North London Waste Authority: New Edmonton ERF

ARUP WRATE Life Cycle Assessment

Independent Peer Review of WRATE Model and Processes

8th June 2015

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Contents

1 Introduction

1.1 This document

Frith Resource Management (FRM) were approached by Arup (herein referred to as 'the client') to perform a peer-review of their WRATE (Waste and Resources Assessment Tool for the Environment) model including user-defined processes. WRATE is a life cycle assessment tool designed to support the analysis of waste management systems and technologies.

This project concerns the proposed development of a new Energy from Waste (EfW) plant, termed an Energy Recovery Facility (ERF) in this instance. The facility is modelled to process Local Authority Collected (LAC) waste. The project is proposed in Edmonton which is under the North London Waste Authority (NLWA) jurisdiction.

FRM has been informed that as this stage of the proposed development most of the detailed design parameters are still to be confirmed. Therefore waste treatment process data mainly uses the default values and allocation rules found within the template processes within WRATE. There are also elements of waste management infrastructure, such as waste transfer stations, that are currently assumed out of scope. This external peer review is undertaken in that light, and the comments should be seen in that context.

Paul Frith (PF) conducted this peer-review of the ERF solution. Paul is experienced and trained using the most recent WRATE software (version 3.0.1.5, with database update 3.0.1.8) at an 'expert' level.

A number of parameters were reviewed, including, but not limited to:

- The WRATE model as a whole, four central scenarios plus the eleven sensitivity variations of each scenario, meaning a total of twenty eight scenarios were reviewed.
- Background spreadsheet containing the calculations for the NO_x emission amendment on the proposed ERF.
- Background spreadsheet containing the calculations for the NO_x emission amendment on the Netherlands ERF in scenario D.
- Background spreadsheet containing a summary of the proposed amendments to the ERF technology.
- Correspondence with Arup w/c 23rd March 2015 – w/c 1st June 2015.
- Review of the allocation tables for all user defined processes.
- Evaluation against comparator default WRATE processes where appropriate.
- Correspondence with Arup w/c 27th April 2015.

All data entry aspects were checked across each of the scenarios.

In terms of the process an external review report was issued by FRM to Arup on 30/03/2015. This contained seven queries and the supporting comment as included in this document. Arup responded to the queries and made the changes indicated in this report, reissuing the model in the process on 31/03/2015. Further modifications have been made to the WRATE model culminating in a second issue of the report. Further modelling has been conducted by Arup to address issues in the background electricity mix of WRATE. A further six scenarios have been modelled for two alternative electricity mixes for three projected years. A variation to the Scenario D was added to include a dirty MRF preparing an RDF fraction for export to an Energy from Waste facility in the Netherlands. This MRF has been user defined and was also checked in the latest iteration of the modelling (w/c 1st June). FRM have checked the changes and additions made and this report concludes the peer review process.

1.2 Description of the model

The ERF solution proposes to process the project waste streams (composition and tonnage) as identified by NLWA for the period 2025/26. NLWA's waste flow assumptions, based on the composition as identified differ from WRATE defaults in terms of the calorific value of the waste. As a consequence, the central WRATE model is altered to reflect the energy output derived from the NLWA calorific value (CV) estimate and the energy recovery performance of the ERF has been amended accordingly to match this CV. A calculation table has been provided by Arup to demonstrate the energy balance and the corresponding impact on the ERF efficiency. There is a sensitivity analysis (Sensitivity 1) that considers the impact of processing a lower CV waste feedstock (the default WRATE composition).

There is no default method to adjust background CV values within WRATE and therefore an alternative method is required in order to approximate and model the 10MJ/kg net CV as requested by NLWA. This has been done by increasing the net heat and net power efficiencies of the treatment technologies by a factor of 1.17 to account for the difference in net CVs; the default net CV in WRATE is 8.54MJ/kg when using the NLWA waste composition. The degree of energy recovery within the model is one of the most significant aspects influencing the global warming potential (GWP) environmental indicator in WRATE, and therefore the approach by the client of amending energy outputs (by amending net efficiencies) to match the energy balance predicted through the ERF solution is appropriate. In recognition of the point that this method of approximating GWP only considers the energy output calculation, the client has also included Sensitivity 1 which uses the default WRATE CV (of 8.54MJ/kg) for the given waste composition. This sensitivity should be applied in circumstances where the WRATE model is compared against other life cycle assessments undertaken in WRATE to ensure comparability. The method applied by Arup for correcting efficiency to match the NLWA CV has been applied correctly based on the reported CV of 10GJ/tonne (or 10MJ/kg) and the net energy recovery efficiency reported by the technology provider.

The WRATE model for this project was provided by the client to FRM – alongside some background data including outline process / scenario and sensitivity descriptions and justifications – to undertake this peer-review.

Sensitivity analyses two and three apply different background energy mixes to reflect default WRATE estimates in the years 2030 and 2035 respectively.

Sensitivity analysis four considers the future scenarios (C – 100% ERF treatment, and D – 50% ERF treatment in the Netherlands, 50% landfill disposal) only, with regard to the degree of energy recovery they would be required to undertake to meet the requirements of the Carbon Intensity Floor (CIF)[1] in 2025/26. This is calculated through a separate model to WRATE which has not been provided (the GLA Greenhouse Gas Calculator). By adopting the same methodology using the WRATE scenarios provided the Scenario C appears to fall below the target of 400gCO_2e/kWh of energy generated, however this applies a different dataset in terms of marginal energy mix, CV and a more recent Life Cycle Inventory than the Greenhouse Gas Calculator. Therefore FRM have not been able to assess this part of the model within this peer review.

