Life Cycle Assessment of the ACT Container Deposit Scheme

UNDERTAKEN BY LIFECYCLES FOR EXCHANGE FOR CHANGE

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Version 1.1

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1 Introduction

1.1 Context

The ACT Container Deposit Scheme (CDS) is a litter reduction initiative that was introduced by the ACT Government in 2018 and coordinated by Exchange for Change. Participants collect and return their empty drink containers at return points across Canberra for a 10 cent refund on each item. The CDS provides consumers with multiple ways to participate across Canberra, with 19 return points available for eligible items to be exchanged for money. There are four types of return points, which are:

- **Drop & Go Pods**
  Unstaffed self-service drop-off locations. Users log in to their account on a touch screen, follow the prompts to fill out a barcode label for each bag of drink containers and place it in the pod chute.
- **Drop & Go Points**
  Similar to Drop & Go Pods, but points are staffed.
- **Cash-back Depots**
  Staffed location with automated counting systems. Users place containers into the automated counting machine. The machine counts the containers and gives the user a ticket which can be used to claim the refund.
- **Reverse Vending Machine (RVM)**
  Self-service machine. Users scan a QR code and feed the containers into the appropriate chute. Electronic refunds are received automatically.

This life cycle assessment (LCA) aims to establish a robust baseline for the environmental benefits of diverting recyclable waste from becoming pollution or landfill. This information will then be used to develop a tool for consumers to estimate the impact of their actions in the hope it will motivate greater participation in the program.

1.2 Life cycle assessment

Life Cycle Assessment (LCA) is a methodology used for assessing the environmental impacts from 'cradle-to-grave' of products and processes. This is achieved by calculating the impact of material flows at each stage of the system, both upstream and downstream. LCA aims to include all important environmental impacts of the product system being studied, in doing so, an LCA seeks to avoid shifting impacts from one life cycle stage to another by including as much of the system as possible. The assessment is undertaken using the framework, principles and specific requirements defined by both the ISO 14040:2006 and ISO14044:2006 standards (International Organization for Standardization 2006).

The general structure of the LCA framework is shown in Figure 1, illustrating the multiple stages of an assessment and the interactions with other stages. The **first** stage in the LCA framework is to define the goal and scope of the study, which describes the reasons for the LCA, outlining the scenarios, boundaries and indicators that are going to be used. The **second** stage is the inventory analysis which aims to build a model of the production system involved in each scenario and describes how each stage of the production process interacts with the environment. The **third** stage of the LCA is the impact assessment in which an inventory of the data is shown against the key indicators used to produce an environmental profile of each scenario. The **final** stage is the interpretation where analyses of the results is provided in addition to a systematic review of the assumptions are made to ensure robust and transparent results.

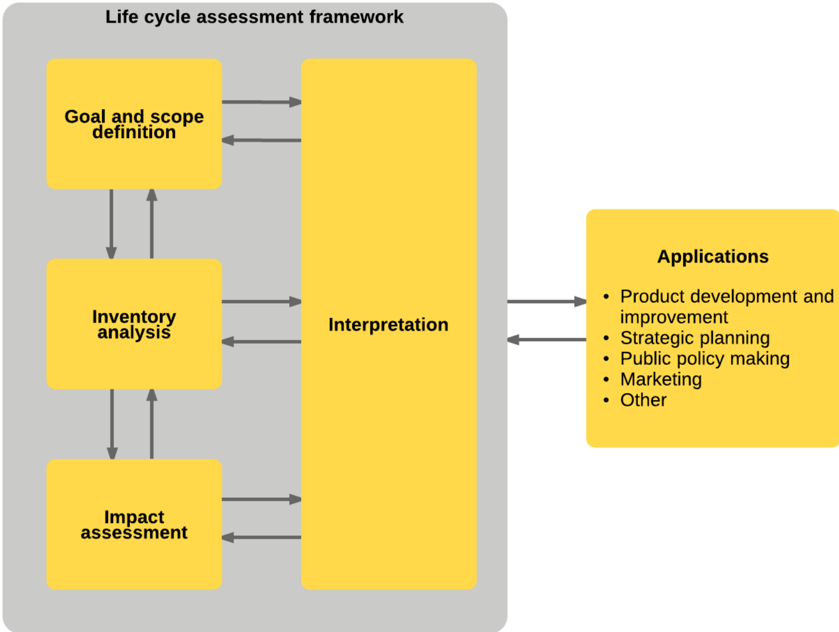

Figure 1 Framework for life cycle assessment

Life Cycle Assessment tries to measure the exchange between human activity, the *'technosphere'*, and the natural world, the *'biosphere'*. This occurs either through the extraction of natural resources or via the emissions of pollutants to the air, water and ground. The measurement is undertaken at the level of the system that is being analysed, which is then further broken down into a series of unit processes that lead to the delivery of the functional unit. The functional unit is ultimately the basis upon which the system surrounds, as defined in the ensuing goal and scope section.

A single unit process is illustrated in Figure 2 which includes the flows to and from the *'biosphere'* as well as flows to and from the *'technosphere'*.

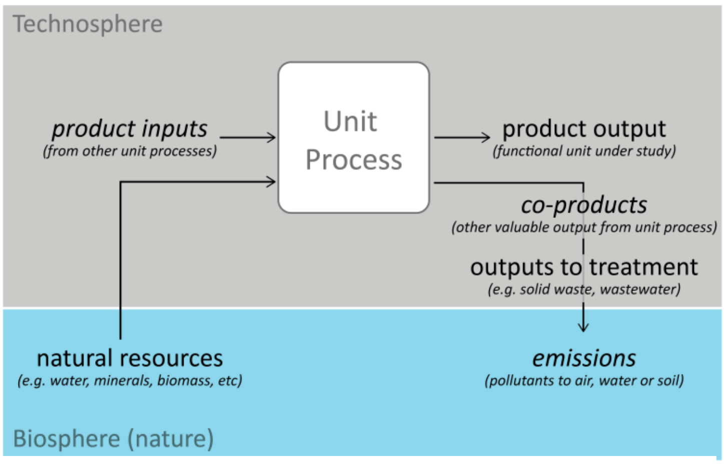

Figure 2 Inputs and outputs of a unit process in LCA.

Unit processes are linked to create a system that produces the functional unit of the study, as illustrated in Figure 3. They can be categorised into foreground unit processes and background unit processes.

Foreground processes are those for which specific data is collected for the study. This includes primary data collected from facilities, secondary data from published papers and modified background processes from existing LCA databases.

Background processes are those for which data are typically sourced from pre-existing databases. The background data are either less important to the study outcomes or are already well-characterised in the existing data sets and therefore do not warrant specific modelling. In some instances, background unit processes may be modified to better reflect the conditions of the study.

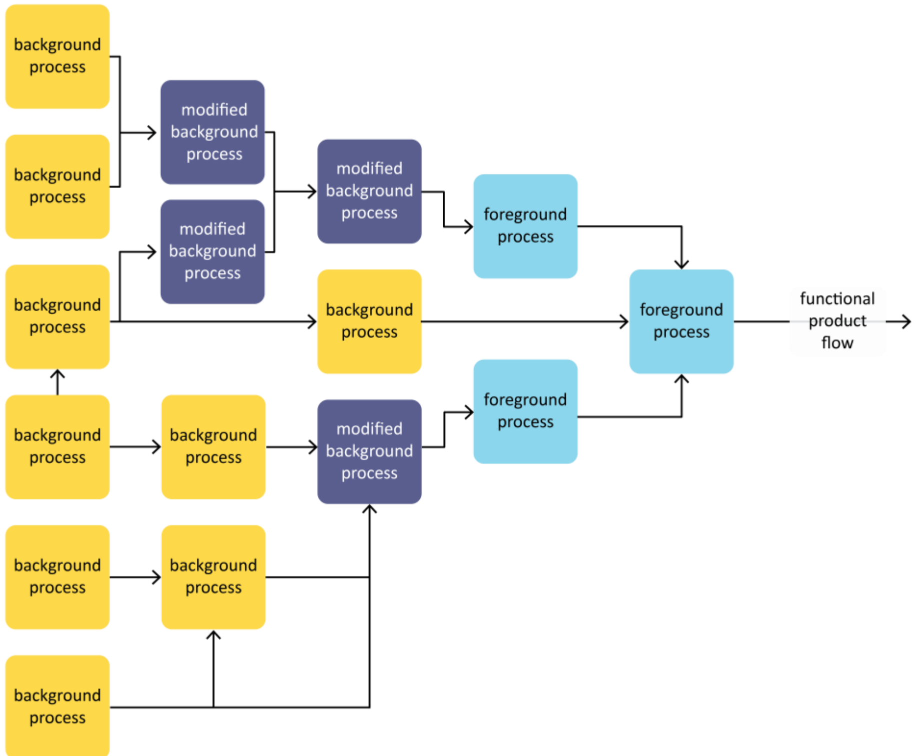

Figure 3 Linking unit processes in an LCA to produce the functional unit.

1 Goal and scope

1.1 Reason for the study

The goal of this LCA is to establish a robust baseline life cycle assessment (LCA) of the ACT Container Deposit Scheme. The baseline will be used to assess potential strategies for improving the implementation of the scheme as well as for further expansion. In addition, the results of the LCA will be used as a basis for the development of a metric system that can be used to demonstrate the associated benefits of the program.

