Life Cycle Assessment of Courier Bags

On behalf of New Zealand Post

thinkstep anz

Client:	**New Zealand Post**
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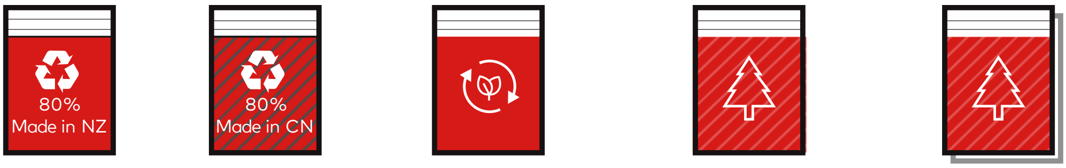
Executive Summary

New Zealand Post (NZ Post) has committed to using 100% reusable, recyclable, or compostable packaging by 2025 or earlier. In support of this commitment, NZ Post engaged thinkstep-anz to carry out a Life Cycle Assessment (LCA) of possible alternatives to replace its domestic courier bags, which – at the time this study was commissioned – were manufactured in China from virgin Low Density Polyethylene (LDPE), a plastic derived from oil. This study follows international standards ISO 14044 and ISO 14067 and covers the full packaging life cycle, including three different disposal options: landfill, recycling, and composting.

We compared five alternative packaging options to the current courier bag

All options we investigated are designed as single-use courier bags, intended to transport A5-sized goods. The study compares the environmental performance of the original oil-derived plastic courier bag to five alternatives:



NZ-made recycled plastic courier bag
LDPE with 80% recycled plastic

Chinese-made recycled plastic courier bag
LDPE with 80% recycled plastic

Home compostable courier bag
Material derived from both plants and oil (made in China)

Kraft paper courier bag
Kraft paper flat courier envelope (made in Australia)

Padded Kraft paper courier bag
Kraft paper courier bag padded with recycled newsprint (made in Australia)

The new courier bag also needed to perform well for non-environmental criteria, such as its functional performance and cost. NZ Post's initial market testing recognised that customers may not choose the flat, Kraft paper courier bag as it feels more like a traditional postal envelope than the original plastic courier bag it was designed to replace. The padded paper courier bag felt and behaved much more like a traditional plastic courier bag and was therefore included in this study, despite it offering better protection than a flat plastic courier bag.

We did not investigate reusable courier bags within this study because of current economic barriers for their use and logistical difficulties in returning them after use. This study intends to understand the impacts of single-use courier bags and the best available options while reusable bags are developed to make them more feasible for widespread use.

The NZ-made recycled plastic courier bag has the lowest carbon footprint

The NZ-made recycled plastic courier bag has the lowest carbon footprint of all courier bags we considered. The carbon footprint of this bag is only 38 percent of the virgin plastic courier bag previously in use (6.7 g CO_2-eq. per bag compared to 17.8 g CO_2-eq.).

The Chinese-made recycled plastic courier bag had the second-lowest carbon footprint of all courier bags considered in this study. A full breakdown of the results can be found in Figure 1.

Replacing virgin plastic courier bags with NZ-made recycled plastic courier bags would lead to a reduction in carbon footprint by a factor of 2.6.

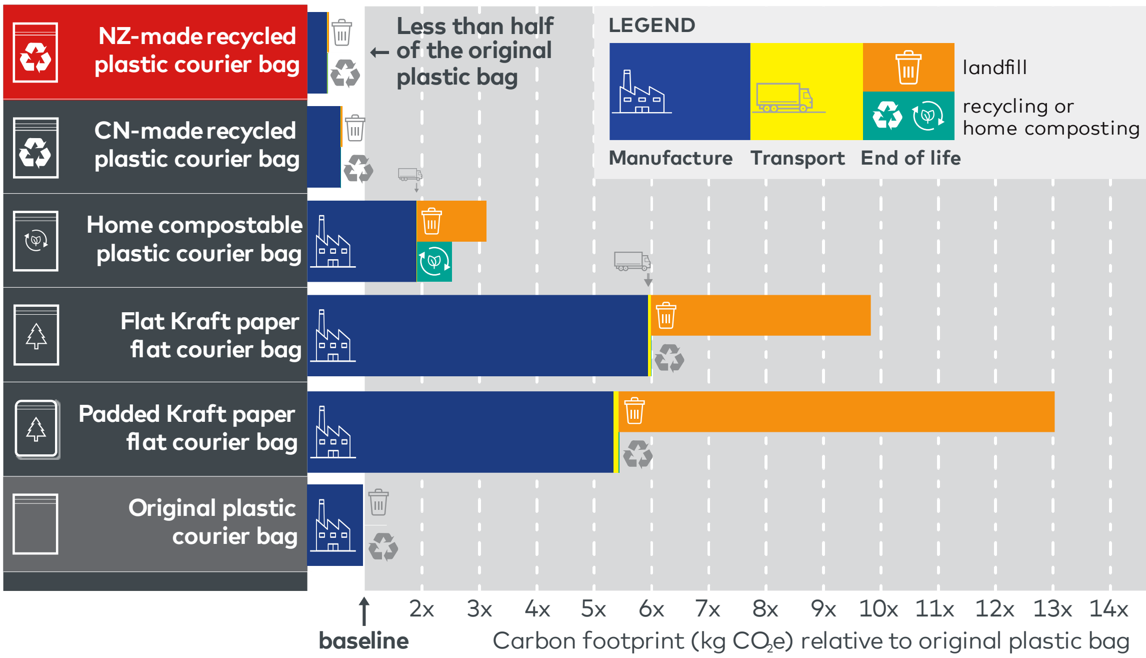


Figure 1: Relative carbon footprint of the three major life cycle stages compared to the original bag

We carried out a hotspot analysis on the environmental results for all courier bag options and consistently found the raw materials to be a leading source of emissions. Electricity was also a significant source of emissions for the plastic and compostable bags.

The carbon footprint for the biodegradable courier bags (the home compostable bag and both paper bags) was also found to be heavily dependent on the end-of-life treatment they received. When placed in the anaerobic environment of a landfill, these items produce methane (a potent greenhouse gas) and this can become the leading form of emissions – up to 58% of the total emissions in the case of the padded courier bag.

The NZ-made recycled plastic courier bag also has the lowest impact across most other environmental indicators

We found that the NZ-made recycled plastic courier bag did not contain any notable risks across the suite of 14 environmental indicators chosen for this study. Environmental indicators were selected based on their relevance to NZ Post's stakeholders and how common they were in other LCA studies.

There were only three indicators where the NZ-made recycled plastic courier bag was not the best performing option: Material Circularity Indictor (MCI), non-hazardous waste disposal, and net use (i.e., consumption) of fresh water.

Of these indicators, the MCI was judged to be the most relevant to NZ Post's stakeholders, as it measures a product's ability to use secondary material and keep materials available in their form of highest value. The NZ-made recycled plastic courier bag offers acceptable material circularity, though it is less circular than paper-based alternatives.

For non-hazardous waste, the recycled plastic courier bag led to the creation of up to 5% more waste than the virgin plastic courier bag. This is because the recycled bag requires slightly more plastic than the virgin bag to provide the same mechanical strength. A slight increase in plastic means that there is slightly more waste throughout the life cycle, from production to end-of-life.

The higher net use of fresh water is due to the recycling process, which uses electricity from the New Zealand grid, much of which comes from hydroelectric power. Importantly, while the NZ-made recycled plastic courier bag consumes more water than the Chinese-made recycled plastic courier bag, the impact of this water consumption is lower than for the Chinese-made bag due to water being more plentiful in New Zealand (on average) than in China.

Taking a holistic view, the NZ-made recycled plastic courier bag has the lowest environment footprint of all courier bags considered in this study. It performs the best in 11 of 14 indicators and not significantly worse in the remaining three indicators. Importantly, these three indicators do not attempt to measure impacts on the environment; rather, they measure things that might contribute to impact (i.e., water consumption and waste production). The NZ-made recycled plastic courier bag performs the best across all indicators that do attempt to measure potential impacts upon the environment.

Table of Contents

1. Goal of the Study

New Zealand Post (NZ Post) is looking to replace its one-way courier bags, sometimes referred to as mailers, with a new, environmentally friendlier alternative. At the time this study was commissioned in late 2019, the bags were manufactured from virgin, oil-derived plastic. While this change is being driven partly by the negative public perception of plastics, NZ Post are committed to avoiding greenwashing by using scientific analysis to substantiate whether the new option is environmentally superior or not. The new courier bag design must also perform well for non-environmental criteria, such technical performance and cost.

NZ Post commissioned thinkstep-anz to carry out a cradle-to-grave Life Cycle Assessment (LCA) to compare the environmental performance of the four potential one-way courier bag options under consideration. The four new courier bags considered are: a recycled Low Density Polyethylene (LDPE) plastic bag, a home compostable plastic bag, and two paper bags: one with recycled newspaper for padding and one flat bag. The current virgin LDPE bag has also been included within the assessment to act as a benchmark and aid in communication of the results. The masses of the courier bags were provided by Sealed Air. The results of this study are intended for public communication by NZ Post and will include comparative assertions.

This study complies with ISO 14044:2006 for life cycle assessment and ISO 14067:2018 for carbon footprinting. As this study is comparative and intended for public communication, it has undergone a critical review by a panel of three independent experts in accordance with ISO 14044:2006. The reviewers' findings can be found in Annex A and the full review commentary is enclosed in Annex E.

2. Scope of the Study

2.1. Product System(s)

The four courier bags assessed in this report are all size A5, meaning they are flexible bags designed to hold A5 items (approximately 148x210mm for flat items) although any item which can fit and be sealed within the bag may be sent. The courier bags' external dimensions vary, and specific dimensions are listed below in Figure 2-1 to Figure 2-4. The courier bags are made predominantly from either fossil fuel derived plastic (for the plastic and home compostable bags) or paper. Each product is intended to contain and protect its contents throughout its use phase of transporting goods.

All courier bags investigated are one-way, single use bags with several different end-of-life scenarios. For all products, the impacts of disposal in landfill are considered along with an alternative scenario, either recycling or composting as appropriate. Further details of the products are listed in Table 2-1. The masses of the courier bags vary so the products can achieve approximately the same tear resistance. For comparatively weaker materials this results in a higher thickness being required.

Care has been taken in this study to correctly distinguish between recycled and recovered material. In accordance with ISO14021:2016 only pre-consumer material which is generated in one commercial process and has been discarded, then collected, for use in another process has been referred to as recycled material. In doing so manufacturing processes which have high loss rates, only to recover the material, are discouraged.

Ecoflex is a brand name for fossil fuel derived, biodegradable material Polybutylene Adipate Terephthalate (PBAT) which is one of the main components within the home compostable bag. Similarly, Ecovio is a brand name for the compound attained in the blending Ecoflex and Polylactic Acid (PLA). Throughout this study, these compounds are referred to by their brand names to present results at the same level as other materials used during manufacture.