Sensitivities 5, 6 and 7 are a variation on the baseline model whereby the background electricity mix has been altered to reflect latest DECC projections for 2025, 2030 and 2035 respectively. This has been done due to the default WRATE electricity mixes showing an increase in coal use over time, which is contrary to DECC projections and energy policy. Arup have approached the WRATE helpdesk for clarification behind this reasoning; however have not been provided with an explanation. Sensitivities 8, 9 and 10 have been conducted for the same years using the National Grid's 'Gone Green' energy projections to inform the background electricity mixes. Sensitivity 11 uses the Netherland's 2012 (most recent available in WRATE) energy mix to reflect differences in marginal energy mix between the UK and the Netherlands, and the subsequent difference in environmental impact of energy recovery technology in the two countries.

This peer-review report considers the whole of each scenario but provides particular attention to the user-defined processes within the WRATE model, as these are the elements for which changes have been made from the peer reviewed default processes in WRATE. The user defined processes are therefore the ERF (and variations thereof), the Materials Recovery Facility (in Scenario D) and the Air Pollution Control residue (APCr) processing facility. The following sections will discuss any observations and queries that were raised as part of this process.

[1] A Greater London Authority energy recovery requirement of ≤400gCO_2e/kwh.

2 Review of the model

2.1 Model background

The model background information has been programmed as displayed in Table 1.

Table 1: Summary of WRATE model background assumptions

Parameter	Main Model	Sensitivity 1	Sensitivity 2	Sensitivity 3	Sensitivity 4	Sensitivities 5, 6 & 7	Sensitivities 8, 9 & 10	Sensitivity 11
Studied Year	2025	2025	2030	2035	2025	-	-	2012
Population	0							
No of Persons per Household	0							
Electricity Mix	UK 2025	UK 2025	UK 2030	UK 2035	UK 2025	DECC 2025 / 30 / 35	N Grid 2025 / 30 / 35	Netherlands 2012
Waste Tonnage	572856 tonnes							
Waste Composition	As modelled in waste projections. Same for all sensitivities.							

The year studied in for the NLWA proposal is 2025. This is a fair assumption. In each case the electricity mix selected is UK, with the exception of the user defined energy mixes used in sensitivities 5 - 10 (user defined) and 11 (Netherlands, 2012). This is a fair assumption. The electricity mix year corresponds with the studied year in each sensitivity.

A population and number of persons per household of nil have been selected in the model and all sensitivities. This is an appropriate assumption because collection activities (collection methods and transportation) are outside the scope of this model. This is the case in all scenarios and sensitivities meaning each is a comparable and fair assessment.

Waste tonnages and compositions are derived from waste projections conducted by NLWA. These are unaltered between scenarios and sensitivities meaning each is a comparable and fair assessment. There are four scenarios (A-D) as described in Sections 2.2 – 2.5, following, and in addition eleven sensitivity analyses have been performed, where one variable has been changed to determine the effect on each scenario.

Sensitivity 1 accounts for use energy outputs when using standard WRATE calorific values (CVs) rather than projected NLWA waste CVs, as discussed in section 1.2. Sensitivities 2 and 3 are simple modifications of the modelled year. These do not impact the direct process burdens of the scenarios (compared with the main model) however have an impact when compared with the offset emissions of cleaner energy mixes in the later years. Sensitivity 4 explores the required energy recovery levels to meet the Greater London Authority's Carbon Intensity Floor, for reasons noted in section 1.2 this sensitivity could not be fully explored.

Sensitivities 5, 6 and 7 explore the effect of using DECCs energy mix projections, and 8, 9 and 10 of using the national grid energy mix projections for 2025, 2030 and 2035 respectively in each case. For sensitivities 5, 6 and 7 the (updated) DECC energy projections published in September 2014 have been used. Arup have maintained the WRATE default energy generation efficiencies, however have updated the baseline and marginal fuel mix figures for CCGT and coal to reflect the DECC projections. These changes have been applied correctly for each of the three sensitivities, with workings provided to demonstrate the calculations used.

