Analysis of Carbon Intensity Floor Calculations

For the proposed Riverside Energy Park

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Report for Doug Simpson, Greater London Authority

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1.0 Introduction

1.1 Introduction to the study

Cory Environmental Holdings Limited has put forward a proposal to develop an integrated multi-technology energy generation park, which is intended to include an Energy Recovery Facility – an energy from waste facility treating residual waste - and an Anaerobic Digestion facility treating source segregated organic waste.

Energy from waste facilities developed within London are required to meet the Carbon Intensity Floor (CIF), which is a metric intended to measure the carbon performance of such facilities. The aim of this report is to undertake some analysis on the likely performance of the Riverside Energy Park against the CIF, considered on the basis of calculations undertaken by Fichtner on behalf of Cory Environmental Holdings Ltd.

Eunomia has worked with the GLA to develop and continually update the CIF since its inception in 2011; it has developed the most recent iteration of the Ready Reckoner, a tool which is now being used by Boroughs and plant developers to calculate the CIF as well as the related Emissions Performance Standard (EPS) targets for London's waste authority waste management activities to collectively meet. The knowledge gained from this development work has therefore been used in undertaking these checks on behalf of the GLA. More information on the EPS and CIF is set out in the Mayor's London Environment Strategy.

This short report presents the output of the technical review of the individual CIF scores of the energy from waste (EfW) facility and AD facility as produced by Fichtner on behalf of Cory, which have been undertaken using the most recent version of the Ready Reckoner produced by Eunomia. The analysis considers whether the generated scores are reasonable. The review has been undertaken considering both the achievement of the current target – set within policy documents as 400 g CO_2 eq. per kWh - and the future, more stringent CIF target which is effectively assumed within the EPS calculations for 2030.

1.2 Policy Background

As was indicated in Section 1.1, this report is focussed on the CIF metric, which calculates the carbon emissions in grams CO_2 eq. per kWh of electricity of energy from waste facilities. Performance against this measure is therefore affected both by the fossil carbon content of the feedstock and the amount of electricity generated. The CIF calculation is to be applied separately to EfW and AD facilities. Where useful heat is also generated at the facility, the carbon offset associated with the use of this heat is also taken into account within the formula.

Policy S18 of the Draft New London Plan states that[1]

[1] https://www.london.gov.uk/what-we-do/planning/london-plan/new-london-plan/draft-new-london-plan/chapter-9-sustainable-infrastructure/policy-si8-waste-capacity

To support the shift towards a low-carbon circular economy, all facilities generating energy from waste should meet, or demonstrate that they can meet in future, a measure of minimum greenhouse gas performance known as the carbon intensity floor (CIF). The CIF is set at 400g of CO2 equivalent generated per kilowatt hour (kwh) of electricity generated. The GLA's free on-line ready reckoner tool can assist boroughs and applicants in measuring and determining performance against the CIF[133]. Achieving the CIF effectively rules out traditional mass burn incineration techniques generating electricity only. Instead, it supports techniques where both heat and power generated are used, and technologies are able to achieve high efficiencies, such as when linked with gas engines and hydrogen fuel cells. More information on how the CIF has been developed and how to meet it can be found in the London Environment Strategy

The EPS target for London by 2030 is to deliver GHG savings of -0.167 tonne CO_2e per tonne of waste managed. Achievement of this target has been modelled assuming that all of London's energy from waste facilities achieve an overall CIF target of 300 g of CO_2 equivalent per kWh of electricity. This figure can be achieved through further development of CHP infrastructure and greater recycling of fossil carbon containing feedstocks (in particular plastics).

The target of 300 g of CO_2 equivalent per kWh was set partly in recognition of the declining carbon intensity of the marginal source of grid electricity. When the EPS was first set in 2011, gas CCGT was the marginal source of grid electricity, with a carbon intensity of approximately 400 g CO_2 equivalent per kWh. The CIF target therefore aimed to ensure that incineration facilities were operating at a similar carbon intensity to that of the marginal source of the grid.

By the time the EPS was revised in 2017, the carbon intensity of the grid was already less than 300 g CO_2 equivalent per kWh. It is due to decline further by 2030 such that by then the carbon intensity of the grid is anticipated to be 118 g CO_2 equivalent per kWh. However, it is recognised that even the achievement of a CIF target of 300 g CO_2 equivalent per kWh is likely to be fairly challenging in the prevailing policy environment; as such, this was chosen as the level for EfW facilities should achieve by 2030. The CIF target was kept at 400 g CO_2 equivalent per kWh of electricity up until at least 2025 in recognition of the challenges associated with developing the necessary infrastructure.

