LIFE CYCLE ASSESSMENT FOR PROJECT KEA

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BASIS OF REPORT

This report has been prepared by SLR Consulting Australia Pty Ltd (SLR) with all reasonable skill, care and diligence, and taking account of the timescale and resources allocated to it by agreement with Babbage Consultants Limited (the Client). Information reported herein is based on the interpretation of data collected, which has been accepted in good faith as being accurate and valid.

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Abbreviations

Term or Acronym	Definition
APCr	Air pollution control residue
BAT	Best available techniques
BAU	Business as usual
CHP	Combined heat and power
CO_2-eq	Carbon dioxide equivalent
Defra	UK Department for Environment, Food and Rural Affairs
EA	UK Environment Agency
ECan	Environment Canterbury
EfW	Energy from waste
eq	Equivalent
ERF	Energy recovery facility
FGT	Flue gas treatment
FGTR	Flue gas treatment residues
GHG	Greenhouse gas
GWP	Global warming potential
H&M	Heat and mass
ISO	International Standards Organization
kV	Kilovolt
LCA	Life cycle assessment
LCI	Life cycle inventory
LCIA	Life cycle impact assessment
LFG	Landfill gas
MSW	Municipal solid waste
MW	Megawatt
SCR	Selective catalytic reduction
SIRRL	South Island Resource Recovery Limited
SNCR	Selective non-catalytic reduction
tpa	Tonne per annum
UDP	WRATE User defined process
WDC	Waimate District Council

1 Introduction

This Life Cycle Assessment (LCA) supports the regulatory assessment process to obtain the necessary resource consents to enable the construction and operation of New Zealand's first large scale Energy from Waste (EfW) Plant (known as Project Kea) in South Canterbury by South Island Resource Recovery Limited (SIRRL).

1.2 Project Kea

Project Kea will be New Zealand's first large scale EfW Plant facility converting both municipal solid waste (MSW) and Construction Waste, otherwise destined to landfill, into steam and electricity. The facility will be located near Glenavy in the South Canterbury region of New Zealand. Project Kea is an initiative from the Joint Venture Partnership between Renew Energy Limited (NZ), China Tianying Incorporated (China) and Europe ZhongYing BV (Belgium). This partnership is called South Island Resource Recovery Limited (SIRRL). Babbage Consultants Limited (Babbage) are leading the resource consenting process for Project Kea and have engaged SLR Consulting NZ Limited (SLR) to prepare the Life Cycle Assessment.

Project Kea will treat up to 365,000 tonnes per year of Municipal Solid Waste (MSW) and Construction Waste with the heat energy released being converted to steam and subsequently electricity via a steam turbine and generator.

The steam generated would be available for local industries to use as a heating source and the electricity would be fed into the local network for primary use by local industries and secondary use to feed the national grid. This provides an embedded local network generation point which:

- strengthens the electricity supply in the local network, and
- provides energy to enable local business expansion and less reliance on fossil fuel generation power.

The waste consumed by the facility would include both organic waste (categorised as a sustainable fuel source like 'biomass') and non-recyclable fossil fuel derived products (i.e., non-recyclable plastics).

Waste will be transported to the site initially by road and eventually by both road and rail with a focus on increasing the quantity transported by rail over time.

Waste received by the site has first been subject to sorting at both source and the transfer station for the removal of recyclable materials. Project Kea supports recycling in that it does not require, nor desire receiving recyclable plastics. The waste received by the facility is that waste that would otherwise be sent to landfill.

Project Kea will use proven Best Available Techniques (BAT) as defined by the Industrial Emissions Directive 2010/75/EU to minimise harmful emissions.

The following solid, liquid, and gaseous material streams will be produced from the facility:

- Flue gas: this will be treated in a multi-step process to reduce contaminants to a compliant level.
- Industrial wastewater: this will be treated to remove contaminants and then 100% recycled back into the process. There will be no industrial wastewater discharge to the environment.
- Domestic wastewater: this will be biologically treated and disposed of to land via drip field.
- Grate ash/bottom ash: this will be sorted to recover metal for recycling and the remaining portion either used as an aggregate or disposed of to landfill.

- Fly ash: this will be treated via a plasma process and create an inert solid which will then be combined with the Grate ash for use as an aggregate or otherwise disposed of to landfill.

The project is expected to generate 30 MW of electricity at either 33kV or 110kV and deliver into the local network, and recover recyclable metal (both ferrous and non-ferrous) and aggregate for road base and concrete manufacture (if bottom ash and vitrified fly ash are recycled).

1.3 International Standards for LCA

International Standards, particularly the *International Standards Organization (ISO) standards ISO 14040 – Life cycle Assessment – Principles and framework* and *ISO 14044 – Life cycle assessment – Requirements and guidelines* (ISO series 14040/14044), provide principles, a framework, and methodological requirements for conducting Life Cycle Assessment (LCA) studies.

SLR believes that the requirements outlined for a LCA in the international standards provide sufficient coverage to evaluate the life cycle impacts of the proposed EfW facility. As a result, this LCA consists of four key phases:

1. Goal and scope definition,
2. Life cycle inventory (LCI),
3. Life cycle impact assessment (LCIA), and
4. Interpretation.

2 Goal and Scope Definition

2.1 Goal of the study

The goal of this LCA is to undertake **a life cycle assessment in accordance with the International Standards (ISO 14040:2006 and ISO 14044)**.

The main driver of this LCA is to address the following key issues:

- to assess the global warming potential (GWP), of the EfW Plant.

The primary audience for the study would be Environment Canterbury (ECan) and Waimate District Council (WDC), the regulatory consenting authorities for Project Kea.

2.2 Scope of the study

The scope of the study considers and clearly defines key aspects of LCA analyses, including the product system(s) studied, the system boundaries, data required and analysis needs, impact categories to be evaluated i.e., methodology of impact assessment and type of critical review.

2.2.1 System boundary, Functional Unit and Reference System

Project Kea is to be located in the South Canterbury region, New Zealand. The EfW Plant will process approximately 365,00 tpa of MSW and Construction Waste. For the purposes of this LCA, the business as usual (BAU) or Baseline scenario, for both MSW and Construction Waste is disposal to landfill.

In order to provide reasonable coverage of the life cycle impacts of the EfW facility, the avoided benefits of not sending waste to landfill (and the fugitive emissions associated with landfill disposal), as well as the benefits of displacing fossil fuel electricity and heat use have been considered.

The objective of this study is to compare the GWP associated with the development of the EfW facility against the waste management baseline, namely, landfill disposal of both MSW and Construction Waste.

The EfW facility would be developed in the context of wider resource recovery system whereby waste material would be converted into energy, and recovered material being recycled where applicable. Hence, following the “cradle-to-grave” approach, the system boundary was extended to include the impacts of waste transport, handling, processing, and disposal. The boundary, therefore, includes the following material and process flows:

- Transport of MSW directly from kerbside collection to the final disposal location,
- Transport of Construction Waste from a transfer station, following the removal of recyclable and reusable materials, to the final disposal location. Note that transport of Construction Waste from the original source to the transfer station and transfer station operation is outside the LCA boundary,
- combustion of fuel for steam and electricity production,
- treatment of fly ash via plasma processing,
- recovery of recyclable metals (both ferrous and non-ferrous),
- recycling of bottom ash and vitrified fly ash offsite,

- transportation of product streams, including metals, bottom ash, and vitrified fly ash,
- avoided impacts from the transport and processing of waste in a landfill, and
- avoided impacts from fossil fuel electricity use and steam generation and use.

A critical parameter in LCA is the “Functional Unit” which is defined as the amount, weight and quality of the specific product or economic function being investigated. In a comparative study, the functional unit has to be the same for all the compared scenarios otherwise inputs and outputs cannot be compared on an equivalent basis. The functional unit for this study is taken to be the total mass of waste processed at the EfW facility. All modelled scenarios use this same functional unit i.e., the identical quantity and composition of total waste managed, which is 365,000 tpa.

The functional unit for this LCA (365,000 tpa of waste) consists of:

1. approximately 182,500 tpa of MSW delivered to the facility, and
2. approximately 182,500 tpa of Construction Waste delivered to the facility.

2.2.2 Cut-off criteria

Cut-off rules enable LCA practitioners to conduct LCA without having to model 100% of the system. Cut-off criteria as defined in the ISO 14040 refers to specification of the amount of material or energy flow, or the level of environmental significance associated with unit processes, or product system, to be excluded from a study. Within the chosen life cycle boundary there has not been any attempt to impose cut-off criteria.

2.2.3 Data quality criteria

Data quality should be addressed throughout the LCA modelling process. The input data for the LCA model consists of the chosen (filtered) information to enable model computations and calculations. All data quality goals should be determined during the goal and scope phase of the LCA and should give guidance on the data collection process. The data quality goals need to explicitly define needs for data representativeness, reliability, and completeness. During the scope phase of the LCA, the input data consists of information necessary to define the system boundary and functional unit. For the life cycle inventory analysis phase, the input data includes information necessary to clearly specify the unit process descriptions, including both technical data and environmental interventions. For characterisation, the data chosen for the impact assessment stage is converted to equivalency factors using characterisation models chosen during the scope. Interpretation of LCA results includes the interpretation of the data quality assessment.

In this LCA, the following components of life cycle inventory data quality have been considered:

- **Flow** – relating to individual values associated with materials. Elementary flows, i.e., exchanges with the environment have been considered, e.g., total waste managed in all scenarios studied.
- **Process** – processes which describe one specific activity (a unit process) for example generating steam from a boiler or aggregate multiple activities (an aggregate process).
- **Model** – which is based on a group of linked processes.

The following data quality indicators have been considered as relevant in this LCA:

Reliability

Reliability was considered as a measure for the data sources, acquisition methods and verification. This LCA applies primary data from Babbage for the EfW facility mass and energy balances. Data based on assumptions have been used for other user defined processes where primary data was not available. Secondary data from verified external databases (through the modelling undertaken) were used for lifecycle inventory data.

Completeness

Completeness was considered as a measure for the representativeness of the sample. This is linked to the goal and scope of the LCA study, particularly the system boundary, including all flows entering, exiting and within the system boundary. The system boundary considers impacts from waste sources (from transportation), some assumptions based on Babbage's knowledge of the waste management cycle were adopted, which can be considered representative data from an adequate sample of sites over an adequate period of time.

Temporal, geographical, and technological correlations

Temporal, geographical, and technological correlations measure for the degree of correspondence between data and the goal and scope of the study. ISO 14044 standards define time-related coverage as the age of the data and the minimum length of time over which data should be collected. Babbage provided data for the EfW facility based on the design and nominal load points. The modelling in this LCA was undertaken using the WRATE tool that utilises a background database supplied by the Ecoinvent centre, a Swiss organisation with unrivalled expertise in supplying consistent and transparent life cycle inventory data. WRATE models the environmental impacts of all phases of a waste management facility's life cycle from construction, operation, maintenance, and decommissioning, including processes associated with waste management and resource recovery. These processes include recycling, transfer stations, thermal treatment, and management of residues from thermal treatment including Bottom ash and Air Pollution Control residue (APCr), otherwise referred to as FGTR.

2.2.4 Impact Categories

Environmental impact categories represent the different types of environmental impacts that are included in an LCA study. These include quantitative characterisation models that link inventory flows to comparable environmental impacts with indicators. In this LCA study, the GWP Lifecycle Impact Assessment (LCIA) indicator was used to assess the environmental impacts of the EfW Plant as outlined in **Table 1**.

Table 1 Life Cycle Impact Category and Indicator used in WRATE

Impact Category	Global warming
Indicator	Global warming potential - GWP 100a
Indicator Units*	kg CO_2 eq** (kg CO_2-e)

*Units in the results section have been changed to kilotons (kt) for presentation

**eq means equivalent (also expressed as e)

3 LCA Approach

SLR conducted this LCA study in accordance with the ISO standards 14040/14044. This section presents the approach and methodology followed in undertaking the LCA for the EfW Plant.

