ENERGIZE MISSOURI

RENEWABLE ENERGY STUDY SUBGRANT

Missouri Department of Natural Resources

Waste to Energy

Subgrant Award No: G11-SEP-RES-15

Prepared for -

Missouri Department of Natural Resources

January 2011

Project No. 58155

Prepared by -

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The ***Energize Missouri Renewable Energy Study Subgrant*** program was created to increase the ability of businesses, governments and organizations to make informed decisions about complex renewable energy systems by understanding and solving information deficiency and technical uncertainties. Program funds are made possible through the American Recovery and Reinvestment Act and the Transform Missouri initiative and administered by the Missouri Department of Natural Resources.

***Acknowledgment*:** "This material is based upon work supported by the U.S. Department of Energy through the Missouri Department of Natural Resources under Award Number DE-EE0000131." ***Disclaimer*:** "This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof."

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1.0 EXECUTIVE SUMMARY

1.1 INTRODUCTION

The Missouri Department of Natural Resources (MDNR) selected Burns & McDonnell to conduct a renewable energy assessment for facility options to convert waste to energy (WTE) (the Study). The purpose of this Study is to perform a waste generation review and technology reviews for the selected treatment options which would beneficially utilize municipal solid waste (MSW), generated in the Kansas City, MO region, for power generation. For each treatment option, a technology was selected for further examination of scope, performance, capital cost and environmental compliance.

This Study was conducted in several phases consisting of a regional waste generation review and facility siting / utility interconnection study, technology reviews, facility permitting and regulatory reviews, indicative facility performance approximations, and pre-feasibility capital cost and preliminary emissions estimating. In the initial phase of the Study, Burns & McDonnell conducted a preliminary review of the waste generated in the Kansas City, MO region in order to finalize each facility size. All treatment options are sized to convert 600 tons per day (tpd) of MSW to energy in the form of electricity. Each 600 tpd treatment option is considered a medium sized commercial facility. After technology and facility size selection were completed, the facility permitting and regulatory reviews were conducted. Finally, feasibility level performance, capital cost, and emissions estimates were finalized.

1.2 WASTE GENERATION REVIEW

Based on the solid waste generation review conducted for the Kansas City, Missouri region, a MSW feed rate of 600 tpd was selected. The facility is sized to accommodate medium to large populated cities or areas within the state of Missouri while taking advantage of the economies of scale of a large WTE facility.

The assumed higher heating value (HHV) of the MSW fuel is 5,000 British thermal units per pound (btu/lb). This HHV is representative of generic residential MSW, which is generally comprised of discarded materials including glass, paper, food residues, yard trimmings, textiles, plastics, and similar waste products. The content and consistency of MSW can vary greatly depending upon location, city, region, and country. Household hazardous wastes (HHW), toxic chemicals, and bulky items larger than 48 inches do not normally form a part of the MSW feed used in WTE plants and this Study assumes these items are not constituents of the MSW delivered to the WTE facility. For screening-level comparison of

the various options considered in this Study , it has been further assumed the MSW will be delivered by truck and that only short term storage will be available onsite.

1.3 TECHNOLOGY REVIEW

A technology review was conducted for each MSW treatment option with specific emphasis on those believed to be commercially available, having operational experience in North America and applicable for MSW fuel. Of the almost 90 WTE facilities currently operating in North America, the majority utilize a conventional combustion technology: a mass burn waterwall boiler. Mass burn combustion of MSW is considered the most proven method for energy production. Plasma gasification, although not a new technology, is not as prevalent in North America for gasifying MSW; there are several plasma gasifiers installed globally, primarily in Japan and Europe. Additionally, there are several plasma gasification technologies with test facility installations and/or proposed commercial scale facilities in North America. Of approximately 40 facilities in the United States which make or utilize refuse derived fuel (RDF), there are few operating facilities which co-fire RDF with coal to generate power. Several more facilities have been de-commissioned, primarily due to economic factors.

For the three MSW treatment options evaluated, the corresponding technologies were selected:

1. Gasification – Plasma technology
2. Mass burn – Waterwall boiler with stoker grate technology
3. RDF – Shredded RDF to be processed and co-fired at an existing coal-fired power facility

The three selected technologies were investigated to define screening level capital cost, performance, and emissions estimates. The summary results of the technologies evaluated are presented in Table 1-1.

Table 1-1: Summary Comparison of Technologies

Description		Gasification	Mass Burn	RDF Co-Firing 850 MW PC Unit	
Project Description					
Technology		Plasma Arc Gasifier	Waterwall Boiler	Existing PC Boiler	
Power Generator		Recip Engines	Steam Turbine	Steam Turbine	
Availability Factor (%)		85%	85%	0.85	
Feedstock		MSW	MSW	MSW RDF	
Heat Rejection		Wet Cooling Tower	Wet Cooling Tower	Wet Cooling Tower	
Type of NOx Control		Good Combustion Practices / SCR	SNCR	SCR	
Type of SO2 Control		SulfaTreat	FGD (dry)	FGD (wet)	
Type of Particulate Control		Scrubber	Fabric Filter	Fabric Filter	
Type of Mercury Control		Carbon Bed	Fabric Filter	Fabric Filter	
Type of CO Control		Good Combustion Practices / CO Catalyst	Combustion Practices	Combustion Practices	
Performance				**100% Coal**	**97% Coal / 3% RDF**
Net Plant Output	kW	20,000	15,000	850,000	848,000
Net Plant Heat Rate (HHV)	Btu/kWh	13,800	16,700	8,970	9,000
Heat Input, MSW Fuel (HHV)	MMBtu/h	250	250	NA	240
Heat Input, Other (HHV)	MMBtu/h	25	NA	7,625	7,390
Net Plant Output Attributable to MSW fuel	kW	18,200	15,000	0	25,200
Net Plant Output Attributable to Other fuel	kW	1,800	0	850,000	822,800
Net Plant Output Attributable to MSW	kWh/ton	730	600	NA	1,010
	kW/tpd	30	25	NA	40
Capital Cost (4Q$2010)					
Total EPC Cost (excluding Owners Cost)	$MM	$ 232	$ 138		$ 46
$/kW, Attributible to MSW/RDF ONLY	$/kW	$ 12,750	$ 9,220		$ 1,810
$/annual ton design capacity, MSW	$/tpy	$ 1,250	$ 740		$ 240
Anticipated Emissions Limits					
NO_x	ppm	82	130		TBD (Based on existing facility air permit and emissions test data)
SO_2	ppm	NA	4.1		
CO	ppm	270	150		
PM/PM_{10}	mg/dscm	NA	9.2		

NOTES:

General

1. All estimates in this table are "screening level" in nature, do not reflect guaranteed information and are not intended for budgetary purposes or project approvals. Estimates concentrate on differential figures between generic options and not absolute values.
2. MSW and RDF fuel higher heating value (HHV) is assumed at 5,000 btu/lb and 7,000 btu/lb, respectively.

Performance

1. Calculations are based on standard combustion calculations and annual average termperature conditions.
2. For plasma gasification, other fuel is met coke and the feed rate is estimated to be 4% of MSW feed rate (24 tpd) at a HHV of 12,600 btu/lb.
3. For RDF co-firing, the 850 MW 100% coal option is included as reference. Other fuel is powder river basin (PRB) coal with a HHV of 8,300 btu/lb.

Capital Cost Estimates

1. Capital costs are based on an engineer, procure, construct (EPC) contracting approach.
2. Capital costs are presented in 2010 dollars.
3. Capital costs exclude escalation, interest during construction, fincancing fees, off-site infrastructure and Owner's costs.

Emissions Limits

1. Emissions limits are anticipated and provided as a basis for selecting air pollution control equipment.
2. For reciprocating engines, utilzed for power generation in the plasma gasification facility, SO_2 and PM limits are not defined as there is no technically feasible control method for an internal combustion engine.
3. Limits are for stack source points only.
4. For the RDF co-firing, the emissions limits are to be determined based on existing facility air permit and emissions test data.

1.4 CONCLUSIONS & RECOMMENDATIONS

The findings, being reported as part of the Study, are inconclusive that one treatment option should be chosen over another. The selection of a treatment option will depend on specific area economic factors, such as tipping fees and power prices. If any technology appears of interest from this initial assessment, Burns & McDonnell recommends performing additional detailed studies to further define a project and its economic viability.

Burns & McDonnell recommends the MDNR utilize the information presented in this Study as a guideline only to share with Missouri utilities and landfill owners to assist them in determining if a selected WTE technology merits further development for its generation fleet.

If a Missouri utility or landfill owner decides to proceed with development of a WTE generation facility, then Burns & McDonnell recommends that the utility or landfill owner proceed with the following steps:

- Meet with the MDNR to discuss how MSW options will be evaluated from a New Source Review (NSR) and New Source Performance Standard (NSPS) standpoint.
- Follow regulatory process to determine what Best Achievable Control Technology (BACT) and Maximum Achievable Control Technology (MACT) requirements will be required.
- Gather vendor emission quotes for MSW treatment options.
- Perform a detailed fuel supply study to identify and evaluate available fuel supplies, budgetary costs for delivery of MSW and determine a range of MSW analyses.
- Perform a detailed feasibility study for any option of interest, including a comprehensive site review with site layouts, detailed performance estimates and development of cost estimates for budgeting purposes.
- If proceeding with a RDF co-firing option, engage existing boiler original equipment manufacturer to determine technical feasibility of the project and required boiler modifications scope of work and performance impacts.