Table 2-1: Details of assessed courier bags

Courier Bag Product	Predominant Material(s)	Mass (g)	Manufacturing Locations Investigated
Virgin LDPE	LDPE	5.03	CN
Recycled LDPE	rLDPE	5.23	NZ & CN
Home Compostable	Ecoflex/Corn starch/Ecovio mix	7.27	CN
Flat Paper	Kraft Paper	37.88	AU
Padded Paper	Kraft paper and recycled newspaper	75.11	AU

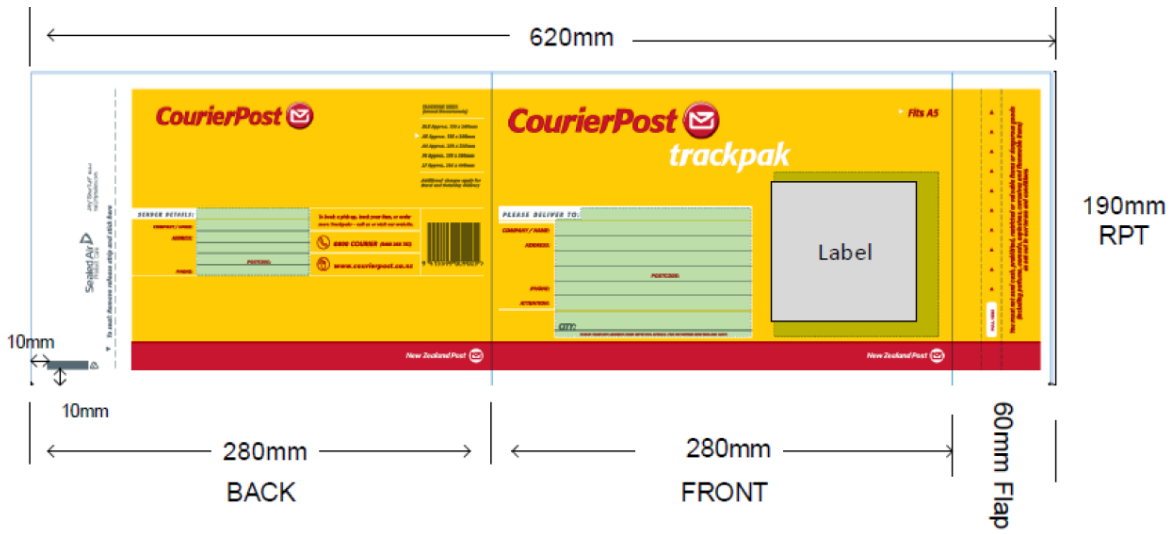


Figure 2-1: Virgin and recycled LDPE courier bag dimensions Source: Sealed Air

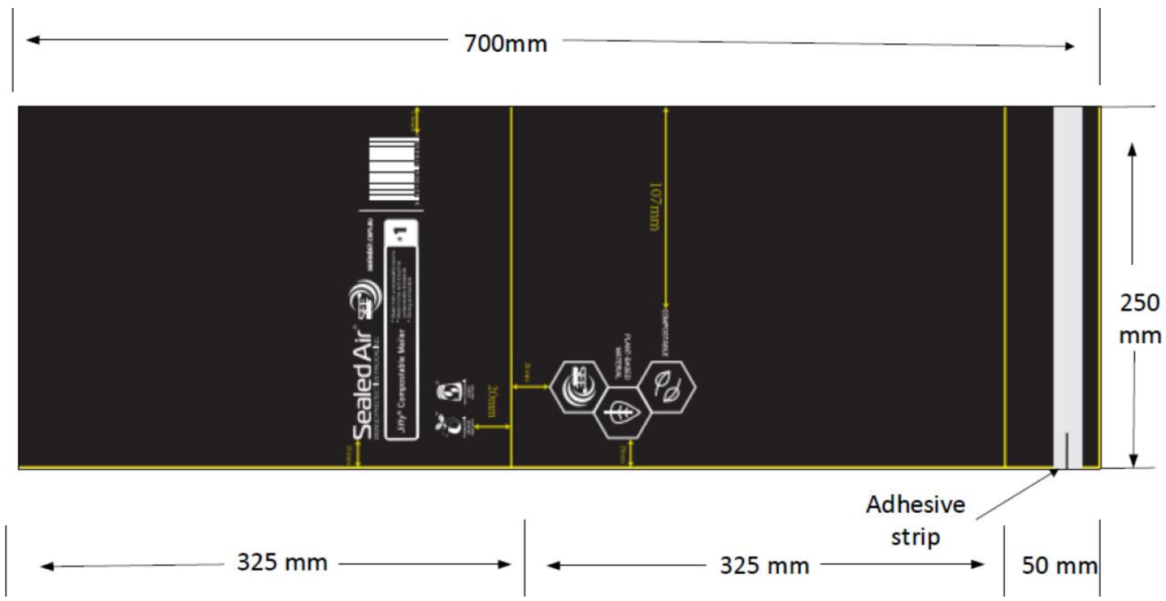
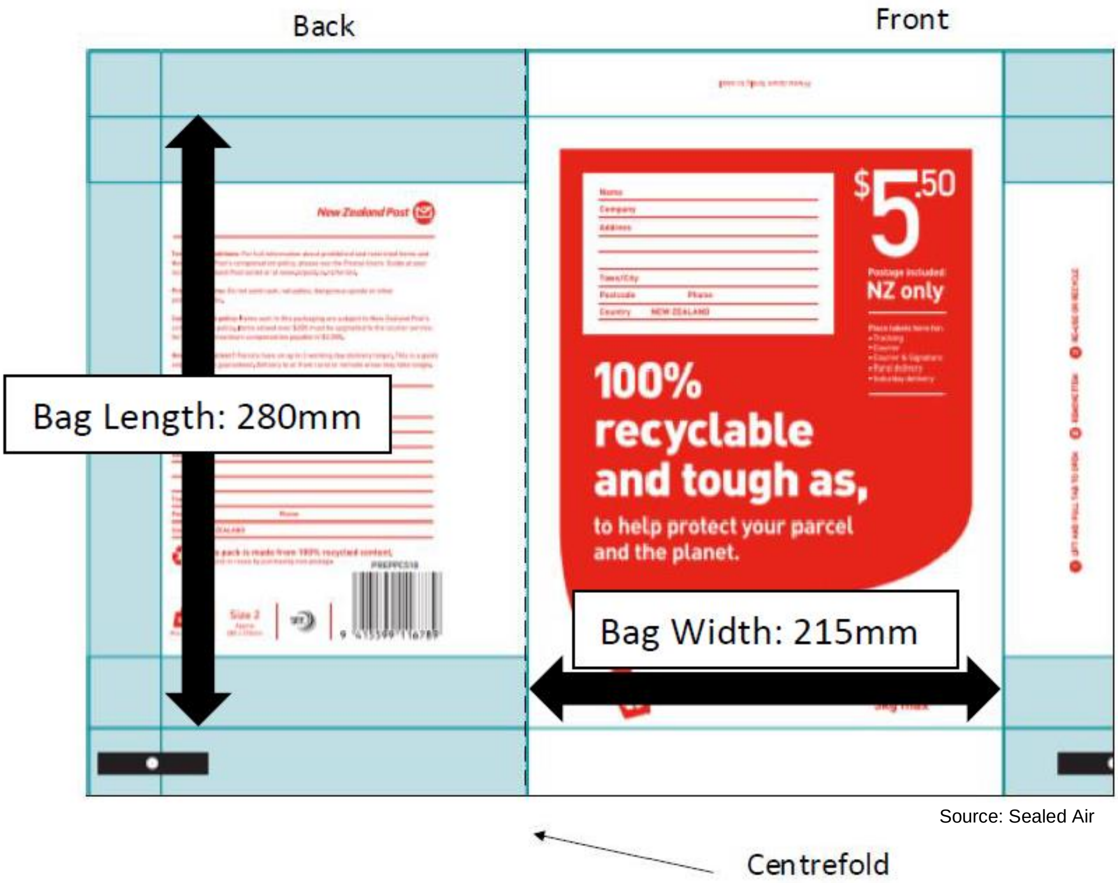
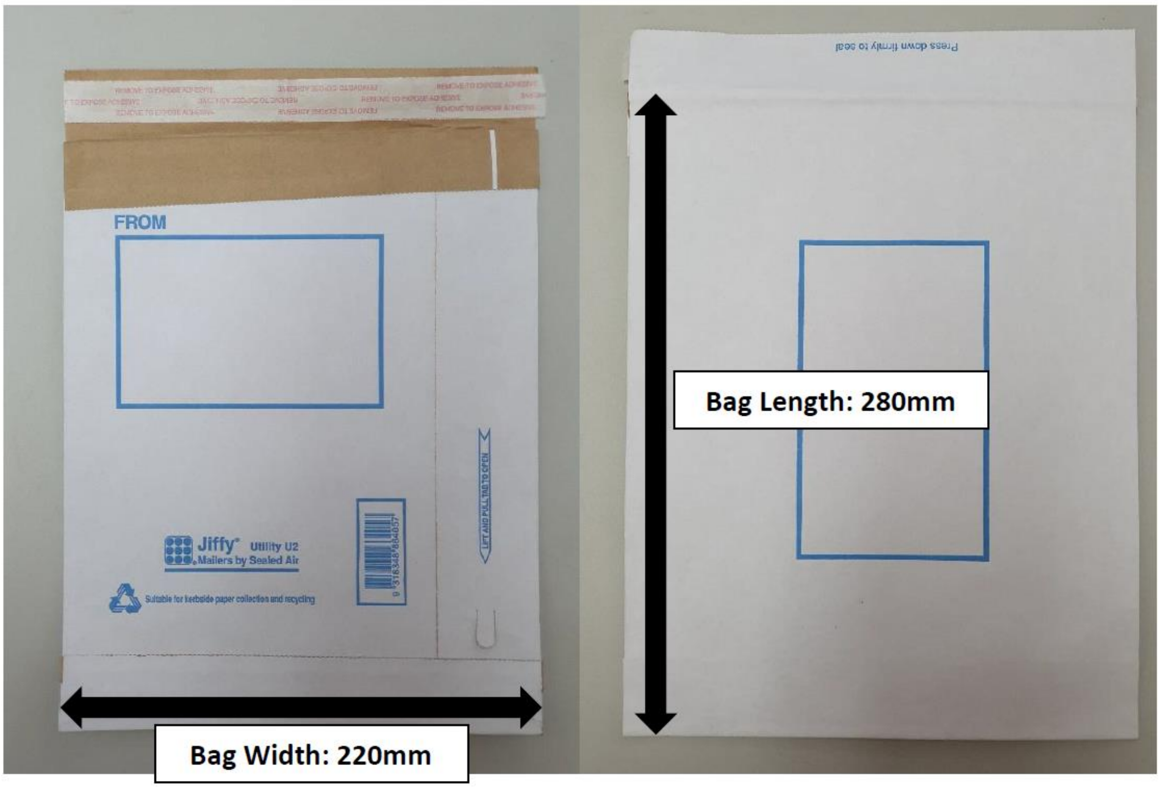


Figure 2-2: Home compostable courier bag dimensions Source: Sealed Air



Source: Sealed Air

Figure 2-3: Padded paper courier bag dimensions



Source: Sealed Air

Figure 2-4: Flat paper courier bag dimensions

2.1.1. Packaging for the Courier Bags

Packaging for the courier bags aid transportation during both freight and retail handling. Courier bags are bunded into packs of 10 to 25 units (depending on the bag thickness) and then put inside plastic bags/liners (referred to as “secondary packaging” within the results section). The bundles are then put into cardboard boxes which are stacked on wooden pallets to transport the bags from the manufacturer to the retailer (referred to as “tertiary packaging” within the results section). A breakdown of the packaging used for each courier bag can be found in Table 2-2.