3.1 Methodology

3.1.1 Introduction

This LCA compares the environmental impacts of the proposed EfW Plant and associated infrastructure against the “counterfactual”, current Baseline – assumed to be landfill disposal of MSW and Construction Waste. Modelling has been undertaken, to assess the following scenarios, which are characterised in more detail at Section 3.2 and Section 3.3:

- Scenario 1 – Baseline/Counterfactual (baseline waste management and landfill disposal of MSW and Construction Waste).
- Scenario 2 – EfW Plant based on an incineration process in an electricity only mode for electricity generation. All waste (both MSW and Construction Waste) would be transported to the EfW facility by road (100%). Both vitrified fly ash and bottom ash (excluding metals recovered at grate) would be recycled as aggregate.
- Scenario 3 – Sensitivity scenario including an EfW Plant based on an incineration process in a combined heat and power (CHP) mode whereby heat would be supplied to a nearby industrial user as steam to replace coal usage [Note: As explained in Section 3.2.5.1 offsetting the use of Coal is not possible in WRATE, so our assessment is based on offsetting oil, a less carbon intensive fuel compared to coal and therefore considered a conservative assumption]. All waste (both MSW and Construction Waste) would be transported to the EfW facility by road (100%). Both vitrified fly ash and bottom ash (excluding metals recovered at grate) would be recycled as aggregate.
- Scenario 4 – Sensitivity scenario including an EfW Plant based on an incineration process in an electricity only mode for electricity generation. All waste (both MSW and Construction Waste) would be transported to the EfW facility by road (50%) and rail (50%), while all product streams (i.e., metals, vitrified fly ash and bottom ash) would be transported via road (100%).
- Scenario 5 – Sensitivity scenario including an EfW Plant based on an incineration process in an electricity only mode for electricity generation. All waste (both MSW and Construction Waste) would be transported to the EfW facility by road (100%). Both vitrified fly ash and bottom ash (excluding metals recovered at grate) would be disposed of in landfill.

The summary of the five scenarios is outlined in **Table 2**.

Table 2 Scenarios Summary

Scenario	Summary
Scenario 1	• baseline – landfill
Scenario 2	• electricity only mode • 100% waste transported via road • vitrified fly ash and bottom ash recycled as aggregate • metals recovery

Scenario	Summary
Scenario 3	• combined heat and power mode • 100% waste transported via road • vitrified fly ash and bottom ash recycled as aggregate • metals recovery
Scenario 4	• electricity only mode • 50% waste transported via road and 50% by rail • vitrified fly ash and bottom ash recycled as aggregate • metals recovery
Scenario 5	• electricity only mode • 100% waste transported via road • vitrified fly ash and bottom ash to landfill • metals recovery

The modelling uses a life cycle assessment tool, WRATE, described in more detail below. It is also noted that the data inputs and outputs for the scenarios i.e., LCI were influenced by the inputs required by the WRATE tool, and as a result, modifications to primary data provided was undertaken, namely:

- Aligning waste category types to those available in the WRATE model (refer to Section 3.2.3)
- WRATE can only model natural gas and oil (or mixed) as heating fuels to offset, whereas the Project Kea will offset the use of coal at a nearby industrial user. Due to this particular limitation of the WRATE model, SLR adopted oil as the offset fuel, instead of coal as a heating fuel to offset (refer to Section 3.2.5)

3.1.2 The WRATE Tool

The WRATE software is a life cycle assessment tool specifically designed to model the environmental impacts of waste and waste management processes. Its predominant use is for assessing the management of municipal and municipal type wastes (which would include Construction Waste types; hence it is appropriate for Project Kea).

As a life cycle assessment tool, WRATE models the environmental impacts of all phases of a waste management facility's life cycle from construction, operation, maintenance, and decommissioning (where applicable). WRATE also models all elements of the waste management process from collection through to disposal.

WRATE was funded and developed by the UK Environment Agency (EA) and released to market in 2007. All users of the software pay a licence fee and must receive training in its use to ensure assessments are carried out to the required standard. SLR is a registered expert user of WRATE.

The use of the WRATE software is endorsed and encouraged by the UK EA and the UK Department for Environment, Food and Rural Affairs (Defra). Over many years the tool has been embedded within the waste management industry assisting with a range of projects for various organisation types:

- environmental impact calculation of options for Local Authority municipal waste management strategy development projects,
- solution testing and business case development for Local Authority and private sector,
- procurement support tool to assess the environmental impacts of bidder solutions within a local authority waste management tender process (many of these procurements received Defra funding),
- planning application support or planning variations (including successful removal of restrictive planning conditions for energy recovery facility (ERF) projects), and
- quantifying the "green" credentials of waste projects being considered by the Green Investment Bank (now Green Investment Group) and annual reporting of carbon impact for investment projects.

The software was developed to comply with the ISO standards for LCA to ensure studies using the WRATE tool can be delivered to a high technical standard. The WRATE tool utilises a background database supplied by the Ecoinvent centre.

The LCA tool helps with the identification and quantification of the following environmental impacts:

- **direct burdens –** defined as emissions from the process itself, for example carbon dioxide as a result of a consequence of combustion or aerobic degradation,
- **indirect burdens –** associated with the supply of energy and materials to the process, for example construction materials, electrical energy for motors and fans, and chemicals for pollution abatement equipment, and
- **avoided burdens –** associated with the recovery of energy and materials from the waste stream resulting in the avoidance of primary energy production and mineral extraction.

The environmental impact of a particular scenario is therefore calculated as the sum of direct burdens, indirect burdens and avoided burdens.

3.2 Life Cycle Inventory Analysis

This section provides the cradle-to-grave LCI for the two key scenarios in Section 3.1.1, i.e., Scenario 1 - the baseline/counterfactual and Scenario 2 - the EfW Plant in electricity only mode. Primary design data were obtained from project documentation provided to SLR, including details of waste sources and transport data. Additional data has been based on assumptions, literature, and publicly available information (where applicable).

3.2.1 Principal Assumptions within a WRATE Model

When developing a project in WRATE, a number of key assumptions must be defined. These assumptions include the tonnage of waste, the composition of the waste, the assessment year (assumed to be 2026 in this LCA Study), and the associated energy mix, which is the assumed energy mix that would be displaced by the energy generated by the EfW Plant. All these assumptions will influence the output results.

The next step is the development of one or more scenarios. It is good practice to include a baseline or business as usual scenario for comparison with other options assessed.

When modelling an EfW Plant within WRATE there are certain key parameters which must be defined (which again influence the output results). The key ERF assumptions include:

- whether the plant is operating in electricity only or CHP mode,

- the type of flue-gas abatement equipment utilised,
- the management route for bottom ash and fly ash, and
- the energy efficiency (for both electricity and heat) of the facility.

Details of the technical solution are presented in the project Kea Life Cycle Analysis Information Packs and these data have been used to define the EfW Plant characteristics in WRATE. These details would be based on the technical specifications or concept for the proposed EfW Plant. SLR has reviewed background information for Project Kea from Babbage, including details of mass and energy balances, waste types and composition data, transport distances and proposed technology descriptions and specifications etc. SLR has confirmed the key assumptions and technical specifications with Babbage.

3.2.2 Project Information – Common to all Scenarios

In order to compare the environmental impacts of the EfW Plant to the counterfactual scenario – baseline waste management (i.e., landfill disposal of MSW and Construction Waste), the common technical parameters described in this section have been adopted. The year 2026 has been adopted as the assessment year.

3.2.2.1 Electricity Mix

The "baseline" electricity mix was based on electricity generation data in New Zealand, by fuel type for calendar year 2021 as obtained from the Ministry of Business, Innovation & Employment (2021)[1]. Based on the discussion with Babbage, the baseline electricity mix was adjusted considering 96% renewable energy for the likely future situation, where the Tiwai Point aluminium smelter closes.

Marginal fuel mix is calculated by considering the carbon intensive energy sources in the baseline fuel mix that are assumed to be offset by the electricity generated by the EfW Plant. **Table 3** shows the baseline fuel mix and the marginal fuel mix adopted for this LCA. Adopting the fuel mix provided in **Table 3** is considered a reasonable assumption for the LCA given the high degree of uncertainty associated with any future forecast of energy mix in New Zealand.

Table 3 Baseline Fuel Mix and Marginal Fuel Mix

LCA Categories	New Zealand Baseline Fuel Mix (96% Renewable)	Marginal Fuel Mix
Coal	1.57%	39.2%
Oil	0.01%	0.3%
Gas	2.42%	60.5%
Gas CCGT	0.00%	0%
Nuclear	0.00%	Not Applicable
Waste	0.10%	Not Applicable
Thermal other	0.00%	Not Applicable
Renewables thermal	1.27%	Not Applicable

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[1] Energy in New Zealand | Ministry of Business, Innovation & Employment, 2021. Retrieved from https://www.mbie.govt.nz/building-and-energy/energy-and-natural-resources/energy-statistics-and-modelling/energy-publications-and-technical-papers/energy-in-new-zealand/

LCA Categories	New Zealand Baseline Fuel Mix (96% Renewable)	Marginal Fuel Mix
Solar PV	0.55%	Not Applicable
Wind	7.09%	Not Applicable
Tidal	0.00%	Not Applicable
Wave	0.00%	Not Applicable
Hydro	65.03%	Not Applicable
Geothermal	21.21%	Not Applicable
Renewable other	0.75%	Not Applicable
Total	**100%**	**100%**

*The "baseline" fuel mix is a parameter used in WRATE, which defines the typical electricity grid and its fuel source contributions and should not be confused with the "baseline" scenario.

**The marginal fuel mix includes only the carbon intensive energy sources, which are assumed to be offset by the electricity generated from the EFW Plant. In this LCA, the marginal fuel mix includes Coal, Oil and Gas.

3.2.3 Feedstock composition

The EfW facility is designed to process MSW and Construction Waste. An assumed composition of MSW and Construction Waste (presented in **Table 4**) was provided to SLR by Babbage. It was also assumed that the composition of feedstock waste streams adopted in this LCA study would remain relatively consistent over the project life.

Table 4 Feedstock MSW and Construction Waste Composition

Waste Category (Provided by Client)	Waste Category (Used in WRATE)	MSW (% by mass)	Construction Waste (% by mass)
Rubbish	Other combustibles	24.28%	0.00%
Recyclable Paper and Cardboard	Paper and card (Other card)	16.75%	15.00%
Compostable Greenwaste	Organics (Garden waste)	11.28%	20.00%
Recyclable Plastic	Other dense plastic	10.60%	0.00%
Non-compostable Greenwaste	Organics (Garden waste)	8.17%	0.00%
Soft plastics	Other film plastic	7.66%	6.00%
Non-recyclable paper	Paper and card (Other paper)	7.27%	0.00%
Clothing and textiles	Unspecified textiles	5.45%	10.00%
Timber	Unspecified wood	1.90%	30.00%
E-Waste	Other Waste electrical and electronic equipment	1.63%	0.00%
Glass	Unspecified glass	1.45%	3.00%
Ferrous Metals	Unspecified ferrous metal	1.22%	2.00%
Non-Ferrous metals	Unspecified non-ferrous metal	0.88%	0.00%
Nappies and Sanitary	Disposable nappies	0.74%	1.00%

Waste Category (Provided by Client)	Waste Category (Used in WRATE)	MSW (% by mass)	Construction Waste (% by mass)
Concrete, Ceramics, Rubble	Non-combustibles (Bricks, blocks, plaster)	0.53%	7.00%
Hazardous waste	Unspecified hazardous household	0.06%	0.00%
Domestic Batteries	Batteries	0.05%	0.00%
Kitchen food waste	Organics (Food waste)	0.05%	0.00%
EPS (polystyrene)	Packaging film	0.03%	0.00%
Aerosol cans		0.00%	0.00%
Rubber	Other combustibles	0.00%	6.00%
Total		**100%**	**100%**

SLR notes that the composition of compostable greenwaste, recyclable paper and cardboard and timber in the Construction Waste stream are relatively high for a residual waste stream. Based on previous discussions with Babbage, it was noted that the composition of the Construction Waste, shown in **Table 4**, is for the Construction Waste stream post-transfer stations, whereby some recyclable and reusable materials would have been recovered.

3.2.3.1 Waste Managed

Babbage have provided total tonnages for all waste from the various sources (e.g., Christchurch, Dunedin, and Central Otago) as noted in **Table 5**. In order to apply the material composition in **Table 4** Babbage have also noted that for the purposes of the assessment the total solid waste is split as 50% MSW and 50% Construction Waste (by mass), and all Construction Waste would be coming from Christchurch A only. This assumption was adopted in the LCA modelling with the tonnages summarised in **Table 5**.

