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Consulting Engineers Limited

GENT FAIRHEAD & CO LIMITED
RIVENHALL IWMF
STACK HEIGHT ASSESSMENT

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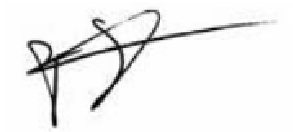
Prepared by:	James Sturman		Associate Senior Consultant	02/03/2017
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TABLE OF CONTENTS

1 INTRODUCTION

As presented in the Supporting Information, the Rivenhall IWMF (the Facility) will have a proposed stack height of 55 metres (above surrounding ground level) which is equivalent to 105 metres Above Ordnance Datum.

In the absence of published Environment Agency guidance that relates directly to BAT for stack height, this report is intended to assess the stack height in a comparable manner to other technology BAT assessments, via an approach discussed with the EA during pre-application discussions, and will address any concerns from local stakeholders with regards the height of the stack. Within this report we will:

(1) Provide a cost-benefit analysis assessment of alternative stack heights against the proposed stack height and NOx emission limit of 150mg/Nm^3.

(2) Explain the influence of building height and location on stack height.

(3) Consider the impact of emissions from the proposed stack height in relation to other EfW facilities which have been permitted by the Environment Agency.

1.1 The Facility

In determining the suitable stack height for the Facility, it is necessary to understand the topography of the site and the surrounding ground and how it has been incorporated into the local environment.

The Facility is located in a former quarry. The base of the Facility will be located below the current ground level. The base of the stack will be located approximately 20m below ground level and the stack height above the existing ground level will be 55 metres. Therefore, the total stack height is 75 metres.

The above information is presented graphically in Figure 1 below:

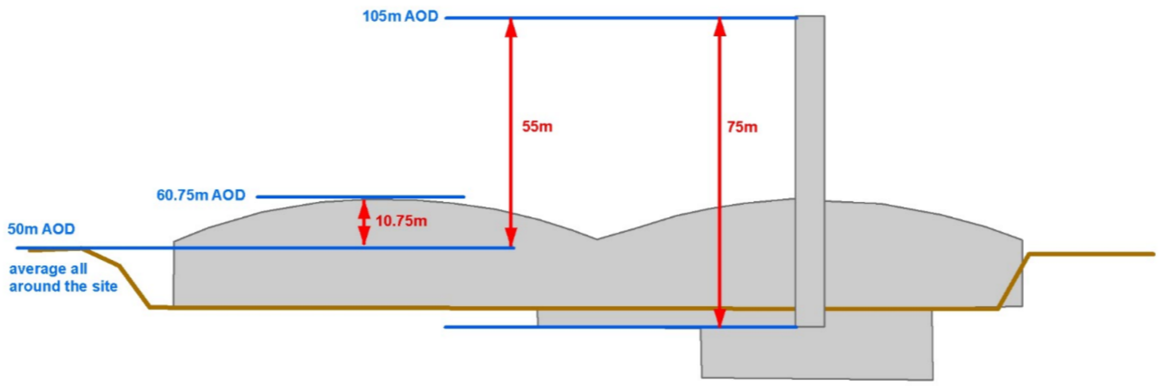

Figure 1 – The topography of the Facility

2 Cost Benefit Analysis

The Cost Benefit Analysis will follow the structure of Technical Guidance Note EPR-H1 and provide commentary, where appropriate on the environmental parameters mentioned within EPR-H1.

For the purposes of this Cost Benefit Analysis data obtained by Fichtner from the contractor responsible for the design and construction of the stack has been obtained. In the costs sections of this analysis, the following unit costs have been assumed for raw materials and capital costs:

(1) Water.. £1 per tonne;
(2) Ammonia solution (25%).. £135 per tonne;
(3) Imported power .... £52 per MWh;
(4) Carbon intensity of electricity consumed within the Facility ....390 kg per MWh;
(5) Additional construction stack costs .... €60,000 per m height.

2.1 Options Considered

The air quality impact associated with a range of stack heights of between 25m and 95m (above surrounding ground level) have been calculated using the conservative air quality model used to predict the air quality impacts within the Dispersion Modelling Assessment (Annex 5). It should be noted that the actual emissions associated with the operation of the CHP facility will be below the emissions concentrations used in the modelling.