Table 2-2: Packaging material breakdown

Product	Packaging Description	Material	Mass per Courier Bag (g)
Virgin LDPE	Plastic liner	Low Density Polyethylene	0.23
	Cardboard	Corrugated Board	0.38
	Wooden Pallet	Wooden Pallet	0.31
rLDPE	Plastic liner	Low Density Polyethylene	0.23
	Cardboard	Corrugated Board	0.38
	Wooden Pallet	Wooden Pallet	0.31
Home compostable bag	Plastic liner	Low Density Polyethylene	0.24
	Cardboard	Corrugated Board	0.80
	Wooden Pallet	Wooden Pallet	0.37
Flat paper bag	Plastic liner	Low Density Polyethylene	0.29
	Cardboard	Corrugated Board	1.50
	Wooden Pallet	Wooden Pallet	4.69
Padded paper bag	Plastic liner	Low Density Polyethylene	0.60
	Cardboard	Corrugated Board	4.40
	Wooden Pallet	Wooden Pallet	4.69

2.2. Product Function(s) and Functional Unit

The functional unit is a single, disposable courier bag for use as protection of any A5 sized goods during distribution. All components which are required to allow the successful functioning of the courier bags, even those not included during use such as adhesive sealing strips or secondary packaging, are included within this study.

The impacts of goods stored within the courier bag are assumed to be associated with the goods and therefore excluded from this study.

The courier bags are manufactured for and delivered to New Zealand Post whose customers then use them within New Zealand Post's courier network for the protection of goods in transport before being disposed of by the consumer who received the bagged goods. At the end of the courier bag's functional life, the bag is assumed to either be landfilled or recycled/composted.

2.3. System Boundary

This study has a 'cradle-to-grave' scope, looking at the extraction of raw materials through to end-of-life, specifically:

- Manufacturing of the raw materials: virgin LDPE (for the current bag – used for comparisons only), recycled LDPE, kraft paper, recycled newspaper, and home compostable plastic.
- Transport of raw materials to the packaging manufacturer.
- Manufacturing of the courier bag.
- Average transport of the courier bag to NZ Post's warehouse(s) and retailers before use.
- Average transport of the courier bag through NZ Post's infrastructure (i.e. when it is used to transport a package for the customer).
- End-of-life disposal of the courier bag, covering:
    1. Landfill (for all bag options)
    2. Recycling (for the LDPE bags and paper bags)
    3. Composting (for the home compostable bag only)

As this investigation focusses solely on the packaging itself, it does not account for the product within the courier bag during the use phase. The five main stages of the investigation can be seen in Figure 2-5.

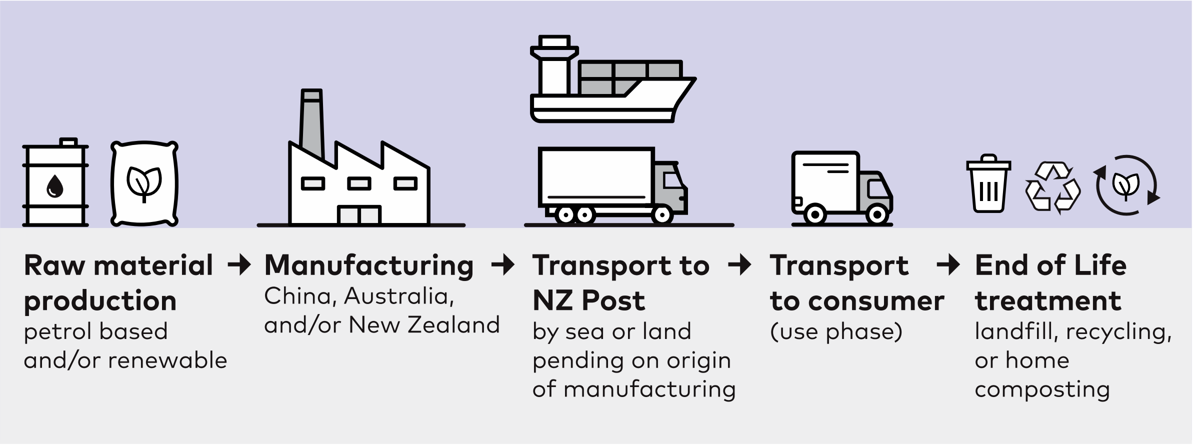


Figure 2-5: System boundary flow diagram

The investigation excludes the biogenic carbon dioxide sequestration and release which occurs during over the life of the paper and constituents within the home compostable bag. Biogenic carbon dioxide has been excluded due to the relatively short life expectancy of the products. However, production of biogenic methane is considered, given its potency as a greenhouse gas.

ISO 14067:2018 requires biogenic carbon to be reported, and this is included in Annex C along with a breakdown of greenhouse gas emissions by type (fossil fuels, biogenic, land use, etc.).

2.3.1. Time Coverage

Data collection for the assessment occurred between January and March 2020. The reference year for this study is 2020.

2.3.2. Technology Coverage

The data collected and assumptions made are intended to represent the packaging industry's best practices in 2020. While primary data were collected for the masses and materials of all bags and components in this study, secondary data from the GaBi Database is used for bag manufacture.

2.3.3. Geographical Coverage

The geographical coverage is representative of New Zealand Post's supplier's supply chains. This study is intended for courier bags used in New Zealand only, not for courier bags that are shipped overseas.

2.4. Allocation

2.4.1. Multi-output Allocation

Multi-output allocation follows the requirements of ISO 14044, section 4.3.4.2. When allocation becomes necessary during the data collection phase, the allocation rule most suitable for the respective process step is applied and documented along with the process in Chapter 3.

Allocation of background data (energy and materials) taken from the GaBi 2020 databases is documented online at http://www.gabi-software.com/support/gabi/gabi-database-2020-lci-documentation/

2.4.2. End-of-Life Allocation

End-of-life allocation addresses the question of how to assign impacts from virgin production processes to material that is recycled and used in future product systems. This is important when a product system uses recycled content or is recycled at end-of-life. The approaches used follow the requirements of ISO 14044, section 4.3.4.3.

While there are many possible approaches to end-of-life allocation, there are two main approaches commonly used in LCA studies: the cut-off approach and the substitution approach (GHG Protocol, 2011). Each approach is described in Figure 2-6.

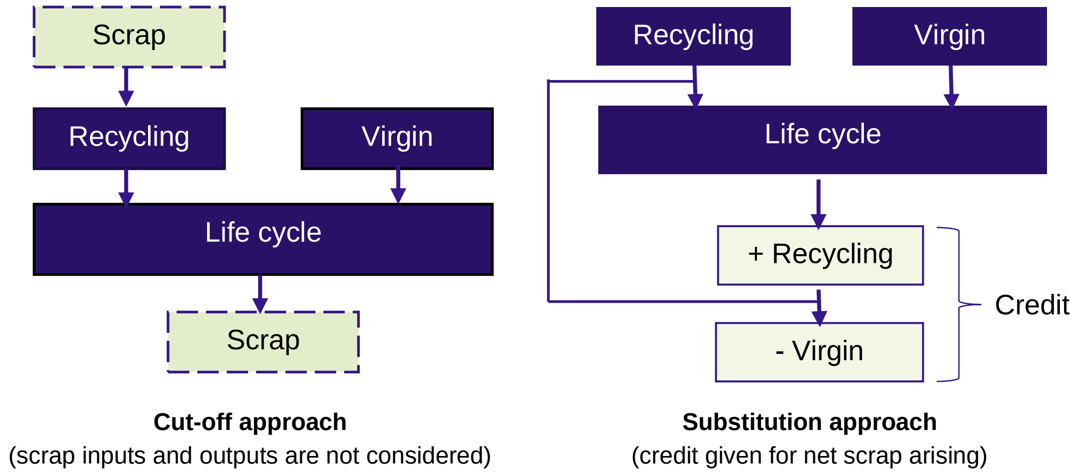


Figure 2-6: Flow diagrams for cut-off and substitution end-of-life allocation methods

This study uses the cut-off method as it is considered the most appropriate for packaging material due to its low economic value and often poor recovery rates. In order to test the sensitivity of the results to this end-of-life allocation method assumption, a study has been conducted in section 4.3.2.

2.5. Cut-off Criteria

Using expert judgement, the following materials and processes have been excluded:

- Packaging of incoming consumables
- Inbound transport of packaging materials
- Printing of labels onto courier bags
- Disposal of shipment packaging

The above exclusions are justified due to their low relative mass or energy contributions to the system. For all other processes within the system boundary, all available energy and material flow data have been included in the model. In cases where no matching life cycle inventories are available to represent a flow, proxy data have been applied based on conservative assumptions regarding environmental impacts.

The choice of proxy data is documented in Chapter 3. The influence of these proxy data on the results of the assessment has been carefully analysed and is discussed in Chapter 5.

2.6. Selection of LCIA Methodology and Impact Categories

New Zealand Post identified climate change, plastics in the environment, and toxicity as the three indicators of greatest relevance to its stakeholders. These indicators are discussed further below. A larger set of indicators has also been included to help identify and avoid burden shifting between environmental impact categories.

Carbon footprint

Carbon footprint is used as the headline environmental indicator within this study as climate change is of high public and institutional interest and often deemed to be the most pressing environmental issue of our time. Within this study, carbon footprint is measured using the Global Warming Potential impact category with current IPCC characterisation factors taken from the 5th Assessment Report (IPCC, 2013) for a 100 year timeframe (GWP100) as required by ISO 14067:2018. It should be noted that there is no scientific justification for selecting a 100 year timeframe over other timeframes.