Table 5 Feedstock MSW and Construction Waste quantities

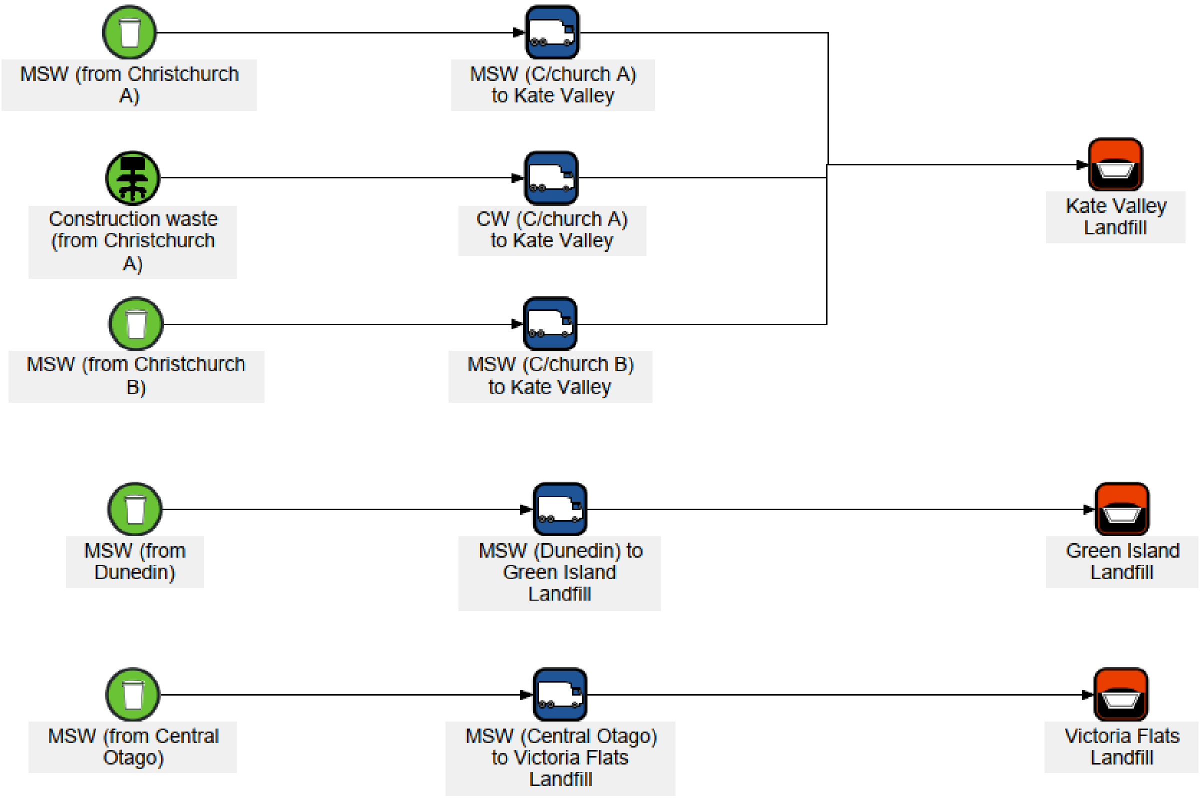
Source	Total Waste Quantity (tpa)	MSW (tpa)	Construction Waste (tpa)
Christchurch (source A)	210,000	27,500	182,500
Christchurch (source B)	50,000	50,000	0
Dunedin	55,000	55,000	0
Central Otago	50,000	50,000	0
Total	**365,000**	**182,500**	**182,500**

3.2.4 Scenario 1 – Baseline/Counterfactual

The baseline scenario was developed to assess the environmental impacts of the current BAU management of the waste streams, particularly landfill disposal of MSW and Construction Waste. **Figure 1** shows a scenario Map from WRATE showing the processes adopted for the baseline scenario.

MSW would be collected from four (4) different sources – Christchurch A, Christchurch B, Dunedin, and Central Otago, while Construction Waste would be collected from Christchurch A only. The waste streams collected from Christchurch would be disposed of at Kate Valley Landfill, while the waste streams collected from Dunedin and Central Otago would be disposed of at Green Island Landfill and Victoria Flats Landfill respectively. All waste streams were assumed to be transported to the landfills via road by truck (100%).

Figure 1 Process flow diagram showing key processes used in WRATE for Scenario 1



3.2.4.1 Landfill assumptions

Since no details of the existing landfills have been provided to SLR, a landfill gas (LFG) capture rate of 90% has been assumed in this LCA study. The 90% capture rate is noted in the technical assessment of the environmental effects of discharges to air to support resource consent applications for the Auckland Regional Landfill project.[2] According to this report prepared for Waste Management NZ Ltd (WMNZ), 90% LFG collection efficiency can be achieved during the post filling stage prior to the post closure phase of the landfill. A LFG collection efficiency of 95% could only be considered for post closure of the landfill after placing the final cap. During the initial stages of filling, the capture rate can vary from 0% to 80% as waste is placed in the landfill and gas extraction systems are progressively installed. Therefore, over the life of a fully engineered landfill, an average 90% gas capture rate is considered relatively high and is therefore considered a conservative assumption.

In regard to other landfill characteristics, SLR used best practice landfill characteristics as per the Technical Guidelines for Disposal to Land.[3] **Table 6** shows the key landfill parameters adopted for the LCA.

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[2] Auckland Regional Landfill, Air Quality Assessment, 2019

[3] Technical Guidelines for Disposal to Land, Waste Management Institute New Zealand, 2018

Table 6 Landfill Characteristics for Business-as-Usual Scenario

Landfill name	Kate Valley	Green Island	Victoria Flats
Gas use	Energy Recovery	Energy Recovery	Energy Recovery
Gas collection efficiency	90%	90%	90%
Liner type	HDPE	HDPE	HDPE
Cap type	Clay	Clay	Clay

3.2.4.2 Other technical assumptions

A summary of other technical characteristics and input data used for the baseline scenario is provided in **Table 7**.

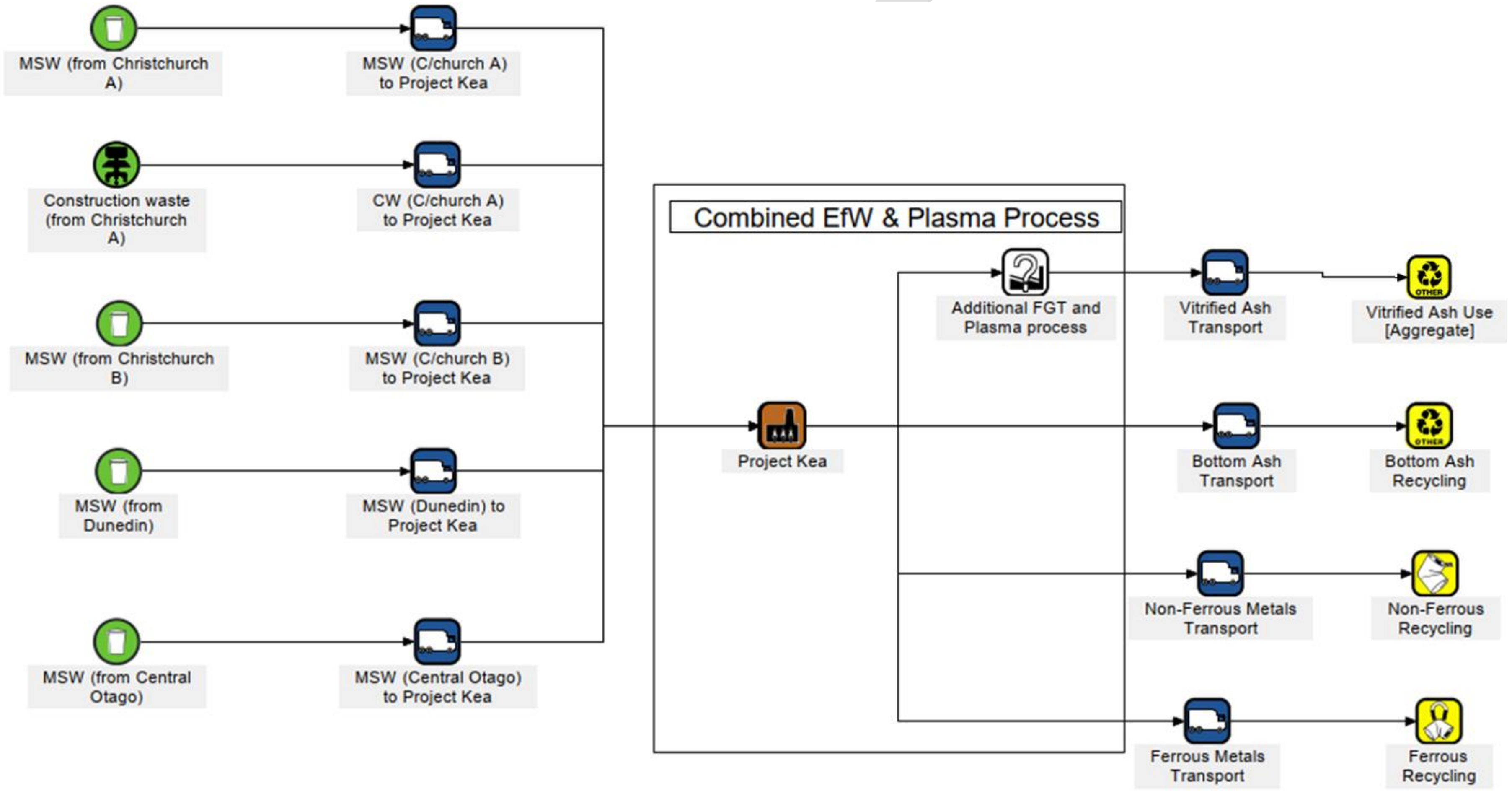
Table 7 Scenario 1 – Baseline/Counterfactual Characteristics

Material Stream	Process Description	Quantity (tpa)	Transport Distance (km/trip)	Reference/Comment
MSW	Transport from Christchurch A to Kate Valley Landfill	27,500	68	Distance based on Babbage assumption
Construction Waste	Transport from Christchurch A to Kate Valley Landfill	182,500	68	Distance based on Babbage assumption
MSW	Transport from Christchurch B to Kate Valley Landfill	50,000	65	Distance based on Babbage assumption
MSW	Transport from Dunedin to Green Island Landfill	55,000	8	Distance based on Babbage assumption
MSW	Transport from Central Otago to Victoria Flats Landfill	50,000	39	Distance based on Babbage assumption

3.2.5 Scenario 2 – EfW Plant

This scenario evaluates the environmental impacts of processing a mix of MSW and Construction Waste at a proposed EfW Plant utilising incineration technology. **Figure 2** shows a scenario map from WRATE showing the processes adopted for Scenario 2 – Base Case EfW Plant.

Figure 2 Process flow diagram showing key processes used in WRATE for Scenario 2



Icons presented in the process flow diagram in **Figure 2** are from the WRATE scenario map. Note: WRATE icons with '?' symbol identify a process which is User Defined, referred to as a User Defined Process or UDP.

It is assumed that MSW would be collected from four (4) different sources – Christchurch A, Christchurch B, Dunedin, and Central Otago, while and Construction Waste would be collected from Christchurch A only. EfW Plant would be based on an incineration process in an electricity only mode for electricity generation. Metals (both ferrous and non-ferrous) would be recovered from the grate, while fly ash would be treated though a plasma process. Both vitrified fly ash and bottom ash (excluding metals recovered at grate) would be recycled as aggregate. All waste streams (both MSW and Construction Waste), and all product streams (i.e., metals, vitrified fly ash and bottom ash) would be transported via road (100%).

