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BENCHMARKING MASS BURN WTE FACILITY PERFORMANCE HOW DOES YOUR FACILITY MEASURE UP?

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ABSTRACT

Owners and operators of waste-to-energy (WTE) facilities have a keen interest in the performance of their facilities since it drives the overall success and cost effectiveness of their projects. There are a number of parameters that are commonly used to gauge the performance of a WTE facility and, in many cases, the contract operator. This paper compares historical data from a number of mass burn WTE facilities to establish benchmarks for various performance criteria. This paper also discusses how these benchmarks compare with performance standards that were used as the basis of design for the existing generation of mass burn WTE facilities and operating contracts and discusses how to set performance expectation levels for new projects.

INTRODUCTION

There are approximately 90 waste-to-energy (WTE) facilities currently in operation in North America. The most common combustion technology used in these facilities is referred to as mass burn waterwall (MBWW) units. MBWW combustors are field erected units consisting of a stoker grate and integral waterwall boiler. MBWW facilities account for approximately 60

percent of the operating facilities in North America and are regarded by most experts as the most tried and proven method of combusting municipal solid waste (MSW) and recovering its energy. Other types of technologies currently in use in North America but to a much more limited extent include mass burn rotary units, mass burn refractory units, mass burn modular units and refuse derived fuel (RDF) units.

The financial success of a WTE facility depends on whether it can consistently achieve certain expected performance levels; primarily waste throughput and energy production. Most of the MBWW facilities currently operating in North America were constructed in the late 1980s and early 1990s and the expected performance levels for these facilities were based on either no operating facilities or a very limited number of operating facilities with only a few years of operating history at the time. This added a certain measure of uncertainty to the expected long-term performance of MBWW facilities. Despite the lack of long-term data, some parameters were included in the operating agreements as performance guarantees in order to provide some financial control for the owner or contract community. Most of these guarantees have proven to be very

conservative, which is not surprising given the very limited data that they were based on and the potentially severe financial consequences contained in the operating agreements for failure to meet a guarantee.

This paper presents a summary of key historical data from 15 MBWW facilities located throughout North America from which to gauge expected long-term performance levels for both existing and proposed new or expanded MBWW facilities. All of the MBWW facilities considered in this review, which represent nearly 30 percent of the total number of MBWW facilities currently operating in North America, have been in

operation for at least 14 years and many are nearing or have passed 20 years of commercial operation. Table 1 includes a list of the MBWW facilities that were reviewed along with some of their key design data and the number of years of operating data considered in this review. This list of MBWW facilities includes facilities operated by all three of the major North American WTE contract operators (Covanta, Veolia, Wheelabrator) plus one municipally operated facility (Portland, ME). While the data in this paper is specific to MBWW facilities, some of the performance indicators may also be relevant to WTE facilities that employ other combustion technologies.

Table 1. MBWW Facilities Used to Assess Long-Term Performance Levels

Facility	Startup Date	No. Units	Steam Conditions (psig/°F)	No. Years of Operating Data Considered
Pinellas, FL	May 1983	3	600/750	5
Hillsborough, FL	October 1987	3	600/750	6
Alexandria, VA	February 1988	3	600/700	6
Vancouver, BC	March 1988	3	435/662	3
Portland, ME	October 1988	2	600/750	9
Long Beach, CA	December 1988	3	650/752	3
Stanislaus, CA	January 1989	2	865/830	6
Charleston, SC	November 1989	2	650/750	3
Huntsville, AL	July 1990	2	350/471	7
Pasco, FL	March 1991	3	865/830	6
Lancaster, PA	June 1991	3	865/830	6
Spokane, WA	November 1991	2	900/830	5
Montgomery, PA	February 1992	2	600/750	3
Lee, FL	December 1994	3	865/830	4
Onondaga, NY	February 1995	3	865/830	6

SELECTED PERFORMANCE INDICATORS

The following indicators are commonly used in the WTE industry to gauge the operational performance of MBWW facilities and are used in this paper to establish performance benchmarks for these facilities based on actual industry experience. Each of these indicators has a direct or indirect impact on facility revenues and/or operating costs.

Boiler and Turbine-Generator Availability

Availability represents the percentage of time that each combustion unit and the turbine-

generator operated during the year. While this type of equipment is designed to operate on a 24 hours per day, 365 days per year basis, a certain level of downtime can be expected over the course of the year related to both scheduled and unscheduled maintenance. Combustion unit and turbine-generator availability have a direct effect on the amount of waste that a facility can process and the amount of electricity it can generate. Downtime due to lack of fuel (i.e., low refuse deliveries), if any, is not normally counted against availability. Ideally, each combustion unit and the turbine-generator

should be operated at as high an online availability as practical to maximize production and revenues.

Boiler Steam Capacity Utilization

Each combustion unit has a design steam rate (pounds per hour) at which the unit is intended to be operated on a continuous basis. This point is often referred to as the unit's "maximum continuous rating" or MCR. Capacity utilization is the ratio of the actual steam production to the design production when the unit is on line. This factor, expressed as a percentage, has a direct effect on the amount of waste that the facility can process and consequently the amount of electricity it can generate. Ideally, each combustion unit should be operated as close to 100 percent of its design steam rating as practical to maximize production and revenues.

Electric Power Generation

Power generation assesses the total amount of energy recovered from the combustion process and converted to electricity (gross electricity), the amount of energy used to operate the plant (in-plant electricity) and the amount of energy available for sale (net electricity). It is common practice in the WTE industry to supply in-plant power needs from the gross power generated by the facility since the energy price received for power sold by the facility is typically less than the cost to purchase power. The total amount of power generated and the percentage of power used in-plant have a direct effect on the amount of power available for sale and consequently the energy revenues received by the facility. A few WTE facilities sell some or all of the steam that they generate instead of converting the thermal energy to electricity. Since electric power generation is primarily dependent on the amount of refuse processed, it is commonly evaluated on a "per ton of refuse processed" basis or, in some instances, converted to a "per ton of reference refuse processed" to take into account variations in the heat content of the refuse as discussed below.

Refuse Heating Value

The throughput and energy recovery potential of a WTE facility is highly dependent on the refuse heating value. Refuse throughput is inversely proportional to heating value within a limited range established during the design of the facility and energy recovery is proportional to refuse heating value. Most WTE facilities estimate the monthly average refuse heating value, generally using a variation of the boiler as a calorimeter method, in order to evaluate annual processing and energy recovery guarantees which are typically tied to a reference heating value.

Residue Generation

Residue generation assesses the amount of material remaining after the combustion process. The amount of material remaining is indicative of the amount of non-combustible material contained in the incoming refuse, the degree of "burnout" achieved during combustion, the water content of the residue after quenching and, to a lesser extent, the quantity of reagents added for pollution control. The greater the amount of residue remaining, the higher the residue hauling and disposal costs. Residue hauling and disposal costs can be best managed by achieving good "burnout" and minimizing the water content. Since residue generation is primarily dependent on the amount of refuse processed, it is commonly evaluated as a percentage of the total throughput. Some MBWW facilities add additional lime to the residue for conditioning purposes. The additional lime is either added through the scrubber via higher slurry flow rates or added directly to the residue after it leaves the combustors. The percentage of residue generated by these facilities is therefore somewhat higher.

Metal Recovery

Metal recovery assesses the amount of ferrous metal and, in an increasing number of WTE facilities, non-ferrous metal that is recovered

from the residue prior to disposal. The more ferrous and non-ferrous metal that is recovered, the lower the quantity of residue requiring disposal, leading to a reduction in the residue hauling and disposal costs. Most WTE facilities remove metals from the residue at the facility. In a few cases, metals are recovered at the residue landfill site prior to disposal. While commodity prices can fluctuate widely, a small amount of additional revenue can usually be realized from the sale of the recovered metals. The sum of the avoided residue disposal costs plus the revenue from the sale of recovered metals is usually enough to at least offset the cost of owning and operating the ferrous and non-ferrous recovery system. Since metal recovery is primarily dependent on the amount of waste processed, it is commonly evaluated as a percentage of the total throughput. While the percent of non-ferrous metals in the residue is relatively small compared to ferrous metals, the commodity price for the non-ferrous metal is significantly higher than ferrous metal, which has driven the interest in retrofitting WTE facilities with non-ferrous metal recovery equipment.