Keeping materials in circulation and out of the natural environment

Leakage of plastics into the environment, while extremely important to New Zealand Post's stakeholders, is out of scope of this study as this is still an emerging area of assessment within LCA and there is not yet a single widely-adopted impact assessment method. That said, all courier bags being investigated in this study are considered by thinkstep-anz to be low-risk products as they are delivered to a person's home or business which presumably has appropriate means for disposal. Quantifying the risk of plastic leakage into the environment was attempted using the "Plastic Leak Project" methodological guidelines and data produced by Quantis (Quantis & EA, 2020). However, while the Plastic Leak Project reinforced the view that courier bags are low risk items, the quantifications for plastic entering the environment were deemed too imprecise to be used for comparative statements within this study.

The Material Circularity Indicator (MCI) from the Ellen MacArthur Foundation (2015) has instead been used as it measures the degree to which a product system keeps materials in circulation at their highest form of value. While the MCI is one of the leading methods to quantify the circularity of a product, it does have limitations. For instance, it assumes there is a market for all materials collected for recycling. However, the current market for post-consumer soft plastics is small and if all the available material were collected then a significant proportion would have to be diverted from landfill.

Toxicity

Human toxicity is evaluated using the USEtox™ characterisation model. USEtox™ is currently the best-available approach to evaluate toxicity in LCA and is the consensus methodology of the UNEP-SETAC Life Cycle Initiative. The precision of the current USEtox™ characterisation factors is within a factor of 100–1,000 for human health (Rosenbaum, et al., 2008). This is a substantial improvement over previously available toxicity characterisation models, but still significantly higher uncertainty than the other impact categories in this study. As a result, toxicity is used to assess 'substances of high concern', but absolute results should not be asserted.

Other indicators

The full set of impact assessment categories and other metrics considered are shown in Table 2-3 and Table 2-4. Ozone depletion potential – which has historically been included in many LCA studies – is not considered in this study. No ozone-depleting substances are emitted in the foreground system under study. Ozone-depleting substances are also increasingly rare in global supply chains, given that the 1987 *Montreal Protocol on Substances that Deplete the Ozone Layer* has been effective in eliminating the use of CFCs, the most harmful chemicals, while complete phase out of less active HCFCs will be achieved by 2030. As a result, it is expected that the ozone layer will return to 1980 levels between 2050 and 2070.

Table 2-3: Impact category descriptions

Impact Category	Description	Unit	Reference
Global Warming Potential (GWP100)	A measure of greenhouse gas emissions, such as CO_2 and methane. These emissions are causing an increase in the absorption of radiation emitted by the earth, increasing the natural greenhouse effect. This may in turn have adverse impacts on ecosystem health, human health, and material welfare.	kg CO_2 equivalent	(IPCC, 2013)
Human Toxicity Potential	A measure of toxic emissions which are directly harmful to the health of humans. The indicator includes both cancerous and non-cancerous human toxins.	Comparative toxic units (CTU_h)	(Rosenbaum, et al., 2008)
Abiotic Resource Depletion (ADP elements, ADP fossil fuels)	The consumption of non-renewable resources leads to a decrease in the future availability of the functions supplied by these resources. Depletion of mineral resources and non-renewable energy resources are reported separately. Depletion of mineral resources is assessed based on ultimate reserves.	kg Sb equivalent, MJ (net calorific value)	(van Oers, et al., 2002) (CML-IA baseline method, Jan 2016 update)
Eutrophication Potential	Eutrophication covers all potential impacts of excessively high levels of macronutrients, the most important of which nitrogen (N) and phosphorus (P). Nutrient enrichment may cause an undesirable shift in species composition and elevated biomass production in both aquatic and terrestrial ecosystems. In aquatic ecosystems increased biomass production may lead to depressed oxygen levels, because of the additional consumption of oxygen in biomass decomposition.	kg PO_4^{3-} equivalent	(Guinée, et al., 2002) (CML-IA baseline method, Jan 2016 update)
Acidification Potential	A measure of emissions that cause acidifying effects to the environment. The acidification potential is a measure of a molecule's capacity to increase the hydrogen ion (H+) concentration in the presence of water, thus decreasing	kg SO_2 equivalent	(Guinée, et al., 2002) (CML-IA baseline method, Jan 2016 update)

Impact Category	Description	Unit	Reference
	the pH value. Potential effects include fish mortality, forest decline and the deterioration of building materials.		
Photochemical Ozone Formation Potential (POFP)	A measure of emissions of precursors that contribute to ground level smog formation (mainly ozone O_3), produced by the reaction of VOC and carbon monoxide in the presence of nitrogen oxides under the influence of UV light. Ground level ozone may be injurious to human health and ecosystems and may also damage crops.	kg NOx equivalent (human health)	(Huijbregts, et al., 2016)
Water Scarcity Footprint (WSF)	An assessment of water scarcity accounting for the net intake and release of fresh water across the life of the product system considering the availability of water in different regions.	Litres of water equivalent (H_2Oe)	(Boulay, et al., 2018)

Table 2-4: Life cycle inventory indicators

Indicator	Description	Unit	Reference
Material Circularity Indicator (MCI)	A measure of how restorative the material flows of a product are.	MCI score; 0-1	(Ellen MacArthur Foundation, 2015), (Goddin, 2020)
Primary Energy Demand (PED)	A measure of the total amount of primary energy extracted from the earth. PED is expressed in energy demand from non-renewable resources (e.g. petroleum, natural gas, etc.) and energy demand from renewable resources (e.g. hydropower, wind energy, solar, etc.). Efficiencies in energy conversion (e.g. power, heat, steam, etc.) are taken into account.	MJ, net calorific value	(Sphera, 2020)
Primary Energy Demand, Non-Renewable (PEDNR)	A measure of the total amount of non-renewable primary energy extracted from the earth. Efficiencies in energy conversion (e.g. power, heat, steam, etc.) are taken into account.	MJ, net calorific value	(Sphera, 2020)
Net use of fresh water (FW)	A measure of the net intake and release of fresh water across the life of the product system. This is not an indicator of environmental impact	Litres of water	(Sphera, 2020) following EN 15804

Indicator	Description	Unit	Reference
	without the addition of information about regional water availability.		
Hazardous waste disposed (HWD)	Hazardous waste sent to permanent disposal (e.g. destruction or specialist landfill).	kg	(Sphera, 2020) following EN 15804
Non-hazardous waste disposed (NHWD)	Hazardous waste sent to permanent disposal (e.g. landfill).	kg	(Sphera, 2020) following EN 15804

It shall be noted that the above impact categories represent impact *potentials*, i.e., they are approximations of environmental impacts that could occur if the emissions would (a) actually follow the underlying impact pathway and (b) meet certain conditions in the receiving environment while doing so. In addition, the inventory only captures the fraction of the total environmental load that corresponds to the functional unit (relative approach). LCIA results are therefore relative expressions only and do not predict actual impacts, the exceeding of thresholds, safety margins, or risks.

As this study intends to support comparative assertions to be disclosed to third parties, no grouping or further quantitative cross-category weighting has been applied. Instead, each impact is discussed in isolation, without reference to other impact categories, before final conclusions and recommendations are made.

2.7. Interpretation to Be Used

The interpretation (Chapter 5) addresses the following topics:

- Identification of significant findings, such as the main process step(s), material(s), and/or emission(s) contributing to the overall results
- Evaluation of completeness, sensitivity, and consistency to justify the exclusion of data from the system boundaries as well as the use of proxy data.
- Conclusions, limitations and recommendations.

Note that as no product outperforms all of its alternatives in each of the impact categories, some form of cross-category evaluation is necessary to draw conclusions regarding the environmental superiority of one product over the other. Since ISO 14044 rules out the use of quantitative weighting factors in comparative assertions to be disclosed to the public, this evaluation will take place qualitatively and the defensibility of the results therefore depend on the author's expertise and ability to convey the underlying line of reasoning that led to the final conclusion.

2.8. Data Quality Requirements

The data used to create the inventory model shall be as precise, complete, consistent, and representative as possible with regards to the goal and scope of the study under given time and budget constraints.

- Measured primary data are considered to be of the highest precision, followed by calculated data, literature data, and estimated data. The goal is to model all relevant foreground processes using measured or calculated primary data.
- Completeness is judged based on the completeness of the inputs and outputs per unit process and the completeness of the unit processes themselves. The goal is to capture all relevant data in this regard.
- Consistency refers to modelling choices and data sources. The goal is to ensure that differences in results reflect actual differences between product systems and are not due to inconsistencies in modelling choices, data sources, emission factors, or other artefacts.
- Reproducibility expresses the degree to which third parties would be able to reproduce the results of the study based on the information contained in this report. The goal is to provide enough transparency with this report so that third parties are able to approximate the reported results. This ability may be limited by the exclusion of confidential primary data and access to the same background data sources.
- Representativeness expresses the degree to which the data matches the geographical, temporal, and technological requirements defined in the study's goal and scope. The goal is to use the most representative primary data for all foreground processes and the most representative industry-average data for all background processes. Whenever such data were not available (e.g., no industry-average data available for a certain country), best-available proxy data were employed.

An evaluation of the data quality with regard to these requirements is provided in Chapter 5 of this report.

2.9. Type and Format of the Report

In accordance with the ISO requirements (ISO, 2006) this document aims to report the results and conclusions of the LCA completely, accurately and without bias to the intended audience. The results, data, methods, assumptions and limitations are presented in a transparent manner and in sufficient detail to convey the complexities, limitations, and trade-offs inherent in the LCA to the reader. This allows the results to be interpreted and used in a manner consistent with the goals of the study.

2.10. Software and Database

The LCA model was created using the GaBi Software system for life cycle engineering, developed by Sphera Solutions, Inc. The GaBi 2020 LCI database (service pack 40) provides the life cycle inventory data for the raw and process materials obtained from the background system.

2.11. Critical Review

As this study is intended to provide comparative assertions that may be made available to the public, ISO14044:2006 requires that it undergo a critical review. This critical review has been conducted by a panel of independent parties at the end of the study:

- Andrew D Moore, Life Cycle Logic (Fremantle, Western Australia)
- Helen Lewis, Helen Lewis Research (Austinmer, New South Wales, Australia)
- Kimberly Robertson, Catalyst Ltd (Rotorua, New Zealand)

The Critical Review Statement can be found in Annex A. The Critical Review Report containing the comments and recommendations by the independent expert(s) as well as the practitioner's responses is available in Annex E.

3. Life Cycle Inventory Analysis

3.1. Data Collection Procedure

The primary data collected in this study includes the mass and material composition of the courier bags. Primary data was collected by New Zealand Post's supplier Sealed Air. Secondary data from the GaBi LCA Database was used for all manufacturing operations.

3.1.1. Product Composition

The material composition of the investigated courier bags can be seen in Table 3-1. Due to the sensitive nature of the compositions of some bags, Table 3-1 displays only high-level information. An exact breakdown of composition and mass can be found in Annex B.

