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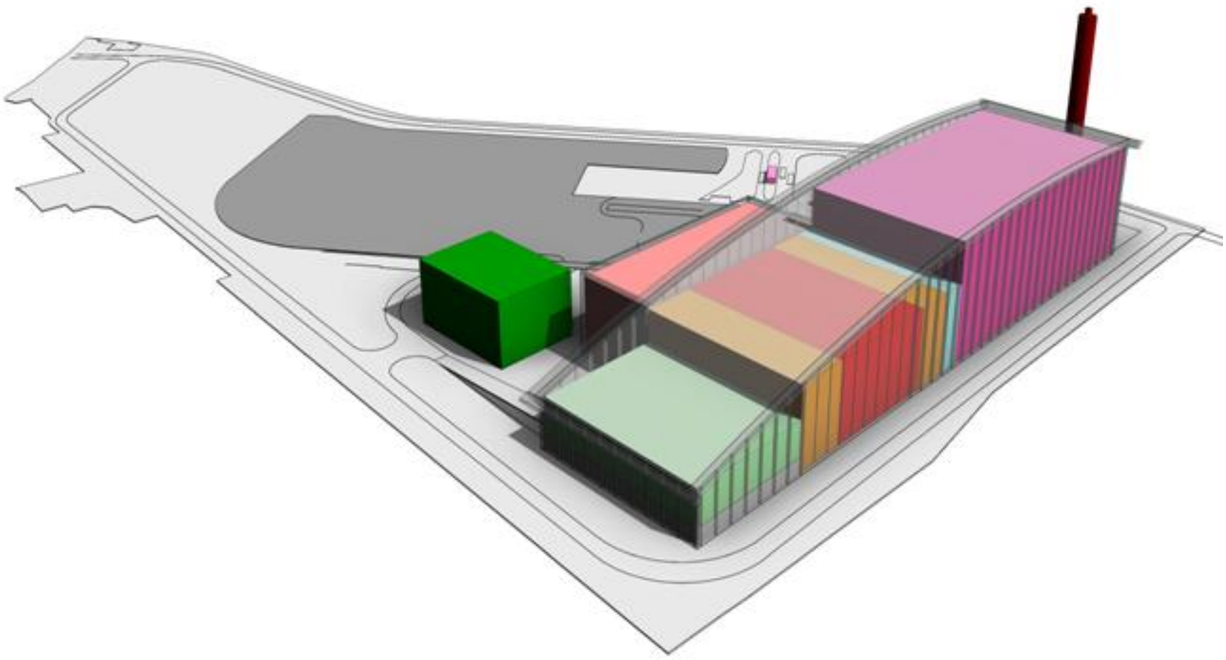
NORTH LONDON HEAT AND POWER PROJECT – DESIGN OF PLANT, NUMBER OF PLANT LINES



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1. EXECUTIVE SUMMARY

The existing Edmonton Energy from Waste (EfW) facility consists of five combustion lines. It was designed to accommodate planned and unplanned shutdowns with minimal disruption to waste processing such that with one line down for maintenance the other lines could continue to function. This is the design concept adopted for many older EfW facilities.

Advances in Energy Recovery Facility (ERF) technology have led to the following improvements evident in recent plants:

- Materials technology – use of better quality steels and alloys, developments in refractory linings, anti-corrosion systems, use of composites.
- Automation – advances in computerised control systems for combustion, steam generation, emissions control, power generation and heat supply.
- Plant design – better understanding of logistics, waste handling, waste processing, combustion gas flow, heat transfer, treatment and removal of pollutants, energy recovery, residue management.
- Manufacturing – higher levels of accuracy and precision with machines and devices leading to higher efficiencies and greater reliability.

The above improvements have increased ERF reliability, availability and performance. This has reduced the need for duplication and redundancy, in particular the number of plant lines, to achieve high availability and reliability. Technology suppliers are now able to provide a single plant line that can process 40 tonnes per hour or more waste. This means that a 600,000 tonnes per annum capacity requirement can be met with two lines that achieve the availability and reliability levels seen by a plant comprising more smaller processing capacity lines.

A two line plant processing 600,000 tonnes per annum of waste offers savings of capital cost and a reduced land take over a five line plant designed to process the same amount of waste. There are some operational advantages for a five line plant in terms of flexibility, but this in turn requires greater maintenance, spares and such with more than twice the number of equipment items to maintain.

Design Change to a 700,000 tpa Facility

NLWA's waste flow modelling showed that a 600,000 tpa facility would not have offered sufficient capacity for future long term needs. Ramboll were requested to assess the feasibility of an increase in mechanical throughput for a two line facility. It is feasible to increase the plant processing capacity to 700,000 tpa. This can be achieved through two 350,000 tpa process lines. This approach will be more cost effective and will have a smaller footprint than a three smaller process line alternative providing the same capacity.