1.2 Intended audience

The audience for the report will be the Exchange for Change organisation which operates the program on behalf of the ACT Government. The environmental impact factors produced in this report will be used to assist in the development of an interactive online tool for estimating the individual consumer benefits of participating in the scheme, as well as for the external marketing and communication of the program. Consequently, the results of this study will be disclosed to the public and represent a comparative assertion.

1.3 Calculation approach

In this LCA, the environmental savings of recycling activities are calculated and connected to individual actions of participants of the container deposit scheme (CDS) in the ACT. This LCA is not a marginal analysis of the benefits of CDS over kerbside recycling schemes nor an assessment of the preference for any packaging material. The environmental benefits are calculated as those flowing directly from the actions of scheme participants without measuring any counter-factual consequences of recycling via kerbside, littering or landfilling of the packaging.

The results from the study are being used to describe to consumers what the outcome is when they recycle their containers through the CDS scheme without reference to what else could be done with the container (a zero baseline). With this in mind all activities modelled start from the point where the consumer decides to participate in the CDS scheme, and relate only to activities of the scheme and the impacts and benefits derived from that point forward.

The environmental benefit of the recycling as part of the container deposit scheme is calculated by first determining the impacts of the scheme collection process and downstream processing of recyclables; and then subtracting the avoided impacts of making these materials using virgin materials feedstocks and processes.

1.4 Functional unit

The functional unit is the basis for comparison of alternatives in LCA. It describes the service delivered by the processes being studied. In this study, the service is the management of beverage containers from the ACT Container Deposit Scheme.

The functional unit is defined as:

"The management of 1000 beverage containers returned through the ACT CDS scheme."

1.5 System boundaries, included and excluded processes

The system boundary describes the process steps included in the LCA. Figure 4 shows the system boundary of this study.

The system boundary includes:

- Depositing of eligible containers at one of the collection points.
- Plastic bags and labels at Drop & Go Points and Pods
- Electricity consumption at drop-off points
- Transportation of the containers from drop-off points to the cash-back depots; from the depots to the material recovery facility (MRF), and from there to the recycler.
- Recycling process to produce secondary materials
- Displacement of virgin material supply chain

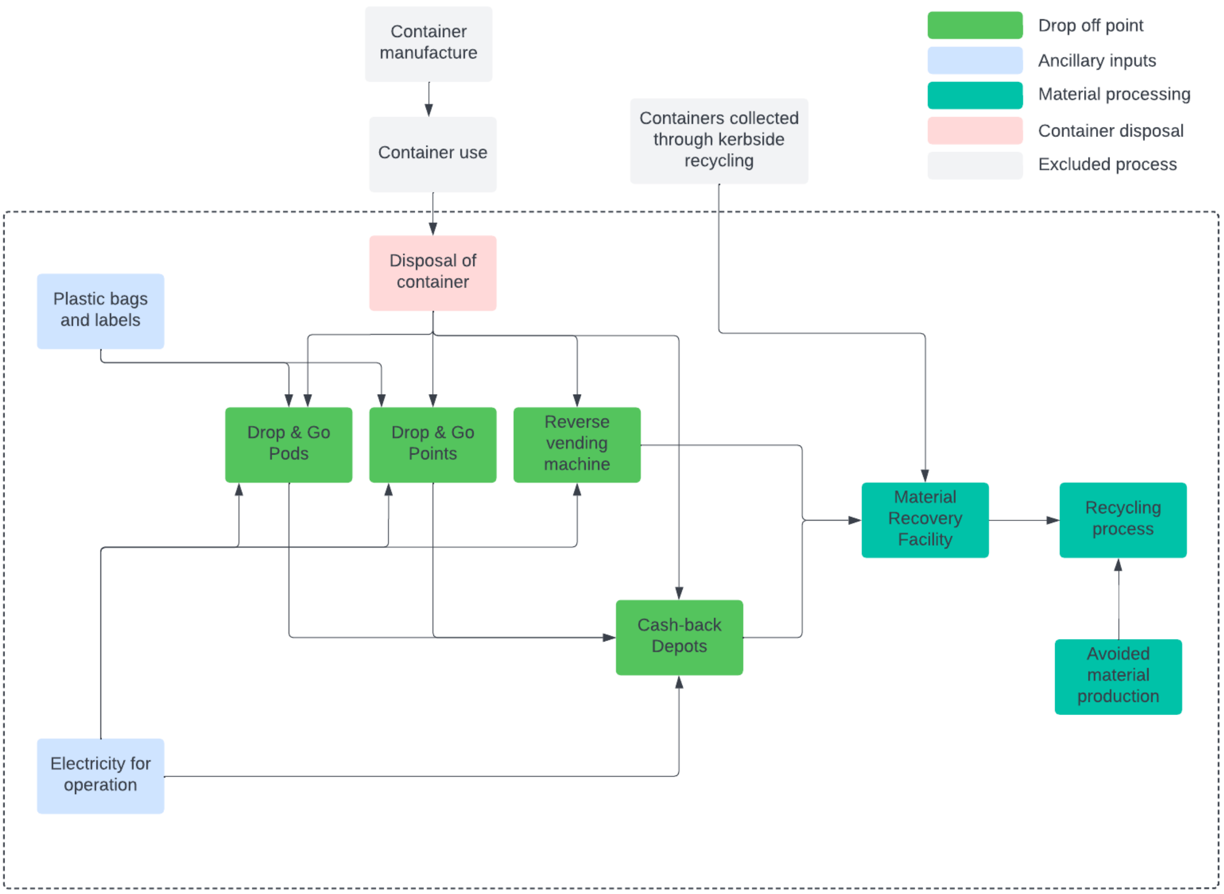

Figure 4 Container deposit system boundary schematic

For this study, the alternative fate of the containers was not considered. While certain activities such as kerbside recycling, littering, and landfill are likely be avoided through the implementation of the ACT CDS, their displacement is not included.

Any excluded flows must fall below the cut-off threshold for this study (below 1% of any impact category included in the LCA). No flows were deliberately excluded due to this threshold, however particularly minor inputs expected to be well below this threshold were not considered. Infrastructure associated with drop-off points such as signage, bins, concrete pads etc was not included as they would be long-lasting and therefore below the cut-off threshold.

1.6 Allocation procedures

Multi-functionality occurs when a single process, or group of processes, produces more than one usable output, or 'co-product'. ISO (International Organization for Standardization 2006) defines a co-product as 'any of two or more products coming from the same unit process or product system'. A product is any good or service, with value for the user. This is distinct from a 'waste', which ISO defines as 'substances or objects which the holder intends or is required to dispose of', and therefore has no value to the user.

In this LCA the main allocation issue relates to the allocation of the recycling credit between the product system which generates the container and the product system which utilises the recycled material as secondary material input.

The GHG protocol for product carbon footprints (Bhatia, Cummis et al. 2011) suggest two options for dealing with recycling credits. The first (for strong recycling markets) is the 0/100 method which provides 100% of the credit to the recycling at the end of a product life. The second is the 100/0 method where 100% of the benefit of recycling is applied to the secondary product and this is for weak recycling markets where new products made from recycled content need to be specified.

The most common drink container materials (glass, PET and aluminium) are all considered as strong recycling markets in the ACT therefore we have applied the 0/100 method. This also fits the premise of the study which is to calculate the benefits derived from the operation of the CDS scheme.

1.7 Data quality requirements

Data quality was assessed for all input data to the LCA and ranked in terms of its fitness for purpose.

The key data quality criteria for the study are:

- Reliability
- Time-related coverage
- Geographical coverage
- Technology coverage

The indicators of data quality are shown in Table 1 for each of the criteria. All major data points in the LCA above 5% net contribution to climate change impacts will be assessed according to these criteria.

Table 1 Data quality assessment framework.

	Poor	Fair	Good	Very good
Reliability	Non-qualified estimate	Qualified estimate	Modelled data	Primary measured data
Time-related coverage	From past production >10 years old	From past production >5 years old and less than 10 years old	From past production >2 years old and less than 5years old	From current production data <2years old
Geographical coverage	From distinctly dissimilar region	From global average	From similar region	From region of interest
Technology coverage	From old or dissimilar technology	Generic technology average	From technology specific to region	From actual technology used

1.8 Impact assessment categories and characterisation models

The impact assessment stage relates the inventory flows to the indicators chosen for the LCA. This is done by classifying which flows relate to each impact category and then selecting a characterisation model that quantifies the relationship of each inventory type to the indicator in question. The calculation of the category indicator results is the sum of all inventory flows multiplied by their relevant characterisation factors. The list of indicators considered in summarised in Table 2.