Table 3-1: Material composition of the courier bags

Courier Bag	Materials	Mass (g±5%)
Virgin LDPE	LDPE with 100% virgin content, colouring pigment and plastic sealing strip	5.03
Recycled LDPE (NZ & CN)	LDPE with 80% recycled content, colouring pigment and plastic sealing strip	5.23
Home Compostable Bag	Ecoflex, corn starch, Ecovio, colouring pigment and plastic sealing strip	7.27
Flat Paper Bag	Kraft paper envelope with EVA adhesive and siliconized paper sealing strip	37.88
Padded Paper Bag	Kraft paper envelope padded with shredded newspaper, sealed using EVA and PVA adhesive, with siliconized paper sealing strip	75.11

3.1.2. Manufacturing

This section describes the processes modelled for the manufacture of each courier bag. For all courier bags detailed below, it is assumed that all domestic transportation occurs by trucking and all international transportation occurs by sea freight.

Virgin LDPE Courier Bag

The virgin LDPE bags consist of a single layer of plastic film mixed with a colouring pigment. The virgin LDPE resin and pigment are both sourced from within China, compounded and extruded together in a single process to form the plastic film. The colouring pigment is added at a 4% rate, by mass, and consists of 50% titanium dioxide and 50% virgin LDPE.

The produced film then has the desired imagery and information printed on its surface before being folded and heat sealed along its edges to form a bag. Offcuts which are produced in both the extrusion and trimming processes are recycled by being used in the next manufacturing cycle.

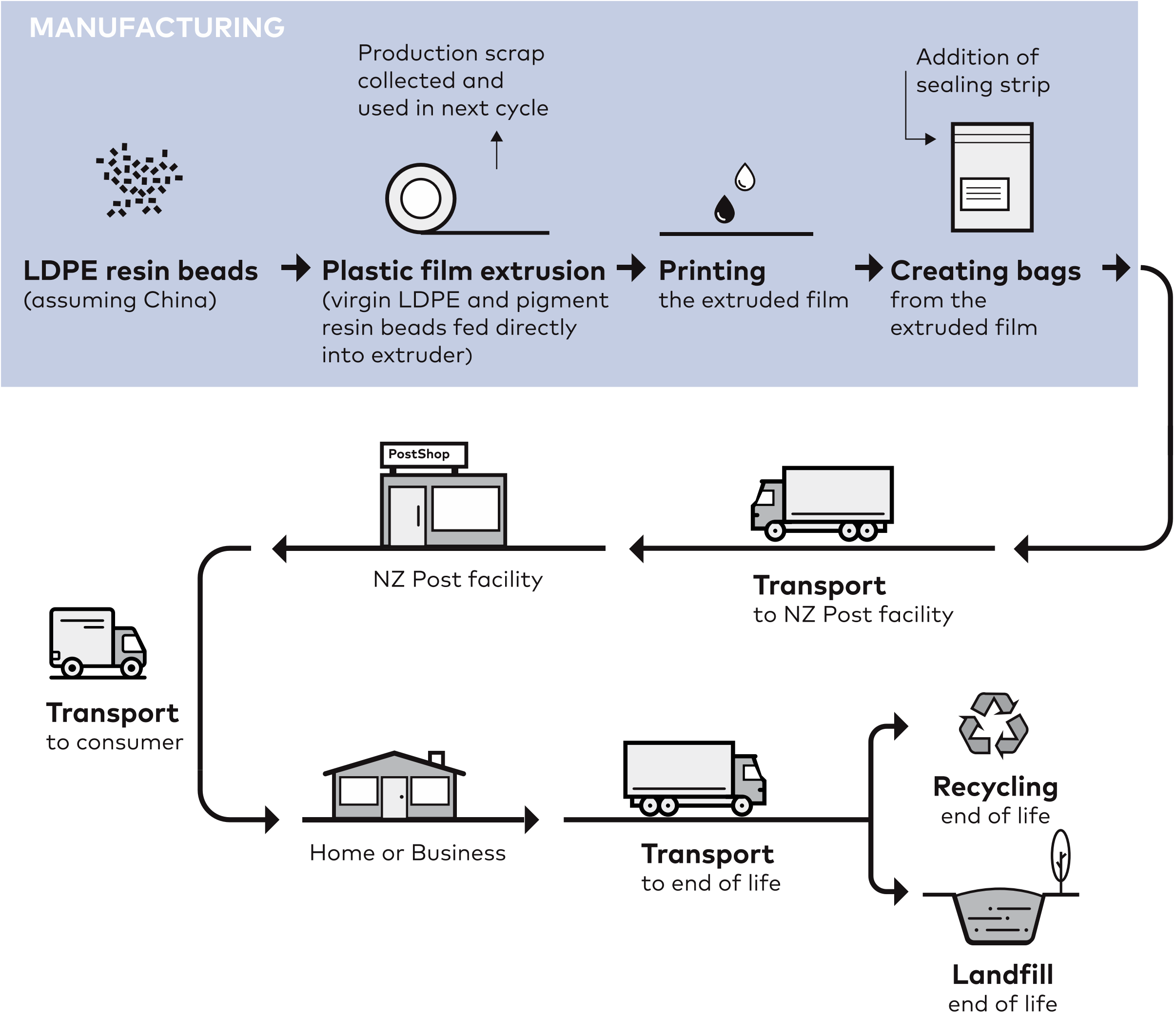


Figure 3-1: Virgin LDPE bag manufacturing stages

Recycled LDPE Courier Bag (NZ)

The bags with recycled content are identical in design to the virgin LDPE bags. However, they have a slight increase in film thickness to account for any decrease in physical performance as a result of the LDPE recycling process.

The recycled granulate which makes up 80% of the courier bag by mass is sourced from post-industrial soft plastic offcuts that would otherwise be sent to landfill. 80% of the total recycled granulate is sourced from New Zealand and the remaining 20% is imported from Australia. To produce the recycled granulate, the plastic offcuts are first shredded and washed before being melted, extruded and granulated.

A process similar to the production of a virgin LDPE bag is used to form the bag. As a result of the recycling stage, there is an additional compounding and granulating stage in production. Recycled LDPE granulate, virgin LDPE granulate, and colouring pigment are mixed with a 20:4:1 ratio, respectively. The colouring pigment is the same as the one used in the virgin LDPE bag and consists of 50% titanium dioxide and 50% virgin LDPE by mass.

The produced film then has imagery and information printed on its surface. The printed film is then folded and has its edges heat sealed to form a bag. Trimmed offcuts in the extrusion and forming processes are recovered for use in the next manufacturing cycle.

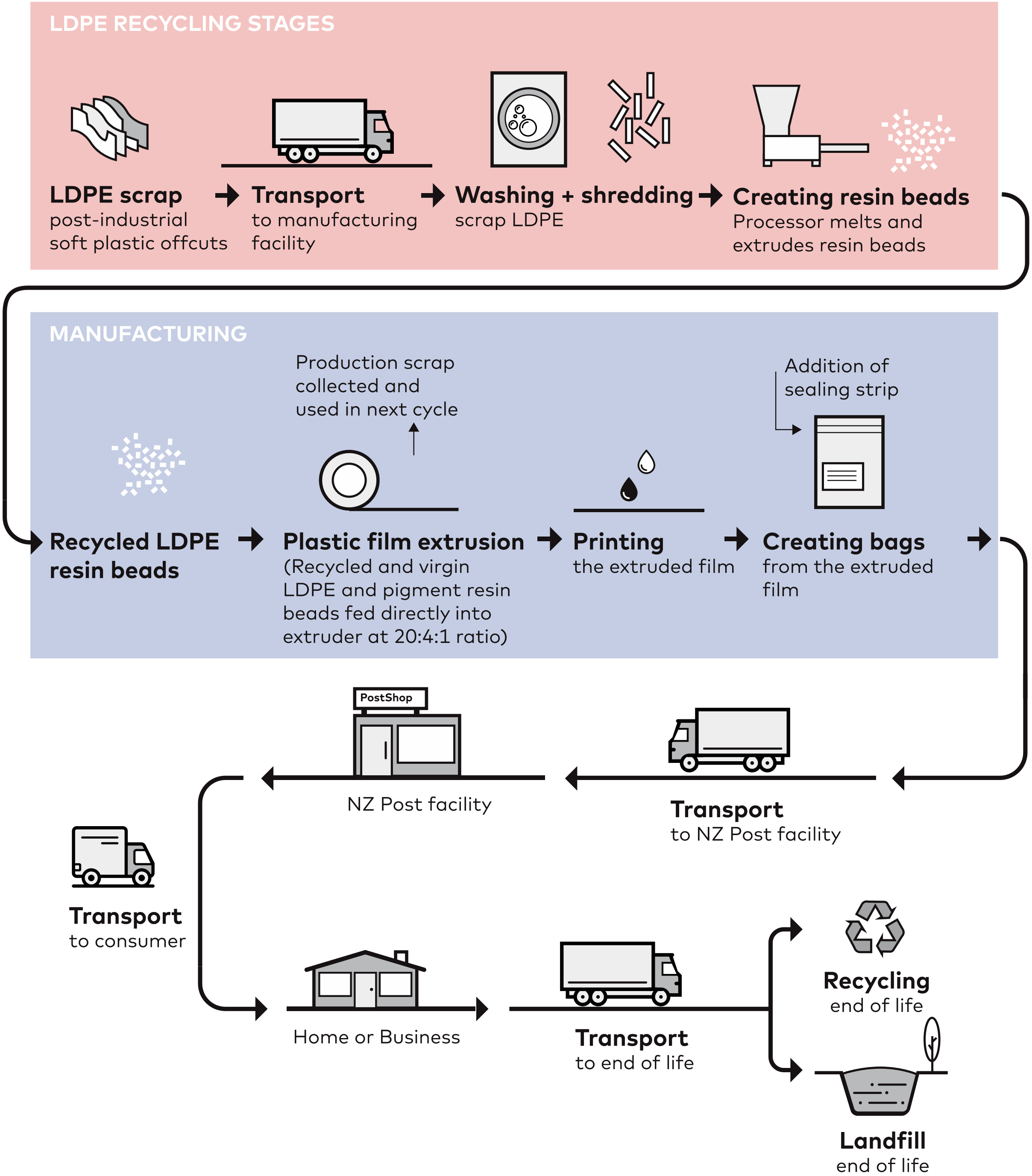


Figure 3-2: Recycled LDPE courier bag manufacturing stages

Recycled LDPE Courier Bag (CN)

In the case of a courier bag made from 80% recycled LDPE in China, the material is assumed to all be sourced from within China instead of a New Zealand Australian mix. While the materials used originate from different locations to the NZ manufactured recycled LDPE bag, there is no difference assumed in the manufacturing process described previously and seen in Figure 3-2.

Home Compostable Courier Bag

Similar to the previous plastic bags, the home compostable bag is made from a single extruded plastic film but consists of a mixture of biodegradable compounds. The thickness of the home compostable bag is the greatest of all the films to account for its lower tear resistance. The home compostable bag is assumed to be produced in a similar process as the recycled LDPE bag and is manufactured in China.