A throughput of 350,000 tpa per processing line requires the combustion of 44 t/h over 8,000 hours per year. Ramboll is of the view that there will be supplier interest and competition to provide a plant based on 350,000 tpa line capacity.

The increase in capacity moves the plant mechanical design point from 38 t/h to 44 t/h. This shifts NLWA's design point to the limitation of a capacity diagram from a mechanical throughput perspective. This implies that NLWA will not be able to process waste at a higher rate than 44 t/h. Therefore, the ERF thermal/power generation capacity cannot be maintained with lower calorific value (CV) waste.

The smaller 38 t/h (300.000 tpa per processing line) plant would provide NLWA with flexibility to maintain maximum thermal/power generation when processing lower calorific value fuels by increasing waste throughput rate.

The waste storage bunker is an important area of any ERF and serves a number of important purposes. These include the ability to receive waste and mix it to create a homogeneous fuel. A homogeneous fuel facilitates (i) optimising and achieving stabilised combustion, (ii) keeping raw flue gas pollutants to levels suitable for stable flue gas treatment plant operations and (iii) better managing other plant operations such as energy production.

Ramboll recommends a bunker capacity equating to a storage capacity of circa two weeks with one line in operation. This is equivalent to one week with both lines in operation. This will provide NLWA with buffer/capacity to manage both waste delivery and plant revision (planned maintenance/servicing) periods.

Ramboll will undertake a study setting out bunker storage options and bunker management scenarios. This will be provided to NLWA to support a decision on bunker storage capacity and aid stake holder discussions.

Grate fired waste technology offers the flexibility to process waste with a wide range of CVs and provides a robust solution for future variations. The current design CV assumption is 10 MJ/kg. CVs lower than this will preclude full use of the thermal capacity, thus less power generation than possible in the nominal design point. Ramboll recommends:

- London Waste Limited (LWL) continue monitoring the CV of incoming waste to establish the current waste CV; and
- A detailed waste compositional study should be conducted prior to detailed design to confirm ERF design CV.

The above will facilitate the design and delivery of a plant better fitting NLWA’s needs and establishing a more robust new ERF at Edmonton.

2. INTRODUCTION

The existing Energy from Waste (EfW) plant at Edmonton consists of five combustion lines. It was designed to accommodate planned and unplanned shutdowns with minimal disruption to waste processing such that with one line down for maintenance the other lines could continue to function. The plant employs vertical boiler design with super heaters exposed to high temperature corrosive gases. This requires a higher repair and maintenance budget than more recent plant designs using a horizontal type boiler with super heaters less exposed to high temperatures.

The purpose of this report is to discuss design concepts and options for the replacement Energy Recovery Facility (ERF) that will give the best overall capital and operating cost package whilst achieving high efficiencies, market leading availability and competitive gate fees.

The value of energy sales is a significant factor and as important as the need to minimise diversion of waste during shutdown periods.

3. ADVANCES IN TECHNOLOGY

Today with the advantage of the experience gained over the past 20 years with increasingly higher quality standards for design and performance ERF technology suppliers can offer designs that are robust and highly efficient. Nonetheless, with any plant it is important to keep capital and Operations and Maintenance (O&M) costs in check. The latest generation of plants benefit from technological advances in the following areas:

- Materials technology – use of better quality steels and alloys, developments in refractory linings, anti-corrosion systems, use of composites.
- Automation – advances in computerised control systems for combustion, steam generation, emissions control, power generation and heat supply.
- Plant design – better understanding of logistics, waste handling, bunker design, waste processing, combustion gas flow, heat transfer, abatement of pollutants, energy recovery, residue management.
- Manufacturing – higher levels of accuracy and precision with machines and devices leading to higher efficiencies and greater reliability.

4. PERFORMANCE

The increase in reliability and availability of processing equipment has resulted in performance levels requiring less duplication and redundancy. Therefore, a reduction in the number of process lines no longer results in lower availability or reliability, provided engineering and design work is done correctly.

A modern ERF is still highly dependent upon certain critical systems and these are duplicated to allow operations to continue during maintenance, for example:

- Dual waste feed cranes, ensuring 100% redundancy, and spare grabs. These are fundamental to continued operation and subject to heavy wear from arduous operation. It is vital to thoroughly mix waste placed in the feed hoppers for each process line, which should hold sufficient waste for a short period of operation. Therefore, feed cranes are in operation all the time and this is assured by a two crane design.
- Boiler water feed pumps are vital for boiler operation and protection. Three pumps are required in order to mitigate the effect of a failure or outage.