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2.0 INTRODUCTION

2.1 GENERAL INFORMATION

The MDNR selected Burns & McDonnell to participate in the Energize Missouri Renewable Energy Study Subgrants program by providing a feasibility level renewable energy study for converting MSW to electricity.

This Study provides screening-level information for three MSW treatment options to convert MSW to energy. The screening-level information includes pre-feasibility level cost estimates, indicative facility performance and preliminary emissions estimates for each option. The proposed facility focuses on the use of generic MSW such that the project is applicable and replicable at landfill sites within the state of Missouri. The treatment options assessed include mass burn, plasma gasification and co-firing RDF at an existing coal-fired facility.

2.2 STATEMENT OF LIMITATIONS

In preparation of this evaluation, Burns & McDonnell has relied upon publically available information and information supplied by technology providers. While Burns & McDonnell has no reason to believe that the information provided, and upon which Burns & McDonnell has relied, is inaccurate or incomplete in any material respect, Burns & McDonnell has not independently verified such information and cannot guarantee its accuracy or completeness.

The information presented herein should serve as preliminary information to enable a Missouri utility, landfill owner/operator, or developer to select a technology of interest for further evaluation. Any and all technologies of interest should be analyzed in additional detailed studies to investigate each technology and its direct application within an owner's resource plan.

Estimates and projections prepared by Burns & McDonnell relating to performance and capital costs are based on Burns & McDonnell's experience, qualifications and judgment as a professional consultant. Since Burns & McDonnell has no control over weather, cost and availability of labor, material and equipment, labor productivity, construction contractor's procedures and methods, unavoidable delays, construction contractor's method of determining prices, economic conditions, government regulations and laws (including interpretation thereof), competitive bidding and market conditions or other factors affecting such estimates or projections, Burns & McDonnell does not guarantee that actual rates, costs,

performance, schedules, etc, will not vary from the estimates and projections prepared by Burns & McDonnell.

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3.0 TECHNOLOGY ASSESSMENT BASIS

3.1 GENERAL ASSUMPTIONS AND CLARIFICATIONS

- Facility utilities, such as potable water supply, waste water discharge, electrical transmission to the grid and natural gas are assumed to be delivered to the site boundary by others. Residue, the material remaining after treatment which contains non-combustible fuel components, is delivered to an on-site landfill. Ferrous and non-ferrous metals are not recovered from the residue prior to disposal.
- Operational costs are not provided for the screening level Study as air quality control system (AQCS) consumable usage rates are determined by a number of factors including air permit limits, chlorine and sulfur content of the fuel, and effectiveness of the selected control devices. In general, all WTE facilities will utilize a form of ammonia to control the emissions of nitrogen oxides (NO_x) and a form of lime and/or carbon to control particulate matter (PM), acid gases, mercury and dioxins/furan.
- All estimates are screening level in nature and are not intended for guarantees or project approval purposes. Estimates concentrate on differentials between options and not absolute numbers.
- Plant site is based on a greenfield site for plasma gasification and mass burn and a brownfield site for RDF processing and co-firing.
- All performance estimates are based on new and clean equipment. Degradation is not included.
- Emission limits are anticipated and provided as a basis for selecting air pollution control equipment included in the capital cost estimates.
- Process water is municipal potable water supply delivered to the site boundary by others.
- Auxiliary fuel for startup, if required, is available and delivered to the site boundary by others.
- Off-site electrical transmission is by others.
- A wet cooling tower is utilized for heat rejection.
- Process water discharge does not include stormwater runoff.
- Onsite infrastructure including fuel gas pipelines and raw water supply within the site boundary are included.
- Gas engines and steam turbine systems are located indoors.

- Estimate for mass burn process water supply rate is based on the average of existing plant data published by Anthony LoRe and Kelsi Oswlad (2009) in Benchmarking Mass Burn WTE Facility Performance, How does your facility measure up?, 17th Annual North American Waste-to-Energy Conference.
- For plasma gasification, process waste water is treated on-site and utilized for makeup.

The following general assumptions were utilized to calculate performance estimates:

- Annual average temperature conditions.
- No consideration of degradation over the operating life of the plant.
- Performance calculations are based on standard combustion calculations utilizing the following fuel characteristic assumptions:
    - MSW: 18.5% ash, 31% moisture, and 0.1% sulfur; 5,000 Btu/lb (HHV)
    - RDF: 4.3% ash, 18% moisture, and 0.1% sulfur; 7,000 Btu/lb (HHV)
    - PRB: 5.5% ash, 30% moisture, and 0.3% sulfur; 8,300 Btu/lb (HHV)
    - Metallurgical (met) coke: up to 10% ash, 5.75% moisture, and up to 1.25% sulfur; 12,600 Btu/lb (HHV)

3.2 CAPITAL COST ASSUMPTIONS

Capital cost estimates are screening level in nature, do not reflect guaranteed costs, and are not intended for budgetary purposes. The estimates concentrate on differential costs between options and not absolute costs. Capital costs are reported as dollars per annual ton design capacity. All facility options process 600 tpd at an assumed 85% plant capacity factor, therefore, the annual design capacity is 186,150 tons per year.

Capital costs for the facility options were developed using in-house experience and sources, including but not limited to, internal cost estimating means and methods, as well as external vendor quotations as obtainable.

The following presents general assumptions utilized in the capital cost estimates:

- All costs are presented in 2010 dollars and exclude escalation, interest during construction, financing fees, and off-site infrastructure.
- Sufficient area to receive, assemble, and temporarily store construction materials is available.
- Rail access is nearby and suitable for receipt of heavy equipment.

- A clear, flat site is assumed. Rock, existing structures, underground utilities, hazardous substance, or other obstructions will not be encountered in the area of the plant.
- No aesthetic landscaping or structures are included.
- Construction costs are based on an engineer, procure, and construct (EPC) philosophy.
- Owner's costs are excluded.

The following project indirect costs are included in capital cost estimates:

- Performance testing and continuous emission monitoring system /stack emissions testing (where applicable)
- Initial fills and consumables, preoperational testing, startup, startup management, and calibration
- Construction/startup technical service
- Site surveys and studies
- Engineering and construction management
- Construction testing
- Operator training
- Startup spare parts
- General liability insurance

3.3 CAPITAL COST EXCLUSIONS

The following costs are excluded from the capital cost estimates:

- Land
- Water rights
- Piling
- Off-site improvements including, road, bridge and rail tracks, fuel gas and water pipelines, and transmission lines outside of site boundary
- Owner's corporate staffing
- Sales tax and duties
- Escalation
- Financing fees
- Interest during construction
- Utility connections to site
- Transmission upgrades
- MSW delivery trucks

- All Owner's costs including, but not limited to:
  - Project development
  - Operations personnel
  - Legal costs
  - Corporate staffing
  - Owner's engineer
  - Permitting and licensing fees

3.4 EMISSIONS ASSUMPTIONS AND CLARIFICATIONS

- All WTE technologies treating MSW produce air emissions. For mass burn and co-firing, the stack air emissions are a result of conventional combustion of the MSW. In plasma gasification treatment, the stack air emissions are an effect of combustion of the syngas produced from the gasification process. The actual stack emissions rates are dependent upon the fuel composition and AQCS installed downstream of the MSW combustion (for mass burn and RDF co-firing) or upstream of the syngas combustion point (for gasification).
- For the conceptual, screening level emissions assessment, air emissions discussed herein include the key substances of concern that would be released from the main stack (point source). Emissions include, but are not limited to, the following criteria air pollutants: particulate matter (PM), sulfur dioxides (SO_2), oxides of nitrogen (NO_x), and carbon monoxide (CO). Referenced herein, in less detail, are hazardous air pollutants (HAPs) consisting of organic constituents, trace metals, acid gases, mercury, polycyclic hydrocarbons, and dioxins and furans, as well as greenhouse gases (GHGs) consisting of mainly carbon dioxide (CO_2).
- As a distinct fuel analysis is not available and technology suppliers are not engaged due to the conceptual phase of this assessment, expected emissions rates are not being reported; however, the anticipated emissions limits are discussed and presented for each technology.
- Anticipated emissions limits represent our research of required NSPS and/or BACT emission limits at this time. Actual NSPS and/or BACT determination will require more definitive information about the project site and fuel selection and will not be fully realized until the air permit application is complete.
- Emission levels are location, fuel and technology specific. Anticipated emission limits provided herein are not definitive. NSPS and/or BACT emission levels change with time, unit type, and fuel type.