Table 2 Impact assessment categories and characterisation models retained in this LCA

Indicator	Description	Characterisation model
Climate change	Measured in kg of carbon dioxide equivalence. This is governed by the increased concentration of gases in the atmosphere that trap heat and lead to increasing global temperatures. These gases are principally carbon dioxide, methane and nitrous oxide.	IPCC model based on 100-year timeframe
Particulate matter	Measure in grams of $PM_{2.5}$. This impact category looks at the respiratory health impacts from particulate matter for PM_{10} and $PM_{2.5}$. This is one of the most dominant immediate risks to human health as identified in the global burden of disease.	TRACI V2.1
Water volume	Measured as litres of water consumed.	Water consumption only, no characterisation applied
Fossil fuel depletion	Measured in MJ of Net Calorific Value (NCV) This impact category measures the amount of the quantification of the specific energy of combustion for fossil fuels.	CML-IA V4.8

The reason these indicators were selected was due to relatability of the impact categories to a generalised audience with assumed minimal understanding of environmental science. The indicators needed to be familiar enough for the results to be relatable for all levels of comprehension. This is why Climate Change and Fossil Fuel depletion were both chosen despite being correlated impacts. Mineral resource depletion may have provided a more comprehensive LCA examination, but as the purpose of this study is to communicate the benefits of secondary resource recovery through recycling energy consumption is a more tangible analogy for a diverse audience with unknown levels of education. Water volume has been used instead of water scarcity as the latter is less tangible for consumers to understand in a simple online calculator.

1.9 Critical review

An independent critical review of the study was undertaken by Blue Environment and the critical review statement is provided in Appendix B.

1.10 Data requirements

To ensure that the results produced by this LCA are of a reputable standard, the quality of the input data must be of sufficient standard. The data used must be the most recent and relevant as possible. This LCA is focused on the collection and processing of resources within the Australian Capital Territory, therefore, where possible specific regional data for the state should be used, and where unavailable, sourced from other regions within mainland Australia. Any inputs related to technology must be within the relevant timeframe of the container deposit scheme. Data which has been sourced externally must be consistent and representative with sources clearly referenced for reproducibility.

2 Life cycle inventory

While hundreds of background processes contribute to the analysis, the most important processes are described here, particularly those affecting the results or those that have been modified from the original source to better represent the inputs to this assessment. Initial data was supplied by the ACT CDS regarding collection totals broken down by material type and drop-off location, as well as an outline of deposit locations. Google Maps was used to estimate transportation distances across the Territory.

2.1 Data on container numbers and distributions

Initial data for the assessment was provided by Exchange for Change which had been collated throughout the entirety of the container deposit scheme. This included 29 drop-off points, the aggregated data for which are summarised in Table 3 and Table 4. The full data set is provided in Appendix A.

Table 3 Breakdown of collections by return point types (FY2018 – FY2021)

Return Point Type	Total
Cash Back Depot	128,387,462
Drop & Go POD	14,516,279
Drop & Go POINT	23,093,546
RVM	94,288
Total	**166,091,575**

Table 4 Breakdown of materials in collections (FY 2018 – FY 2021)

Total Collection Volume	Percentage (number of containers)
Aluminium	49%
Glass	25%
HDPE	1%
Liquid Paper Board	3%
PET	21%
Steel	<1%

2.3 Assumptions on containers and drop-off points

Assumptions are an essential part of LCA in circumstances where data has not been supplied or specific information is unable to be obtained. Assumptions are used to fill in the data gaps in order to produce the most complete model possible. Table 5 sets out the assumptions which have been made during this LCA and are considered to have some minimal influence on the outcome of the study. Assumptions can be easily adjusted in the model if more information becomes available or if any changes are made to the scope of the assessment.

Table 5 List of modelling assumptions

Item	Assumption	Input	Source
Aluminium can	Mass	14.9g	Reference.com (2020)
Glass bottle	Mass	227g	Saxco (2020)
HDPE bottle	Mass	60g	Rice (2015)
PET bottle	Mass	9.9g	PETRA (2021)
Liquid paperboard carton	Mass	28.6g	Schlecht and Wellenreuther (2020)
Steel container	Mass	37.5g	Exchange for change
Average mass of container	Mass	68.9g	Author assumption, based on distribution of different container types
Reverse Vending Machine	Units	1	Exchange for Change
Drop & Go Points	Units	18	Exchange for Change
Drop & Go Pods	Units	6	Exchange for Change
Cash-back depots	Units	4	Exchange for Change
RVM energy consumption	Energy	275 kWh/month	Based on power data provided by Exchange for Change. Assumed 12hrs/day in standby mode, 6hrs/day using one lane, and 6hrs/day using both lanes.
Drop & Go Point energy consumption	Energy	106 kWh/month	Exchange for Change. Per Drop & Go Point
Drop & Go Pod energy consumption	Energy	27 kWh/month	Exchange for Change. Per Drop & Go Pod
Fyshwick Cash-back Depot energy consumption	Energy	7,780 kWh/month	Exchange for Change
Mitchell Cash-back Depot energy consumption	Energy	2,631 kWh/month	Exchange for Change
Phillip Cash-back Depot energy consumption	Energy	1,000 kWh/month	Exchange for Change
Belconnen Cash-back Depot energy consumption	Energy	2,127 kWh/month	Exchange for Change
Plastic bag weight (for Drop & Go Points and Pods)	Mass	25g	Author assumption. Assumed 0.1% of mass is made up of label. Assumed 1 bag typically used for 40 containers

2.1 Assumptions on transport

There are multiple transport legs included in the system boundary. Containers are first dropped off by customers at the collection points. Containers dropped off at Drop & Go Points and Pods get transported to cash-back depots. The choice of cash-back depot depends on current capacity and may not be the closest depot to the collection point. It was assumed that 40% of these containers were taken to the nearest cash-back depot, with the remaining 60% distributed evenly among the remaining cash-back depots. All containers are then taken to the MRF, where they are separated, and then on to the recycler. Transport distance assumptions are shown below in Table 6.

Table 6 Transport assumptions

Item	Assumption	Input	Source
Drop-off transport distance to shopping centres and IGAs	Distance	0km	Assumed no extra travel for dropping containers at shopping centres and IGAs
Drop-off transport distance to other drop-off locations	Distance	5km	Assumed 5km travel diversion to drop off containers at locations that are not shopping centres or IGAs
Transport distance, drop-off point to cash-back depot	Distance	Various	Transport distances between each drop-off location and each cash-back depot were measured using Google Maps
Transport distance, cash-back depot to MRF	Distance	Various	Transport distances between each cash-back depot and the MRF were measured using Google Maps
Transport distance, MRF to recycler	Distance	290km	Assumed recycler in Sydney location
Transport Truck	Size	16-28t, fleet average	Author assumption

2.2 Recycling inventory data

The following tables outline the inventory data used for the recycling processes in the LCA.

Table 7 to Table 12 outline the inventory processes which are based on recycling inventories originally published in James, Grant et al. (2003) and Grant, James et al. (2001) with some minor modifications to suit the CDS collection and processing.   Background data were sourced from AusLCI version 1.34 (ALCAS 2021) – identified with "/AU U" suffix or from EcoInvent version 3.7 recycling cut-off version (Weidema, Bauer et al. 2019) identified with "| Cut-off, U" suffix

Table 7 Inventory data for recycling of PET containers, per tonne

Process	Item	Amount	Unit	Comment
Recycling PET (per tonne)				
Avoided product	Polyethylene terephthalate, granulate, bottle grade [RoW]| production | Cut-off, U	0.9	t	Assuming 90% recovery of PET from bottle mass deposited.
Materials/fuels	Tap water, at user, New South Wales/AU U	31.25	t	Based on 16 tonne of PET using 1000 KL of hot water per day. 50% reuse
	Sodium hydroxide, without water, in 50% solution state [GLO]market for | Cut-off, U	2.5	kg	Based on 2% caustic (pers comm Visy plastics) for hot wash process. (range given as 1.2 to 2.3)
	transport, truck, 16 to 28t, fleet average/AU U	290	tkm	Assumed to be reprocessed in Sydney
Electricity/heat	Natural gas, combusted, New South Wales Metro, NGA values/AU U	8.6701	MJ	Water heating, based on natural gas hot water system
	electricity, low voltage, Australian/AU U	1	kWh	shredding- from (Idemat 1996) 1KWh per tonne
	electricity, low voltage, Australian/AU U	3	kWh	One tonne per hour on conveyor 3KWh per Hour
	electricity, low voltage, Australian/AU U	20	kWh	course milling (12mm particles) from Idemat 1996 20KWh per tonne
	electricity, low voltage, Australian/AU U	3.6	kWh	fine milling (4mm particles) - from Idemat 1996 3.6KWh per tonne
	electricity, low voltage, Australian/AU U	0.36	kWh	separation in fluid tank -, from Idemat 1996 0.36KWh per tonne
	electricity, low voltage, Australian/AU U	4.5	kWh	water separation in spin drier - from Idemat 1996 4.5 kWh per tonne
	natural gas, burned in <30MW wall fired boiler /AU U	2.2	GJ	Drying - from Idemat 1996 2,2 GJ/ tonne
	electricity, low voltage, Australian/AU U	10.8	kWh	Bailer 12KWh per tonne 0.9t
	electricity, low voltage, Australian/AU U	746	kWh	Extrusion of PET, 746 kWh per tonne from Swiss data on PE (Buwal 250)
Emissions to water	Suspended solids, unspecified	1520	g	876mg/l (Visy Plastics 2000)
	Suspended solids, unspecified	972	g	560mg/l (Visy Plastics 2000)
	Sulfur, total oxidised	8.68	g	5mg/l (Visy Plastics 2000)
	Nitrogen, total	20.8	g	12mg/l (Visy Plastics 2000)
Waste and emissions	wastewater treatment, New South Wales/AU U	9.1	l	