3.2.5.1 EfW User Defined Process (UDP)

The proposed EfW Plant configuration features what could be considered relatively unique combinations of technologies. These unique combinations include the use of both Selective Non-Catalytic Reduction (SNCR) and Selective Catalytic Reduction (SCR) for NO_X removal, the use of dry injection, semi-dry and wet scrubbing systems in the flue gas treatment (FGT) train as well as the use of a plasma treatment process for fly ash management. Furthermore, SLR notes that the WRATE tool allows development of a 'Flexible EfW Process' whereby the key parameters can be specified, e.g., energy recovery type (i.e., electricity only or CHP), flue gas treatment type (i.e., wet or dry), heating fuel to offset (gas, oil or mixed) and NO_X reduction type (i.e., SNCR or SCR). The proposed EfW configuration for Project Kea will require a combination of the 'Flexible EfW Process' and an additional user defined process (UDP). A UDP is where a WRATE standard process is duplicated, and changes are made to the background allocation data table to better represent the process or treatment technology that is not a WRATE standard process. Hence SLR has developed a UDP to allow coverage of the following:

- modelling both SCR and SNCR in regard to NO_X control,
- inclusion of dry, semi-dry and wet flue gas treatment, and
- fly ash treatment using a plasma process.

SLR notes that WRATE can only model natural gas and oil (or mixed) as heating fuels to offset. Due to this particular limitation of the WRATE model, SLR adopted oil as the offset fuel, instead of coal as a heating fuel to offset. It is noted that oil typically generates more emissions than natural gas. It is estimated that the expected emissions from coal would be higher than modelling results (from oil) and therefore this assessment can be considered conservative in its results for the avoided burdens from heat use.[4]

SLR assumed that the typical configuration of the WRATE Flexible Energy from Waste Process would feature SNCR and Dry FGT. The UDP was then developed using a standard WRATE Transfer Station Process, and modifying its data in the background allocation table, particularly to account for the increased consumables and water associated with utilising both SNCR and SCR for NO_X removal, and the use of dry injection, semi-dry and wet scrubbing systems for Project Kea. Additional energy requirements associated with multiple gas clean-up processes and the plasma process were accounted for by adjusting the energy efficiency assumptions within the WRATE Flexible Energy from Waste Process itself.

The following table shows a summary of the consumables and water use characteristics adopted for the UDP for a total EfW throughput of 365,000 tpa.

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[4] Natural gas vs. Coal – a positive impact on the environment; https://www.gasvessel.eu/news/natural-gas-vs-coal-impact-on-the-environment/#:~:text=Natural%20gas%20is%20a%20fossil%20fuel%2C%20though%20the,with%20emissions%20from%20a%20typical%20new%20coal%20plant.

Table 8 Summary of the consumables and water use characteristics adopted for the UDP

Stage	Additional Burden	Tonnage [t/year]	Material Name	Comments
SCR	Additional Chemical Usage [25% Ammonia]	1,034	Anhydrous ammonia	25% factor applied to obtain the ammonia value only
FGT	Additional sodium bicarbonate usage	1,980	Sodium bicarbonate	
FGT	Additional NaOH [30% Solution] usage (wet scrubber)	1,139	Sodium hydroxide	Material entered as "Sodium Hydroxide 28%", background against "sodium hydroxide, 50%." as best fit with options available within WRATE.
FGT	Total water usage [Wet scrubber]	198,330	Mains Water	
FGT	Wastewater from wet scrubbing system	19,973	Water (Sewer)	
Plasma Treatment	Additive No. 1 - SiO_2	6,387	Silicon dioxide	Excluded. WRATE does not include silicon dioxide, silica, or quartz within the material options list. Hence this was not included in the UDP.
Plasma Treatment	Additive No. 2 - Na_2CO_3	2,737	Sodium carbonate	
Plasma Treatment	Additive No. 3 - NaOH [30%]	2,555	Sodium hydroxide	Included within total NaOH value below
Plasma Treatment	Additive No. 4 - HCl [30%]	365	Hydrochloric acid	
Plasma Treatment	Additive No. 5 - $CaCl_2$ [30%]	1,825	Calcium chloride	Excluded. WRATE does not include Calcium chloride within the material options list. Hence this was not included in the UDP
Plasma Treatment	30% Lye	175	"Lye" most commonly refers to sodium hydroxide NaOH	Included within total NaOH value below

Stage	Additional Burden	Tonnage [t/year]	Material Name	Comments
Plasma Treatment	Total water usage [Plasma]	21,173	Mains Water	
Plasma Treatment	Total NaOH [30%]	2,730	Sodium hydroxide	The total of Additive No. 3 plus 30% Lye. Material entered as "Sodium Hydroxide 28%", background against "sodium hydroxide, 50%..." as best fit with options available within WRATE.

SLR notes that the UDP characteristics presented in **Table 8** above would be similar for both the electricity only and the CHP EfW configurations.

3.2.5.2 Grate Incinerator Specification

The incineration process is modelled using a default WRATE Incinerator (Flexible Energy from Waste) Process for MSW and Construction Waste (total throughput of 365,000 tpa). The characteristic of this process, adopted in WRATE modelling, is shown in **Table 9**.

Table 9 Incineration unit characteristics for Scenario 2 - EfW Plant

Process Property	Specification	Comment
Energy Recovery type	Electricity only	Base case EfW configuration
Gross electrical efficiency	24%	Gross electrical efficiency has been adjusted from 26% to 24% based on an energy balance undertaken by SLR to account for power consumption of the additional FGT treatment and plasma processes.
Flue gas cleaning system	Dry	
Reduction type	SNCR	
Ferrous recovery	80%	Information provided by Babbage
Non -ferrous recovery	50%	Information provided by Babbage

It is noted that gross electrical efficiency was calculated from the heat and mass (H&M) balances, assuming no steam export to a nearby industrial user, and accounting for electricity usage of the plasma system.

3.2.5.3 Other technical assumptions

A summary of other technical characteristics and input data used for the EfW Plant scenario is provided in **Table 10**.

Table 10 Transportation Characteristics for Scenario 2 - EfW Plant

Material Stream	Process Description	Quantity (tpa)	Transport Distance (km/trip)	Reference/Comment
MSW	Transport from Christchurch A to EfW facility	27,500	280	Distance based on Babbage assumption
Construction Waste	Transport from Christchurch A to EfW facility	182,500	280	Distance based on Babbage assumption
MSW	Transport from Christchurch B to EfW facility	50,000	289	Distance based on Babbage assumption
MSW	Transport from Dunedin to EfW facility	55,000	176	Distance based on Babbage assumption
MSW	Transport from Central Otago to EfW facility	50,000	286	Distance based on Babbage assumption
Metal (ferrous and non-ferrous)	Transport from EfW facility to recycling	WRATE Calculated	63	Distance based on Babbage assumption

Material Stream	Process Description	Quantity (tpa)	Transport Distance (km/trip)	Reference/Comment
Bottom ash	Transport from EfW facility to recycling	WRATE Calculated	63	Distance based on Babbage assumption
Vitrified fly ash	Transport from EfW facility to recycling	WRATE Calculated	63	Distance based on Babbage assumption

It is also noted that a landfill process has been selected for vitrified fly ash management to allow WRATE to run the results, noting that 'Processed Materials' (i.e., APCR) cannot be recycled in WRATE. The WRATE results have been adjusted manually during reporting to account for impacts/benefits of reusing the vitrified ash as aggregate.

3.3 Sensitivity Analysis

Three further scenarios have been developed to undertake sensitivity testing on key factors, principally the following:

- Scenario 3 – EfW Plant based on an incineration process in a combined heat and power mode for electricity and heat generation. All waste (both MSW and Construction Waste) would be transported to the EfW facility by road (100%). Both vitrified fly ash and bottom ash (excluding metals recovered at grate) would be recycled as aggregate.

- Scenario 4 – EfW Plant based on an incineration process an electricity only mode for electricity generation. All waste (both MSW and Construction Waste) would be transported to the EfW facility by road (50%) and rail (50%). Both vitrified fly ash and bottom ash (excluding metals recovered at grate) would be recycled as aggregate.

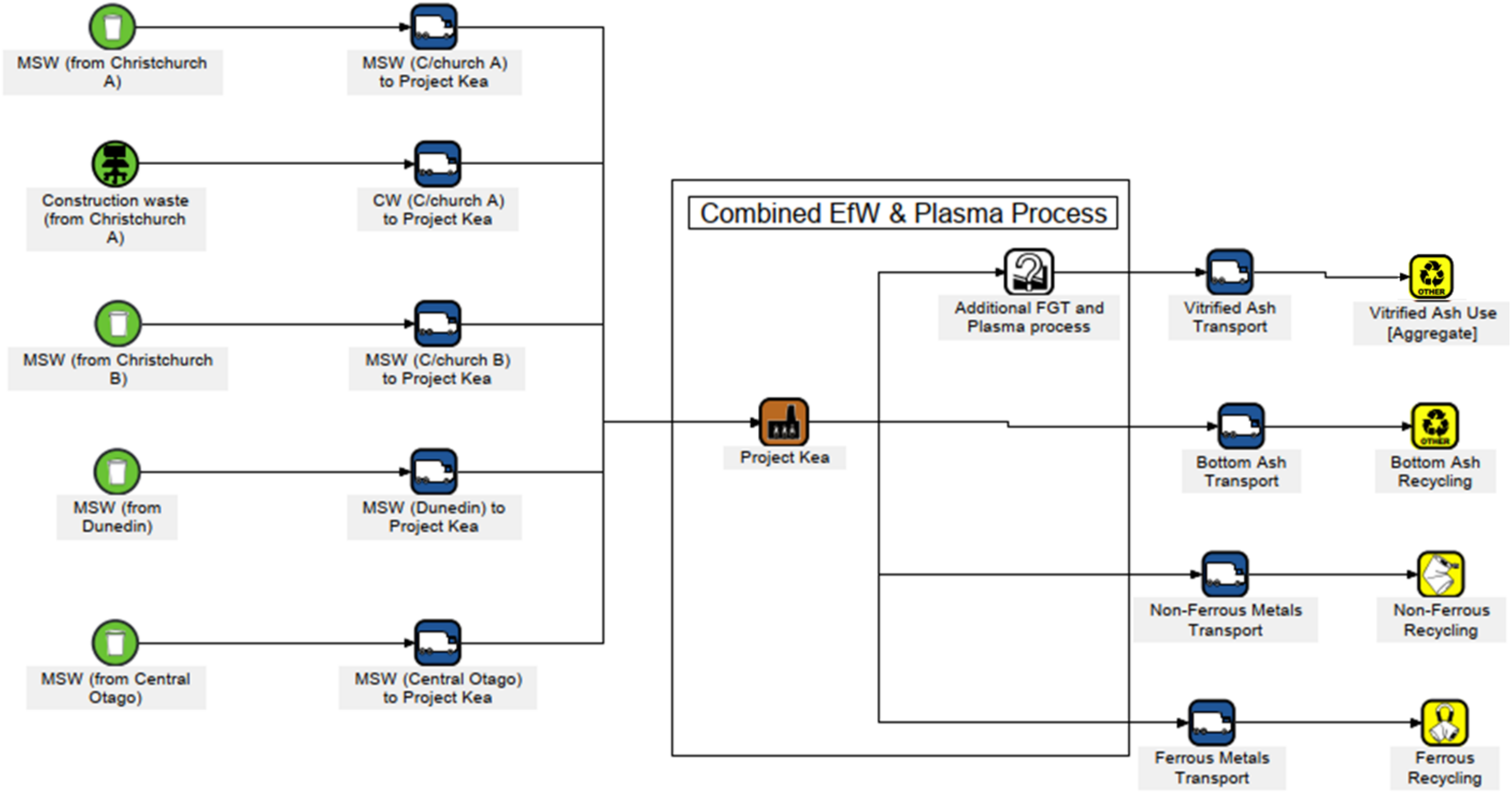
- Scenario 5 – EfW Plant based on an incineration process in an electricity only mode for electricity generation. All waste (both MSW and Construction Waste) would be transported to the EfW facility by road (100%). Both vitrified fly ash and bottom ash (excluding metals recovered at grate) would be disposed in landfill.

3.3.1 Scenario 3

Figure 3 shows a scenario map from WRATE showing the processes adopted for Scenario 3 – EFW Plant.

It is assumed that MSW would be collected from four (4) different sources – Christchurch A, Christchurch B, Dunedin, and Central Otago, while and Construction Waste would be collected from Christchurch A only. EfW Plant would be based on an incineration process in a combined heat and power (CHP) mode for electricity and heat generation. Metals (both ferrous and non-ferrous) would be recovered from the grate, while fly ash would be treated though a plasma process. Both vitrified fly ash and bottom ash (excluding metals recovered at grate) would be recycled as aggregate. All waste streams (both MSW and Construction Waste), and all product streams (i.e., metals, vitrified fly ash and bottom ash) would be transported via road (100%).