Reagent Usage

Various reagents such as lime, activated carbon and urea/ammonia are used at WTE facilities to control acid gases, mercury/dioxins and nitrogen oxides, respectively. Their consumption has a direct effect on the operating costs of the facility and, since many of these reagents and/or their byproducts end up as a solid material in the residue, they may also have some effect on the cost of residue hauling and disposal. Since reagent usage is primarily dependent on the amount of refuse processed, it is commonly evaluated on a “per ton of refuse processed” basis. Some WTE facility contracts include a risk sharing arrangement on these reagents where a maximum usage guarantee is included. The costs for reagent usage up to the guarantees are a pass-through to the owner or contract community while the costs for usage above the

guarantees are the responsibility of the contract operator.

Utility Usage

Various utilities such as water, sewer, purchased power, and auxiliary fuel are used at WTE facilities and are often a pass through cost to the owner or contract community. Their consumption has a direct effect on the operating costs of the facility. Since utility usage is primarily dependent on the amount of refuse processed, it is commonly evaluated on a “per ton of refuse processed” basis. Some WTE facility contracts include a risk sharing arrangement for these utilities that is similar to the provisions for reagents.

DATA ANALYSIS

Operating data for the most recent three to nine years was reviewed for each of the 15 MBWW facilities listed in Table 1. Collectively, a total of 78 operating years of data was considered in this review. The results of this review are summarized below and in the accompanying figures for the above selected performance criteria.

Boiler and Turbine-Generator Availability

Figure 1 includes a summary of average annual boiler availability versus years of operation for each of the 15 MBWW facilities. This data indicates that boiler availability tends to fluctuate on an annual basis depending on the specific maintenance needs and that the percentage variation is generally small. This data also suggests that in most cases annual boiler availability does not decline appreciably with facility age even as a facility approaches 20 years of operation. Individual years with significantly lower boiler availability typically are associated with implementation of one or more major capital repairs such as replacement of sections of the furnace waterwall or superheater banks. The data in Figure 1 suggests that annual boiler availabilities in the range of 88-92 percent can reasonably be expected on a long term basis with proper maintenance.

Figure 1. Comparison of Boiler Availability Over Time

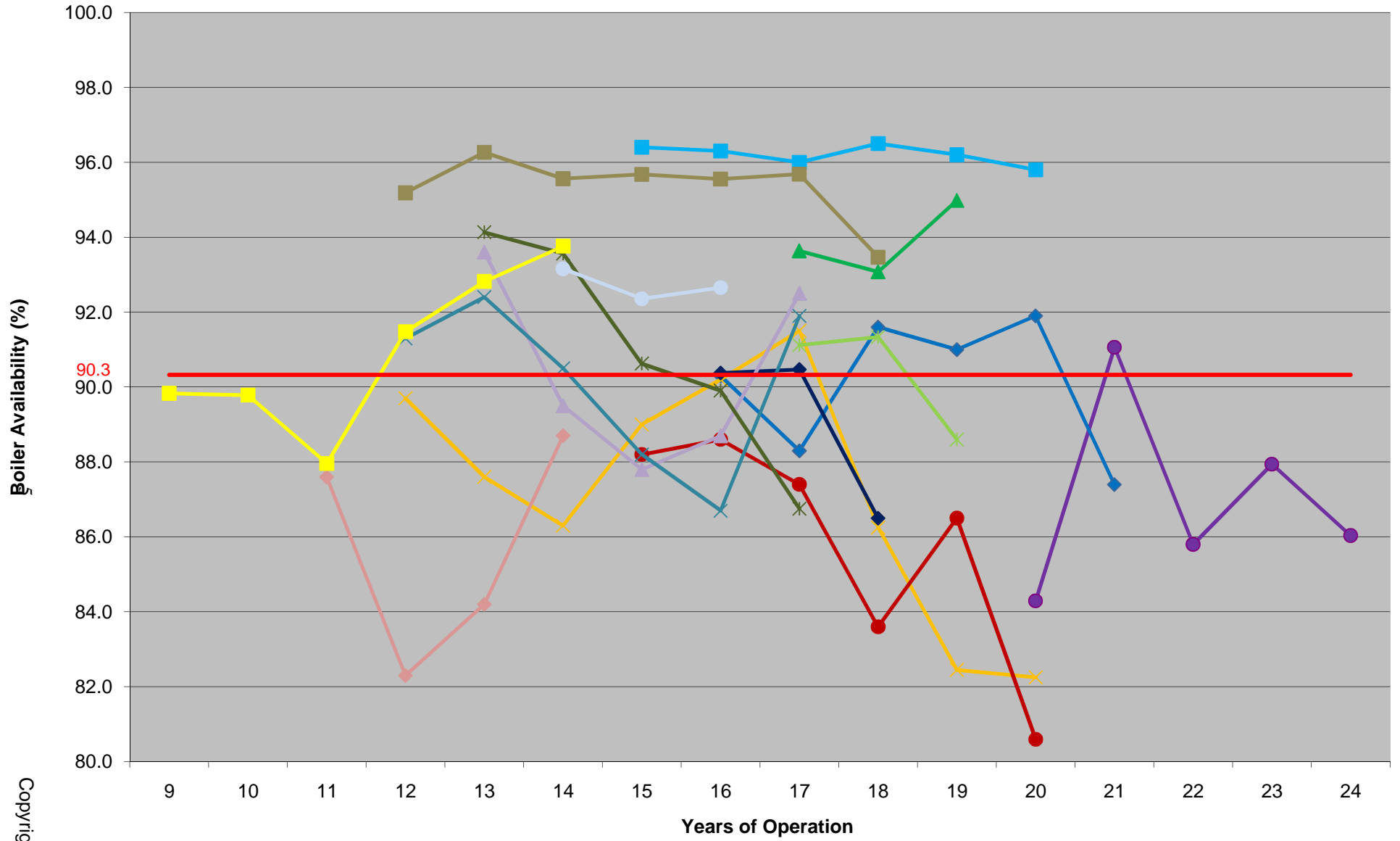


Figure 2 includes a summary of average annual turbine-generator availability versus years of operation for 14 of the MBWW facilities. The Huntsville, AL facility sells only steam and does not have a turbine-generator. This data indicates that turbine-generator availability is relatively stable on a year to year basis except when major overhauls or extraordinary maintenance is performed. This data also suggests that turbine-generator availability, like boiler availability, does not decline appreciably with facility age even as a facility approaches 20 years of operation. The data in Figure 2 suggests that annual turbine-generator availabilities in the range of 94-99 percent can reasonably be expected on a long term basis with proper maintenance. Turbine-generators typically undergo major overhauls every 5-7 years and availability during these years can be expected to be 4-5 percent lower than normal as a result. A few MBWW facilities with only two combustion units take both units off line at the same time for scheduled maintenance which results in a somewhat lower annual turbine-generator availability for these facilities.

Boiler Steam Capacity Utilization

Figure 3 includes a summary of average annual boiler steam capacity utilization versus years of operation for 14 of the MBWW facilities. This data indicates that boiler steam capacity utilization tends to fluctuate on a year to year basis. This data also suggests that steam capacity utilization can decline over time as a facility ages but that this decline is not necessarily permanent. Factors that may contribute to a short term decline in steam capacity utilization could include, for example, the condition of the boiler tubes and/or bags in the fabric filter baghouse. In both cases, concerns over thinning boiler tube wall thickness or excessive pressure drop across dirty filter bags could require the operator to lower steam flow set points. Lower steam capacity utilization can also occur during periods of reduced refuse inventory. Some operators may also lower steam flow set points to reduce the severity of boiler fouling, attempting instead to achieve

better long-term performance by reducing the frequency of downtime associated with boiler cleaning. The data in Figure 3 suggests that boiler steam capacity utilizations in the range of 95-100 percent of design can reasonably be expected on a long term basis.

Electrical Power Production

Figure 4 includes a summary of average annual gross electrical production, net electrical production and in-plant electrical consumption for the 14 MBWW facilities that generate electricity. This data suggests that gross electrical production, net electrical production and in-plant electrical consumption rates in the range of 550-650 KWH/ton, 450-550 KWH/ton and 80-110 KWH/ton, respectively, can reasonably be expected on a long-term basis. The exact amount of electricity per ton of refuse processed will vary by facility depending on a number of factors including the heating value of the refuse processed, the design steam conditions, the size and efficiency of the turbine-generator, the type of steam condensing system used (i.e., evaporative cooling tower or air cooled condenser) and whether the facility exports any steam. Of all these factors, the refuse heating value has the greatest impact on the per ton electrical generation rate. The Vancouver BC and Charleston SC facilities have comparatively low gross electrical generation rates because they both divert a portion of their steam through a dedicated turbine extraction and sell it to a nearby steam customer.