Table 8 Inventory data for recycling of aluminium containers, per tonne

Recycling Aluminium (per tonne)				
Avoided products	Aluminium, primary, ingot [UN-OCEANIA] | production | Cut-off, U	0.95	t	Clean quality of aluminium is assumed to result in high yield of aluminium.
Materials/fuels	transport, truck, 28t, fleet average/AU U	290	tkm	Transport to reprocessor
	Transport, freight, sea, transoceanic ship [GLO]market for | Cut-off, U	9658	tkm	Transport of scrap to reprocessing in China
	Aluminium, wrought alloy [RER}|] treatment of aluminium scrap, post-consumer, prepared for recycling, at remelter | Cut-off, U	1	t	Ecoinvent process for processing aluminium scrap

Table 9 Inventory data for recycling of steel cans, per tonne

Recycling Steel (per tonne)				
Avoided products	pig iron {RoW}| pig iron production | Cut-off, S	0.91	t	Losses occur
Materials/fuels	transport, truck, 28t, fleet average/AU U	290	tkm	Transport to reprocessor
	Steel/tinplate shred and detinning	0.23	t	25 % of .95kg of tinplate delivered is detinned prior to use in Blast Furnace
	Steel/tinplate shredding	0.72	t	75 % of of .95kg of tinplate delivered is detinned prior to use in Blast Furnace

Table 10 Inventory data for recycling of glass containers, per tonne

Recycling Glass (per tonne)				
Avoided products	Glass batch without cullet, GLO	0.95	t	
	natural gas, burned in <30MW wall fired boiler /AU U	0.735	GJ	Based on assumption of 2.5% energy savings per 10% of cullet. Current usage approximately 50%. Glass gas energy usage
Materials/fuels	diesel, burned in building machine, <30 MW /AU U	10.18	MJ	Front end loader, 0.02 of an hour 509 MJ per hour
	electricity, low voltage, Australian/AU U	0.5	kWh	Conveyor 3kW - 10 minutes
	electricity, low voltage, Australian/AU U	0.25	kWh	Glass breaker. Estimated from equipment specifications 2 Hp - 1.49 kW - 10 minutes
	electricity, low voltage, Australian/AU U	0.5	kWh	Magnetic separator 3KW - 10 minutes
	electricity, low voltage, Australian/AU U	0.5	kWh	Trommel screen 3KW - 10 minutes Nishtala 1997
	transport, truck, 40t load/AU U	290	tkm	Cullet transport
Final waste flows	Waste, unspecified	0.02	t	2% of incoming material classified as waste sent to landfill.

Table 11 Inventory data for recycling of liquid packaging board containers, per tonne

Recycling Liquid Packaging Board (per tonne)				
Avoided products	Paper, woodfree, coated [RoW] market for | Cut-off, U	750	kg	Lower fibre recovery due to lamination.
Electricity/heat	Graphic paper, 100% recycled [RoW] production | Cut-off, U	1000	kg	
Materials/fuels	transport, truck, 40t load/AU U	290	tkm	
Waste and emissions	waste treatment, inert waste, at landfill/AU U	200	kg	
	waste treatment, mixed paper, at landfill/AU U	50	kg	

Table 12 Inventory data for recycling of HDPE containers, per tonne

Recycling HDPE (per tonne)				
Avoided products	high density polyethylene, average, at plant/AU U	0.87	t	
Materials/Fuels	transport, truck, 28t, 10 tonne load	290	tkm	Transport to processor. Lighter load truck assumed
Materials/Fuels	tap water, at user, New South Wales/AU U	6.7	t	
	Sodium hydroxide, without water, in 50% solution state [GLO]market for | Cut-off, U	2.5	kg	Based on 2% caustic (pers comm visy plastics) for hot wash process (range given as 1.2 to 2.3).
	natural gas, combusted, New South Wales Metro, NGA values/AU U	1.86	MJ	Water heating, based on natural gas hot water system
Electricity/heat	electricity, low voltage, Australian/AU U	1	kWh	shredding- from(Idemat 1996) 1KWh per tonne
	electricity, low voltage, Australian/AU U	3	kWh	One tonne per hour on conveyor 3KWh per Hour
	electricity, low voltage, Australian/AU U	20	kWh	course milling (12mm particles) from Idemat 1996 20KWh per tonne
	electricity, low voltage, Australian/AU U	3.6	kWh	fine milling (4mm particles) - from Idemat 1996 3.6KWh per tonne
	electricity, low voltage, Australian/AU U	0.36	kWh	separation in fluid tank -, from Idemat 1996 0.36KWh per tonne
	electricity, low voltage, Australian/AU U	4.5	kWh	water separation in spin drier - from Idemat 1996 4.5 KWh per tonne
	natural gas, burned in <30MW wall fired boiler /AU U	2.2	GJ	Drying - from Idemat 1996 2,2 GJ/ tonne
	electricity, low voltage, Australian/AU U	140	kWh	746 KWh per tonne from swiss data on PE (Buwal 250)
Emissions to water	Suspended solids, unspecified	1520	g	876mg/l (Visy Plastics 2000)
	Suspended solids, unspecified	972	g	560mg/l (Visy Plastics 2000)
	Sulfur, total oxidised	8.68	g	5mg/l (Visy Plastics 2000)
	Nitrogen, total	20.8	g	12mg/l (Visy Plastics 2000)
Waste and emissions	wastewater treatment, New South Wales/AU U	9.1	l	
Final waste flows	Waste, unspecified	0.13	t	

3 Impact assessment results

The impact assessment stage relates the inventory flows to the indicators chosen for the LCA. This is done by classifying which flows relate to which impact indicator and then selecting a characterisation model that quantifies the relationship of each inventory type to the indicator in question.

The impact assessment results are presented in Table 13. The results show that recycling 1000 containers through the ACT CDS causes net environmental benefits in all impact categories assessed. For the results presented in this section, a negative value indicates an environmental saving, i.e. the recycling of 1000 containers through the ACT CDS saves 145 kgCO2-eq.

In Section 4.1, the results are further investigated using a contribution analysis to investigate the sources of impacts and savings for each impact category.

Table 13 Benefits for 1000 containers recycled through ACT CDS

Impact category	Per 1000 Containers	Unit
Climate Change	-145	kg CO2 eq
Fossil fuel depletion	-1,551	MJ NCV
Water volume	-6,686	L
Particulate matter	-85	g PM2.5

The LCIA results produced by this study are relative expressions and therefore do not predict impacts on category endpoints, nor the exceeding of thresholds and safety margins or risks.

3.1 Limitations and opportunities for improvement

The limitations of this assessment relate to the use of background and literature data to represent production processes when primary data is unavailable. The details of the limitations are provided below:

- Collection and transportation procedures across the Territory.
- Various assumptions made regarding the masses of containers.
- Consumer return behaviour (e.g. Distance travelled to deposit, number of items returned, frequency of trips, etc.).

The variable masses and composition of containers on the market make definitive impact assessments difficult as the sorting process is limited by this diversity. As the containers for this scheme require intact barcodes to assess their eligibility, a potential avenue for improving the accuracy of the LCA would be to keep a registry of exact products in order to generate an improved model. However, whether this extra information would have a significant influence on the overall impacts across the categories is unlikely as care was taken to ensure the most complete dataset available was utilised.

4 Interpretation

The interpretation step examines the results through a series of analyses and checks to better understand the results of the LCA, and to ensure any conclusions drawn from the LCA are robust and well supported by the data. The interpretation stage is divided in two sections:

- a contribution analysis, which is used to assess the relative contribution of each life cycle stage to the overall result
- a series of sensitivity analyses, which are used to increase the robustness of conclusions from the LCA and provide further insights into the observed environmental impacts.

4.1 Contribution analysis

For the contribution analysis, the environmental impacts and benefits are broken down into the following categories: consumer transport, CDS transport, CDS electricity and plastic bags, recycling processes, avoided virgin aluminium, avoided virgin PET, avoided virgin glass, and avoided other. Environmental impacts are shown in yellow, while enviornmental savings are shown in navy. The overall net result is shown in red.

The climate change contribution analysis is shown in Figure 5. The results show that the main benefit of the recycling is due to the avoided production of virgin aluminium. When the aluminium cans are recycled, demand for virgin aluminium decreases and the high-energy processes required for aluminium smelting are avoided. The majority of the increases in impacts is driven by the electricity and plastic bags used at collection points, and the recycling process itself, though the overall net result shows a clear climate change benefit.