Whereas the CIF focuses only on the treatment of energy from waste, the EPS considers the carbon impacts of waste management in terms of tonnes of CO_2 equivalent per tonne of waste managed. The scope of these activities includes waste collected for recycling (including source segregated organic waste) as well as residual waste management activities (including landfill as well as energy from waste). The EPS applies to local authority collected waste; as such, commercial waste collected by local authorities is also included within the target calculations.

Alongside these targets, London Boroughs must also work towards meeting the Mayor's recycling target of 65% of municipal waste by 2030. After exhausting options to improve recycling at the kerbside, another option for increasing recycling is to put in place additional sorting facilities for the residual waste, which aim to remove additional recycling from the waste stream prior to it being incinerated.

Where this type of pre-treatment targets plastics – particularly plastic film – this also has the effect of significantly reducing the carbon emissions arising from energy from waste, thereby also reducing the CIF score of the facility as well as improving recycling performance. The EPS modelling therefore assumes that some pre-treatment will be required for energy from waste in order to achieve both the Mayor's recycling targets and the EPS target itself. It is therefore important to consider the carbon performance of the facility within the context of these other policy measures, as well as in respect of the CIF target performance itself.

2.0 Review of Assumptions and Outputs

2.1 Technical Considerations

2.1.1 Calorific Value Definitions

The energy content of the feedstock is considered in terms of its calorific value, which can be defined as:[2]

> *the quantity of heat produced by the complete combustion of a given mass of a fuel, usually expressed in joules per kilogram*

Technical information in support of the Dutch energy from biomass database, Phyllis, confirms that different variants of the calorific value exist, namely: [3]

- The Gross Calorific Value (GCV), also known as the gross heating value or higher heating value;
- The Net Calorific Value (NCV) – also known as the lower heating value.

The GCV accounts for the total amount of energy produced in the combustion process. This includes the energy that is lost to the atmosphere as a result of evaporating the water formed during combustion (the water being formed when hydrogen in the fuel combines with oxygen). The energy consumed in evaporating the moisture of the fuel is sometimes referred to as the *latent heat of evaporation*.

The NCV, on the other hand, excludes the heat consumed from the evaporation of this water. The NCV is commonly used to establish the useful energy content of a fuel, as the heat energy arising from the evaporation of water is typically not recovered in many combustion processes and is lost to the atmosphere with the flue gases.[4] The capture of this heat requires the condensation of water in the flue gases; the heat can be used in a district heating or cooling systems or for low temperature industrial applications.

Both the NCV and the GCV are used in different contexts. In compiling its data on the UK's energy consumption, the UK government provides data on the energy content of fuels using the GCV in its headline results, but also provides information on the NCV of fuels. In its

[2] From the Collins English Dictionary: https://www.collinsdictionary.com/dictionary/english/calorific-value
[3] See https://phyllis.nl/Home/Help
[4] Swedish Energy Agency (2009) Discussion paper on Calorific Values

guidance document on the methodology used to calculate the energy balances of fuels, it notes that:[5]

> *NCVs are generally more used than GCVs when building [energy] balances, since most current technologies are still not able to recover the latent heat, which would thus not be treated as part of a fuel's energy providing capability. However, providing both gross and net calorific values while making clear which one is used in the balance is considered good practice. This allows the monitoring of technological advances in respect to recovering latent heat.*

In line with many tools considering the energy produced from waste – including the Government's WRATE tool which was previously used to evaluate the performance of waste facilities in procurement processes - the CIF Ready Reckoner uses the NCV to establish the calorific value of the feedstock to energy from waste facilities, which is calculated, in turn, from the NCV of the constituent materials that comprise residual waste. The rationale for using the NCV as the unit for measuring the energy content is that the latent heat of evaporation is typically not recovered via combustion processes.

2.1.2 Generation Efficiencies

A key factor in the CIF calculation is the electrical generation efficiency. This is used to calculate the amount of electrical output produced from the feedstock, using the following formula:

$$\text{Electrical generation efficiency} = \frac{\text{Energy out in the form of electricity (MJ)}}{\text{Energy content of feedstock (MJ)}}$$

The energy content is calculated from the calorific value of the feedstock. The heat generation efficiency can also be calculated; in this case, the top line of the formula instead considers the amount of heat energy that is produced.