Figure 3 Process flow diagram showing key processes used in WRATE for Scenario 3



The characteristic of the incinerator process, adopted in WRATE modelling, is shown in **Table 11**.

Table 11 Incineration unit characteristics for Scenario 3

Process Property	Specification	Comment
Energy Recovery type	CHP	
Heat supplied to	Large Industrial Heat User	Steam exported to a nearby industrial user
Heating fuel to offset	Oil	WRATE does not include coal in the list of heating fuels to offset, hence oil was selected for this LCA study
Gross electrical efficiency	16%	Gross electrical efficiency has been adjusted from 19 % to 16% based on an energy balance undertaken by SLR to account for power consumption of the additional FGT treatment and plasma processes
Heat efficiency	33%	Heat efficiency has been based on an energy balance undertaken by SLR and includes steam supplied to the nearby industrial user, heat use of the additional FGT treatment and plasma processes and condensate return from the industrial user
Flue gas cleaning system	Dry	
Reduction type	SNCR	
Ferrous recovery	80%	Information provided by Babbage
Non -ferrous recovery	50%	Information provided by Babbage

It is noted that gross electrical efficiency and heat efficiency were calculated from the H&M balances assuming 40tph steam export to a nearby industrial user and accounting for electricity usage of the plasma system.

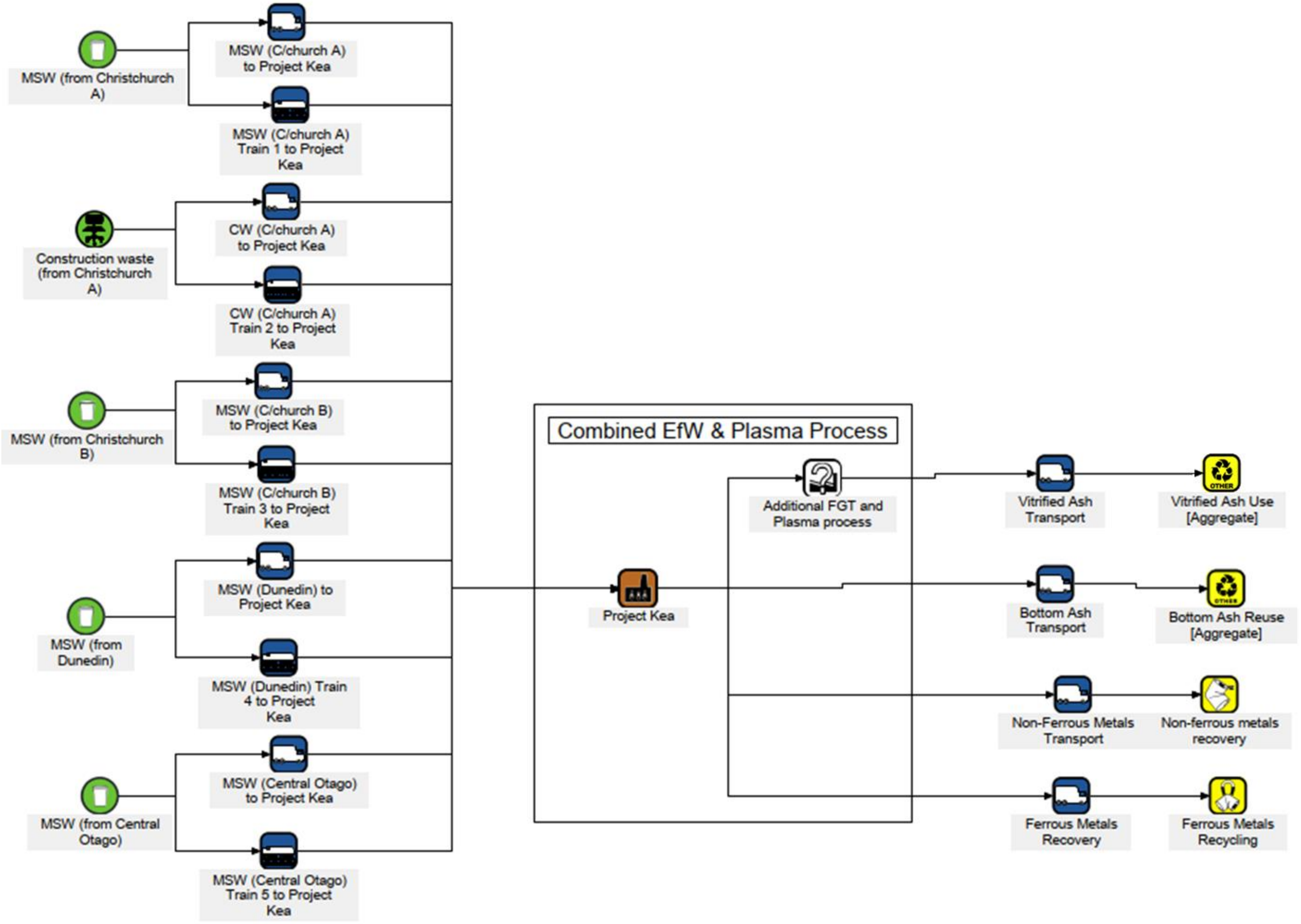
Other technical characteristics (including UDP and transportation characteristics) are similar to the Scenario 2, as described in Section **3.2.5**.

3.3.2 Scenario 4

Figure 4 shows a scenario map from WRATE showing the processes adopted for Scenario 4 – EfW Plant.

It is assumed that MSW would be collected from four (4) different sources – Christchurch A, Christchurch B, Dunedin, and Central Otago, while and Construction Waste would be collected from Christchurch A only. EfW Plant would be based on an incineration process in an electricity only mode for electricity generation. Metals (both ferrous and non-ferrous) would be recovered from the grate, while fly ash would be treated though a plasma process. Both vitrified fly ash and bottom ash (excluding metals recovered at grate) would be recycled as aggregate. All waste (both MSW and Construction Waste) would be transported to the EfW facility by road (50%) and rail (50%), while all product streams (i.e., metals, vitrified fly ash and bottom ash) would be transported via road (100%).

Figure 4 Process flow diagram showing key processes used in WRATE for Scenario 4



The incineration process (including the UDP) is similar to the Scenario 2 configuration, as described in Section **3.2.5**. A summary of other technical characteristics and input data used for this EfW Plant scenario is provided in **Table 12**.

Table 12 Transportation Characteristics for Scenario 4

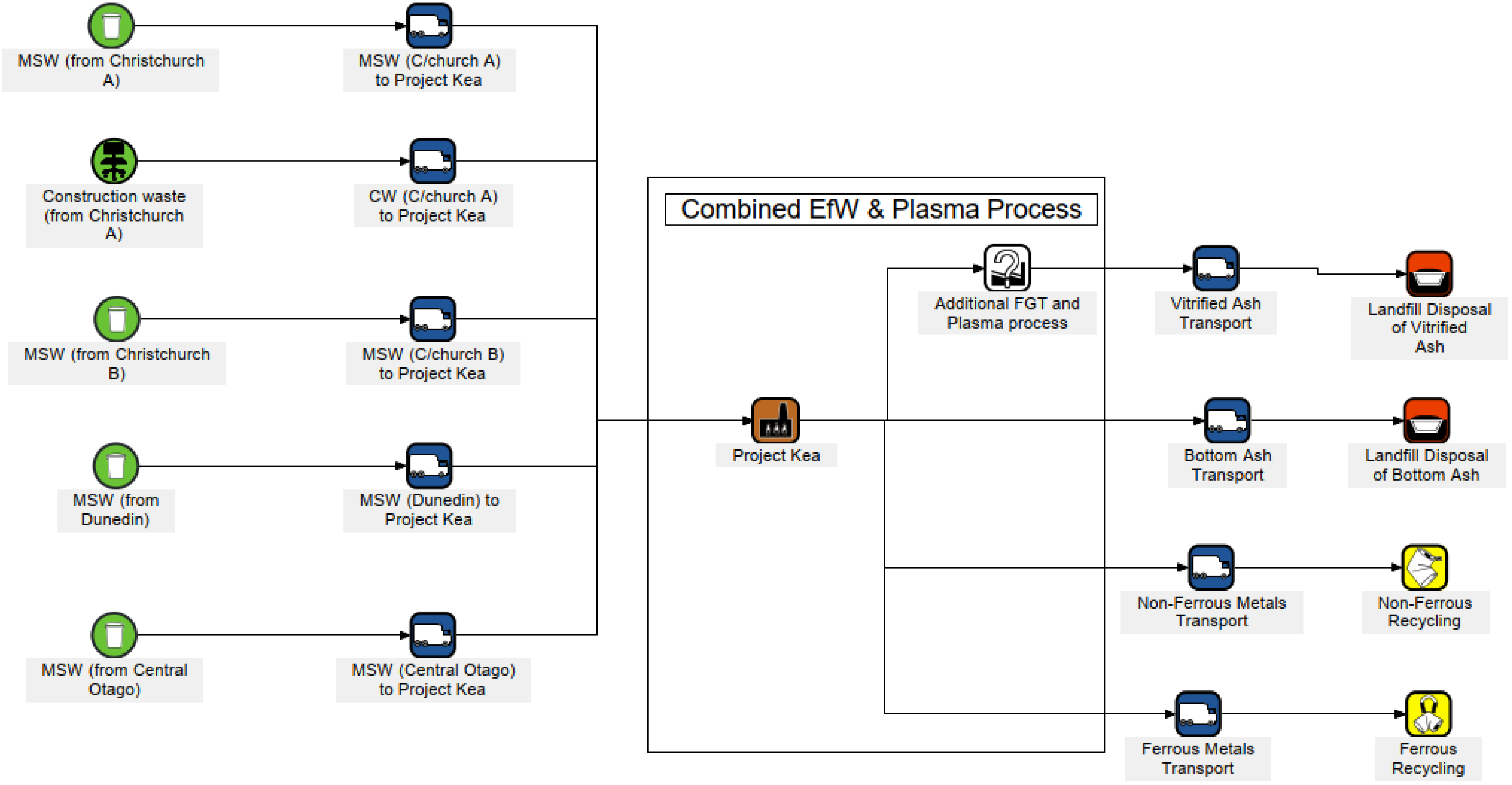
Material Stream	Process Description	Quantity (tpa)	Transport Distance (km/trip)	Reference/Comment
MSW	Transport from Christchurch A to EfW facility by road	13,750	280	Distance based on Babbage assumption
MSW	Transport from Christchurch A to EfW facility by rail	13,750	280	Distance based on Babbage assumption
Construction Waste	Transport from Christchurch A to EfW facility by road	91,250	280	Distance based on Babbage assumption
Construction Waste	Transport from Christchurch A to EfW facility by rail	91,250	280	Distance based on Babbage assumption
MSW	Transport from Christchurch B to EfW facility by road	25,000	289	Distance based on Babbage assumption
MSW	Transport from Christchurch B to EfW facility by rail	25,000	289	Distance based on Babbage assumption
MSW	Transport from Dunedin to EfW facility by road	27,500	176	Distance based on Babbage assumption
MSW	Transport from Dunedin to EfW facility by rail	27,500	176	Distance based on Babbage assumption
MSW	Transport from Central Otago to EfW facility by road	25,000	286	Distance based on Babbage assumption
MSW	Transport from Central Otago to EfW facility by rail	25,000	286	Distance based on Babbage assumption
Metal (ferrous and non-ferrous)	Transport from EfW facility to recycling	WRATE calculated	63	Distance based on Babbage assumption
Bottom ash	Transport from EfW facility to recycling	WRATE calculated	63	Distance based on Babbage assumption
Vitrified fly ash	Transport from EfW facility to recycling	WRATE calculated	63	Distance based on Babbage assumption

3.3.3 Scenario 5

Figure 5 shows a scenario map from WRATE showing the processes adopted for Scenario 5 – EfW Plant.