Furthermore, the costs associated with the stack heights have also been estimated. This information is presented in Table 2-1:

Table 2-1 – Process Contributions and Stack Costs

Stack Height (m) (above surrounding ground level)	Annual Mean Process Contribution (as % of AQAL) at Point of Maximum Impact with an emission limit of NOx of 150 mg/Nm^3	Stack costs (€m)
25	7.8%	1.7 (1)
30	6.0%	2.05 (1)
35	4.8%	2.4
40	4.0%	2.75
45	3.3%	3.1
50	2.8%	3.45
55	2.4%	3.7
60	2.1%	4.05
65	1.8%	4.4
75	1.4%	5.1
85	1.1%	5.7
95	0.9%	6.4

Note:
(1) These stack costs have been factored from the incremental stack height costs provided by the contractor

Using the information presented in Table 2-1, the marginal abatement costs associated with increasing the stack height have been calculated and are presented in Figure 2 and Figure 3. The intention of the marginal abatement cost assessment is to identify the point at which the additional costs associated with increasing the stack height are not proportionate to the environmental benefits gained. This is a recognised form of analysis when considering environmental benefits versus marginal cost increases and has been discussed with the EA during pre-application discussions.

Figure 2 draws a line between each of the points and identifies the point at which there is a stepped change between the costs associated with increasing the stack height against the environmental benefits from reducing the PC. Figure 3 applies a 'line of best fit' between the marginal cost abatement for all of the assessed stack heights.