5. PLANT DESIGN LAYOUT

Today, following many years of experience and development, the processing capacity of a single line can be 40 tonnes per hour or more waste. This means that a processing capacity of more than 300,000 tonnes per annum per line is possible and several such lines are under construction. Furthermore, informal discussions with a number of technology suppliers have confirmed the market's interest in and readiness to bid and supply plants with single line processing capacities of 300,000 tonnes per annum. Therefore, a capacity of more than 600,000 tonnes can be met with two processing lines and there are a number of reference plants that can demonstrate high efficiency and good reliability at this scale. NLWA's design of 350,000 tonne per annum plant lines is discussed below (**Section 9**).

A likely firing diagram for a 300,000 tonnes per annum plant is provided below (**Figure 1**).

	LP1	LP2	LP3	LP4	LP5	LP6	LP7	LP8	LP9	LP10
MJ/kg	10,0	8,9	13,0	13,0	8,9	13,0	11,7	7,0	7,0	7,0
t/h fuel	37,5	42,0	28,8	30,3	44,1	22,5	22,5	37,5	42,0	44,1
MW fired	104	104	104	109	109	81	73	73	82	86
tonne per day*	900	1010	690	730	1060	540	540	900	1010	1060
tonne per year*	300.000	336.000	231.000	242.000	353.000	180.000	180.000	300.000	336.000	353.000

* 8000 hours/year operation

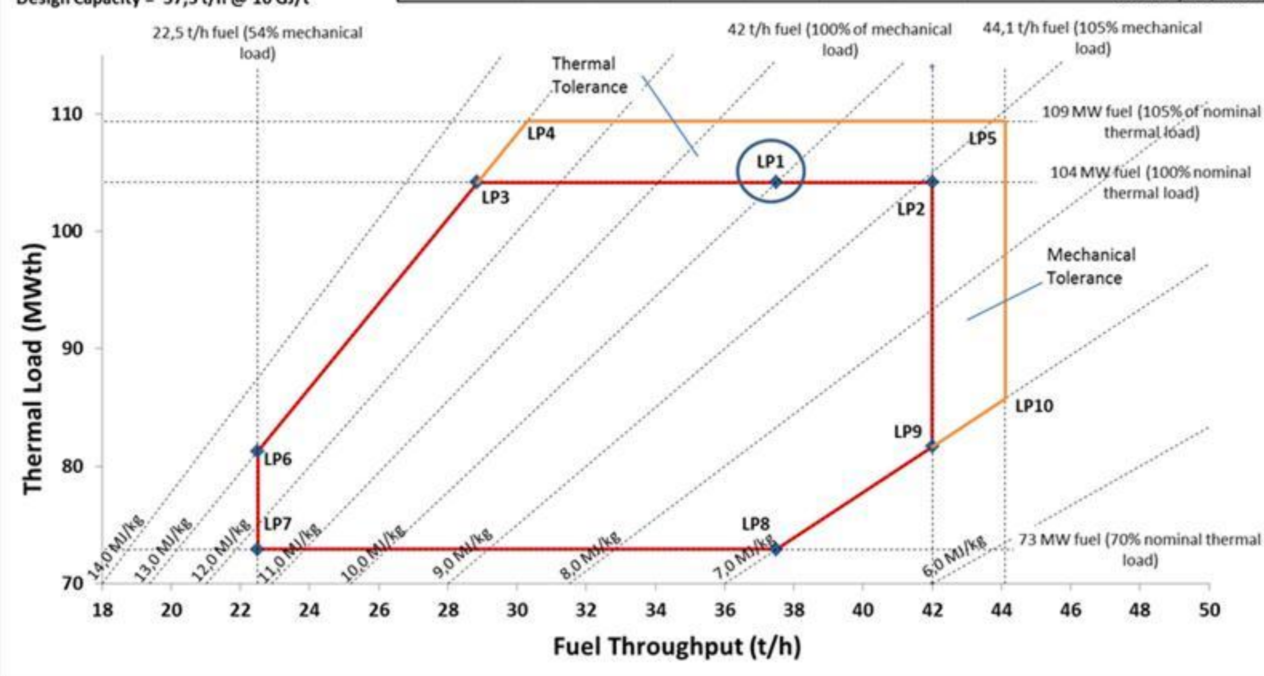


Figure 1: Plant capacity diagram with a design CV of 10 MJ/kg (300 ktpa line)[1]

6. ADVANTAGES OF HIGHER PROCESSING CAPACITY PER LINE

The impact of reliable large capacity processing lines is primarily one of lower capital cost (construction and commissioning). There is also a knock on effect for operations and maintenance with less of a need for critical spares. The higher level of automation in a modern plant also results in lower manpower requirements.