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4.0 SOLID WASTE GENERATION

Solid waste generation in the Kansas City, Missouri region was assumed to include incorporated cities in Cass, Clay, Jackson, and Platte counties. Additional assumptions for waste generation projections include:

- Population increases per Mid-America Regional Council (MARC), *Long Range Forecast*, February 2006
- Residential and commercial waste and construction and demolition (C&D) waste per capita generation rate increases of 0.64 percent and 0.42 percent, respectively, annually per Franklin Associates, a Division of ERG, *Strategic Directions and Policy Recommendations for Solid Waste Management in the Bistate Kansas City Metropolitan Region*, October 2003 http://www.marc.org/environment/solidwaste/pdfs/statusreport.pdf
- No change in current management programs or diversion rates

Waste generation projections were completed for years 2010, 2015, and 2020. The residential and commercial waste summary is included in Table 4-1.

Table 4-1: Residential and Commercial Waste Projections

Year	County	Population	Residential and Commercial Waste (tons)
2010	Cass	71,633	53,323
	Clay	102,652	79,281
	Jackson	799,826	698,224
	Platte	27,655	20,580
	Total	**1,001,766**	**851,408**
2015	Cass	78,567	60,405
	Clay	109,850	87,530
	Jackson	815,842	734,437
	Platte	29,467	22,666
	Total	**1,033,727**	**905,037**
2020	Cass	85,502	67,890
	Clay	117,049	96,229
	Jackson	831,857	772,263
	Platte	31,280	24,865
	Total	**1,065,687**	**961,247**

Notes:
1. Values obtained from Strategy for Sustainable Solid Waste Management, Burns & McDonnell, March 2009.

C&D waste is typically categorized as one waste stream; however, it consists of two distinct sectors: construction waste and demolition waste. Construction waste is typically homogeneous, cleaner, and can be separated with relative ease. Demolition waste tends to be mixed material, and is more difficult to separate. Approximately 10.8% of Missouri's C&D waste is categorized as construction and 89.2% is classified as demolition per Midwest Assistance Program (MAP), *The 2008 Missouri Waste Composition Study*, March 2009 (http://www.dnr.mo.gov/env/swmp/docs/wcs2008.pdf).

The C&D waste summary is presented in Table 4-2. Because some treatment technologies being evaluated require a more intensive up-front screening of the fuel, the C&D waste in the region was estimated two ways:

- Inclusive of all construction and demolition waste
- Excluding metal and masonry from the construction and demolition waste estimates (masonry includes inert materials, such as brick, concrete, rock, and soil)

Table 4-2: Construction and Demolition Waste Projections

Year	County	Population	Total C&D Waste (tons)	Construction Waste[2] (tons)	Separated Construction Waste[3] (tons)	Demolition Waste[4] (tons)	Separated Demolition Waste[5] (tons)	Total Segregated C&D Waste (tons)
2010	Cass	71,633	23,125	2,498	2,238	20,628	17,451	19,689
	Clay	102,652	36,134	3,903	3,497	32,232	27,268	30,765
	Jackson	799,826	322,599	34,841	31,217	287,758	243,443	274,661
	Platte	27,655	8,543	923	827	7,621	6,447	7,274
	Total	**1,001,766**	**390,402**	**42,163**	**37,778**	**348,238**	**294,610**	**332,388**
2015	Cass	78,567	25,928	2,800	2,509	23,127	19,566	22,075
	Clay	109,850	39,473	4,263	3,820	35,210	29,788	33,608
	Jackson	815,842	335,773	36,264	32,492	299,510	253,385	285,877
	Platte	29,467	9,318	1,006	902	8,312	7,032	7,934
	Total	**1,033,727**	**410,492**	**44,333**	**39,723**	**366,159**	**309,771**	**349,493**
2020	Cass	85,502	28,838	3,115	2,791	25,724	21,762	24,553
	Clay	117,049	42,938	4,637	4,155	38,300	32,402	36,557
	Jackson	831,857	349,361	37,731	33,807	311,630	263,639	297,446
	Platte	31,280	10,122	1,093	980	9,029	7,639	8,618
	Total	**1,065,687**	**431,259**	**46,576**	**41,732**	**384,683**	**325,442**	**367,174**

Notes:

1. Values obtained from Strategy for Sustainable Solid Waste Management, Burns & McDonnell, March 2009.
2. Construction waste accounts for approximately 10.8% of the total C&D waste (MAP, 2009).
3. Metal and masonry materials (approximately 10.4%) was removed from the total construction waste tonnage (MAP, 2009).
4. Demolition waste accounts for approximately 89.2% of the total C&D waste (MAP, 2009).
5. Metal and masonry materials (approximately 15.4%) was removed from the total demolition waste tonnage (MAP, 2009).

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5.0 FACILITY SITING AND UTILITY INTERCONNECTION

5.1 FACILITY SITING

Several environmental, social and economic factors should be considered when siting a waste processing facility. The following discussion is not an inclusive list of these issues, and more evaluation would be necessary prior to proceeding with preliminary site selection.

The facility location would be required to meet the criteria defined by Missouri's Code of State Regulations, Title 10, Division 80 – Solid Waste Management. Facilities are typically more economical over a life-cycle when located near the centroid of the waste stream, thereby reducing haul distances and capital requirements for infrastructure. Ideally, existing transportation mechanisms would be sufficient to serve the heavy traffic that would frequent the facility. Additionally, it is preferred that utilities would also be in close proximity, reducing site development costs. In WTE applications, site selection is also dependent upon the distance from the power purchaser.

Often, MSW facilities are met with community opposition, and the strength and source of the potential opposition should be considered. Ideal locations would have a limited impact on the community and would be in an area where zoning currently allows for such a facility.

The City of Kansas City, Missouri, is currently pursuing development of the EcoCenter, a material recovery facility (MRF), which would house the infrastructure required to process the region's solid waste stream. Plans for this campus currently include areas for emerging MRF technologies. A partnership with the City at this location could potentially create energy efficiencies for both facilities. Additionally, developing the facilities at the same location would have less of an environmental and social impact than establishing two separate sites.

5.2 UTILITY INTERCONNECTION

Kansas City Power & Light (KCPL) provided in-kind assistance to Burns & McDonnell by performing a utility interconnection review. For utility interconnection, the facility was to be located in the general vicinity of KCPL's Hawthorn Power Plant, which is sited on the Missouri River nine miles northeast of downtown Kansas City, Missouri.

There is ample transmission capability in the vicinity of the Hawthorn Power Plant to accommodate an additional 15 to 20 MW of generation capacity. Available interconnection voltages are 345, 161, and 69 kV. Interconnection at 345 kV is probably cost prohibitive for this size of generator.

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6.0 PERMITTING AND REGULATORY

6.1 GASIFICATION AND MASS BURN

The following permits are anticipated to be required for MSW mass burn combustion and plasma gasification facilities located at greenfield sites:

1. Air construction permit (Prevention of Significant Deterioration (PSD) or minor source construction permit),
    a. If PSD permit is required, the unit will need to perform a BACT analysis for pollutants subject to PSD. This will likely result in the addition of controls for NO_x, SO_2, and PM. The major source threshold for this unit is 100 tons per year (as it is a listed source) of any pollutant.
    b. If a PSD permit is not required, it is likely that emissions have been controlled already with controls similar to the BACT controls to reduce emissions to below the PSD major source thresholds.
    c. The mass burn/gasification unit will likely be subject to the NSPS, Subpart Eb – Standards of performance for large municipal waste combustors for which construction is commenced after September 20, 1994 or for which modification or reconstruction is commenced after June 19, 1996. This rule has potential limits for NO_x, SO_2, PM, dioxins/furans, mercury, lead, HCl and opacity. This rule applies to those units that combust more than 250 tons per day of MSW.
    d. There is a National Emission Standard for Hazardous Air Pollutants (NESHAP) for hazardous waste combustion (40 CFR Part 63, Subpart EEE); however, MSW /RDF fuel should have the hazardous components removed, and therefore, this NESHAP should not apply. Similarly, the Resource Conservation and Recovery Act (RCRA) requirements under 40 CFR Part 266 should also not apply because this fuel will not meet the definition of hazardous waste.
2. Air operating permit (Title V or minor source) - applied for up to one year after commencing operation,
3. Solid Waste/Transfer Station permit (from the MDNR) - permit for transporting solid waste to the site for combustion,
4. NPDES Operating Permit (Process Wastewater / Stormwater Discharge) - must follow requirements of primary categorical industry and is required prior to operation,
5. NPDES Construction Permit – Includes Stormwater Pollution Prevention Plan (SWPPP) and Notice of Intent,

6. Wetlands Assessment Study and Certification - Determine need for Corps of Engineers Section 404 permit, MDNR 401 permit and to determine any development restrictions to construction and design.
7. Phase I Cultural Resources Investigation - Research potential significant impacts to cultural resources on plant site. Coordinate with MO State Historic Preservation Office (SHPO). Complete preliminary database search.
8. Threatened and Endangered Species Clearance - Field investigations and data base research. Determine any development restrictions to construction and design.
9. Environmental Impact Report (NEPA Survey) - may be required if a Federal action is required, such as a wetland permit or use of Federal money. An Environmental Assessment or an Environmental Impact Statement may be required for the project.
10. Phase I Environmental Site Assessment (ASTM E1527) - Property transfer, visual, non-intrusive assessment. Survey to determine potential site contamination that may require remediation.
11. Land Use / Rezoning - Physical survey and legal description of re-zoned real estate required for zoning application and approval.