Refuse Higher Heating Value

Figure 5 includes a summary of the estimated average annual refuse heating value for 13 of the MBWW facilities over the past 5 years. This data suggests that the average annual refuse higher heating value has, in most cases, been above 5,000 Btu/lb. This is considerably higher than the 4,500 Btu/lb value used as the basis of design for many of the existing WTE facilities in North America. The data in Figure 5 also suggests that the trend of increasing refuse heating value observed over the past 20 years has leveled off, at least for the time being. This

Figure 2. Comparison of Turbine-Generator Availability Over Time

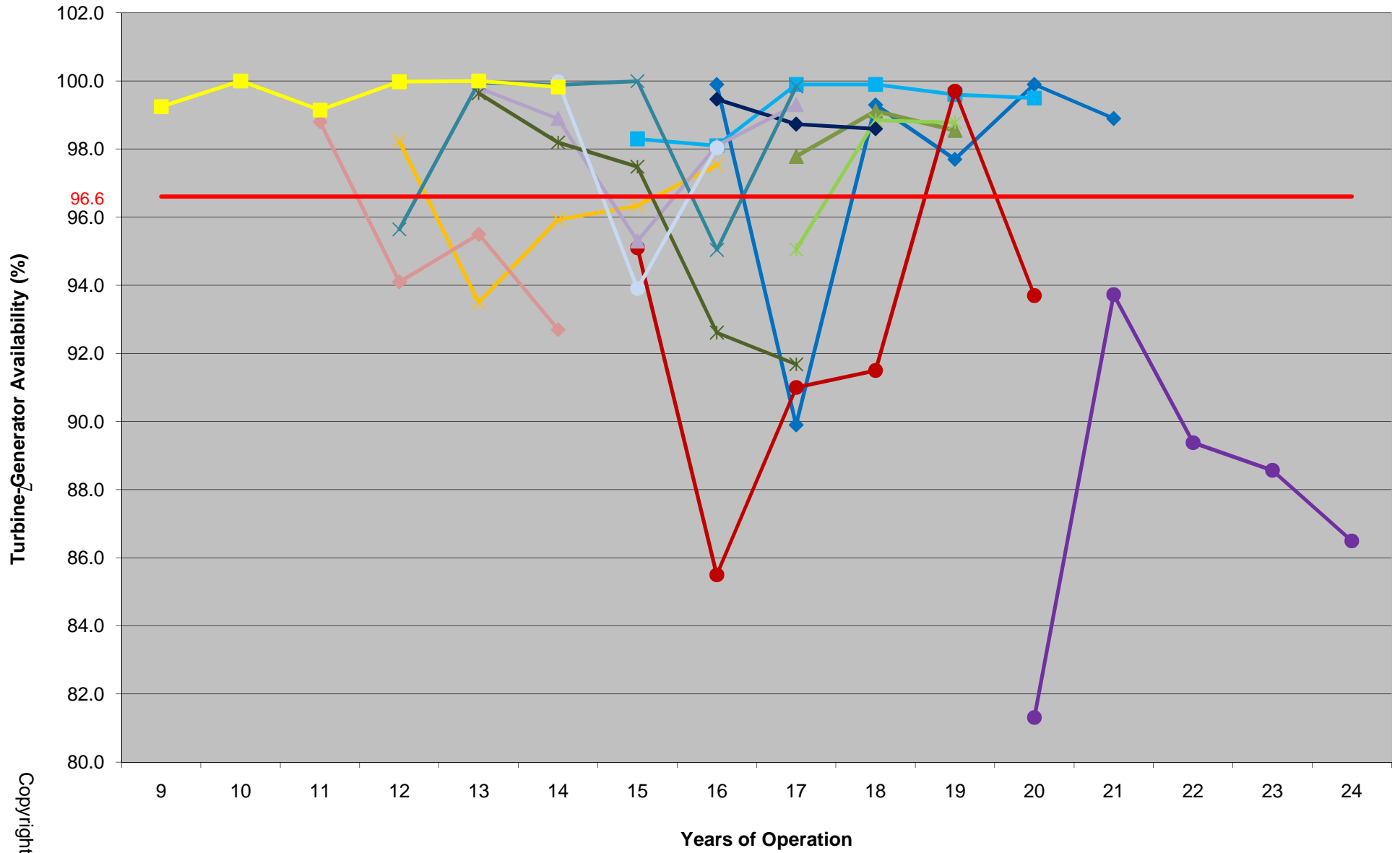


Figure 3 - Comparison of Boiler Steam Capacity Utilization Over Time

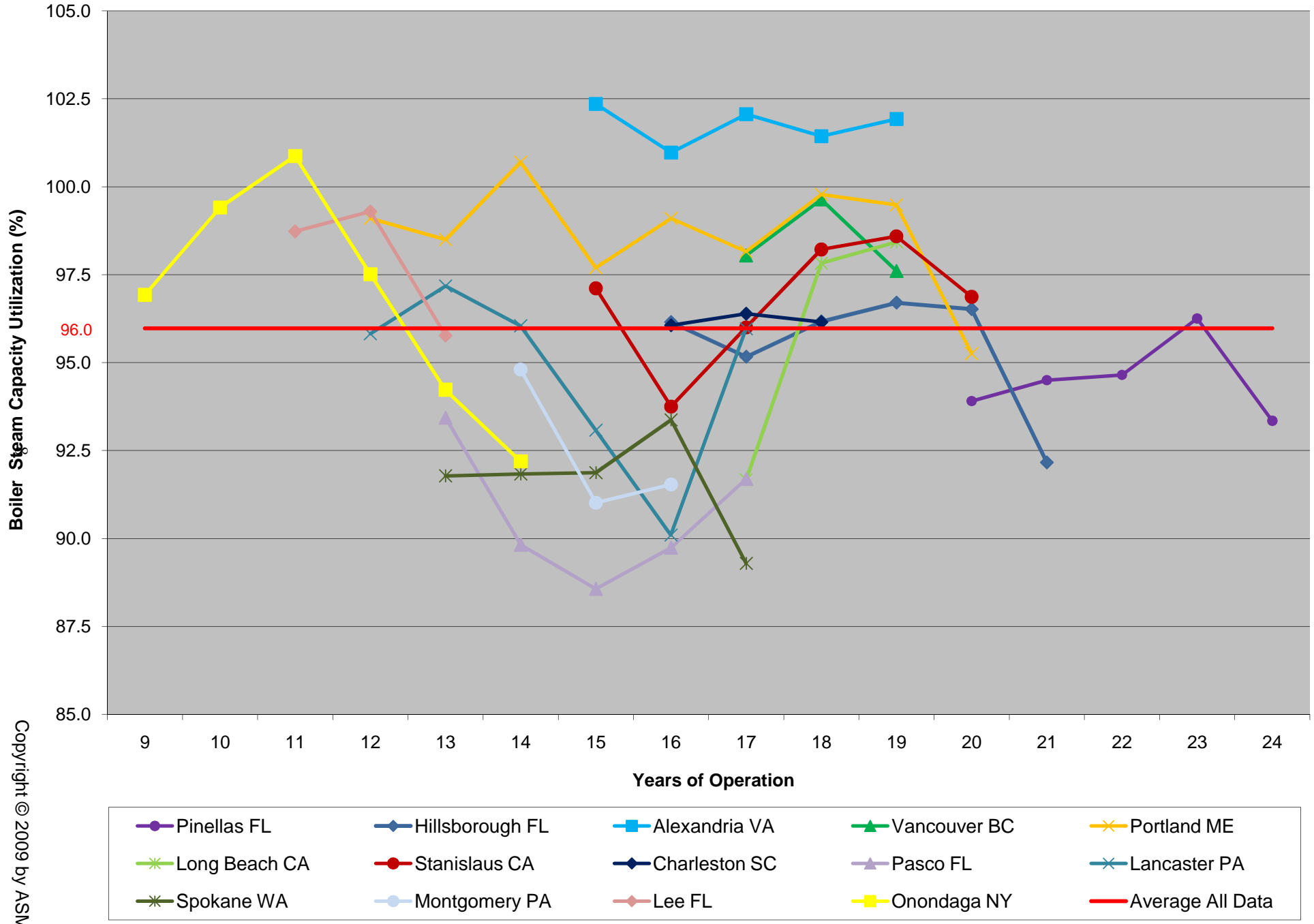


Figure 4. Comparison of Electrical Generation and Usage

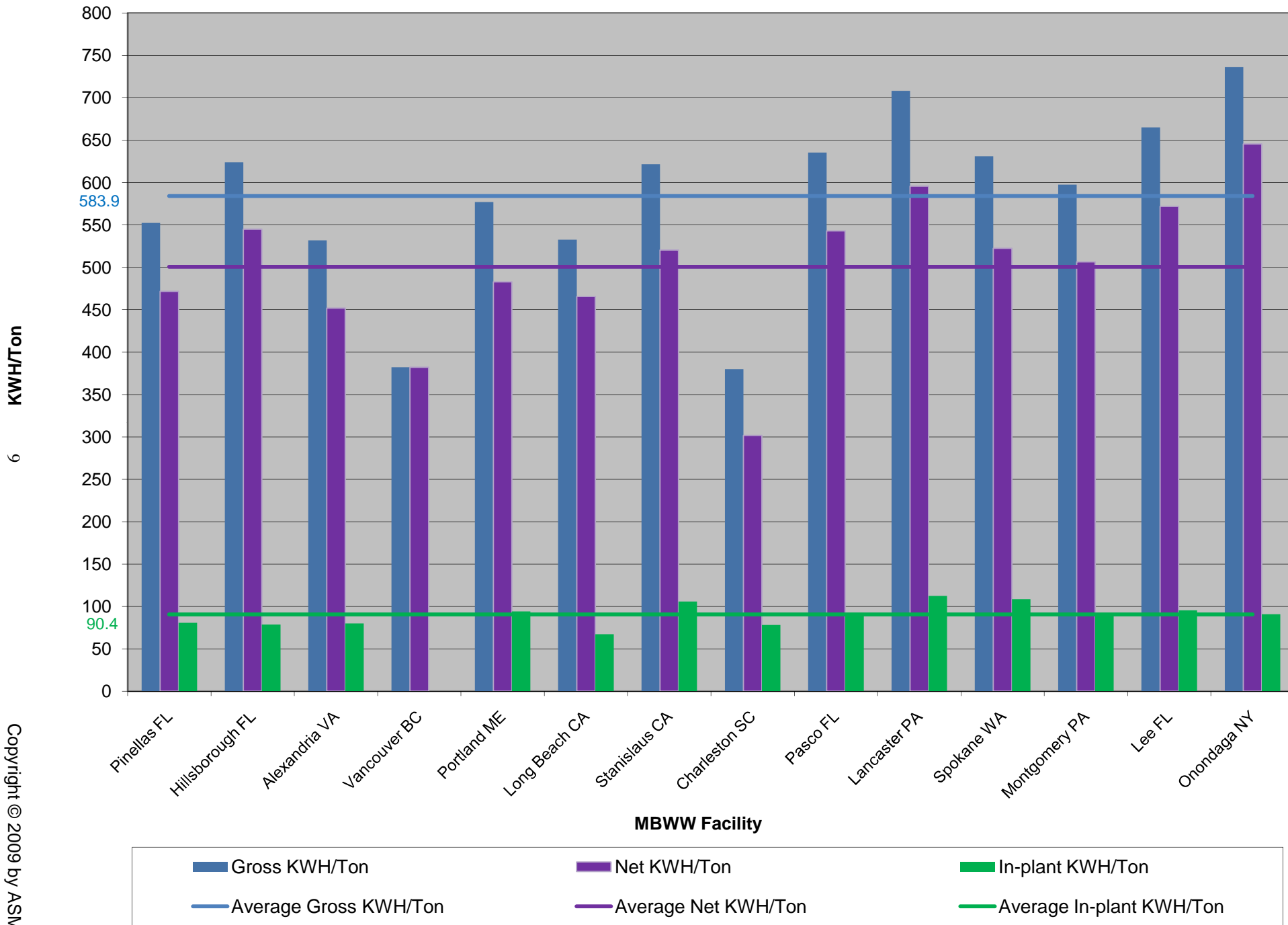