A single compounding stage is used to homogenise Ecoflex granulate, Ecovio granulate, corn starch and a colouring pigment (titanium dioxide) before it is extruded as a film. The produced film then has any desired imagery and information printed on its surface. The printed film is then folded and has its edges heat sealed to form a bag. Offcuts produced at any stage are sent to landfill.

An overview of the manufacturing stages for the home compostable bag can be seen below in Figure 3-3.

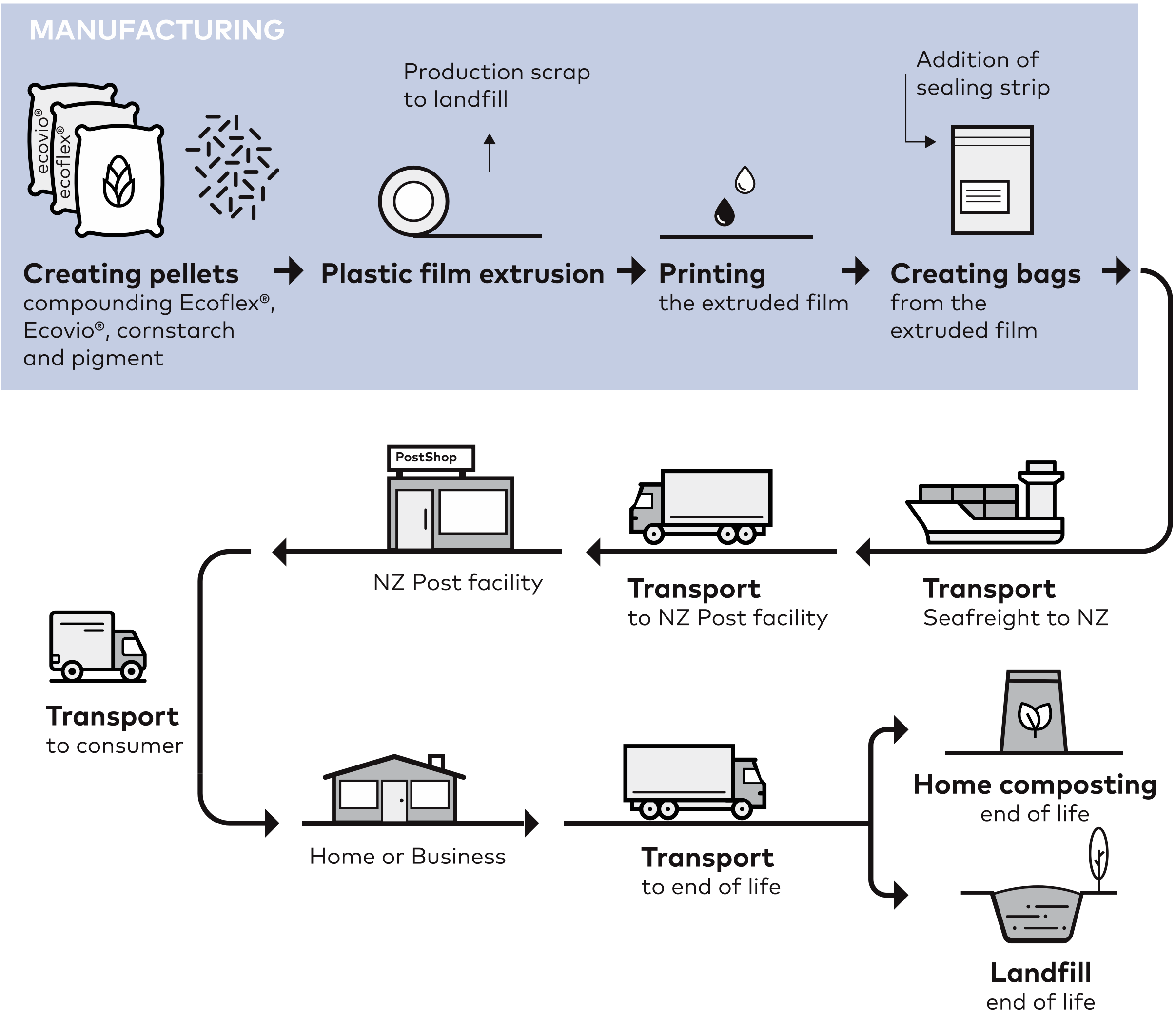


Figure 3-3: Home compostable courier bag manufacturing stages

Flat Paper Courier Bags

The flat paper bags are manufactured in Victoria, Australia. Kraft paper is purchased in sheets before having the envelope blanks cut out. The blanks are then folded and sealed with a combination of EVA and PVA adhesives to form an envelope. The final stage of production is adding the additional strip of adhesive which the user later utilises to seal the envelope. To maintain the functionality of the sealing strip, it is protected by a siliconized strip of paper.

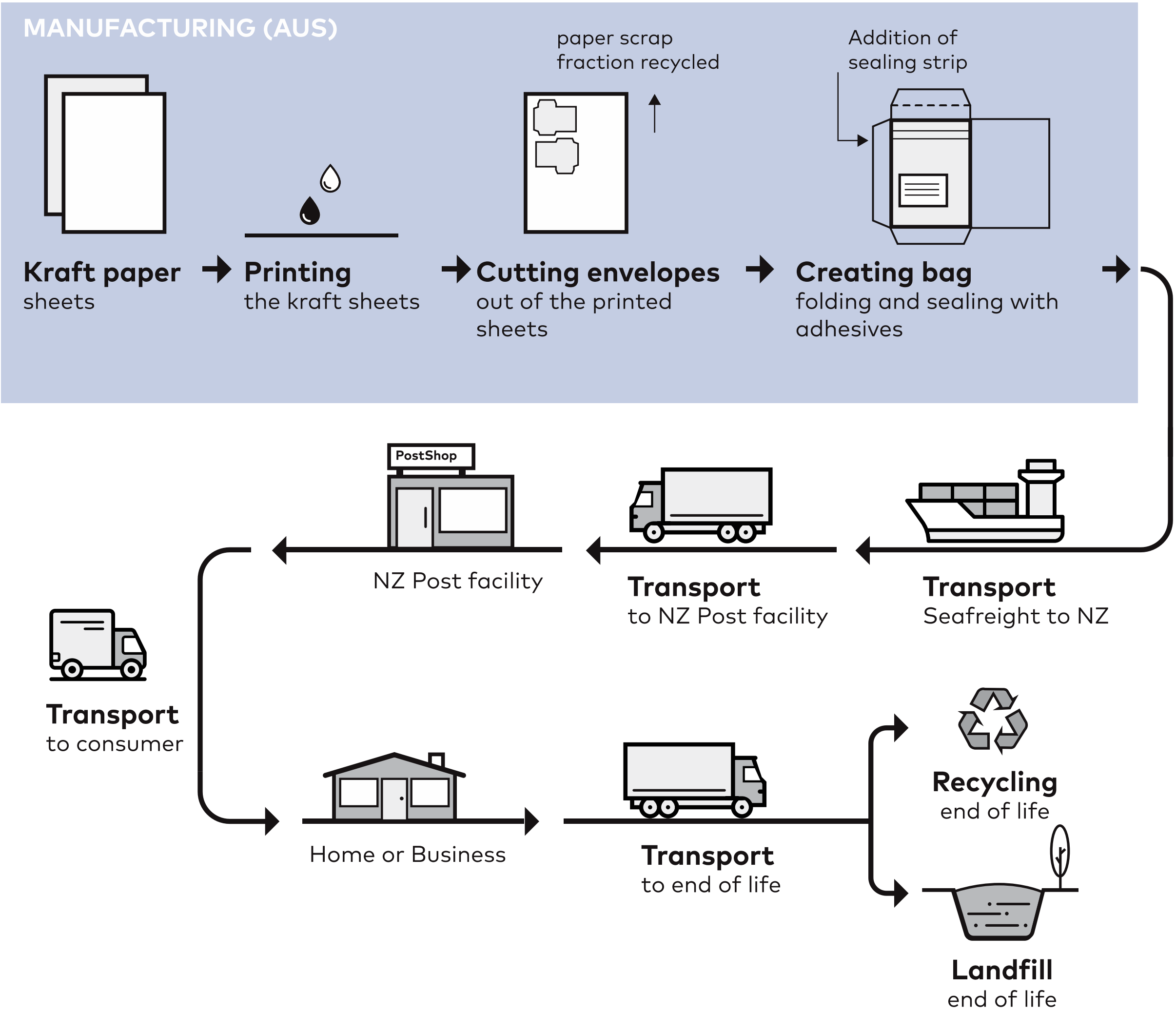


Figure 3-4: Flat paper courier bag manufacturing stages

Padded Paper Courier Bags

The padded paper bags are manufactured in Victoria, Australia in a similar way to the flat paper bags above. The kraft paper is purchased in sheets before having the envelope blanks cut out. Scrap newspaper is trucked in from a facility 50 km away before being shredded on site. To ensure the shredded newspaper remains evenly distributed within the courier bag walls, the cut envelope blank has PVA adhesive applied to the interior surface. The blanks, with shredded newspaper, are then folded and sealed with EVA adhesive to form an envelope. The final stage of production is adding the additional strip of adhesive which the user later utilises to seal the envelope. To maintain the functionality of the sealing strip, it is protected by a siliconized strip of paper.

