., a few of which still operate today. These systems were much larger than that needed for the City of Ames, with unit capacities on the order of 1,000 TPD.

Bubbling fluidized bed combustion systems have been successfully applied to RDF applications for many years but require a finer RDF size of 4" minus, similar to the RDF currently produced by the City of Ames. A leading supplier of bubbling fluidized bed combustion systems is Metso:Outotec. A schematic of their combustor is shown below in **Figure 9**.

In the Metso:Outotec system, waste is fed to the combustor by a metering bin located above the combustor. The metered RDF flows by gravity to the inlet of an air-swept spreader that disperses the RDF across the bubbling bed of the combustor. The City's current pneumatic system for transporting and feeding RDF could feed the metering bin, or alternately, replace the metering bin and feed the RDF directly to the bubbling bed combustor. Metso:Outotec has some experience with this type of direct pneumatic feed to their bubbling bed combustion systems. A summary of all the various combustion system technologies considered in the study are included in **Appendix G**.

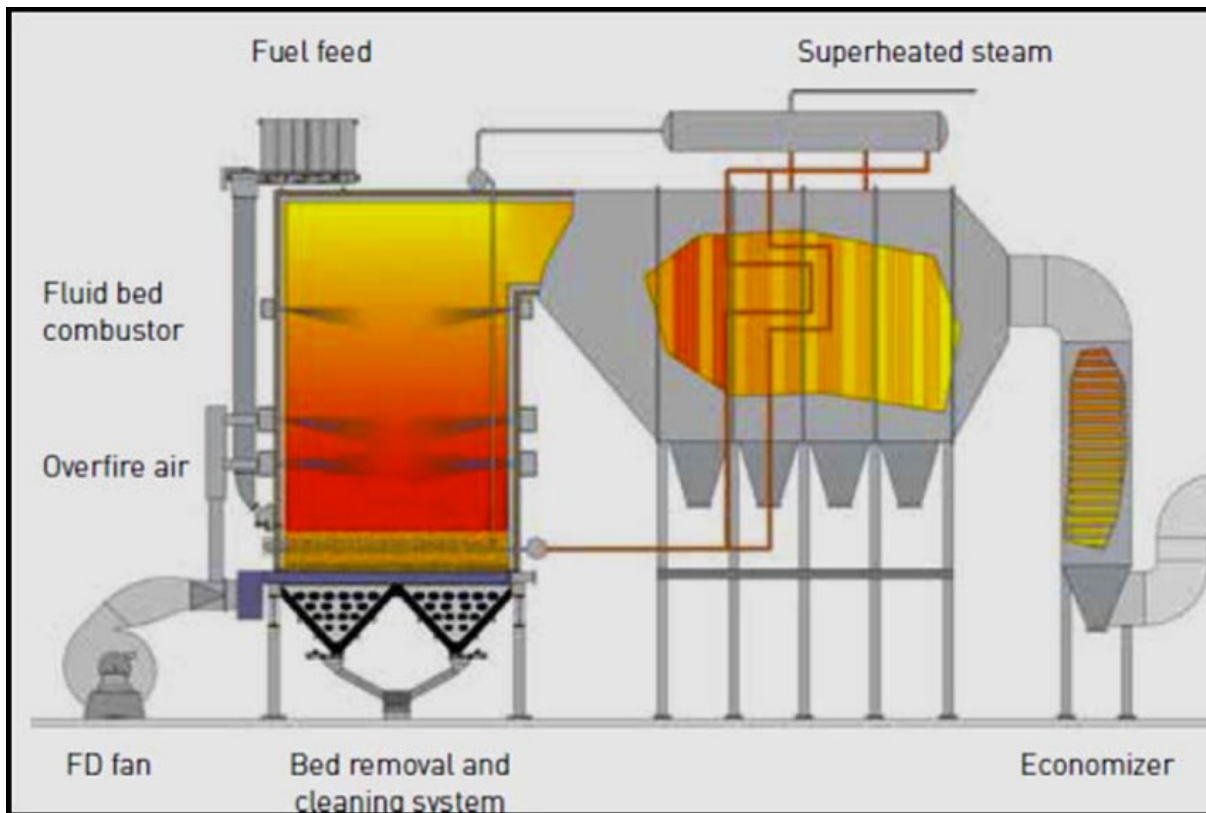


Figure 9: Metso-Outotec Bubbling Fluidized Bed Combustor for <4" RDF

RDF entering the hot, bubbling bed dries and combusts at a relatively low temperature and provides a well-mixed system that promotes efficient combustion and prevents localized high temperature areas where melting of the ash could occur. This controlled combustion condition requires less excess air when compared to suspension fired systems and leads to lower CO and NO_x emissions from the combustor. Non-combustible inorganics in the RDF are removed from the bubbling bed automatically by Outotec's proprietary bed material cleaning system that recovers the bed material sand for recycling back to the combustor and rejects ash and other inerts.

Metso:Outotec has commercial experience processing RDF in their bubbling fluidized bed combustion systems, including French Island and the City of Tacoma in the U.S., three Italian facilities in Ravenna, Bergamo, Massafra, and several new facilities in the UK.

Inclined reciprocating grate systems are by far the most common combustion system used throughout the world for the combustion of municipal solid waste. While inclined reciprocating grates are designed to combust unprocessed MSW, they could also be used for the combustion of RDF. However, the mechanical design of these systems is thought to be overkill for a processed RDF feedstock, particularly one that is sized to 4", as is currently produced by the City of Ames RRP.

3.2.5 Boiler Design

The boiler design would depend on the type of RDF combustion system, but we believe the best combustor design for 4" RDF to be the bubbling fluidized bed combustion system. With a bubbling fluidized bed system, separate boiler modules can be used for the convection and economizer sections. **Figure 10** below shows the typical boiler arrangement for a bubbling fluidized bed combustion system.

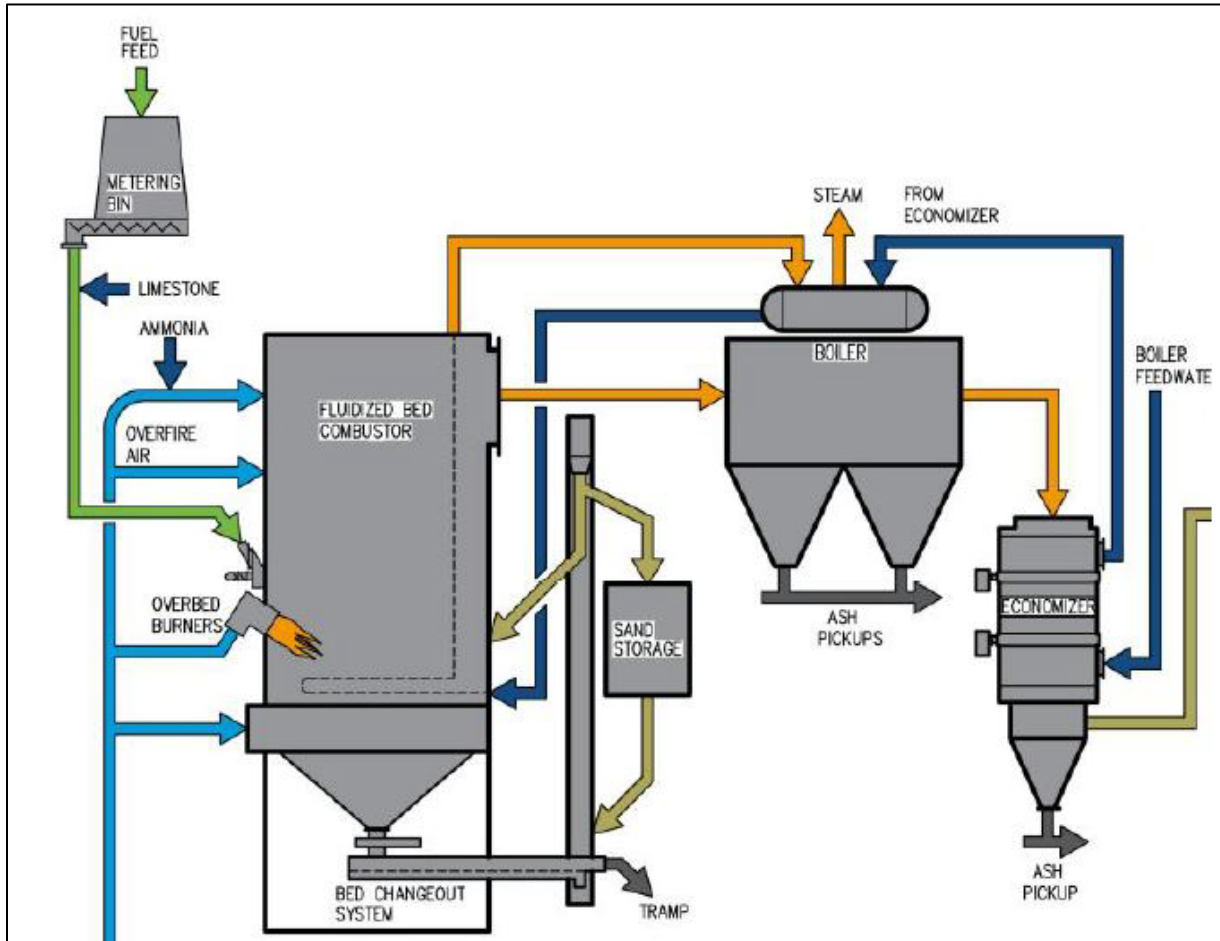


Figure 10: Typical Bubbling Fluidized Bed Combustor Boiler

The detailed design of the boiler will consider the high fouling and corrosion potential of the RDF feedstock, driven by the high chlorine content of MSW and RDF. Management of boiler fouling and corrosion has always been a significant challenge in the waste-to-energy industry and boiler design features, along with operation and maintenance approaches, have been developed to control fouling and minimize corrosion to ensure reliable operation. Flue gas and steam conditions will be set to control maximum boiler tube wall temperatures in the steam superheat section where the highest corrosion potential exists. Boiler tube arrangements and spacing will be designed to minimize fouling and allow for effective on-line cleaning. Protective alloys will also be used in select areas to prevent high corrosion rates.

More details on boiler designs are provided in **Appendix H**.

3.2.6 Power Plant System Summary

A new RDF-only boiler would be installed in the building space where Unit 5 and 6 boilers and associated coal bunkers are located. To account for growth the boiler's continuous design capacity would be at least 125 tons/day. The boiler would receive RDF from the existing 8" feed lines from the existing storage bin. The boiler would be designed to produce 600 psig, 750F steam. The existing steam turbine 5 (ST5) would be refurbished to use this steam. A new condenser would be installed at the lower level, if the existing condenser is not reusable, to condense the turbine exhaust steam. The new condenser would be equipped to handle the duty of the turbine in bypass mode, a feature not available on the current condenser. This allows the boiler to continue operating should the steam turbine be off-line for planned or unplanned events. The ST8 condenser would remain as-is since Unit 8 is for backup operation only. It has been confirmed by the vendor that the cooling tower serving Unit 7 can be upgraded to accommodate the incremental heat



rejection of ST5. Other select equipment from old boiler 5 may be reusable depending on its condition (e. g. surface condenser, boiler feed-pumps) subject to inspection. The steam turbine generator would be rewound, and the existing electric interconnection infrastructure utilized. New electric distribution power and motor control centers would be provided to serve the Unit 9 equipment. Various systems (e.g., compressed air) would be integrated with the existing system for redundancy. The Ovation control system would also be expanded to include the operation of Unit 9 in the existing control room.

New equipment would include a dry scrubber and baghouse. NOx emission would be controlled using ammonia injection into a Selective Non-Catalytic Reducer (SNCR). These systems are described in further detail later in this report.

Units 7 and 8 would continue to operate as capacity resources burning natural gas only. Unit 8, since it is the larger of the two, would co-fire RDF with natural gas as a backup when Unit 9 is unavailable. Unit 7 could also be a second backup for RDF co-firing.

Fly ash collected from the baghouse and boiler will be conveyed via screw conveyors to a fly ash storage silo. A new dedicated Continuous Emissions Monitoring System (CEMS) would be provided in the stack to monitor pollutants exiting the stack and COMS for opacity.

3.2.7 Balance of Power Plant Equipment

All of the existing equipment currently used to support the operation of Units 7 and 8 would be maintained.

For the new Unit 9, the following is a list of balance of plant (BOP) equipment anticipated:

- New boiler feed pumps, condensate pumps and cooling water pumps
- Modification and/or refurbishment of the existing ST5, and associated steam turbine condenser for re-use
- New steam, condensate, cooling water and makeup water piping
- New stack, CEMS, and COMS
- New generator step-up (GSU) transformer and associated high voltage electrical support and interconnect equipment
- New step-down transformer and power distribution system
- ST5 condenser would reject heat to the existing cooling tower serving Unit 7 which can be upgraded to handle both Unit 7 and Unit 9 heat rejection at a fraction of the cost of a new cooling tower.
- New instrumentation and controls
- New foundations
- Platforms, ladders, stairs and railings to enable maintenance and operation

The following existing plant systems would be extended for Unit 9 and augmented as necessary:

- Natural gas supply (for startup and shutdown)
- RDF pneumatic feedlines from the existing 4 supply lines to Unit 9
- Compressed air



- Un-interrupted power system (UPS)
- Distributed control system
- Fire protection system

3.2.8 Emission Control

The EPA has defined the Best Available Control Technology (BACT) for waste combustion systems to be the combination of a dry scrubber and baghouse that treats the flue gas exiting the boiler. These systems are proven to meet the EPA limits on particulates, SO₂, HCl, mercury, trace metals and dioxins, and would be the recommended emission control system following a bubbling fluidized bed combustor for RDF. The scrubber / baghouse is typically augmented with the injection of powder activated carbon (PAC) into the flue gas at the entrance of the scrubber for additional control of both mercury and dioxins. CO and NO_x are combustion-related emissions that are controlled by combustion control methods. Additional NO_x control is typically achieved by Selective Non-Catalytic Reduction (SNCR) which injects aqueous ammonia or urea into the upper furnace of the combustor. The scrubber / baghouse, PAC injection and SNCR systems are described in more detail in *Appendix I*.

3.2.9 Ash Handling/Disposal

Fly ash collected from the baghouse and boiler will be conveyed via screw conveyors to a fly ash storage silo. The fly ash will then be conditioned with water to control dusting before being combined with the bottom ash exiting the combustor. This combining of the fly ash and bottom ash typically occurs on a pan or belt conveyor to form the combined ash that is then conveyed to an ash storage area. The combined ash will then be loaded into trucks for transport and disposal in a landfill.

The combined ash will contain heavy metals of environmental concern, requiring regular sampling and testing to ensure it is below the EPA toxicity limits as determined by the Toxicity Characteristic Leaching Procedure (TCLP). More detailed discussion on ash sampling and testing will be provided in **Section 5 – Environmental Impacts**. Note that the RDF will contain heavy metals that were present in the MSW in trace, parts per million levels. These heavy metals are not recovered in the RRP, which only recovers ferrous and non-ferrous metals for recycling.

3.2.10 Electric Energy Sales

Electricity sales would continue as they are conducted today, however the supply of power from the PP to the City would be approximately 1/10th of the current electricity production. The reduced power is a result of eliminating the co-firing with natural gas in the new primary Unit 9 as the lead boiler. In the financial model, the difference between the electricity generated by co-firing natural gas in Option 1 and electricity generated in Option 2A would be purchased on the day ahead wholesale market at the hourly MISO price (i.e., the Location Marginal Price, LMP) for the Ames interconnect node. In 2021, the on-peak and off-peak average LMP for Ames was \$30/MWh and \$17/MWh respectively. This is significantly less than the power plant's variable costs to make electricity with natural gas. Assuming a 95% transportation contract utilization rate, the average "all-in" (commodity plus transportation) gas price to the power plant would be \$3.48/dth based on Ames 2021 contract prices. The gross heat rates of Unit 7 and 8 when co-firing with natural gas are historically 11,552 and 11,161 BTU/kWh respectively as measured by the power plant. Therefore, the average electric production cost using Unit 8's latest heat rate is \$38.84/MWh ($(\$3.48/\text{dth}) * (11,161 \text{ BTU}/\text{kWh}) / (1000)$), excluding other variable costs (e.g., consumables) and fixed costs. Therefore, significant cost savings could be realized when natural gas consumption is eliminated.

The cost of natural gas for consumption in Unit 8 as a backup boiler in Option 2A is reflected in the financial model. Since Unit 8 is assumed to operate no more than 10% of the year as the backup boiler, maintaining the current gas contract arrangements for Option 2A and Option 3A is uneconomical since the fixed cost of gas transportation would have to be absorbed over very few hours of gas utilization. At a 10% utilization factor, the average gas price would climb from \$3.48/dth (the Option 1 average price in the model) to over \$15/dth (refer to **Figure 11**). For Option 2A and other non-base options, an assumed Citygate premium of

\$1.00/dth was used on top of the \$5.00/dth for purchasing the gas for Unit 8 as needed from the local utility. The premium and the \$/dth price are adjustable in the model.

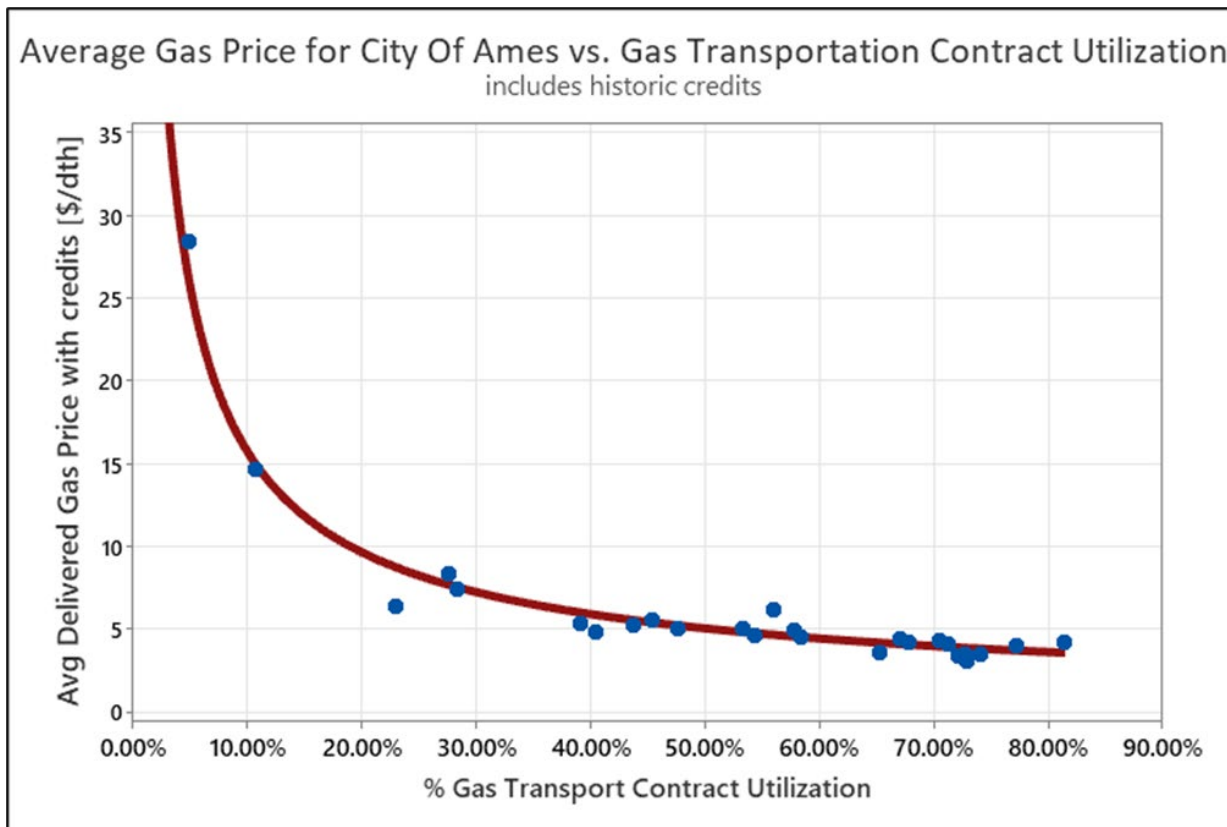


Figure 11: Avg. PP Gas Price vs. Gas Transportation Utilization (JAN2021-MAR2021)⁷

Unit 7 and 8 would be maintained by the City as capacity resources for the MISO, burning natural gas only. They would be bid into the Day Ahead (electric) Market (DAM) based on Citygate gas prices in effect at the time. It is estimated that Units 7 and 8 would be selected to operate less than 5% of the time. The associated contracts for well head gas and firm transportation should be cancelled as the capacity utilization would be very small. Natural gas would only be needed for backup Unit 8 co-firing, resulting in a very high average price for gas (See **Figure 11**). Citygate spot market gas purchases would be made as needed for startup and shutdown of all Units. Gas purchases for Units 7 and 8 as capacity resources are excluded from the Waste-to-Energy economics as there would be no more co-firing with RDF in these boilers.

3.2.11 Process Flow and Mass and Heat Balance

The Overall process flow diagram for Option 2A is shown in **Figure 12**. The data for the mass and heat balances are shown in **Appendix F**.

⁷ Includes average well-head gas commodity price of \$2.83/dth (JAN2019 – MAR2021)

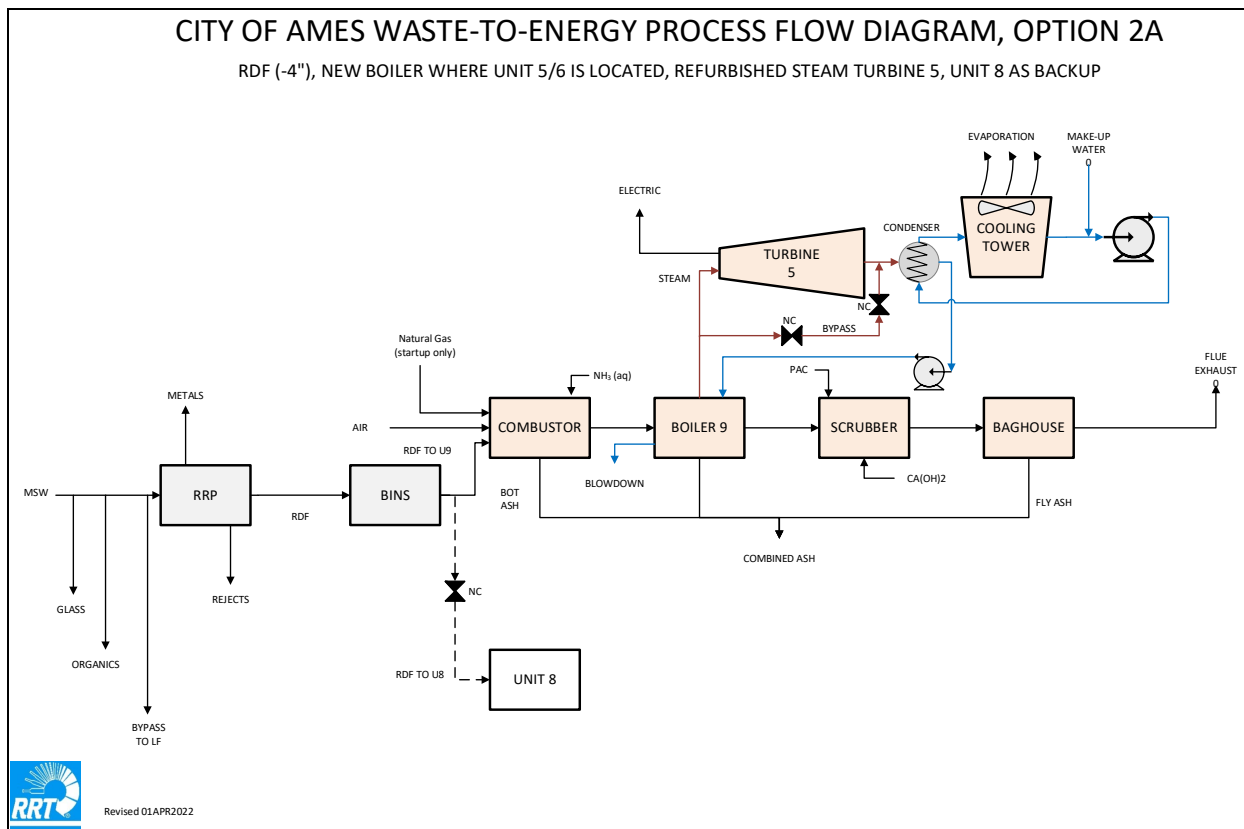


Figure 12: Option 2A Overall Process Flow Diagram

3.2.12 Building/Facility Description and Considerations

For this option, the existing RRP building would remain as is.

The existing PP building where Units 5 and 6 boilers and turbines are located would be vacated, and the space reused for the new boiler. Sufficient access would have to be made to allow for the removal of units 5 and 6 (which the City currently plans to do in 2022) and installation of unit 9 and its related new equipment. This would include removal of windows, doors and potential roof sections. A structural review would be needed to confirm the building shell is adequate for intended use. Some structural re-enforcing to comply with the latest codes is assumed.

3.2.13 Preliminary Conceptual Facility Layouts

A preliminary conceptual layout for the installation of a new dedicated RDF-only combustion boiler, scrubber and baghouse where retired Units 5 and 6 are currently installed is shown in **Figure 13**. The new equipment will also occupy the space of the coal bunkers. The City is planning to remediate and remove the coal bunkers along with Combustion Units 5 and 6 according to the current CIP Plan. ST5 will be refurbished or replaced, pending an equipment internal inspection, to confirm its condition, and the ST5 generator will be rewound. It was confirmed with the vendor that the existing cooling tower for Unit 7 can be upgraded to also reject the heat from the new or refurbished steam turbine (ST5).

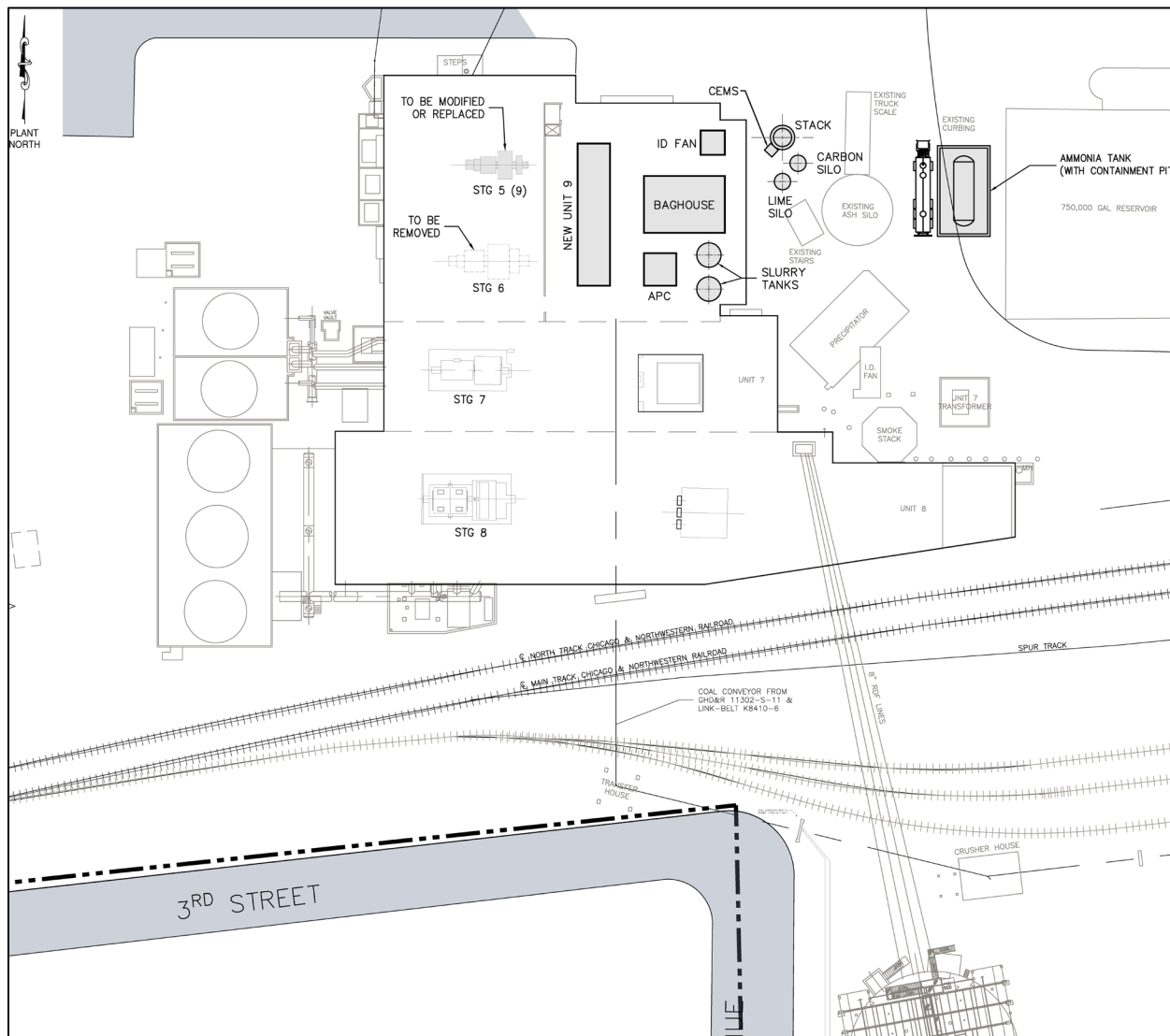


Figure 13: Option 2A Preliminary Conceptual Layout



3.3 Option 2B – Modified RRP (20” RDF) with Two New RDF Combustion Units

The following items characterize the key elements of Option 2B

- Processing MSW into a larger RDF, no greater than 20 inches in size, and reusing the existing RRP building and installing new MSW processing equipment.
- Two new, state-of-the-art RDF-only combustion boilers (Units 9 and 10) installed at the coal yard due to insufficient space in the existing power plant. Units 7 and 8 are not able to be utilized due to the larger sized RDF and thus why two new units are required for this option.
- Natural gas will be used only for startup, shutdown, and flame stability of the boilers but will not be required for normal operating mode.
- Conveyers to move the large RDF to the power plant tipping floor. RDF conveyance using the existing pneumatic system will not work for this size of material.
- New RDF storage system at the new RDF storage building located at the coal yard.
- Power would be generated from refurbished steam turbine 5 (ST5) and updated to utilize the steam from Units 9 and 10. A new electronic control system, new steam condenser and an electric generator rewind are also assumed. An internal inspection would be conducted to confirm the feasibility and cost of the steam path refurbishment and generator rewind. A cost-benefit analysis would compare the expected performance and cost of the refurbishments vs. installing a new steam turbine and generator of comparable size. Power would be delivered to the grid via the existing electrical infrastructure.
- Steam turbines 7 and 8 will not be able to accept the new RDF boiler steam conditions and will remain as capacity only resources.
- Unit 7 and 8 would be bid into the electric market based on Citygate gas prices. Gas purchases for Units 7 and 8 would be excluded from the Waste-to-Energy economics as there would be no more co-firing with RDF in these boilers.
- New Balance of Plant (BOP) equipment and systems for the power plant would be installed to support the installation and operation of the Unit 9 and 10 boilers and associated emissions control equipment in a new plant building.
- Steam from the new RDF boilers would be piped over to the existing power plant as throttle steam to generate power in ST5. Condensate would be pumped back to the boilers at the coal yard. Power would be delivered to the grid via the existing electrical infrastructure.