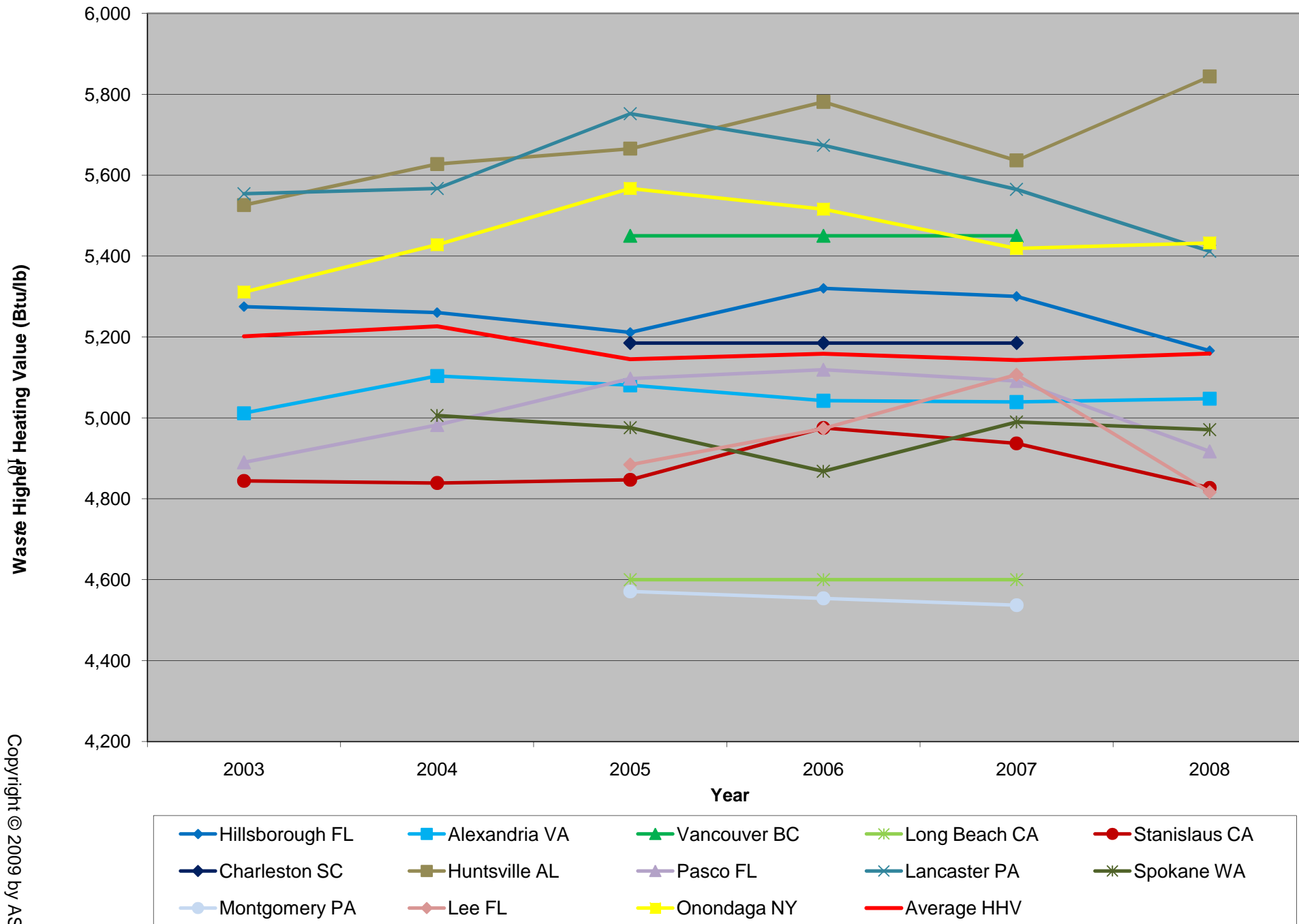


Figure 5. Comparison of Waste Higher Heating Value



likely reflects that the diversion of low heating value components such as yard waste, glass, and metal containers has peaked. Further increases in refuse heating value are possible in the future if, for example, programs are implemented to divert food waste or the plastic content of the waste stream increases significantly. Short term decreases in the refuse heating value may also occur if the recent downturn in the economy continues and funding limitations force communities to scale back or eliminate their recycling programs. The data in Figure 5 suggests that the downturn in the economy over the past couple of years, which has reduced the quantity of waste generated, also appears to have reduced the refuse heating value in some cases, possibly due to a reduction in consumer packing for example.