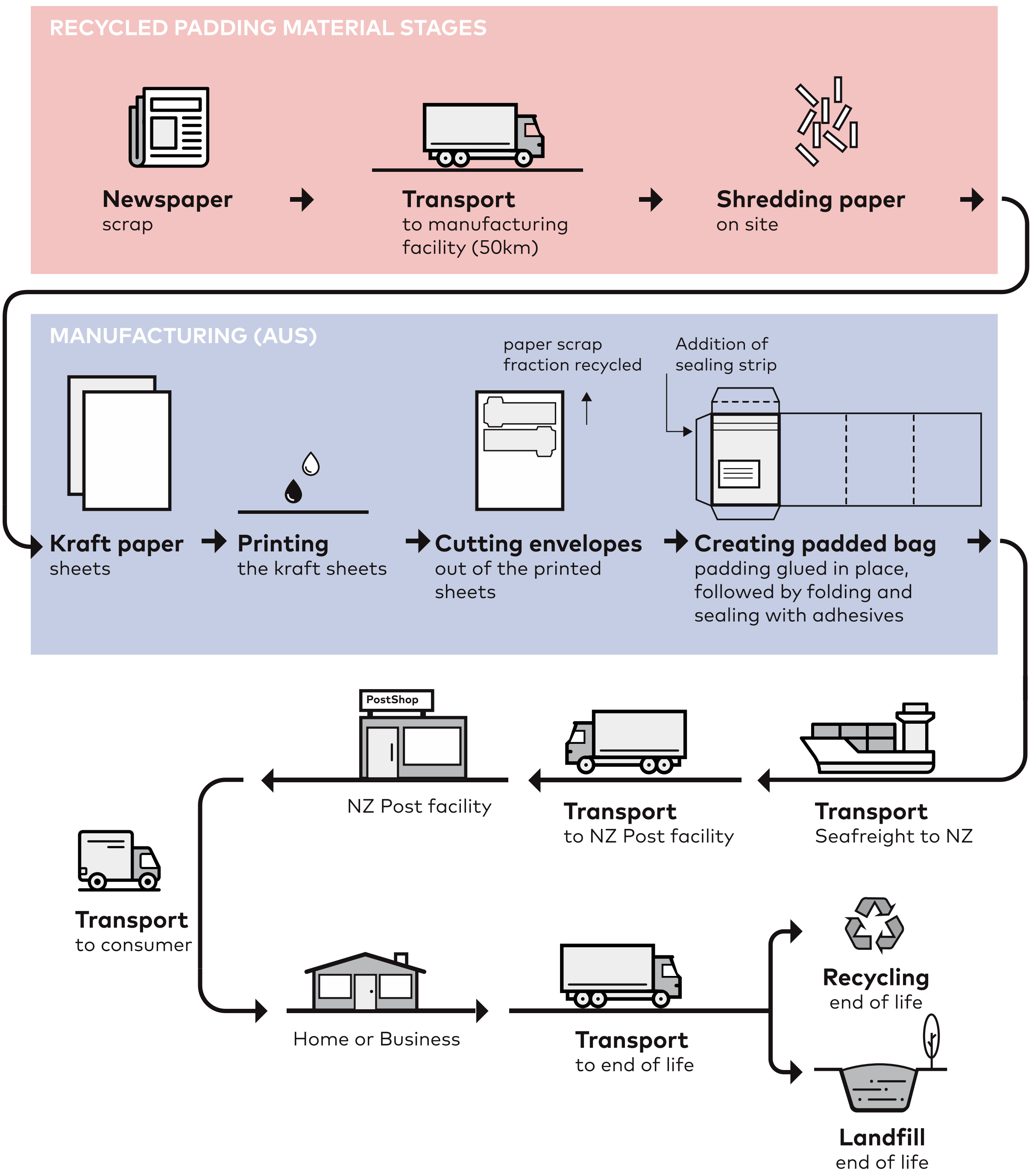


Figure 3-5: Padded paper courier bag manufacturing stages

3.1.3. Distribution

After manufacture, courier bags are transported to NZ Post distribution centres through a combination of trucking and sea freight (if they are manufactured outside of New Zealand). The courier bags are then trucked to customers during the use phase and then again to end-of-life treatment. While the international travel distances vary between products, the trucking distances travelled within NZ remains consistent for the use phase. The only exception to distribution in the end-of-life scenarios is in the case of home composting, where no further travel is required. The breakdown of the distribution distances from the manufacturers to NZ Post's facility are found in Table 3-2. All shipping distances have been calculated as the distance between the port of

Auckland and either the port of Shanghai or the port of Sydney using the online sea route distance calculator: http://ports.com/sea-route/. A national trucking distance of 150km for all courier bags has been selected as this is the distance between the port of Auckland and the NZ Post sorting facility in Hamilton.

Table 3-2: Distribution distances of bags to reach the NZ Post facility

Courier Bag	International shipping distance (km)	National trucking distance to NZ Post (km)
Virgin LDPE bag	11,578	150
Recycled LDPE bag (NZ)	NA	150
Recycled LDPE bag (CN)	11,578	150
Home compostable bag	11,578	150
Flat paper bag	2,463	150
Padded paper bag	2,463	150

3.1.4. Use

The use phase is modelled as trucking from NZ Post to the consumer, estimated as 75km.

3.1.5. End-of-Life

All products have two end-of-life scenarios depending on the material they are made from. The first scenario assumes the courier bags are sent to landfill. The second scenario is recycling or, in the case of the home compostable bag, composting.

In the landfill scenario, plastic bags are considered inert. The impacts from landfilling inert material are a result of the 25km of trucking to the landfill and the further processes which are involved with physically landfilling the product.

Landfilling of the home compostable and paper materials are modelled using a customised landfill model built by thinkstep-anz. While neither the home compostable bag nor paper bags are inert, they do not completely breakdown in landfill. The degree of degradation of the paper bags is assumed to be 49% of its mass in all cases (Australian Government, 2019a) with the remaining 51% of the paper bags being sequestered.

As the compostable plastic and paper break down in the absence of oxygen when placed in a landfill, they form a mixture of carbon dioxide and methane known as landfill gas. The landfill gas production and capture rates are significant due to the potency of methane as a greenhouse gas. In this model there is a 1:1 ratio of the degraded material mass into CO_2 and methane gas. The carbon content of the degradable portions (excluding pigments and adhesives) of the two bags are 59.2% and 45% for the compostable bag and paper bags, respectively.

The methane capture rates for specific landfills can range from 0% (uncovered landfill with no gas collection) to near 100% (covered landfill with highly effective gas collection). Large, modern landfills within New Zealand typically have high rates of gas collection, though older and smaller landfills can have limited or no gas collection. For landfills that do capture gas, instantaneous collection efficiencies can range from 50% to near 100% (Barlaz, et al., 2009). When weighted over the lifetime of the landfill, collection efficiencies range between 55% and 91% (Barlaz, et al., 2009).

The baseline results within this body of this report apply weighted national average gas collection rates for New Zealand. The weighted national average methane capture rate has been calculated as 53% by the author, based on a list of landfills with/without landfill gas collection (Ministry for the Environment, 2019), the estimated population served by each landfill, and an assumed lifetime landfill gas collection effectiveness of 85% (Hyder Consulting Group, 2007).

In comparison, GaBi's standard landfill datasets assume a gas capture rate of 50% in Europe, and 64% in the United States (Sphera, 2020).

After capture, it is assumed that 25% of all landfill gas is flared with the remaining 75% used for energy recovery in an alternator/generator (Carre, 2011). For the remaining methane which escapes, 10% is assumed to be oxidized to form CO_2 as it permeates through the soil cover of the landfill.

Any products which are to be recycled are modelled using the cut-off method described previously. As a result, the only impacts from recycling are due to the transportation of material to a recycling facility which is assumed to be 25km away for all products.

To model the composting of the home compostable bag, a commercial windrow process has been used. The impacts arising from diesel, electricity and machine oil use in commercial composting has a minimal impact does not significantly change the impacts of composting (Anderson, 2010) and therefore commercial composting is an appropriate conservative proxy. No transport distance is associated with the home composting as the process is assumed occur on their property.

In the process of composting, 90% of the mass of the product is assumed to degrade and the remaining 10% stays sequestered as organic material (Greene, 2007). As composting is assumed to be conducted in an aerobic environment, only 0.9% of the degraded carbon is released as methane (IPCC, 2006).

3.2. Background Data

3.2.1. Fuels and Energy

A mixture of national and regional averages for both fuel inputs and electricity grid mixes were obtained from the GaBi 2020 databases. Table 3-3 shows the most relevant LCI datasets used in modelling the product systems. Electricity consumption was modelled using national and regional grid mixes which account for importation of electricity from neighbouring regions where appropriate.

Documentation for all GaBi datasets can be found at http://gabi-software.com/support/gabi/gabi-database-2020-lci-documentation/

The proxy column is used to indicate whether a dataset accurately represents the desired material or process. A No* indicates the use of a geographical proxy where the region of manufacture is expected to have little influence on its environmental profile. A Yes* indicates the use of a geographical proxy where the region of manufacture is expected to materially influence its environmental profile.

Note that all GaBi datasets have their upstream energy (and any upstream energy present in their upstream materials) updated at least annually. In addition, all GaBi datasets are updated whenever the technology or geographical mix of the producers of a product changes significantly.

Table 3-3: Key energy datasets used in inventory analysis

Energy	Location	Dataset	Data Provider	Reference Year	Proxy?
Electricity	NZ	Electricity grid mix 1kV-60kV	Sphera	2016	No
Electricity	AU	Electricity grid mix 1kV-60kV (VIC)	Sphera	2016	No
Electricity	CN	Electricity grid mix 1kV-60kV	Sphera	2016	No
Thermal Energy	NZ	Thermal energy from natural gas	Sphera	2016	No
Thermal Energy	CN	Thermal energy from natural gas	Sphera	2016	No

As electricity was consistently found to be an emissions hotspot the breakdown of each country's electricity grid mix can be found below in Table 3-4. As New Zealand's electricity grid can change between years, a sensitivity study was conducted in section 4.4.

Table 3-4: Electricity generation methods of utilised grid mixes in 2016

Grid Mix	Electricity Generation Method	National Grid Composition (%)
New Zealand National Grid	Hydro	59.88%
	Geothermal	17.28%
	Natural Gas	13.49%
	Wind	5.36%
	Coal Gases	1.40%
	Hard Coal	1.01%
	Biomass	0.77%
	Biogas	0.64%
	Other	0.17%
State of Victoria, Australia Grid	Lignite	80.02%
	Hydro	6.27%
	Wind	6.25%
	Natural Gas	3.24%
	Imported from Tasmania	2.35%
	Imported from New South Wales	1.14%
	Imported from South Australia	0.68%
	Other	0.05%
China National Grid	Hard Coal	66.76%
	Hydro	19.19%
	Wind	3.81%
	Nuclear	3.43%
	Natural Gas	2.74%
	Coal Gases	1.46%
	Photovoltaic	1.21%

Grid Mix	Electricity Generation Method	National Grid Composition (%)
	Biomass	1.04%
	Other	0.36%

3.2.2. Raw Materials and Processes

Data for upstream and downstream raw materials and unit processes were obtained from the GaBi 2020 database. Table 3-5 shows the most relevant LCI datasets used in modelling the product systems. Where inputs where modelled with components, the components' datasets and relative percentages are included. Documentation for all GaBi datasets can be found at http://gabi-software.com/support/gabi/gabi-database-2020-lci-documentation/.