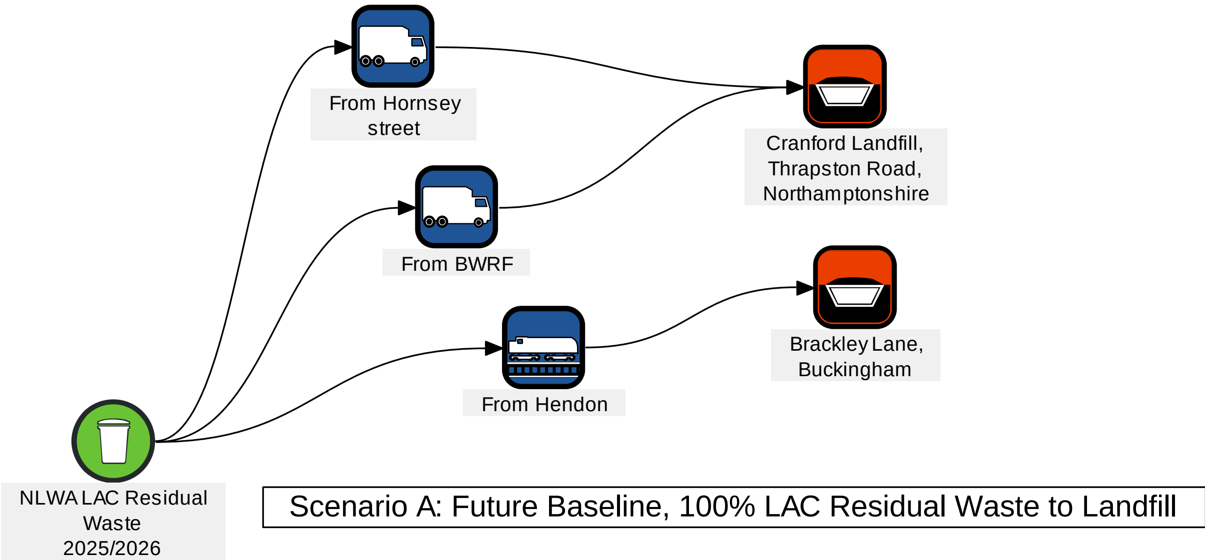
A similar exercise has been undertaken for sensitivities 8, 9 and 10 using the national grid's 'Gone Green' UK energy projections (2014). In this instance the energy generation efficiencies have been maintained with the baseline fuel mix changed (for all parameters) to reflect the national grid projections. The marginal fuel mix, used by WRATE to calculate emissions associated with the source of displaced energy, is changed in this case to a worst case scenario whereby only renewable energy is displaced. This has been done in the ration of projected renewable energy sources. These changes have been applied correctly for each of the three sensitivities, with workings provided to demonstrate the calculations used. As noted by Arup, the makeup of the marginal fuel mix in these sensitivities means these models are rightly marked as a worst case scenario as it is probable that the energy source displaced by the development will be 'dirtier' in composition.

There is an additional sensitivity concerning scenario D (where 50% of the waste is exported for energy recovery in the Netherlands), in this sensitivity (no. 11D) the background energy mix was changed to reflect the Netherlands energy mix from WRATE. In this instance WRATE only has electricity mixes available for 2002 and 2012; therefore 2012 has been selected as the closest relevant electricity mix.

2.2 Scenario A: Baseline

Scenario A assumes that all project waste is disposed to landfill. This scenario is identical for all sensitivities, notwithstanding alterations to the project background information as discussed previously. Waste is distributed in a ratio of 10.54%, 21.41% and 68.05% from Hornsey Street (road transfer station), BWRF (road transfer station) and Hendon (rail transfer station) respectively. Transfer stations are not modelled in this scenario. This is a consistent approach with all other scenarios and sensitivities. Query 1, as detailed below, concerns the appropriateness of this approach.

Figure 1: Schematic of scenario A – all sensitivities



Hornsey Street transport is modelled using the standard WRATE process 'Intermodal road transport v3 (12026)' with a trip distance of 128km and a urban:rural:motorway mix of 33:33:34. The selected WRATE default process is the most appropriate transport method for waste from a transfer station to a disposal site and therefore is modelled suitably. The trip distance has been verified using google mapping software. A road mix of 33:33:34 is appropriate for a high level assessment[2] such as this. Alterations to this road mix would have small impacts on the climate change and NO_x impacts of the model; these are not substantial in comparison to process emissions and offsets from landfill/EfW processes.

BWRF transport is modelled using the standard WRATE process 'Intermodal road transport v3 (12026)' with a trip distance of 130km and a urban:rural:motorway mix of 33:33:34. The selected WRATE default process is the most appropriate transport method for waste from a transfer station to a disposal site and therefore is modelled suitably. The trip distance has been verified using google mapping software. A road mix of 33%, 33% and % 34[3] (rural, urban and motorway respectively) is appropriate for a high level assessment such as this. Alterations to this road mix would have small

[2] See note in section 1.1

[3] All further road transport processes for all scenarios and sensitivities use default WRATE road mixes. As stated this are suitable for a high level model such as this, and therefore are not refereed to separately in each instance in this report.

impacts on the climate change and NO_x impacts of the model; however these are not substantial in comparison to process emissions / offsets from landfill/EfW processes.

Hendon transport is modelled using the standard WRATE process 'Rail transport v3 (12072)' with a trip distance of 96km. The selected WRATE default process is the most appropriate transport method for waste from a rail transfer station to a disposal site and therefore is modelled suitably. The trip distance has been verified using google mapping software.

Query 1: Transfer station infrastructure

FRM Query	The inclusion of transfer station processes in the model will allow the model to assess the difference in burdens between use of rail and road transport transfer facilities. The high burdens associated with infrastructure at rail transfer stations will have a greater impact on some scenarios compared with others. Consider including transfer facilities in the scope of assessment.
ARUP Response	The client has confirmed that transfer station infrastructure is out of scope at this stage. Transfer transport processes have not been included.
FRM Comment	This response and approach is acceptable for a high level assessment. If more detailed life cycle assessment is required at a later stage transfer facility burdens should be included within the scope of an assessment.