[1] Plant thermal input is the product of the waste amounts processed and the calorific value of waste. The plant will have a fixed thermal capacity determined at the design stage. This is 104 MWth for the design illustrated above. This capacity is met by processing 37.5 t/h of fuel at the design point (a design calorific value of 10 GJ/t). When waste has a lower calorific value than 10 GJ/t more waste needs to be processed to match the thermal capacity of 104 MWth. Similarly less waste is needed when waste calorific value if greater than 10 GJ/t. The volumes of waste need to remain within the defined plant capacities set out above. Electrical output from the plant will depend on the thermal input into the boiler, thus less power will be produced when the thermal load is lower than the design capacity of 104 MWth.

As with any advanced processing facility, there needs to be an effective repair and maintenance strategy. Its effectiveness is heavily influenced by the plant layout and engineering so that planned shutdowns can be kept short and repair works can be carried out safely. This requires good arrangements for access at all levels within the plant and good cranes, hoists and other devices for the maintenance works. Adequate workshops and stores also need to be configured into the design.

A further advantage of using fewer process lines is land use. A five line plant of 600,000 tpa throughput will have a significantly larger footprint than a two line plant with the same processing capacity. In terms of building height a two line plant will not be higher than a five line plant.

The reason for this is related to the combustion characteristics and the need to maintain 850 °C for two seconds – the retention time. The combustion chamber and boiler first pass is usually designed to achieve a particular steady gas velocity. This delivers a stabilised flow running parallel to the heating surfaces allowing even heat transfer and distribution. It is important to avoid hot spots, areas prone to erosion and stalled flow conditions where deposits can build up. As a consequence the height of the boiler first pass is not directly proportional to the plant throughput i.e. a 20 tph is almost the same as the height of a 40 tph boiler.

7. ADVANTAGES OF A FIVE LINE PLANT

The key advantage of a five line plant is the flexibility to adapt to changing volumes and characteristics of waste and the ability to continue processing 80% of the intended throughput if one line goes down.

A twin line plant needs both lines operating for a single steam turbine to operate in its optimal point. However, if one line stops the turbine will be able to continue operating albeit slightly below its maximum efficiency. On a five line plant the loss of one line will have less impact on power efficiency. The impact of this aspect will be small.

8. CONCLUSIONS: 600,000 TPA FACILITY

A two line plant offers savings of capital cost and a reduced land take. There are some operational advantages for a five line plant in terms of flexibility but this in turn requires greater maintenance, spares and such with more than twice the number of equipment items to maintain.

9. DESIGN CHANGE TO A 700,000 TPA FACILITY

NLWA's waste flow modelling showed that a 600,000 tpa facility would not offer sufficient capacity for its long term needs. Ramboll were requested to assess the feasibility of an increase in mechanical throughput for a two line facility. Accordingly, this addition to Ramboll's report is provided to consider issues related to plant capacity change from two 300,000 tpa process lines to two 350,000 tpa process lines.

The points addressed are as follows:

- The market for a 350,000 tpa plant
- An expected capacity/firing diagram
- Operational implications of 2 lines at higher capacity
    - Availability, flexibility, maintenance
    - Bunker size consideration
    - Maintenance requirements
    - Time required to bring a line/plant back into operations
    - Approach to plant redundancy and strategic spares storage
- 3 smaller lines at 233,000 tpa v 2 lines at 350,000 tpa
- Higher recycling trend impacts on waste CV

9.1 The Market for 350,000 tpa Plant Lines

The NLWA is seeking to implement a two line facility, each with a processing capacity of 350,000 tpa with a design CV of 10 GJ/t, thus thermal rating of 122 MWth. The total processing capacity of the plant at the design CV will be 700,000 tpa, with 8,000 hours per annum operations.

A number of plants are already under construction or in procurement with line capacities close to 350,000 tpa. These have been tendered by recognised suppliers offering competitive proposals for these projects. The Amager facility in Copenhagen, Denmark, which is in construction, is one such example. This plant will comprise two process lines, each with a processing capacity of 42 tph (with a CV of 9.6 GJ/t) corresponding to a thermal capacity of 112 MWth. Furthermore, a single line facility in the UK with planning consent for 300,000 tpa has applied to increase its capacity to a single 350,000 tpa facility.

Given the competition experienced for current similar capacity process line plants, Ramboll believes that NLWA will be able to obtain competitive tenders from recognised suppliers for a two 350,000 tpa process line facility.

