North London Heat and Power Project

Carbon impact screening Edmonton ERF

by RAMBOLL

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Ramboll is a leading international engineering consultancy assisting NLWA in the process of development and procurement of the new Edmonton ERF facility.

1. INTRODUCTION

The North London Heat and Power Project is North London Waste Authority's proposal to build an Energy Recovery Facility (ERF) with associated buildings and works. It will replace the existing energy from waste plant at the Edmonton EcoPark by around 2025.

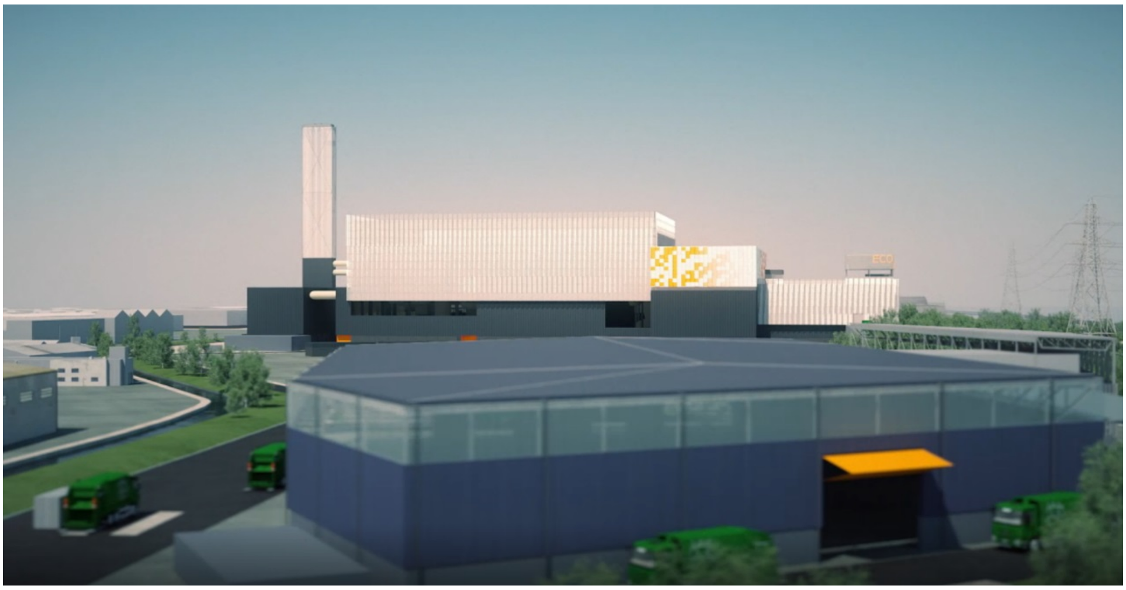
This new facility will generate electricity and provide district heating. It is classified as a Nationally Significant Infrastructure Project

The Edmonton EcoPark site of about 38 acres is used for waste management and is managed by LondonEnergy Ltd, which operates the existing Energy from Waste facility.

The future waste management activities on the site will include Energy from Waste, waste transfer and recovery of materials.

1.1 Goal and scope

The purpose of this study is to identify the total carbon impact of the new Edmonton ERF facility when in full commercial operation and compare its carbon footprint to the alternative for residual waste disposal which is landfill. The impact assessment will cover the full operational lifecycle of the facility based on available design data at this point of development.