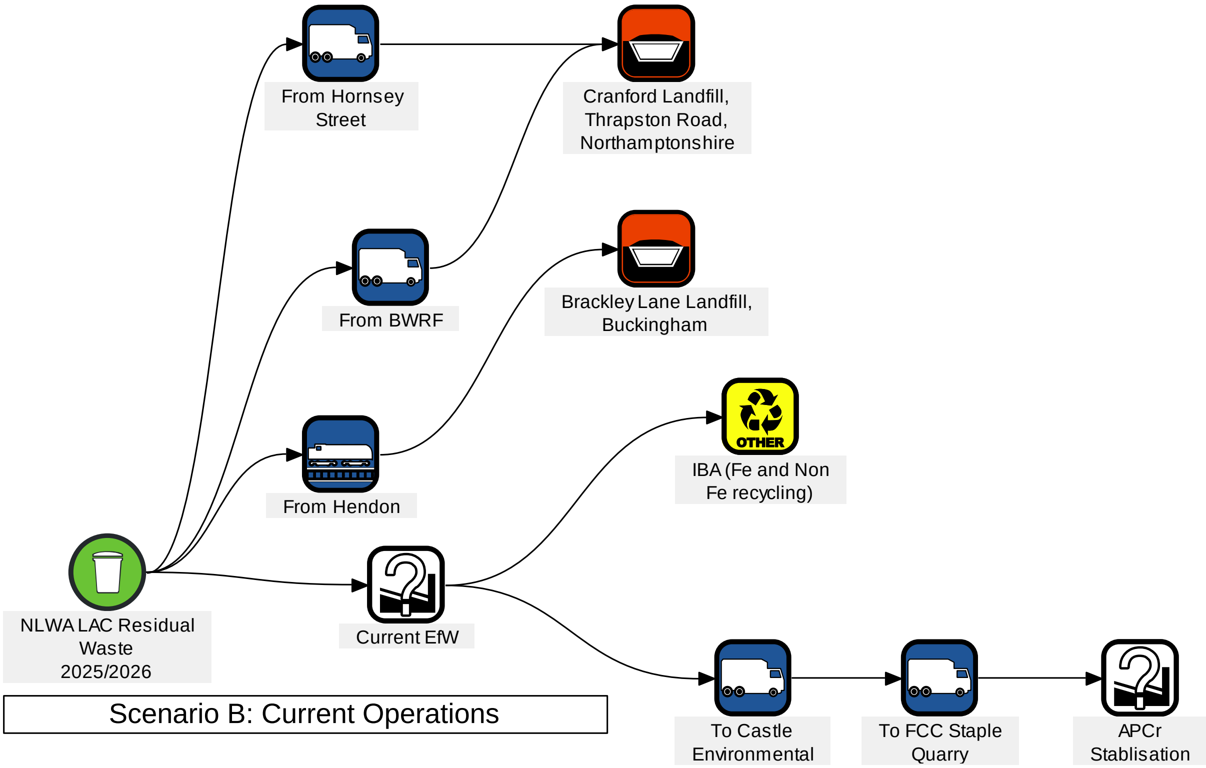
Waste disposal is modelled through two landfill sites at Cranford (Northamptonshire) for waste transported by road from Hornsey Street and BWRF, and Brackley Lane (Buckinghamshire) for waste from Hendon transported by rail. Both facilities use the WRATE default process 'Flexible landfill 5000000 tonnes (11256)' with an assumed landfill gas efficiency of 50% in the absence of provided data. The recovered gas is used for energy recovery purposes. This is an appropriate assumption for a moderately performing landfill, and for the purposes of a high level assessment is a sufficient assumption. Both facilities are appropriately scaled to incoming waste. In both cases it has been assumed that a clay liner is used at the landfill sites. This is a conservative assumption as plastic liners and caps will improve landfill performance. At Brackley Lane a clay cap has been assumed, again as a conservative estimate. For Cranford Landfill a HDPE cap has been used as a proxy for LDPE cap. This is an appropriate assumption and most closely reflects the landfill operation and burdens. This approach has been applied consistently and for the purposes of a high level assessment is an appropriate assumption.

Each of the ten sensitivities for the baseline scenario has been tested to ensure that no changes have been made. This assessment has highlighted no alterations and therefore the sensitivities are comparable on a like for like basis.

2.3 Scenario B: Current operation

Scenario B models the current treatment of the NLWA targeted waste stream. This is treated through an established EfW facility that produces electricity for export to the national grid. Waste is distributed so that the majority (94.265%) is treated through the EfW plant, with the remaining quantity (5.735%) disposed of to landfill. The remaining quantity of waste retains the distribution ratio of 10.54%, 21.41% and 68.05% from Hornsey Street (road transfer station), BWRF (road transfer station) and Hendon (rail transfer station) as used in Scenario A. Transfer stations are not modelled in this scenario. This is a consistent approach with all other scenarios and sensitivities.

Figure 2: Schematic of scenario B – all sensitivities



Waste sent directly to landfill processes is treated using the same transport parameters (including distances and default processes) and landfill facilities as described in Scenario A. The majority of the waste is modelled through an adapted EfW facility based on the default WRATE flexible EfW process. For this scenario the process (ID. 11356) is adapted to reflect changes to the energy efficiency and waste production of the facility. The process has been modelled selecting a dry SNCR flue gas treatment with a net electrical efficiency of 20.3427% applied, as specified by supporting energy balance documentation. Metal extraction has been removed from the process reflecting current operation where metals are recovered at a later stage elsewhere on the Edmonton site. APCr output has been amended using actual data. A summary of changes to the allocations is provided in

Table 2.