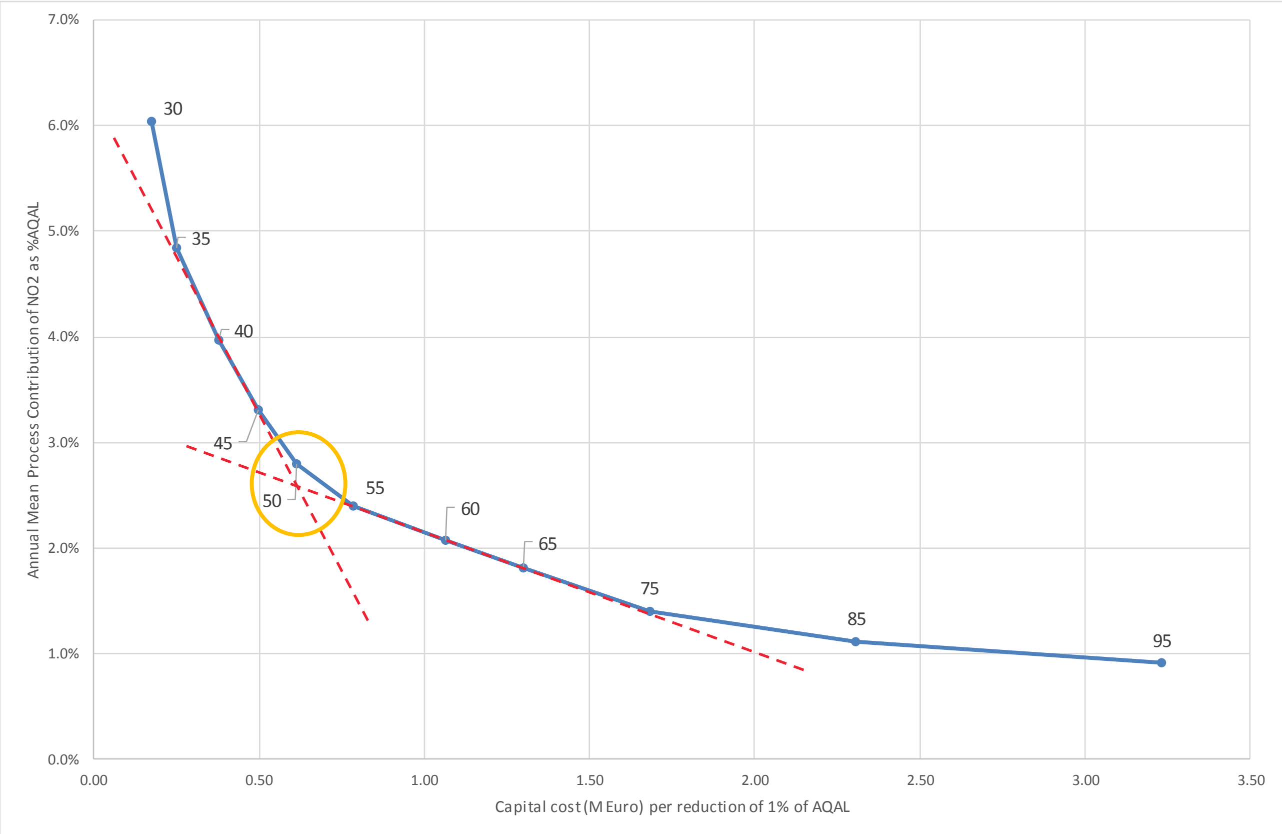

Figure 2 – Marginal Cost Abatement Assessment

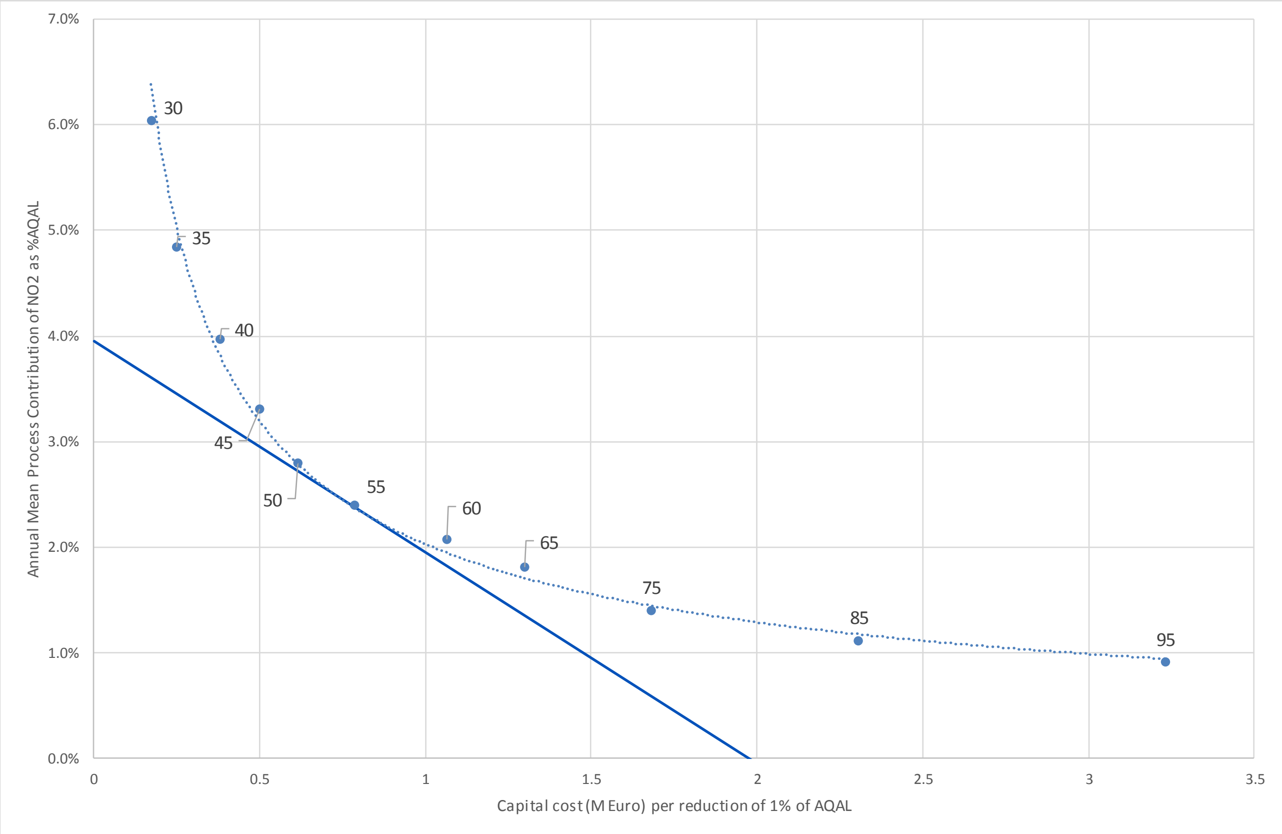

Figure 3 – Marginal Cost Abatement Assessment

As can be seen from Figure 2 and Figure 3, the additional costs associated with increasing the stack height more than 55m above the existing ground level (75m from the base of the stack) are not considered to be proportionate compared to the improvement in air quality impact associated with increasing the stack height any further.