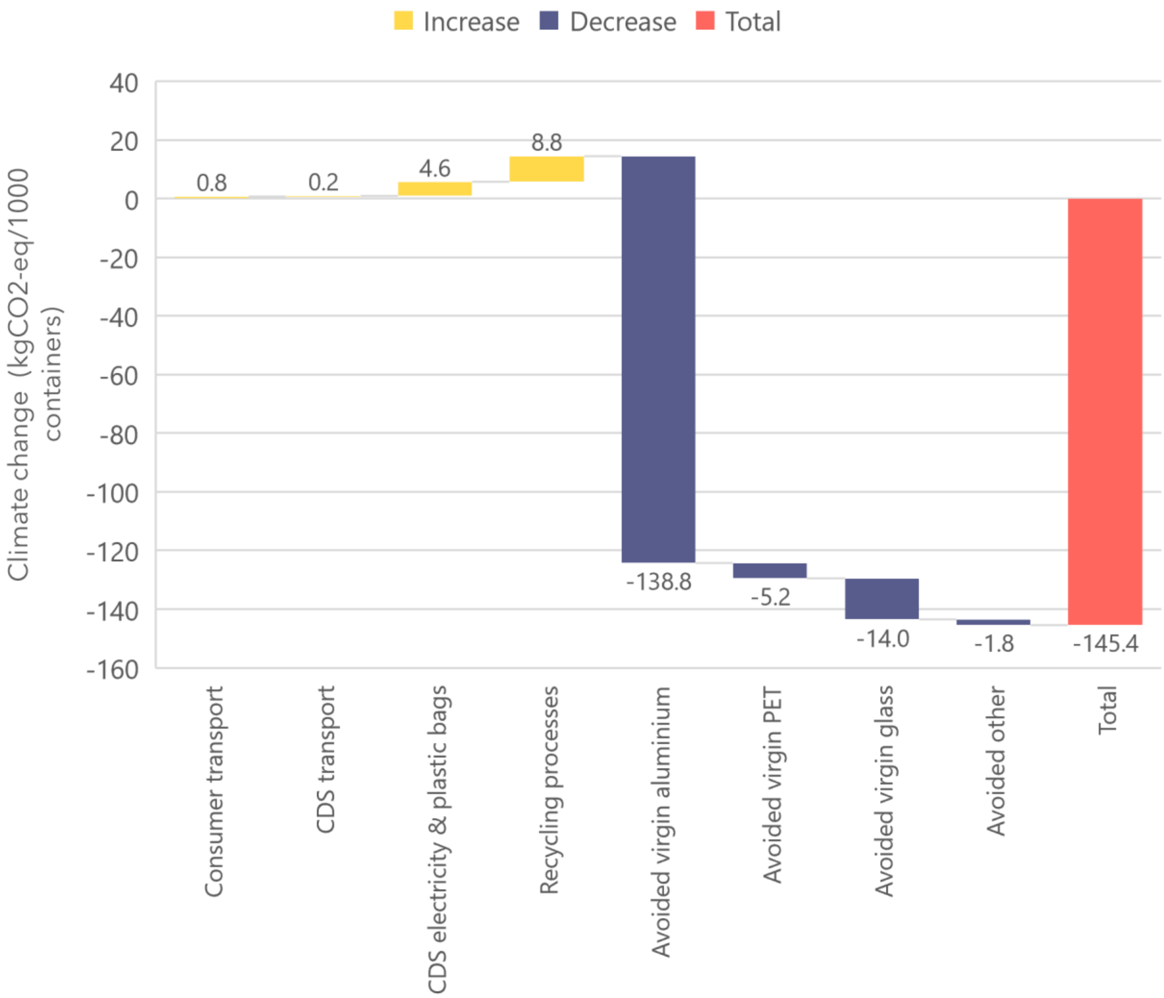

Figure 5 Contribution analysis - Climate change, per 1000 containers

Figure 6 shows the fossil fuel depletion is very similar to the climate change impacts with the high savings resulting from the avoidance of aluminium primary production.

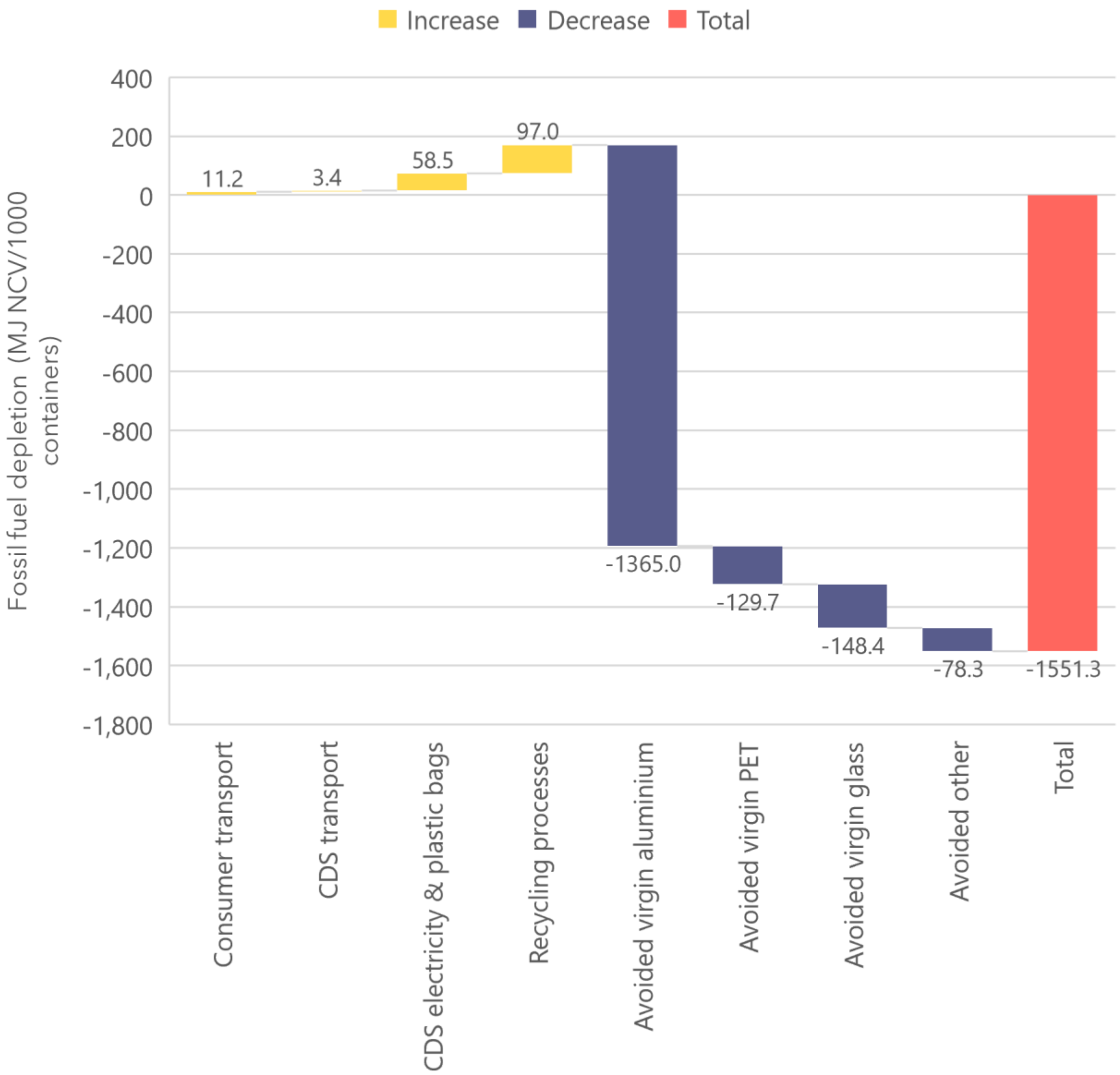

Figure 6 Contribution analysis – fossil fuel depletion, per 1000 containers

Figure 7 shows the direct water use impacts resulting from the CDS. Again, avoided glass and aluminium production is the main source of water use saving. For aluminium, the water use is in the transformation of alumina from bauxite as well as the required energy generation. For glass, the production of soda ash and washing sand add to the water impacts of the virgin materials.