6.2 REFUSE-DERIVED FUEL CO-FIRING

KCPL also provided in-kind assistance to Burns & McDonnell by performing a permitting and regulatory review for the RDF treatment option. The following is a list of potential permitting issues, concerns and challenges with co-firing RDF at an existing coal-fired generation facility.

1. Necessity of construction permit for boiler modifications necessary to co-fire RDF.
2. Necessity of construction permit for fuel handling modifications necessary to co-fire RDF.
3. Reissuance of operating permit to include required construction permit provisions.
4. Ability to meet existing air emission limits while co-firing RDF.
5. Ability to meet future air emission limits while co-firing RDF.
6. Reclassification of electric generating unit to sanitary waste incinerator with more stringent emission limits.
7. General public or neighbor concerns regarding emissions from the co-firing RDF.
8. Potential reclassification of ash as hazardous waste with additional handling and disposal requirements.
9. Potential impacts on permitted beneficial use of ash from co-firing RDF.
10. Potential impacts on permitted landfill disposal of ash from co-firing RDF.
11. General public or neighbor concerns regarding ash disposal from co-firing RDF.
12. Potential permitting or general public impacts from transportation of RDF to facility by truck.

13. Public opposition because of uncertainties over health, safety, odor, and traffic impacts (since co-firing unit selected likely to be located near urban centers where the waste is generated).
14. Possible conflicts betwe en co-firing use for el ectricity generation and waste reduction and recycling efforts.

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7.0 AIR PERMIT REGULATIONS

The major obstacle to evaluating the emissions for this Study is determining the applicable air permitting regulations. At the time of this Study several of the regulations have not been finalized. Additionally, the Environmental Protection Agency (EPA) is currently redefining the term "solid waste". The regulations potentially applicable to a project will vary depending on the definition of "solid waste" and how each regulation addresses the fuel type.

The three 600 tpd MSW treatment options evaluated are:

- Option 1 - Plasma gasification for greenfield power generation of approximately 20 MW
- Option 2 - Mass burn waterwall boiler for greenfield power generation of 15 MW
- Option 3 - Processed MSW to RDF, co-fire 425 tpd RDF in an existing 850 MW coal fired boiler (approximately 3 percent of heat input). The existing unit has modern emissions control devices including selective catalytic reduction (SCR), wet flue gas desulfurization (FGD) and fabric filter.

7.1 PREVENTION OF SIGNIFICANT DETERIORATION (PSD)

The first air permitting issue to consider is whether or not PSD permitting will be required. The PSD major source thresholds for a "listed" facility are applicable to Options 1 and 2. If the greenfield site qualifies as a major "facility" for any single pollutant, then all pollutants must be compared to the major "project" thresholds to determine if PSD is triggered. PSD is triggered when any one pollutant surpasses the threshold limit.

Option 3 assumes a brownfield facility that is already a PSD major source, so this option will be compared to the PSD major project thresholds to determine whether or not PSD permitting will be required. See Table 7-1 for the PSD permitting thresholds.

Table 7-1: PSD Permitting Thresholds

Pollutant	Greenfield Site Major Facility Thresholds) (Options 1 and 2) (tpy)	Greenfield Site Major Project Thresholds) (Options 1 and 2) (tpy)	Brownfield Site Major Project Thresholds (Option 3) (tpy)
CO	100	100	100
PM_{10}	100	15	15
$PM_{2.5}$	100	10	10
SO_2	100	40	40
NO_x	100	40	40
VOC	100	40	40
CO_2	100,000	75,000	75,000

7.2 BEST AVAILABLE CONTROL TECHNOLOGY (BACT)

If PSD is triggered, which is likely for all three options, then the emissions limits will be based on a BACT analysis. BACT limits are determined on a case-by-case basis; however, a review of previous BACT determinations can provide guidance as to what control levels are considered feasible and achievable. A review of EPA's Reasonable Available Control Technology (RACT) / BACT / Lowest Achievable Emission Rate (LAER) Clearinghouse (RBLC) yields the limits for boilers as shown in Table 7-2. BACT limits for MSW gasification and combustion of syngas in a turbine or engine are not shown since there is little precedent. For Options 2 and 3, refer to Table 7-2 for the criteria pollutant BACT rates for MSW combustion.

Table 7-2: Recent Criteria Pollutant BACT Rates for MSW Combustion in a Boiler

Pollutant	Control Method	ppm	mg/dscm	gr/dscf
CO	Good Combustion Practices	100		
Lead	Fabric Filter (Baghouse)		0.14-0.38	0.00013
NO_x	Selective Non-Catalytic	90-250		
Particulate Matter	Fabric Filter (Baghouse)		12-24	0.011
SO_2	Dry Scrubbers	26-30		
VOC	Good Combustion Practices	25		

7.3 NEW SOURCE PERFORMANCE STANDARD (NSPS)

The applicable NSPS limits will be the minimum requirements if a BACT analysis is required; BACT can be no less stringent than NSPS.

For Option 1, it is not clear if the gasification of MSW will be subject to same NSPS or on a NSPS specific to the type of unit combusting the syngas: boiler, engine, or turbine. As there is limited data available for gasification of MSW, an applicability determination will need to be made by EPA to resolve the question of which NSPS is applicable.

For Options 2 or 3, the NSPSs are the minimum requirements that will need to be met and one of the NSPSs for waste combustors will apply: Subpart CCCC. NSPS Subpart CCCC applies to Commercial and Industrial Solid Waste Incineration (CISWI) for which construction is commenced after November 30, 1999 or for which modification or reconstruction is commenced on or after June 1, 2001. NSPS Subpart CCCC is referred to as the CISWI Rule and has not been finalized, so determining the final limitations is not possible. Refer to Table 7-3 for DRAFT CISWI Rule limitations. Under Options 2 and 3, the boilers would be an "energy conversion unit." "Energy recovery units" are boilers or process heaters that do not combust solid waste.

Table 7-3: CISWI NSPS Rule – Emission Limitations (DRAFT)

For the air pollutant	You must meet this emission limitation[1]	Using this averaging time	And determining compliance using this method
Cadmium	0.00041 milligrams per dry standard cubic meter.	3-run average (collect a minimum volume of 2 dry standard cubic meters).	Performance test (Method 29 of Appendix A– 8 of this part). Use ICPMS for the analytical finish.
Carbon monoxide	150 parts per million dry volume.	3-run average (1 hour minimum sample time per run).	Performance test (Method 10 of Appendix A– 4 of this part).
Dioxins/furans (total mass basis)	0.75 nanograms per dry standard cubic meter.	3-run average (collect a minimum volume of 1 dry standard cubic meter).	Performance test (Method 23 of Appendix A– 7 of this part).
Dioxins/furans (toxic equivalency basis)	0.059 nanograms per dry standard cubic meter.	3-run average (collect a minimum volume of 1 dry standard cubic meter).	Performance test (Method 23 of Appendix A– 7 of this part).
Hydrogen chloride	1.5 parts per million dry volume.	3-run average (collect a minimum volume of 1 dry standard cubic meter).	Performance test (Method 26A of Appendix A–8 of this part).
Lead	0.002 milligrams per dry standard cubic meter.	3-run average (collect a minimum volume of 2 dry standard cubic meters).	Performance test (Method 29 of Appendix A– 8 of this part). Use ICPMS for the analytical finish.
Mercury	0.00096 milligrams per dry standard cubic meter.	3-run average (collect a minimum volume of 2 dry standard cubic meters).	Performance test (Method 29 of Appendix A of this part).
Opacity	1%	6-minute averages; 1-hour block average for units that operate dry control systems.	Continuous opacity monitoring (Performance specification 1 of Appendix B of this part), unless equipped with a wet scrubber.
Oxides of nitrogen	130 parts per million dry volume.	3-run average (1 hour minimum sample time per run).	Performance test (Method 7E of Appendix A– 4 of this part).
Particulate matter filterable	9.2 milligrams per dry standard cubic meter.	3-run average (collect a minimum volume of 1 dry standard cubic meter).	Performance test (Method 5 or 29 of Appendix A–3 or Appendix A–8 of this part) if the unit has a design capacity less than or equal to 250 MMBtu/hr; or PM CEMS (performance specification 11 of Appendix B of this part) if the unit has a design capacity greater than 250 MMBtu/hr.
Sulfur dioxide	4.1 parts per million dry volume.	3-run average (1 hour minimum sample time per run).	Performance test (Method 6 or 6c of Appendix A–4 of this part. Use a span gas with a concentration of 20 ppm or less.
Fugitive ash	Visible emissions for no more than 5% of the hourly observation period.	Three 1-hour observation periods.	Visible emission test (Method 22 of Appendix A–7 of this part).