Table 2: User defined process for current EfW

Parameter	User Defined WRATE process	Default WRATE process	Comment
Lifespan	55 years	25 years	See Query 2.
Energy Recovered	=[USER_TOTAL.NET_CV]*0.203427	User defined variable (front screen)	Changed to reflect reported actual energy outputs. Source ARUP Energy Balance.
Process Output > Non Ferrous Metals	0	User defined variable (front screen)	Changed to reflect later removal at IBA treatment facility.
Process Output > Ferrous Metals	0	User defined variable (front screen)	Changed to reflect later removal at IBA treatment facility.
Electricity to Grid	=[USER_TOTAL.NET_CV]*0.203189	User defined variable (front screen)	Slight discrepancies in factors used, see Query 3.
Process Waste Output > Bottom Ash (IBA)	=[USER_WASTE_FRACTIONS_TOTAL]*0.13999	=([USER_TOTAL.ASH]*0.91+([USER_WASTE_FRACTIONS.NON_FERROUS]+[USER_WASTE_FRACTIONS.RDF_1_12])*0.05+0.2*((([USER_WASTE_FRACTIONS.FERROUS_METAL]+[USER_WASTE_FRACTIONS.RDF_1_11])*(1-[USER_PROCESS_PARAM.FE_RECOVERY]))+([USER_TOTAL.ASH]*0.91)+(([USER_WASTE_FRACTIONS.NON_FERROUS]+[USER_WASTE_FRACTIONS.RDF_1_12])*(1-[USER_PROCESS_PARAM.NON_FE_RECOVERY]))))	See Query 4.
Process Waste Output > Bottom Ash Ferrous	=[USER_WASTE_FRACTIONS.FERROUS_METAL]*0.90	User defined variable (front screen)	Within acceptable industry practice range. Mass flow provided by NLWA would require factor of 1.0; 0.9 used as realistic maximum.
Process Waste Output > Bottom Ash Non Ferrous	=[USER_WASTE_FRACTIONS.NON_FERROUS]*0.0.31137	User defined variable (front screen)	Within acceptable industry practice range.
Process Waste Output > Air	=[USER_WASTE_FRACTIONS_T	=ifequal([USER_PROCESS_PARAM.SCRUBBER_TYPE],[SCRUBBER_TYPE.DRY],(	See Query 5.

Pollution Control	OTAL]*.03368	[USER_TOTAL.ASH]*0.09)+([USER_WASTE_FRACTIONS_TOTAL]*0.02875),([USER_TOTAL.ASH]*0.09)+([USER_WASTE_FRACTIONS_TOTAL]*0.025))	

Query 2: Lifespan of current EfW

FRM Query	The extended life of the facility to 55 years will reduce the annualised impact of construction burdens. The current facility will have been refurbished during its current lifespan and would therefore have required major reconstruction works, and therefore it is suggested to revert back to the default 25 year lifespan.
ARUP Response	Agreed. This has been changed back to 25 years to provide a fairer like for like comparison.
FRM Comment	This response is noted and the amended approach is appropriate.

Query 3: Discrepancies between WRATE process net efficiencies and supporting net efficiencies

FRM Query	The electrical efficiency modelled in WRATE for the headline energy output indicator is 20.3427% which differs from the electricity to grid factor of 20.3189%. Consider updating 'electricity to grid' factor to match energy output in order to correctly measure carbon equivalent impacts of offset energy use.
ARUP Response	Amended to match 20.3427%.
FRM Comment	This response and the amended approach are acceptable.

Query 4: Incinerator Bottom Ash (IBA) output

FRM Query	The calculated IBA output (non-metals) is lower than the default WRATE process. We would expect an IBA output (total including metals) of between 20 and 30% of input material. In this scenario a return of 13.999% is achieved. We would suggest that the output of non-metal IBA is increased in line with the default WRATE flexible EfW process.
ARUP Response	Agreed that bottom ash seems low compared to typical values for similar facilities. However 13.999% of input material reflects the mass balance data for 2013/14 as provided by NLWA for the current EfW facility.
FRM Comment	This response is acceptable as the IBA from the current EfW is measured rather than estimated in the 2013/14 data. Therefore FRM agree that, although lower than standard EfW performance, this is an acceptable approach to modelling in WRATE having been provided with evidenced mass balance data.

Query 5: APCr output

FRM Query	The calculated APC residues output is lower than the default WRATE process. We would expect an APCr output of between 3.5 and 4.5% of input material depending on the abatement control method selected. In this scenario a return of 3.368% is achieved. We would suggest that the output APCr is increased in line with the default WRATE flexible EfW process.
ARUP Response	Mass of APCr (info as provided by NLWA) for 2013/14 from current EfW is

FRM Comment	17,985 tonnes. Factored to current operations in 2025 (factor of 1.011 compared to 2013/14) this gives 18,187 tonnes of APCr or 3.368% of input material.
	This response is acceptable as the APCr from the current EfW is measured rather than estimated in the 2013/14 data. Therefore FRM agree that, although lower than standard EfW performance, this is an acceptable approach to modelling in WRATE having been provided with evidenced mass balance data. Further, although the figure falls outside values modelled by the WRATE default processes, it is still within industry ranges and therefore an acceptable use of the WRATE model.