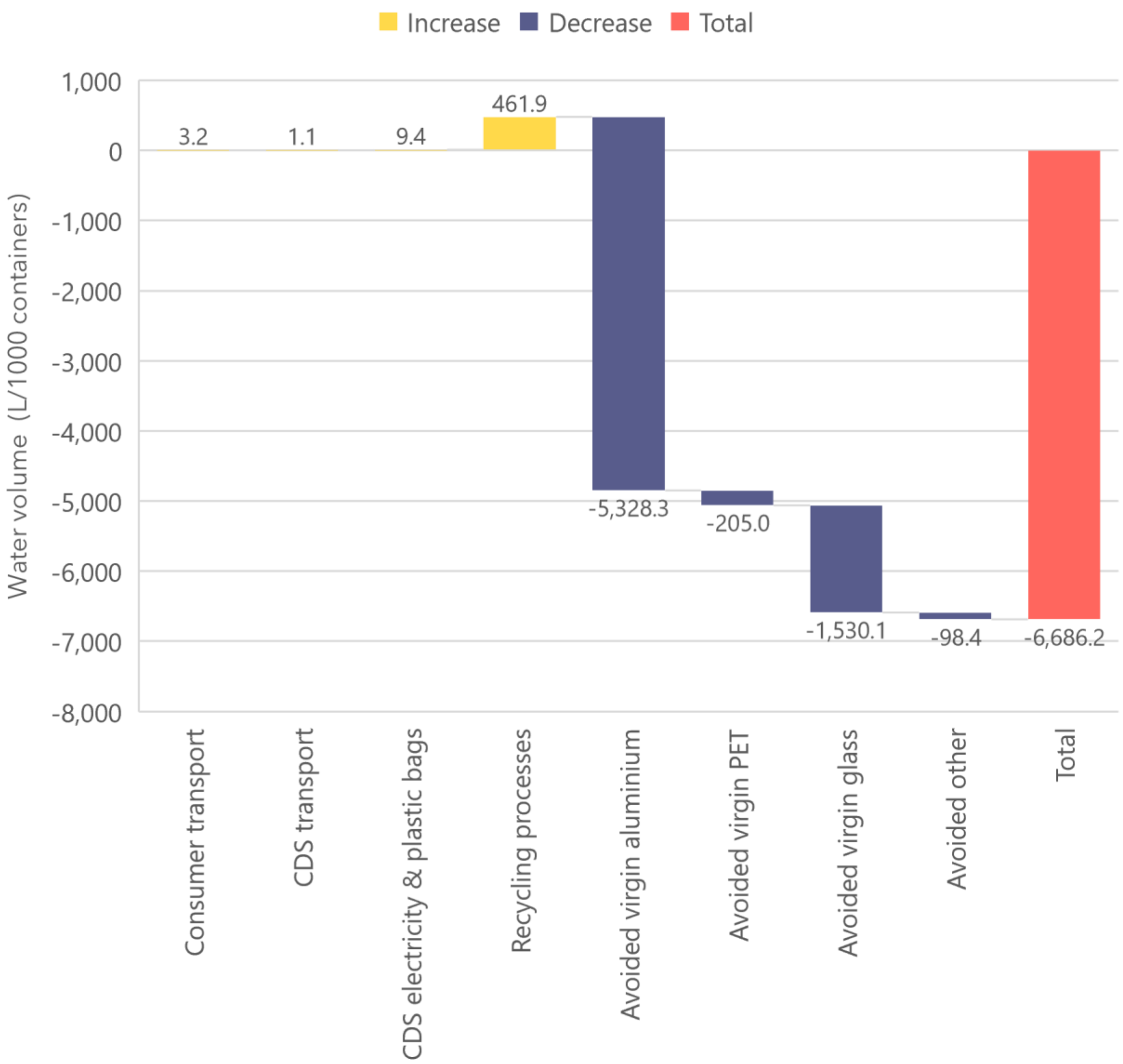

Figure 7 Contribution analysis - Water volume, per 1000 containers

Figure 8 shows the impacts and savings in particulate matter impacts. The impact savings follow a similar pattern to the climate change results, with the benefits mostly occurring from the energy production requirement of virgin materials, and subsequent avoidance with recycling.

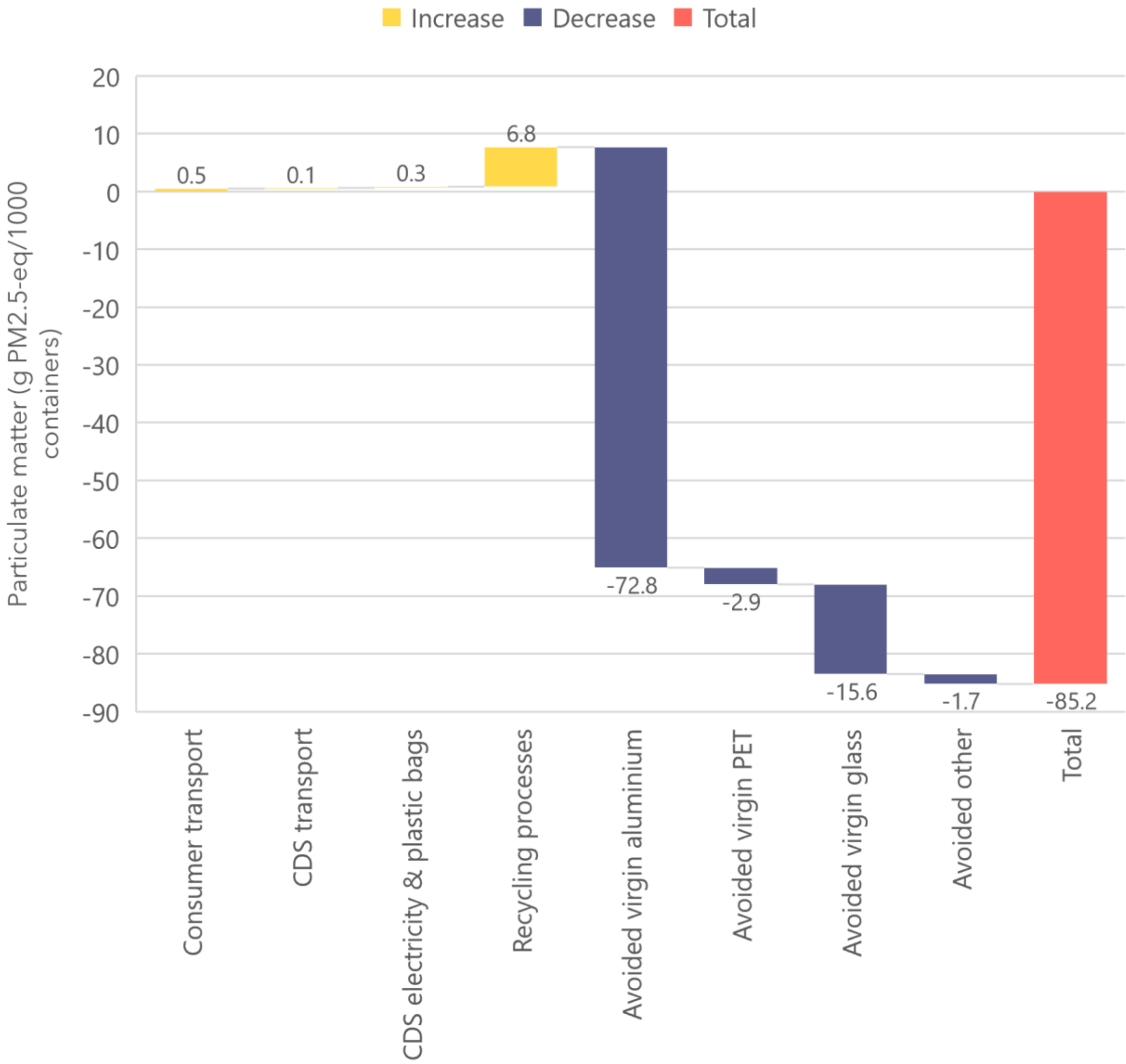

Figure 8 Contribution analysis - Particulate matter, per 1000 containers

4.2 Impacts per kg of different materials recycled

Table 14 shows the impacts and benefits of recycling the three most common materials (aluminium, glass and PET) through the CDS. The largest net benefits are seen for aluminium, where recycling 1kg results in savings of 17.7 kgCO_2-eq. Benefits are shown in green, with environmental impacts shown in red. The colour scheme shows that the other indicators follow similar patterns in their distribution to individual stages of the life cycle.

Table 14 Results for 1kg material entering CDS

Material	Consumer transport	CDS transport	CDS electricity	Recycling processes	Avoided material	Net impact
Climate change (kgCO2-eq)						
Aluminium	0.01	0.003	0.3	0.9	-19.0	-17.7
Glass	0.01	0.003	0.02	0.03	-0.3	-0.2
PET	0.01	0.003	0.5	0.9	-2.5	-1.1
Fossil fuel depletion (MJ NCV)						
Aluminium	0.2	0.05	3.9	10.4	-186.4	-171.9
Glass	0.2	0.05	0.3	0.5	-3.3	-2.4
PET	0.2	0.1	5.9	11.0	-61.5	-44.4
Water volume (L)						
Aluminium	0.05	0.02	0.6	43.7	-727.7	-683.4
Glass	0.05	0.02	0.04	0.4	-26.5	-26.0
PET	0.05	0.02	1.0	34.2	-97.2	-61.9
Particulate matter (g PM2.5-eq)						
Aluminium	0.01	0.001	0.02	0.7	-9.9	-9.2
Glass	0.01	0.001	0.001	0.016	-0.3	-0.2
PET	0.01	0.001	0.03	0.2	-1.4	-1.2

Figure 9 shows the climate change contribution analysis for the three most common container materials. It has been rescaled to show the contribution analysis for 1kg 10kg and 50kg of material for aluminium PET and glass respectively. It shows the processing of PET is proportionally higher than the other two materials, relatively to the virgin material offset. However, for all materials there are clear net environmental benefits.