3.3.1 MSW Storage

The modified MSW processing equipment for Option 2B will be installed in the existing RRP building. The front-end storage capabilities at the RRP are not expected to change from the base case Option 1 and Option 2A. The 2-day storage capacity available on the existing RRP tipping floor is expected to be sufficient for dealing with downtimes and maintenance issues in the facility.

3.3.2 Modified Resource Recovery Plant (RRP)

The new RRP will be designed to process an average of 25 TPH. The system will be able to recover 80% or more of RDF in the form of 8” to 20” minus material, while recovering ferrous and non-ferrous metals and separating the rejects. New equipment as depicted in **Figure 14** below will be installed in the existing RRP building.

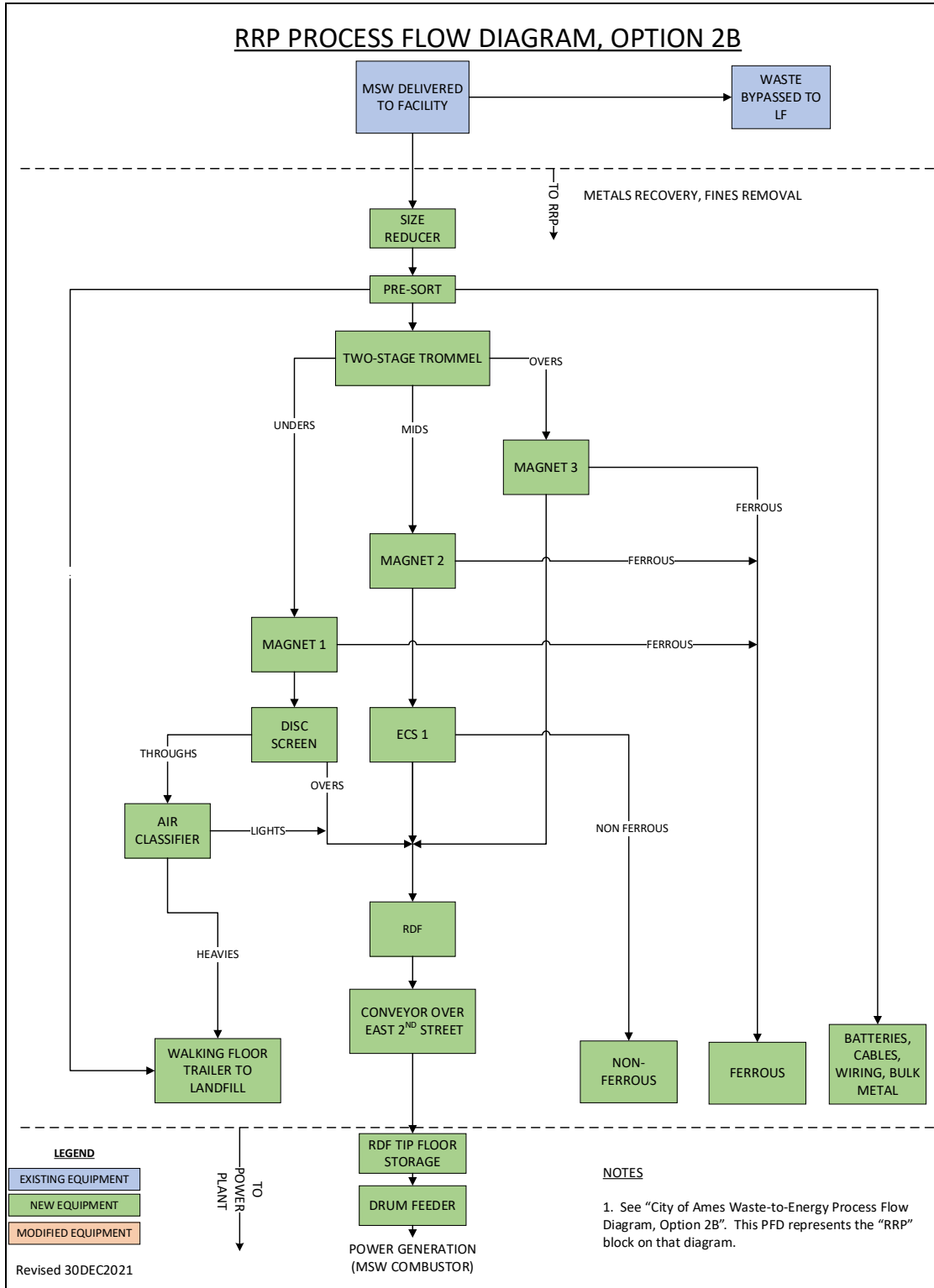


Figure 14: Option 2B RRP Process Flow Diagram

Reusing the existing building would result in large capital savings, however this approach would also negatively impact the ability to continue to run the existing facility while the construction work is going on.



For this study, it was assumed that the existing building would be re-used and therefore the City will have to plan for interim operations and divert the MSW during the modifications to the RRP for this option.

The incoming MSW is sorted on the RRP tipping floor to remove large un-processible and bulky items, such as mattresses, furniture, propane tanks, etc. Materials unloaded on the floor will be visually inspected and moved with a front-end loader toward the infeed conveyor area for processing or to the bypass area for landfilling if the material contains non-processible materials.

The MSW suitable for processing is loaded by the loader into the elevated hopper of an infeed conveyor. This process requires the operator to fill the infeed hopper to an even level along its length to keep the system running at a uniform rate. The infeed conveyor is equipped with a variable frequency drive (VFD) to regulate the conveyor speed and maintain constant and even flow of material onto the size reducer. The role of the new size reducer is to liberate the material, reduce it to a particle size of 20" minus and protect the downstream equipment from large bulky objects.

This 20" minus material will be conveyed to a pre-sort station where sorters will manually remove bulk metals such as cables, wiring, pots and pans, batteries, and pipes and drop them through a set of chutes. Another set of drop chutes will be designated for removal of non-processible materials that were missed during the feeding process, such as carpets, textiles, wood, etc. These items must be removed to prevent system jams and potential damage to downstream process equipment. These non-processible bulky objects picked off manually from the pre-sort conveyor will be deposited into bunkers beneath the sort platform to be later landfilled or salvaged (as applicable).

The MSW after having been sorted to remove the various undesirables will continue to the rotary trommel for mechanical separation into three different fractions by size. The trommel is a rotary screen containing heavy duty screens with two screening sections and different opening sizes. Although not necessary, the trommel can include sharp metal spikes mounted within the first part to open bags and liberate materials for more efficient separation.

The first section of the trommel will remove the "fines" fraction consisting of organics, broken glass, small paper items, food waste, stones, paper clips, bolts, inert material and other items that can pass through the holes. This material will drop onto a conveyor under the trommel, and a magnet will remove ferrous metals from this stream prior to being transferred to a disc screen. The disc screen removes the 1" minus material from this fraction, which continues into an air classifier, separating the light material from the heavy fraction. The heavy fraction material along with the other rejects from the plant will be shipped to landfill via transfer trailers. The light fraction from the air classifier will be combined with the overs (1" plus) from the disc screen.

The final size of the trommel screens will be designed and selected during the engineering phase. As an example, for the purpose of the mass balance, the screen sizes were assumed as described in this section. The second section of the trommel will have 7" holes to create a plus 2.5" /minus 7" fraction also called "middlings." A suspended magnet located over the head pulley of conveyor transferring middlings will remove ferrous metal containers from the feed stream. The middlings will continue onto an eddy current separator (ECS) that will remove aluminum beverage cans (UBC) and other non-ferrous material from this feedstock and discharge them into a non-ferrous bin. Ferrous metals collected from the three magnets in the plant will be combined and transferred to a ferrous bin or bunker.

The plus 7" fraction, also called "overs", coming out of the trommel, is dropped on a conveyor with a suspended electro-magnet to remove any ferrous materials from the feed. The remaining material is combined with the overs from the disc screen, the lights from the air classifier and the middlings coming out from the ECS, resulting in the recovered RDF stream, which is ready for combustion.

The RRP equipment can be supplied by a variety of manufacturers, with careful consideration of design features for this type of application and systems integration. Part of the existing equipment in the RRP, such as magnets or ECS could be reused in this option, however for the purpose of the financial model all equipment was assumed to be new. Moreover, depending on the timeline for this option implementation, a

majority of the existing equipment at the RRP will become obsolete, therefore installing new equipment will be recommended.

3.3.3 RDF Transport and Storage

The RDF from the RRP will be transported to the RDF storage area using a belt conveyor system. The conveyor will be running overhead across East 2nd Street from the existing RRP building to the new RDF storage building contiguous to the new power plant building located at the coal yard. The conveyor system will be enclosed in a tube gallery, similar to **Figure 15**, to avoid spillages and other environmental issues and will include a walkway platform for access and maintenance.



Figure 15: Conveyor Transport System with Tubular Gallery

Sufficient space will be provided in a new storage building on the coal yard for storing approximately 400 tons of the large RDF, which is approximately 3 days of storage with no combustion. A front-end loader will be used to move and stack the material on the floor as well as feed an infeed conveyor system with a drum feeder which will meter the RDF to the boilers.

Given the RDF will be stored on a new storage floor contiguous to the new power plant the existing RDF storage bin can be decommissioned or repurposed. The cost of demolition or any repairs and upgrades associated with the existing bin were not included in the financial model.

3.3.4 Large RDF Combustion System

20" minus RDF is too large and heterogenous of a material to be combusted in suspension-fired or bubbling bed combustors that can be used for the finer RDF in Options 2A and 3A. To combust the large 20" minus RDF, a mass-burn grate system designed for unprocessed MSW would have to be used.

Inclined reciprocating grate systems are by far the most common combustion system used throughout the world for the combustion of municipal solid waste. These systems are offered by a number of proven

suppliers. Inclined reciprocating grates are designed to combust unprocessed MSW and would be well suited for the combustion of the large 20” minus RDF.

One of the world’s most established suppliers of mass-burn combustion systems is Martin GmbH of Germany, who have supplied nearly 1000 units in over 500 plants around the world since 1960. The Martin system employs an inclined, reverse-acting, reciprocating grate where the grate bars move counter to the downward movement of the waste by gravity, providing enhanced stoking of the burning bed of waste. **Figure 16** provides a schematic of the Martin system showing the major components.

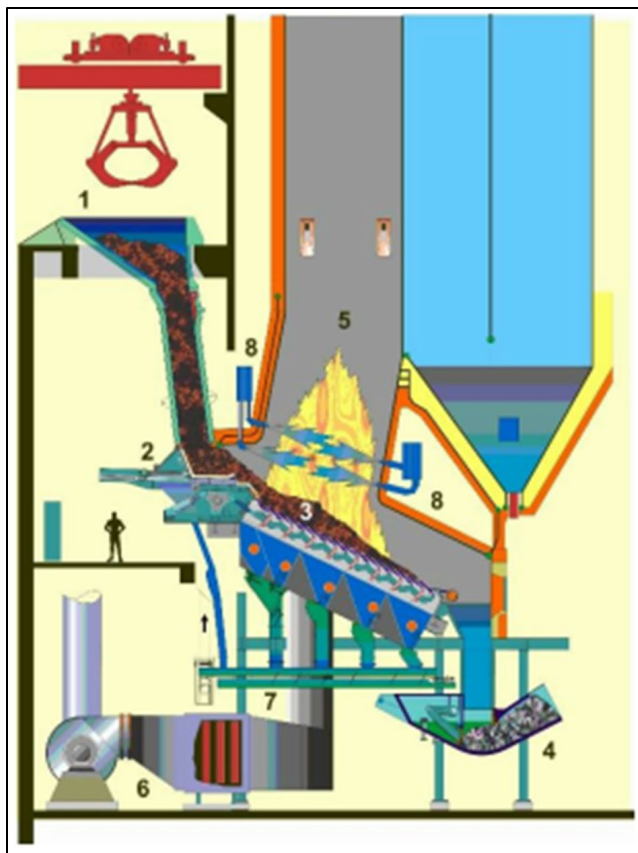


Figure Legend	
1	Feed Hopper
2	Hydraulic Ram Feeder
3	Inclined Combustion Grate
4	Bottom Ash Discharger
5	Furnace
6	Primary Combustion Air Supply
7	Ash Siftings Collection
8	Secondary Combustion Air

Figure 16: Martin Mass-Burn Combustion System

As the waste moves down the grate, it first dries from radiation of the flames and primary air flowing up through the grate. Combustible material in the waste then volatilizes and combusts in the main combustion zone. Secondary air is injected through nozzles in both the front and rear walls above the grate to ensure complete combustion of the burning gases. The combustion of the waste is substantially completed in the top two thirds of the grate. In the bottom third, additional air flow through the grate ensures good burnout and cooling of the ash residue. At the end of the grate, the ash residue falls into a water filled ash discharger that quenches the ash and discharges it to a metal pan conveyor.

There are a number of other major suppliers of mass-burn combustion systems, including Hitachi Zosen INOVA, Detroit Stoker, B&W Volund and Keppel Seghers. As with Martin, these suppliers offer mass-burn combustion systems using inclined, reciprocating grates, but with forward moving grate bars. Although the equipment is somewhat different between the suppliers, the processes are essentially the same for the combustion of MSW or RDF.

Another lesser-known European supplier of mass-burn combustion systems is Ruths S.p.A. of Genova, Italy. They offer both inclined and horizontal reciprocating grates for the combustion of MSW, which could

also be used for the combustion of large 20" minus RDF. **Figure 17** below shows a general arrangement drawing of their inclined grate system. They are a proven supplier specializing in smaller capacity units with reference plants throughout Europe and parts of Asia. The option of a horizontal grate system would reduce construction costs and further lower the elevation of the feed chute for a conveyor feed system when compared to the inclined, reciprocating grate systems.

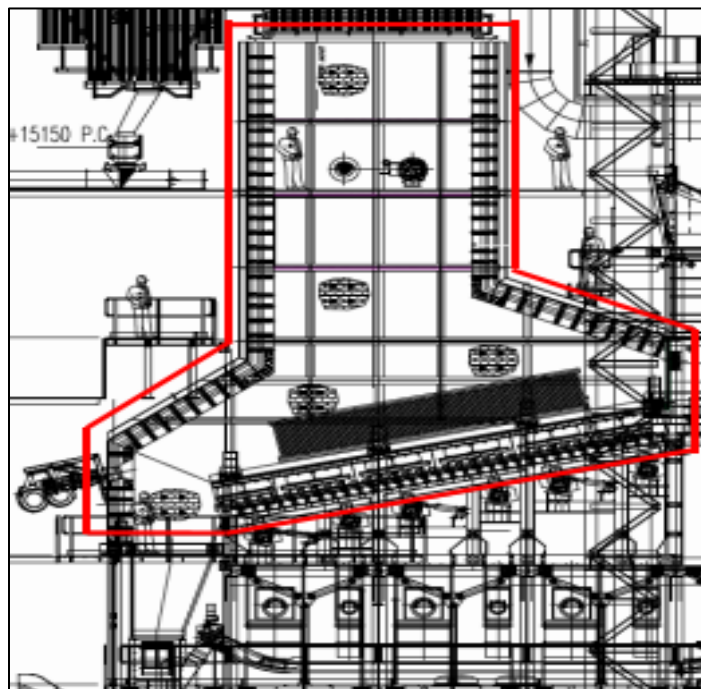


Figure 17: Ruths Inclined Reciprocation Grate Combustor

3.3.5 Boiler Design

Mass-burn, inclined reciprocating grate combustors typically use a boiler design with multiple vertical radiant waterwall passes, followed by a horizontal convection section for steam superheat and additional steam generation. The flue gas would then go to an economizer section before exiting the boiler. This boiler design is typically field-fabricated for larger mass-burn units. More details on these boiler designs are provided in **Appendix H**.

Some suppliers, such as Ruths, which specializes in smaller mass-burn units, offer a modular design approach to maximize shop fabrication and reduce field construction costs and time. **Figure 18** below shows a schematic of their boiler design where the evaporator bundles (blue), superheater bundles (red), and economizer bundles (green) would all be shop-fabricated and delivered to the field for placement. This design and construction approach would reduce capital costs for the smaller unit sizes being evaluated for the City of Ames.

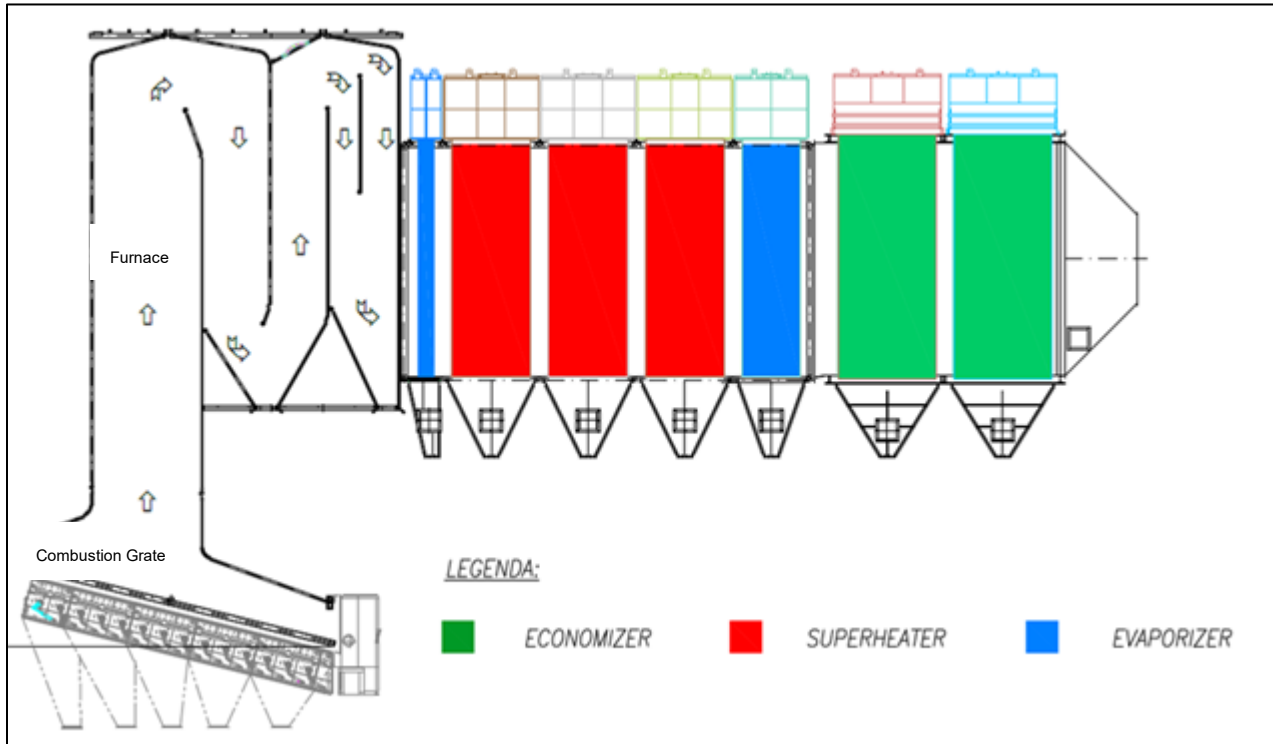


Figure 18: Ruths Modular Boiler Design

As with Option 2A, the detailed design of the boiler will consider the high fouling due to ash and corrosion driven by the high chlorine content of MSW and RDF. Management of boiler fouling and corrosion has always been a significant challenge in the waste-to-energy industry and boiler design features along with operation and maintenance approaches have been developed to control fouling and minimize corrosion to ensure reliable operation. Flue gas and steam conditions will be set to control maximum boiler tube wall temperatures in the steam superheat section where the highest corrosion potential exists. Boiler tube arrangements and spacing will be designed to minimize fouling and allow for effective on-line cleaning. Protective alloys will also be used in select areas to prevent high corrosion rates.

3.3.6 Balance of Plant Equipment

The new boiler plant will require new auxiliary systems including:

- New building, associated services (civil works, foundations plumbing, HVAC, locker room, control room. parking),
- Utilities (water, sewer, natural gas, electric)
- Fire protection
- Distributed control system, instrumentation, controls
- Compressed air system
- Auxiliary cooling system for boiler feed pumps, air compressors, grates, if required)
- New stacks, CEMS, and COMS



- 4160 V power distribution
- 480 V power distribution
- Ash collection and handling system
- Uninterrupted Power System (batteries and backup generator connection at existing plant)
- Platforms, ladders and railings
- Plant lighting and security systems, including fencing
- Boiler feed system
- Calcium Hydroxide ($\text{Ca}(\text{OH})_2$) storage and injection system

In addition, all of the upgrades to the existing power plant described in 2A would be provided to support the conversion of steam to electricity. These would include:

- Cooling water system (piping, circulating pumps and cooling tower No.7 expansion)
- Condensate forwarding pumps
- ST insulation
- Certain 4160 V and 480 V electric supplies
- Generator Step-Up (GSU) transformer, breaker, and relays

3.3.7 Emission Control

As with Option 2A for RDF, the Best Available Control Technology (BACT) for mass-burn combustion systems would be the combination of a dry scrubber and baghouse that treats the flue gas exiting the boiler. This system is proven to meet the EPA limits on particulates, SO_2 , HCl, mercury, trace metals and dioxins. The scrubber / baghouse is typically augmented with the injection of powder activated carbon (PAC) into the flue gas at the entrance of the scrubber for additional control of both mercury and dioxins. CO and NO_x are combustion-related emissions that are controlled by combustion control methods. Additional NO_x control is typically achieved by Selective Non-Catalytic Reduction (SNCR) which injects aqueous ammonia or urea into the upper furnace of the combustor. The scrubber / baghouse, PAC injection and SNCR systems are described in more detail in **Appendix I**.

3.3.8 Ash Handling/Disposal

Fly ash collected from the baghouse and boiler will be conveyed via screw conveyors to a fly ash storage silo. The fly ash will then be conditioned with water to control dusting before being combined with the bottom ash that is removed from the combustor by the ash discharger. This combining of the fly ash and bottom ash typically occurs on a pan or belt conveyor to form the combined ash that is then conveyed to an ash storage area. The combined ash will then be loaded into trucks for transport and disposal in a landfill.

The combined ash will require regular sampling and testing to ensure it is below the EPA toxicity limits as determined by the Toxicity Characteristic Leaching Procedure (TCLP). More detailed discussion on ash sampling and testing will be provided in **Section 5 – Environmental Impacts**. Note that the RDF will contain heavy metals that were present in the MSW in trace parts per million levels. These heavy metals are not recovered in the RRP, which only recovers ferrous and non-ferrous metals for recycling.



3.3.9 Electric Energy Sales

The electric energy sales, for Option 2B, would be the same as Option 2A, but is repeated here for thoroughness.

Electricity generated by refurbished ST5 will be first used to power the existing plant parasitic loads and the new RRP. The remainder of the power will be delivered to the City grid via the existing high voltage electric infrastructure.

Electricity sales would continue as they are conducted today, however the supply of power from the PP to the City would be approximately 1/10th of the current electricity production. The reduced production of power is a result of elimination of the co-firing with natural gas. For the financial model, the difference between the electricity generated by co-firing natural gas in Option 1 and electricity generated in Option 2A would be purchased on the day-ahead MISO Zone 3 LMP price at the Ames interconnect node.

Units 7 and 8 would be maintained by the City as capacity resources, burning natural gas only. The generation would be bid into the Day Ahead (electric) Market (DAM) based on market Citygate gas prices in effect at the time. It is estimated that Units 7 and 8 would be selected to operate less than 5% of the time because of their efficiency and cost of natural gas fuel. The associated contracts for well head gas and firm transportation are expected to be cancelled since the capacity utilization would be very small (as gas would only be needed for startups and shutdowns in Units 9 and 10 and for very limited operation in Units 7 and 8). This low utilization would result in a very high average price for gas (see **Figure 11**). Citygate spot market gas purchases would be made as needed, for startup and shutdown of Units 9 and 10.

3.3.10 Process Flow and Mass and Heat Balance

Figure 19 shows the overall process diagram for Option 2B. The supporting mass and heat balance data is shown in **Appendix F**.

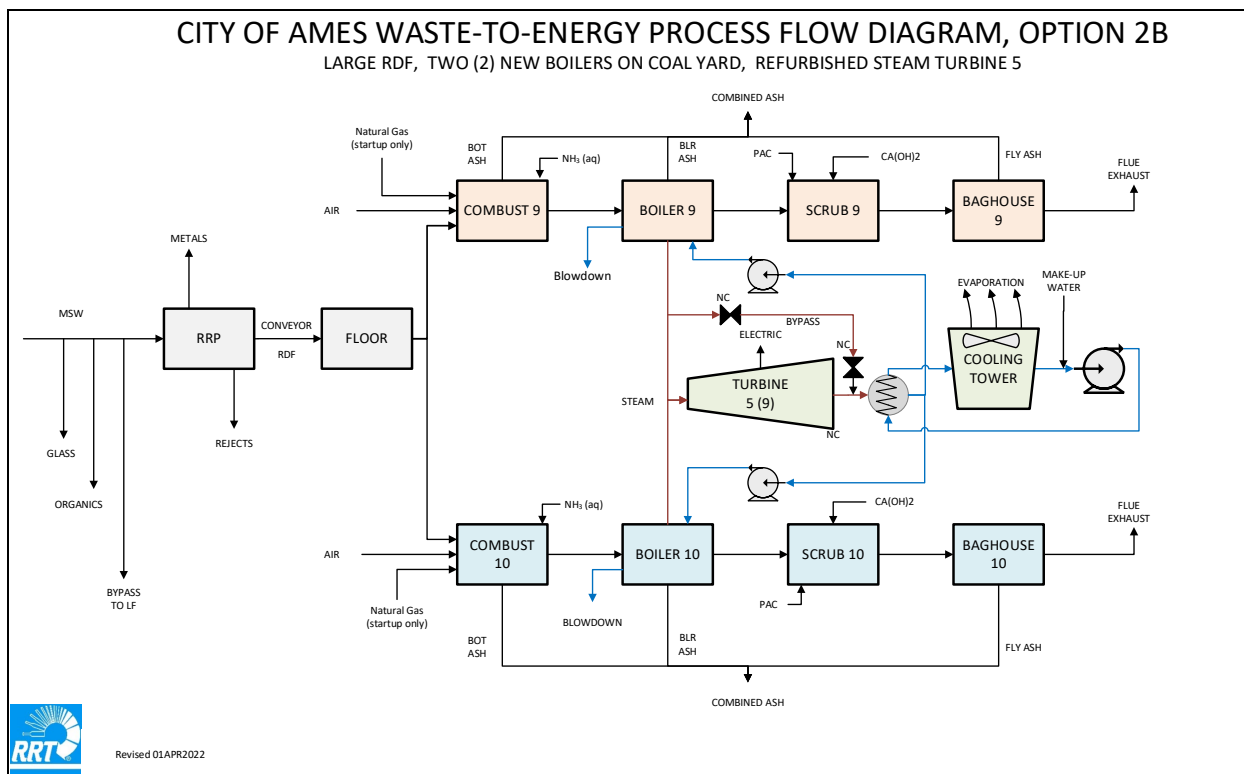


Figure 19: Option 2B Overall Process Diagram

3.3.11 Building/Facility Description and Considerations

For Option 2B the existing RRP would be modified to a single shred system and continue to provide metal removal. Processed (large) RDF will be conveyed via conveyor (see **Figure 20**) to a new RDF storage building located on the coal yard. The overall footprint of the RRP would not be expected to be modified for Option 2B. The conveying system would cross East 2nd Street at an elevation of approximately 14 ft. The new power plant would have a tipping floor capable of holding 4 days of storage.

A new power plant building would be adjacent to the RDF storage area and would contain loading conveyors, combustor/boilers, scrubbers and baghouses for each unit. Steam would be piped over to the steam turbine room in the existing plant on the north side of the railroad tracks. The new building would include walkways, parking, and utility interconnects (water, sewer, electric service etc.). A control room would include equipment enabling remote monitoring of the existing plant.

3.3.12 Preliminary Conceptual Facility Layout

Due to the larger size RDF, the existing boilers could not be used as backup, necessitating two new boilers. Two new appropriately-sized RDF-only boilers, together with their required emissions controls system (scrubber and baghouse) are assumed to be located in the coal yard site just north of the existing RRP. Note that the large RDF particles are too heavy to be pneumatically conveyed. A conveyor tube system would be used to move the RDF, from the existing RRP over 2nd Street to the new storage building. In the storage building front loaders would push the RDF into hoppers feeding inclined conveyors up to the boiler feed hopper. The steam turbine generator and electrical interconnecting infrastructure at the existing power plant can be utilized by piping the steam created by Units 9 and 10 to refurbished ST5 and pumping the condensate back to the new boilers. Units 7 and 8 remain as capacity units and would no longer consume

RDF. See **Figure 20**, below. This layout makes use of the existing RRP. A new RRP could also be placed adjacent to the PP for additional capital cost.