9.2 Capacity Diagram

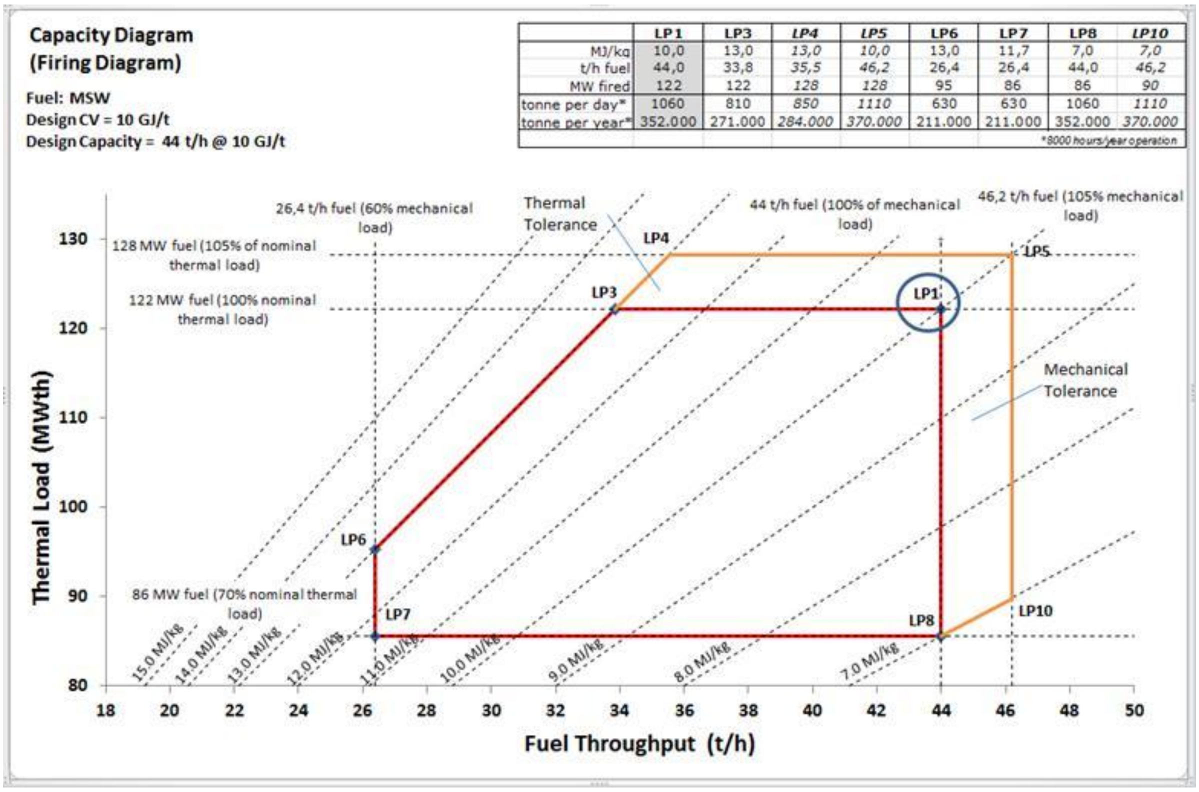
The capacity diagram of an ERF sets out the operational range of the plant with respect to mechanical processing and thermal throughput. The diagram forms the basis of guarantees from supplier with respect to acceptable caloric values and expected energy yields. The ideal diagram from an operational perspective provides flexibility for processing fuels with both increases and decreases in waste CV relative to the design point. The rate of throughput would need to be increased or decreased accordingly to match plant thermal capacity. Grate fired technology provides thermal and mechanical tolerances offering additional capacity to operate within for short periods.

One of the key drivers of a capacity diagram, and thus plant design, is waste design CV. NLWA has advised Ramboll to assume a design CV of 10 MJ/kg. It is recommended that this CV is confirmed through a test programme or information readily available at the existing LondonWaste Limited plant.

Figure 2 shows the capacity diagram Ramboll foresees for a 350,000 tpa processing line with a design CV of 10 MJ/kg. Key observations from the capacity diagram are as follows:

- The design point mechanical capacity of the plant is at the upper limit of the operational range.
- The thermal capacity of the plant is at the upper end of the boiler capacities for ERF plants.
- The full thermal capacity of the ERF can be utilised with a higher waste CV than 10 MJ/kg. The mechanical throughput capacity will reduce in line with increasing waste CV – as on any other ERF plant.
- Waste with a CV of less than 10 MJ/kg will preclude utilising the full thermal capacity of the ERF due to limitations on how much waste can be supplied to the grate/furnace. This is with the exception of mechanical tolerances that are acceptable for limited and short periods.
- Ramboll has undertaken modelling to estimate plant outputs on the basis of firing 44 t/h (thus 88 t/h for two lines) of waste with a calorific value of 10 GJ/t. This analysis shows that the plant will yield circa 70 MWe (gross) with both lines in operation. If 44 t/h (thus 88 t/h for two lines) of waste with a CV of 9 GJ/t is processed, the power output will reduce to circa 62 MWe (gross).