Residue Generation and Metals Recovery

Figure 6 includes a summary of average total residue generation and ferrous metal recovery rates for the 15 MBWW facilities. This data suggests that total residue generation and ferrous metal recovery rates in the range of 25-30 percent and 1-3 percent of the refuse throughput, respectively, can reasonably be expected. Some MBWW facilities add additional lime and/or Portland cement to their residue stream to condition the fly ash which increases the overall residue generation rate. Only four of the MBWW facilities reviewed have non-ferrous metal recovery systems and two of these systems have only been in operation for approximately one year. The limited amount of data from these four facilities suggests that non-ferrous metal recovery rates in the range of 0.10-0.15 percent of the refuse throughput can reasonably be expected. The exact amount of metal recovery will depend in large part on the amount of ferrous and non-ferrous metals present in the incoming waste stream and the processes used to recover and remove loose ash from the metal. Facilities located in communities with aggressive recycling programs tend to have lower metal recovery rates as a result.

Pebble Lime and Activated Carbon Usage

Figures 7 and 8 include summaries of average pebble lime and activated carbon usage for most of the MBWW facilities. This data suggests that pebble lime and activated carbon usage rates in the range of 15-20 lbs/ton and 0.6-1.0 lbs/ton, respectively, can reasonably be expected. The exact amount of pebble lime used per ton of refuse processed will vary by facility based on a number of factors including the permit limits for acid gases, the chlorine and sulfur content of the incoming waste stream, the type of particulate control device used and whether the facility is adding additional lime through the scrubbers to condition the fly ash. The Portland ME facility, for example, uses an electrostatic precipitator for particulate control and therefore has a higher lime (and carbon) utilization rate since this type of device does not afford the same opportunity for additional reagent contact as a fabric filter baghouse does. Review of the data in Figure 8 indicates that there is a greater degree of variability in carbon usage from facility to facility. The exact amount of carbon used per ton of refuse processed will also vary by facility based on a number of factors including the permit limit for mercury and dioxins/furans and the mercury content of the incoming waste stream. Some states, for example, have enacted a more stringent standard for mercury emissions than the federal limit and some states have banned the sale of thermometers and thermostats that contain mercury and/or enacted more aggressive mercury recycling regulations.

Urea and Ammonia Usage

Figure 9 includes a summary of urea and ammonia usage for 13 of the MBWW facilities. Three of the facilities use urea only, one facility uses anhydrous ammonia only, seven facilities use aqueous ammonia only, one facility (Lee, FL) uses both urea and aqueous ammonia and one facility (Spokane WA) uses both urea and anhydrous ammonia. Aqueous ammonia is used in the two original units at the Lee FL facility while urea is used in the new unit that