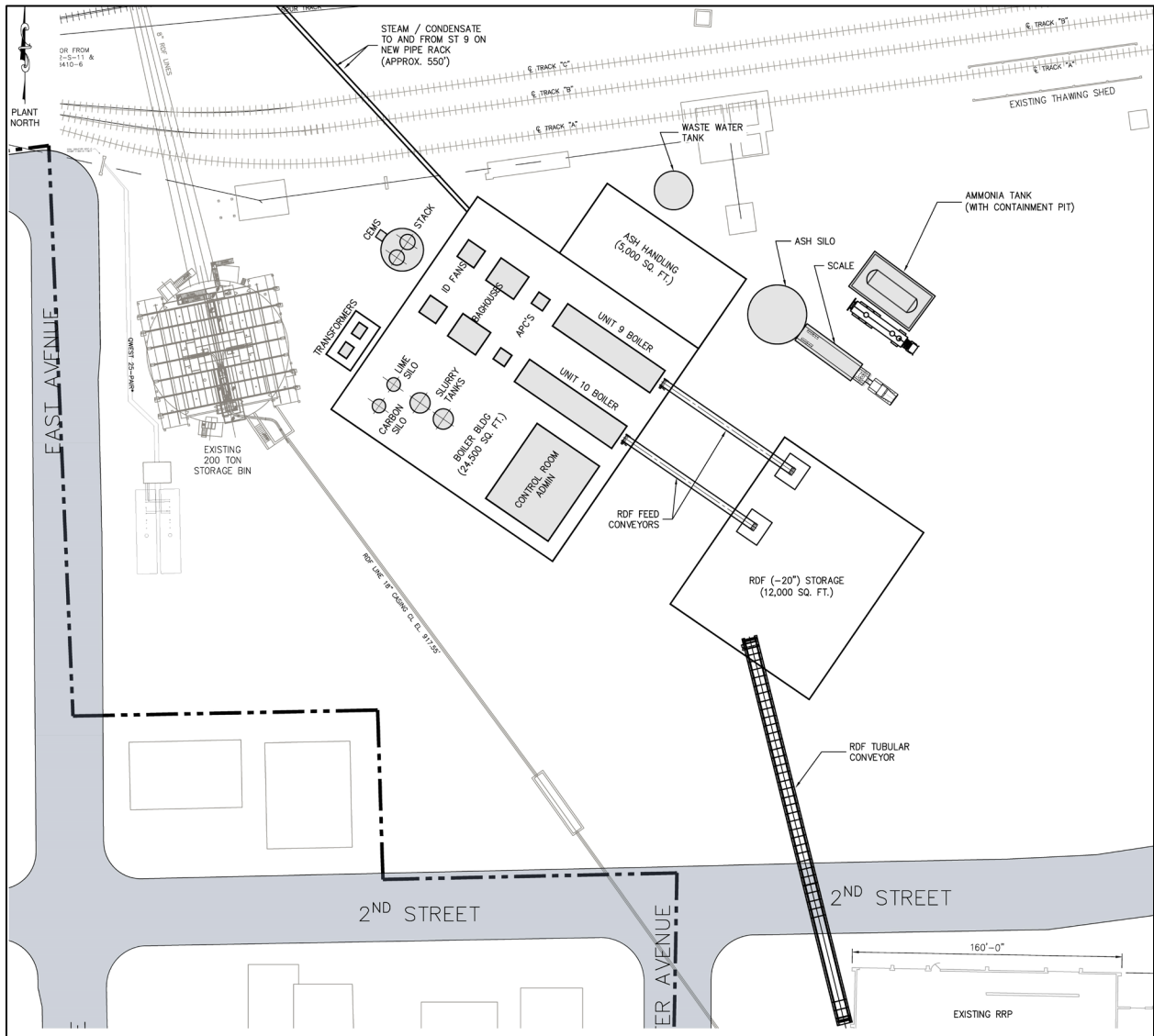


Figure 20: Option 2B Preliminary Conceptual Layout



3.4 Options 3A-1 & 3A-2 - New RRP and New RDF Combustion Unit(s)

Option 3A-1 – New RRP and New RDF Combustion Unit (Coal Yard)

The following items characterize the key elements of Option 3A-1 for a new S-O-A RRP and RDF boiler constructed at the coal yard location.

A new S-O-A RRP plant would be designed to provide improved sorting, extraction and processing to produce 4 inch minus RDF (same as is currently produced). Using newer, improved methods and technology based on the waste composition study last conducted by the City in 2016, the RRP processing rate would increase from a historic maximum of 65% to an approximately 81% recovery rate for RDF produced from the incoming waste stream. Major features would include the following:

- More front-end storage of MSW at the inlet to the new RRP receiving floor (for when RRP is out of service).
- One new, state-of-the-art RDF-only combustion boiler (Unit 9) would be installed in the coal yard. Natural gas will be used only for startup, shutdowns, and flame stability of Unit 9.
- As a backup, maintain and operate Unit 8 as currently designed (co-fired with natural gas) when Unit 9 is unavailable. While Unit 7 could also be used as a backup, Unit 7 is smaller than Unit 8 and therefore would not be able to handle as much RDF.
- A new RDF pneumatic conveyor transport system from the new S-O-A RRP to a new 200 tons storage bin at the coal yard. A new pneumatic conveyance would also be installed from the S-O-A RRP to the existing 200 ton storage bin. Once the new S-O-A RRP and conveyance systems are operational, the existing storage bins would be refurbished to enable a parallel system from the S-O-A RRP to Unit 9, providing a total of approximately 400 tons of total storage.
- Power would be generated from refurbished steam turbine 5 (ST5) and updated to utilize the steam from Unit 9. A new electronic control system, new steam condenser and an electric generator rewind are also assumed. An internal inspection would be conducted to confirm the feasibility and cost of the steam path refurbishment and generator rewind. A cost-benefit analysis would compare the expected performance and cost of the refurbishments vs. installing a new steam turbine and generator of comparable size. Power would be delivered to the grid via the existing electrical infrastructure.
- Steam turbines 7 and 8 will not be able to accept the new RDF boiler steam conditions and will remain as capacity only resources.

Option 3A-2 – New RRP and Two New RDF Combustion Units (Greenfield Site)

Option 3A-2 is assumed to be constructed on a new industrial site that is not near the existing facilities. The primary reason to construct a new remote RRP and PP facility would be the economics of selling steam to a thermal host versus exporting electricity. Major features would include:

- The new S-O-A RRP, RDF storage and PP would be located on a new industrial site, totally detached from Units 7 and 8. Therefore 3A-2 would require (a) two new equally sized RDF boilers, (b) a new building, (c) utility services (water, sewer, electric) and (d) all new auxiliary services.
- The new facility would sell steam to a neighboring industrial user continuously (24 hrs./day and 7 days/week).
- The boilers should be capable of consuming a minimum of ~85 TPD each for a combined capacity of 170 TPD. The 85 TPD boilers would provide a lower installed cost without resulting in undesirable part load operation (below 70%) during parallel operation over the project life. A storage size of 400



tons would provide approximately 13 days while one unit is operating before bypassing is required (see RDF/MSW Storage Analysis in **Appendix B**). Alternatively, two 100% capacity boilers (145 TPD) could be installed to provide complete redundancy. The cost premium for the installation of the larger boilers would be partially offset by less storage. Sizing in between 85-145 TPD would result in years of undesirable part load operation during which the boilers would operate in parallel. The lower cost configuration is included in the financial model for the purposes of this evaluation.

- The pneumatic conveyor transport system would be all new from the S-O-A RPP to two new storage bins, and then also from the bins to the new PP.
- Units 7 and 8 would be maintained by the City as capacity resources when burning natural gas only.
- For Option 3A-2, a back pressure steam turbine would be utilized to generate some in-house power prior to delivering the steam to a steam host. The steam host is assumed to return 85% of the flow as condensate.

The new RRP's MSW processing equipment for options 3A-1 and 3A-2 will be installed in the new building. The design for both options will include a tipping floor which can accommodate approximately 400 tons of MSW in case of downtime. Three to four days of storage is an industry standard for MSW facilities. Storing MSW for longer periods could cause issues with potential generation of methane gas, spontaneous combustion through the reactions of various chemical compounds in waste, and bacteria and other sanitary hazards from the decomposition of waste. Moreover, the City's experience in the existing RRP plant and RRT's understanding of issues in other facilities show that spontaneous combustion can occur in piled MSW due to batteries and other ignition sources and therefore, proper fire detection and suppression systems would be in place.

3.4.1 New State-of-the-Art Resource Recovery Plant

The new S-O-A RRP will be designed to process an average of 25 TPH. The system will be able to recover approximately 81% of RDF while recovering ferrous and non-ferrous metals and separating the rejects. A Process Flow Diagram (PFD) for the State-of-the-Art RRP is depicted in **Figure 21**.

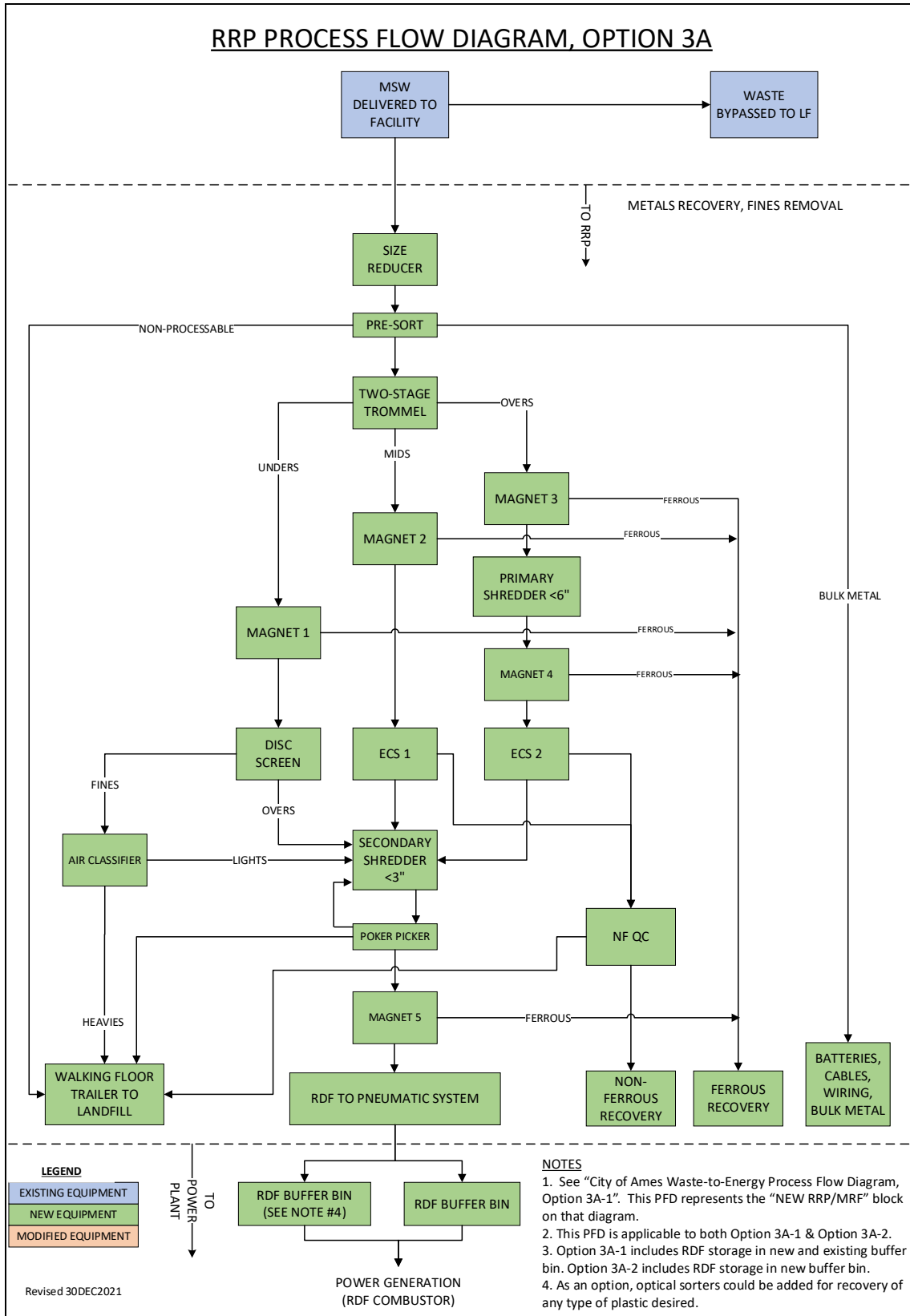


Figure 21: Process Flow Diagram for State-of-the-Art RRP



The incoming MSW is sorted on the tipping floor to remove large un-processible and bulky items, such as mattresses, propane tanks, etc. Materials unloaded on the floor will be visually inspected and moved with a front-end loader toward the infeed conveyor area for processing or to the bypass area for land filling if the material contains non-processible materials.

The MSW suitable for processing is loaded by the loader into the elevated hopper of an infeed conveyor. This process requires the operator to fill the infeed hopper to an even level along its length to keep the system running at a uniform rate. The infeed conveyor is equipped with a variable frequency drive (VFD) to regulate the conveyor speed and maintain constant and even flow of material onto the size reducer. The role of the size reducer is to liberate the material, reduce it to a particle size of 8" minus, and protect the downstream equipment from large bulky objects.

The reduced size material will be conveyed to a pre-sort station where sorters will remove bulk metals such as cables, wiring, pots and pans, batteries, small appliances and pipes and drop them through a set of chutes. Another set of drop chutes will be designated for removal of non-processible materials that were missed during the feeding process, such as carpets, textiles, wood, etc. These items must be removed to prevent system jams and potential damage to downstream process equipment. These non-processible bulky objects picked off the pre-sort conveyor will be deposited into bunkers beneath the pre-sort platform. From the bunkers materials are loaded into trailers and shipped offsite for landfilling.

The MSW after having been sorted to remove the various undesirable materials will continue to the rotary trommel for mechanical separation into three different fractions by size. The trommel is a rotary screen containing heavy duty screens with two screening sections and different opening sizes. Although not necessary, the trommel can include sharp metal spikes mounted within the first part of the trommel to open bags and liberate materials for more efficient separation.

The first section of the trommel will remove the "fines" fraction consisting of organics, broken glass, small paper items, food waste, stones, paper clips, bolts, inert material and other items that can pass through the holes. The actual screen openings size will be designed during engineering phase, however 2 1/2" diameter holes were considered in the RRT mass balance. This material will drop onto a conveyor under the trommel, and a magnet will remove ferrous metals from this stream prior to being transferred to a disc screen. The disc screen removes the minus 1" material from this fraction. This material along with the other fines from the plant will be shipped to landfill via walking floor trailers. The plus 1" material going over the disc screen drops into the secondary shredder.

The actual screen openings size will be designed during engineering phase; however, for the mass balance the second section of the trommel was assumed to have 7" holes to create a plus 2 1/2" to minus 7" fraction also called "middlings". A suspended magnet located over the head pulley of conveyor transferring middlings will remove ferrous metal containers from the feed stream.

The middlings will continue onto an ECS feeder which feeds an eddy current separator (ECS). The eddy current separator removes aluminum beverage cans (UBC) and other non-ferrous material from this feed and discharges it to a conveyor with a sorting area to QC the non-ferrous stream and remove any contaminants and other non-ferrous. The middlings material remaining after non-ferrous removal drops into the secondary shredder.

The plus 7" fraction, also called "overs", coming out of the trommel is dropped on a suspended electro-magnet to remove any ferrous materials from the feed. The remaining material drops into the primary shredder which reduces the size of the material to minus 6". From the primary shredder, the material is transported via a series of conveyors and will undergo further ferrous removal by a suspended head pulley magnet and non-ferrous removal by a second dedicated ECS. Ferrous metals collected from the four magnets in the plant will be combined and transferred to a ferrous bunker. Non-ferrous metals from the two eddy current separators will combine into a non-ferrous QC manual sorting line before being transferred to the non-ferrous bunker.



The remaining overs fraction will be dropped into the secondary shredder along with the remaining middlings fraction and the overs from the disc screen. The secondary shredder will reduce the particle size to minus 4" and generate the final RDF. An automatic poker picker will remove any pokers or long materials which were missed in the upstream processing. The RDF will be transferred to the RDF buffer bin using a pneumatic system via underground lines.

The S-O-A RRP overall metal recovery is approximately 7%, an increase of nearly double compared to Option 1 (the existing RRP). As an option, if the recycled plastics markets increase in value in the future, optical sorters could be added for recovery of high value plastics by specific type.

The RRP equipment can be supplied by a variety of manufacturers, with careful consideration to design features for this type of application and systems integration.

Shredders are one of the most important pieces of equipment in the new design. They are also operationally and maintenance-wise the most intensive pieces of equipment. RRT had favorable experience with manufacturers who offer reliable and robust equipment such as SSI, Lindner, Komptech, Metso USA, Vecoplan and other quality equipment providers.

Figure 22 depicts a Metso pre-shredder and **Figure 23** depicts an SSI Pri-Max shredder. A typical shredder includes rotating knives, chassis support, and the power pack. The rotating knives are usually provided with two forward and two backward cutting tips. Between each set of counter knives, a free opening in the cutting table will ensure that sand, soil, gravel, and small metal fragments fall straight through without causing wear in the cutting area. The achieved size will depend on the number of knives and the type of waste.



Figure 22: Metso USA M&J Pre-Shred 2000S



Figure 23: SSI Pri-MAX Shredder

Most shredders are equipped with electronic surveillance with alarms for shaft, conveyor, hydraulic oil (pressure, temperature, and level), oil cooler and central lubrication. In case of overload, the shafts will rotate in the opposite direction, redistribute the material, and continue the shredding. In order to protect the system against the effects of un-processible materials, the shafts will stop automatically after changing rotation 5 times, giving an alarm signal for the operator.

The primary shredder will include (2) independently operating, bi-rotational shafts to minimize bridging, jamming and wrapping. The shaft speed control is configurable through touch-screen control panel and automatic lubrication system for main shaft bearings are standard features in the industry.

The ferrous metals recovery is achieved with magnetic separators from Eriez, Steinert or equivalent and include a suspended permanent magnet, with a magnetic circuit, magnetic protection, and a self-cleaning system. Deflector plates extend past the head pulleys to help minimize ferrous material from becoming stuck to the magnet box are added features to be considered.

Non-ferrous metals could be recovered using eddy current separators from manufacturers such as Steinert, Eriez, IMRO or equivalent. A non-ferrous metal separator consists of a short conveyor driven from the feed end and a rapidly rotating system of permanent magnets (the pole system) which generates high-frequency changing magnetic fields in the head drum. These fields create strong eddy currents in the non-ferrous metal parts causing the non-ferrous metals to jump out of the remaining material flow. One of the



technologies from Steinert includes a magnetic pole system arranged eccentrically in the head pulley of non-ferrous metal separators to better concentrate the effect of the magnetic alternating fields in the area at which the material is experiencing the greatest force impact, located at the discharge point from the conveyor belt. The pole system is adjustable enabling a position to be optimally configured to the material feed.

A two-stage rotary trommel screen is included in the design for the purpose of separating out the fines and middlings material from the MSW waste stream. The recommended screen hole size will be designed during the engineering phase and will be based on overall MRF design and performance requirements. The screen sizes described in this option are based on RRT's experience. The screen sections of the trommel are made up of individual, replaceable screen panels. The trommel is supported at the inlet and outlet ends by fabricated steel base, with no other supports in-between. The rotary trommel is equipped with an inlet chute, discharge hoppers and dust hoods/cover over the trommel.

The new RRP building will include a dust collection and filtration system, consisting of pick-up hoods throughout the plant, a baghouse for air filtration with airlock and dust removal system, fans, interconnecting ductwork as well as controls, fire explosion valves and fire protection safety features.

The new RRP system will be provided with safety control systems, E-stops, fire protection system as well as modern process monitoring and controls integrated in a SCADA system.

3.4.2 RDF Transport and Storage

For Option 3A-1, the RDF processed by the S-O-A RRP will be stored in two parallel storage systems, the existing RDF bin and a new one installed in parallel, with a total nominal capacity of 400 tons. The new 200-ton storage bin will be fed in parallel from the S-O-A RRP through its own pneumatic conveyance system along with a pneumatic feed system to move RDF to either Unit 8 or 9. The existing storage system would be modified to pneumatically receive RDF from the new S-O-A RRP and new conveyance line(s) to supply RDF to Unit 9 in addition to Unit 8. The 400 tons will initially accommodate a partial power plant outage of Unit 9 for 14 days, however, should the projected MSW growth materialize, that amount of storage will only support approximately 7 days of downtime for Unit 9 (operation on Unit 8).

For Option 3A-2, two new, parallel, 200-ton capacity bins would be provided with parallel supply and feed systems to Units 9 and 10. Refer to **Appendix B** for a more detailed RDF/MSW Storage Analysis.

For both options 3A-1 and 3A-2, the new storage systems will include infeed, storage and discharge components similar to what is use today in Option 1. This includes an automatic infeed conveyor system, roof covered dual bunkers for RDF storage, distributing and stacking RDF equipment and enclosed automatic discharge conveyors for reclaiming and metering the material while providing a constant volumetric feed to the Power Plant. The system will require new controls, interlocks, and programming to be operated in conjunction with the combustion system. The new storage system will include its own dedicated automatic conveyor transport lines, one from the RRP to storage and one from storage to the power plant. For Option 3A-1, if both the new and existing RDF storage systems are down (unlikely) for repairs or maintenance, the existing RRP building could be used to provide additional storage by making the existing 14" line bi-directional for the purpose of pneumatically conveying the RDF to and from the existing bin from/to the existing RRP (bypass option). For the purpose of the financial model and comparing options 3A-1 and 3A-2 on the same basis, the storage system was assumed to be the same in both options and the bypass option was not included.

The upgrades to the existing bin can occur once the new bin is built and commissioned allowing for the RRP operations to continue without the need to divert MSW. The upgrades will include new stainless-steel walls and a roof. Of the total four existing pneumatic lines to the boiler, only two are currently being used to convey RDF from the existing bin to the PP. As part of 3A-1 upgrades, RRT recommends restoring one of the existing unused lines to improve fuel delivery reliability and redundancy to Unit 8.

As mentioned in Option 2A, there are several issues with RDF type of material, which need to be considered when designing a new transport and storage system. The RDF is not free flowing and needs to be reclaimed from storage by using an auger or a drag chain type of system. These systems are often referred to as live



bottom storage bins. Augers can have geometry issues with maximum lengths or compacting against the bin wall and wrapping. Drag chains come with other drawbacks, such as being easier to break or stretch and sometimes their flights get twisted. The cost for these different types of reclaiming systems, however, is comparable to each other.

Given RDF is highly compressible and will easily compact by its weight, a cone bottom bin is not a recommended solution, and neither are cylindrical or sphere-shaped bins as commonly seen for storing biomass or grains. The best arrangement is a rectangular base bin with trapezoidal walls or roof covered storage bunkers with bottom discharge conveyors. In addition, the RDF retains moisture and can form clumps in freezing temperatures therefore insulating the storage systems should be strongly considered to minimize these issues.

For the purposes of the financial model, an enclosed transfer conveyor system was considered for feeding the RDF to and from the new storage system for both Option 3A-1 and 3A-2. Due to the final location and site layout for Option 3A-2 not yet being selected, RRT estimated in the financial model that the S-O-A RRP, new storage bins and PP will be in relatively close proximity to each other, and steam and condensate piped 100 ft to a steam host. However, if the bins and PP cannot be adjacent to each other we are estimating an incremental cost of \$5.1M in capital cost for additional conveyance for each 1000 ft of distance between them.

3.4.3 RDF Combustion System

The RDF produced by a new RRP will be similar to the RDF currently produced by the City of Ames' existing RRP system. For this reason, the RDF Combustion Systems that would be used to process the RDF in Option 3A will be the same as Option 2A.

As with Option 2A, the bubbling fluidized bed combustion system would be the preferred technology for processing the 4" minus RDF in Option 3A. As discussed in Option 2A, a leading supplier of bubbling fluidized bed combustion systems is Metso:Outotec. The Metso:Outotec combustion system was described in **Section 3.2.4**, with further details provided in **Appendix G**.

Metso:Outotec has commercial experience processing RDF in their bubbling fluidized bed combustion systems, including French Island and the City of Tacoma in the U.S., three Italian facilities in Ravenna, Bergamo, and Massafra, and several new facilities in the UK.

3.4.4 Boiler Design

Similar to Option 2A, the boiler design for a bubbling fluidized bed combustion system would have separate modules for the convection and economizer sections. This boiler design is described in Option 2A and more details are also provided in **Appendix H**.

As with the previous options, the detailed design of the boiler will consider the high fouling due to ash and corrosion driven by the high chlorine content of MSW and RDF. Management of boiler fouling and corrosion has always been a significant challenge in the waste-to-energy industry and boiler design features along with operation and maintenance approaches have been developed to control fouling and minimize corrosion to ensure reliable operation. Flue gas and steam conditions will be set to control maximum boiler tube wall temperatures in the steam superheat section where the highest corrosion potential exists. Boiler tube arrangements and spacing will be designed to minimize fouling and allow for effective on-line cleaning. Protective alloys will also be used in select areas to prevent high corrosion rates.

3.4.5 Balance of Power Plant Equipment

For option 3A-1, the Power plant BOP equipment would be similar to option 2B.

The following is a list of power plant BOP equipment anticipated for one new combustor, Unit 9:

- New boiler feed pumps, condensate pumps and cooling water pumps
- Modification and/or refurbishment of the existing ST5, and associated steam turbine condenser for re-use



- New steam, condensate, cooling water and makeup water piping
- New stack, CEMS and COMS systems
- New generator step-up (GSU) transformer and associated high voltage electrical support and interconnect equipment
- New step-down transformer and power distribution system
- For Option 3A-1, the plant would be connected to the existing cooling tower serving Unit 7 which can be upgraded to handle both Unit 7 and refurbished ST5 heat rejection at a fraction of the cost of a new cooling tower
- For Option 3A-2, a back pressure steam turbine would be utilized to generate some in-house power prior to delivering the steam to a steam host. The steam host is assumed to return 85% of the flow as condensate.
- New instrumentation and controls
- New foundations
- Platforms, ladders, stairs, and railings to enable maintenance and operation

3.4.6 Emission Control

As with Options 2A, the Best Available Control Technology (BACT) for a bubbling fluidized bed combustion system for RDF would be the combination of a dry scrubber and baghouse that treats the flue gas exiting the boiler. This system is proven to meet the EPA limits on particulates, SO₂, HCl, mercury, trace metals and dioxins. The scrubber / baghouse is typically augmented with the injection of powder activated carbon (PAC) into the flue gas at the entrance of the scrubber for additional control of both mercury and dioxins. CO and NO_x are combustion-related emissions that are controlled by combustion control methods. Additional NO_x control is typically achieved by Selective Non-Catalytic Reduction (SNCR) which injects aqueous ammonia or urea into the upper furnace of the combustor. The scrubber/baghouse, PAC injection and SNCR systems are described in more detail in **Appendix I**.

3.4.7 Ash Handling/Disposal

Similar to Option 2A, fly ash collected from the baghouse and boiler will be conveyed via screw conveyors to a fly ash storage silo. The fly ash will then be conditioned with water to control dusting before being combined with the bottom ash exiting the combustor. This combining of the fly ash and bottom ash typically occurs on a pan or belt conveyor to form the combined ash that is then conveyed to an ash storage area. The combined ash will then be loaded into trucks for transport and disposal in a landfill.

The combined ash will contain heavy metals of environmental concern, requiring regular sampling and testing to ensure it is below the EPA toxicity limits as determined by the Toxicity Characteristic Leaching Procedure (TCLP). A more detailed discussion on ash sampling and testing is provided in **Section 5 Environmental Impacts**. Note that the RDF will contain heavy metals that were present in the MSW in trace parts per million levels. These heavy metals are not recovered in the RRP, which only recovers ferrous and non-ferrous metals for recycling.

There would be no difference in the ash handling between Options 3A-1 and 3A-2 except there would be duplicate systems for each new boiler in Option 3A-2.



3.4.8 Electric (Option 3A-1) or Thermal (Option 3A- 2) Energy Sales

For Option 3A-1 electricity sales would continue as they are conducted today, however the supply of power from the PP to the City would be approximately $1/10^{\text{th}}$ of the current electricity export. The reduced power is a result of eliminating the co-firing with natural gas in the new primary Unit 9. For the financial model, the difference between the electricity generated by co-firing natural gas in Option 1 and electricity generated in Option 3A would be purchased on the day ahead MISO Zone 3 wholesale market price. (i.e., the Location Marginal Price, LMP) for the Ames interconnect node. In 2020, the on-peak and off-peak average LMP for Ames was \$30/MWh and \$17/MWh respectively. This is significantly less than the power plant's current costs of \$57.5/MWh to make electricity with natural gas at \$5.00/dth. (See Option 2A math). Therefore, significant power supply costs savings are provided when natural gas consumption is eliminated.

In Option 3A-1, the financial model includes the cost of natural gas for co-firing in Unit 8 when it is operated as the backup boiler. Since Unit 8 is assumed to operate no more than 10% of the year as the backup boiler, maintaining the current gas transportation contract arrangements for Option 2A are uneconomical since the fixed cost of gas transportation would have to be absorbed over very few hours of gas utilization. At a 10% utilization factor, the average delivered gas price would climb from \$5.00/dth (the Option 1 average price used in the model) to over \$15/dth gas (refer back to **Figure 11**). For Option 3A, and other non-base case options, an assumed Citygate premium of \$1.00/dth over the \$5.00/dth for purchasing the gas as-needed from the local gas distribution utility. The Citygate gas premium was arrived at in consultation with the City of Ames Electric Department and is adjustable in the model.

Under Option 3A-1, Units 7 and 8 would be maintained by the City as capacity resources for the MISO when burning natural gas only. They would be bid into the Day Ahead (electric) Market (DAM) based on Citygate gas prices in effect at the time. It is estimated that Units 7 and 8 would be selected to operate less than 5% of the time. Gas purchases for Units 7 and 8 as capacity resources are excluded from the Waste-to-Energy economics as there would be no more co-firing with RDF in these boilers.

For Option 3A-2 there would be no electric sales, but rather steam would be sold to an industrial customer (host). Gas for startup, shutdown, and flame stabilization is included in the model for Units 9 and 10. All power generated by the back pressure turbine would be utilized by the MSW plant and PP. Should the host have a temporary interruption, a steam “dump” condenser would be provided with cooling tower to enable the continued operation of the RRP and power plant. Should the steam host's ability to take all of the steam all of the time be inconsistent, a condensing steam turbine with 150 psig extraction could be substituted for the back pressure steam turbine to add flexibility to generate power and/or steam. However, less steam can be sold with an extraction/condensing steam turbine since some minimal amount of steam (approximately 5-10%) must always be condensed, reducing the maximum steam sales possible. The need for this alternative equipment would be vetted with the contract negotiations with the host, including contract risk, guarantees, cost sharing etc. Additional infrastructure would also be required to export the electricity should the steam host default in the future. For the model and cost estimate, RRT assumed a back pressure steam turbine exhausting at 150 psig/535F steam conditions with all exhaust steam provided to the steam host. The steam is assumed priced at 80% of the \$/MMBtu of natural gas as a proxy for the host's avoided production cost to produce the same steam from natural gas. A standby “dump condenser” and cooling tower is also assumed for times when the steam host's process is off-line and they cannot accept the steam.

3.4.9 Process Flow and Mass and Heat Balance

Figure 24 and **Figure 25** are the overall process flow diagrams for Option 3A-1 and 3A-2 respectively. Supporting mass and heat balance data is shown in **Appendix F**.