Notes:

1. All emission limitations (except for opacity) are measured at 7 percent oxygen, dry basis at standard conditions.

There are also specific NSPS requirements for spark ignition (SI) engines and combustion turbines which might apply under Option 1. For syngas combustion, the applicable NSPS requirements will depend on whether the unit is an engine or a turbine. For Option 1, the syngas combustion method will be in SI engines; therefore, Tables 7-4 is applicable. Table 7-5 applies to combustion turbines and is included for reference.

Table 7-4: NSPS Emission Limits for Engines and Turbines under Subpart JJJJ (Spark Ignition Engines)

Engine Type and Fuel	Maximum Engine Power	Manufacture Date	Emission Standards[2]					
			g/HP-hr			ppmvd at 15% O_2		
			NO_X	CO	VOC[3]	NO_X	CO	VOC[3]
Non-Emergency SI Natural Gas and Non-Emergency SI Lean Burn LPG	HP≥500	7/1/2010	1.0	2.0	0.7	82	270	60

Notes:

1. Owners and operators of new or reconstructed non-emergency lean burn SI stationary engines with a site rating of greater than or equal to 250 brake HP located at a major source that are meeting the requirements of 40 CFR part 63, subpart ZZZZ, Table 2A do not have to comply with the CO emission standards of Table 1 of this subpart.
2. Owners and operators of stationary non-certified SI engines may choose to comply with the emission standards in units of either g/HP-hr or ppmvd at 15 percent O_2.
3. For purposes of this subpart, when calculating emissions of volatile organic compounds, emissions of formaldehyde should not be included.

Table 7-5: NSPS Emission Limits for Engines and Turbines under Subpart KKKK (Combustion Turbines)

Pollutant	Combustion turbine type	Combustion turbine heat input at peak load (HHV)	Emission Standard
NO_X	New turbine firing fuels other than natural gas, electric generating	≤ 50 MMBtu/hr	96 ppm at 15 percent O_2 or 700 ng/J of useful output (5.5 lb/MWh)
NO_X	New turbine firing fuels other than natural gas	> 50 MMBtu/h and ≤ 850 MMBtu/hr	74 ppm at 15 percent O_2 or 460 ng/J of useful output (3.6 lb/MWh)
NO_X	New, modified, or reconstructed turbine firing fuels other than natural gas	> 850 MMBtu/hr	42 ppm at 15 percent O_2 or 160 ng/J of useful output (1.3 lb/MWh)
SO_2	Stationary Combustion turbine, all fuels, except those turbines located in Alaska	All sizes	No gases can be discharged into the atmosphere which contain SO_2 in excess of 110 ng/J (0.90 lb/MW-hr)
SO_2	Stationary Combustion turbine, all fuels, if turbine is simultaneous firing, each fuel must meet the requirement	All sizes	Fuel cannot have a total potential sulfur emissions in excess of 26 ng SO_2/J (0.060 lb SO2/MMBtu) heat input
SO_2	Stationary Combustion turbine, burning at least 50% biogas based on heat input	All sizes	No gases can be discharged into the atmosphere from the source which contain SO_2 in excess of 65 ng/J (0.15 lb/MMBtu)

7.4 MAXIMUM AVAILABLE CONTROL TECHNOLOGY (MACT)

If a facility burns a solid waste, as defined by EPA's new definition of solid waste, then that facility is covered under the CISWI Rule (which is technically not a MACT, but a NSPS). The CISWI Rule is currently a draft and should be finalized prior to the January 16, 2011 promulgation deadline for the Boiler MACT; therefore, under the current proposed rules there is no separate MACT applicable for Options 2 and 3. A final determination cannot be made until the rules are promulgated.

For Option 1, MACT Subpart ZZZZ limit may apply for engines described as four stroke, lean burn, greater than 500 hp, utilization of oxidation catalyst, non-emergency use, and at a major source of HAPs. Refer to Table 7-6 for the emissions limitations.

Table 7-6: NSPS Emission Limits for Engines and Turbines under Subpart KKKK

Engine Type	You must meet the following emission limitation, except during periods of startup
4SLB stationary RICE	a. Reduce CO emission by 93 percent or more; or b. Limit concentration of formaldehyde in the stationary RICE exhaust to 14 ppmvd or less @ 15 percent O_2

4SLB = 4 Stroke Lean Burn
RICE = Reciprocating Internal Combustion Engine

7.5 SUMMARY

Each facility option is potentially subject to three separate regulatory requirements: NSPS, MACT, and PSD/BACT. BACT is a part of the PSD permit and is only required if the project meets the tpy definition of a major modification. NSPS and MACT apply regardless of the project's tpy emissions; their applicability is based on unit capacity, construction date, and whether or not the facility is classified as a major source of HAPs. In the event that more than one of these regulations apply to a single pollutant, the most stringent requirement takes precedence.

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8.0 GASIFICATION

A high level review of different gasification technologies was conducted; with specific emphasis on those available and applicable to MSW fuel. The list generated was narrowed to supplier companies with commercial operating experience and further refined to those with a North American base. From the revised list, and publically available information on various projects and studies, plasma gasification was selected as the technology for the gasification treatment option. The following provides a conceptual general description of the plasma gasification facility.

8.1 GENERAL DESCRIPTION

8.1.1 MSW Treatment by Plasma Gasifier

In addition to MSW, metallurgical (met) coke and limestone are utilized as feeds in the plasma gasification process. The met coke is used as an absorption bed for the heat energy generated by the plasma torches and helps to maintain heat input in the gasification zone of the gasifier by releasing heat as the met coke slowly combusts. Limestone is used to control the melting properties of the slag by lowering the melting point of the inorganic compounds, to ensure satisfactory characteristics, and additionally ensuring the slag is fully vitrified.

A plasma gasifier design incorporates a vertical shaft with plasma torches that heat the met coke, which in turn gasifies the MSW fed through the top of the vessel. The gasifier is internally lined with a refractory brick to withstand the high internal temperatures and corrosive operating conditions. The number of plasma torches varies depending upon the technology provider; additional torches can be added to the gasifier to increase total capacity.

The updraft gasification process converts the organic component of the MSW into a synthesis gas (syngas) consisting primarily of hydrogen (H_2) and carbon monoxide (CO) which exits at the top of the vessel, while the inorganic components are converted into a molten slag and exit via the bottom. The gasifier operates with very high temperatures in the lower portion of the reactor and both oxygen/air and steam are injected in the lower portion of the gasifier to promote the chemical reaction.

The syngas exits the gasifier around 1,650 – 2,020 °F at near atmospheric pressure. The gas is then quenched and cleaned in selected downstream cleanup processes. The molten slag meanwhile is a mixture of non-combustible inorganic and recoverable metals that is sent to a slag handling system for further processing.

The flexible operation of the plasma torches, by ramping up or down the input electrical power or the rate of plasma flow, allows any variation in the fuel quantity, moisture and composition, to be accommodated; thus, maintaining a constant gasifier temperature. Plasma gasifiers can therefore accept fuels of variable particle size, containing coarse lumps and fine powders, with minimal feed preparation. However, in general, fuels with higher average moisture or inorganic contents lead to lower gasification reaction and syngas temperatures and lower efficiency, and fuels with lower average carbon contents lead to a lower syngas quality and/or heating value.

8.1.2 MSW Handling System

A MSW fuel handling and shredding system, comprised of truck unloading, a storage bunker, transfer equipment, and pre-gasification shredding, is located on-site. MSW trucks entering the facility are weighed before proceeding to the unloading area. The trucks dump into the storage bunker and transfer equipment (front end loaders, an overhead crane, or similar) is utilized to transfer the MSW from storage to a shredding mill for minor size reduction to not greater than three feet. The moving equipment is also utilized for handling of met coke and limestone. For the gasification technology proposed, no pre-separation of the MSW is required, including no front-end recovery of recyclables or metals.

8.1.3 Gas Cleanup

Variations in MSW fuel composition produce a variation in the constituents of raw syngas generated by the plasma gasifier. The syngas leaving the gasifier contains contaminants, such as particulate, aerosols, chlorides, dioxins/furans, sulfur compounds, etc, that must be removed prior to utilization. As plasma gasification is a proprietary process, simulation software can not accurately estimate the raw syngas and contaminant compositions. Therefore Burns & McDonnell has used publically available information to estimate the syngas composition and cleanup equipment required to meet, and likely exceed, the anticipated emissions limits. The control technologies selected for the facility to reduce the pollutants in the raw syngas prior to combustion in the engines include:

- Primary cyclone, scrubber and wet electrostatic precipitator (ESP) for particulate, aerosols, and chlorides removal (including dioxins/furans)
- Carbon bed filters for removal of trace quantities of mercury and for conversion of carbonyl sulfides (COS) to hydrogen sulfide (H_2S) and carbon dioxide (CO_2)
- SulfaTreat for H_2S gas (sulfur) removal

8.1.4 Power Generation

The two most common configurations for power generation in existing commercial MSW plasma gasification facilities involve a boiler and steam turbine, or use of multiple reciprocating engines. Based on commercial experience of selected technology providers, reciprocating engines are selected for combusting the syngas to produce electricity. It is anticipated that the syngas generated will fully load 17 engines, each generating an estimated 1,700 kW gross output.