Taking this into consideration, the following stack heights (above surrounding ground level) have been assessed in more detail as part of the following emissions analysis and air quality modelling:

- 40m;
- 45m;
- 50m; and
- 55m.

2.2 Environmental Performance

2.2.1 Emissions to Air

As identified in the Dispersion Modelling Assessment (Annex 5), emissions of all pollutants have been screened as insignificant at the point of maximum impact, except for 15 minute sulphur dioxide; annual mean nitrogen dioxide; annual mean VOC's (expressed as benzene and 1,3-butadiene; and annual mean cadmium). However, in relation to these pollutants, these are unlikely to give rise to significant pollution in that the PEC is less than 100% (taking expected modelling uncertainties into account) of both the long term and short term ES.

For the purposes of determining the suitable stack height only emissions of NOx have been considered as it is understood that this is acknowledged by the EA as the most sensitive pollutant taking into consideration those pollutants which cannot be screened out as insignificant.

The impact of emissions to air is considered in the Air Dispersion Assessment, presented in Annex 5 to the Environmental Permit application. Furthermore, an assessment to justify the proposed technologies for the abatement of NOx has been undertaken, and is presented in Annex 6. This assessment justifies that the use of SNCR to abate emissions of NOx is considered to represent BAT for the IWMF.

The following table presents the predicted ground level concentrations for the different stack heights considered. It should be noted that the assessment conservatively considers the impact at the point of maximum impact assuming that the emission is released at the proposed emission limit for NOx (150 mg/Nm^3), which is equivalent to one of the lowest NOx emission limits for a waste incineration plant in the UK.

As well as increasing the stack height, the technology provider has indicated that it would be possible to further reduce the emission limit for NOx from 150mg/m^3 to 100mg/m^3 using the proposed NOx abatement technology (SNCR). Whilst GFC understands that this emission limit may have been achieved on only two other facilities in Europe, it is unproven in any other EfW facility using this technology in the UK. Furthermore, limited data sets relating to maximum daily emissions indicate potential difficulties in agreeing with the EA that this is an available emission limit. However, at an emission limit of 150 mg/Nm^3 data from other EfW facilities using SNCR NOx abatement systems confirm that daily maximum can be guaranteed not to be exceeded and, under normal operations, daily emission limits will be lower. Therefore, GFC considers that the lower limit of 100 mg/Nm^3 cannot be considered to be 'available' until there is sufficient data demonstrating that it can be achieved on a long-term basis.

Table 2-2 – Air Emissions – Process Contributions at Point of Maximum Impact with an emission limit of NOx of 150 mg/Nm^3

Stack Heights (above surrounding ground level)		40m	45m	50m	55m
Long Term					
Process Contribution (PC)	µg/m^3	1.54	1.28	1.08	0.93
Background	µg/m^3	18.6	18.6	18.6	18.6
Predicted Environmental Contribution (PEC)	µg/m^3	20.14	19.88	19.68	19.53
Air Quality Objective (AQAL)	µg/m^3	40	40	40	40
PC as % of AQAL	%	3.8%	3.2%	2.7%	2.3%
PEC as % of AQAL	%	50.3%	49.7%	49.2%	48.8%
Short Term					
Process Contribution (PC)	µg/m^3	26.48	22.07	19.00	17.12
Background	µg/m^3	37.2	37.2	37.2	37.2
Predicted Environmental Contribution (PEC)	µg/m^3	63.68	59.27	56.20	54.32
Air Quality Objective (AQAL)	µg/m^3	200	200	200	200

Table 2-2 – Air Emissions – Process Contributions at Point of Maximum Impact with an emission limit of NOx of 150 mg/Nm^3					
Stack Heights (above surrounding ground level)		**40m**	**45m**	**50m**	**55m**
PC as % of AQAL	%	13.2%	11.0%	9.5%	8.6%
PEC as % of AQAL	%	31.8%	29.6%	28.1%	27.2%

It can be seen that there are no predicted exceedances of AQALs for any of the stack heights. Increasing the stack height reduces the PC and the PEC. Whilst it is not possible to screen the impact as insignificant at any of the proposed stack heights, even though significant pollution will not arise, the following analysis determines what stack height is proposed to be BAT to minimise both the emissions and the impact of those emissions.