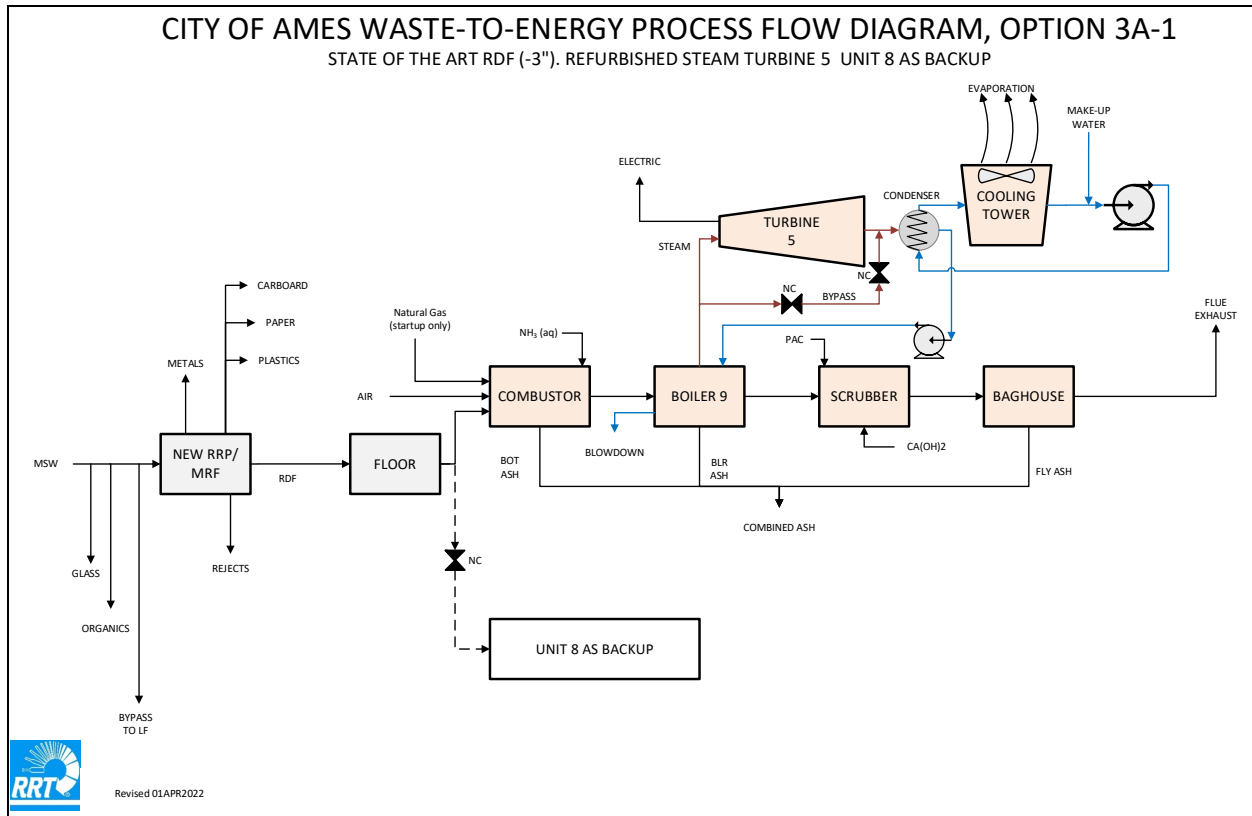


Figure 24: Option 3A-1 Overall Process Flow Diagram

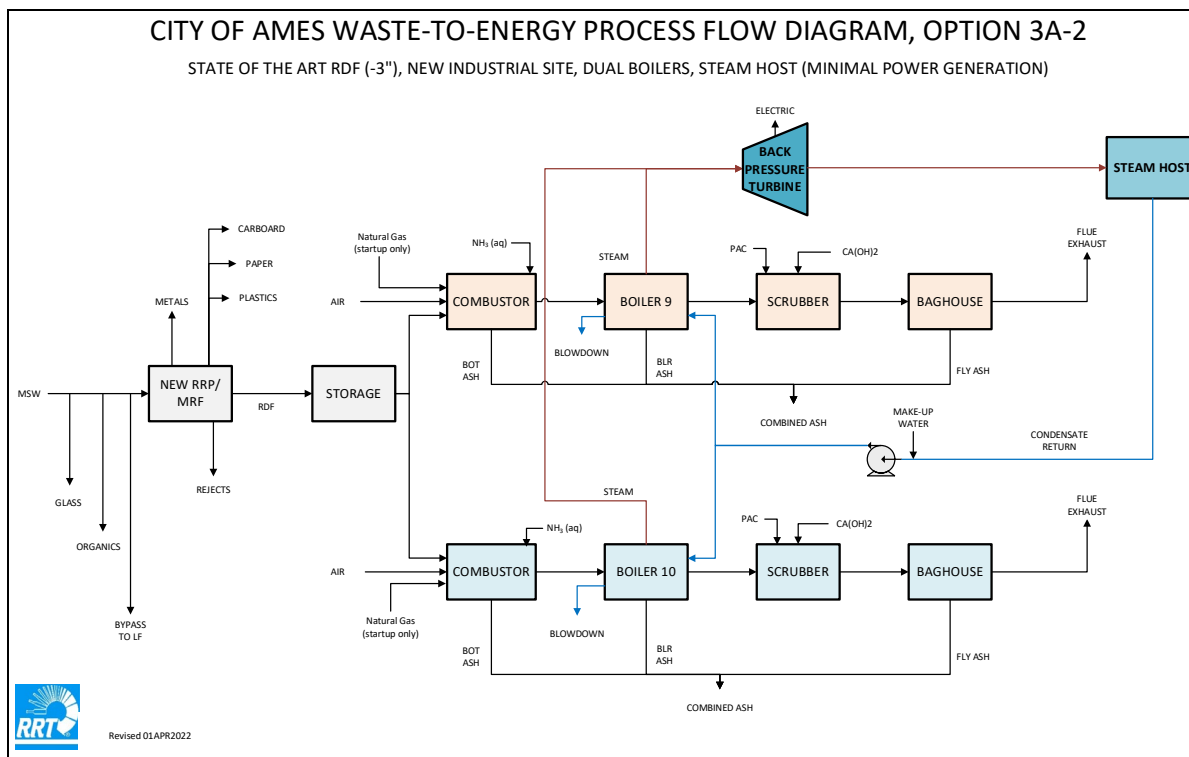


Figure 25: Option 3A-2 Overall Process Flow Diagram

3.4.10 Building/Facility Description and Considerations

For Option 3A-1 a new S-O-A RRP would be constructed in the coal yard in a new building. The existing RRP would remain operational and functional until the S-O-A RRP and associated new conveyance systems are commissioned. New parallel conveyance systems would be installed to send RDF to a new storage system (located at the coal yard) and to the existing storage bins. RDF from either storage system would be delivered to Unit 9 to be constructed at the coal yard. Once the new S-O-A RRP, a new storage system and associated conveyance systems are commissioned, the existing storage bin will be refurbished. The existing bin will be renovated to accommodate pneumatic conveyance from the S-O-A RRP. The old RRP could then be de-commissioned and re-purposed for a customer convenience center, additional recycling/recovery activities (e.g., organics), serve as supplement (bypass) storage by making the existing conveyance system bidirectional or some other beneficial use for the City.

3.4.11 Preliminary Conceptual Facility Layouts

The power plant layout for Option 3A-1 is shown below in **Figure 26 on page 66**. It includes a new dedicated RDF-only combustion-boiler, scrubber and baghouse in a stand-alone building located at the existing coal yard. The City is planning to remediate the coal yard and remove two underground oil storage tanks that are no longer used. New pneumatic conveyance lines would be installed to move the RDF from the new RRP to both storage bins, and then to the new boiler plant. The RRP will include additional storage which is shown in the preliminary conceptual layout. Parallel conveyance feeds system will be installed to provide flexibility and redundancy. The new facility will be equipped with additional equipment such as an ash silo, administrative area, control room, educational space, and a potential sustainability campus with drop-off areas for food waste, metal, glass and other desired diversion materials. The conveyance lines from the existing bin to the existing power plant would remain to enable operating Unit 8 (and possibly Unit 7) as a backup, as it is currently utilized. Steam produced would be piped over to the existing power plant on a new



pipe rack. Condensate would be returned on the same rack. Other utilities such as communications, auxiliary power, fire and potable water, demineralized water and natural gas would also be included to take advantage of the close proximity of the existing power plant and available auxiliary services that would also be needed for the new steam turbine. ST5 will be refurbished with a new steam path and valves, pending an equipment internal inspection to confirm the current condition, and the generator will be rewound. It was confirmed with the supplier of the Unit 7 cooling tower that it can be upgraded to reject the heat of condensation from the steam from the refurbished steam turbine (ST5).

For Option 3A-2, which is based on thermal sales to an industrial, a new RRP, two parallel 200-ton (each) RDF storage systems, two boilers, pollution control equipment, back pressure steam turbine, associated support equipment and the building to house everything that is required at a new greenfield site. For Option 3A-2 there would be no electric sales. Should the host have a temporary interruption, a steam “dump” condenser would be provided with cooling tower to enable the continued operation of the RRP and power plant. Should the steam host’s ability to continuously take all the steam be a concern a condensing steam turbine with 150 psig extraction could be substituted for the back pressure steam turbine to add flexibility to generate power and/or steam. However, less steam can be sold with an extraction/condensing steam turbine since some minimal amount of steam (approximately 5-10%) must always be condensed, reducing the maximum steam sales possible. The need for this alternative equipment would be vetted with the contract negotiations with the host, including contract risk, guarantees, cost sharing, etc.

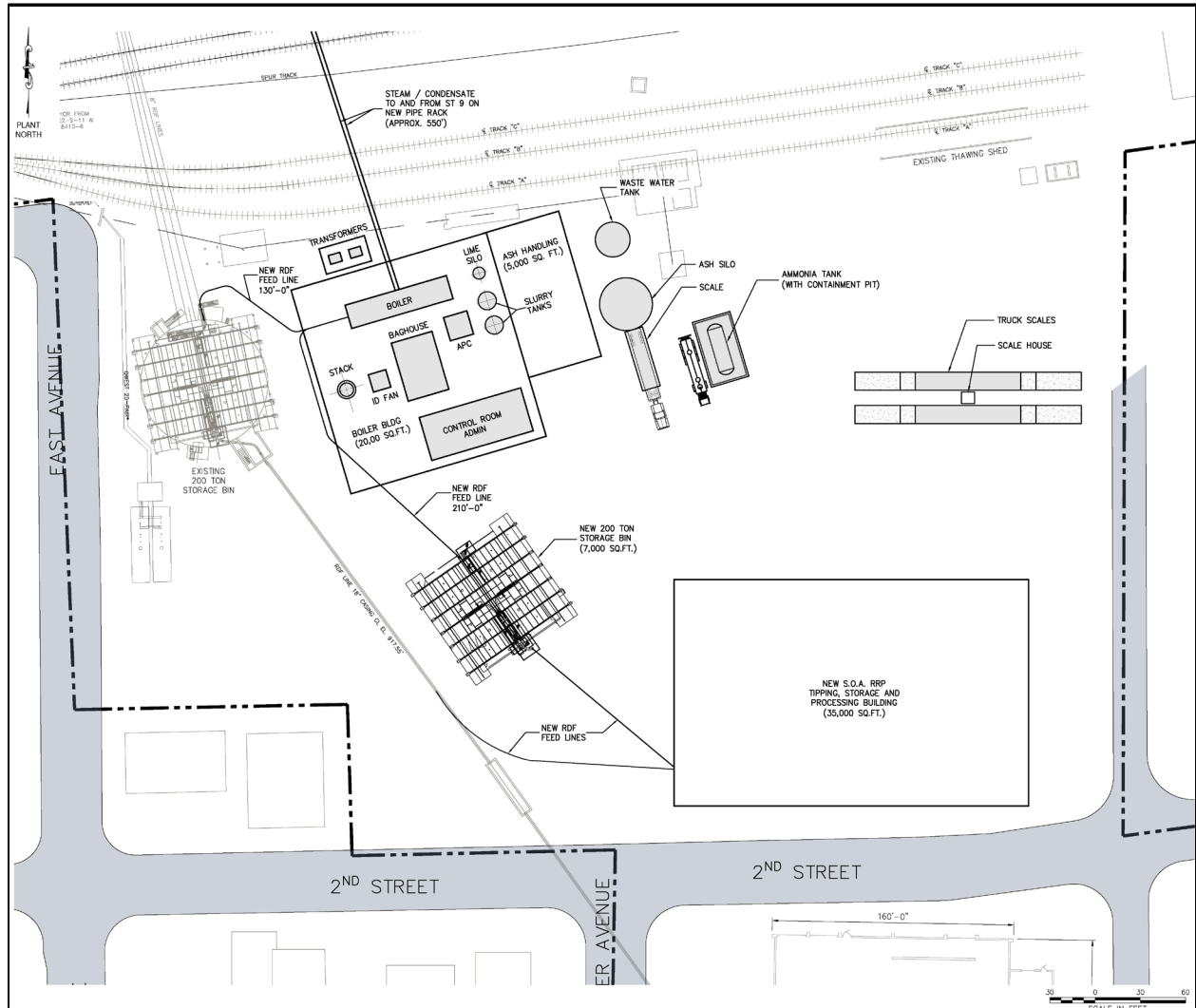


Figure 26: Option 3A-1 Preliminary Conceptual Layout of New SOA RRP and RDF Storage

The power plant layout for Option 3A-2 is shown below in **Figure 27**.

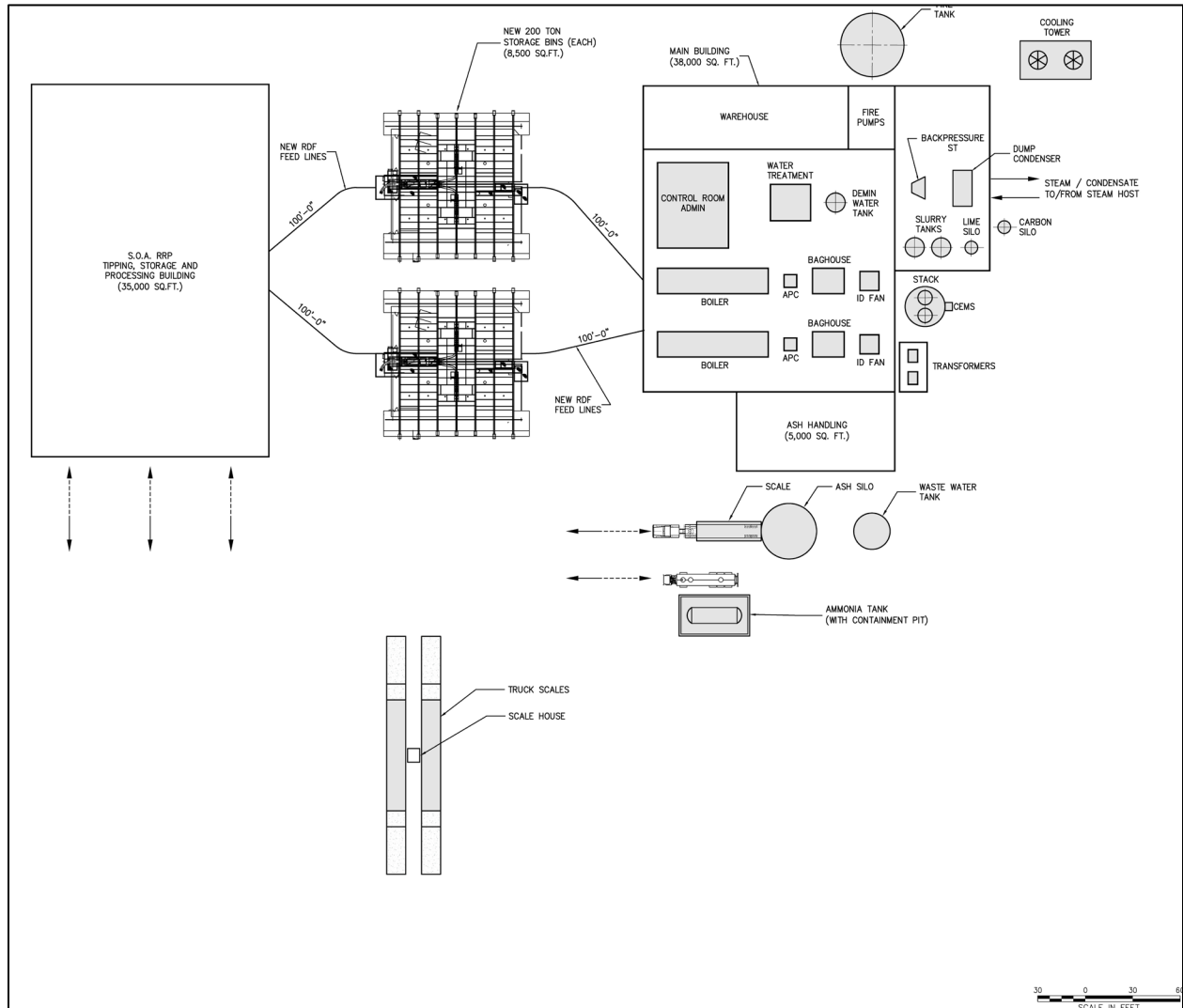


Figure 27: Option 3A-2 Preliminary Conceptual Layout for Industrial Site



3.5 Options 3B-1 & 3B-2 – Two New MSW Mass Burn Combustion Units

The following items characterize the key elements of Option 3B

- The facility includes front-end storage of approximately 4 days of MSW at the mass burn facility receiving floor (extra room required for manipulation of MSW). Two new MSW boilers designed to operate in parallel to consume the MSW. The boilers would each have a scrubber and baghouse for emissions controls.
- Units 7 and 8 would be maintained by the City as capacity resources for the MISO when burning natural gas only. They would not interface with Units 9 and 10.
- New Balance of Plant (BOP) equipment and systems would be installed to support the installation and operation of Units 9 and 10.

Option 3B-1 (Coal Yard)

- The boilers, scrubbers, and baghouse would be located at the coal yard, under the same roof as the MSW tipping floor. The ash handling and metal recovery system will be at the same location in an adjacent building/structure.
- Power would be generated from refurbished steam turbine 5 (ST5) and updated to utilize the steam from Units 9 and 10. A new electronic control system, new steam condenser and an electric generator rewind are also assumed. An internal inspection would be conducted to confirm the feasibility and cost of the steam path refurbishment and generator rewind. A cost-benefit analysis would compare the expected performance and cost of the refurbishments vs. installing a new steam turbine and generator of comparable size. Power would be delivered to the grid via the existing electrical infrastructure. Steam turbines 7 and 8 will not be able to accept the new MSW boiler steam conditions.
- Similar to Option 2B, steam would be piped to refurbished ST5 located at the existing steam plant and condensate will be returned to the new boilers at the coal yard

Option 3B-2 (Greenfield Site)

- A new dedicated facility that includes two combustors capable of burning unprocessed MSW, tipping floor storage, emissions equipment and steam turbine generator would be located on a new industrial site and thus totally detached from the existing power plant. The ash handling and metal recovery system will be at the same location in an adjacent building/structure. Therefore 3B-2 would require (a) two (2) new MSW boilers, (b) a new building, c) utility services (water, sewer, electric) and (d) all new auxiliary services. The boilers should be capable of consuming a minimum of ~100 TPD for a combined capacity of 200 TPD. The 100 TPD boilers would provide the lower installed cost without resulting in undesirable part load operation (below 70%) during parallel operation over the life of the model. This sizing would require 300 tons of storage to provide up to ~3 days of no combustion (includes buffer handling space) before bypassing is required (see the RDF/MSW Storage Analysis in **Appendix B**). Alternatively, two 100% capacity boilers (178 TPD) could be installed to provide complete redundancy. The cost premium for the installation of the larger boilers would be minimally offset by reduced storage. Boiler sizing in between 100-178 TPD would result in years of undesirable part load operation during which the boilers would operate in parallel. Therefore, the lower cost configuration is included in the financial model for the purposes of this evaluation.
- The new facility would sell steam to a neighboring industrial user continuously (24 hrs./day and 7 days/week).



3.5.1 MSW Storage

The MSW receiving and storage for Options 3B-1 and 3B-2 will be on a new tipping floor with approximately 400 tons of MSW capacity in the same building as the new power plant. The front-end MSW storage will provide approximately 4 days of storage throughout the evaluation period (see Appendix B) to accommodate downtimes and maintenance issues during single combustor operation. Three to four days of storage is an industry standard for mass burn facilities. Storing MSW for longer periods could cause issues with potential generation of methane gas, spontaneous combustion through the reactions of various chemical compounds in waste, and bacteria and other sanitary hazards from the decomposition of waste. Moreover, the City's experience in the existing RRP plant and RRT's understanding of issues in other facilities show that spontaneous combustion can occur in piled MSW due to batteries and other ignition sources and therefore proper fire detection and suppression systems will be required.

3.5.2 MSW Pre-Processing System

An MSW pre-processing system is not being considered as part of Options 3B-1 and 3B-2. In both these options, the MSW will be received on a new tipping floor, located inside the power plant building. From the tipping floor, a front-end loader would push the MSW pile to the storage bunkers or to the boiler feeding system. In RRT's experience, a pit and crane would be more expensive, especially in light of the low throughput of the system compared to the industry. The site and soil conditions would also have a significant impact on final cost. A more detailed analysis investigating a tipping floor versus a pit design could be conducted once a site location and final option is selected.

The boiler feeding system will consist of an inclined belt conveyor with a drum feeder that will feed and meter the material into the boiler infeed hopper.

Metals will be recovered post-combustion using an ash handling and metal recovery system, as described in **Section 3.5.7**.

Although the combustion technology used in Option 3B does not require pre-sorting of incoming MSW, RRT recommends considering a pre-processing system as an overlay option for long term financial and environmental benefits. Based on RRT's experience, the addition of MSW pre-sorting in front of mass burn combustion could decrease the air emission concentrations and even moisture content at the stack due to the removal of fines, organics, batteries, and other electronic waste. The MSW pre-sorting system would also increase the calorific value of the material combusted by the removal of non-combustible matter. Lastly, the removal of fines and bulky items upstream is expected to reduce the wear and downtime of equipment, increase overall availability, and reduce the rate of slag buildup on the combustor walls.

RRT conducted a study analyzing the impact of MSW pre-sorting prior to combustion (results were presented at NAWTEC Conference in 2016 and published in Renewable Energy from Waste Magazine July – August 2016, Page 26 – 29 by N. Egosi, S. Ciuta, D. Huang, titled The Upsides of Front-End Processing) at one facility in Minnesota. The results showed that the average heating value of the MSW after pre-sorting increased by over 20%. Moreover, most air pollutants concentration reduced by more than 50%. Most significant were reductions in mercury, cadmium, lead, particulate matter, dioxins and HCl. Due to these reasons, the facility noticed reduced usage of chemicals, activated carbon and hydrated lime for the APC systems. Front-end metal recovery exhibits much higher metal recovery rates than metal recovery from bottom ash.

If the City decides to go with front end metal recovery in lieu of post combustion metal recovery (utilized in this study) the front end would consist of all new equipment installed in a new building connected to the combustion equipment building. The pre-sorting system would remove fines and rejects and recover ferrous and non-ferrous metals through a combination of trommel screening, magnets, ECS, disc screening and air classifier. The estimated capital cost for a system this size would be in the range of \$19M - \$20M and would include all the equipment, building requirements, as well as 3 days of MSW storage on the front-end and 4 days of pre-processed MSW on the back-end prior to feeding the boiler.

RDF/MSW Transport and Storage



Option 3B is unique in that it does not include MSW pre-sorting and does not generate RDF, therefore storage provisions on post-processing are not applicable.

3.5.3 MSW Combustion System

Similar to Option 2B, a mass-burn combustion system designed for unprocessed MSW would be used to combust the MSW in Option 3B. Inclined reciprocating grate systems are by far the most common combustion system used throughout the world for the combustion of municipal solid waste. These systems are offered by a number of proven suppliers including Martin, Hitachi Zosen INOVA, Detroit Stoker, B&W Volund, Keppel Seghers and Ruths. All of these suppliers offer inclined, reciprocating grate systems and although the equipment is somewhat different between the suppliers, the processes are essentially the same for the combustion of unprocessed MSW or large RDF. These systems were briefly described in **Section 3.3.4** and thoroughly discussed in **Appendix G**.

3.5.4 Boiler Design

As with Option 2B, the recommended boiler for smaller mass-burn units would employ a modular design approach to maximize shop fabrication and reduce field construction cost and time. This type of boiler was previously described in Option 2B, with more details provided in **Appendix H**.

As with the previous options, the detailed design of the boiler will consider the high fouling due to ash and corrosion driven by the high chlorine content of the material. Management of boiler fouling and corrosion has always been a significant challenge in the waste-to-energy industry and boiler design features along with operation and maintenance approaches have been developed to control fouling and minimize corrosion to ensure reliable operation. Flue gas and steam conditions will be set to control maximum boiler tube wall temperatures in the steam superheat section where the highest corrosion potential exists. Boiler tube arrangements and spacing will be designed to minimize fouling and allow for effective on-line cleaning. Protective alloys will also be used in select areas to prevent high corrosion rates.

3.5.5 Balance of Power Plant Equipment

For option 3B-1, the Power plant BOP equipment would be the same as in option 2B but is repeated here for thoroughness.

The following is a list of balance of power plant (BOP) equipment anticipated for two mass burn combustors, Unit 9 and 10:

- New boiler feed pumps, condensate pumps and cooling water pumps
- Modification and/or refurbishment of the existing ST5, and associated steam turbine condenser for re-use
- New steam, condensate, cooling water and makeup water piping
- New stack, CEMS and COMS systems.
- New generator step-up (GSU) transformer and associated high voltage electrical support and interconnect equipment
- New step-down transformer and power distribution system
- For Option 3B-1, the plant would be connected to the existing cooling tower serving Unit 7 which can be upgraded to handle both Unit 7 and refurbished ST5 heat rejection at a fraction of the cost of a new cooling tower.



- For Option 3B-2, a back pressure steam turbine would be utilized to generate some in-house power prior to delivering the steam to a steam host. The steam host is assumed to return 85% of the flow as condensate.
- New instrumentation and controls
- New foundations
- Platforms, ladders, stairs, and railings to enable maintenance and operation

In Option 3B-1, the existing plant systems listed below would be extended to the new equipment. For Option 3B-2 all these systems would be new.

- Natural gas supply (for startup and shutdown)
- Compressed air
- Un-interrupted power system (UPS)
- Distributed control system (DCS)
- Fire protection system
- HVAC

3.5.6 Emission Control

As with Option 2B, the Best Available Control Technology (BACT) for a mass-burn combustion system would be the combination of a dry scrubber and baghouse that treats the flue gas exiting the boiler. This system is proven to meet the EPA limits on particulates, SO₂, HCl, mercury, trace metals and dioxins. The scrubber / baghouse is typically augmented with the injection of powder activated carbon (PAC) into the flue gas at the entrance of the scrubber for additional control of both mercury and dioxins. CO and NO_x are combustion-related emissions that are controlled by combustion control methods. Additional NO_x control is typically achieved by Selective Non-Catalytic Reduction (SNCR) which injects aqueous ammonia or urea into the upper furnace of the combustor. The scrubber/baghouse, PAC injection and SNCR systems are described in more detail in *Appendix I*.

3.5.7 Ferrous/Non-Ferrous Recovery

The ferrous and non-ferrous recovery for Option 3B-1 and Option 3B-2 will occur post combustion and will be part of the ash handling system. The resale value of post-combustion recovered ferrous and non-ferrous metal will be lower compared to pre-combustion metals. This is due to contamination, mixing of other metals and ash contamination, and sale value is expected to be approximately 30% less for this material. The bottom ash from the ash dischargers will combine on to a vibratory conveyor with Grizzly discharge section. The Grizzly finger deck section (**Figure 28**): will screen the material. The oversized residue material will be transferred by a front-end loader into a bunker and from there it will be loaded into trucks and shipped to a landfill.

The remaining material falling through the Grizzly deck will discharge onto another conveyor and will be conveyed by a drum magnet feeder conveyor to a rotary drum magnet for ferrous metals recovery. The stream ejected by the magnet will undergo an additional screening step, using a vibratory screen to separate the ferrous materials from any residue. The recovered metals will be transferred by conveyors to a storage bunker and then shipped off to scrap markets. The residue will be transferred to the residue storage bunker. The material not removed by the magnet will continue onto a series of conveyors to an eddy current separator for non-ferrous recovery into a storage bunker. This last step will separate non-

ferrous metals from the residue. The residue will combine with the conditioned fly ash on a conveyor before being discharged into a storage bunker. Another option would be to load the combined material stream directly into trailers or roll-off containers.



Figure 28: General Kinematics Grizzly Deck Design

3.5.8 Ash Handling/Disposal

Fly ash collected from the baghouse and boiler will be conveyed via screw conveyors to a fly ash storage silo. The fly ash will then be conditioned with water to control dusting before being combined with the bottom residue ash from the ash handling and metal recovery system described in **Section 3.5.8**. This combining of the fly ash and residue bottom ash will occur on the belt conveyor prior to storage. The combined ash will then be loaded into trucks for transport and disposal in a landfill.

The combined ash will contain heavy metals of environmental concern, requiring regular sampling and testing to ensure it is below the EPA toxicity limits as determined by the Toxicity Characteristic Leaching Procedure (TCLP). A more detailed discussion on ash sampling and testing is provided in **Section 5 - Environmental Impacts**.

3.5.9 Electric (Option 3B-1) or Thermal (Option 3B-2) Energy Sales

For Option 3B-1, electricity sales would continue as they are conducted today, however the supply of power from the PP to the City would be approximately 1/10th of the current electricity export. The reduced power



is a result of elimination of the co-firing with natural gas. For the financial model, the difference between the electricity generated by co-firing natural gas in Option 1 and electricity generated in Option 3B-1 would be purchased on the day ahead MISO wholesale market price (i.e., the Location Marginal Price, LMP) for the Ames interconnect node. In 2020, the on-peak and off-peak average LMP for Ames was \$30/MWh and \$17/MWh respectively. This is significantly less than the power plant's current costs of \$57.5/MWh to make electricity with natural gas at \$5.00/dth (See Option 2A for math). Therefore, significant power supply cost savings are provided when natural gas consumption is eliminated.

Units 7 and 8 would be maintained by the City as capacity resources for the MISO burning natural gas only. They would be bid into the Day Ahead (electric) Market (DAM) based on Citygate gas prices in effect at the time. It is estimated that Units 7 and 8 would be selected to operate less than 5% of the time. The associated contracts for well head gas and firm transportation would be cancelled since the capacity utilization would be very small (Refer back to **Figure 11**). Citygate spot market gas purchases would be made as needed, for startup and shutdown of Units 9 and 10. Gas purchases for Units 7 and 8 as capacity resources would totally be excluded from the Waste-to-Energy economics as there would be no more co-firing with RDF in these boilers.