In the case of the electrical generation efficiency, the CIF formula requires the gross electrical generation efficiency value to be entered. This is the total amount of electricity that is generated, including any electricity generated by the plant that is consumed by the facility rather than being exported to the electricity grid. The final CIF calculation is thus adjusted for any electricity that is used by the process.

In the case of heat generation efficiency, the value to be entered into the CIF reflects the amount of useful heat, i.e., that which can be used by a district heating system, for example, or by an industrial process.

Either variant of the calorific value can be used to calculate the energy generation efficiency of a facility. It is important, however, to be consistent in the method of efficiency calculation. Where the NCV is used as the basis for measuring the energy content of the feedstock, if the energy captured via the condensation of flue gases is also included within the energy balance calculations, this will effectively result in an overestimation of the plant's total efficiency.[6] The standard developed by the UK government for the quality assurance of

[5] BEIS (u.d.) Methodology Notes on the Energy Balance
[6] Swedish Energy Agency (2009) Discussion paper on Calorific Values

CHP schemes therefore advises the use of the GCV when calculating the energy balances of CHP schemes; as such, the GCV is used by Cory in its Combined Heat and Power assessment of the proposed facility.

2.1.3 Limits to Electricity Generation at Incineration Facilities

Most waste incineration involves the generation of electricity using a steam turbine. Steam turbines can achieve power generation efficiencies of up to 37% for some feedstocks, but higher generation efficiencies require higher steam parameters – i.e., increases in temperature and pressure. The electrical generation efficiency of an incinerator is limited by highly corrosive nature of municipal solid waste (MSW). Significant problems are caused by chlorine in the waste, which causes corrosion of the boiler tubes. To avoid this, incinerators using the moving grate technology commonly operate at a temperature range of 400-425 degrees C and 40-50 bar pressure. This, however, limits the gross electrical generation efficiency to around 24% (calculated based on the NCV).[7]

A range of techniques can be utilised to increase the generation efficiency from this point; techniques include dividing the stream and the reheating the less corrosive part to raise to the temperature and pressure of this fraction, and the application of additional boiler cladding, which offers further protection against the corrosion that would otherwise occur by increasing the pressure. An alternative approach is to use the fluidised bed technology, which inherently operates at a higher temperature and pressure.[8] Such an approach typically requires additional pre-treatment of the waste.

The European Commission provides data on the performance of incineration facilities in its document on the Best Available Techniques Reference Document for Waste Incineration.[9] The above discussion is supported by the data this document provides on a wide range of European EfW facilities in respect of the electrical generation efficiencies. The data confirms that the majority of European incineration plant achieve a gross electrical generation efficiency of around 25-27%, with very few European plant even slightly exceeding a gross electrical generation efficiency of 30%; those that do are typically operating at higher temperature and steam pressures than those indicated above.

2.2 Energy Generation at the Riverside Energy Park

Cory sets out its expectation in respect of the energy generation at the REP which is anticipated to generate energy via two facilities:

- An Energy Recovery Facility (ERF), generating electricity (and potentially heat) through the combustion of municipal solid waste. Cory have since informed the GLA that the proposed ERF would apply moving grate technology; and

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[7] Bogale W and Vigano F (2014) A preliminary comparative performance evaluation of highly efficient waste-to-energy plants, Energy Procedia, 45, pp1315-1324

[8] Matsuoka and Imaizumi (2017) Performance of fluidized bed incineration facilities and their potential, Ebara Engineering Review, 253

[9] European Commission (2018) Best Available Techniques (BAT) Reference Document for Waste Incineration, Final Draft, December 2018

- An Anaerobic Digestion (AD) facility, generating biogas from the degradation of separately collected food and garden waste.

The Combined Heat and Power Assessment relating to the Riverside Energy Park confirms the following information in respect of energy generation at the ERF:[10]

- The NCV of residual waste is stated as 9 MJ / kg according to section 5.3.
- The GCV is also presented on page 58; this is stated as 10.8 MJ / kg.
- Page 29 of the CHP Assessment confirms the intention to install an air-cooled condenser at the REP ERF.