2.2.1.1 Sensitive Human Receptors

At a stack height of 40m above surrounding ground level:

- The impact of annual mean emissions of nitrogen dioxide at the sensitive receptors with the highest predicted impact is 2.9% of the AQAL.
- There will be a maximum of twenty-six receptors which will not be able to be screened as 'insignificant' for annual mean emissions of nitrogen dioxide.

At a stack height of 45m above surrounding ground level:

- The impact of annual mean emission of nitrogen dioxide at the sensitive receptors with the highest predicted impact is 2.6% of the AQAL.
- There will be a maximum of five receptors which will not be able to be screened as 'insignificant' for annual mean emissions of nitrogen dioxide.

At a stack height of 50m above surrounding ground level:

- The impact of annual mean emission of nitrogen dioxide at the sensitive receptors with the highest predicted impact is 2.4% of the AQAL.
- There will be a maximum of three receptors which will not be able to be screened as 'insignificant' for annual mean emissions of nitrogen dioxide.

At a stack height of 55m above surrounding ground level:

- The impact of emission of NOx at the sensitive receptors with the highest predicted impact is 2.2% of the AQAL.
- There will be a maximum of three receptors which will not be able to be screened as 'insignificant' for annual mean emissions of nitrogen dioxide.

Taking the above into consideration, it is concluded that:

- the impact of annual mean nitrogen dioxide cannot be screened out as insignificant at all sensitive receptors; and
- increasing the stack height from 40m to 55m will enable an additional twenty-three residential receptors to be screened as 'insignificant' for annual mean emissions of nitrogen dioxide, whilst reducing the predicted impact on the most impacted receptor by 0.7% of the AQAL. In accordance with the IAQM (2015) guidance this impact would be described as '*negligible*'.

2.2.1.2 Sensitive Ecological Receptors

As shown in the Air Dispersion Modelling Assessment, the impact of emissions to air from the Facility are screened as insignificant for all sensitive ecological receptors. Therefore, the impact of emissions upon ecological receptors has not been considered within this assessment.

2.2.2 Emissions to Water

There are no emissions to water associated with any of the stack heights considered.

2.2.3 Photochemical Ozone Creation Potential

Nitrogen dioxide has a photochemical ozone creation potential (POCP) value relative to Ethylene of 2.8 and nitrogen oxide has a POCP value relative to Ethylene of -42.7. The POCP associated with the SNCR system used to abate emissions of NOx from the CHP Plant will be the same for the alternative stack heights. The POCP associated with emissions from the Facility is -17,200 irrelevant of the stack height. This is negative, as the abatement of NOx has a negative impact on POCP, therefore in abating more NOx it will further reduce the POCP.

2.2.4 Global Warming Potential

The direct emissions of greenhouse gases are the same for each of the stack heights being considered. However, the energy consumption will be slightly different for each stack height due to the increase in power consumption of the ID fan associated with increases in stack height. The additional power consumption is considered to be insignificant (<1kW) compared to the overall power consumption of the Facility.

In order to calculate the global warming potential of the overall electricity consumption associated with the abatement of NOx, the figure of 390kg carbon dioxide per MWh has been used, as applied in the Greenhouse Gas Assessment presented in Annex 5 of the Environmental Permit application. Taking this into consideration, the GWP potential associated with the abatement of NOx is 2,100 tonnes per annum CO_2 equivalent.

2.2.5 Raw Materials

The estimated consumption of raw materials associated with each stack height will be the same, as this is determined by the NOx abatement system. As detailed in the NOx BAT assessment, refer to Annex 6, the SNCR system associated with the abatement of NOx will consume approximately 1,500 tonnes per annum of ammonia.

2.2.6 Waste Streams

There are no waste streams associated with any of the options.

2.3 Costs

The estimated costs associated with each option are presented below. In order for direct comparisons to be made, the costs are presented as annualised costs, with the capital investment and financing costs spread over a 30-year lifetime with a rate of return of 9%, using the method recommended in Technical Guidance Note EPR-H1.