For Option 3B-2 there would be no electric sales. All power generated by the back pressure turbine would be utilized by the MSW plant and PP. Should the host have a temporary interruption, a steam “dump” condenser would be provided with cooling tower to enable the continued operation of the RRP and power plant. Should the steam host's ability to continuously take all of the steam be a concern, a condensing steam turbine with 150 psig extraction could be substituted for the back pressure steam turbine to add flexibility to generate power and/or steam. However, less steam can be sold with an extraction/condensing steam turbine since some minimal amount of steam (~5-10%) must always be condensed, reducing the maximum steam sales possible. The need for this alternative equipment would be vetted with the contract negotiations with the host, including contract risk, guarantees, cost sharing etc. Additional infrastructure would also be required to export the electricity should the steam host default in the future. For the model and cost estimate, RRT assumed a back pressure steam turbine exhausting at 150 psig/535F steam conditions with all exhaust steam provided to the steam host. The steam is assumed priced at 80% of the \$/MMBtu of natural gas as a proxy for the host's avoided production cost to produce the same steam from natural gas. A standby “dump condenser” and cooling tower is also assumed for times when the steam host's process is off-line and they cannot accept the steam.

3.5.10 Process Flow and Mass and Heat Balance

Overall process flow diagrams for Options 3B-1 and 3B-2 are depicted in **Figure 29** and **Figure 30**, below. Supporting mass and heat balance data is shown in **Appendix F**.

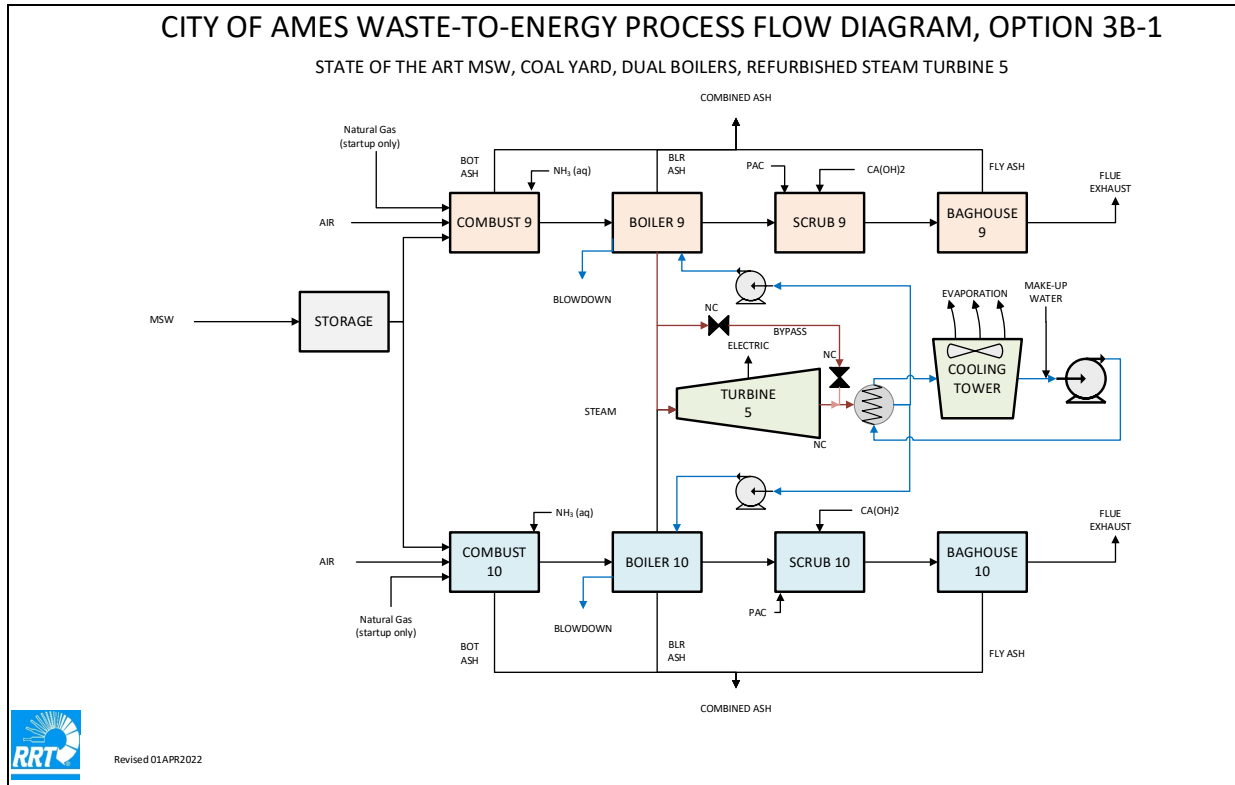


Figure 29: Option 3B-1 Overall Process Flow Diagram

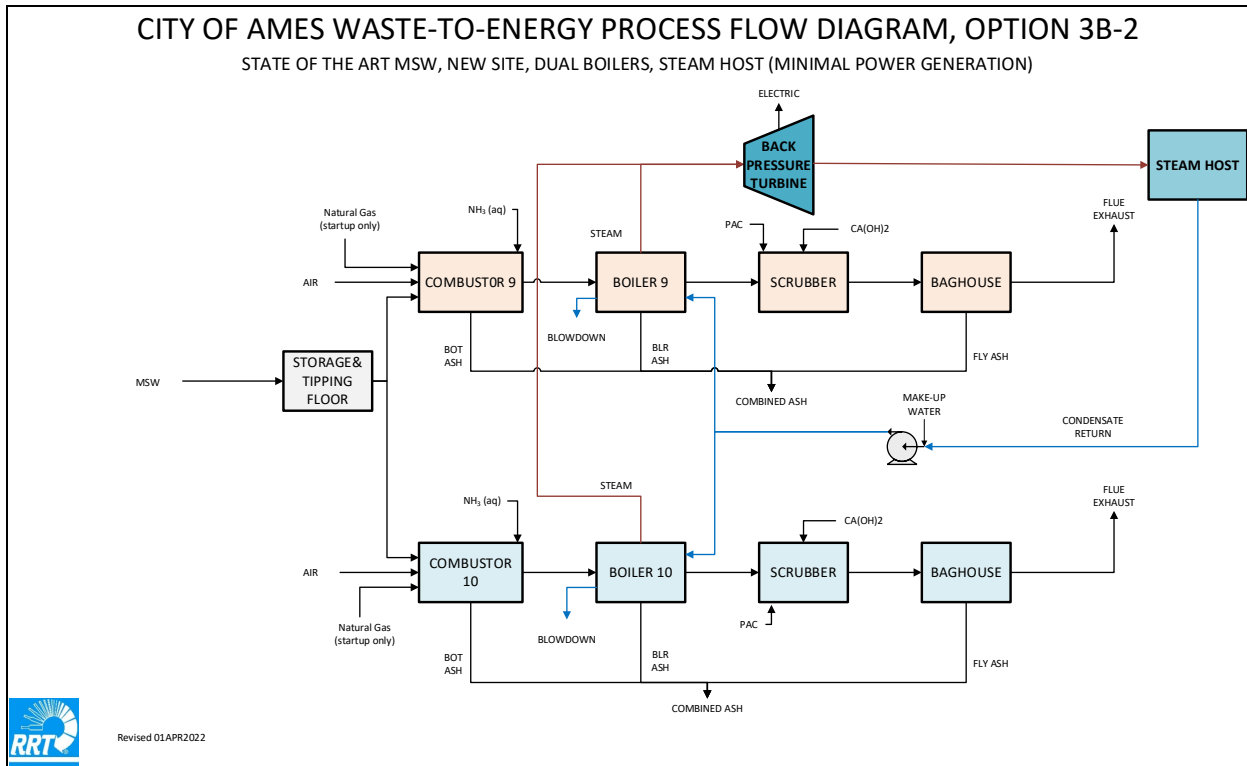


Figure 30: Option 3B-2 Overall Process Flow Diagram

3.5.11 Building/Facility Description and Considerations

The facility includes two new unprocessed MSW combustors and an air pollution control system for each. This option also includes an attached building that houses the post-combustion ash handling and metal recovery system. The MSW will be received at an up-front MSW receiving tip floor in the same building. The tipping floor has been designed for the industry standard of 3 days of storage to feed the combustor which avoids environmental and reduced fire risks. The new facility will also be equipped with an administrative area, control room, education space and potentially a sustainability campus with drop off areas for food waste, metal, glass and other desired diversion materials.

3.5.12 Preliminary Conceptual Facility Layouts

A layout has been provided for Option 3B-1 (Figure 31), which locates a new MSW combustion system at the existing coal yard. A similar preliminary conceptual layout on a new generic industrial site is provided in Figure 32 for Option 3B-2.

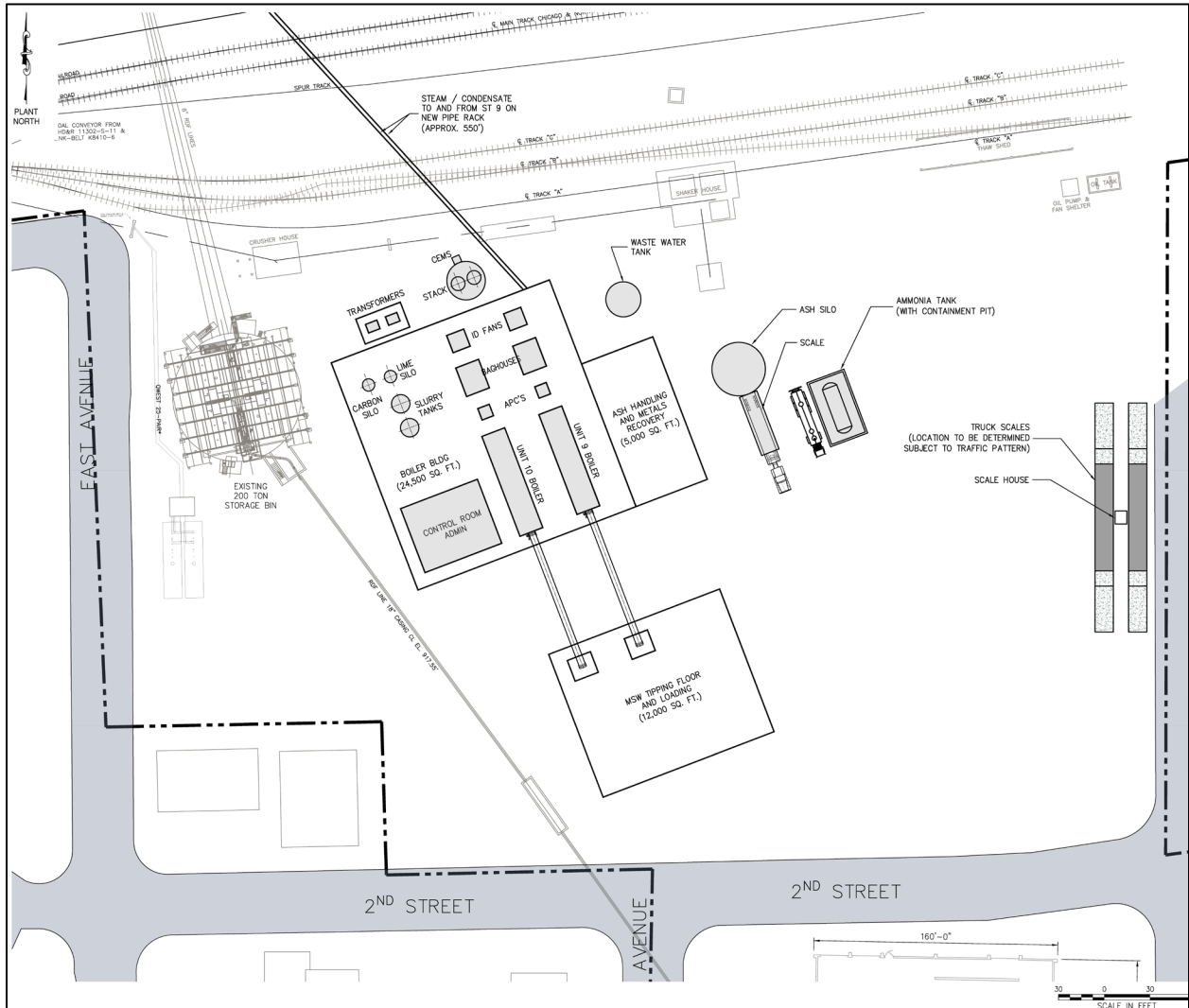


Figure 31: Option 3B-1 Preliminary Conceptual Layout at Coal Yard

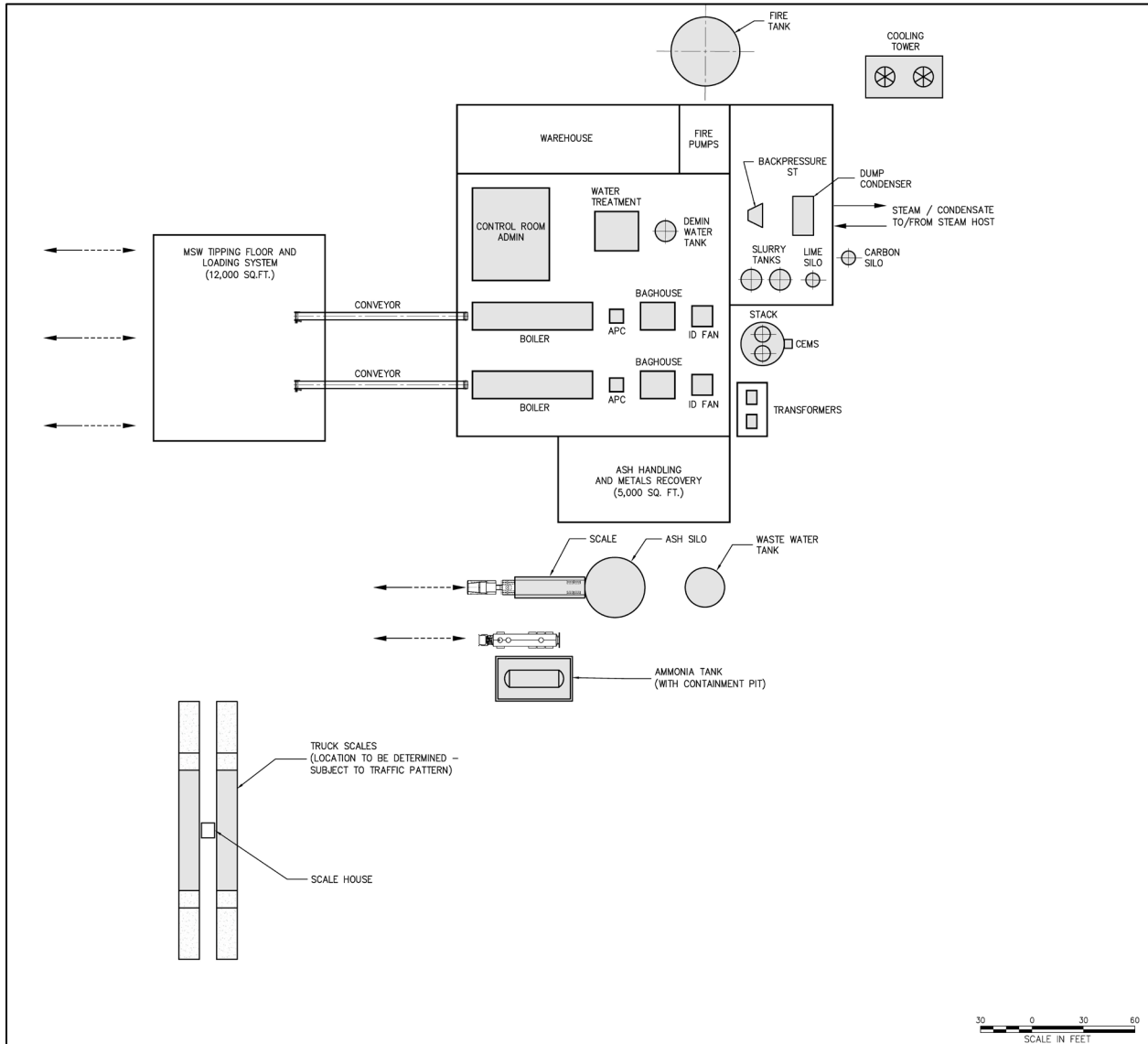


Figure 32: Option 3B-2 Preliminary Conceptual Layout for Greenfield Site



Page 78 intentionally blank



4 FINANCIAL ANALYSIS

4.1 Overview and Methodology

A comprehensive financial model, using Microsoft Excel, was prepared to evaluate the seven options including the City's current operations (Base Case). This model is of critical importance to this study and for the City to utilize in their decision-making process. For each option, the model is structured to follow the flow of energy production starting with the collection of MSW at the RRP Plant (or PP in MSW combustion options) and culminating in the exportation (or sale) of electricity or steam by the Power Plant. Each option has its own color-coded tab in a common excel file and each has a 'waste handling' calculations section (RRP or MSW) which feeds into the power plant section. Both the RRP and PP sections of the model are then split into three main subsections: Production Information, Revenue, and Operating Costs. The City staff were provided an overview and walkthrough of the financial model to allow them to make adjustments in the assumptions tab, which will allow the City to consider the financial impacts of potential "what if" scenarios as key inputs are modified.

Based on the mass and heat balance for each option, the financial model utilizes the NPV to compare the operating costs, including fuel, O&M, debt payments and Capital Improvement Plan (CIP) expenses against the initial upfront capital costs for that option. Material recovery rates, sorting efficiencies, effectiveness of equipment are estimated by RRT based on RRT's extensive experience with sorting facilities, RDF and MSW handling, boiler characteristics, and energy conversion projects. Each option modeled within the excel file operates in its own tab and draws data from specific tabs in the excel file. Data tabs include assumptions, O&M budget, capital costs and debt service. For ease of use, the assumptions tab allows the user to adjust certain factors and their corresponding escalation rates that link to all the models to evaluate model sensitivities. This allows the City to evaluate the seven options with different external factors and allows for multiple "what-if" scenarios. Examples of user definable inputs include inflation indices, the price of natural gas, natural gas escalation rates, labor escalation rates, insurance escalation rates, tipping fees, metal recycling values and other key parameters. Each option also utilizes some unique, option-specific, set of assumptions that can be adjusted by the user, such as boiler efficiency and ash recovery rate. For each option the estimated capital cost of construction and financing was added in 2024 (year 2) and the project impacts are calculated 2 years later after construction is complete.

Debt service for each option's capital cost is included as part of the power plant operating cost. Debt payments are calculated based on a 20-year City bond (other than the base case, which has no additional capital financing) using the Electric Revenue Bond model and the respective capital cost for each option, prevailing 'Aaa' rates + historic 2015B spreads for Ames +160 bps. For a detailed description of the bond evaluation process developed by Capital Market Advisors (CMA) see **Appendix J**. Other tabs included in the model provide reference data for each option for capital costs, operating costs, staffing, debt financing calculations and historic information for reference purposes.

4.1.1 Production Information (Waste Assumptions)

All models assume the exact same amount of MSW is available to be processed. This amount starts at 52,000 tons in 2021 and grows at an annual average rate of 1.1% to match the expected population growth of the City of Ames which results in a 27% total growth by the year 2044. All models assume the funded "at the curb" programs for organics and glass continue to divert material from the waste stream at the same success rate.

The production information of the RRP for the Base Case was obtained from the RRP's 2021 Operating data and 2022 budget projections. Some figures were then adjusted based on input from the RRP staff for what a "normal" year without system downtime and some operational issues experienced in 2020-2021. For the base case, the model reflects the current system capacity limitation to consume RDF in the boilers at a rate of 32,000 tons/year. This equates to a maximum input to the RRP of 49,005 TPY. Therefore, all MSW received over the limit bypasses the RRP and is sent directly to landfill. The 2021 recovery rates for the existing RRP are kept constant over the model time horizon for the base case (Option 1) by assuming that no system upgrades are made, but regular maintenance occurs on the system to keep it performing at



current levels. The RRP effluents include rejects (large bulky items and hazardous materials), ferrous metals, non-ferrous metals, process rejects and RDF.

Each option differs in how effectively it converts the MSW received at the RRP (or in the case of Option 3B, the MSW plant) into kilowatt-hours (or steam in the case of Options 3A-2 and 3B-2) of energy exported. Processing rates were determined by RRT for each option based on the respective processing efficiencies of the equipment depicted in the RRP provided PFDs. As in option 1, these processing rates are kept constant for the entire time horizon for each model.

Once the RDF is processed, it is sent to the power plant where each option has combustion boilers of different sizes, types, and availability to accept RDF/MSW. The RDF/MSW that is consumed by the power plant is treated as a variable cost to the power plant.

A key City goal is to minimize material that goes to the landfill. However, in each case there is some material that must be directed to a landfill and that includes bulky items and for the RDF units, RRP process rejects. For Option 1 that also includes MSW beyond the current System capability. Note that for all options, should the larger (or both) combustors be off-line for an extended time such that the System storage is full, any incremental MSW would also be directed to landfill. Ash residue from the combustion process is sent to a separate landfill.

The assumed average annual inflation rate over the evaluation period is 2.13%. The model provides for unit rates (tipping, hauling, ferrous recovery value etc.) and is structured to enable custom escalation indices for each to easily conduct sensitivity analyses. The escalation rates utilized in the model for this report were determined with input from the City's RRP and PP managers.

4.1.2 Levelized Power Export

In order to accurately compare the options, one very important criterion was kept consistent across all options and that was the assumption to provide the same amount of electrical energy to the City as the base case provides. If the amount of electricity to the City is kept constant, each option can be evaluated on the net benefit to the City. The electricity supplied by the PP in Option 1 (the "Base Case") is calculated based upon RDF production assumptions and the permit requirement to co-fire 30% RDF with 70% natural gas. In all of the remaining cases the electricity generated is notably less due to the avoidance of co-firing with natural gas (note some gas is still burned in Unit 8 as a backup in options 2A and 3A and for boiler warmup in all cases). For each option's shortfall amount of electricity below the base case amount, the model assumes the shortfall is purchased from the MISO at the Location Margin Price (LMP) for the "Ames" node on the day-ahead market rates to make up the difference. The LMP used is the annual average for 2021 on-peak and off-peak periods during the respective hours of the year. On-peak hours are 46.58% of the year. For 2021, average on-peak and off-peak values were \$0.030/kWh and \$0.017/kWh respectively. MISO has also announced their intention to invest in transmission re-enforcements as a result of the "Texas Freeze," which occurred in February 2021. While the transmission re-enforcements are primarily targeted in the Southern MISO zone, these investment costs could affect the pricing in the Northern MISO zone which Iowa is a part of. Therefore, the variable cost of MISO LMP prices is assumed in the model calculations to grow modestly at 0.5% per year. The model allows the flexibility to apply different escalation/de-escalation rates for a sensitivity analysis. Due to the predominance of wind energy available in Iowa, the MISO electricity price is much cheaper than the cost to produce the same power from co-firing with natural gas in Units 7 and 8 in the base case. This operating cost savings is a primary factor for considering moving away from the current operations (Base Case).

4.1.3 Revenue Modeling

For each option the various applicable revenue streams were determined and are summarized in this section.

Variable revenue for the RRP included per capita charges of \$10.50/person and MSW tipping fees of \$62.50/ton. Due to capacity limitations, the MSW that cannot be accepted is turned away and no tipping fee is collected (Option 1). Revenue from the recovery of ferrous and non-ferrous metals were calculated



at \$65/ton and \$980/ton respectively. For internal cost accounting, RDF transfer fees from the RRP to the PP are currently \$30.31/ton. Since the RRP produces the RDF as a fuel for the PP, the RDF transfer fee is also a variable operating cost to the PP. For the model, this transfer cost is held constant across all options.

For the PP, a baseline electric revenue stream is utilized across all options. To calculate the revenue stream, RRT utilized the fundamental concept that the City's target profit is zero for all budget years. Therefore, the base revenue stream is calculated as the revenue from City's electricity sales and associated average annual escalation of that revenue to ensure the "revenue less expenditures" is at or above zero in the base case for all years being evaluated. For 2022 this revenue is calculated to be \$37.9M and the average annual escalation required would be 1.76%. Because this revenue stream is fixed across all of the options, the non-base case options that have lower operating costs (including debt financing) than the base case will show annual "profits" (revenue less expenditures). Positive "profits" would indicate the City's opportunity to reduce revenues by lowering their electric rates, MSW tipping fees, or a combination of both. Negative "profits" would indicate an increase in one or more of the aforementioned revenues to cover the shortfall. For options 3A-2 and 3B-2 where there are steam sales to a steam host, the unit price for steam is 80% of the natural gas cost in \$/MMBTU for the respective year.

4.1.4 Expenses Modeling, Including Debt Service

The variable and fixed operating cost for each option was determined in consultation with City RRP and PP managers and review of historic cost data.

RRP Expenses

RRP variable costs consists of post processing waste rejection hauling and tipping costs, (\$15.68/ton and \$52.00/ton respectively), electricity, and program waste diversion costs for organics and glass. The diversion program costs for both the glass and organics were \$9,000 each in 2021 and their effective rate is carried forward across all options at \$281/ton and \$40/ton respectively. If the City decides to grow one or both of these programs, the model allows them to adjust these costs to see the impact on the overall budget. Fixed costs include labor, maintenance, capital improvements (CIP) and (existing) debt payments. Other diversion costs (e.g., hazardous waste and yard waste drop-off and handling) and other City overhead allocations remain unchanged across all of the options. The primary fixed cost for the RRP is the cost of labor. The RRP currently employs four administration personnel, 11 O&M, and 2.5 part time staff for a total of 17.5 Full Time Equivalents (FTEs). The RRP's other fixed costs are adjusted for each option including CIP and associated debt service. The total labor cost may differ case-to-case depending on the number of FTE necessary to operate the RRP Plant. Operating and maintenance costs for Option 1 were obtained from the 2022/23 Ames budgets. The O&M, including CIP costs, were extrapolated to 2044 in constant dollars. An annual CIP reserve for plant improvements of \$304,500 was chosen to represent the estimated average cost that could be expected knowing the age, operating conditions, and historic experience with the existing operations.

PP Expenses

The PP's operating cost consists of both variable and fixed costs. PP variable costs includes natural gas, chemicals, emissions fees, parasitic electric loads, and ash hauling/tipping costs, and payments to the RRP for the RDF fuel. For Option 1, the largest variable operating costs, by a significant margin, is natural gas fuel. With the plant combusting RDF and running at design capacity, the natural gas fuel is estimated to cost approximately \$18.5M annually assuming an all-in delivered cost of gas to the plant of \$5.00/dth. Fuel pricing has been exhibiting an upward volatility in recent months as shown in **Figure 33** below (red circle). The model enables inserting different fuel rates and different escalations for sensitivity analyses. The annual escalation used in the model for natural gas fuel is 1% per year.

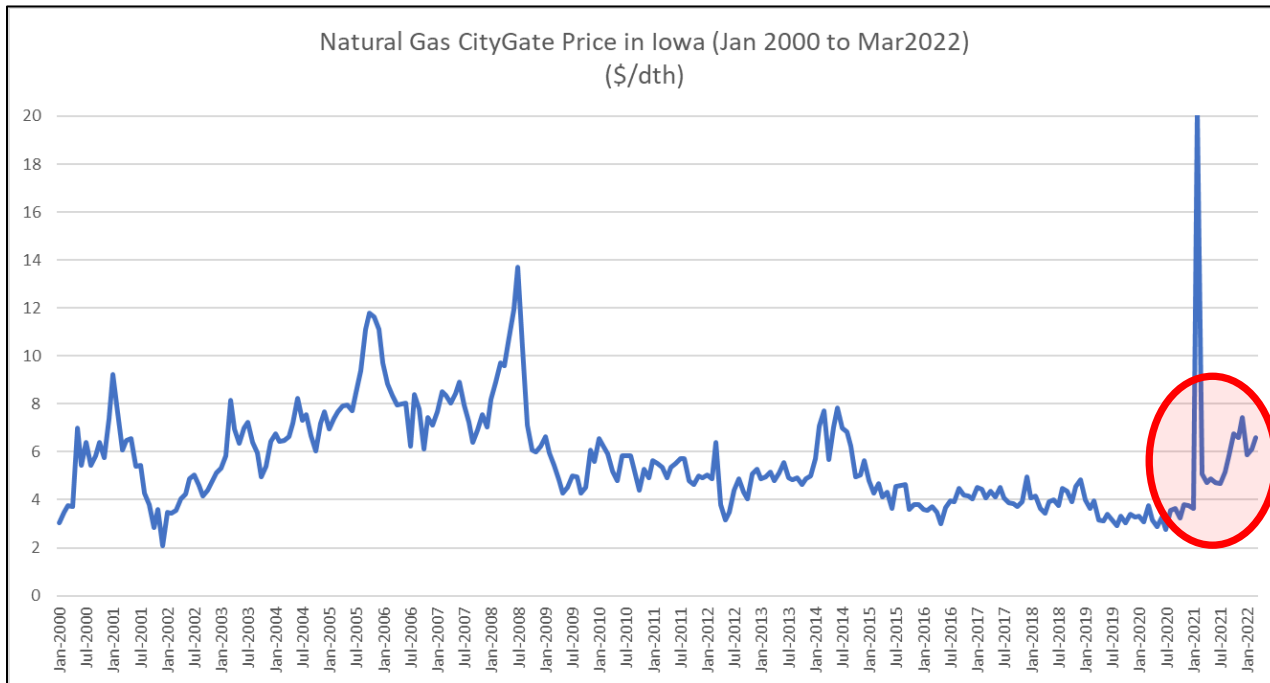


Figure 33: Natural Gas Citygate Price in Iowa, U.S. EIA

Currently the natural gas fuel cost to Ames is composed of a combination of various fixed transportation components and a well-head commodity component. The City’s natural gas transportation costs are fixed costs to transport 12,000 dth/day to the City, which is the amount required for the co-firing of natural gas in Unit 8 in Option 1. This cost structure would continue in the base case (Option 1). Under all of the other options gas is only required for (a) startup, shutdown, and flame stabilization and (b) to co-fire with RDF in Unit 8 as a backup boiler (<10% of year in cases 2A and 3A). The small amount of gas for startup and shutdown gas is calculated in the model for all options. This volume of gas is fairly uniform across all of the options and therefore not a differentiator. The very low utilization factor of the fixed transportation in the non-base cases (see **Figure 11**) would drive the need to terminate the well-head and transportation contracts because they would be uneconomical to maintain for the non-base cases gas purchases. For options other than the base case it would be most economical to purchase gas from the local distribution company (LDC) at the industrial firm tariff rate or Citygate prices. The Option 1 gas price used in the model is \$5.00/dth and assumes a 95% utilization rate of the gas transportation contract, Using the data from **Figure 33** above, the monthly average Citygate price premium from the LDC) is estimated to be \$1.00/dth over the effective Option 1 “burner tip” price. Therefore, Options 2A, 2B, 3A and 3B have a burner tip gas price of \$1.00/dth over that of Option 1.

One other PP variable cost is ash hauling and tipping costs of \$15.68/ton and \$52.00/ton respectively, which was included in the model for all options.