2. GLOSSARY

APC residue	Residue from combustion and flue gas treatment containing the fly ash and spent cleaning reagents
Biogenic waste	Waste from biological material from living or recently living organisms such as wood or tomatoes
Bottom ash	Incinerator Bottom Ash (IBA) – i.e. stone, rubble, pottery, sand and other heavy ash including metals that are left after waste is burnt in an incinerator.
Calorific Value	Calorific Value (CV) – is the amount of energy contained within waste. The net value of CV (NCV) is the amount of energy released during combustion.
ERF	Energy Recovery Facility (ERF) refers to the planned Edmonton ERF at Edmonton Ecopark.
Fossil fuel derived waste	For the most part plastic originating from crude oil which has been retrieved from underground and has the potential to increase the current CO_2 content in the atmosphere.
kW, kWh **MW, MWh**	kW (kilowatt) is energy flow, i.e. energy per time unit, 1 kW = 1 kJ/s, kilojoule per second. MW is megawatt, 1 MW = 1000 kW. kWh is an energy unit (electrical or thermal). 1 kWh is one kilowatt hour, one kW working for one hour. 1 kWh = 3600 kJ. MWh is megawatt hour. 1 MWh = 1000 kWh.
Sequestered Carbon	Carbon that is not decomposed in the short to medium term and may be stored long term in a landfill. Only biogenic matter carbon is counted as sequestered. Fossil carbon is considered to remain unconverted in the landfill, and this is not counted as sequestered as it represents the reference state.
Residual waste	Residual waste is waste that in principle cannot be recycled or is not available to recycle for hygienic, environmental, economic or other reasons.
CO_2, N_2O, CH_4, C	Carbon Dioxide (CO_2), Nitrous Oxide (N_2O) and Methane (CH_4). C stands for Carbon.
Carbon Dioxide Equivalents, CO_{2e}	When comparing gases that will contribute to global warming this is done in a uniform unit comparable to the effect of carbon dioxide equivalents (CO_{2e}). Conversion is done using the Global Warming Potentials of the respective gases.
Global warming potential	The Global Warming Potential (GWP) is the potential environmental impact on global warming due to a given emission. The unit is CO_2 equi-valents or CO_{2e}. In this study the used GWP of methane is 25 (one kg of methane is equivalent to 25 kg of CO_2), and for nitrous oxide is used 298.
IPCC	Intergovernmental Panel on Climate Change is the United Nations body for assessing the science related to climate change

3. METHODOLOGY

The carbon impact is the sum of the emissions less any savings. It does need to account for the production and consumption of process additives and such. However, when adding the carbon impacts and subtracting the savings from other areas, such as fossil fueled energy production that is displaced, a recognised guideline needs to be followed. This approach also allows the study to be compared with others using the same. The DEFRA[1] guideline “Energy recovery for residual waste - A carbon based modelling approach”, February 2014 has been followed in this study allowing comparison with similar studies using the same guideline.

The guideline suggests conducting a third party review. This would however only be relevant when actual data from the facility becomes available later in the project, and it has hence not been conducted.

3.1 Functional unit

The assessment requires a quantified description of the product system and the performance it fulfils. This quantified description is called the “functional unit” of the product system. The functional unit provides the reference to which all other data in the product systems are normalized. The functional unit here is the treatment of 700 000 tonnes of residual waste produced in North London, UK. This corresponds to the planned design capacity of the Edmonton ERF[2].

[1] DEFRA is Department for Environment, Food and Rural Affairs

3.2 System boundaries

The main scenario is the treatment of the waste at the new Edmonton ERF and includes production of electricity and 35 MW of district heating. All relevant upstream and downstream processes to the carbon balance are taken into consideration. Processes not significant to the overall carbon impact have not been included. The boundary starts at the waste reception at Edmonton ERF Ecopark site and ends by using the energy, disposing of the residues and emission of cleaned flue gas to the atmosphere.

3.3 Modelling

The carbon impact study is modelled using a simple accounting principle based on the upstream, direct, and downstream approach. These principles are named after the three origins of impacts and are described below.

Upstream impacts account for all inputs to the treatment method and the emissions associated with these – an example could be use of lime cleaning the flue gas before the chimney stack at the ERF. All carbon emissions associated with use of lime in the ERF are included.

Direct emissions are the emissions from a facility to the environment. An example could be the fossil CO_2 emissions from the

[2] 700 000 Residual waste at a calorific value of 10 GJ/tonne and 45 % fossil carbon content

chimney stack of the ERF or the landfill gas emissions (methane, etc.) emitted from the landfill site.

Downstream emissions are those emitted by materials produced during their lifetime. One example could be production and sale of electricity at the landfill or the ERF. The electricity sold will displace other electricity production in the grid. The carbon impact is then the savings of CO_2 emissions by the displaced electricity production.

3.4 Waste

The waste to be received by the Edmonton ERF is collected locally and is municipal solid waste including residential and commercial waste. The Calorific value is assumed to be 10 GJ/tonne which is also the value used for ERF technology design purposes.

3.4.1 Bio waste

The carbon content of the waste can be of either fossil or biogenic origin. As an example, the carbon in a tomato is biogenic and in a plastic bag it is fossil. The carbon origin of the NLWA waste to be received by the future Edmonton ERF is not known and hence some assumption must be made.