The current scenario involves treatment of IBA on site therefore no transport is included. The WRATE default process 'IBA rec & FE/nonFe recovery v3 (12028)' is used. This is the most appropriate process for this treatment.

The APCr stabilisation process (modelled using the WRATE waste minimisation process) has been altered with waste restrictions amended to allow APC residues. This change has been correctly implemented in the WRATE model. The management of APCr is via a treatment/recycling process which is not represented as a default technology in WRATE. It is likely to be environmentally more preferable than landfill and therefore in discussion with ARUP we concur that a waste minimisation process is appropriate for the management of this waste stream given the current level of information available. A waste minimisation process removes both positive and negative impacts from the management of APCr. It should also be noted that the same assumption has been applied across all scenarios where APCr is managed.

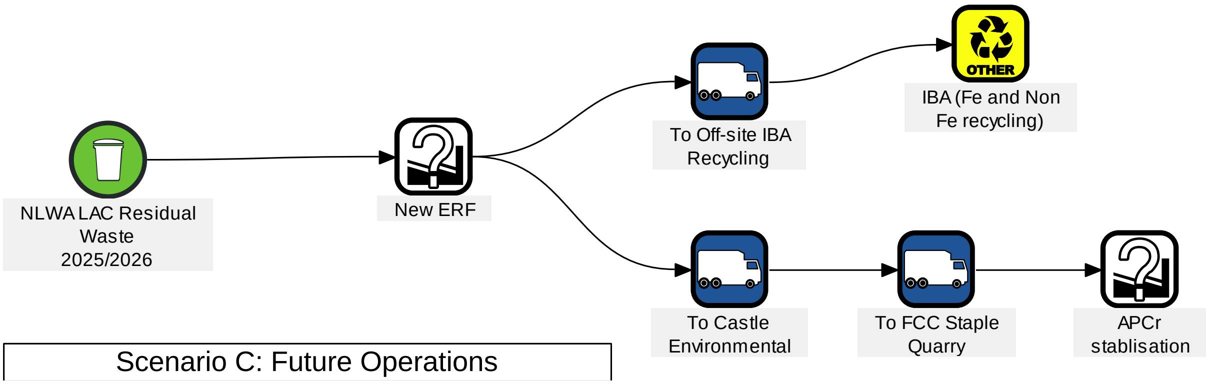
APCr is transported for offsite treatment at the APCr stabilisation facility detailed above. This involves onward treatment (Query 5 re. quantity of material). WRATE does not allow onward transport of stabilised APCr (i.e. post-minimisation process) and therefore two transport elements are included before the APCr stabilisation process in the model. This is an appropriate use of the WRATE model. Distances for transport post- and pre-treatment are 130km using 'intermodal road transport v3 (12026)' – the most appropriate WRATE process for this transportation. These distances have been cross checked using Google mapping software and are correct.

For each sensitivity the correct electricity recovery efficiency has been applied (this is unchanged for Sensitivities 2-4 and 5-10). A net electrical energy efficiency of 17.366% has been applied in Sensitivity 1 to account for default WRATE calorific values. This has been applied correctly in accordance with the energy balance calculations provided by the client. All other processes have been unaltered from the main model with the exception of changes to background electricity mixes as previously recorded.

2.4 Scenario C: Future operations

Scenario C models the future treatment of the NLWA targeted waste stream exclusively through a new ERF. The proposed ERF recovers both electrical and thermal energy for export. This is a consistent approach with all other sensitivities of the future operation.

Figure 3: Schematic of Scenario C – all sensitivities



The waste is modelled through an adapted ERF technology based on the default WRATE flexible EfW process. For this scenario the 'Flexible EfW v3 process (ID. 11362)' is adapted to reflect changes to the energy efficiency and waste production of the facility. The process has been modelled selecting a wet SCR flue gas treatment system. The ERF has a net electrical efficiency of 30.083% and net thermal efficiency of 20% applied (with the exception of sensitivities 1 and 4). This would represent best practice levels of performance (in terms of electrical efficiency). These efficiencies differ slightly from the specified values presented in the supplied energy balance documentation (see query 6 below). Metal extraction has been removed from the process reflecting expected operation where metals are recovered at a later stage rather than at the grate. A summary of changes to the allocations is provided in Table 3.

Table 3: User defined process for proposed ERF

Parameter	User Defined WRATE process	Default WRATE process	Comment
Energy Recovered	=([USER_TOTAL.NET_CV]*0.30083)+([USER_TOTAL.NET_CV]*0.2)	User defined variable (front screen)	Changed to reflect reported actual energy outputs. Source ARUP Energy Balance. Slight discrepancy, see Query 6.
External Heat	=[USER_TOTAL.NET_CV]*0.2000	User defined variable (front screen)	See Query 6 below.
Electricity to the Grid	=[USER_TOTAL.NET_CV]*0.30083	User defined variable (front screen)	See Query 6 below.
Process Emissions > Nitrogen Oxides to Air	259782 kg	Calculated	See text below.