Section 7.3 of the CHP Assessment confirms the following:

- Annual nominal throughput is stated as 655,000 tonnes;
- The gross electrical output for the facility - in "*fully condensing mode*" - is stated as circa 70 MWe; and
- The parasitic load (relating to electricity consumed on-site) is stated as 6.1 MW.

Assuming the facility operates for 8,000 hours per annum, the gross electrical generation efficiency can be calculated as 34%, using the above NCV, electrical output and tonnage data. With respect to the discussion previously set out in Section 2.1.3, clearly this is some way above the usual electrical generation efficiency of incineration plant – such performance places the facility at the very top of the range of European plant in respect of gross electricity generation efficiencies. Whilst performance at this level is technically possible, it requires some additional effort, as indicated in Section 2.1.3. However, no justification for the very high performance of the proposed facility is provided within the CHP Assessment.

The use of the NCV to calculate generation efficiencies is appropriate where no recovery of the latent heat of evaporation occurs at the facility, as was previously discussed in Section 2.1.1. However, if the facility is recovering some of the energy through condensation – as is implied by the information supplied in the CHP Assessment - the use of the NCV to calculate the gross electrical generation efficiency of the facility could overstate the efficiency by up to 30%, depending on how much moisture is actually being recovered through the condensation process.[11] In such circumstances, it is more appropriate to use the GCV as the measure for the energy content of the feedstock, or to adjust the energy output values accordingly. Cory states in its CHP Assessment that the GCV is 10.8 MJ / kg. This implies a reduction in the electrical generation efficiency of 20% (when compared to its stated NCV of 9 MJ / kg), taking the gross efficiency down from 34% to 27%.

Although the facility will have the technical potential to operate in CHP mode, it is not clear that this potential will be realised, given that the adjacent Cory Riverside Resource Recovery

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[10] Cory Riverside Energy (2018) Riverside Energy Park: Combined Heat and Power Assessment, Volume 05, November 2018

[11] The moisture content of waste is typically in the order of 30%; this is therefore the maximum amount of moisture that would be available for energy recovery. However, not all of this moisture may be recoverable through the condensation process, as appears to be the case for the Riverside ERF (based on the difference between the GCV and NCV).

Facility (RRRF) could meet the feasible heat demand with 70% of its heat supply capacity.[12] It is therefore most likely that the ERF will continue to generate only electricity.

2.3 CIF Calculations for Riverside Energy Park

Calculations submitted by Cory using Eunomia's Ready Reckoner tool – and undertaken with a gross electrical generation efficiency of 34% for power-only mode - confirm the facility just meets the current CIF target of 400 g CO_2e per kWh of electricity when generating only electricity. There is slight variation in the score depending on which composition is used within the tool - performance is slightly better using Cory's own composition data in comparison to that seen where the score is modelled using the default waste composition in the tool for London Local Authority Collected Waste.

It is intended that the facility will treat a significant quantity of commercial wastes, the composition of which is not known. Particularly given the uncertainties associated with composition modelling, the CIF scores should be seen as indicative, and not as a precise indicator of performance.

Some improvement in the score is seen when the facility operates in CHP mode; the best score achieved is 323 g CO_2e / kWh of electricity. The aforementioned CIF calculations have been repeated in our own version of the tool, and the same results generated.

However, it is important to note that the achievement of the current CIF target in power-only mode is contingent on the gross generation efficiency figure being the appropriate one to use. As was discussed above, this is efficiency calculation is based on the NCV being used as the measure for the energy content of the feedstock. If the GCV is used – arguably a more realistic measure of feedstock energy content if condensate is being recovered, as was discussed above in Section 2.2 – the facility would fall some way short of achieving the target of 400 g CO_2e / kWh of electricity in power-only mode.

Results from the CIF calculations are summarised in Table 1. The calculations for the ERF have been undertaken using the default LACW composition, and include consideration of the parasitic load of the facility. Values are provided for the facility operating in electricity only mode as well as CHP mode, and are calculated using both the NCV and GCV (calculated based on the data supplied in Cory's CHP assessment). The table also includes, for reference, the CIF baseline, calculated as part of the EPS update report published in 2018.[13]

[12] The RRRF is equipped with an unutilised heat off-take arrangement with a capacity of 28.6 MW that could supply up to 200 GWh of heat each year.