Experience from the measurement and analysis of UK waste with similar collection schemes to those in the NLWA area reveals a fossil carbon percentage in the range 35 – 55 % and in this study 45 % is used as an average. Once the facility is in full operation the waste processed can be analysed for its actual carbon composition. For the purpose of carbon impact evaluation only the emissions from waste of fossil origin are considered. This is in line with commonly used principles and follows the logic that the tomato carbon will be emitted but was also taken out of the atmosphere when the tomato grew.

3.5 Technologies

3.5.1 Waste to Energy

The technical design values proposed for the Edmonton ERF have been used to make this carbon impact study. The design data is used as the basis for the ongoing project and represents the best knowledge available in mid-2019. The district heating connection is also in the design phase and it is assumed that 35 MW of district heating energy will be delivered to the local community. Energy produced from the ERF displaces alternative sources and according to the Defra guideline on carbon impact assessments the alternative is efficient power generation technology with natural gas as a fuel. The carbon intensity of the alternative is 373 kg CO_{2e} per MWh electricity produced (CO_{2e} stands for CO_2 equivalents, comprising the combined effect of CO_2 and other climate gases).

As the waste is combusted in an ERF, all of the carbon (biogenic and fossil) is converted to CO_2. As a general rule of thumb one tonne of CO_2 is emitted when one tonne of waste is combusted. As per the IPCC convention[3], only fossil CO_2 is considered to be derived from fossil fuels and counted towards global warming impacts. In addition to the CO_2 emitted via the chimney stack, CO_2 is also emitted indirectly as a result of the consumption of ammonia, lime and the like at the ERF and these are also accounted for in the model.

[3] IPCC: Emissions from Waste Incineration: Good practise guidance (reference on page 1) here

3.5.2 Transportation

Transportation is a source of CO_{2e} emissions and this is taken into account in the model. Transport of input waste to the ERF may be excluded because all waste input is considered to be local. In the alternative disposal option, the waste would still need collection and transport to a waste transfer station (at the Edmonton Ecopark site). Therefore, it is only the transport of waste from the transfer station to the landfill disposal site that is considered. The distances between the Edmonton site and potential landfill sites vary from 80 to 200 km and the model calculation is based on a 100 km average distance. A fully loaded truck (carrying 22 tonnes per load) and an empty return trip to London are assumed.

3.5.3 Landfill

The Carbon Impact of landfilling of the waste is calculated using the Defra guideline methodology and assumptions.

According to the Defra guideline landfill gas produced will contain both methane and carbon dioxide mixed approximately 1:1 by volume. 66% of the landfill gas, and therefore 66% of methane by mass is captured and burned. Of the gas captured around 50% is used to generate energy, the remainder is flared.

Of the remaining 34%, some 3%-points will be oxidised to CO_2 before it is released into the atmosphere. The remaining 31% of methane is released into the atmosphere.

For the purposes of the model the energy production from methane in landfill gas is assumed to have an electrical conversion efficiency of 41% of the net calorific value of methane of 50 MJ/kg. It is assumed that the source of energy being replaced is the same as for the ERF.

3.5.4 Methane as CO_{2e}

The 31% of the methane remaining is assumed to be released into the atmosphere where it acts as a greenhouse gas. The relative potency of methane as a greenhouse gas is usually selected at 25 times that of CO_2 based on the IPCC estimates for the year 2008 and for a 100-year time frame. In 2013 the IPCC raised the so-called global warming potential (GWP) of methane to 34 times that of CO_2 when considering climate carbon feedback. However, the former value of 25 is still widely used as a standard value. Hence, using 25 as the factor in this study is considered a conservative approach.

4. ANALYSIS

Scenarios:

- **Edmonton EcoPark ERF**
- **Remote Landfill site**

4.1 Scenario 1 ERF Edmonton

Upstream impacts include emissions from the manufacture and delivery of consumables associated with processing of waste (ammonia, lime etc). Transport distance from likely lime suppliers is also considered as well as transport and processing of residues (Bottom ash and APC residues)

Direct impacts include the emission of CO_2 (and methane and N_2O). For CO_2, only the fossil share of the emission is included as biogenic CO_2 is considered carbon neutral.

Downstream impacts are offset emissions from the alternative production of outputs from the ERF and include;

1) the power production that is offset by the power generation by the ERF and has an emission factor of 373 kg CO_{2e}/MWh.

2) The heat production that is offset by the heat generation at the ERF. The assumed alternative heat production is natural gas fired boilers (heat only) with an emission factor of 236 kg CO_{2e}/MWh.