It is assumed that MSW would be collected from four (4) different sources – Christchurch A, Christchurch B, Dunedin, and Central Otago, while and Construction Waste would be collected from Christchurch A only. EfW Plant would be based on an incineration process in an electricity only mode for electricity generation. Metals (both ferrous and non-ferrous) would be recovered from the grate, while fly ash would be treated though a plasma process. Both vitrified fly ash and bottom ash (excluding metals recovered at grate) would be disposed at landfill. All waste streams (both MSW and Construction Waste), and all product streams (i.e., metals, vitrified fly ash and bottom ash) would be transported via road (100%).

Figure 5 Process flow diagram showing key processes used in WRATE for Scenario 5



Icons presented in the process flow diagram in **Figure 5** are from the WRATE scenario map. Note: WRATE icons with '?' symbol identify processes which are User Defined.

The incineration process (including the UDP) is similar to the Scenario 2, as described in Section **3.2.5**. A summary of other technical characteristics and input data used for this EfW Plant scenario is provided in **Table 13**.

Table 13 Transportation Characteristics for Scenario 5

Material Stream	Process Description	Quantity (tpa)	Transport Distance (km/trip)	Reference/Comment
MSW	Transport from Christchurch A to EfW facility	27,500	280	Distance based on Babbage assumption
Construction Waste	Transport from Christchurch A to EfW facility	182,500	280	Distance based on Babbage assumption
MSW	Transport from Christchurch B to EfW facility	50,000	289	Distance based on Babbage assumption
MSW	Transport from Dunedin to EfW facility	55,000	176	Distance based on Babbage assumption
MSW	Transport from Central Otago to EfW facility	50,000	286	Distance based on Babbage assumption
Metal (ferrous and non-ferrous)	Transport from EfW facility to recycling	WRATE calculated	63	Distance based on Babbage assumption
Bottom ash	Transport from EfW facility to Kate Valley landfill	WRATE calculated	280	Distance based on Babbage assumption
Vitrified fly ash	Transport from EfW facility to Kate Valley landfill	WRATE calculated	280	Distance based on Babbage assumption

Since no details of the landfill, for fly ash and bottom ash disposal, have been provided to SLR, in this LCA study, a LFG capture rate of 90% has been assumed.[5] In regard to landfill characteristics, SLR used best practice landfill characteristics as per the Technical Guidelines for Disposal to Land[6]. **Table 14** shows the key landfill parameters to be adopted for the LCA.

Table 14 Landfill Characteristics for Scenario 5

Landfill name	Assumed landfill
Gas use	Energy Recovery
Gas collection efficiency	90%
Liner type	HDPE
Cap type	Clay

The results from the LCA for these sensitivity scenarios for GWP impact category are presented in the following section.

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[5] Auckland Regional Landfill, Air Quality Assessment, 2019

[6] Technical Guidelines for Disposal to Land, Waste Management Institute New Zealand, 2018

3.4 Data quality assessment

It is understood that the results of a LCA study can be affected by several uncertainties sources, particularly due to methodological choices, initial assumptions, system boundaries and quality of the available data. As a result, in this LCA, sensitivity analysis has been undertaken noting that some data inputs are uncertain.

4 Modelling Results

4.1 Introduction

Results of the LCA modelling are presented and discussed below. In interpreting the result, it is worth remembering that the functional unit for comparison is 365 ktpa total waste managed, and that the environmental impact for each scenario comprises the following contributions:

- **Direct Burdens –** defined as emissions from the process itself,
- **Indirect Burdens –** associated with the supply of energy and materials to the process, for example construction materials, electrical energy for motors and fans, and chemicals for pollution abatement equipment, and
- **Avoided Burdens –** associated with the recovery of energy and materials from the waste stream resulting in the avoidance of primary energy production and mineral extraction.

Since each scenario is based on the same functional unit, it is possible to directly determine the net benefit of a scenario against the baseline/counterfactual.

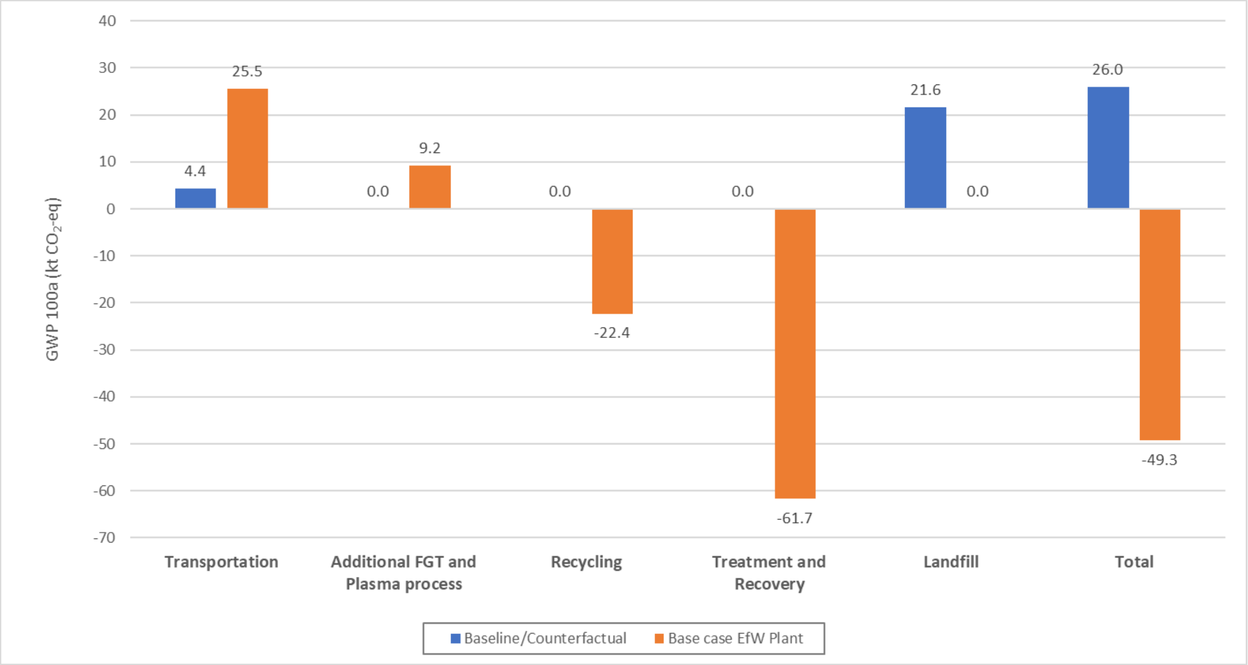
The GWP results are presented as CO_2 equivalent (CO_2-eq), which accounts for the emissions of various greenhouse gases (GHGs), including carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). CO_2 equivalent is a unit of measurement that is used to standardise the climate effects of the various greenhouse gases.

4.2 Results – Comparison of Scenario 1 and Scenario 2

The results presented in this section show a comparison of the Baseline scenario vs the EfW Plant for Global Warming Potential (GWP) impact category. Avoided burdens are shown as negative values and burdens are shown as positive values in the figures providing results from WRATE analysis.

Figure 6 shows results of the WRATE analysis for GWP for the two scenarios assessed in this LCA study: Baseline vs EfW Plant (operating in electricity only mode) for the assessment year 2026.

Figure 6 Comparison of GWP of Baseline vs EfW Plant



Based on the results from WRATE analysis, it is noted that treatment and recovery (i.e., thermal processing and recovery of heat) of MSW and Construction Waste would result in the most significant reduction of carbon impacts (a carbon impact saving of 61.7 kt CO_2-eq), followed by recycling of bottom ash, vitrified fly ash, and metals recovered from the Project (a carbon saving of 22.4 kt CO_2-eq). Carbon impacts from transportation of waste and products, and UDP for additional FGT and plasma process are also significant. Transportation of waste and products, and the UDP would result in the carbon burdens for GWP impact category assessed in this LCA study. Landfill disposal of MSW and Construction Waste would result in a carbon burden in the Baseline (21.6 kt CO_2-eq). This is typically due to the GWP of LFG emissions, particularly methane and carbon dioxide.

Overall, the results from WRATE analysis indicate that development of the EfW Plant for treatment of MSW and Construction Waste would result in a significant reduction in carbon impacts (overall avoided carbon burden of 49.3 kt CO_2-eq) compared to the Baseline scenario (overall carbon burden of 26 kt CO_2-eq). This results in a net avoided burden of the proposed EfW facility of 75.3 kt CO_2-eq (i.e., 26 + 49.3 kt CO_2-eq).

4.3 Sensitivity results

Figure 7 presents the sensitivity results for WRATE analysis of the GWP impact category for the EfW Plant. The results based on the Baseline scenario are also presented for comparison.