The PP fixed costs include labor, maintenance, insurance, debt payments and CIP. The RDF bin O&M costs are also included in the power plant values. Operating and maintenance costs for Option 1 were obtained for the Power Plant from the 2020/21 and 2021/22 budgets. For Option 1, labor costs are approximately \$6.1M based on 41 Full Time Equivalent (FTEs) and an historic allocation of overtime. Other fixed costs for the base case are \$7.0M for maintenance, \$0.46M in insurance, \$1M in existing debt, and \$4M in CIP. In consultation with the plant manager, the O&M, including CIP costs of all applicable options includes the labor and maintenance to maintain the existing Units 7 and 8 as capacity resources for the City. These values for the on-going O&M of the capacity resources were developed with significant



input from the PP manager. A CIP of \$4M for all applicable options was chosen to represent the estimated average CIP dollars that could be expected knowing the age, operating conditions, and historic experience with the existing operations. For the new facilities the CIP would cover plant improvements and for the existing equipment the CIP would cover equipment replacements and major repairs over \$130k. Note that the fixed O&M costs for all options also include the estimated costs needed to maintain Unit 7 and Unit 8 in serviceable condition to serve as capacity resources to the City of Ames. This includes, in particular, the off-site options 3A-2 and 3B-2 where the new and existing generating plants are not adjacent to each other.

Debt Service

For all options except the base case, the debt service (loan repayment) is calculated assuming City Electric Revenue Bond in 2024 at prevailing ‘Aaa’ rates + 2015B spreads + 160 bps, for 20-years. This project financing would support pre-ordering of equipment and commencement of construction in 2024 with commercial operation occurring sometime in 2026. For a detailed description of the bond evaluation process developed by Capital Market Advisors (CMA) see **Appendix J**.

4.1.5 Capital Costs

For each option, an AACE Level 4 opinion of probable capital cost to implement each WTE option was prepared by RRT. RRT leveraged its experience as both an engineering firm and constructor to provide a functional and accurate cost estimate for a project at this early conceptual phase. An explanation of the methodology used to develop the capital costs as well as a capital cost summary table are provided in **Appendix K**. It should be noted that current material market volatility makes estimating project and equipment costs extremely difficult and current indications show that this market volatility may not regulate in the next 12 months. Ideally, by the time this project is initiated by the City, there will be better supply chain and material cost stabilization to provide an even more accurate cost estimate.

4.1.6 Net Present Value

The Net Present Value (NPV) for each option is then calculated using capital costs and “profit/loss” (revenue vs. total expenses) which includes bond payments over the 20-year bond term between 2025 and 2044. The options are best compared to each other using the NPV. The higher the NPV compared to Option 1, the more attractive the option. For each case, the NPV for the RRP-only and PP-only are also calculated in the model to show the respective impact on the two cost centers, but the overall NPV is of primary importance to the City.

4.1.7 Internal Rate of Return

Another parameter to evaluate alternative options is the use of Internal Rate of Return (IRR). The IRR is the interest rate at which the total present value of the investment cost equals the total present value of the resulting annual cash flows. In other words, the IRR is the interest rate that equates the project investment cost (negative cash flow) to the stream of resulting annual net benefits (usually positive cash flows) as a result of implementing the project. The term ‘internal’ refers to the fact that the calculation excludes external risk factors. Corporations use IRR in capital budgeting to compare the profitability of capital projects in terms of the rate of return. The higher a project’s IRR, the more desirable it is to undertake the project.

4.1.8 Impacts Not Modelled

It should be noted that the financial model does not currently consider outside-the-fence costs (such as transportation) associated with the implementation of any of the Options. For example, Options 3A-2 and 3B-2 include a new RDF boiler or MSW combustor built at a new industrial site. To get the waste to this remote site (potentially outside the City), it will likely require some level of change in hauling costs which could impact collection pricing. This analysis was not part of the study and may need to be evaluated further if an industrial user is identified and the City selects either Option 3A-2 or 3B-2. These costs are related to implementing the new options but not inherent to developing or operating the boiler or combustor and therefore were outside the scope of this study. This additional transportation specific study could also consider costs for potential increased maintenance of transportation infrastructure caused by the new trash



hauling traffic patterns created due to a remote RRP and PP. The results of this further analysis could later be added as inputs to the financial model.

Additional costs not currently included in the financial model are items such as public education or outreach efforts, which could be added when they are determined by the City.

4.2 Financial Model Results

For each year of the analysis period and for each option analyzed, the revenue, operation and maintenance costs are calculated for the respective plants. Capital costs developed for each option were developed along with the costs of debt in the form of City of Ames 20-year Electric Bonds issued in 2025 to support the estimated construction. In addition, the NPV and IRR are calculated assuming \$5.00/dth for the base case. The impact of a range of natural gas prices on Profit, NPV and IRR are presented in **Tables 7, 8 and 9**.

Revenue less Expenditures (Profit)

The average annual 'Revenues less Expenditures' ('Profit')⁸ from 2025 to 2044 is plotted in **Figure 34**. This is the period from financing to the end of the 20-year bond repayment period for all six new options. The base case is slightly greater than zero since, as previously explained, the common revenue stream was specifically selected so that no single year resulted in a negative cash flow in the Base Case. All of the average annual Profit values also include the respective debt repayments. The Profit shown in **Figure 34** is based on an average gas price of \$5.00/dth for Option 1 (Base Case). Other options would not utilize the gas transportation contracts (due to very low gas transportation contract utilization) and are assumed to have a \$1.00/dth gas premium to purchase gas at the Citygate.

Option 2A has notably the highest annual average Profit. A principal driver of the higher Profit is that Option 2A has the lowest estimated capital cost and therefore the lowest debt service. In contrast, Option 3A-2 has the lowest average annual Profit, due in large part to this option having the highest capital costs. Since the Profit is less than zero, the operation of Option 3A-2 would require an increase in revenue (i.e., rate increases) above the base case revenue stream to achieve break-even operations within the City.

⁸ Even though the City Electric Department operates as a non-profit, the word "Profit" in this report is used as a synonym for 'Revenue less Expenses' in the Options model calculations.

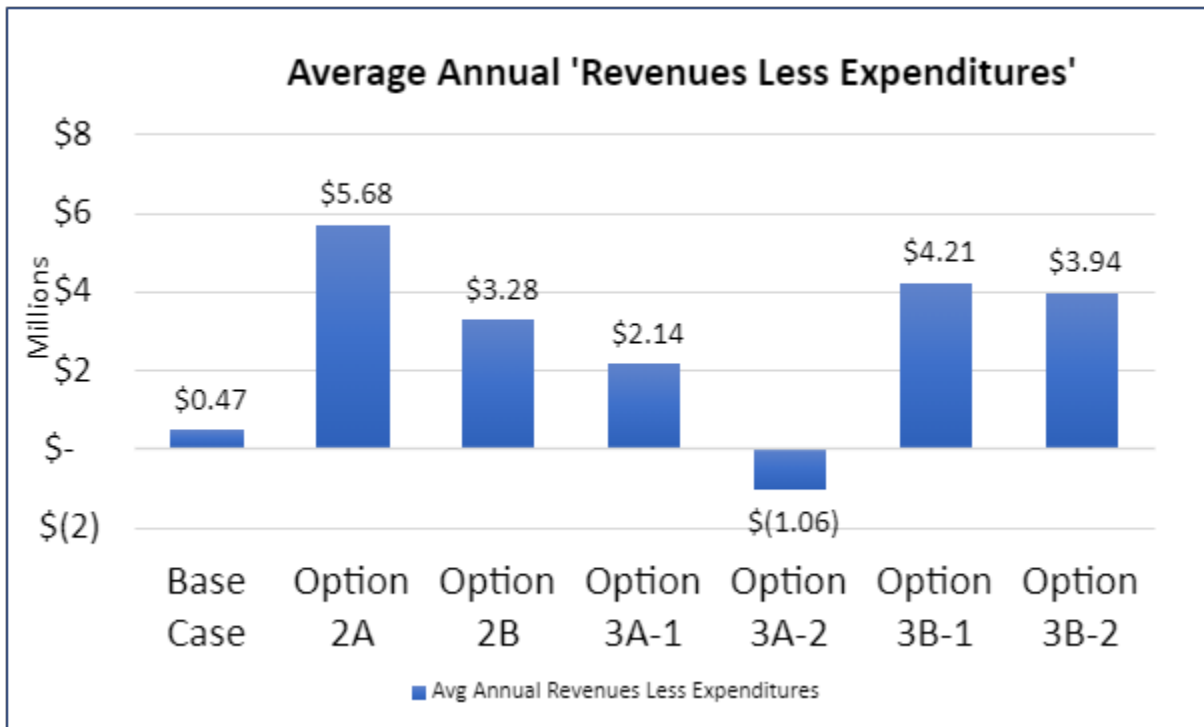


Figure 34: Average Annual Profit for Each Option (@\$5.00/dth)

Net Present Value (NPV)

The Net Present Value is a key financial metric to consider in evaluating all the options over the entire 20-year bond period from 2025 to 2044. The NPV is used to calculate today’s value of cash inflows and outflows of each option. A positive NPV indicates that the project has a positive overall value and therefore is an attractive option for the City versus the Base Case. The NPV improvement of each option over the base case is plotted in

Figure 35, using an Option 1 gas price of \$5.00/dth. Consistent with the average annual Profit of each option, Option 2A exhibits the highest NPV, followed by the MSW mass burn options, 3B-1 and 3B-2. The higher NPV of Option 2A is driven by the lower debt service, despite the need to burn natural gas when utilizing Unit 8 as backup.

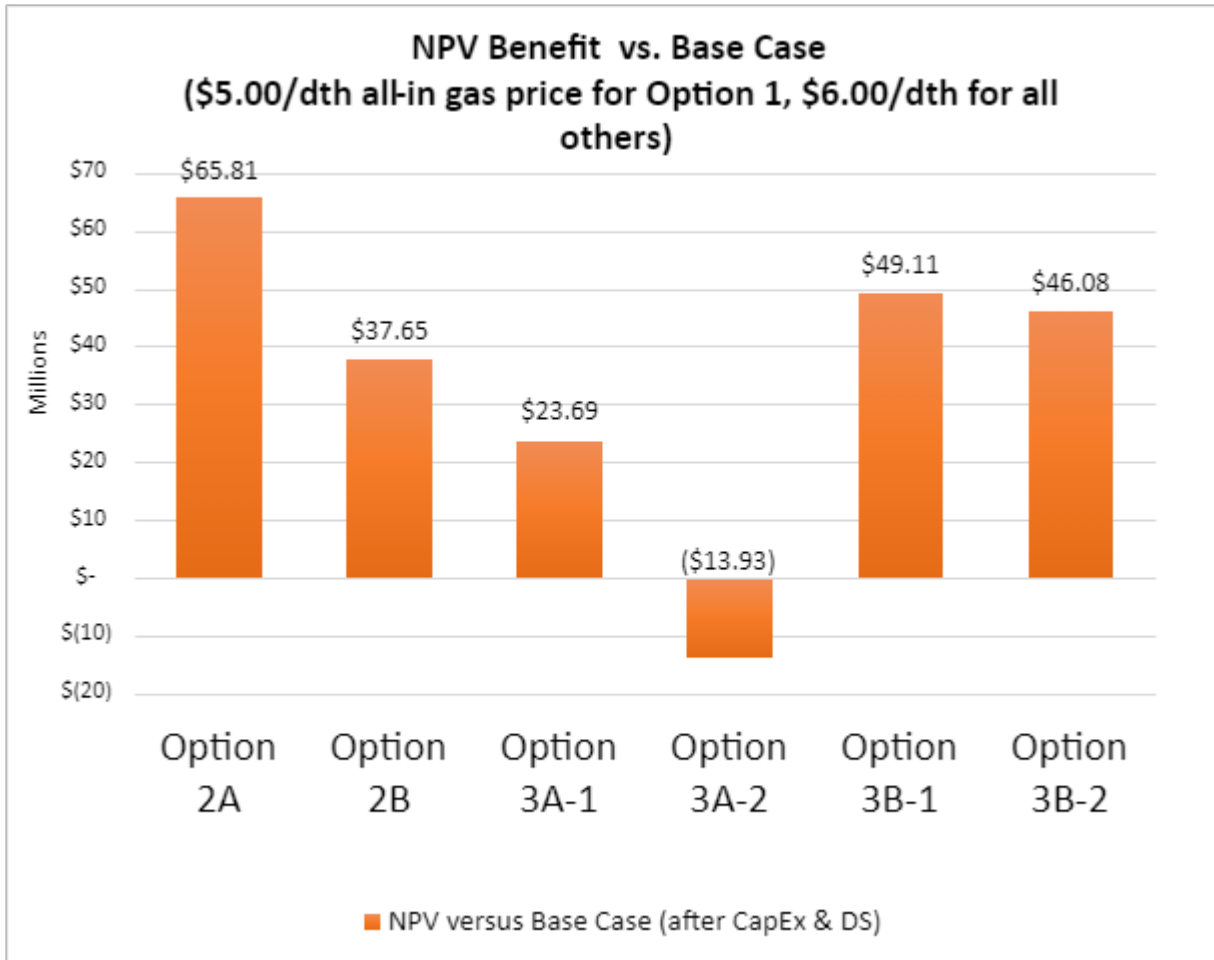


Figure 35: NPV of Each Option vs. Base Case

Internal Rate of Return

Another parameter to evaluate alternative options is the use of Internal Rate of Return (IRR). The IRR is the interest rate at which the total present value of the investment cost equals the total present value of the net future benefits. In other words, the IRR is the interest rate that equates the project investment cost (negative cash flow) to the stream of resulting annual net future benefits (usually positive cash flows) as a result of implementing the project. The term ‘internal’ refers to the fact that the calculation excludes other external factors, such as inflation, etc. For these calculations, the cost of interest as part of the bond financing is included. A comparison of the IRR for each Option is presented in **Figure 36** assuming a base case gas price of \$5.00/dth. As previously explained, all other cases assume a \$1.00/dth premium to reflect Citygate gas purchases instead of wellhead and transportation contracts utilized in the base case.

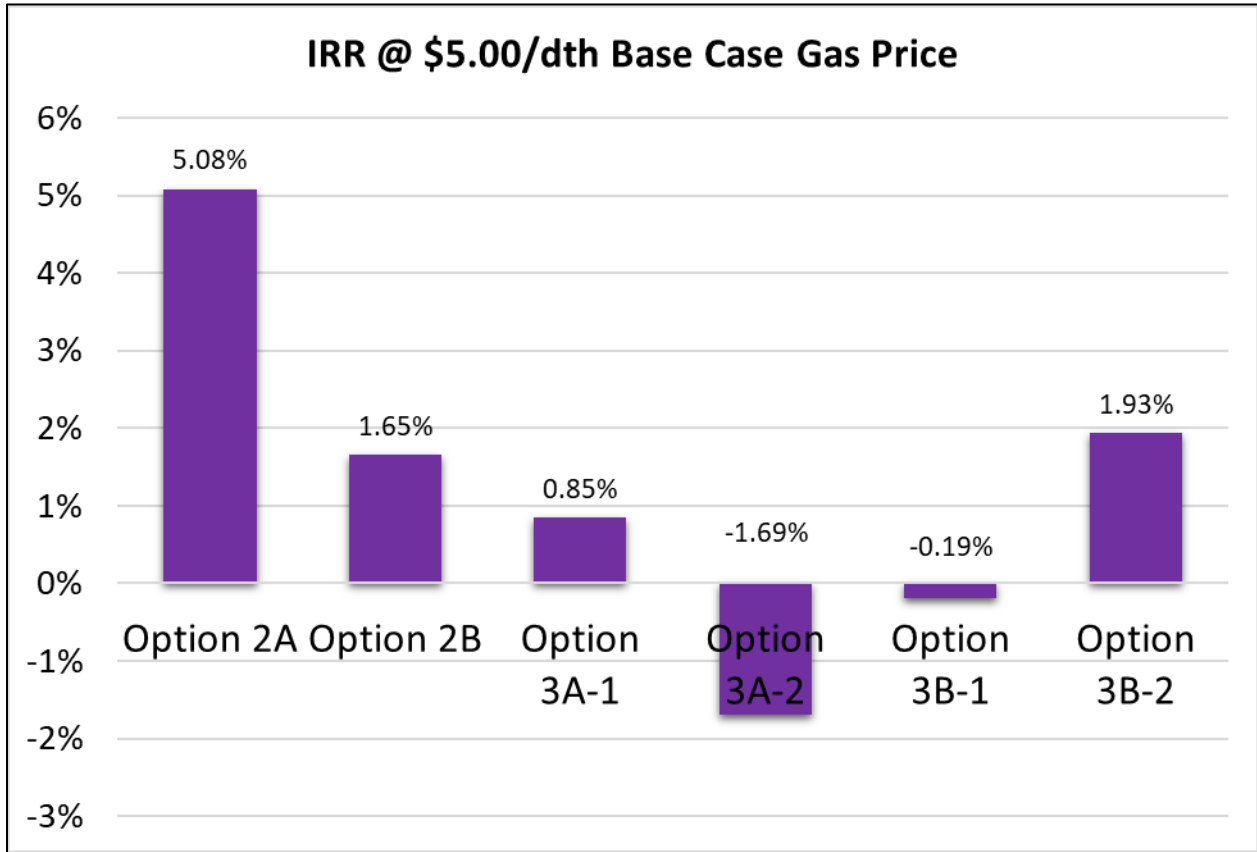


Figure 36: IRR for Alternatives to Base Case [@\$5.00/dth]

4.3 Effect of Natural Gas Pricing

RRT performed a sensitivity analysis to determine the impact of natural gas prices on Profit, NPV, and IRR. The financial results are shown in **Tables 7, 8 and 9** and are graphed in **Figure 37, 38 and 39** respectively. It should be noted that there are secondary impacts of alternate gas prices that may also affect the economics of each option, such as the replacement cost for electricity (energy and capacity), price of other commodities, price of consumables, transportation costs, etc. These impacts are not modeled as they are outside the scope of this study.

From **Table 7** and **Figure 37**, it can be seen that the price of natural gas significantly impacts the operating cost of the Base Case (Option 1) and only slightly impacts Options 2A and 3A. Options 3A-2 and 3B-2 profits improve with higher natural gas prices because the unit price of steam sold to an industrial user is linked to the avoided cost of natural gas to the host.

Table 7: Sensitivity of Average Annual Profit to Base Case Natural Gas Price (\$M/yr)

Base Case Gas Price	Base Case	Option 2A	Option 2B	Option 3A-1	Option 3A-2	Option 3B-1	Option 3B-2
\$4.00/dth	\$4.6	\$6.3	\$3.3	\$2.8	(\$1.6)	\$4.2	\$3.6
\$5.00/dth	\$0.5	\$5.7	\$3.3	\$2.1	(\$1.1)	\$4.2	\$3.9
\$6.00/dth	(\$3.7)	\$5.1	\$3.3	\$1.5	(\$0.6)	\$4.2	\$4.3
\$7.00/dth	(\$7.8)	\$4.5	\$3.3	\$0.9	(\$0.1)	\$4.2	\$4.7
\$8.00/dth	(\$12.0)	\$3.9	\$3.3	\$0.2	\$0.4	\$4.2	\$5.1

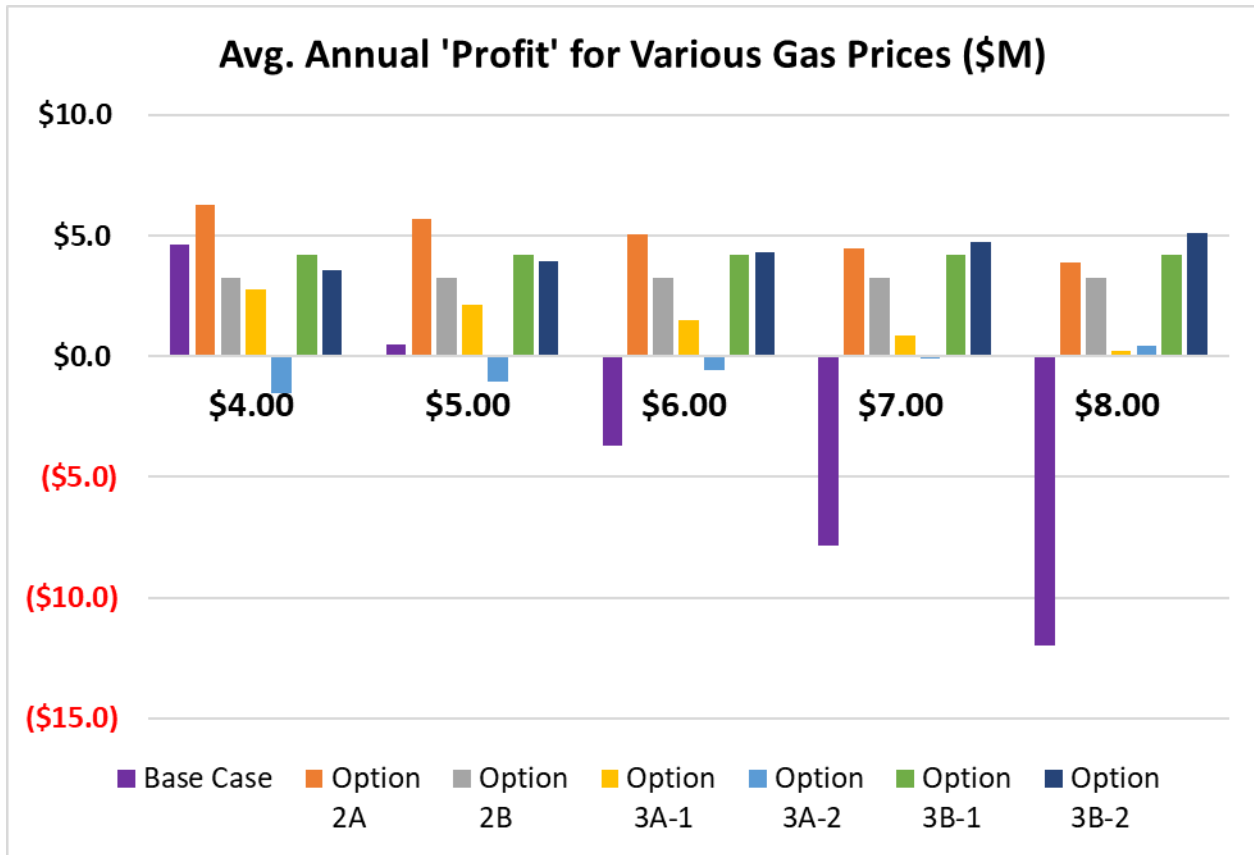


Figure 37: Option Profit Sensitivity to Gas Prices (\$M)

From **Table 8** and **Figure 38**, it can be seen that Option 2A is the only Option with a consistently positive NPV across all gas prices modeled in this analysis. When the base case “all-in” contract gas price rises to \$7.00/dth, the NPV of Option 3B-2 surpasses the NPV of Option 2A. This is driven by increased revenue from steam sales (which is linked to the industrial steam user’s price of natural gas). This increased revenue is applicable for both Option 3B-2 and 3A-2.

Table 8: Sensitivity of 'NPV vs. Base' Case to Gas Prices (\$M)*

Base Case Gas Price	Option 2A	Option 2B	Option 3A-1	Option 3A-2	Option 3B-1	Option 3B-2
4.00/dth	22.3	(13.1)	(19.3)	(70.7)	(1.6)	(9.5)
5.00/dth	65.8	37.6	23.7	(13.9)	49.1	46.1
6.00/dth	109.3	88.4	66.7	42.8	99.9	101.6
7.00/dth	152.8	139.1	109.7	99.5	150.6	157.2
8.00/dth	323.0	371.2	318.5	396.4	380.6	413.3

*Highest NPV for each base gas price shown in blue

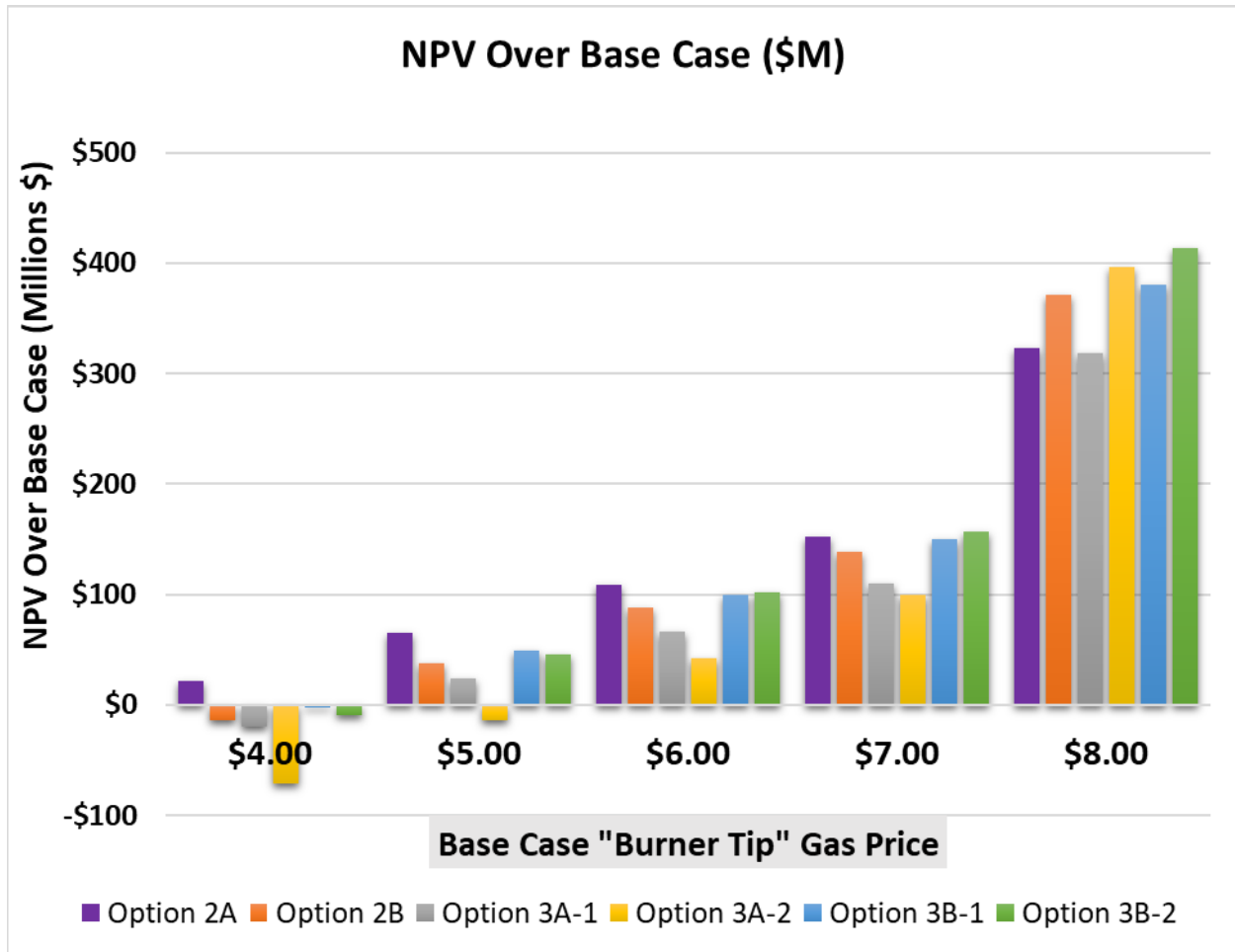


Figure 38: Option NPV over Base Case for Various Gas Prices

The IRR calculation for each non-base case option determines the interest rate that would yield the incremental cash flow over the base case given the capital investment associated with that option. Similar to the NPV sensitivity analysis, the calculated IRR for Option 2A is consistently positive for all of the gas prices modeled in this analysis. The IRR sensitivity results in **Table 9** are graphically depicted in **Figure 39**.



Table 9: Sensitivity of Option IRR to Gas Prices (% IRR)*

Base Case Gas Price	Option 2A	Option 2B	Option 3A-1	Option 3A-2	Option 3B-1	Option 3B-2
\$4.00/dth	1.34%	-1.88%	-2.48%	-5.30%	-4.84%	-1.55%
\$5.00/dth	5.08%	1.65%	0.85%	-1.69%	-0.19%	1.93%
\$6.00/dth	8.38%	4.67%	3.70%	1.26%	3.40%	4.91%
\$7.00/dth	11.41%	7.36%	6.24%	3.82%	6.47%	7.58%
\$8.00/dth	14.27%	9.86%	8.60%	6.13%	9.23%	10.06%

*Highest IRR for each base case gas price shown in blue

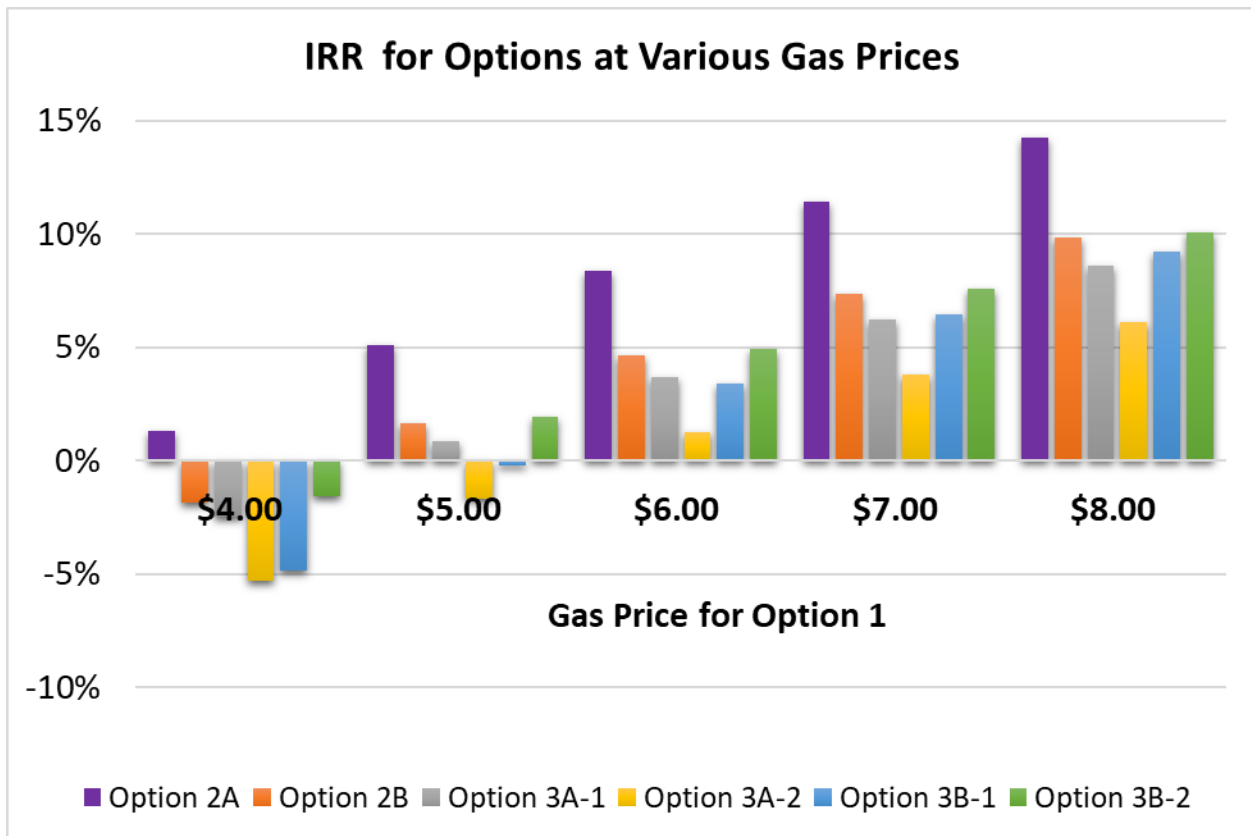


Figure 39: IRR for Options at Various Gas Prices



5 ENVIRONMENTAL IMPACTS

5.1 Federal and State Air Permits

5.1.1 Title V Operating Permits⁹

Congress established the Title V Operating Permit program as part of the 1990 Clean Air Act Amendments. The operating permits are legally enforceable documents designed to improve compliance by clarifying what facilities (also called “sources”) must do to control air pollution. Title V Permits are issued to all “major” sources, with “major” being a regulatory term defined by the type of fuel used, the size or capacity of the facility, and the emissions outputs of specified pollutants on an annual basis. In particular, a facility is a “major source” if its annual emissions for any air pollutant is 100 tons per year (TPY) or more. There are a few other defining criteria such as being located on Indian Land or within an air quality non-attainment area.¹⁰ Most Title V Permits are issued by state or local agencies as “Clean Air Act part 71” permits. The Permits include pollution control requirements from both the EPA and the state (if any apply). Of special note, in Iowa each *source* of emissions is permitted, and a given plant or facility might have more than one source at a single location. For example, even though a MRF might not require an air permit by rule or definition, there might be other equipment or emissions sources at the facility which do require a permit.