Figure 6. Comparison of Residue Generation and Ferrous Metal Recovery

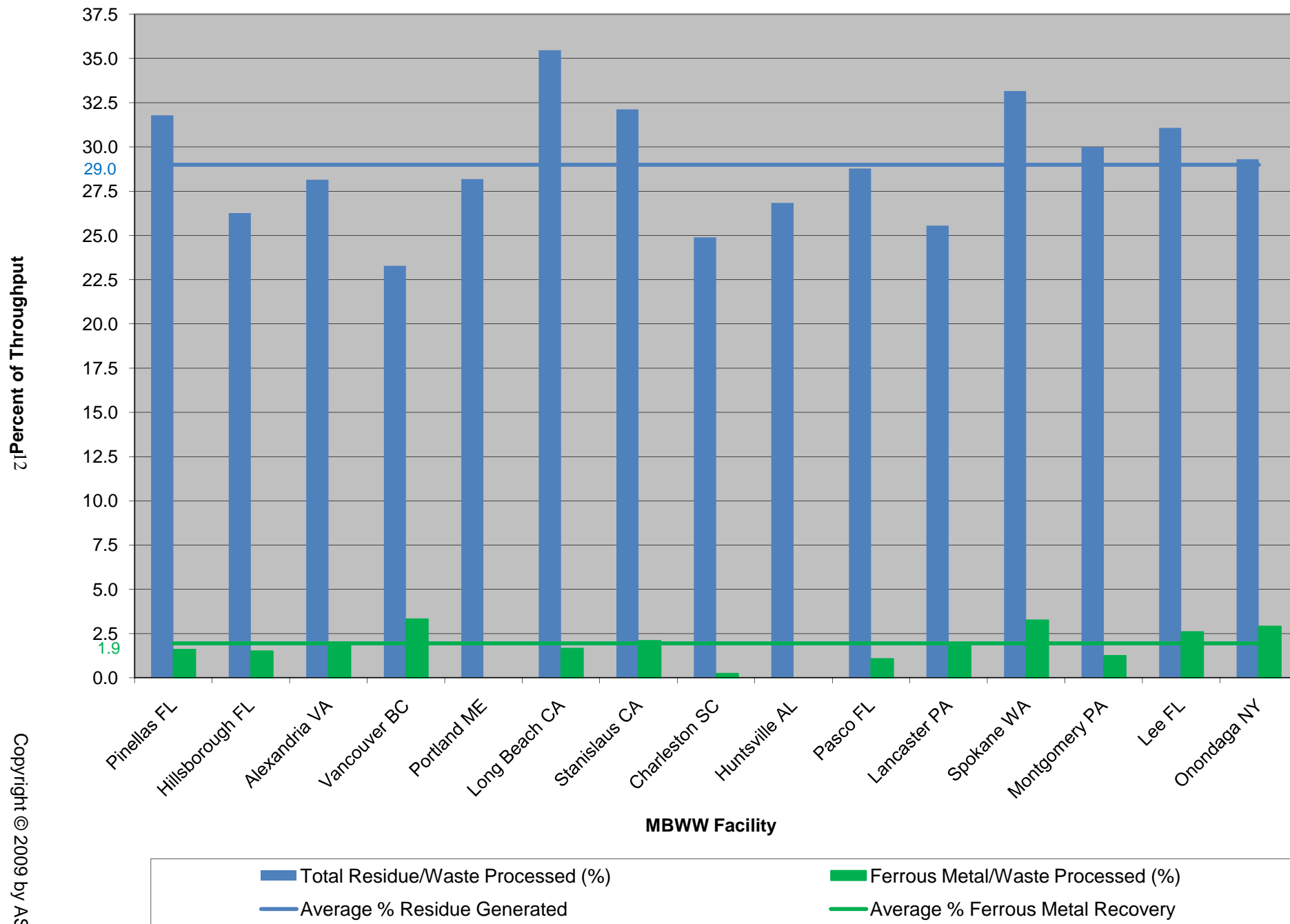


Figure 7. Comparison of Pebble Lime Feed Rates

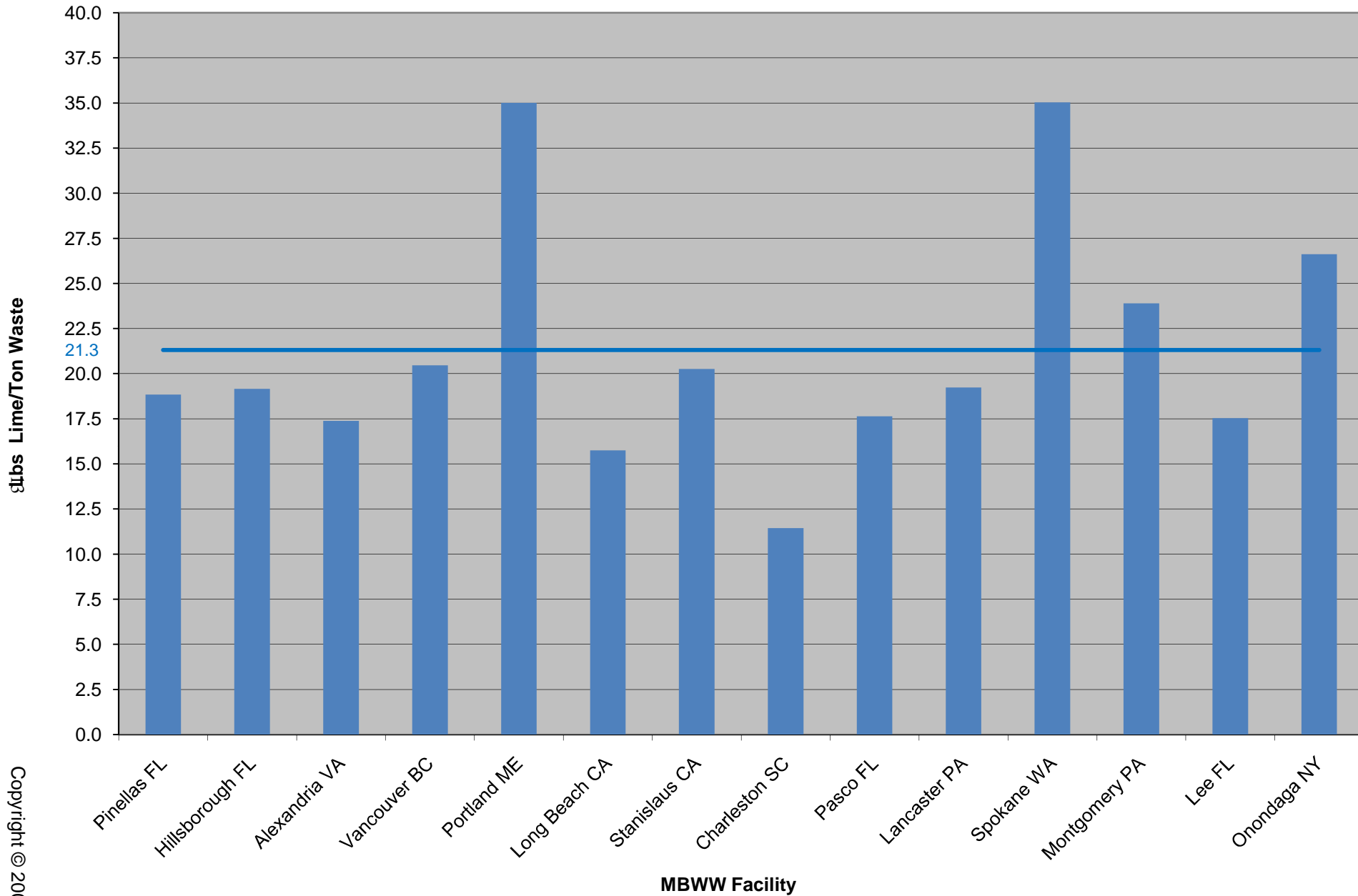


Figure 8. Comparison of Carbon Feed Rates

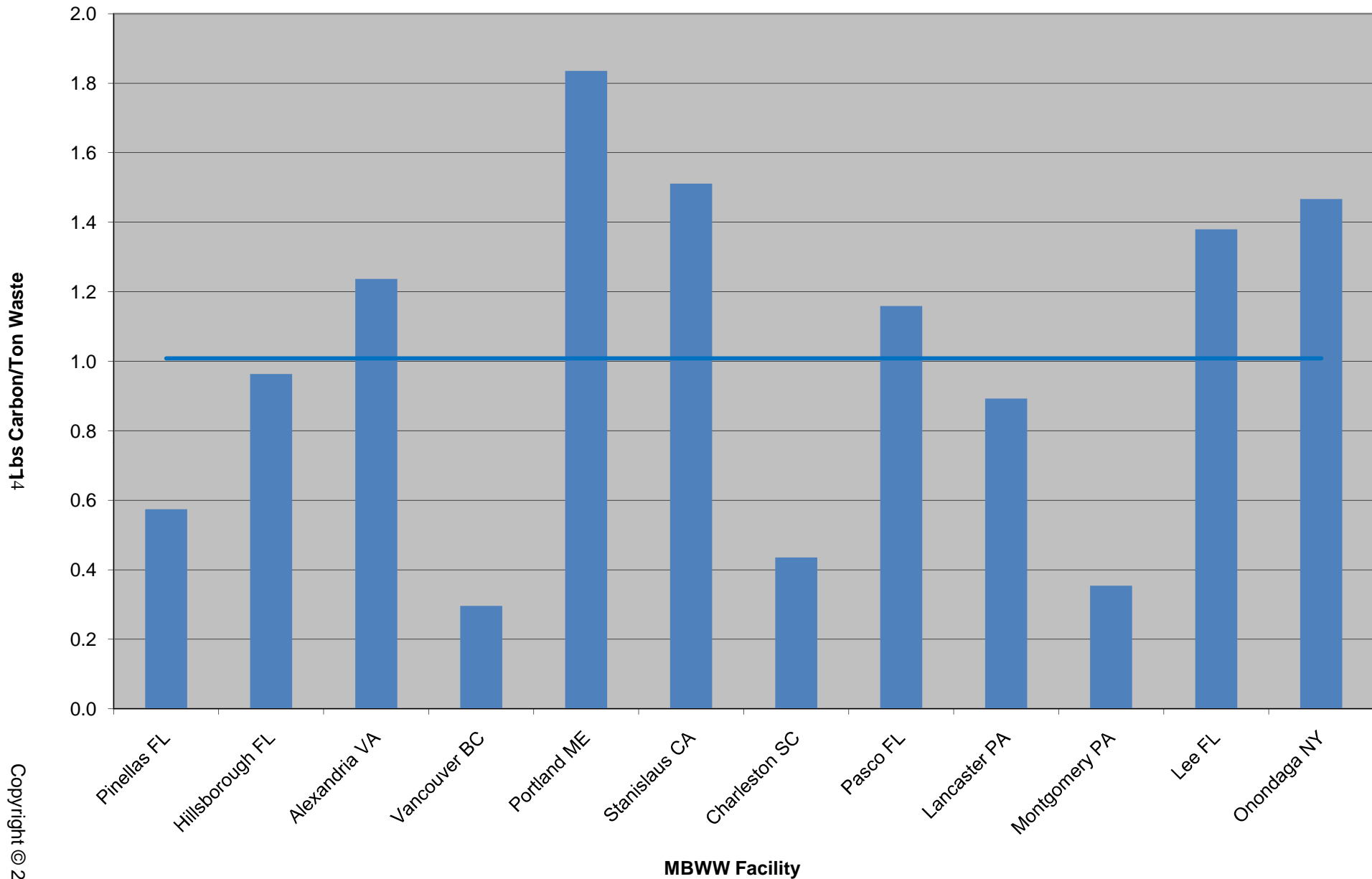
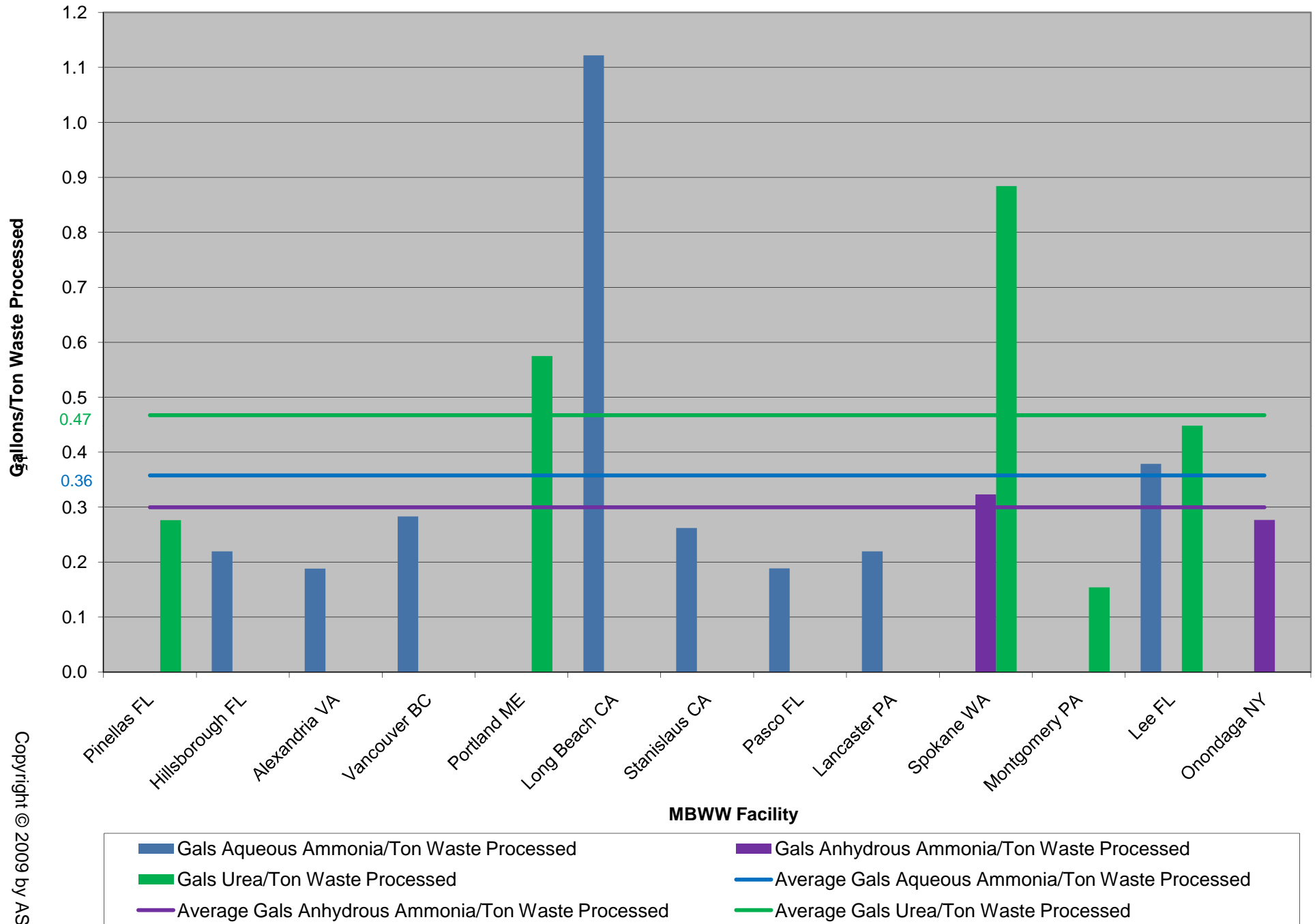