Table 2-3 – Costs

Parameter	Unit	Stack height (above surrounding ground level)			
		40m	45m	50m	55m
Capital Cost	£	£3,300,000	£3,600,000	£3,900,000	£4,200,000
Annualised Capital Cost	£ p.a.	£321,000	£350,000	£380,000	£409,000
Maintenance	£ p.a.	£76,000	£92,000	£108,000	£124,000
Reagents	£ p.a.	£308,000	£308,000	£308,000	£308,000

Table 2-3 – Costs					
Parameter	**Unit**	**Stack height (above surrounding ground level)**			
		40m	**45m**	**50m**	**55m**
Total Annualised Cost	**£ p.a.**	**£1,263,000**	**£1,302,000**	**£1,342,000**	**£1,381,000**

2.4 Conclusions

The additional costs associated with increasing the stack height more than 55m above the existing ground level (75m from the base of the stack) are not considered to be proportionate compared to the improvement in air quality impact associated with increasing the stack height any further. Therefore, the assessment has only considered the following stack heights:

- 40m;
- 45m;
- 50m; and
- 55m.

The table below compares the four stack heights.

Table 2-4 – Comparison Table, NOx Abatement Options with an emission limit of NOx of 150 mg/Nm³					
Parameter	**Units**	**Stack height (above surrounding ground level)**			
		40m	**45m**	**50m**	**55m**
Impact of Long Term emissions of NO_x at Point of Maximum Impact	% PC of AQAL	3.8%	3.2%	2.7%	2.3%
No. of residential properties which cannot be screened as '*insignificant*'		26	5	3	3
POCP		2,100	2,100	2,100	2,100
Ammonia solution	tpa	1,500	1,500	1,500	1,500
Total Annualised Cost	£ p.a.	£1,263,000	£1,302,000	£1,342,000	£1,381,000

As can be seen from information presented in Table 2-4, increasing the stack from 40m to 55m will:

- reduce the long-term PC for nitrogen dioxide from 3.8% to 2.3% of the AQAL;
- reduces the number of residential properties, from twenty-six to three, which are screened as 'insignificant' from the impact of long term emissions of nitrogen dioxide;
- increase the annualised costs associated with the stack by approximately £120,000.

The increase in costs is considered to be insignificant when compared to the environmental benefits associated with increasing the stack.

As well as increasing the stack height, the technology provider has indicated that it would be possible to further reduce the emission limit for NOx from 150mg/m^3 to 100mg/m^3 using the proposed NOx abatement technology (SNCR). Whilst GFC understands that this emission limit may have been achieved on only two other facilities in Europe, it is unproven in any other EfW facility using this technology in the UK. Furthermore, limited data sets relating to maximum daily emissions indicate potential difficulties in agreeing with the EA that this is an available emission limit. However, at an emission limit of 150 mg/Nm^3 data from other EfW facilities using SNCR NOx abatement systems confirm that daily maximum can be guaranteed not to be exceeded and, under normal operations, daily emission limits will be lower. Therefore, GFC considers that the lower limit of 100 mg/Nm^3 cannot be considered to be 'available' until there is sufficient data demonstrating that it can be achieved on a long-term basis.

Taking this into consideration, it is concluded that a 55m (above surrounding ground level) stack with an emission limit for NOx of 150mg/m^3 represents BAT for the Rivenhall IWMF.

3 Stack Height Comparisons

The comparison of the stack height for an energy-from-waste plant compared with other similar plants, and indeed any large-scale combustion plant, depends on a number of factors. In this section of this report, we have explained the different influences in order to demonstrate that the proposed stack height of 55m above surrounding ground level, as selected following the above assessment related to BAT, is not inconsistent with other facilities.

For the purposes of this discussion, there are three factors which need to be considered when determining a suitable height for a stack, as follows:

(1) building height;

(2) plant capacity; and

(3) the sensitivity of the surrounding environment.

3.1 Building Height

The primary determining factor for stack height is the height of any nearby buildings. This is because buildings have a significant effect on air flows. If the stack is not tall enough to ensure that the emissions are released outside of the influence of buildings, then emissions will be brought rapidly to ground level, leading to high ground level concentrations. This has been recognised for many years, starting with the old rule-of-thumb that stacks should be at least 3 metres taller than the building they are on and moving through Technical Guidance Note D1, where the height and length of the building were key inputs in determining appropriate stack heights. It continues to be recognised in atmospheric dispersion modelling, as any buildings which are less than a third of the stack height are excluded from a model.