[13] Eunomia (2018) Greenhouse Gas Emissions Performance Standard for London's Local Authority Collected Waste – 2017 Update

Table 1: CIF Calculations for the Riverside ERF

Facility		CIF score, g CO2e / kWh electricity
Cory ERF REP – using NCV	Electricity only mode	400
	Minimum heat case	394
	Maximum heat case	323
Cory ERF REP – using GCV	Electricity only mode	482
	Minimum heat case	476
	Maximum heat case	410
CIF baseline	All London 2015/6	700

2.4 Compliance with the EPS and Future Targets

As was noted in Section 2.3, the CIF score in the maximum heat case is 323 g CO_2e / kWh electricity of electricity. London's EPS performance in 2030 is calculated assuming all EfW facilities across the city reach the target of 300 g CO_2e / kWh, as was discussed in Section 1.2. The performance of the Riverside ERF in the best case therefore falls a little way short of the average performance required by all London's EfW in 2030.

In setting the both the EPS and CIF targets, it was recognised that performance across the boroughs was likely to vary, in part due to constraints placed on some boroughs in respect of long-term contracts such as those between existing waste authorities and EfW facilities. In practice, the achievement of the EPS target in 2030 therefore requires some facilities to exceed the standard of 300 g CO_2e / kWh, and typically, there is likely to be more scope for increased performance in new contracts. However, the CIF calculations suggest that the Riverside ERF will not exceed the 2030 CIF target, thereby constraining London's ability to achieve the EPS at this point.

The challenges associated with developing CHP infrastructure were recognised when the EPS and CIF targets were revisited in 2017. Alongside achieving these targets - as was indicated in Section 1.2 - boroughs also need to work towards meeting the Mayor's recycling target which requires 65% of municipal waste is to be recycled by 2030. Achievement across London of the CIF, the EPS and the Mayor's recycling target is possible if further pre-treatment of residual waste takes place prior to some of the waste being sent for incineration – providing the pre-treatment focusses on the recycling of significant quantities of the plastic waste (particularly plastic). There is, however, no evidence that Cory has considered incorporating this additional treatment step within its facility. As such, the design of the Riverside ERF also constrains London's ability to achieve the Mayor's 2030 recycling target.

3.0 Conclusions

The points from the above analysis of the performance of the Riverside ERF can be summarised as follows.

- Calculations undertaken using Eunomia's Ready Reckoner using assumptions provided by Cory suggest that the facility will just meet the current CIF target of 400 g CO_2e / kWh electricity. This is however contingent on the facility achieving, in practice, a very high gross electrical generation efficiency of 34%.
- Whilst achievement of this level of electrical generation efficiency is technically possible, this requires some additional effort. No detail is set out in the documentation provided to date by Cory confirming how this efficiency will be achieved.
- The Ready Reckoner tool calculates the energy generation benefits using the NCV. The aforementioned electrical generation efficiency assumption of 34% will not be valid if the facility is, in fact, recovering some additional energy from the water vapour, which appears to be the case from information provided in Cory's CHP assessment. Use of the NCV to calculate the fuel's energy content in this case will tend to overstate the efficiency by 20-30%. In this situation, it would be more appropriate to use the GCV of the input waste to calculate the efficiency, or to adjust the energy output values accordingly. When the GCV is used rather than the NCV to calculate the energy balance, the facility fails to meet the target in power-only mode by some distance.
- Although the facility will have the technical potential to operate in CHP mode, it is not clear that this potential will be realised, given that the adjacent Cory Riverside Resource Recovery Facility (RRRF) could meet the feasible heat demand with 70% of its heat supply capacity. It is therefore most likely that the ERF will continue to generate only electricity.
- London's EPS has been set assuming all EfW facilities meet a target of 300 g CO_2e / kWh electricity by 2030. Even in the best-case scenario presented by Cory with regards to CHP development, the facility will fail to meet this target. The facility's design will therefore constrain London's ability to meet the EPS target in 2030.
- Given the need to meet the EPS, the CIF and the Mayor of London's recycling target of 65% by 2030, it was assumed that London would need to develop additional pre-treatment facilities which remove plastic waste from the residual stream prior to this being sent to incineration. The best opportunities for this to be developed will come from it being included within new treatment capacity. However, there is no evidence that Cory has considered this as part of its proposal. As such, given the difficulties in further improving kerbside recycling collections, the facility design also constrains London's ability to meet the Mayor's 2030 recycling target.