8.1.5 Waste Streams

The main byproduct from the gasification process is inorganic metal and mineral content that is converted into a molten slag in the gasifier. The slag continuously flows out of the gasifier through a tap hole at the bottom of the vessel, cooled and broken apart into small granules, dropped into a water bath and collected by a drag chain conveyor.

Waste water, generated by condensing water vapor from the syngas stream during cooling is treated on-site for recovery; a small stream is discharged to a nearby municipal water treatment facility.

This Study assumes the byproduct slag, as well as byproducts or consumables from the syngas cleanup, are not suitable for reuse. All byproducts are disposed of in an on-site landfill.

8.2 PERFORMANCE

The net power produced by the facility is estimated at 20,000 kW. The net plant attributable to MSW only is estimated at 18,200 kW; equating to a net generation rate per ton MSW consumption of 800 kWh/ton. The equivalent net plant heat rate, based on the HHV of the MSW plus addition of met coke, is calculated to be 13,800 Btu/kWh.

Other process and utility streams required by or discharged during normal operation of the plasma gasification facility include:

- Met coke feed rate to the gasifier is estimated to be 4% of the MSW feed rate, or 2,000 pounds per hour. The anticipated HHV of met coke is 12,600 btu/lb.
- Residue, or ash byproduct generation, including ferrous and non-ferrous metals; delivered to on-site landfill at an estimated rate of 3 tpd.
- No process water makeup is required; due to the incoming moisture content of the MSW and condensate recovery and treatment for reuse.

- Waste water is treated and discharged at an estimated rate of less than 10 gpm.
- AQCS consumables include limestone, activated carbon, and SulfaTreat reactant, as well as aqueous ammonia and CO catalyst for NO_x and CO control, respectively, downstream of the syngas fired engines.

8.3 CAPITAL COST

The screening level EPC capital cost, excluding Owner's costs, to install a 600 tpd MSW plasma gasification facility is $232,000,000. Based on an overall net plant output of 20,000 kW, the capital EPC investment (without Owner's cost) is estimated at $11,600/kW; or a value of $12,750 when attributable to MSW only. On the basis of 7,446 hours of operation per year (85% availability), the annual facility design capacity is 186,150 tons per year; the capital EPC investment (without Owner's cost) based on annual design capacity is estimated at $1,250 per annual ton MSW consumed.

The capital cost estimate is based on a greenfield site and the following scope definition:

- MSW receiving, storage, shredding and transfer system
- Plasma arc gasification reactor, plasma torches and associated equipment
- Syngas cooling/heat recovery
- Syngas pretreatment equipment including, but not limited to:
    - Cyclone, scrubber, and wet-ESP for particulate, aerosol and chloride removal
    - Carbon beds for contingent mercury (Hg) removal
    - Proprietary SulfaTreat process for hydrogen sulfide (H_2S) removal
- Waste water treatment and recovery system
- Treated syngas delivery system
- Power generation block consisting of syngas-fired spark ignition reciprocating engines and exhaust treatment including:
    - Selective catalytic reduction using aqueous ammonia to reduce NO_x
    - CO oxidization catalyst for CO reduction
- Balance of plant includes
    - Administration/control and warehouse building
    - Auxiliary boiler for startup steam requirements
    - Flare system for syngas treatment during startup, shutdown or upset conditions

8.4 EMISSIONS

Stack air emissions are generated by the engines during combustion of the syngas. Burns & McDonnell contacted a few engine manufacturers to discuss guidelines for estimating these emissions. As the subsequent clean syngas can vary widely in composition, manufacturers of reciprocating engines are reluctant to provide performance and emissions assessments without detailed analysis conducted in their own laboratory. As it is not common to subcontract manufacturers for such work during the course of a conceptual study, Burns & McDonnell has not been able to accurately estimate the emission rates generated by the gasification facility.

For screening level purposes of the Study, the permit limits and control technologies shown in Table 8-1 are anticipated.

Table 8-1: Gasification Pollutant Emissions Limits and Control Method

Pollutant	Emission Limit (@ 15% O_2)	Control Method
NO_x	82 ppmvd	Good Combustion Practices / SCR
CO	270 ppmvd	Good Combustion Practices / CO Catalyst

Notes:
1. SO_2 and PM are not defined as there is no technically feasible control method for internal combustion engines.

It is important to note, due to the lack of precedent for MSW gasification, an applicability determination from EPA is required to determine which NSPS and MACT standards apply. This preliminary action does not commit the requester to any specific action, but it does provide clarification for analyzing gas cleanup options and ultimately estimating emissions. The request is initiated with a letter from Burns & McDonnell to the MDNR and EPA Region VII.

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9.0 MASS BURN

Several mass burn boiler combustion technologies, having experience with alternative fuels, were investigated. The most common combustion technology was selected; a mass burn waterwall unit consisting of a stoker grate and integral waterwall boiler. Other technologies currently in use throughout North America include mass burn rotary units, mass burn refractory units, and mass burn modular units. An overall description of the mass burn waterwall boiler facility is provided herein.

9.1 GENERAL DESCRIPTION

9.1.1 MSW Treatment by Mass Burn Combustion

A stoker grate boiler utilizes a grate system in the lower section which moves the MSW through the combustion zone. For MSW combustion, vendors recommend a reciprograte technology. This grate system alternates stationary and moving grates throughout the bed. As the moveable grates reciprograte, the MSW is pushed through the combustion chamber. Air is introduced into the boiler under the grate and through an over-fire air system. Fuel enters the boiler through chutes and is distributed across the grate. Stoker boilers operate at the highest possible efficiencies and lowest emissions when the fuel is spread evenly across the grate. Due to the high gas velocities around the grate, stoker boilers can have high amounts of unburned fuel carried over and out of the furnace. Bottom ash is discharged from the finishing grate into a wet bottom ash hopper for transportation to ash load out. Stoker boilers combustion ash is typically 35 percent bottom ash and 65 percent fly ash.

Stoker boiler technology is well suited for combusting a variety of fuel constituents found in MSW. The lower section of the boiler is constructed to handle corrosive conditions and fuel variability. The reciprograte is constructed of high alloy stainless steel.

9.1.2 MSW Handling System

A MSW handling system, consisting of truck unloading, fuel yard, and transfer equipment, is used to move the MSW into the boiler. MSW trucks entering the facility are weighed via truck scales and then proceed to the unloading area. At the unloading area, trucks are either positioned to dump onto active reclaim conveyors or onto the dead reserve. A dozer is used to move the MSW on to the active reclaim conveyors. The MSW yard is operated on a first in, first out supply basis to ensure MSW is used in the order it is received. Yard operators are responsible for isolating MSW sized larger than 12” x 12” x 48” ; the isolated MSW is manually reduced in size on-site, if possible, or returned to the landfill by others. Active reclaim chain conveyors transfer the sized MSW to the boiler combustion chamber.

9.1.3 Gas Cleanup

Based on the permitting review conducted for the mass burn facility, it is anticipated that a selective non-catalytic reduction (SNCR), dry FGD and fabric filter are required for emissions control. The SNCR requires urea fed from the urea storage and handling system and the dry FGD requires lime fed from the lime storage and handling system.

9.1.4 Power Generation

Steam, generated (at 900 psi and 830 ^{o}F) by the boiler drives a steam turbine generator to create electricity. The net power generated is estimate to be 15,000 kW.

9.1.5 Waste Streams

The main byproducts from combustion of MSW in a boiler with associated emissions control equipment are bottom ash and byproduct, a combination of fly ash and lime. This Study assumes the combustion byproducts are not suitable for reuse and all byproducts are disposed of on-site. Additionally, waste water generated on-site is discharged to a nearby municipal water treatment facility.

9.2 PERFORMANCE

The net power produced by the facility is estimated at 15,000 kW. The net plant heat rate, based on the HHV of the fuel, is 16,700 Btu/kWh.

Other process and utility streams required by or discharged from the facility during normal operation include:

- Potable water consumption; at a rate of 190 gpm (460 gallons per ton of MSW treated).
- Waste water generation and discharge; at a rate of 40 gpm (100 gallons per ton of MSW treated).
- Residue or ash byproduct generation, including ferrous and non-ferrous metals; delivered to on-site landfill at a rate of 130 tpd.
- AQCS consumables include pebble lime and urea; at a rate of 200 lb/hr and 110 lb/hr, respectively.

9.3 CAPITAL COST

The screening level EPC capital cost, excluding Owner's costs, to install a 600 tpd MSW mass burn facility is $138,000,000. Based on a net plant output of 15,000 kW, the capital EPC investment (without Owner's cost) is estimated at $9,220/kW. On the basis of 7,446 hours of operation per year (85% availability), the annual facility design capacity is 186,150 tons per year; the capital EPC investment (without Owner's cost) based on annual design capacity is estimated at $740 per annual ton MSW consumed.