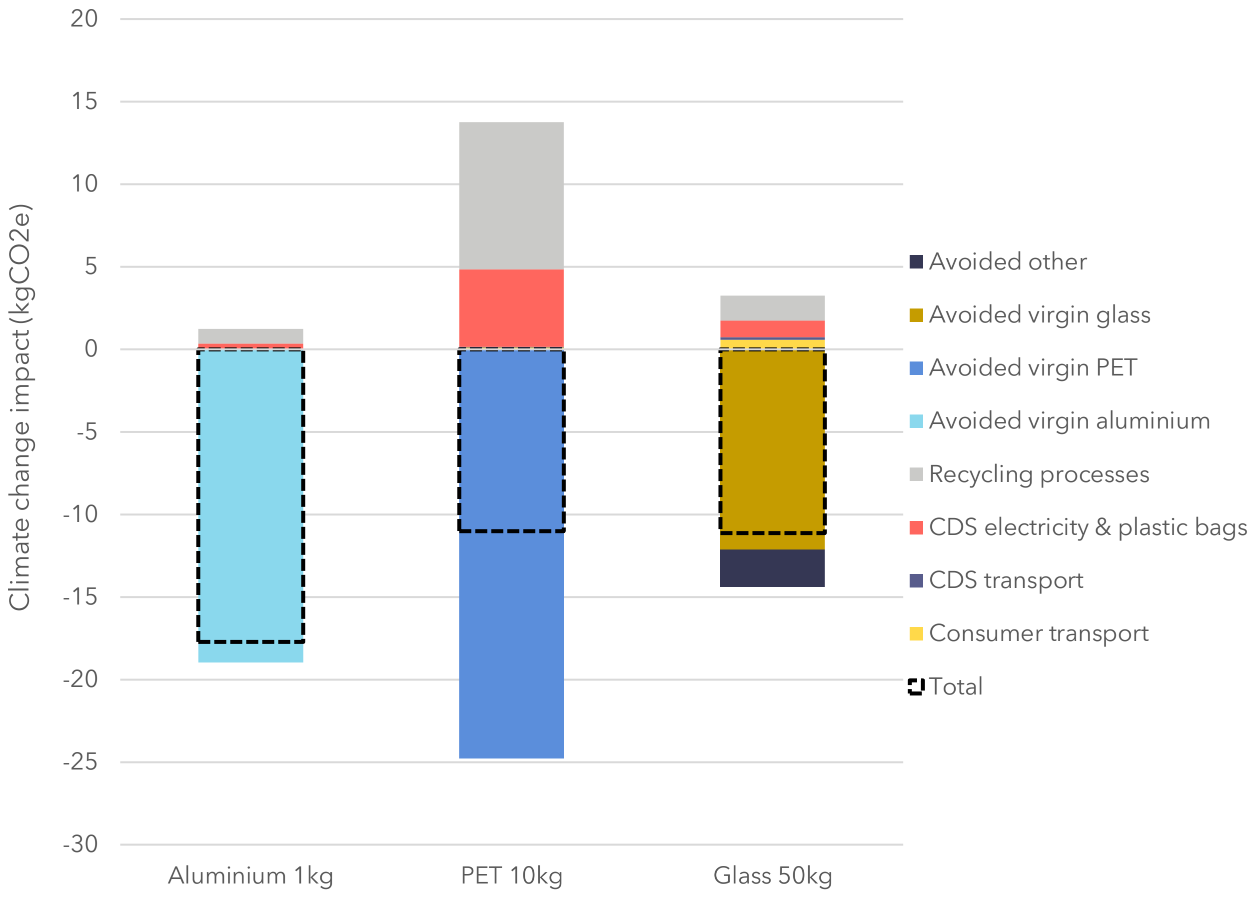

Figure 9 Climate change impacts in kg CO2e per kg of aluminium, 10 kg of PET and 50kg of glass material entering CDS

4.3 Sensitivity analysis

The sensitivity analysis is an important part of the LCA process in which the robustness of the study can be tested to determine whether the data quality needs to be improved, as well as to aide in the interpretation of the results (Wei, 2015). The sensitivity analysis highlights the most important set of parameters which have interacted with the calculation of the model and can therefore influence the uncertainty of the process. The choice of sensitivity methods should be in accordance with both the degree of correlation and the magnitude of uncertainty (Wei, 2015).

4.3.1 Container mix and weights

Some of the key parameters in this study are the weights of the different container types and the relative amounts of different containers. The purpose of this analysis is to determine how sensitive the results are to changes in these parameters. This gives an indication of the robustness of the results. The container masses of the three most common containers (aluminium, glass and PET) were increased by 10% to give the first three scenarios. The relative fraction of each of these container materials was also increased by 2% (with the remaining two container types experiencing a decrease of 1%). The sensitivity analysis results are shown in Table 15. Note that the increase in container mass was not carried through to a resultant increase in transport.

Table 15 Sensitivity analysis, per 1000 containers

Impact category	Unit	Baseline	Alu Mass +10%	Glass Mass +10%	PET Mass +10%	Alu Fra +2% (-1% others)	Glass Fra +2% (-1% others)	PET Fra +2% (-1% others)
Climate change	kg CO2-eq	-145	-159	-147	-146	-150	-144	-142
Energy depletion	MJ NCV	-1,551	-1,680	-1,568	-1,562	-1,592	-1,533	-1,529
Water volume	L	-6,686	-7,187	-6,837	-6,700	-6,825	-6,697	-6,538
Particulate matter	g PM2.5-eq	-85	-92	-87	-86	-87	-85	-84

Table 15 shows the result of increasing the masses of each container type by 10%. For the aluminium container, this results in an increase in total savings around 9%. When compared against the baseline results, the altered mass of the glass and PET containers had minimal effect on the overall climate change impact, increasing the savings by 1% or less. This trend is similar with the remaining impact categories, with the 10% change in mass of the aluminium can causing a 7-8% change in total impact in the other categories. This indicates the results are quite sensitive to the mass of the aluminium can, since it makes up the largest portion of the total containers and also results in the largest savings of all the material types. However, given the fairly standard size and shape of aluminium cans, there is low uncertainty in the aluminium can weight used in the study.

The sensitivity analysis also looked at the impact of altering the percentage make up of returned containers by increasing the quantity of one material by 2% whilst reducing the other two by 1% each. Since the per kg benefits of recycling aluminium are considerably higher than the other two materials, a higher percentage of aluminium results in larger savings, while higher percentage of other materials results in lower benefits when compared to the baseline. A 2% increase in the aluminium fraction resulted in a 3% increase in climate change savings, but a 2% increase in the glass or PET fraction resulted in a 1-2% decrease in climate change savings.

4.4 Data quality assessment

The quality of key datapoints was assessed and is reported in Table 16, showing that the most critical aspects of the model were modelled from good or very good quality data.

Table 16 Data quality assessment.

	Approximate % Climate change Contribution	Reliability	Time-related coverage	Geographical coverage	Technology coverage	Comment
Aluminium recycling	<5%	Good	Fair	Fair	Good	Secondary aluminium process from Ecoinvent based on European data from 2008 adapted to rest of world
Virgin aluminium offset	>75%	Good	Good	Good	Very good	World Aluminium Council data for Oceania region
PET recycling	<1%	Good	Fair	Fair	Good	Ecoinvent based on Swiss data from 2010 regionalised to RoW
Virgin PET offset	<5%	Good	Poor	Fair	Good	European plastic association data from 2000
Glass recycling	<1%	Poor	Fair	Good	Good	Data from Victoria packaging study from 2003
Glass batch offset	>25%	Good	Fair	Fair	Good	Based on Ecoinvent data for ROW. Energy savings in glass furnace from theoretical study.
Transport distances	<1%	Good	Good	Good	Good	Estimated based on actual transport distances
Transport type	<1%	Good	Good	Good	Fair	Exact vehicle specifications not known

4.6 Equivalence Metrics

To communicate the benefits of the ACT CDS program, a table of metrics was developed using familiar activities which can be analogous with the results of this LCA more easily. The impact and corresponding metric are displayed in Table 17.

Table 17 Equivalence metrics, per 1000 containers

Impact	Metric	Result	Source
Climate change	Kilometres of driving avoided	576	US EPA (av. Passenger car = 252.5g / km)
Fossil fuel depletion	Hours of TV use avoided	1,608	Average of 205cm (49") TVs on the market
Water use	Hours showering avoided	12	Hunter Water (av. shower head = 9L/minute)
Particulate matter	kg of wood in wood heater avoided	9	Australian Air Quality Group

Climate change impact is typically calculated and presented in kilograms of carbon dioxide equivalent (kg CO2-eq), which scales in the influence of other greenhouse gas emissions that have greater or lesser influence on global warming compared to CO_2 such as methane or nitrous oxide. Creating metrics that are analogous with CO_2 is innately difficult due to the variables associated with emission and absorption rates. The United States Environmental Protection Agency (US EPA) calculated the emissions produced by an averaged sized passenger vehicle to be 404g per mile (US EPA, 2021). This will vary depending on the type of car, driving behaviour, fuel quality, and a multitude of other factors but is accurate for an unknown audience that represents the variability of these influences, however, was chosen due to the spectrum of comprehension for a broad audience. Using the results from the LCA it was calculated that for every 1000 containers returned there is an avoidance of 145kgCO_2-eq, which is comparable to the emissions produced by driving 576km.

Abiotic depletion is a measure of the amount of energy available by the combustion fossil fuels, which is why it is presented in megajoules (MJ). In order to make a comparable metric the energy unit was converted into watt hours (Wh) to make it more relatable. As most people in modern at least watched a television it can encompass a large portion of the population. As TVs are sold in a variety of sizes, the energy consumption of a 49-inch LCD TV was chosen as it is middle of the range between 100-150W of energy per hour of use. Using the results from the LCA it was calculated that for every 1000 containers returned there is an avoidance of 1,551MJ of abiotic depletion (fossil fuels) which is the equivalence of 1,608 hours of TV usage.