Figure 9. Comparison of Ammonia and Urea Feed Rates



went on line in 2007. The Spokane WA facility was originally designed with an anhydrous ammonia system. A urea based system was installed in 2005 and the anhydrous ammonia system is used as a backup system. Review of the data in Figure 9 suggests that urea, anhydrous ammonia and aqueous ammonia usage rates in the ranges of 0.30-0.50 gal/ton, 0.25-0.35 gal/ton and 0.20-0.40 gal/ton, respectively, can reasonably be expected. The exact amount of urea, anhydrous ammonia or aqueous ammonia used per ton of refuse processed will vary by facility based on a number of factors including the permit limit for NO_x, the nitrogen content of the incoming waste stream and the effectiveness of the injection system. New units can be expected to have significantly more stringent NO_x emission limits which could increase usage rates even with improved NO_x removal technologies.

Process Water Usage

Figure 10 includes a summary of process water usage for 10 of the MBWW facilities. This data suggests that process water usage rates in the range of 450-550 gal/ton can reasonably be expected for facilities that employ an evaporative cooling tower. For facilities like Onondaga NY, Spokane WA and Vancouver BC that use an air cooled condenser, process water usage decreases significantly to approximately 75-150 gal/ton. Many MBWW facilities with evaporative cooling towers utilize non-potable sources for cooling water, such as treated effluent from wastewater treatment plants or on site stormwater ponds, in order to reduce dependence on potable water resources. The quality of the water source will impact water usage rates as will in-house process wastewater reuse programs.

Auxiliary Fuel Usage

Figure 11 includes a summary of auxiliary fuel usage for 13 of the MBWW facilities. While most WTE facilities use natural gas, a few facilities rely on fuel oil or propane as their auxiliary fuel. The data in Figure 11 suggests that auxiliary fuel usage rates in the range of 20-40 Btu/lb can reasonably be expected. This

represents less than one percent of the total heat input. The exact amount of auxiliary fuel used per pound of refuse processed will vary by facility based on a number of factors including the permit conditions, the number of boiler startups and shutdowns, the moisture content of the incoming waste stream and whether auxiliary fuel is also used for building heat during the winter months.

OPERATING PERFORMANCE SUMMARY

Table 2 below summarizes the operating data for the 15 MBWW facilities reviewed in this paper.

PLANNING BENCHMARKS FOR NEW MBWW UNITS

Those planning new WTE facilities or expansions of existing facilities now have the benefit of more than 20 years of solid operating experience that was not available at the time the current generation of WTE facilities were developed. The experience discussed in this paper suggests that a number of changes may be warranted in the basis of design for new MBWW units. The suggested planning benchmarks for new MBWW units are discussed below.

Boiler Availability

Financial projections for WTE facilities rely heavily on the expected facility throughput which sets the expected tipping fee revenues. The expected annual throughput for the existing generation of MBWW facilities was based, in most cases, on an assumed average annual boiler availability of 85 percent. The expectation at the time that these projects were developed was that boiler availability would likely decline over time reaching 85 toward the end of the 20 year planning period. As discussed above, the actual boiler availability demonstrated over the past 20 years has, in most cases, been consistently higher than 85 percent, even for those facilities that have been in operation for 20 or more years. Based on this experience, it appears reasonable to assume a design boiler availability of 88-90 percent for new MBWW units which, if included in an operating contract,