The figures in later sections of this assessment show the significance of buildings. As presented in Annex 5, the graphs showing the process contribution with different stack heights show dramatic reductions as the stack height increases from 25m to 35m and then smaller decreases with taller stack heights.

3.2 Plant Capacity

The capacity of the plant also has an effect on stack height, but this is more complex because there are three different effects competing with each other.

(1) A larger plant will release a greater mass of pollutants, assuming that it runs at the same emission limit, and so it has the potential to lead to higher ground level concentrations.

(2) However, a larger plant releases a greater volume of total flue gases. These have an increased buoyancy effect, which improves the dispersion of pollutants.

(3) A larger plant will need a larger building. However, this is not necessarily a taller building. The height of the building for an incineration plant is primarily determined by the height of the boiler, and the height of the boiler is related to the capacity of each stream. For example, a plant which has a single stream with a capacity of 150,000 tpa would have the same building height as a 300,000 tpa plant which has two streams, both with a capacity of 150,000 tpa. The building would be larger, but not smaller. It should be noted that the Rivenhall CHP has two streams.

The relationship between capacity and building height is further complicated by the addition of architectural features, which can serve to improve the appearance of a building but almost always lead to an increase in height, or by lowering part of the plant, normally the boiler, into the ground.

3.3 Surrounding Environment

The third main influence on stack height is the surrounding environment. Again, this can have a number of different effects.

(1) If the surrounding environment is particularly sensitive, it can be necessary to increase the height of the stack to improve dispersion and reduce the impact of the plant. Examples of this are the Cornwall EfW plant, where the stack height was increased to protect a sensitive habitat, and the Beddington EfW plant, where the stack height was increased to protect a local Air Quality Management Area.

(2) Conversely, if the surrounding environment is not sensitive or does not include many receptors or residential properties, a shorter stack might be acceptable.

(3) Finally, the surrounding environment might be sensitive to visual impacts. This can lead to the building being buried underground and to the height of the stack being reduced, in order to reduce the visual impact of the plant. This was the case at Rivenhall.

3.4 Stack Heights of other plants

Permit applications and decision documents for a number of other incineration and co-incineration plants have been reviewed. All of this information is in the public domain.

Figure 4 below compares the stack height above ground level with the plant throughout for 33 waste and waste wood plants with throughputs above 100,000 tonnes per annum. It can be seen that the relationship between throughput and stack height is quite weak, with a lot of spread around the line at the lower end.

The red square shows the Rivenhall plant with a stack height of 75m (55 m above surrounding ground level) stack, for comparison purposes.