3) Metals: ore extraction and processing that is offset by the metals recovered from IBA from the ERF.

The net energy production of the facility is designed to be 527,000 MWh electricity and 280,000 MWh district heat per year.

This corresponds to the production of 750 kWh electricity and 400 kWh of heat per tonne of waste combusted.

The energy sold from the ERF offsets the CO_{2e} emissions from other energy production and is calculated as follows:

1. **Electricity**
   0.75 *MWh/tonne x 373 kg CO_{2e}/MWh = 281 kg CO_{2e}/tonne of waste*
2. **District heat**
   0.4 MWh/tonne x 236 kg CO_{2e}/MWh = 94 kg CO_{2e}/tonne of waste
3. **Metals**
   Recycling of metals account for 40 kg CO_{2e}/tonne of waste

The total offset from the ERF is calculated as the sum of the offsets from electricity (281), district heat (94) and IBA metals (40) and amounts to 415 kg CO_{2e} per tonne of waste.

Total carbon impact from Edmonton ERF

28,000 tonnes of CO_{2e} treating 700 000 tonnes of waste

40 kg CO_{2e} per tonne of waste treated

The emissions from the ERF are calculated as the sum of direct emissions and upstream emissions and shown as: Direct emissions of CO_2 per tonne of waste (439 kg CO_2) + methane *(0.1 kg CO_{2e})* + *N_2O (1.7 kg CO_{2e}).* Indirect emissions include Consumables (14 kg CO_{2e}). Sum of direct and indirect emissions equal 455 kg of CO_{2e} per tonne of waste.

The total of emissions and offset is calculated as:

Total Emissions – Total Offset = Total net emission and calculates to 40 kg of CO_{2e} per tonne of waste.

4.2 Scenario 2 Landfill

Upstream impacts include emissions from transport to the landfill which is calculated as 9 kg CO_{2e} / tonne of waste landfilled or 6,200 tonnes of CO_{2e}/year.

Direct impacts arising from the landfill of waste include emission of methane (CH_4). The CO_2 emission with the landfill gas is not considered as it is biogenic. Emissions are not considered from the use of landfill gas for energy production and no emissions are included for activities related to the operation of the landfill such as compacting and coverage.

Downstream impacts are offset emissions from the alternative production of outputs from the landfill and include power production by conversion of landfill gas.

The calculation of carbon emissions from landfill over a year is as follows:

1. **Total Carbon (C)**
   700,000 x 26.6% carbon = 186,000 tonnes carbon

2. **Organic Carbon Sequestered**
   Total Carbon – Carbon conversion in landfill – Fossil Carbon = 100 %- 27% - 45%= 28% of total carbon. Recalculation of carbon to equivalent CO_2 makes 191,000 tonnes CO_{2e}

3. **Total Methane**
   Total carbon x 27% x 50% (methane share of landfill-gas) x 16/12 (C to CH_4) = 34,000 tonnes CH_4

4. **Methane for power production**
   66% capture x 50% utilisation x total methane = 22,000 tonnes CH_4

5. **Methane Released to Atmosphere**
   31 % release x total methane = 10,400 tonnes CH_4

The methane is then recalculated to the equivalent CO_2 effect using the GWP multiplication factor of 25 as described earlier.

The landfill will produce electricity from the combustion of the collected gas typically in a reciprocating piston engine driving a generator and this corresponds to 23,500 tonnes of CO_{2e} offset per year using the same offset emission factor as used for electricity produced at the ERF.

Total impact from the landfill

243,000 tonnes of CO_{2e} from 700 000 tonnes of waste

347 kg CO_{2e} per tonne of waste disposed

The total carbon emission is the sum of the transport emission and the direct emissions (as methane) with subtraction of the offset emissions due to electricity production. In total the calculated emissions of CO_{2e} is 347 kg of CO_{2e}/tonne of waste or 243,000 tonnes of CO_{2e} per year.

”The main scenario is the treatment of waste at the new Edmonton ERF and includes production of electricity and district heating. “

4.2.1 Carbon sequestration

The analysis above does not include the effect of carbon sequestration. because this is not included in the Defra guideline.

Sequestration is the term used to describe the carbon from organic matter that remains in the landfill and is not converted into CO_2 or methane, thereby providing a sink of carbon and potentially CO_2.