Figure 10 . Comparison of Process Water Usage

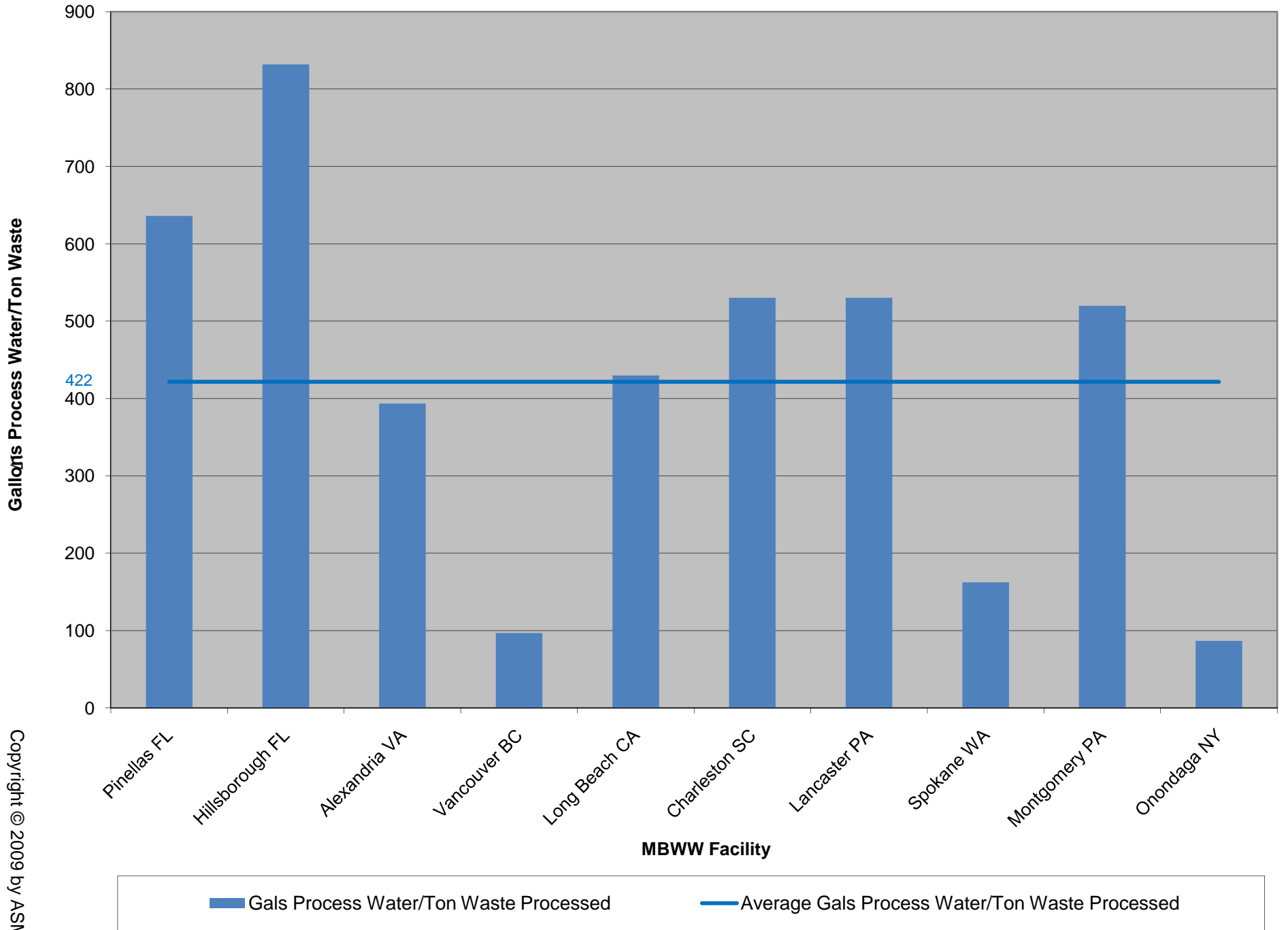


Figure 11. Comparison of Auxiliary Fuel Usage

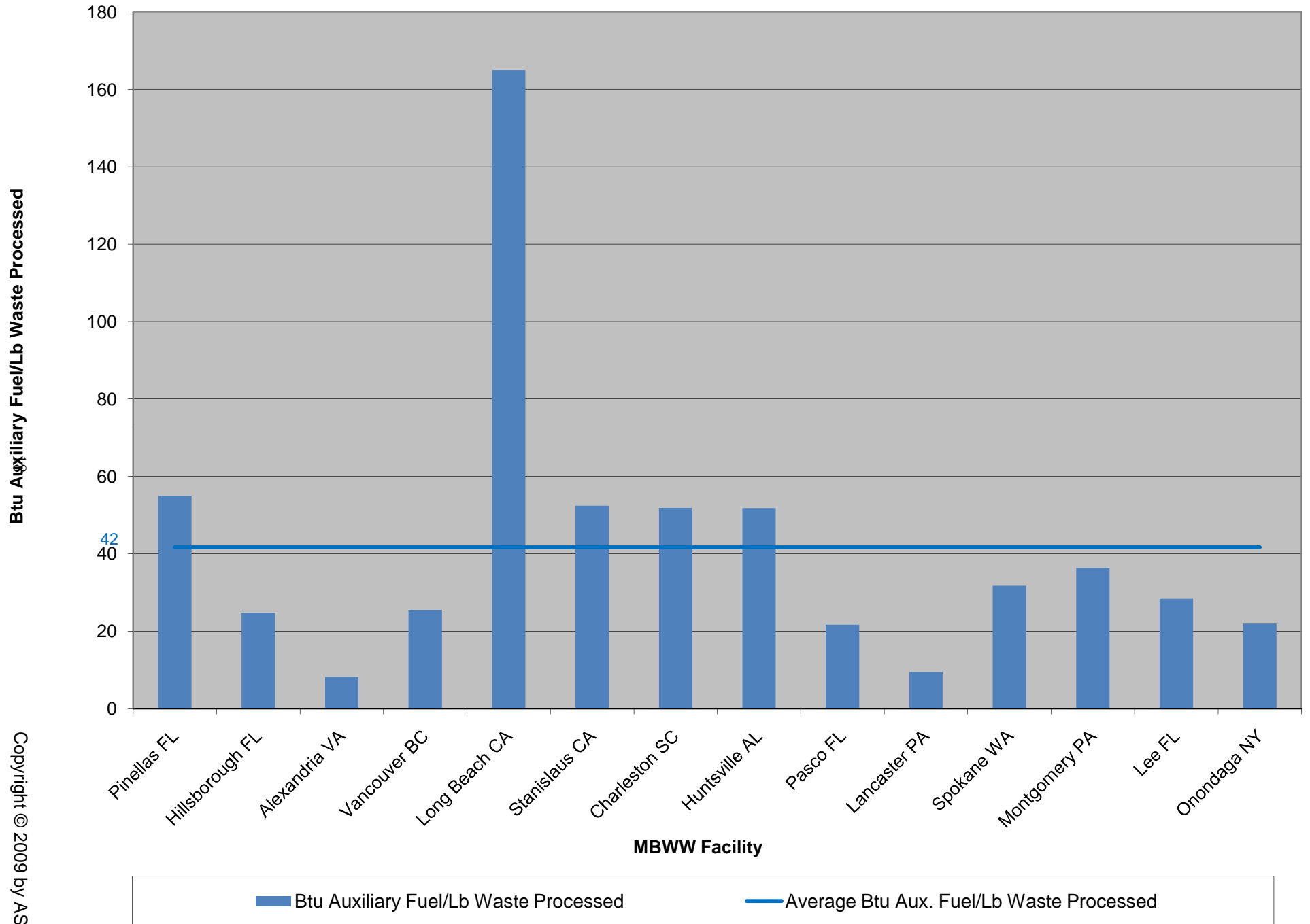


Table 2. Summary of MBWW Operating Data

Parameter	No. Facilities Reviewed	High	Low	Average
Boiler Availability (%)	15	96.2	85.7	90.3
Turbine-Generator Availability (%)	14	99.7	87.9	96.6
Boiler Steam Capacity Utilization (%)	14	101.8	90.7	96.0
Gross Electrical Production (KWH/Ton)	14	736	380	584
Net Electrical Production (KWH/Ton)	14	645	302	500
In-plant Electrical Consumption (KWH/Ton)	13	112	67	90
2003-2008 Refuse HHV (Btu/Lb)	13	5,844	4,537	5,151
Residue Generation (%)	15	35.5	23.3	29.0
Ferrous Metal Recovery (%)	13	3.3	0.2	1.9
Non-Ferrous Metal Recovery (%)	4	0.15	0.07	0.10
Pebble Lime Usage (Lbs/Ton)	14	35.0	11.4	21.3
Activated Carbon Usage (Lbs/Ton)	12	1.84	0.30	1.01
Aqueous Ammonia Usage (Gal/Ton)	8	1.12	0.19	0.36
Anhydrous Ammonia Usage (Gal/Ton)	2	0.32	0.28	0.30
Urea Usage (Gal/Ton)	4	0.88	0.15	0.47
Process Water Usage (Gal/Ton)	10	832	87	422
Auxiliary Fuel Usage (Btu/Lb)	13	165	8	42

would not unreasonably increase the risk to a contract operator.

Refuse Heating Value

MBWW units are sized based on a design heat release (MMBtu/hr) which is determined by the product of the design refuse heating value and the design refuse throughput. Many of the MBWW facilities currently operating in North America were designed based on an average annual refuse higher heating value of 4,500 Btu/lb, with some at 4,800 or 5,000 Btu/lb. As discussed above, current estimates suggest that refuse heating value is now on the order of 5,000-5,500 Btu/lb in most locations.

Processing waste with a refuse heating value higher than design results in a corresponding decrease in the facility's throughput capacity, thereby reducing tipping fee revenues. The increase in the refuse higher heating value observed over the past 20 years is related to a number of factors including the presence of a higher percentage of plastics in the waste stream and the diversion of relatively low heating value materials such as yard waste and bottles and cans to composting and recycling programs. Some jurisdictions are also

considering diverting food waste to compost programs which, if implemented, would increase the heating value of the remaining waste stream further. Based on this experience, it appears reasonable to use a design refuse heating value of at least 5,000 Btu/lb for new MBWW units.

Steam Conditions

Most of the MBWW facilities that were designed prior to 1987 limited the design steam conditions to approximately 600 psig and 750 °F due to concerns related to the life of the superheater section of the boiler. The design steam conditions for most of the MBWW facilities developed after 1987 were increased to approximately 865 psig and 830 °F based on the initial experience of the early facilities. The MBWW facilities evaluated in this paper include units operating with design steam conditions up to 900 psig, 830 °F. Review of the performance data suggests that the higher and more efficient steam conditions do not materially affect boiler availability. Based on this experience, it appears reasonable to assume design steam conditions on the order of 865 psig and 830 °F for new MBWW units.

Net Electricity Generation

Financial projections for WTE facilities rely heavily on the expected net electricity generation which establishes the expected energy revenues. The actual net electricity generation rates demonstrated by the currently operating MBWW facilities are considerably higher than originally expected due largely to an increase in the refuse heating value. As discussed above, refuse heating values have increased by 10-20 percent over the past 20 years and further increases are possible in the future. Based on this experience, it appears reasonable to expect a net electricity generation rate in the range of 550-650 KWH/ton for new MBWW units designed with a refuse heating value on the order of 5,000-5,500 Btu/lb and steam conditions of approximately 865 psig and 830 °F.

CONCLUSION

The current generation of WTE facilities was developed based on no operating experience or very limited operating experience and, as a result, there were a lot of uncertainties relative to the long-term performance of these facilities. This paper reviewed the historical performance of 15 MBWW facilities, which represents 15 percent of the total number of WTE facilities currently in operation in North America and nearly 30 percent of the total number of operating MBWW facilities.

The performance of these facilities has, for the most part, been better than originally expected, and no material decline in performance has been observed as these facilities reach or exceed the end of their original 20 year planning horizon. Many of these facilities are expected to continue to operate for the foreseeable future although certain major capital repairs and replacement work may be necessary to maintain similar performance levels for another 20 year planning period.

The operating experience over the past 20 plus years also provides valuable information for those planning new MBWW facilities or expansions of existing facilities. The extensive

operating experience that currently exists and was highlighted in this paper should translate into a lower performance risk to contract operators and more favorable operating and maintenance pricing and revenue expectations to owners and contract communities.

ACKNOWLEDGEMENTS

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