Notwithstanding the above, solid waste incineration units are particularly identified as being required to have a Title V Permit regardless of size under Section 129 of the Clean Air Act. Relevant to this project, both a mass-burn incinerator and an RDF boiler¹¹ would be categorized as a solid waste incineration unit, or Municipal Waste Combustor (MWC). All MWCs are categorized as one of the following:

- “Large” (greater than 250 TPD combusted),¹²
- “Small” (35 to 250 TPD combusted),¹³ or
- “Other” (fewer than 35 TPD combusted).¹⁴

Within the “Small” category, there are two classes, and the classes have to do with the aggregate plant combustion capacity where the unit(s) are located¹⁵: Class I units are small MWCs located at municipal

⁹ Much of the information in this passage sourced from the U.S. EPA via <https://www.epa.gov/title-v-operating-permits/basic-information-about-operating-permits> and <https://www.epa.gov/title-v-operating-permits/who-has-obtain-title-v-permit>

¹⁰ In air quality non-attainment areas, the thresholds are even lower than 100 TPY; however, that condition does not apply in Ames.

¹¹ 40 CFR §60.51b defines all types of refuse-derived fuel as a type of municipal solid waste which is produced by processing municipal solid waste through shredding and size classification, and refuse-derived fuel stokers as a type of MWC technology.

¹² <https://www.epa.gov/stationary-sources-air-pollution/large-municipal-waste-combustors-lmwc-new-source-performance>

¹³ <https://www.epa.gov/stationary-sources-air-pollution/small-municipal-waste-combustors-smwc-new-source-performance>

¹⁴ <https://www.epa.gov/stationary-sources-air-pollution/other-solid-waste-incinerators-oswi-new-source-performance>

¹⁵ Aggregate plant combustion capacity means all MWCs at a plant location, combined. An individual combustor might itself be “Small,” but part of a larger plant combusting greater than 250 TPD.



waste combustion plants with an aggregate plant combustion capacity greater than 250 TPD and Class II units are located at municipal waste combustion plants with an aggregate plant combustion capacity less than or equal to 250 TPD. The requirements for Class I and Class II units are identical except that Class I units have a nitrogen oxides emission limit and require continuous emission monitoring, recordkeeping, and reporting requirements for nitrogen oxides. Class II units do not have a nitrogen oxide emission limit. Additionally, Class II units are eligible for the reduced testing option provided in the code.

5.1.2 Section 129, Section 111, and New Source Performance Standards

To repeat, all MWCs regardless of size are required to have a Title V air permit under Section 129, which directs the EPA Administrator to develop regulations under Section 111 of the Act limiting emissions of nine air pollutants from four categories of solid waste incineration units, including MWCs. The pollutants are:

- Particulate matter,
- Carbon monoxide,
- Dioxins/furans,
- Sulfur dioxide,
- Nitrogen oxides,
- Hydrogen chloride,
- Lead,
- Mercury, and
- Cadmium.

The new source performance standards (NSPSs) and Emission Guidelines for new and existing MWCs fulfill the requirements of Sections 111 and 129. The NSPSs consist of five major components:¹⁶

- a) Preconstruction requirements.
 1. Materials separation plan.
 2. Siting analysis.
- b) Good combustion practices.
 1. Operator training.
 2. Operator certification.
 3. Operating requirements.

¹⁶ <https://www.govinfo.gov/content/pkg/CFR-2015-title40-vol7/pdf/CFR-2015-title40-vol7-part60-subpartAAAA.pdf>



- c) Emission limits.
- d) Monitoring and stack testing.
- e) Recordkeeping and reporting.

It is in the application of the NSPS that the facility sizes (“Large” or “Small”) come into consideration and where the fulfillment of the five major components varies as provided for in the laws and regulations. Relevant to this project, all of the MWCs in the Options are designed for less than 250 TPD combustion, meaning they would each be categorized as a “Small” MWC. If any of them are part of a facility with an aggregate plant combustion capacity of greater than 250 TPD, they would be Small Class I; if not, they would all be Small Class II.

5.1.3 Iowa DNR Permitting

Air and Construction

As noted above, in Iowa, each individual smokestack or emission point receives an air permit. New facilities must be designed to meet emissions standards and not result in a violation of ambient air quality standards. Prior to construction, an IDNR Air Quality Construction permit will also be required. Facilities meeting state and federal requirements are issued construction permits, which also include operating requirements to assure continued compliance.

Projects which are large or complex require more detailed analysis. Under the Clean Air Act and/or due to the impact large emission sources can have on a region, this includes those that involve the following:

- Major Source Non-Attainment Area permitting,¹⁷ for facilities located in air quality non-attainment areas (not applicable to Ames);
- State Implementation Plan (SIP) maintenance areas,¹⁸ where an area was redesignated from non-attainment to attainment (not applicable to Ames);
- Prevention of Significant Deterioration (PSD),¹⁹ for new facilities or modifications in areas with air quality attainment status (likely applicable to Ames); and,
- Brand new (greenfield) facilities (applicable to some of the Options in this study).

Other permits such as drinking water, flood plains, storm water and wastewater might also be required. That determination cannot be made within the scope of this project and would be completed once detailed design engineering and site selection is performed.

Solid Waste

The DNR is also the agency which implements the state’s solid waste regulations, Chapter 455, Division IV, Part I, Sections 455B.301-455B.316 of the Iowa Code. The DNR has the authority to issue solid waste permits to various facilities, one of which is for a sanitary disposal project (SDP). In the past, the Ames RRP had a permit as an SDP; however, a regulatory review by the DNR determined that the SDP permit is only

¹⁷ <https://www.epa.gov/nsr/nonattainment-nsr-basic-information>

¹⁸ <https://www.iowadnr.gov/Environmental-Protection/Air-Quality/Implementation-Plans>

¹⁹ <https://www.epa.gov/nsr/prevention-significant-deterioration-basic-information>



for landfills, incinerators without resource recovery, and transfer stations which send material to such facilities. The SDP permit which had previously been in place at the RRP was not renewed.

The regulatory review noted the following reasons, among others, for why a resource recovery facility with combustion was not an SDP:

- The nature of resource recovery means the act of combustion is not the “final” disposition of the waste, and without such finality (a defining factor of SDPs) a resource recovery facility cannot be an SDP.
- By the same accounting, combustion with energy recovery is more akin to recycling, in that it takes “an otherwise discarded material and create[s] something new with it.”
- The solid waste hierarchy in Iowa Code section 455B.301A establishes clearly that combustion with energy recovery is different than and preferred to landfilling or incineration; this leads to the reasoning that an energy recovery facility should not be regulated as a landfill.
- Similarly, it is the stated and the apparent intent of the state’s solid waste laws and regulations to encourage reduction, recycling, and otherwise diverting and recovering resources as opposed to disposal.²⁰ The DNR has stated that imposing the burden of an SDP permit on a resource recovery facility would be in opposition to that intent.
- Case law²¹ has established that “If the primary purpose of the facility is to manufacture a product, then it would not be a sanitary disposal project. When applying this reasoning to the determination of whether an energy recovery facility is required to obtain a sanitary disposal project permit it is clear, so long as the purpose of the facility is not “final disposition” (disposal)...the facility does not constitute a sanitary disposal project.”
- Iowa is delegated to implement RCRA Subtitle D, which does not require the state to permit recycling or resource recovery facilities.

By definition, the Options explored in this project involve resource recovery systems and waste conversion technologies:²²

“*Resource recovery system*” means the recovery and separation of ferrous metals and nonferrous metals and glass and aluminum and the preparation and burning of solid waste as fuel to produce electricity.

“*Waste conversion technologies*” means thermal, chemical, mechanical, and biological processes capable of converting waste from which recyclable materials have been substantially diverted or removed into useful products and chemicals, green fuels such as ethanol and biodiesel, and clean, renewable energy. “Waste conversion technologies” includes but is not limited to anaerobic digestion, plasma gasification, and pyrolysis, except the term does not include gasification and pyrolysis facilities that process post-use polymers or recoverable feedstocks.

Besides SDPs, the DNR has twenty-three other types of solid waste permits, including Incinerators (INC), MRFs (MRF), Processing Facilities (PRO), and Recycling Facilities (REC). Clearly, a resource recovery

²⁰ 455B.301A “Declaration of policy”

²¹ ABC Disposal v. Iowa Dept. of Natural Resources, 681 N.W.2d 596, 605-606 (Iowa 2004)

²² 455B.301 Definitions



facility and a waste conversion technology are neither INC nor MRF. At present, there are no active permits for PRO or REC.

While the information herein is not intended to construe that a solid waste permit would not be required for any of the Options in this project, there is currently no apparent regulatory, policy, or case law precedent indicating such a requirement.

5.1.4 Other Permitting and Regulatory Considerations

Options 3A-1 and 3B-1 involve the re-development of the Coal Yard, and Options 3A-2 and 3B-2 involve development of an unspecified Greenfield site. Once a site is selected and the conditions of the Coal Yard are more fully understood, through detailed site investigations, more will be known about what other permits, actions, and uses of the sites can be expected. However, the commercial development or re-development of any site for any purpose will require a number of permits and regulatory allowances.

In the City of Ames, a Major Site Development Plan²³ will likely be required by the Planning Division, including review by the Development Review Committee (DRC). Depending on the outcome of that process, a Special Use Permit or a Conditional Use Permit might be required. Factors influencing the development of the site also include flood plains, land use, and many other policies and priorities of the City as a governing body.

For construction of the facility, there will be various permits required from the City of Ames Inspections Division. According to information immediately available,²⁴ the following are some of the permits that may be required for developing a site or constructing a building:

- Building Permits, of which there are several types including code modification, site erosion and sediment control, demolition, driveways and curb cuts, changes to meters, new building, ramps, signage, and stairs.
- Electrical Permits
- Plumbing Permits
- Mechanical Permits

The City of Ames and the State of Iowa have adopted model codes and standards, with local amendments as appropriate to address local conditions. The adopted codes are part of state and local law and are enforceable.²⁵ These codes include:

- 2015 International Building Code
- 2015 International Existing Building Code
- 2015 International Fire Code
- 2021 Uniform Plumbing Code
- 2021 International Mechanical Code
- 2012 International Energy Conservation Code
- 2020 National Electrical Code

²³ <https://www.cityofames.org/home/showpublisheddocument/57857/637328251268000000>

²⁴ <https://www.cityofames.org/government/departments-divisions-i-z/inspections/building-permits>

²⁵ <https://www.cityofames.org/government/departments-divisions-i-z/inspections/building-permits/building-codes>



- Accessibility ICC A117.1-2009
- Current National Fire Protection Association Standards

There may be Federal programs or requirements which are administered at different levels of government which will have particular application (like with Air Permits) to the selected option; however, absent a selected site, details should not be speculated.

5.2 Comparative Analysis of Environmental and Program Impacts

5.2.1 Air Emissions Summary

The EPA Maximum Achievable Control Technology (MACT) emission standards for MWCs are listed in **Table 10** below. As a new facility is permitted, some State regulatory authorities may look to further tighten the standards for some or all of the pollutants and could potentially utilize the most recently developed WTE facilities, in the country or even around the world, as a baseline for the new facility's air emissions requirements.

Table 10: MSW Combustor Emission Limits

Pollutant	Symbol	Units	EPA	Typical Performance With SOA APC Performance
Particulate Matter	PM	mg/dscm	25	12
Sulfur Dioxide	SO ₂	ppm	30	24
Hydrogen Chloride	HCl	ppm	25	20
Nitrogen Oxides	NO _x	ppm	205	50
Carbon Monoxide	CO	ppm	100	100
Dioxins / Furans	PCDD/P	ng/dscm	30	10
Mercury	Hg	µg/dscm	50	25
Cadmium	Cd	µg/dscm	35	10
Lead	Pb	µg/dscm	400	125

Note: All concentrations are measured at the standard conditions of 7 vol% O₂.

The scrubber/baghouse emission control system that would be used in the waste combustion systems for Options 2A, 2B, 3A and 3B is proven and reliable for meeting the EPA emission standards for PM, SO₂, HCl, Cd, Pb and dioxins / furans. Mercury is somewhat unique relative to other trace metals in that it is a very volatile metal and largely present in the vapor phase at the boiler outlet and through the scrubber/baghouse system. Significant amounts of mercury are adsorbed by the Ca(OH)₂ in the scrubber, as well as by excess Ca(OH)₂ and fly ash unburned carbon in the baghouse. This level of mercury control is often adequate to meet the Federal mercury emission limit, although the pneumatic injection of powder activated carbon (PAC) into the flue gas prior to the scrubber is often added to achieve lower levels of mercury control and ensure compliance with the emission standard. PAC injection also enhances the control of dioxins, further reducing these emissions relative to the EPA limits.

CO and NO_x are combustion-related emissions that are not controlled by the scrubber/baghouse system. CO is controlled by combustion control methods that would easily meet the EPA standard of 100 ppm for both the combustion of RDF and MSW. NO_x is also partially controlled by combustion control methods that may be adequate to meet the EPA standard of 205 ppm, depending on the combustor design. However, most modern waste-to-energy facilities also employ Selective Non-Catalytic Reduction (SNCR) systems to further reduce NO_x emissions and ensure compliance with the Federal MACT standard. An SNCR system can easily be added to the combustor design and injects aqueous ammonia or urea into the upper furnace of the combustor at a flue gas temperature range of 1650 to 1800 F. In this temperature range, NO_x reacts with NH₃ to produce N₂ and H₂O. SNCR is sometimes called Thermal DeNO_x because the reduction



reactions are driven by the high flue gas temperatures and do not require a catalyst. SNCR systems can typically achieve 40–60% reductions in NOx exiting the combustor. Combined with combustion control measures, an SNCR system would typically achieve NOx emissions in the range of 100 to 150 ppm. More advanced SNCR systems have also been developed that, when combined with staged combustion approaches, can achieve NOx levels below 100 ppm.

For the Small MWCs systems being evaluated by the City of Ames, it is unlikely that the emission control standards will be significantly below those of the Federal MACT standards. However, should lower emission standards be required, it is even more unlikely that they would be lower than those for PBREF No. 2 listed in Table 4 on Page 13, above. A modern waste-to-energy facility employing a scrubber/baghouse system, powder activated carbon injection, SNCR and good combustion controls would be able to reliably meet all of the PBREF No. 2 emission standards, with the exception of the NOx standard of 50 ppm. Should this lower NOx standard be required, additional control in the form of a selective catalytic reduction (SCR) system would be required and would add significant capital and operating costs to the project. An SCR system would have to be placed on the clean flue gas following the baghouse and require reheating of the flue gas to temperatures in the range of 500 to 700 F for the NOx reduction reactions to take place. The system would also require additional fan power and steam to reheat the flue gas, reducing the net power output of the WTE facility. Expensive catalyst replacements every 3 to 5 years would also contribute to the high operating costs of an SCR system. Again, for the Small MWCs being evaluated by the City of Ames it is unlikely that this more stringent NOx standard would be required, and therefore not included in the analysis.

The estimated emissions for each of the Options being evaluated were calculated based on typical waste elemental composition, expected emissions control efficiencies and stack gas flow rates. The estimate emissions for the Options are presented in Table 11, below. The emissions from the existing Units 7 and 8 in Option 1, and from Unit 8 back-up operation in Options 2A and 3A-1, are estimated to be from the contribution of the RDF fuel only, and not including any emissions from the natural gas combustion, which would only contribute to CO and NOx.

Table 11: Expected Actual Emissions - All Options

Pollutant	Units	Option 1 Base Case	Option 2A 4"RDF 5/6 building	Option 2B 20" RDF Coal Yard	Option 3A-1 4"RDF Coal Yard	Option 3A-2 4"RDF Industrial Site	Option 3B-1 MSW Coal Yard	Option 3B-2 MSW Industrial Site
SO2	TPY	129.7	29.6	18.7	32.1	19.5	31.2	31.2
HCl	TPY	333.3	44.0	9.6	45.3	10.0	12.8	12.8
NOx	TPY	71.7	67.9	143.1	77.5	75.1	149.3	149.3
CO	TPY	2.2	3.3	22.9	3.8	3.8	25.2	25.2

The emission quantities of PM, SO₂, HCl, Hg, Cd and Pd are primarily dependent on the quantity of RDF or MSW being combusted in the various options, along with some impact from the estimated reduction of the sulfur and chlorine content in the RDF vs. MSW. The emission quantities of CO and NOx also depend on the type of combustor, with bubbling bed combustion of 4" RDF having lower CO and NOx levels exiting the combustors relative to inclined grate combustors for MSW and 20" RDF.

The dioxin/furan (PCDD/PCDF) emission quantities are also dependent on the quantity of waste being combusted, with an estimated removal efficiency across the scrubber/baghouse system. The formation of dioxin/furans in the existing Units 7 and 8 in Option 1, and from Unit 8 back-up operation in Options 2A and 3A-1 are estimated to be the same as for typical waste combustors, however these units do not have scrubber/baghouse control systems to remove the dioxin/furans that are formed.



5.2.2 Greenhouse Gas (GHG) Emissions Summary

When evaluating the greenhouse gas emissions from the waste-to-energy options being evaluated by the City of Ames, there are four contributing components that must be considered, as follows:

1. **CO₂ generated from the combustion of the non-biogenic fraction of the waste.** The U.S. EPA has determined that 35% of the organic content in municipal waste is non-biogenic, coming from fossil sources made up mainly of plastics. The remaining organic content in waste is biogenic, made up mainly of paper, cardboard, wood and food waste, and represents a renewable source of CO₂ emissions.
2. **CO₂ generated from the combustion of natural gas in Units 7 and 8.** Natural gas is used for the co-combustion of RDF in the existing Units 7 and 8. This occurs to the largest extent in Option 1, where natural gas is consumed for the co-combustion of all of the RDF, and to lesser extents in Options 2A and 3A, where natural gas is only consumed for back-up operation approximately 10% of the time.
3. **Equivalent CO₂ generated by the landfilling of by-passed waste.** Landfilled waste generates methane emissions as it decomposes, which is a much more potent greenhouse gas than CO₂. For the City of Ames, by-passed waste will go to the Boone County Landfill that currently does not have plans to add a methane recovery system, leading to an equivalent CO₂ emission factor of 1.3 tons of equivalent CO₂ for every ton of waste landfilled. This equivalent CO₂ emission factor was determined by paleBLUEdot and Orange Environmental in the Ames Community Greenhouse Gas Inventory Study completed in August of 2020. Should the Boone County Landfill add methane recovery in the future, or if the City were to send the by-passed waste to another landfill with methane recovery, this emission factor would be reduced to 0.88 tons of equivalent CO₂ per ton of waste landfilled.
4. **CO₂ generated by the production of purchased, replaced power.** The City of Ames currently generates power from the operation of Units 7 and 8. If the City were to install new units for the dedicated combustion of RDF or MSW, the reduced power generation would have to be replaced by purchasing that power from external sources. This occurs in all cases except Option 1, which is the base case for this analysis. The CO₂ emissions associated with the purchased power from MISO for Zone 3 will average 611.1 pounds per MWhr (EPA Egrid for the State of Iowa in 2020).

Table 12 below details the CO₂ emissions from each of the four components discussed above for the options being evaluated by the City of Ames. The results show that Option 1 has the highest greenhouse gas emissions of CO₂ due to the high level of natural gas combustion in existing Units 7 and 8. The results are also graphed in **Figure 40**. All of the other options would yield similar greenhouse gas emissions, ranging from approximately 45% to 50% below the CO₂ emissions of Option 1. Option 3B-1 would have the lowest CO₂ emissions, but within a range of about 10% of the other options with a new dedicated waste combustion system. It should be noted that for each of these options with a new waste combustion system (Options 2A, 2B, 3A and 3B), the major component of their CO₂ emissions comes from replaced power, from the MISO grid, which is based on the EPA GHG value for power produced in Iowa of 611.1 pounds per MWhr. If the City were able to replace this power from renewable sources, it would eliminate this additional CO₂ emission from this component and significantly reduce the greenhouse gas emissions for these options.



Table 12: Net GHG Annual CO2 Emissions Based on Avg. Annual Waste Flows²⁶

Option	1	2A	2B	3A-1	3A-2	3B-1	3B-2
CO ₂ from Combustion of Non-Biogenic Fraction of Waste (TPY)	15,070	19,133	22,368	22,904	22,763	22,000	22,000
CO ₂ from Combustion of Natural Gas (TPY)	221,760	24,283	0	24,283	0	0	0
Equivalent CO ₂ from Landfilling of By-Passed Waste (TPY)	16,194	2,718	5,639	6,283	6,291	776	776
CO ₂ from Replaced Fossil-Based Power (TPY)	0	89,086	98,109	90,012	107,138	100,053	107,516
Total Equivalent CO₂ Emissions (TPY)	253,024	135,220	126,116	143,481	136,192	122,829	130,292

²⁶ CO₂ from Replaced Fossil-Based Power provided by US EPA Egrid CO₂ output emission rate for all fuels value for Iowa, 2020 (MISO Zone 3)

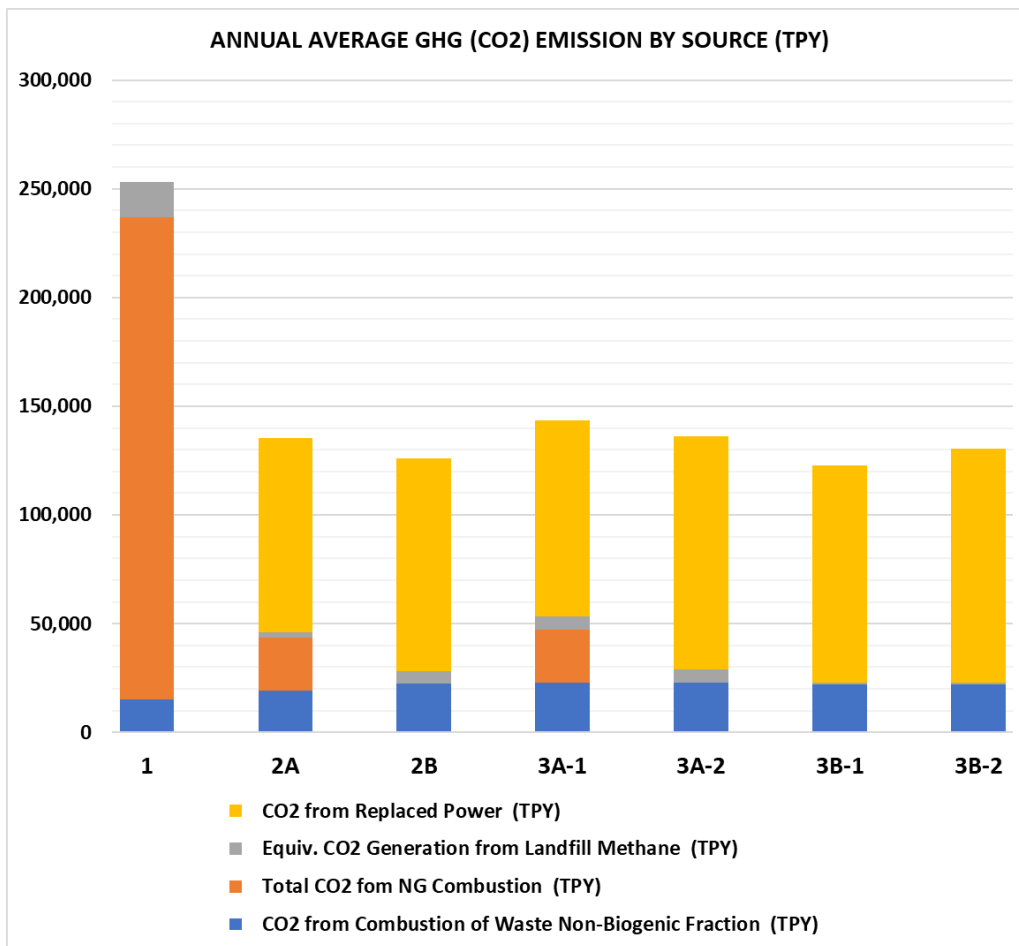


Figure 40: GHG Equivalent Emission for Each Option

5.2.3 Water, Utilities and Processing System Requirements

In all options, water is used in two forms: (a) makeup of water discharged from the boiler steam system for blowdown and (b) makeup water to the cooling tower which is lost due to evaporation caused by rejection of the residual Rankine cycle heat. The boiler water makeup is sourced from the City of Ames and treated through a reverse osmosis system to remove impurities, with the discharge concentrate going to City sewer along with the blowdown from the boilers. The cooling tower makeup water is provided from well water.

In all the Options except Option 1, water consumption will be approximately 10% of the current water usage due to the operation of RDF-only or MSW-only boilers, which have a significantly smaller steam cycle than the current co-fired boilers. For the limited times that Boiler 8 would be operating as a backup in Option 2A or 3A-1, the hourly water usage rate would be the same as in Option 1 Base Case.

5.2.4 Ash

The ash from the combustion of RDF or MSW contains heavy metals of environmental concern, requiring regular sampling and testing to ensure the leachability is below the EPA toxicity limits as determined by the Toxicity Characteristic Leaching Procedure (TCLP). The TCLP test involves the mixing of a sample of ash with an acidic solution for 18 hours. The solubility of heavy metals in the ash will be a function of the final alkalinity of the leaching solution, which in turn, is a function of the alkalinity content of the ash. The majority



of the alkalinity content in ash from the combustion of MSW comes from excess $\text{Ca}(\text{OH})_2$ from the scrubber, which is collected with the fly ash in the baghouse. The fly ash will then be mixed with the bottom ash from the combustor to produce a combined ash stream for disposal.

The two metals of primary concern in ash from the combustion of MSW are lead and cadmium. Cadmium is only soluble in acidic conditions, but lead is amphoteric, meaning it is soluble in acidic conditions, as well as very alkaline conditions. Both metals are insoluble at neutral to slightly alkaline conditions. To ensure waste-to-energy ash is non-toxic and passes the TCLP test, the alkaline content must be monitored and controlled to ensure the final pH of the TCLP test falls in the neutral to slightly alkaline range of 7.0 to 10.0. The excess $\text{Ca}(\text{OH})_2$ required in the scrubber to achieve efficient SO_2 and HCl removal is typically adequate to achieve the necessary alkalinity content in the combined ash exiting the waste-to-energy plant. But it will be important to monitor this alkalinity content through a regular ash sampling and analysis program.

Iowa regulations may require a regular ash sampling and analysis program to demonstrate compliance with the TCLP test. These ash sampling and analysis requirements vary widely between states, from a single ash sampling and analysis after start-up of the facility, to annual, quarterly or monthly sampling and analysis frequencies. Regardless of the States requirements, it is recommended that the owner/operator of a WTE facility establish a regular ash sampling and analysis program to demonstrate ongoing compliance with the Federal requirements on ash toxicity.

5.3 Program Impacts and Considerations

The City of Ames possesses a progressive waste management program and has been an industry leader for decades by its approach to utilizing waste as a resource. As the City reviews its options for the next 20 or more years, there are other program enhancements and modified approaches that could be considered, which are beyond an upgraded RRP and PP. Most of the following program considerations would require policy changes or revisions to how waste is managed throughout the area. This narrative is provided to allow for consideration by the City, but detailed analysis of the impact of each of these programs goes beyond the scope of this study and would require the City to make specific policy changes to implement.

5.3.1 Increased/expanded recycling program

Stakeholders in Ames have expressed interest in growing curbside recycling and drop-off programs in the city. There are some parties active in the recycling and solid waste management industry who have expressed the viewpoint that recycling and waste-to-energy are incompatible. This viewpoint argues that the demand for combustible, high heating value materials at combustion facilities competes with recycling programs and the diversion of paper and plastic. There are many long-standing programs in the U.S. and abroad where robust recycling programs and combustion-based disposal facilities thrive together. The following are two regional examples, but there are more across the country and in Canada:

- Pope/Douglas Solid Waste Management in Alexandria, MN, operates a waste-to-energy facility serving the two counties in its agreement in addition to several other surrounding counties. At the same time, a 2015 report by the Minnesota Pollution Control Agency on the state's Recycling and Solid Waste Infrastructure²⁷ showed that Pope and Douglas Counties recycled in excess of 14,000 tons of typical recyclables (paper, plastic, metal, and glass) from a combined jurisdiction of about 49,000 people, or 1.6 pounds per day. This is a commendable performance level.
- Olmsted County, MN, operates a WTE facility and is currently working with RRT to replace its existing recycling capacity with a more robust facility that is closer to the customers there—i.e., they need their own capacity rather than relying on farther-away capacity, despite having a WTE plant.