The third category of water volume is the amount of water which is effectively saved by the recycling of containers. As it is difficult to envisage large amounts of water by volume, the metric of minutes showering was chosen to aide with conceptualisation. According to most water authorities, a water efficient showerhead dispenses 9 litres of water per minute of showering (Water 2021). Using the results from the LCA it was calculated that for every 1000 containers returned there is an avoidance of 12 hours of showering.

The final category is the quantity of fine particles that are less than 2.5 microns in size produced by a given process. These particles are of concern to the environment as well as human health as they can be inhaled and absorbed directly into tissue and the blood stream with adverse consequences (NSW Government, 2020). As the particles are impossible to see with the human eye their impact is therefore difficult to conceptualise. To achieve a communicable format, kilograms of wood in a wood fired heater was chosen to be akin with particulate matter as woodsmoke is a common source of PM2.5 particles which negatively impact upon human health (AAQG 2021). Using the results from the LCA it was calculated that for every 1000 containers returned there is an avoidance of 85g of PM2.5 emitted, which is the same amount produced by the burning of 9kg of firewood.

5 Conclusion

The results from this LCA show there are substantial benefits associated with the recycling of common beverage container materials. The results have been quantified for the communication of these benefits to participants of the ACT CDS program. While there is some variability and uncertainty in the results, the numbers presented are robust as long the fraction of aluminium collected remains a significant component in the mix of containers.

Note this is not a consequential study and doesn't not represent the marginal benefits of implementing the CDS scheme on top of the pre-existing kerbside program. The calculation also makes no assessment of impacts of avoided littering or landfill disposal of beverage containers.

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Appendix A. Collection data

Table 18 Collection data, number of containers, FY2018-FY2021

Type	Collection point name	Suburb	Aluminium	Glass	HDPE	LPB	PET	Steel	Total
Cash Back Depot	Belconnen	Belconnen	4,914,440	2,925,393	196,453	306,301	2,534,951	1,172	10,878,710
Cash Back Depot	Depot Fyshwick	Fyshwick	29,905,136	8,490,478	345,922	632,299	6,010,357	18,200	45,402,392
Cash Back Depot	Depot Mitchell	Mitchell	15,892,139	11,491,485	627,238	1,279,053	9,853,409	7,869	39,151,193
Cash Back Depot	Depot Phillip	Phillip	13,726,452	10,023,875	626,692	950,964	7,623,546	3,638	32,955,167
Drop & Go POD	Amaroo District Playing Fields	Amaroo	875,478	453,953	30,351	62,000	507,580	1,694	1,931,056
Drop & Go POD	Charnwood Shopping Centre	Charnwood	1,123,420	580,471	34,970	59,025	454,891	1,216	2,253,993
Drop & Go POD	Hawker Shops	Hawker	1,122,518	591,602	37,654	57,917	497,767	1,176	2,308,634
Drop & Go POD	Kambah District Playing Field	Kambah	776,759	454,975	27,827	34,006	288,901	1,144	1,583,612
Drop & Go POD	RDOC Gungahlin	Gungahlin	1,145,083	573,694	42,103	80,081	674,978	1,956	2,517,895
Drop & Go POD	RDOC Tuggeranong	Greenway	1,957,564	972,122	54,720	109,365	825,768	1,550	3,921,089
Drop & Go POINT	ACT Basketball Belconnen	Belconnen	8,850	5,386	316	609	7,960	47	23,168
Drop & Go POINT	Anglicare Fyshwick	Fyshwick	113	241	8	2	253		617
Drop & Go POINT	Anglicare Jamison	Macquarie	24,378	16,702	1,021	2,624	21,930	75	66,730
Drop & Go POINT	Anglicare Phillip	Phillip	2,863	2,106	92	546	3,686		9,293
Drop & Go POINT	Belconnen (Kiosk)	Belconnen	378,933	207,864	13,771	23,895	185,359	14	809,836
Drop & Go POINT	Depot Fyshwick (Kiosk)	Fyshwick	1,714,162	783,254	49,110	82,029	846,566	2,159	3,477,280
Drop & Go POINT	Depot Mitchell (Kiosk)	Mitchell	1,462,451	772,363	51,451	104,559	887,202	834	3,278,860
Drop & Go POINT	Depot Phillip (Kiosk)	Phillip	1,540,570	1,031,909	71,241	99,317	856,056	502	3,599,595
Drop & Go POINT	IGA Evatt	Evatt	102,559	63,879	4,818	13,002	59,197	2,402	245,857
Drop & Go POINT	IGA Farrer	Farrer	110,897	52,293	3,609	6,280	46,851	69	219,999
Drop & Go POINT	IGA Nicholls Express Site	Nicholls	8,708	2,340	168	555	3,504	19	15,294
Drop & Go POINT	Salvos Fyshwick	Fyshwick	138,955	93,048	8,587	11,559	101,340	374	353,863
Drop & Go POINT	Salvos Mitchell	Mitchell	147,046	58,573	6,666	18,812	110,032	488	341,617
Drop & Go POINT	Salvos Phillip	Phillip	229,260	133,282	12,744	22,678	166,779	485	565,228
Drop & Go POINT	Salvos Tuggeranong	Greenway	356,196	222,115	13,805	24,277	236,731	978	854,102
Drop & Go POINT	Vinnies Belconnen	Belconnen	2,425,378	1,397,416	104,810	157,399	1,615,119	6,753	5,706,875
Drop & Go POINT	Vinnies Dickson	Dickson	686,366	451,160	37,579	49,622	487,711	3,457	1,715,895
Drop & Go POINT	Vinnies Tuggeranong	Greenway	802,782	459,656	32,440	56,714	456,113	1,732	1,809,437
RVM	Erindale Reverse Vending Machine	Wanniassa	38,166	30,027	826	2,385	22,612	272	94,288
Total			**81,617,622**	**42,341,662**	**2,436,992**	**4,247,875**	**35,387,149**	**60,275**	**166,091,575**

Appendix B. Critical Review Statement

blue environment pty ltd

1. The critical review brief

1.1 Report reviewed

As requested by Exchange for Change (ACT) Pty Ltd (EfC), Blue Environment Pty Ltd has undertaken this LCA critical review of the Lifecycles Pty Ltd report(s):

- ***Life Cycle Assessment of the ACT Container Deposit Scheme – 14 July 2022 (version 1.1)*** (Boyden, et al., 2022) (as provided to Blue Environment on the 18 July 2022).

The reviewed report documents the life cycle assessment (LCA) conducted on the Australian Capital Territory (ACT) Return and Earn container deposit scheme, which has been undertaken for the following purpose (Boyden, et al., 2022, p. 8):

> *The goal of this LCA is to establish a robust baseline life cycle assessment (LCA) of the ACT Container Deposit Scheme. The baseline will be used to assess potential strategies for improving the implementation of the scheme as well as for further expansion. In addition, the results of the LCA will be used as a basis for the development of a metric system that can be used to demonstrate the associated benefits of the program.*

The LCA may be used to make public/marketing claims. More specifically, the LCA is intended to generate environmental impact factors that will be used to populate an online recycling benefits calculator for public use (or similar resource).

1.2 Review purpose

The aim of this peer review is to provide a third-party opinion on how the LCA report identified in Section 1.1 was conducted and whether this was undertaken in line with the requirements of the LCA standards ISO 14040:2006 and ISO 14044:2006.

1.3 Scope of work

The critical review scope, as specified in the International Standard ISO 14044:2006 (ISO, 2006b), has been a review to determine if:

- 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
- the study report is transparent and consistent.

The review has been undertaken with reference to relevant guidance provided in the following standards and guidelines:

- The LCA standards ISO 14040:2006 and ISO 14044:2006.
- Auditing and Assurance Standards Board 2013 – *Standard on Related Services ASRS 4400 Agreed-Upon Procedures Engagements to Report Factual Findings.*

2. Peer review statement

The LCA identified in Section 1.1 has been peer reviewed by an independent practitioner (Kyle O'Farrell) as stated in ISO 14044 Clauses 6.1 and 6.2. The review has been performed to provide assurance of the credibility of the LCA and its results.

The reviewed report is considered to meet requirements of the LCA standards ISO 14040:2006 and ISO 14044:2006.

The details findings of the peer review are summarised in Section 4 of this review report.

3. Reviewer competency statement

I, Kyle O'Farrell, state that my competency in undertaking a peer review of the LCA is demonstrated through my qualification as an '*LCA Certified Practitioner*' (LCACP), as certified by the Australia Life Cycle Assessment Society (ALCAS).

I am a Director at Blue Environment Pty Ltd, and an EIANZ Certified Environmental Practitioner (CEnvP), and also an Australian LCA Society (ALCAS) member. I regularly undertake Green Building Council of Australia (GBCA) Green Star credit compliance LCA peer reviews, Climate Active program carbon neutrality certification verifications, and reviews of LCA studies more generally.

I affirm that I have had no prior involvement in the preparation of the LCA report or supporting documentation under review, and are not aware of any actual or perceived conflict of interest in having completed this engagement.

Signed

Kyle O'Farrell

Director

22 July 2022