Ramboll expects the design for a 300,000 tpa line plant to offer more flexibility with lower CVs than that offered by the 350,000 tpa plant line. This is due to increased mechanical capacity relative to the design point at 10 MJ/kg offering the ability to feed more waste to match ERF thermal capacity. However, such an approach is only relevant and of benefit as long as the ERF does not process more than it is allowed to under its operational permit.



	LP1	LP3	LP4	LP5	LP6	LP7	LP8	LP10
MJ/kg	10,0	13,0	13,0	10,0	13,0	11,7	7,0	7,0
t/h fuel	44,0	33,8	35,5	46,2	26,4	26,4	44,0	46,2
MW fired	122	122	128	128	95	86	86	90
tonne per day*	1060	810	850	1110	630	630	1060	1110
tonne per year*	352.000	271.000	284.000	370.000	211.000	211.000	352.000	370.000

*8000 hours/year operation

Figure 2: Plant capacity diagram with a design CV of 10 MJ/kg (350 ktpa line)

9.3 Operational Implications

The key implications of increasing ERF line capacity from 300,000 tpa to 350,000 tpa, indicated in the above firing diagram, are outlined below.

Overall we would expect the difference between the two plants to be limited to the following:

- Same availability (hours per year)
- Same maintenance requirements
- Same performance guarantees
- Same approach to plant redundancy and strategic spares storage
- Time required to bring line back to operation will largely be the same
- Bunker size will increase pro-rata with the capacity upgrade (i.e. by 17%). In both cases the bunker has to be typically designed for a two week capacity with one line in operation. This facilitates continued services with time for maintenance on one line. This is further discussed in **Section 9.4**.

Plant flexibility with respect to waste CV is discussed above in **Section 9.2**. An overview of waste CV impacts on the operations of 300,000 and 350,000 tpa plant lines is summarised below.

Consequence Scenario	Line size	
	300,000 tpa	350,000
Higher CV than the design point	Throughput (tph) will be reduced to maintain max thermal input	Throughput (tph) will be reduced to maintain max thermal input
Lower CV than design value	Throughput (tph) may be increased to maintain same thermal max. (Strategy subject to permit limitations on max. tonnage) The estimated gross power output, when firing waste with a CV of 10 GJ/t (37.5 t/h (thus 75 t/h for two lines)), is 60 MWe. If waste with a CV of 9 GJ/t is processed, the power output will be maintained at 60 MWe (gross) by increasing waste processing capacity to 41.7 t/h (thus 84.4 t/h for two lines).	Throughput (tph) will be maintained at max (44 tph). Thermal input/output will be reduced correspondingly. As illustrated above, if waste with a CV of 9 GJ/t is processed (44 t/h (thus 88 t/h for two lines)), the power output will reduce from 70 MWe (gross) (with 10 GJ/t CV waste) to circa 62 MWe (gross).
Variations around design value	Reduced throughput (tph) during periods with high CV may be made up from a tonnage throughput perspective during periods with low CV	Reduced throughput (tph) during periods with high CV cannot be made up from a tonnage throughput perspective during periods with low CV

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9.4 Bunker Sizing

The waste storage bunker is an important area of any ERF plant and serves a number of purposes. These include the ability to receive and mix waste to create a homogeneous fuel. A homogeneous fuel facilitates (i) optimising and achieving stabilised combustion, (ii) keeping raw flue gas pollutants to levels suitable for stable flue gas treatment plant operations and (iii) better managing other plant operations such as energy production etc.

Bunker sizing and management has two further goals. These are:

(i) Maintain sufficient fuel in the bunker for continuous plant operations in the event of waste supply disruptions. This avoids plant shutdowns and restarts, which can be costly occurrences. Shutdowns and restarts could each typically be in the order to 8 to 12 hours. Therefore each occurrence can result in disrupting operations of a day or so.

(ii) Enable continued waste reception in the event of plant shutdown, both planned and unplanned. This will help to maintain the Boroughs' ability to continue their waste collection services when the plant is not able to process waste. This could be through processing a limited capacity if one process line is shut or total processing capacity loss if both lines are not operating. Planned maintenance can be arranged such that one line is in operation whilst work is performed on the other lines. Maintenance will also require periods where both lines are down at the same time, typically for work on common systems i.e. piping, cabling, electrical systems etc. The total downtime for each process line, both planned and unplanned, would typically be in the order of 5 weeks i.e. typical of a modern well designed and operated ERF. Maintenance works may typically require both lines to be shut for up to 2 weeks, perhaps on an annual basis. The balance of the time will be required for works on the individual lines.

Bunker management and plant maintenance needs to balance the above operational goals through maintaining sufficient fuel levels to cope with waste delivery disruptions and making capacity available for waste reception in the event of planned/unplanned shut downs. Therefore, bunker sizing needs to be such that both goals can be met.