²⁷ <https://www.pca.state.mn.us/sites/default/files/w-sw1-09.pdf>



In energy recovery, one of the highest-value materials is plastic. Iowa’s container deposit system means that many plastic containers are diverted from disposal for redemption. Many aluminum containers are also redeemed, as are glass. The net impact of a curbside and/or drop-off recycling program in Ames, which would presumably siphon more metal, glass, and plastic from the material going to the WTE facility, would be marginal. Glass is actually undesirable in the boilers, and there is plenty of plastic still available in the waste stream despite additional plastic containers being recycled. In actuality, the loss of metal and its revenue stream to recycling is just as impactful to a WTE facility as the “loss” of plastic. These impacts are the same for all the Options discussed in this report.

Another consideration in starting or expanding a recycling program is the availability of MRF capacity. The return on investment for developing MRF lines is largely dependent on the volume of material to be processed, in addition to the quality. If the City wants to expand and develop a recycling program, it must consider both the availability of MRF capacity within economical hauling distance and/or the return on investment of building its own processing capacity.

5.3.2 Organics Diversion

The City has a program for diverting organic material from disposal. This is directly supportive of resource recovery. Combustion does not benefit from wet, heavy material. In addition to the moisture content, the material adds to the weight of each load in an economic system which uses tonnage as its primary cost driver. The Olmsted and Pope/Douglas programs mentioned above both have organics diversion as major parts of their programs. The Pope/Douglas program has 10 drop off sites for organics recycling,²⁸ and in August 2021 broke ground on an engineered composting facility to serve its two member counties along with four other surrounding solid waste agencies.²⁹

5.3.3 Outreach and Education Programs

A robust and valuable outreach and education program regarding conservation and waste reduction is possible in a community which uses WTE for disposal. After thirty years, the American public is acquainted with and accustomed to recycling. Whereas many legacy programs used aversion to landfilling as a motivator for recycling, individuals with lifelong familiarity with recycling know and/or can understand other reasons such as the per-ton costs of WTE and the climate impacts of using virgin materials in manufacturing. This knowledge and activism can also be harnessed to encourage organics diversion. While opponents of mixed waste processing, single stream recycling, and WTE have argued for decades that a waste system that is “too easy” discourages individuals from thinking about their waste and discards, this has proven untrue in communities across North America, Europe, and Asia. For example, Sweden, Denmark, and the Netherlands are among the countries with the most waste-to-energy facilities, and also possess some of the highest recycling rates in the world.³⁰

Information about emerging Federal grant funding opportunities for outreach and education is found in the subsection related to the RECYCLE Act of 2021 below.

5.3.4 Grant Funding Opportunities

State of Iowa Solid Waste Alternatives Program (SWAP)

SWAP works to reduce the amount of solid waste generated and landfilled in Iowa. Through a competitive process, financial assistance is available for a variety of projects, including source reduction, recycling and education. The program provides financial assistance in the form of forgivable loans, zero interest loans,

²⁸ <https://popedouglasrecycle.com/waste-type/organics-recycling-drop-sites/>

²⁹ <https://popedouglasrecycle.com/composting-facility-breaks-ground/>

³⁰ <https://news.climate.columbia.edu/2016/10/18/putting-garbage-to-good-use-with-waste-to-energy/>



and 3 percent interest loans. A 25% minimum cash match is required for each budget line item requesting funding assistance. Projects are selected through a competitive process. Emphasis for selected projects is placed on tonnage avoided or reduced, sustainability and ability to replicate.

Any unit of local government, public or private group or individual is eligible to apply for program funds. The City of Ames has been awarded SWAP grants three times in the past:

- In 1990 for a recycling drop-off center.
- In 2011 to purchase and put into service at the RRF an electronically driven transfer auger for the collection and processing of combustible fine materials.
- In 2016 for consulting work to develop and implement a 2-part study leading to enhanced waste diversion, increased efficiency, and increased awareness and understanding of citizen value and interest in additional waste management related services.

Funds can be used for such items as:

- Waste reduction equipment and installation
- Recycling, collection, processing, or hauling equipment (including installation)
- Development, printing and distribution of educational materials
- Planning and implementation of educational forums, workshops, etc.
- Purchase and installation of recycled content products
- Salaries directly related to implementation and operation of the project

Extra consideration is given to applications addressing large or hard-to-manage targeted waste streams.

Federal Legislation

Recently, two major pieces of Federal legislation have been passed which prioritize the recovery of recyclable materials as part of rebuilding the economy in this country to be less linear and more circular. The first is the Save Our Seas 2.0 Act of 2020 (sometimes abbreviated SOS 2.0) and the second is the Recycling Enhancements to Collection and Yield through Consumer Learning and Education Act of 2021 (usually referred to as The RECYCLE Act). Both of these programs have the stated purposes of improving recycling infrastructure, reducing waste, developing a circular economy, and building sustainability from a different perspective than in the past. Rather than setting performance measures along a linear economy, these two Acts aim to incentivize and support innovations and call for the development of infrastructure to support a more circular and sustainable approach. The intended result is both environmental protection and economic stability and prosperity.

Save Our Seas 2.0 Act of 2020

As the name would imply, Save Our Seas 2.0 has a stated purpose of reducing marine debris and ocean-bound plastics. It has three main Titles, or topics:

- Title I Combating Marine Debris
- Title II Enhanced Global Engagement to Combat Marine Debris
- Title III Improving Domestic Infrastructure to Prevent Marine Debris

Title I is about “strengthening the United States’ domestic marine debris response capability.” It primarily establishes a “Marine Debris Foundation” (Subtitle B) which is to be a charitable non-profit organization and not an agency of the U.S. government. The purpose of the Foundation will be to support the efforts of Federal agencies using private funds and to administer a newly-created “Genius Prize,” including developing the details of it and raising some of the funds associated with the effort. The description in the Act does not state who is eligible for entering the competition. Perhaps the Foundation would decide that when designing the competition.



Title II of SOS 2.0 is about “enhancing global engagement to combat marine debris, including formalizing U.S. policy on international cooperation, enhancing federal agency outreach to other countries, and exploring the potential for a new international agreement on the challenge.” It is mostly a policy statement, declaring that it is a priority of the U.S. Government to work with partners around the globe on these issues. These measures are more about activity at sea and working with other nations on the global problem of marine debris and ocean-bound plastics.

Title III provides for “improving domestic infrastructure to prevent marine debris through new grants for and studies of waste management and mitigation.” The concept is that, if plastics are more greatly valued because of improved ability to collect them, recover them as a commodity, and utilize them as a feedstock, then there should be less of them making their way into waterways. In essence, the economic system will want to retain something valuable rather than allowing it to be lost and end up in the oceans.

Although an act aimed at controlling marine debris might not seem immediately relevant to Ames, Title III of SOS 2.0 explicitly ties the urgency of marine debris and ocean-bound plastic to the need for improved domestic infrastructure to recover plastics and re-integrate them into the economy. It sets the stage for future innovative diversion programs to be part of an emerging new national strategy.

RECYCLE Act of 2021

The RECYCLE Act is part of a much larger legislative action, the Infrastructure Investment and Jobs Act and does two primary things: creates four new grant programs for recycling infrastructure and allocates funding for them, along with millions of dollars in new funding for the EPA’s existing Pollution Prevention (P2) grants program. In resource documents issued by the White House and as reported in industry and legal publications, the grant funding allocations for FY22 to FY26 (five years) are:

- \$20 million per year for Pollution Prevention grants (supplements existing program)
- \$55 million per year for the new SOS 2.0 Solid Waste Infrastructure for Recycling (SWIFR) grant program
- \$15 million per year for new Education and Outreach on prevention and recycling
- \$25 million, combined, for a new battery collection best practices program (\$10 million) and new voluntary labeling program (\$15 million)

A brief description of these grant programs is listed below. Where not otherwise cited, sources are the Administration guidebook and the EPA fact sheet.

Pollution Prevention Grants

Abbreviated P2, this is a long-time program at EPA and is open only to States, Tribes, State-Sponsored Institutions, or Tribal Institutions. It is not open to the City of Ames, but the State of Iowa could apply and support the City. The grantees use the funds to provide technical assistance to businesses so they can adopt source reduction practices and technologies which benefit their businesses and their communities. P2 grants are not limited to solid waste programs, and past projects have addressed water consumption, wastewater release, air emissions, and more.

SOS 2.0 and RECYCLE Act Grants

In introducing the new grant programs, the Administration’s guidance describes how the funding falls into four major areas: the SWIFR grants, the Reduce, Reuse and Recycle Education and Outreach Grants, and the two Battery programs (Best Practices and Voluntary Labeling). For each of these new programs, the guidance notes that stakeholder outreach and engagement to inform development of grant program will begin in the 2nd quarter of 2022 and advises eligible recipients to begin thinking about solid waste management infrastructure needs to advance their programs. Because these are new programs, the level of specificity for eligible projects is not available as it is for the P2 grant program. For the SWIFR and Recycling Education grants, the funding opportunity is estimated to be available in the 4th quarter of 2022.



The SWIFR grants—\$55 million per year for five years, available until expended—are provided in section 302(a) of the Save Our Seas 2.0 Act (Public Law 116–224). The grants are for projects to implement the National Recycling Strategy (prepared by the EPA), or other projects which support improvements to local post-consumer materials management, including municipal recycling programs. Importantly, the EPA has confirmed in public meetings that cities are eligible recipients of these grants. Thus, this is an entirely new grant funding opportunity.

The Reduce, Reuse, Recycle Education and Outreach Grants—\$15 million per year for five years, available until expended—will be focused on improving the effectiveness of residential and community recycling programs through public education and outreach. As with the SWIFR grants, cities are eligible recipients. The projects should inform the public about residential or community recycling programs, provide information about the recycled materials that are accepted, increase collection rates and decrease contamination.

5.3.5 Other Impacts and Considerations

Whenever new facilities are developed, regulatory agencies are not the only parties with concerns. Both individuals and organizations in the public will need to be engaged and their questions and apprehensions addressed. For example, while combustion is not new to Ames, there may be concerns about noise, odor, vehicle traffic, emissions, dust, and other “good neighbor” items, when developing a new facility, modifying structures/systems, or expanding the existing facility’s capacity. Options 3A-2 and 3B-2, where new facilities are being provided at a yet to be determined industrial site, will likely require a greater level of environmental assessment due to the change in location and operations for the City.

To address these concerns (at both a potential new site and the existing site), the City may need to perform a public outreach process to gather information, concerns, and key considerations for the siting and design of the selected option. In addition, a transportation study (as discussed in **Section 4.1**) could be performed to identify and describe environmental impacts due to additional or altered trucking, transfer, or right of way modifications necessary for implementing a specific option. This resulting information can help inform the public and decision-makers. There are also usually larger contextual impacts of development which will be important to various individuals and stakeholders, including the benefit of remediating brownfields, the value of economic development, environmental justice, user habits and expectations, etc. Other studies that might be helpful or required could include impacts on stormwater, soil conservation, wildlife habitat, or other environmental considerations.



Page 106 intentionally blank



6 TIMELINE OF COMPLETION

Option 1, the existing and currently operating RRP and PP, serves as the base case. There is no construction or timeline of completion of work required for the continued functioning of the plant.

In the various options evaluated, the new Resource Recovery Plant and new power plant will be constructed on one of three sites, depending on the option.

The three site options are listed below:

1. Installing new equipment in the renovated structures sections of the existing power plant and RRP, while using much of the existing structure and existing support facilities and equipment.
2. Constructing a new facility on the site of the existing coal storage yard. A significant portion of the existing refuse conveying, storage equipment, power production and power delivery infrastructure would be integrated and continue to be utilized.
3. Constructing an entirely new facility on a “green field” site located in or near an industrial area adjacent to a steam host to enable the sale of steam.

An estimated timeline of completion for key engineering, bid, permitting and construction activities is shown in **Figure 41**. A copy of the schedule is also found in **Appendix L**. Due to the details of the individual options not being fully designed, there will be some variance of activity durations between the new versus modified system options, but these were not included within this high-level assessment. It should be noted that the permitting activity, which will likely have a significant impact on the selected option’s overall timeline, is not included in the schedule below as it was specifically precluded in the City’s RFP document.

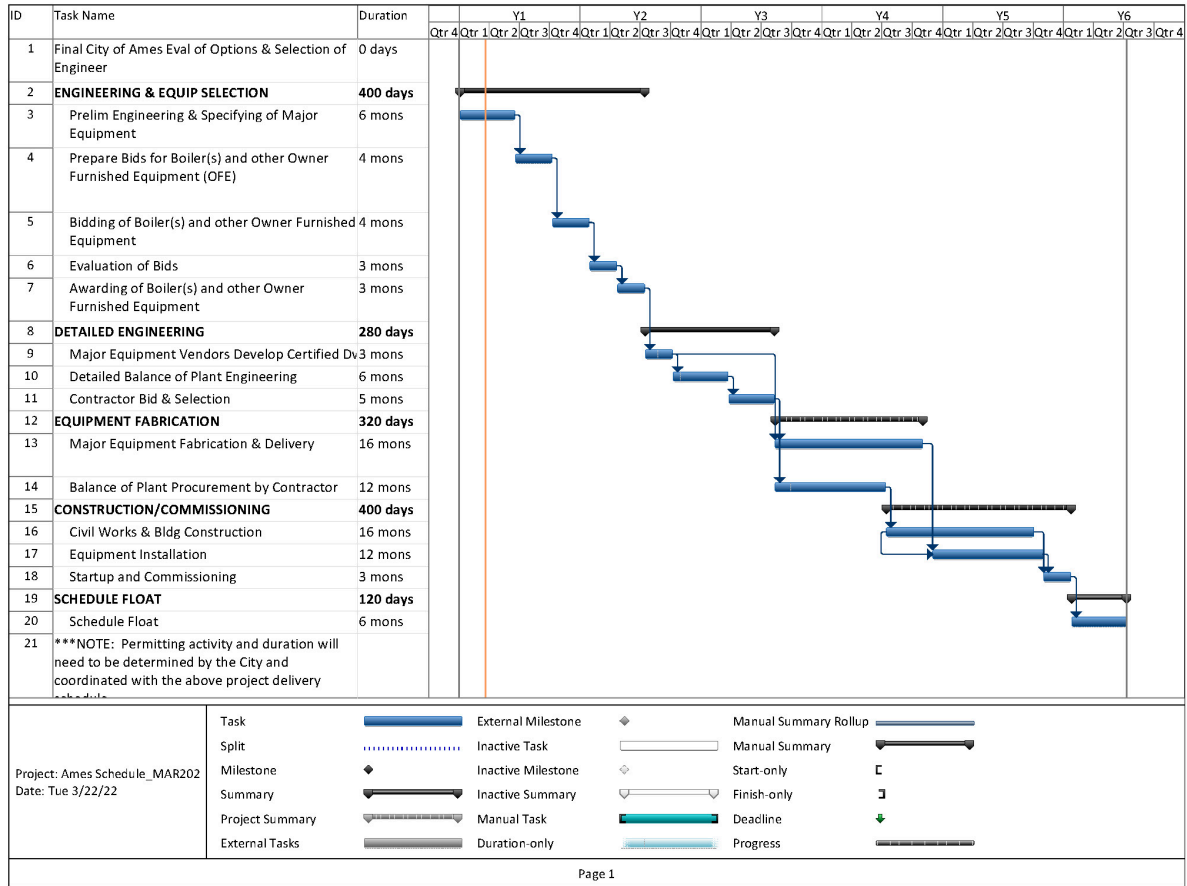


Figure 41: Estimated Timeline for Completing a Project

6.1 Considerations for Construction Inside Existing Buildings

In order to be able to utilize the existing structure for the new equipment (Option 2A), all of the existing equipment should be removed, and the remaining structural steel, piping and foundations should be inspected, and 3D scanned to create a set of baseline drawings. Then preparation of the structure in areas where the new equipment will interfere with the existing structure and/or reinforced or relocated must be accomplished prior to installing any of the new equipment. The loads from the new equipment must be supported on the existing piers and/or new piers. Structural members would likely need to be installed to receive the new equipment loads.

Construction access to the exterior walls and roof will be necessary to allow for installation of the equipment. The coal bunkers would be removed, and a replacement wall installed to enable use of the space for the new equipment. Delivery of the equipment, structural steel, piping and other large components will be delivered by train to a convenient rail siding and then by truck using local roads. Construction and laydown areas as well as trailer areas will be identified on the site for use by the contractor. Portions of the adjacent water treatment plant and/or the coal storage yard may be utilized for this purpose as well as contractor construction trailers and parking for construction workers. Careful planning will be required to arrange for the arrival of equipment to the site, storing it properly and transporting it to the erection locations in a smooth, productive workflow. A comprehensive safety program will be needed to account for the erection



of components above workers, prevent fires from welding, ventilation of the workspace, weather protection, fall protection and other potential hazards during the project.

A comprehensive commissioning and startup program will be developed using the engineer's and the manufacturers' specifications along with the owner's requirements to bring the completed facility into commercial operation.

6.2 Considerations for Construction on the Coal Yard

Construction of the new facility on the coal yard site is somewhat similar to working on a previously developed site. All existing underground utilities and structures would have to be identified and relocated or removed if they encroach on the location of the new facility.

The existing coal handling equipment would be protected from damage during the construction duration. The existing RDF handling system (for applicable options) would be modified and protected to be able to be put into service for the new facility. Interconnections to the existing services such as the conveyance lines would be coordinated with operations to minimize downtime.

Laydown and storage of the equipment delivered to the site could be accommodated on the coal yard site or on nearby available space. Construction trailers would be located on the coal yard site and on nearby areas either City owned or rented property.

Delivery of equipment and material would be shipped by train to one of many nearby rail sidings for large, heavy loads and then by truck for the balance.

Careful planning will be required to arrange for the arrival of equipment to the site, store it properly and transport it to the erection locations in a smooth, productive workflow. A comprehensive safety program will be needed to account for the erection of components over working crews, prevent fires from welding, weather protection, fall protection and other potential hazards during the project.

A comprehensive commissioning and startup program will be developed using the engineer's and the manufacturers' specifications along with the City's requirements to bring the completed facility into commercial operation.

6.3 Considerations for Construction of the new Facility on a "Greenfield Site"

The Greenfield site allows for construction of the new facility to be executed with the least interactions and no required shutdowns of the existing facilities. The actual site will need to be investigated for any underground utilities, structures and interferences so they can be addressed before construction commences.

Deliveries to the site would be by rail for large loads using nearby rail spurs and the balance of the trip by truck. Laydown and storage areas, as well as trailers for storage, offices and crew change trailers should be on adjacent areas of the new building site.

Careful planning will be required to arrange for the arrival of equipment to the site, store it properly and transport it to the erection locations in a smooth, productive workflow. A comprehensive safety program will be needed to account for the erection of components over working crews, prevent fires from welding, weather protection, fall protection and other potential hazards during the project.

A comprehensive commissioning and startup program will be developed using the engineer's and the manufacturer's specifications along with the City's requirements to bring the completed facility into commercial operation.

6.4 Key Activities and Narrative for all Options

Regardless of which site arrangement is selected, the following activities will be required:

- Detailed project execution plan,
- Comprehensive project controls process to manage and forecast progress, cost and schedule,



- Change process,
- Comprehensive safety program written specifically for the project,
- Permit compliance process,
- Detailed logistics and material control plan,
- Startup and commissioning plan,
- Quality Management Process.

The schedule presented in **Figure 41** is a high-level timeline of completion for the project. Each of the options will have some variability from this indicative schedule. The following items describe some of the key City and selected engineering activities necessary for execution of the options in the study. Due to numerous factors such as material availability, concurrent construction activities in the region, technology selected, permitting of a new or existing facility, coordination with a potential industrial energy user (as applicable), and other typical factors that affect construction the actual timeline of the project will likely vary from these early planning durations.

From the options presented in this report, the City should evaluate the technical and financial merit of each. Then the permitting of the top one or two options should be discussed with regulators to gauge the ability to permit the project. The City will likely want to take site visits to operating units of the preliminarily selected technologies either prior to or during the permitting discussion process. From these activities the City would then select one option to move forward, unless further review and analysis is needed by a consultant to support the City's decision between a couple of short-listed options.

During the selection of a preferred option, the City would select an engineer to lead the design and procurement of major equipment for the project using its normal procurement process. An environmental consultant will also be needed to provide the necessary support for the air permit and other DNR related requirements. The proper preparation may require detailed boiler emissions guarantees, stack sizing etc. The exact needs would be ascertained during conversations with the Iowa DNR. Equipment procurement will be required to select the boiler and emissions processing system (scrubber, baghouse etc.). The City's engineer would prepare the boiler and emissions bid specifications.

Using the boiler and emissions processing certified drawings, the Engineer will prepare the permit drawings for submittal to the IDNR and authority having jurisdiction. Site survey and site investigations (e.g., soil analysis, soil resistivity, steel inspections etc.) would be required.

The Permit application will be submitted to the IDNR for review and approval. Reconnaissance and permit expediting may accelerate this time period; however, the unknown is the public comment and community resistance/support for the application. Through the duration of the permit review the engineering consultant will continue work on the project by preparing the civil and structural design, remainder of the Balance of Plant (BOP) drawings, equipment specifications, etc. This documentation will serve to define in detail the scope of work required to be completed by the successful construction contractor. The Contractor selection process can occur prior to receipt of permit approval. The construction contract will not be released until the construction permit is released.

Once the contractor is released, they would release the major, and long lead equipment to the manufacturers (if not already released by the City). The BOP engineering must be completed during this time. The Contractor would order BOP components and materials, staffing procedures and mobilization equipment (trailers etc.). Once mobilized the Contractor will begin construction. It is recommended that the City nominate independent inspection of the equipment during manufacturing prior to shipment as well as during installation.



Civil and building construction would occur while fabrication of major equipment is underway. This will allow the building(s) to be ready for receipt of the equipment in a proper sequencing of construction. The major equipment and ancillary systems would be installed/constructed and lead into a start-up and commissioning phase.

The new equipment will be pressure tested, pre-functionally tested, bump tested, and functionally tested with each respective system. Once all systems are tested, they will be integrated together with a formal test and commissioning phase. The contractor would turn the facility over to the City after performance testing and commercial operation of the new and/or upgraded facility would commence.



Page 112 intentionally blank



7 ADVANTAGES AND DISADVANTAGES OF PROPOSED OPTIONS

The following section details several advantages and disadvantages of each option analyzed. The listed “pros” and “cons” of each option should not be taken as recommendations, but rather key technical, environmental, and financial considerations to compare each option to the other options considered in this study. The descriptions within the individual options are only a partial list of advantages and disadvantages and a more complete comparison table is provided in **Appendix M**.

7.1 Option 1 – Resource Recovery and Power Plants As-is (Base Case)

One of the key reasons this study was commissioned by the City was to plot the course for the next 20 years of their RRP and PP facilities and the associated systems to process the City and surrounding area’s MSW, protect the environment, and create usable energy. The existing system has worked very well for most of the last 40 years but has some aging components and affecting reliability and the associated costs with combusting RDF with natural gas.

Advantages

The base case has a few advantages as compared to the other options in this study and includes the following:

- There will not be any downtime for construction, which will be required for all other options being considered.
- No new major capital expenditures other than the regular annual maintenance and general capital improvement projects.
- The base case does not require any new buildings to be constructed and thus it will save on capital costs and associated soft costs for engineering and permitting of the facilities.
- The City staff will save significant time and effort with the base case as they will not be required to manage the planning, engineering, permitting and construction required for all the other options in the study.
- The other options will require new debt service and thus is an advantage of Option 1.

Disadvantages

The existing operations of the base case were discussed in detail with the City staff and through RRT’s technical and financial analysis the following list of key disadvantages was developed.

- Re-occurring issues with the existing RDF storage bin.
- High corrosion issues at boiler (Units 7 and 8) which have hopefully been addressed with recent boiler tube coating projects but could potentially continue to be an issue. The higher boiler steam temperature conditions of the existing system contribute to the corrosion issue.
- One of the biggest disadvantages with the base case is the significant cost of natural gas to co-fire with RDF in both Units 7 and 8 as required by the operating permit’s limitation of 30% RDF to 70% natural gas, by weight. At the modeled throughput and \$5/dth gas, this represents approximately \$11-13M annually in power costs over the cost to purchase the same power from the MISO in the other options.
- The City’s electric generation is closely coupled to the price of natural gas (which has been more volatility recently) as a result of the large (70% or more) natural gas co-firing requirement under the PP Title V air permit. Therefore, the City of Ames Electric Department is not able to take advantage of the increasingly available, lower cost, renewable electric energy available in Iowa.



- The current system (Option 1) is already at its total RDF processing capacity, which will result in a much higher amount of MSW taken to the landfill over the next 20 years.
- The co-combustion of natural gas with RDF creates the most GHG emissions as compared to the other options considered.

7.2 Option 2A – Existing RRP with a New RDF Combustion Unit in the Existing PP

Option 2A utilizes the existing RRP and addresses a few existing processing system issues, but primarily this option replaces the existing co-fired boilers with a new RDF boiler for combustion of only RDF during normal operations (outside of start-up, shutdown, and backup operating modes). This option provides several advantages over the current operations, and these are listed below:

Advantages

- Some system limitations in the RRP plant will be addressed such as improved throughput and increase material separation efficiency, including a new air knife and eddy current separator.
- A cost savings compared to other new RDF options by re-use of the existing RRP building and power equipment in the existing PP.
- Significant reduction of natural gas usage as compared to Option 1. Only back-up operations (utilizing Unit 8) and start-up will require natural gas.
- The new RDF unit would not require natural gas for normal operations and therefore the operating costs will be significantly reduced as well as GHG emissions.
- The impact of changes in natural gas prices on PP operating costs would be much smaller due to the reduced reliance on natural gas.
- ST5 would serve as additional generation capacity.

Disadvantages

- Required system downtime to construct RRP modifications to improve operations as well as time to construct and tie in the new RDF boiler (Unit 9) to the existing base plant at the power plant.
- Co-firing of natural gas with Unit 8 during backup mode is still required when the new RDF boiler is unavailable. This brings with it the continued reliance on natural gas, its associated higher GHG emission rate, and higher operating costs during co-firing.

7.3 Option 2B – Modified RRP (20" RDF) with Two New RDF Combustion Units

Option 2B takes the existing RRP and modifies it to provide a coarse shred (20" minus) RDF for combustion in two new boilers at the coal yard.

Advantages

- New RRP equipment versus older equipment in Options 1 and 2A.
 - Less equipment compared to 3A and 2A and thus less O&M.
 - The newer equipment and fewer hours of operation will also reduce O&M.
 - Increased throughput, but still provides metal recovery and fines removal.



- Less overall capital expenditure as compared to Options 3A and 3B, which are primarily new construction options.
- With two redundant combustion units, Unit 8 will not be needed for back-up therefore reducing the use of natural gas and the amount of GHG emissions.
- ST5 would serve as additional generation capacity.

Disadvantages

- This option will require new RDF storage and conveyance to the boilers because the current pneumatic feed system will not accommodate the larger RDF material. The conveyance system to transfer the larger RDF material and the new PP combustion units will increase the associated capital costs in this option as compared to Options 1 and 2A.
- Option 2B will also require two new MSW boilers (similar to mass burn MSW boilers) to combust the larger RDF material. This larger material will not allow Unit 8 to be utilized as a back-up boiler for combustion of waste, thus increasing capital cost.
- There will be a significant system down-time to install the new equipment in the existing RRP.
- Additional workforce will be required at the PP to load the boiler with the larger RDF (end-loader or material handler), but this is balanced by the reduced RRP staff.

7.4 Options 3A-1 & 3A-2: New RRP and New RDF Combustion Unit(s)

Option 3A consists of two sub-options with a new facility at the existing coal yard (Option 3A-1) and a greenfield site located adjacent to an industrial user (Option 3A-2) that will take steam from the plant. Option 3A will have the greatest amount of new equipment, compared to all options, and will include a new state-of-the-art RRP.

Advantages

- S-O-A RRP with new equipment
 - Increased throughput requiring potentially fewer shifts
 - Increased RDF recovery and quality from the MSW
 - Better metal recovery (increased quantity and quality for resale) and removal of rejects
 - Both the building and RDF bin will be new and will result in less downtime during construction than options by allowing the City to utilize the existing RRP building and associated systems.
- Reduced RRP operating costs from the base case because of increased processing throughput.
- Redundancy of RDF storage bins/systems will provide greater reliability and less downtime during maintenance for either of the bins.
- Option 3A-2 also provides the additional benefit of alternative revenue from steam sales versus electrical sales.
- Improved emissions and GHG impacts on the environment.



- Natural gas usage reduction for Option 3A-1 (Unit 8 as back-up) and almost entirely reducing natural gas usage for Option 3A-2 (gas for start-up only). This will result in significant financial savings on operations and a reduced GHG impact.
- For 3A-1, ST5 would serve as additional generation capacity for the City.

Disadvantages

- Requires additional maintenance due to the increased amount of equipment.
- As a result of this new equipment, this option has the largest capital cost of the RRP evaluated systems.
- Option 3A-2 will require land purchase or lease next to an industrial location.
- Option 3A-2 is dependent on the long-term sale of steam which brings with it the associated contractual, operational, and market risks of the host industry.
- Option 3A-2 would not provide the City with incremental electric generation as all the energy produced would go to an industrial steam user.

7.5 Options 3B-1 & 3B-2: Two New MSW Mass Burn Combustion Units

Option 3B has two sub options considered with two new MSW combustors at the existing coal yard (Option 3B-1) and a greenfield site adjacent to an industrial user (Option 3B-2).

Advantages

- No RRP equipment and less overall equipment, resulting in less overall maintenance than the other options.
- Metal recovery is still achieved after combustion and the system is moderately less expensive than front-end metal recovery.
- Mass burn combustion of MSW is a widely used and accepted approach to processing waste and has a variety of suppliers.
- The existing buildings would not be altered significantly in Option 3B-1 and therefore most of the construction could occur without interrupting existing operations. For Option 3B-2 there would be no interruption to existing operations.
- For Options 3B-1 and 3B-2 the existing boilers (Units 7 and 8) could remain as capacity resources for the MISO burning natural gas only.
- The greatest level of landfill diversion by volume of all options considered (2nd highest by mass).
- The new ST5 would serve as incremental capacity.
- Option 3B-2 also provides the benefit of alternative revenue from steam sales versus electrical sales.

Disadvantages

- Option 3B is a change in how the City has traditionally processed MSW.



- The unremoved fines and bulky material will wear the equipment and the boiler faster and thus require increased maintenance.
- The recovery rate and value of the metals from post-combustion processing will both be reduced with these two mass burn options.
- The mass-burn combustion emits higher NOx and CO raw emissions.
- Option 3B-2 would not provide the City with incremental generation as all the energy produced would go to an industrial steam user.

Page 117 concludes this document



RRT Design & Construction
A Service of Enviro-Services & Constructors, Inc.
1 Huntington Quadrangle, Suite 3S01
Melville, New York 11747
631-756-1060
631-756-1064 (fax)
info@rrtenviro.com
www.rrtenviro.com