The capital cost estimate is based on a greenfield site and the following scope definition:

- MSW material receiving, storage, handling, and transfer system
- Integral waterwall mass burn boiler with a stoker grate
- Air quality control system consisting of:
  - Selective non-catalytic reduction system using anhydrous ammonia to control NO_X
  - Semi-dry flue gas desulfurization system using pebble lime to control SO_2 and acid gases.
  - Activated carbon injection system for contingent Hg control.
  - Pulse jet fabric filter for particulate control.
- Steam turbine generator, condenser and feedwater system
- Miscellaneous balance of plant systems

9.4 EMISSIONS

Emission limits for the mass burn boiler are based on the draft limits presented in the CISWI NSPS Rule, which is not yet finalized. The proposed CISWI limits are required, at a minimum, and are typically more stringent than historical BACT determinations for MSW boilers.

The proposed CISWI rule for SO_2 is particularly stringent and it is possible that equipment vendors will not guarantee this permit limit can be met using dry scrubber technology. However, for the purposes of this study a dry scrubber has been assumed since the CISWI rule is currently in draft form and a dry scrubber has historically been considered BACT for SO_2 control with MSW boilers. Upon final NSPS permit limits, scrubber vendors should be contacted to verify technology capabilities.

For the screening level purposes of this study the emissions limits and control technologies shown in Table 9-1 are assumed.

Table 9-1: Mass Burn Pollutant Emissions Limits and Control Method

Pollutant	Emission Limit (@ 15% O_2)	Control Method
NO_x	130 ppmvd	SNCR
SO_2	4.1 ppmvd	Dry Scrubber
CO	150 ppmvd	Good Combustion Practices
PM	9.2 milligrams per day standard cubic meter	Fabric Filter

Due to the varying fuel characteristics of MSW and the present draft requirements of the CISWI NSPS, an activated carbon injection system has been included in the mass burn MSW capital cost estimate for contingent mercury control. High levels of mercury control have been noted with dry scrubbers and fabric filters. Again, upon final NSPS permit limits, equipment vendors should be contacted to verify technology capabilities.

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10.0 REFUSE DERIVED FUEL (RDF)

This Study investigated technology for a greenfield RDF processing facility capable of handling 600 tpd MSW. For co-firing RDF, the Study assumes the RDF processing facility is located adjacent to a brownfield, pulverized coal (PC) boiler power generating facility. The existing PC unit is assumed to be an 850 MW PC boiler, operating with supercritical steam conditions and burning Powder River Basin (PRB) coal. The existing AQCS consists of a SCR system, FGD system and fabric filter.

10.1 GENERAL DESCRIPTION

10.1.1 MSW Treatment by RDF Co-Firing

Co-firing is the process of burning a secondary fuel along with another fuel in a combustion process. Co-firing RDF is technically feasible and has been commercially demonstrated in several types of boilers including PC boilers, fluidized-bed boilers, and spreader stokers.

PC boilers designed to burn coal can typically co-fire alternate fuels up to 5 to 10 percent of the total boiler heat input without significant boiler modifications or effects on boiler efficiency and performance. Boiler manufacturers recommend installing a separate handling and feed system in order to control the flow of coal and secondary fuel independently of one another. Secondary fuels, such as biomass, have been successfully introduced into the boiler through the coal handling system by mixing the fuel in the coal yard. However, problems relating to pulverizer mill pluggage and mill fire hazards have been noted. Additionally, existing mill capacity may limit the amount of secondary fuel, such as RDF, that could be fed through the mill; due to the large volume of RDF compared to coal. For the purposes of this Study, utilizing an existing coal handling system to convey the RDF is not recommended and a separate, dedicated RDF handling system is included. An RDF co-firing rate of 3 percent of the total heat input to the boiler will be used for the Study.

The RDF fuel is sized to less than, or equal to, one-quarter inch in all directions for injection into the boiler to ensure complete combustion. RDF typically contains high amounts of moisture, and therefore a small particle size is required to ensure enough residence time in the combustion zone to vaporize the moisture and burn the fuel, thus, preventing carbon carryover.

10.1.2 MSW Handling and Processing

Upon entering the RDF processing facility, MSW trucks will be weighed via truck scales and proceed to the unloading area. At the unloading area, trucks either dump to the active reclaim conveyors or to the

dead reserve. A dozer is required to move the MSW in the yard on to the active reclaim conveyors. The MSW yard would be operated on a first in, first out supply basis to ensure MSW is used in the order it is received. Yard operators will isolate all MSW sized larger than 4" x 4" x 48". The oversized MSW will be returned by others to the landfill.

The MSW is processed to RDF by removing the inert and non-combustible components such as glass, metal, dirt, etc. These components make up approximately 29% of the MSW stream and will be returned by others to the landfill or to other recycling or processing facilities. The remaining RDF will consist of paper, cardboard, plastic, and biomass. After processing, the 600 tpd of MSW will be reduced to approximately 425 tpd of RDF. The RDF will be shredded to less than one-quarter inch in all directions. The shredded RDF will then be conveyed out of the processing facility to fuel bins next to the adjacent PC boiler. This Study assumes two fuel bins will provide short term live storage for the sized RDF fuel.

RDF will be fed from each storage bin by four screw feeders and dropped through an airlock into a pneumatic feed system which will inject the RDF into the boiler through dedicated ports.

A preliminary investigation was conducted for alternate processing of the RDF into RDF pellets. RDF pelletizing is considered for projects that want to condense the volume of RDF and to create a stable product for shipment or long term storage. Pelletizing is an expensive process that requires additional size reduction, drying and pelletizing equipment. The additional processing was deemed unnecessary and uneconomical as the waste is assumed to be burned in nearby facilities and no long term storage is necessary.

10.1.3 Gas Cleanup

The existing AQCS includes a SCR, wet FGD and fabric filter for emissions controls. Co-firing RDF can affect SCR emissions control technologies. A general discussion regarding impacts to emissions control equipment and waste streams due to co-firing MSW is included in Section 10.4.

10.1.4 Waste Streams

The main byproducts from co-firing RDF in a PRB coal fired boiler and associated emissions control equipment are ash and the scrubber byproduct. Due to the lower ash and sulfur contents of RDF compared to PRB coal, the amounts of ash and scrubber byproducts are anticipated to decrease when co-firing RDF.

Co-firing RDF raises concerns of an existing plants ability to dispose of fly ash if it is currently used for beneficial purposes. The American Society of Testing and Materials (ASTM) standard C618, for fly ash use in concrete, defines fly ash as a combustion byproduct produced from burning coal only. Strict interpretation of this standard may result in an existing plant unable to dispose of fly ash for concrete production. If fly ash at the existing facility is sold or given away for beneficial purposes, it is recommended that any plans to co-fire RDF be discussed with the end user to ensure co-firing RDF will not affect their ability to dispose of ash.

10.2 PERFORMANCE

Approximately 425 tpd of RDF is co-fired in the existing PC boiler. Co-firing 425 tpd RDF is equivalent to approximately 3 percent of total heat input into the existing 850 MW PC unit. The net power generation attributable to RDF is estimated at 25,200 kW. Co-firing RDF is estimated to decrease the boiler efficiency due to the lower energy content of the RDF; however, due to the low quantity of RDF being co-fired, the lower boiler efficiency is estimated to be minimal to overall unit performance. The net plant heat rate is estimated to increase 20 Btu/kWh when co-firing RDF over burning 100 percent PRB coal.

Utilities for the MSW to RDF processing facility are assumed to be interconnected to the existing coal-fired facility. The differential process water supply and discharge for the RDF system is assumed to be negligible compared to the existing 850 MW unit.

10.3 CAPITAL COST

The screening level EPC capital cost, excluding Owner's costs, to install a 600 tpd MSW to RDF processing facility and retrofit an existing 850 MW PC unit to co-fire 425 of RDF is estimated at $46,000,000. Based on a net plant output of 25,200 kW attributable to RDF, the capital EPC investment (excluding Owner's cost) is estimated at $1,810/kW. On the basis of 7,446 hours of operation per year (85% availability), the annual processing facility design capacity is 186,150 tons per year; the capital EPC investment (excluding Owner's cost) based on annual design capacity is estimated at $240 per annual ton MSW processed and co-fired.

The capital cost estimate is based on the following scope definition:

- MSW to RDF processing facility located adjacent to the existing power plant
- Co-firing three percent heat input into an existing pulverized coal boiler
- No modifications to the existing boiler's air quality control system

- RDF top-sized to ¼" in all directions
- RDF material handling system

10.4 EMISSIONS

The modification of an existing coal-fired boiler to co-fire RDF will be the most complicated option for permitting due to the lower PSD thresholds. Additionally, any modifications to the material handling system will count towards the project's fugitive dust emissions. If the project includes an increase to the boiler heat input or if the boiler increases annual operation after the modification (regardless of whether or not the modification is the cause of the increased usage), there will be PSD issues. The boiler could be subject to PSD permitting. Assuming that its current controls still represent BACT, the PSD permit process will add 12-18 months to the project schedule and open up the boiler's operation to public scrutiny. In the worst case, the current controls would be considered to not represent BACT and upgrades could be required. Of special concern is BACT for CO_2 since this is a new PSD pollutant and there is no current precedent for what constitutes BACT for CO_2.