ERF plants in the UK have typically been designed with storage capacities equivalent to 3 to 5 days of storage equivalent to the plant throughput capacity. The approach to bunker sizing for European plants is typically a storage capacity equivalent to two weeks of operations with one line in operation. This lends itself to a storage volume equivalent to 7 days of processing with two lines in operation. The difference in approach is mainly accounted for (i) the competitive financial environment ERF plants in the UK are delivered under i.e. smaller bunkers lead to cost savings (ii) desire to limit "long term" waste storage, thus a preference for smaller bunkers. Thereby, the resulting bunker capacities for ERF plants in the UK mean a more limited buffer time and the need to divert waste to other facilities, if capacity is available, or landfill when plants are undergoing maintenance lasting more than a few days, planned or unplanned.

Ramboll recommends a bunker capacity in line with ERF plants in Europe. This would provide NLWA with a greater buffer/capacity to manage both waste deliveries and plant shutdown related disruptions. **Appendix 1** presents bunker storage and dimension information for a 5 day and 7 days storage capacity bunker (equivalent to both process lines operating). If required, the plant will be able to store additional waste by stacking against the boiler hall side wall of the bunker and provide capacity for continued waste reception on the opposite wall with tipping bay openings. These measures are proven in many similar scale projects and should be specified and implemented on the NLWA plant.

9.5 Three Smaller Capacity Lines at v Two Larger Capacity Lines

An alternative approach for NLWA to provide a processing capacity of 700,000 tpa (still at 10 MJ/kg) is the implementation of three 233,000 tpa capacity process lines. One nominal advantage of this approach is that more references are available than for this size of process lines. However, as mentioned above, Ramboll is of the view and has the experience that the market is ready and able to offer the larger lines.

Furthermore, as mentioned above for the 300,000 tpa capacity process lines, the smaller processing lines will offer some extra flexibility in terms of how lower CVs may be accommodated. However, if the plant has permit restrictions on throughput, then this flexibility may not be any significant benefit.

A configuration based on three smaller lines will yield an increase in capital cost requirements.

Other notable adverse differences will include a much greater plant footprint for a three line facility. This is despite the smaller capacity per line. The additional footprint will primarily be in the facility width, which will increase from 70 m for two 350,000 tpa lines to circa 90 m for three 233,000 tpa lines.

It should also be noted that three smaller capacity lines will result in higher operational cost. This will be as a result of factors including the need for more operational staff, spare parts as well as other maintenance/service costs.

Overall Ramboll is of the view that it is feasible for NLWA to provide a processing capacity of 700,000 tpa with two process lines, each with a capacity of 350,000 tpa (design CV of 10 MJ/kg) and that this will be more advantageous from a footprint as well as a financial perspective.

9.6 Higher Recycling Trend Impacts on Waste CV

Municipal solid waste (MSW) comprises various fractions/waste types with differing properties. **Table 1** sets out the caloric value of the expected waste types. These values have been determined by extensive laboratory testing (Warren Springs) and are widely used as the basis for estimating the theoretical calorific vale of waste.

The information presented in **Table 1** shows that the caloric value of waste fractions varies widely from glass (LHV ~0.55 GJ/t) to plastics (~25 to 30 GJ/t LHV).

	Warren Springs (1986)	
	HHV (GJ/t)	LHV (GJ/t)
Paper and Card	12	10.5
Plastics	27	25
Textiles	15	13.5
Misc. Combustibles	13.5	12
Misc. Non-Combustibles	1.48	1.43
Glass	0.56	0.55
Putrescibles (organic waste)	5.6	3.7
Cans / Metals	0	0
<10mm	3.6	2.3
dense plastic	30	28

Table 1: Waste types and their calorific value

Table 2 details waste composition from a confidential UK based Ramboll project. The information details waste composition findings from recent years and the expected composition in the short and medium term. The general trend/aim in this case is recycling increases for paper and card, plastics and glass. There is also a notable difference in the reduction of putrescible materials. Therefore, these materials are expected to make up a smaller fraction of MSW, thus a noticeable proportional increases in "misc combustibles". These trends would be typical of increasing the separation of recyclables at households and a general trend towards less production or separate collection of organic waste.

	2009/2010	2012/2013	2015/2016	2019/2020	2024/2025
Paper and Card	19.20%	20.10%	18.70%	17.50%	17.50%
Plastics	13.80%	13.50%	11.90%	8.40%	8.30%
Textiles	3.90%	3.50%	3.60%	3.30%	3.30%
Misc comb	16.50%	21.80%	24.00%	27.80%	27.80%
Misc non-comb	3.40%	4.10%	4.40%	5.10%	5.10%
Glass	4.10%	4.30%	4.30%	3.30%	3.20%
Putrescibles	32.90%	25.70%	25.90%	26.80%	26.90%
Cans / Metals	3.80%	3.90%	3.70%	3.90%	3.90%
<10mm	2.40%	3.30%	3.40%	4.00%	3.90%
Total	**100%**	**100%**	**100%**	**100%**	**100%**

Table 2: A waste composition example for the UK and expected composition variations

Table 3 sets out Ramboll's estimate of the MSW calorific value with the waste fractions for the composition given for the different periods. Results show a drop in calorific value from the current levels of circa 10 MJ/kg to 9.1 MJ/kg.