Query 6: ERF process energy efficiency discrepancy

FRM Query	There is a discrepancy between the user defined WRATE process efficiencies and those presented in the energy balance. For the main model, and Sensitivities 2 and 3, the WRATE process is modelled with efficiencies of 30.083% (electrical) and 20% (thermal), whilst the calculated energy balance figures are 30.1184% and 20.0223% respectively. This results in the WRATE model being more conservative with a 0.12% reduction in energy generation compared to the calculated output in the energy balance. There will be associated, albeit small, impacts on avoided emissions as a result of this also negatively affecting the solutions modelled performance. For Sensitivity 1 the thermal efficiency input in WRATE is 19.99%, whereas the energy balance suggests an efficiency of 20.02%, again resulting in a conservative energy output. Sensitivity 4 is modelled in line with the energy balance with regards energy efficiencies of the technology. It is recommended that the efficiencies are updated to match the energy balance provided.
ARUP Response	This is in part due to net CV within WRATE changing. Based on the NLWA waste composition WRATE originally calculated the net CV as 8.55 MJ/kg. For reasons unknown WRATE now calculates the net CV MJ/kg as 8.54, and seems to have stabilised as this value after repeat re-calculations of the model. It may be a rounding error within the software. This discrepancy makes a slight difference to the factor applied to the efficiencies to mimic a CV of 10 MJ/kg. All values amended and checked so now correct and consistent.
FRM Comment	This response is noted and the amended approach is appropriate.

It should be noted whilst heat is recovered from the ERF it has been agreed with the client (correspondence with ARUP 25/03/2015) that no district heating infrastructure will be included within the WRATE model. The reasoning behind this is that there is some uncertainty surrounding potential users of the heat, and the potential for a single high energy user being available near to the site. Again, in the light of a high level study, we believe that this is a reasonable position.

The level of performance achieved by the Selective Catalytic Reduction (SCR) flue gas treatment equipment for NO_x emissions has been modelled as delivering 80mg/Nm^3. This is a conservative figure and is within the bounds of expected performance. In the light of the nature of this study it is considered appropriate to retain this assumption; however as more detailed investigations of the proposal move forward it would be recommended that further evidence is provided to confirm and accurately model NO_x emission levels.

The future scenario involves treatment of IBA off site therefore the WRATE transport process 'Intermodal road transport v3 (12026)' has been used with an assumed distance of 40km as no site has been identified. This is a reasonable assumption as there is currently at least one other IBA treatment facilities within this radius. The WRATE default process 'IBA rec & FE/non Fe recovery v3 (12028)' is used. This is the most appropriate process for this treatment. IBA output from the process is 22%, which is within the expected bounds of an ERF technology and is unchanged from the standard WRATE flexible EfW facility.

APCr is transported for off-site treatment at the APCr stabilisation facility as detailed in Scenario B. WRATE does not allow onward transport of stabilised APCr (i.e. post-minimisation process) and therefore two transport elements are included before the APCr stabilisation process as with Scenario B. This is an appropriate use of the WRATE model. Distances for transport post-treatment is 201.8km and 51.2km respectively using ‘intermodal road transport v3 (12026)’ – the most appropriate WRATE process for this transportation. These distances have been cross checked using Google mapping software and are correct. APCr output from the ERF is approximately 4% of input waste, which is within the expected bounds of an ERF technology and is unchanged from the standard WRATE flexible EfW facility.

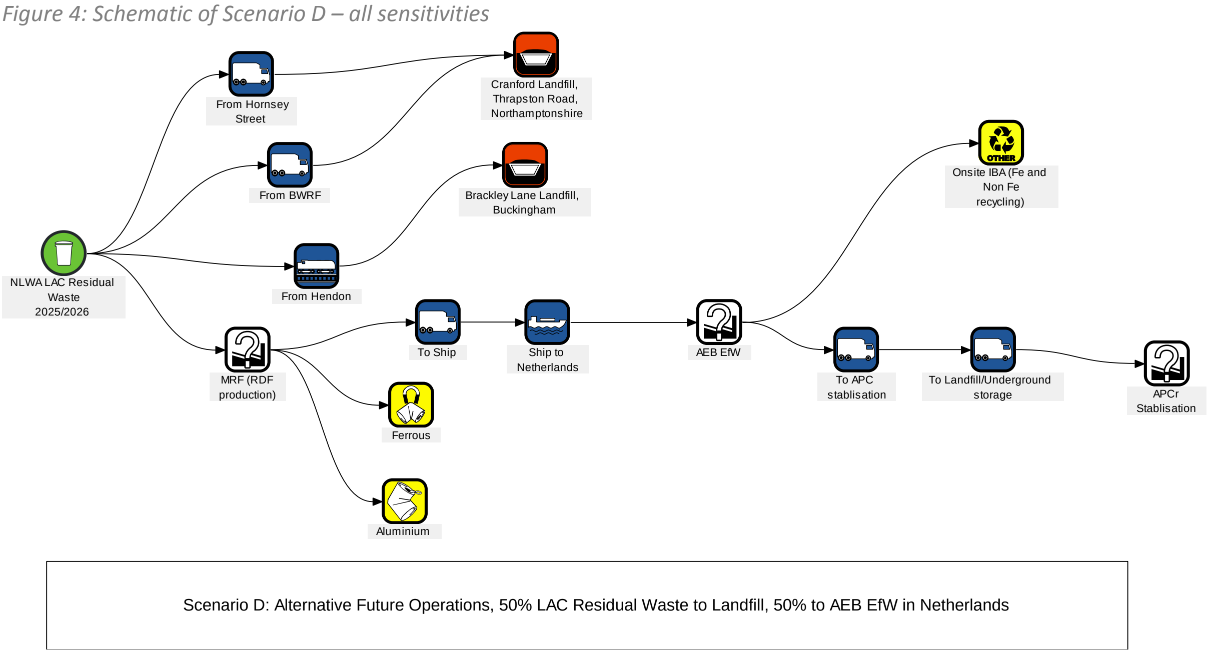
2.5 Scenario D: Alternative future baseline

Scenario D models the future treatment of the NLWA targeted waste stream with an ERF in Amsterdam treating 50% of the waste stream (after a sorting / RDF preparation stage) and the remainder being sent to landfill at the current ratio as discussed in Scenario A. A modelling error has been made whereby waste distribution to the separate landfill routes appears to have been misapplied (see Query 7). The proposed ERF to be used recovers both electrical and thermal energy for export. This is a consistent approach with all other sensitivities of the future operation.