The MDNR has previously allowed coal-fired boilers to burn alternate fuels in a limited quantity in order to measure emissions and determine if the fuel is viable. Such a request should be discussed with the MDNR to ensure that the appropriate application is submitted.

Since the CISWI regulations are still draft, it is unclear what the final limitations of the CISWI Rule will be. Further unit specific evaluation of existing environmental permits and possibly a co-firing demonstration will be required to determine any changes to the unit's permits or AQCS for co-firing RDF.

The following is a discussion of the anticipated impacts to pollutants and control technologies at an existing 850 MW coal-fired facility when co-firing RDF at a rate of three percent heat input. The discussion is based on the existing coal boiler burning PRB coal with a SCR, wet FGD and fabric filter for emissions control.

NO_x emissions from plants that have co-fired renewable energy fuels, such as biomass, have shown a range of changes to emissions since production of NO_x is dependent on several unit specific factors outside of the control of a RDF co-firing system. These factors include fuel, boiler geometry, and combustion temperature. Co-firing RDF can also affect the existing NO_x control technology. RDF contains approximately 25 percent biomass. SCR vendors have noted that forms of biomass can produce

fly ash and contains alkalis which may accelerate SCR catalyst deactivation. Research into SCR and catalyst designs, that can mitigate these effects, is currently on-going.

For the purposes of estimating AQCS consumables, the Study assumes NO_x emissions will remain unchanged from firing 100 percent coal to co-firing RDF due to the uncertainty of the affect to the unit when co-firing RDF. Burns & McDonnell recommends a co-firing demonstration test be conducted at the existing unit to establish emission information for the environmental regulatory process. SO_2 emissions produced in the boiler from RDF are anticipated to be less than 0.50 lb/MMBtu. The existing facility is assumed to be burning PRB coal, which has a typical SO_2 emission rate between 0.5 to 1.5 lb/MMBtu. When co-firing RDF, SO_2 emissions produced in the boiler are anticipated to decrease, on a lb/MMBtu basis, due to the lower sulfur content of the RDF. This SO_2 emission decrease however will be marginal as RDF only constitutes three percent of the total heat input. For purposes of estimating AQCS consumables, this study assumes SO_2 emissions will remain unchanged from firing 100 percent coal to co-firing RDF due to the uncertainty of the actual SO_2 content of the fuels and unknowns regarding the structure of the existing plants air permit or operations philosophy. PM emissions from the facility when co-firing RDF are anticipated to meet applicable permit levels through fabric filter control. CO emissions from the facility when co-firing RDF are anticipated to meet applicable permit levels through good combustion practices.

PM and CO emissions from the facility when co-firing RDF are anticipated to meet applicable permit levels through fabric filter control and good combustion practices, respectively.

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11.0 ADDITIONAL RESOURCES

In June 2010, the State of Missouri implemented a Renewable Portfolio Standard (RPS) electricity incentive which includes MSW. Information on the incentive can be found on the Database of State Incentives for Renewables & Efficiency (DSIRE) website:
http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=MO08R&re=1&ee=1

Burns & McDonnell reviewed sever al publically available resources during the course of t his Study. A list of those resources, which may be of interest, is provided in this Section. Web links for recommended resources that are publically available for review and use are provided below.

Proceedings from the 16 th, 17th and 18th Annual North Americ an Waste-to-Energy Conference (NAWTEC) include:

- MSW Gasification – Understanding the Challenges (NAWTEC16-1952)
  http://www.seas.columbia.edu/earth/wtert/sofos/nawtec/nawtec16/nawtec16-1952.pdf
- Benchmarking Mass Burn WTE Facility Performance - How do es your facility measure up? (NAWTEC17-2335)
  http://www.seas.columbia.edu/earth/wtert/sofos/nawtec/nawtec17/nawtec17-2335.pdf
- Potential for Reducing the Capital Costs of WTE Facilities (NAWTEC17-2366)
  http://www.seas.columbia.edu/earth/wtert/sofos/eecnawtec/nawtec17/nawtec17-2366.pdf
- Economic Feasibility of a Plasma Arc Gasification Plant, City of Marion, Iowa, (NAWTEC18-3502) http://www.seas.columbia.edu/earth/wtert/sofos/nawtec/nawtec18/nawtec18-3502.pdf

The Energy Recovery Council (ERC), formerly known as the I ntegrated Waste Service s Association (IWSA), publishes current information about the waste-to-energy industry in the United States. A sample of publications is listed below.

- The 2007 IWSA Directory of Waste-to-Energy Plants
  http://www.energyrecoverycouncil.org/userfiles/file/IWSA_2007_Directory.pdf
- The 2010 ERC Directory of Waste-to-Energy Plants
  http://www.wte.org/userfiles/file/ERC_2010_Directory.pdf
- Additional Waste-to-Energy downloads from the ERC can be found here:
  http://www.wte.org/waste-energy-resources-a2985

A more in-depth technical review of MSW treatment practices was recently conducted and published by Stantec for the Environment Quality Branch of the Environmental Protection Division located in Victoria, British Columbia, Canada. Waste to Energy: A Technical Review of Municipal Solid Waste Treatment Practices, Final Report, http://www.env.gov.bc.ca/epd/epdpa/mpp/pdfs/BCMOE-WTE-Emissions-final.pdf

A report examining the health, safety, and environmental records of established plasma gasification facilities was prepared by Dovetail Partners, Inc. for the City of Palisade, MN. The report was issued in July 2010 and is titled Plasma Gasification: An Examination of the Health, Safety, and Environmental Records of Established Facilities.
http://www.dovetailinc.org/files/u1/PlasmaGasificationRptFinal6710.pdf

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12.0 CONCLUSIONS & RECOMMENDATIONS

12.1 CONCLUSIONS

Burns & McDonnell assisted the MDNR by conducting a waste generation and technology review of three MSW treatment options: gasification, mass burn and RDF co-firing. Adequate MSW fuel is available from medium to large populated cities, or areas, within the state of Missouri to supply a commercial scale 600 tpd facility. The findings, reported herein, include preliminary screening level performance, capital cost and emission estimates for three WTE facility options and are inconclusive that one treatment option should be chosen over another. The selection of a treatment option will depend on specific area economic factors, such as tipping fees and power prices.

In general, requirements for renewable power generation are increasing and MSW provides an option for a stable source of renewable generation with benefits of reuse of waste materials and local economic benefits of job creation and potential reductions in criteria pollutants and greenhouse gas emissions.

Gasification was determined to have the highest facility capital cost and likely, highest risk option. Co-firing RDF at an existing 850 MW coal unit at a rate of 3 percent heat input to the boiler was determined to have a minimal impact to performance. At 3 percent heat input, or 425 tpd of RDF, the co-fired MSW produces approximately 25 MW of renewable generation.

Burns & McDonnell, along with assistance from Kansas City Power & Light, conducted a permitting and regulatory review of the treatment. Three primary regulations will need to be further researched: NSR, NSPS, PSD/BACT and MACT. These regulations may apply to unit modifications or new emissions sources.

12.2 RECOMMENDATIONS

Burns & McDonnell recommends the MDNR utilize the information presented in this Study as a guideline only to share with Missouri utilities and landfill owners to assist them in determining if a selected WTE technology merits further development for its generation fleet.

If any technology appears of interest from this initial assessment, Burns & McDonnell recommends performing additional detailed studies to further define a project and its economic viability. Furthermore, the information reported is intended to provide Missouri utilities and landfill owners/operators with basic

information of the MSW treatment options commercially available for generation of electricity . More detailed studies should be performed to refine capital costs and performance should one or more treatment options look attractive.

If a Missouri utility or landfill owner decides to proceed with development of a WTE generation facility, then Burns & McDonnell recommends that the utility or landfill owner proceed with the following steps:

- Meet with the MDNR to discuss how MSW options will be evaluated from a New Source Review (NSR) and New Source Performance Standard (NSPS) standpoint.
- Follow regulatory process to determine what Best Achievable Control Technology (BACT) and Maximum Achievable Control Technology (MACT) requirements will be required.
- Gather vendor emission quotes for MSW treatment options.
- Perform a detailed fuel supply study to identify and evaluate available fuel supplies, budgetary costs for delivery of MSW and determine a range of MSW analyses.
- Perform a detailed feasibility study for any option of interest, including a comprehensive site review with site layouts, detailed performance estimates and development of cost estimates for budgeting purposes.
- If proceeding with a RDF co-firing option, engage existing boiler original equipment manufacturer to determine technical feasibility of the project and required boiler modifications scope of work and performance impacts.

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