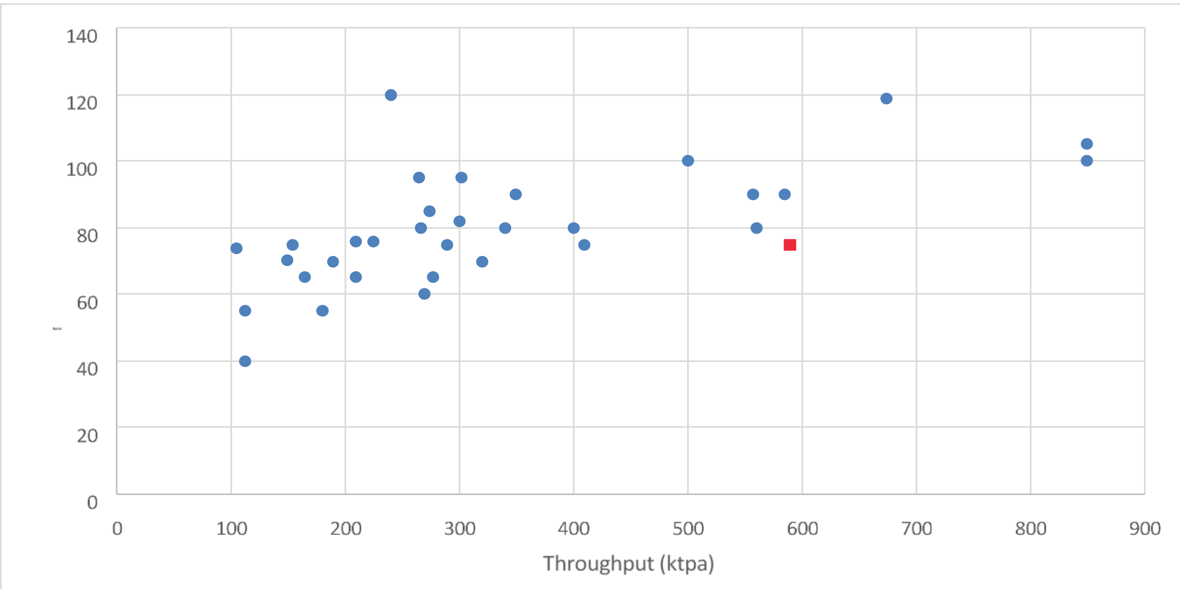

Figure 4 – Stack Height against Throughput

Figure 5 below shows the relationship between stack height and building height for the 28 plants for which we have building height data. It can be seen that there is a clearer relationship and that the proposed stack height for Rivenhall is above the line of best fit. This is true both if we consider the plant to have a stack height of 55m (35 m above surrounding ground level) and a building height of 10m and if we consider the plant to have a stack height of 75m (55 m above surrounding ground level) and a building height of approximately 30 m. This demonstrates that the proposed stack height, when properly compared with its immediate surroundings of the CHP Plant building, is not inconsistent with other similar facilities in the UK. The red squares show the Rivenhall plant with a stack height of 55m (35 m above surrounding ground level) or 75m (55 m above surrounding ground level) stack, for comparison purposes.

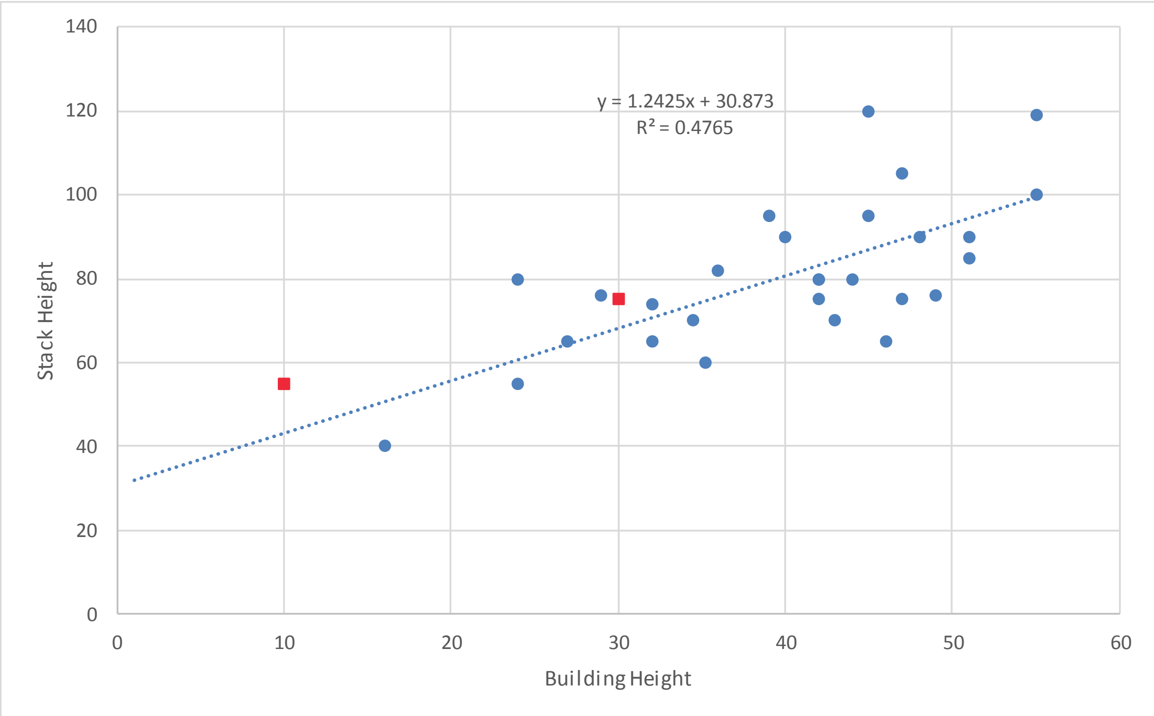

Figure 5 Stack Height against Building Height

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