Figure 7 Sensitivity results of GWP for all scenarios

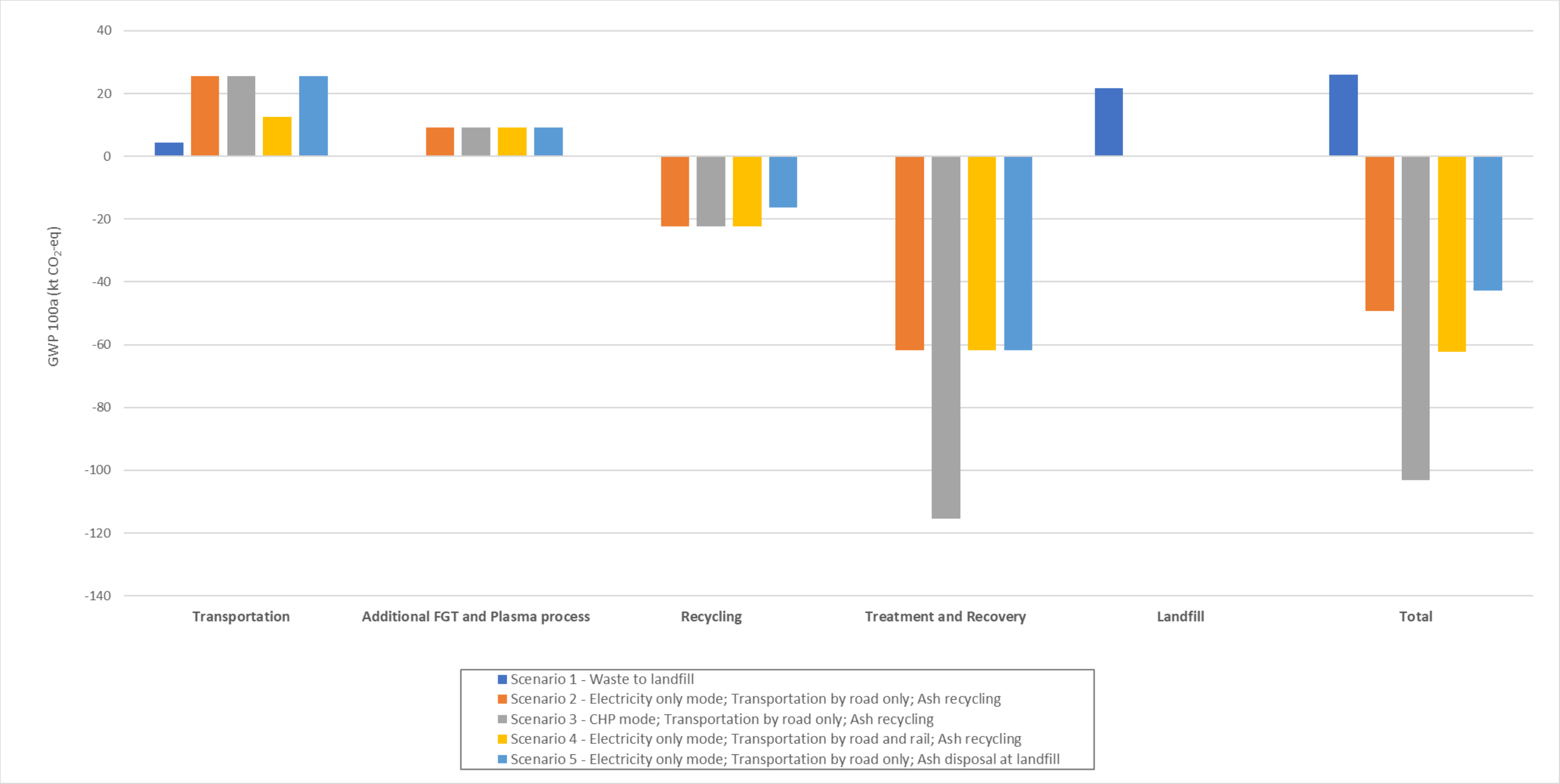


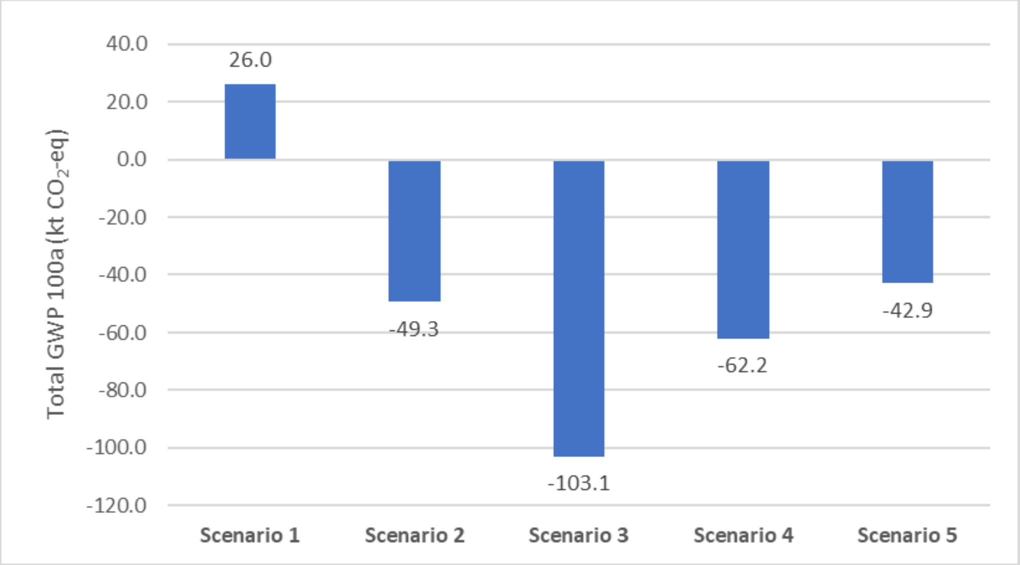
Figure 7 shows that for all the scenarios (i.e., Scenario 2, Scenario 3, Scenario 4, and Scenario 5) the EfW Plant would result in a significant net carbon benefit compared to the Baseline scenario (Scenario 1). Among all EfW scenarios, the EfW Plant with CHP mode (Scenario 3) would result in highest avoided total carbon burden of 103.1 kt CO_2-eq, due to generation and exportation of both steam and electricity to the nearby industrial user. The most prominent difference in avoided carbon burden was observed in the treatment and recovery step (i.e., incineration) of the entire process. This is due to the provision of generating electricity (offsetting fossil-based fuels as noted in the marginal energy mix (refer to Section 3.2.2.1) rather than using electricity from grid.

The results also indicate that transportation of MSW and Construction Waste from sources to the EfW Plant by road and rail (assumed 50%/50% split by mass) would result in reduced carbon burden than transportation by road only (100% by mass), as shown in Scenario 2 and Scenario 4. Ash (both bottom ash and vitrified ash) recycling would result in a reduction in carbon impacts (overall avoided carbon burden of 49.3 kt CO_2-eq in Scenario 2) compared to the ash disposal in landfill (overall avoided carbon burden of 42.9 kt CO_2-eq in Scenario 5); this could be predominantly associated with the recycling of bottom ash.

4.4 Summary of Results

Figure 8 shows a summary of the total LCA burdens from the WRATE analysis of the two principal scenarios and three sensitivity scenarios evaluated (365ktpa of waste input).

Figure 8 Summary of total LCA Burdens (365ktpa of waste input)



The results indicate the following:

- All EfW scenarios would result in significant reduction in carbon impacts compared to the current Baseline scenario – landfill disposal of MSW and Construction Waste.

- Among all scenarios with EfW Plant, highest avoided total carbon burden would be expected in the EfW Plant with CHP mode. It is noted that SIRRL would look to operate the plant in CHP mode subject to identification and agreement of a heat offtake agreement(s). These are often difficult to agree until the EfW is constructed and operational; therefore, the facility may commence construction as electricity mode only and be transitioned to CHP mode, which would deliver carbon improvements.
- Transportation of MSW and Construction Waste from sources to the EfW Plant by road (50% by mass) and rail (50% by mass) would result in reduced carbon burden than transportation only by road (100% mass). SIRRL's preference to maximise rail movement is subjected to technical and financial viability assessments.
- Ash (both bottom ash and vitrified ash) recycling would result in a significant reduction in carbon impacts compared to the ash disposal in landfill. The majority of the carbon benefits are associated with recycling of bottom ash. Overall, recycling of the bottom ash and vitrified ash delivers improvements against landfill.

5 Life cycle interpretation

5.1 Interpretation of LCA results

Section 4 presents results from the WRATE analysis of the principal and sensitivity scenarios assessed (365 ktpa of waste input). These results from WRATE analysis of the GWP impact category, as summarised in **Figure 8**, indicate that the EfW Plant operated in either CHP or electricity only mode would be preferable (most preferably CHP mode) to the current management method of landfill disposal for MSW and Construction Waste. The results also indicate the following:

- Treatment and recovery (i.e., thermal processing and recovery of heat) of waste would result in most significant avoided burdens for the GWP impact category assessed, followed by recycling of recovered materials due to the avoided burdens that would result from the use of primary raw materials.
- Transportation of waste and products, and the additional FGT and plasma process would result in the carbon burdens for GWP impact category assessed in this LCA study.
- Transportation by road (50% of waste by mass) and rail (50% of waste by mass) would result in reduced carbon burden than transportation only by road (100% of waste by mass).
- Recycling of ash would result in a significant reduction in carbon impacts compared to the disposal of ash in landfill (this is predominantly associated with the benefits of recovering metals from the bottom ash).
- Energy recovery at the EfW Plant via steam and electricity export to the nearby industrial user would result in avoided burdens associated with oil-generated steam and grid electricity requirements for GWP impact category assessed.
- Processing MSW and Construction Waste at the EfW Plant would reduce/diminish the volume of waste disposed to landfill hence environmental benefits from thermal treatment of waste would result from avoided burdens associated with landfill disposal for GWP impact category assessed.

Based on these results from the assessment of the global warming potential impact category, it is concluded that the proposed EfW Plant would deliver significant environmental benefits for the global warming potential impact category compared to the baseline scenario.

5.2 Study Limitations

This study has been undertaken based on design data provided by Babbage. While design development can result in potential changes to the proposed operating conditions, the results of this LCA may not always reflect the actual operating conditions of the EfW Plant. As a result, the LCA can be updated using actual operating data following commissioning and annual operating data once the plant becomes operational.

As noted in **Section 3.2.5**, the WRATE tool for the development of a 'Flexible EfW Process' can only model either SCR or SNCR (not both) for NO_X reduction, and either wet or dry (not both) for flue gas treatment. Additionally, no plasma process is included in WRATE. Hence, for the proposed EfW configuration for Project Kea, SLR used a combination of the 'Flexible EfW Process' and an additional user defined process. Moreover, WRATE can only model natural gas and oil (or mixed) as heating fuels to offset. Due to this particular limitation of the WRATE model, SLR adopted oil as the offset fuel, instead of coal as a heating fuel to offset. Furthermore, as discussed in Section **3.2.5.3**, 'Processed Materials' (i.e., APCR) cannot be recycled in WRATE. In order to allow WRATE to run the results, a landfill process has been selected for vitrified fly ash management, with manual adjustment to the results undertaken outside of the WRATE model to reflect the proposal for vitrified ash recycling.

6 Critical Review

The results of the LCA would be communicated to third parties. According to ISO 14044, if the results of the LCA are to be shared or communicated with any third party other than the commissioner of the LCA study, then a third-party report shall be prepared, and a critical review of the report would be required.

The critical review of the LCA study would need to be conducted by a LCA practitioner. Based on a request from Babbage, SLR commissioned Frith Resource Management as the LCA practitioner to undertake the peer review of the LCA report. The peer review was done by Muaaz Wright-Syed as lead author and Paul Frith as reviewer from Frith Resource Management.

According to the critical review, the LCA study has been carried out to industry standard, in-line with ISO14044:2006, and in a scientifically rigorous and objectively justifiable manner. The modelling was all conducted appropriately and well explained in the report. There was no comment identified in the review.

The peer view report by Frith Resource Management is presented in **Appendix A**.

7 Conclusions

This report presents the LCA for two principal scenarios and three sensitivity scenarios assessing the current and proposed management of 365ktpa of waste. Modelling has been carried out using the UK Environment Agency's life cycle assessment tool WRATE. The modelled scenarios are as follows:

- Scenario 1 – Baseline/Counterfactual (baseline waste management and landfill disposal of MSW and Construction Waste).
- Scenario 2 – EfW Plant based on an incineration process in an electricity only mode for electricity generation. All waste (both MSW and Construction Waste) would be transported to the EfW facility by road (100%). Both vitrified fly ash and bottom ash (excluding metals recovered at grate) would be recycled as aggregate.
- Scenario 3 – EfW Plant based on an incineration process in a combined heat and power mode for electricity and heat generation. All waste (both MSW and Construction Waste) would be transported to the EfW facility by road (100%). Both vitrified fly ash and bottom ash (excluding metals recovered at grate) would be recycled as aggregate.
- Scenario 4 – EfW Plant based on an incineration process an electricity only mode for electricity generation. All waste (both MSW and Construction Waste) would be transported to the EfW facility by road (50%) and rail (50%). Both vitrified fly ash and bottom ash (excluding metals recovered at grate) would be recycled as aggregate.
- Scenario 5 – EfW Plant based on an incineration process in an electricity only mode for electricity generation. All waste (both MSW and Construction Waste) would be transported to the EfW facility by road (100%). Both vitrified fly ash and bottom ash (excluding metals recovered at grate) would be disposed in landfill.

The results of the WRATE modelling demonstrate the following:

- approval of the resource consent application and therefore the processing and recovery of 365ktpa of MSW and Construction Waste at the EfW Plant would deliver overall environmental benefits for GWP impact category assessed over the current management method (baseline scenario) which involves landfill disposal of MSW and Construction Waste.
- among all scenarios with EfW Plant, highest avoided total carbon burden would be expected in the EfW Plant with CHP mode, however all electricity only mode scenarios deliver GWP benefits. For the EfW Plant CHP mode scenario (Scenario 3), additional environmental benefits are as a result of recycling of material recovered at the facility, avoided burdens through diversion of MSW and Construction Waste from landfill and avoided burdens through recovery of energy at the EfW Plant – offsetting existing oil generated steam and grid electricity requirements at the facility.
- the results show that treatment and recovery of energy (i.e., incineration) has a significant benefit on all EfW scenarios considered.
- sensitivity analysis has shown how the net environmental benefit would be higher should the transportation includes both road and rail (instead of road only).

- ash recycling has significant carbon benefit compared to the ash disposal in landfill, predominantly resulting from recycling from the bottom ash.

- treatment of MSW and Construction Waste at the EfW Plant would contribute to the generation of additional renewable energy in the form of heat (if the plant is operated in CHP mode) and electricity for a nearby industrial user, thus utilising domestic resources to produce energy for local demand and increasing energy security.

On this basis, it is concluded that the EfW Plant with electricity only mode would deliver significant environmental benefits over landfill disposal based on the global warming potential impact category assessed, with a net avoided carbon burden of 75.3 kt CO_2-eq (i.e., 26 + 49.3 kt CO_2-eq). If the facility is operated in CHP mode, the carbon impact benefits would be even greater, with a net avoided burden of 129.1 kt CO_2-eq (i.e., 26 + 103.1 kt CO_2-eq).

8 Feedback

At SLR, we are committed to delivering professional quality service to our clients. We are constantly looking for ways to improve the quality of our deliverables and our service to our clients. Client feedback is a valuable tool in helping us prioritise services and resources according to our client needs.

To achieve this, your feedback on the team's performance, deliverables and service are valuable and SLR welcome all feedback via https://www.slrconsulting.com/en/feedback. We recognise the value of your time and we will make a $10 donation to our 2022 Charity Partner – Lifeline, for every completed form.