Query 7: Miscellaneous waste distribution

FRM Query	In previous scenarios waste has been distributed 10.54:21.41:68.05 to Hornsey Street (road transfer station), BWRF (road transfer station) and Hendon (rail transfer station) respectively. In Scenario D Hendon street is modelled correctly, however waste destined for BWRF appears to have been erroneously modelled through Hendon and vice versa. This error requires remodelling of the scenario and all associated sensitivities.
ARUP Response	This has been corrected.
FRM Comment	This response is noted and the amended approach is appropriate.

Figure 4: Schematic of Scenario D – all sensitivities



This scenario has been amended from a previous version, to include a dirty MRF to extract metals and form a crude RDF for export to the AEB Energy from Waste plant in Amsterdam. The energy balance has been changed to reflect the AEB plant, handling 50% of the contract waste. The remodelled ERF process has WRATE ID 11381, and is detailed in

Table 4. The MRF process has WRATE ID 11388, is based on the default WRATE process MRF (for cement kiln/gasifier/pyrolysis) v3, and is amended as detailed in Table 5.

Table 4: User defined process for proposed ERF (Scenario D)

Parameter	User Defined WRATE process	Default WRATE process	Comment
Energy Recovered	=([USER_TOTAL.NET_CV]*0.29894)+([USER_TOTAL.NET_CV]*0.4)	User defined variable (front screen)	Changed to reflect reported actual energy outputs. Source ARUP Energy Balance.
Electricity to Grid	=[USER_TOTAL.NET_CV]*0.29894	User defined variable (front screen)	
External Heat	=[USER_TOTAL.NET_CV]*0.4000	User defined variable (front screen)	
Process Emissions > Nitrogen Oxides to Air	129891 kg	Calculated	See comments re. Scenario C NO_x.

Table 5: User defined process for proposed dirty MRF (Scenario D)

Parameter	User Defined WRATE process	Default WRATE process	Comment
Energy Input	3888000.0 MJ =([USER_WASTE_FRACTIONS_TOTAL]/[PROCESS_PARAM.CAPACITY])*[PROC_ENERGY_INPUTS.GRID.MACHINERIES]	3888000.00 MJ [Missing allocation rule]	Allocation rule inserted to fix inbuilt error in WRATE process: 30 kwh per tonne input. Calculated on a monthly basis over a two year period (2001-2003) x 36000 tpa
Material Outputs	=[USER_WASTE_FRACTIONS.FINE_MATERIAL]-[USER_FINE_MATERIAL.MOISTURE Same formula for all replacement RDF fractions	=(0.41*([USER_WASTE_FRACTIONS.FINE_MATERIAL]-[USER_FINE_MATERIAL.MOISTURE])) Same formula for all fractions with exception of metals factor	Allocation rules changed to reflect that all materials out is an RDF fraction for recovery with the exception of metals. Only metals are recovered for recycling.
Material Waste Outputs	Allocations removed Same formula for all fractions	=([USER_WASTE_FRACTIONS.FINE_MATERIAL]/[WASTE_FRACTIONS.FINE_MATERIAL])*[PROC_WASTES.LANDFILL.FINE_MATERIAL.ROAD] Same formula for all fractions	As above, all material is recovered as an RDF or recyclate, therefore no process waste out.

All transport components of the scenario have been checked and match the details modelled for previous scenarios. They have been copied correctly for all sensitivities.

3 Conclusions

FRM has conducted a peer review of the Arup WRATE model (and sensitivities) and find that the methodology and construction of the model have been appropriately applied.

The review has been undertaken in the light that this is a high level model to facilitate comparison between options (with a degree of sensitivity analysis). It is recommended that a more thorough modelling exercise, including a greater degree of technical substantiation, is provided for any more detailed assessment e.g. as part of a procurement exercise or to support a funding application.

We note that there is a discrepancy between the WRATE default calorific value for the given waste composition and the NLWA reported calorific value for the same waste composition. This discrepancy has been addressed by Arup through modelling both the NLWA and default CVs (the main WRATE project file and Sensitivity 1 respectively).

We could only partially review Sensitivity 4 (carbon intensity floor calculation) as this a policy driven factor that is calculated using the GLA Greenhouse Gas Calculator rather than WRATE. We are informed that this calculator will be submitted in parallel with the WRATE report. We have, however, undertaken a check of the direct process burdens of the ERF for the amount of energy recovered in this sensitivity and WRATE reports that it is below the maximum CIF threshold of 400gCO_2e/kWh.

Overall FRM consider that the model and choice of sensitivities are appropriate and has been conducted using reasonable assumptions and due care and diligence.