	2009/2010	2012/2013	2015/2016	2019/2020	2024/2025
Average LHV (MJ/kg)	9.9	10.0	9.8	9.1	9.1

Table 3: Expected waste LHV variation with the above composition variations

The above example illustrates the dependency of calorific value on waste composition. The removal of some materials for recycling, i.e. plastics, will yield reductions in the average waste CV. However, the removal/reduction of other materials, i.e. putrescible, will yield an increase in the average waste calorific value. Therefore, there is a tendency for variations in waste composition to provide a balance with respect to the average calorific value. Whilst a change in CV is inevitable with waste composition variations, this balancing act somewhat limits a large difference with respect to the base CV. Ramboll's UK project findings and the general view/experience in the future planning of European plants supports this view.

As discussed above, grate fired waste technology offers the flexibility to process waste with a wide range of CV and provides a robust solution for future variations. The process lines that can be sourced for NLWA's two 350,000 tpa lines offer a greater flexibility and the ability to use thermal plant capacity with increase in CV. The current design CV assumption is 10 MJ/kg. CVs lower than this will preclude full use of the thermal capacity, thus less power generation than the current design case. Hence, Ramboll recommends:

- LondonWaste Limited continue monitoring the CV of incoming waste to establish the current waste CV; and

- A detailed waste compositional study should be conducted prior to detailed design to confirm the ERF design CV.

The above will facilitate the design and delivery of a plant better fitting NLWA's needs and establishing a more robust new ERF at Edmonton.

As illustrated above, if waste with a CV of 9 GJ/t is processed (44 t/h (thus 88 t/h for two lines)), the power output will reduce from 70 MWe (gross) with 10 GJ/t CV waste to circa 62 MWe (gross).

10. APPENDIX 1: WASTE BUNKER SIZING

Preliminary Waste Bunker Information – 5 day capacity Consideration and ~7 day Capacity Option

The following cases are presented below:

- Initial 5 day capacity design in line with UK plants
- ~7 day capacity design in line with European plants

Hydraulic Storage Capacity (Processing Capacity Equivalent)		5 Days (Initial Consideration)	6.8 Days (Adjustment with Tipping Floor Level Rise & Bunker Width)
Key Plant Parameters			
Plant Processing Capacity	t/h	87.5 (Two lines, 43.75 t/h per line)	
Annual Availability	h	8,000	
Annual Throughput	t/y	700,000	
Design CV	MJ/kg	10	
Thermal Input	MWth	244 (122MWth/line)	
Bunker Storage Parameters (Approximate)			
Hydraulic Volume Storage Amount	t	10,500	14,300
Waste Density in the Bunker	kg/m^3	350	350
Hydraulic Volume Required		30,000	40,800
Hydraulic Bunker Depth (fixed by geology and tipping floor height)	m	16	20
Bunker Length (fixed by plant width)	m	68	68
Bunker Width (Variable for capacity needs, but need to consider crane span)	m	28	30

Hydraulic Storage Capacity (Processing Capacity Equivalent)		5 Days (Initial Consideration)	6.8 Days (Adjustment with Tipping Floor Level Rise & Bunker Width)
Bunker Outer Parameters (Allowing 1m wall and base thickness)			
Hydraulic Bunker Depth (fixed by geology and tipping floor height)	m	17	21
Bunker Length (fixed by plant width)	m	70	70
Bunker With (Variable for capacity needs, but need to consider crane span)	m	30	32
Material Excavation (Approximate)			
Ground Level at Bunker Area	mAOD	12.5	12.5
Below Ground Excavation (outer parameters – current design)	m	11.5	11.5
Excavation Volume (Excluding Foundations)	m^3	24,200 Thus ~26,000 With Margin for Sheet Piling of Walls	25,800 Thus ~28,000 With Margin for Sheet Piling of Walls
Indication of Material Excavated - Materials to 2 mAOD (BH 306)	• Made Ground: Variable historic demolition rubble, including ash and clinker • Alluvium: Silty clay • Kempton Park Gravel (River Terrace Deposits): Variably sandy, silty and clay gravels • London Clay: Grey, occasionally sandy or silty clay From Amec Draft Factual Ground Investigation Report, 14 August 2014, (Section 2.3 Geology)		