Appendix A

Peer Review Report

FRITH
RESOURCE
MANAGEMENT

PROJECT KEA - LIFE CYCLE ASSESSMENT - PEER REVIEW REPORT

August 2022

Acknowledgements:

Frith Resource Management would like to thank the essential contributions from colleagues at SLR, Babbage Consultants, and South Island Resource Recovery Limited (SIRRL), namely Bithi Roy, Neville Tawona and Chani Lokuge.

Disclaimer:

Frith Resource Management Ltd (FRM) is an independent waste and resource management consultancy providing advice in accordance with the project brief. FRM has taken all reasonable care and diligence in the preparation of this report to ensure that all facts and analysis presented are as accurate as possible within the scope of the project. However no guarantee is provided in respect of the information presented, and FRM is not responsible for decisions or actions taken on the basis of the content of this report.

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File name: 20220823 Review Report v0.3 F

Contents

1 Introduction

Frith Resource Management Ltd (FRM) were tasked with providing an expert peer review for a life-cycle analysis study carried out by SLR Consulting (SLR) for Babbage Consultants (Babbage) who are leading the consenting process for Project KEA. FRM has delivered WRATE assessments for a range of treatment processes and waste collection arrangements to support due diligence assessments, procurements and options appraisals. Clients include local authorities, consultancies and waste management contractors. Our capability statement for carbon modelling is attached for reference (Appendix A). Example WRATE projects have included:

- Assessment for a prospective EfW in Glasgow
- Assessment for Hay Hall gasification development and the Port Clarence EfW
- Review of WRATE analysis on a pyrolysis process treating waste plastics
- Assessment of different food and garden waste collection and treatment systems for central Government (Defra) in the UK
- Carbon evaluation of tenders for residual household waste treatment (various Councils)

The Life Cycle Assessment (LCA) peer reviewed within this report supports the regulatory assessment process to enable the construction and operation of New Zealand's first large scale Energy from Waste (EfW) project in South Canterbury (Project KEA) by South Island Resource Recovery Limited (SIRRL). For a detailed understanding of this project and the study itself, the reader is referred to the 'LIFE CYCLE ASSESSMENT FOR PROJECT KEA' Report prepared by SLR.

1.1 Review Process and Workflow

In the first instance, all the information and assumptions used to construct the original WRATE model, along with the actual WRATE model (as a .lca file) were requested from SLR. The information received comprised of a spreadsheet containing relevant calculations and inputs for the WRATE model (particularly regarding the user defined processes within the EfW plant and overall energy balance), .lca file for the model itself, and the current draft of the 'LIFE CYCLE ASSESSMENT FOR PROJECT KEA' Report prepared by SLR for Babbage. As specified in the proposal and correspondence with SLR, this verification and review was carried out in accordance with ISO 14044:2006 (see below for an extract for the document). The document was consulted throughout the review process to ensure compliance with the standard.

The information received was carefully reviewed, the references and calculations were checked accordingly and traced back to original sources for verification. The .lca file was also explored in detail, testing out various parts of the model and checking input data, modifications of background allocation tables and ensuring the outputs were being generated correctly. Particular attention was paid to checking the user defined process as part of the EfW plant, which models bespoke treatment processes for gas and solid waste products. The assumptions highlighted in the main report and the spreadsheet were carefully examined to ensure they were scientifically rigorous, justifiable, and suitable for the KEA EfW Plant.

ISO14044:2006: "The critical review process shall ensure that the methods used to carry out the LCA are consistent with this International Standard, the methods used to carry out the LCA are scientifically and technically valid, the data used are appropriate and reasonable in relation to the goal of the study, the interpretations reflect the limitations identified and the goal of the study, and the study report is transparent and consistent."

2 Detailed Reviewer Feedback

The methods used to carry out the LCA are consistent with ISO14044:2006, whereby the goal and scope are outlined and defined clearly. Moreover, the System boundary, Functional Unit and Reference System are also defined clearly. The inventory used and the processes used are described clearly, and where required, the modifications made to parts of the models (e.g., User Defined Processes for Selective Non-catalytic Reduction – SNCR, Selective Catalytic Reduction – SCR and Plasma Treatment - PT) have been outlined clearly and accompanied with calculations and supporting references, as well as mass balance diagrams and schematics of key areas of the plant. Similarly, the impact categories and data quality criteria are included within the report as well. In accordance with ISO14044:2006, benefits of the KEA Facility (relative to the baseline) are specified and highlighted clearly by reporting the results of the LCA individually without agglomerating various impact categories into a single overall score or number.

2.1 Assumptions & Methodology

The assumptions provided regarding the indicative composition of the input wastes, and the energy mix (baseline and marginal) are sufficiently justified and referenced. Where background allocation tables for various WRATE processes have been modified, these have been based on client data. Furthermore, checking these data within the .lca WRATE file indicate that these modifications have been made correctly (and referenced appropriately in the appendices and main text).

KEA EfW plant workflows and supporting calculations provided (from the appendices), step-wise process efficiencies and average transport distances are based on client data, and have been justified and referenced appropriately in the report.

2.1.1 Transfer Stations & Intermediate Facilities

Transfer stations and intermediate facilities for the delivery of waste to the treatment / disposal process are not present in any of the WRATE models. The MSW waste stream is thought to be collected directly from the kerbside and sent to the landfill (Baseline) or EfW plant so there are no transfer station and/or intermediate facilities for that waste stream to be considered, only the transport of waste from the source to the final disposal location.

Construction waste (previously referred to as Commercial) is expected to arrive at the landfill and/or EfW after passing through a transfer station where recyclables will be extracted, with the residual waste being transported to the final disposal location. As such, for Construction Waste, transport from the source to the transfer station, and associated transfer station operation, was considered outside the boundary of the LCA, as it is common to both the baseline and alternative EfW scenarios.

This approach is scientifically justifiable and omission of intermediate facilities and transfer stations from all the modelling work is considered to be a reasonable choice.

2.2 WRATE .lca Model

The main changes from defaults in the WRATE model are summarized below:

- Flexible EfW Plant – Gross electrical efficiency has been adjusted from 26% to 24% to account for power consumption of the additional FGT treatment and plasma processes. Ferrous recovery and non-ferrous recovery are set at 80% and 50% respectively (for Scenario 2 – base case for EfW). These are reasonable levels of metals recovery.

- User-Defined Process (SNCR, SCR & PT) – SNCR, SCR & PT processes are modelled and coupled with WRATE's flexible EfW module. The mass-balance and energy requirements are modelled based on client data and key information is present in the report appendices, whilst the design of the UDP and step-by-step calculations were provided by SLR.

- Energy mixes from New Zealand's Ministry of Business, Innovation & Employment (current and forecasted) are justified, referenced and adjusted appropriately and input into the model correctly.

2.2.1 Baseline – Scenario 1

Data inputs into the model have been carried out correctly.

The landfill used for final disposal is a 'modern' landfill (WRATE ID No. 11255), this is a flexible landfill model with a modified efficiency of landfill gas recovery (90% is selected). This degree of performance of the landfills is high, but justifiable, as these are considered 'modern' landfills, and the efficiency is also based on SLR's industry experience. It also represents a conservative assumption in terms of the landfill comparator, which offers for a more robust comparison in carbon terms due to the high efficiency of gas capture. Other key design features (e.g., cap + liner are both made of clay) are also appropriately modelled.

2.2.2 Alternative Scenarios

Scenarios 2,3,4 and 5 all include the same EfW element (the flexible EfW module + UDP for advanced treatment of by-products and waste). In scenario 2 there is only electricity generation at the EfW plant (24% efficiency), whereas in 3, there is combined heat and power generation at 33% and 16% efficiencies respectively. It is noted that for setting the efficiency at the EfW plant for these scenarios, accompanying energy balance calculations have been provided by SLR and take into account all the necessary inputs outputs and usage/losses within the system (including the UDP). This is carried out to a good standard with all the key data provided by the client and used and input correctly into the calculations supplied. Due to the additional treatment processes taking place within the UDP module of the models, the efficiencies for these scenarios could be considered slightly lower than wide-spread practice.

For scenarios 4 and 5, the key changes revolve around use of rail for transport of part of the input tonnage (50%), and use of landfill for disposal of fly ash and bottom ash, instead of being recycled.

2.2.3 User-Defined Process (UDP) Characteristics

The UDP process was created by SLR as KEA features what could be considered relatively unique combinations of technologies. These unique combinations include the use of both SNCR and SCR for NOx removal, the use of dry injection, semi-dry and wet scrubbing systems in the flue gas treatment (FGT) train as well as the use of Plasma Treatment (PT) process for fly ash management.

"Project KEA Energy Balance + UDP Characteristics" spreadsheet clearly outlines not only the step-by-step process and decision-making behind the UDP, it also provides details of the calculations for each of the UDP steps (SCR, FGT and PT). The input data for the UDP has been provided in the appendices in the main report and referenced appropriately.

Energy consumption for PT is quite high, and it would be beneficial to highlight the advantage of on-site PT of the fly ash within the main report to provide some context (e.g., regulatory requirement[1]).

2.2.4 Test runs with a Standard Flexible EfW Plant & Vitrified Fly Ash Impacts Adjustment

To check the UDP as well as the main components of the model (e.g., EfW), we isolated these aspects and copied over the models to run them separately to test that the EfW and UDP processes were working correctly together. This was indeed the case.

For vitrified fly ash, as WRATE does not have a module to recycle flyash into aggregate, this has been carried out outside WRATE by adjusting the raw LCA results by using IBA recycling to aggregate as an example. This approach is appropriate due to the limitations within WRATE regarding flyash recycling and treatment. The results used for this calculation and the step-by-step process of adjusting the results (explained within the supplied spreadsheet) has been checked and was done correctly.

2.3 Results and Implications

It is noted that the results quoted within the main report and data supplied were checked, tested and are reproducible using the latest version of the WRATE model. The results, data and assumptions were presented and discussed within the report appropriately and in a scientifically rigorous manner, noting the minor comments raised in this report.

3 Concluding Remarks

A WRATE LCA model for the proposed EfW plant has been reviewed. The main report, input data, background data, and associated references have been reviewed and detailed feedback has been provided. As part of the feedback, some potential comments have been proposed, where appropriate, and detailed checks on the .lca file have been carried out.

In summary, it is established that the WRATE LCA study reviewed within this report has been carried out to industry standard, in-line with ISO14044:2006, and in a scientifically rigorous and objectively justifiable manner.

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[1] A waste to energy guide for New Zealand: https://environment.govt.nz/assets/Publications/Files/waste-to-energy-guide-for-new-zealand.pdf

4 Appendix A

FRITH RESOURCE MANAGEMENT

MANAGING CARBON & ACHIEVING NET-ZERO

Carbon Assessment

- We **assess** and explore options for **minimising** the **carbon impacts** of Council services.
- We apply **specialist** models (e.g. Kerbside Analysis Tool (KAT) for collection modelling, Waste and Resources Assessment Tool for the Environment (WRATE) for environmental impacts of waste management activities) to provide **detailed, bespoke and accurate accounting of carbon emissions**.
- We also offer **Scope 1, 2 and 3** (e.g. transportation-related) carbon assessments. We utilise appropriate emission factors to **calculate the resulting footprint** and present findings graphically and clearly.

Cutting-Edge Research

- Our team possesses a **strong track-record** in state-of-the-art **academic** and applied **research**.
- We were commissioned by the **International Solid Waste Association (ISWA)** for research into sustainable & alternative waste collection vehicles and fuels.
- We supported **Department for Environment, Food and Rural Affairs (Defra)** in an evaluation of the carbon impact of waste treatment processes.
- We have made **valuable contributions** to provide an **evidence base for Government policy** and **advancement of waste management research** which has been **published** in peer-reviewed academic journals and, **cited globally** by our peers working in this field. An example is provided **here.**

*"Frith RM combined their **excellent technical knowledge** and **thoroughly professional approach** with a friendly down to earth manner. First draft documents were **very high quality**, responses to queries were **swift** and the final product was **comprehensive** yet easy to understand. That is quite an achievement for such a specialist area of work".*

Norfolk County Council – Carbon Assessment for Residual Waste Procurement

FRM was incorporated in 2008 and specialises in waste and resource management consultancy. We give advice, modelling support and expertise through our team of Chartered Engineers, Environmentalists, Logisticians and Waste Managers who support or lead on waste and environmental projects.

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