Since fossil carbon is broken down extremely slowly into CO_2, it can be neglected. Biogenic carbon from organic matter however is primarily degraded into CO_2 and methane as accounted for above. However, the biogenic carbon that is not degraded will have taken up CO_2, but not released it again, hence a net carbon sink. Over the 100-year time span, that is considered for the model, the sequestered biogenic carbon is estimated to correspond to some 191,000 tonnes of CO_{2e} per year.

Some life cycle assessments include this sequestered carbon as a CO_{2e} saving when organic waste is landfilled. The saving is accounted for with a factor between 0 and 1 to take into consideration that the carbon is not stored forever and might generate methane and CO_2 at some point.

4.3 Uncertainty

There are a number of different assumptions behind the calculations, all of which affect the results. Here is a list of the most important ones.

1. Waste composition and especially the ratio of biogenic to fossil content is of major importance in the calculation of carbon impact. Similarly, the calorific value of the waste is important because it affects the potential for energy generation from waste and the amount of other fossil-based energy production that can be displaced.

2. The efficiency of the ERF is important because it affects the offset that can be achieved. Also, the delivery of 35 MW of district heating has a strong influence on the offset. The displaced energy production source / technology (here efficient natural gas fuelled power production such as a gas turbine) is offset by the production of energy at the ERF.

3. Carbon sequestration in landfill as a carbon sink is often considered as making an important contribution to the reduction of CO_{2e} emissions. In the landfill, it is expected that a significant proportion of organic matter breaks down to generate methane and carbon dioxide but some will remain. The amount of organic matter left is counted as carbon sequestration but the amount is difficult to determine and yet potentially has a significant effect.

4. Landfill Methane emissions are of great importance, and there is a high degree of uncertainty as to the quantum of methane emissions from landfills over the 100-year time span. There can be a significant initial period where uncapped landfill cells release landfill gas including methane to atmosphere and it is difficult to engineer a landfill to contain the gas so that it is all recovered for energy generation or flaring. Landfills can also generate significant volumes of leachate and the collection and treatment of leachate may have an additional carbon impact.

25 times

Methane effect relative to CO_2 on global warming

5. The impact factor used for methane is 25. If it is increased to 34, as has been suggested by the IPCC in 2013, the methane effect of landfill emissions is raised to 354,000 tonnes of CO_{2e} per year (from 260,000 tonnes of CO_{2e} when assuming GWP at 25). It may even be considered to apply a shorter time span, in which case the GWP of methane would be much higher, e.g. 86 for a 20-year time span, and hence, much higher climate effect of landfill.

6. The effects of methane and nitrous oxide arising directly from the ERF have been included but are insignificant in their contribution. In fact, the ERF will probably have a net negative methane emission since concentrations might be lower in the chimney stack than in the average London air the facility takes in as part of the combustion process.

7. N_2O emissions from landfilling has, in line with the approach of Defra, not been included. There are studies indicating significant N_2O emission from landfills, adding to the risk and uncertainty of landfilling towards climate impacts.

5. CONCLUSION

Reviewing the scenarios in parallel shows the net impact of the Edmonton ERF compared to the alternative. The results show that significant carbon impacts are saved when using the ERF rather than landfill. The ERF impact is 40 kg CO_{2e} per tonne of waste and the landfill impact is 347 kg CO_{2e} per tonne (without including for the effect of carbon sequestration). Hence, the net impact is -307 kg CO_{2e} per tonne or -215,000 tonnes of CO_{2e} per year. This is the amount of CO_{2e} saved when using the ERF instead of a landfill.

The calculation results lead to the following findings:

- Significantly more low carbon energy is produced at the ERF compared to the landfill
- Large global warming impacts can be avoided when diverting waste from the landfill to the ERF.
- Many heavy truck vehicle movements are avoided in London and the surroundings when utilising the ERF compared to the more remote landfill. This will both save emissions as well as noise, congestion and potential for accidents on the roads.
- The ERF will save significant amounts of CO_{2e} by recovery of metals from the bottom ash.

In conclusion the ERF represents a significant saving of CO_{2e} emissions compared to the landfill scenario. The more energy distributed from the ERF the lower the total carbon impact and the carbon impact per tonne of waste treated

215,000 tonnes of CO_{2e}

saved annually when diverting 700 000 tonnes of waste from landfill to the ERF

307 kg CO_{2e}

saved per tonne of waste diverted from landfill to the ERF