Table 3-5: Key material and process datasets used in modelling

Material/ process	Geo	Dataset	(%)	Data Provider	Year	Proxy?
Plastic Film Extrusion	GLO	Plastic Film (PE, PVC, PVC)	-	Sphera	2019	No
Virgin LDPE	CN	Polyethylene Low Density Granulate	-	Sphera	2019	No
Colour Pigment	MY	Titanium Dioxide Pigment (chloride process)	-	Sphera	2019	No*
Ecoflex	CN	Polyethylene terephthalate granulate (PET) via DMT	-	Sphera	2019	Yes
Corn Starch	CN	Corn Wet Mill (starch slurry) (mass allocation)	-	Sphera	2019	No
Corn Grain	CN	Corn grain cultivation (35% H2O content)	-	Sphera	2019	No
Paper	EU-28	Kraft paper (EN15804 A1-A3)	-	Sphera	2019	Yes*
Adhesive	EU-28	Starch glue (for paper/cardboard)	-	Sphera	2019	No*
Granulator	DE	Granulator	-	Sphera	2019	No*
Washing	DE	Washing (plastic recycling)	-	Sphera	2019	No*
Pelletizing and compounding	DE	Pelletizing and compounding	-	Sphera	2019	No*
Paper Adhesive Seal						
Silicone	DE	Silicone rubber (RTV-2, condensation)		Sphera	2019	No*

Material/ process	Geo	Dataset	(%)	Data Provider	Year	Proxy?
Paper	EU-28	Kraft paper (EN15804 A1-A3)[1]		Sphera	2019	Yes*
Plastic Adhesive Seal						
Silicone	DE	Silicone rubber (RTV-2, condensation)		Sphera	2019	No*
Plastic Strip		Biaxially Orientated Polypropylene		Sphera	2019	No
Ecovio						
PLA	DE	Polylatic acid (PLA), polylactide, continuous process)	20%	Sphera	2019	No*
Ecoflex	CN	Polyethylene terephthalate granulate (PET) via DMT	80%	Sphera	2019	Yes
Others						
Newspaper	-	(Burden-free due to cut-off allocation method)	-	-	-	No
Landfill of home compostable / paper bags	NZ	Landfill for wood products (cut-off allocation)	-	thinkstep-anz	2020	Yes
Plastic on landfill	EU-28	Plastic waste on landfill	-	Sphera	2019	No*
Home Composting	NZ	Composting (excl. biogenic CO2 release) windrow	-	(UNSW, 2006) and (IPCC, 2006)	2006	Yes
Recycling	-	(Burden-free due to cut-off allocation method)	-	-	-	No

* The GaBi/FEFCO kraft paper dataset has been modified to reflect the carbon footprint of the paper supplier, Opal Paper Australia. The carbon footprint of their paper products is 2.50 $kgCO_2e/kg$ (Paper Australia Pty Ltd, 2019). No adjustments have been made for other indicators due to a lack of data.

Table 3-6 to Table 3-10 show the key mass and energy flows from cradle-to-gate for a single courier bag. It is assumed that all energy inputs to the system are lost as waste heat.

Table 3-6: Key material flows for the manufacturing of the virgin LDPE courier bag

Input	Quantity Unit
Electricity	1.48E-02 MJ
Thermal energy from natural gas	1.02E-03 MJ
Virgin LDPE (courier bag)	4.80E-03 kg
Colouring pigment	9.79E-05 kg
Sealing strip	1.43E-04 kg
Lubricants	9.81E-07 kg
Virgin LDPE (secondary packaging)	2.30E-04 kg
Corrugated box (secondary packaging)	3.80E-04 kg
Wooden pallet (secondary packaging)	3.13E-04 kg
Output	
Virgin LDPE courier bag	5.03E-03 kg
Waste to landfill	6.84E-06 kg
Secondary packaging for reuse/disposal	9.23E-04 kg

Table 3-7: Key material datasets for the manufacturing of the LDPE courier bags (NZ & CN)

Input	Quantity Unit
Electricity	2.40E-02 MJ
Thermal energy from natural gas	7.32E-03 MJ
Virgin LDPE (courier bag)	9.17E-04 kg
Recycled LDPE (courier bag)	4.08E-03 kg
Colouring pigment	1.02E-04 kg
Sealing strip	1.43E-04 kg
Lubricants	1.02E-06 kg
Ground water	1.29E-02 kg
Virgin LDPE (secondary packaging)	2.30E-04 kg
Corrugated box (tertiary packaging)	3.80E-04 kg
Wooden pallet (tertiary packaging)	3.13E-04 kg
Output	
rLDPE courier bag	5.23E-03 kg
Waste to landfill	7.12E-06 kg
Processed water to river	1.29E-02 kg
Secondary packaging for reuse/disposal	9.23E-04 kg

Table 3-8: Key material flows for the manufacturing of the home compostable courier bag

Input	Quantity Unit
Electricity	2.17E-02 MJ
Thermal energy from natural gas	1.47E-03 MJ
Corn starch	7.35E-03 kg
PBAT	3.68E-03 kg
Ecovio	1.15E-03 kg
Colour pigment	1.58E-04 kg
Sealing strip	1.91E-04 kg
Lubricants	1.42E-06 kg
Virgin LDPE (secondary packaging)	2.41E-04 kg
Corrugated box (tertiary packaging)	8.00E-04 kg
Wooden pallet (tertiary packaging)	3.70E-04 kg
Output	
Home compostable bag	7.46E-03 kg
Water vapour	4.80E-03 kg
Waste to landfill	2.81E-04 kg
Secondary packaging for reuse/disposal	1.41E-03 kg

Table 3-9: Key material flows for the manufacturing of the flat paper courier bag

Input	Quantity Unit
Electricity	7.58E-03 MJ
Kraft paper	3.34E-02 kg
Starch glue	4.14E-03 kg
Siliconized paper	2.00E-03 kg
Virgin LDPE (secondary packaging)	2.88E-04 kg
Corrugated box (tertiary packaging)	4.40E-03 kg
Wooden pallet (tertiary packaging)	4.69E-03 kg
Output	
Flat courier bag	3.79E-02 kg
Waste paper for recycling	1.64E-03 kg
Secondary packaging for reuse/disposal	9.38E-03 kg

Table 3-10: Key material flows for the manufacturing of the padded paper courier bag

Input	Quantity	Unit
Electricity	1.50E-02	MJ
Kraft paper	2.65E-02	kg
Starch glue	4.14E-03	kg
Siliconized paper	2.00E-03	kg
Newspaper	4.38E-02	kg
Virgin LDPE (secondary packaging)	6.02E-04	kg
Corrugated box (tertiary packaging)	1.50E-03	kg
Wooden pallet (tertiary packaging)	4.69E-04	kg
Output		
Padded courier bag	7.51E-02	kg
Waste paper for recycling	1.35E-03	kg
Secondary packaging for reuse/disposal	6.79E-03	kg

3.2.3. Transportation

Average transportation distances and modes of transport are included for the transport of the raw materials, operating materials, and auxiliary materials to production and assembly facilities.

The GaBi 2020 database was used to model transportation. Transportation was modelled using global transportation datasets. Fuels were modelled using Australian data as a proxy for New Zealand. The default parameters were used for all transportations processes except distance and utilisation (in the case of end-of-life transportation). Utilisation for end-of-life treatment transport was set to a value of 0.5 (50%).

Table 3-11: Transportation and fuel datasets

Mode / fuels	Geographic Reference	Dataset	Data Provider	Reference Year	Proxy?
Truck	GLO	Euro 0 – 6 mix, 20 – 26t gross weight / 17.3t payload capacity	Sphera	2019	No
Truck	GLO	Euro 0 – 6 mix, up to 7.5 t gross weight / 2.7t payload capacity	Sphera	2019	No
Container Ship	GLO	Container ship, 5,000 to 200,000 dwt payload capacity, ocean going	Sphera	2019	No
Diesel	AU	Diesel mix at filling station	Sphera	2016	No*
Heavy Fuel	AU	Heavy fuel oil at refinery (2.5wt.% S)	Sphera	2016	No*

3.2.4. End-of-Life and Recovery

The processes used to model the different end-of-life options for the courier bags after delivery to consumers can be seen in Table 3-12.

Table 3-12: End-of-life processes

Process	Geographic Reference	Dataset	Data Provider	Reference Year	Proxy?
Plastic on landfill	EU-28	Plastic waste on Landfill	Sphera	2019	No*
Degradable materials on landfill	NZ	Landfill for wood products	thinkstep-anz	2020	Yes
Home composting	NZ	Composting (excl. biogenic CO2 release) windrow	(UNSW, 2006) and (IPCC, 2006)	2006	Yes
Recycling	N/A	N/A	N/A	N/A	No

4. Results Analysis

This chapter contains the results for the impact categories and additional metrics defined in section 2.6. It shall be reiterated at this point that the reported impact categories represent impact potentials, i.e., they are approximations of environmental impacts that could occur if the emissions would (a) follow the underlying impact pathway and (b) meet certain conditions in the receiving environment while doing so. In addition, the inventory only captures that fraction of the total environmental load that corresponds to the chosen functional unit (relative approach).

LCIA results are therefore relative expressions only and do not predict actual impacts, the exceeding of thresholds, safety margins, or risks.

The results for the Material Circularity Indicator have been calculated using an updated version of the tool prepared by James Goddin, one the original tool's co-creators (Goddin, 2020). The updated version now accounts for bio-based materials, which was out of scope in the original version (Ellen MacArthur Foundation, 2015). Importantly for this analysis, the default full-system recycling efficiencies have been applied (which is only 22% for plastics). New Zealand Post could theoretically put in place systems to improve these recycling efficiencies, which would then improve the MCI score; however, this is left for an area of future work and out of scope of the current analysis.

It is important to note that the kraft paper for the flat paper and padded paper courier bag is sourced from Opal's Maryvale Paper Mill (formerly Australian Paper) in Victoria, Australia. The kraft paper has been modelled using data for average European kraft paper manufacture from the European Corrugated Packaging Association (FEFCO, 2019). The carbon footprint of the GaBi/FEFCO dataset is 0.46 kg CO_2e per kg of paper versus Opal's 2.50 kg CO_2e per kg of paper (Paper Australia Pty Ltd, 2019). A manual correction factor for the additional fossil fuel carbon emissions has been applied, meaning that the carbon footprint results correctly reflect the real supply chain. However, all remaining indicators are modelled using the GaBi/FEFCO data. This large difference in carbon footprint suggests that a much larger share of Opal's energy comes from fossil fuel sources rather than renewable sources. The outcome of this is that most of the other environmental indicators for the flat paper and padded paper bags are likely underestimated, and the real paper bags would likely have higher impacts than those reported in this study. This is particularly true for abiotic depletion of fossil fuels (ADPF) and also for indicators that are affected by fossil fuel combustion, such as photochemical ozone formation potential (POFP), acidification potential (AP) and eutrophication potential (EP).

4.1. Assessment Results

Table 4-1: GWP and MCI assessment results for each potential courier bag

Scenario	GWP (kg CO2-eq.)	Relative GWP* (%)	MCI (0-1)
Landfilled at end-of-life			
Virgin LDPE Bag	0.0178	100%	0.1
Recycled LDPE Bag NZ	0.0067	38%	0.2
Recycled LDPE Bag CN	0.0108	61%	0.2
Home Compostable Bag	0.0555	310%	0.1
Flat Paper Bag	0.1747	970%	0.1
Padded Paper Bag	0.2317	1300%	0.4
Recycled at end-of-life			
Virgin LDPE Bag	0.0174	98%	0.1
Recycled LDPE Bag NZ	0.0063	35%	0.3
Recycled LDPE Bag CN	0.0104	58%	0.3
Home Compostable Bag	0.0448	250%	0.5
Flat Paper Bag	0.1067	600%	0.5
Padded Paper Bag	0.0967	540%	0.6

*Results for relative results are compared to a virgin LDPE bag landfilled at end-of-life.

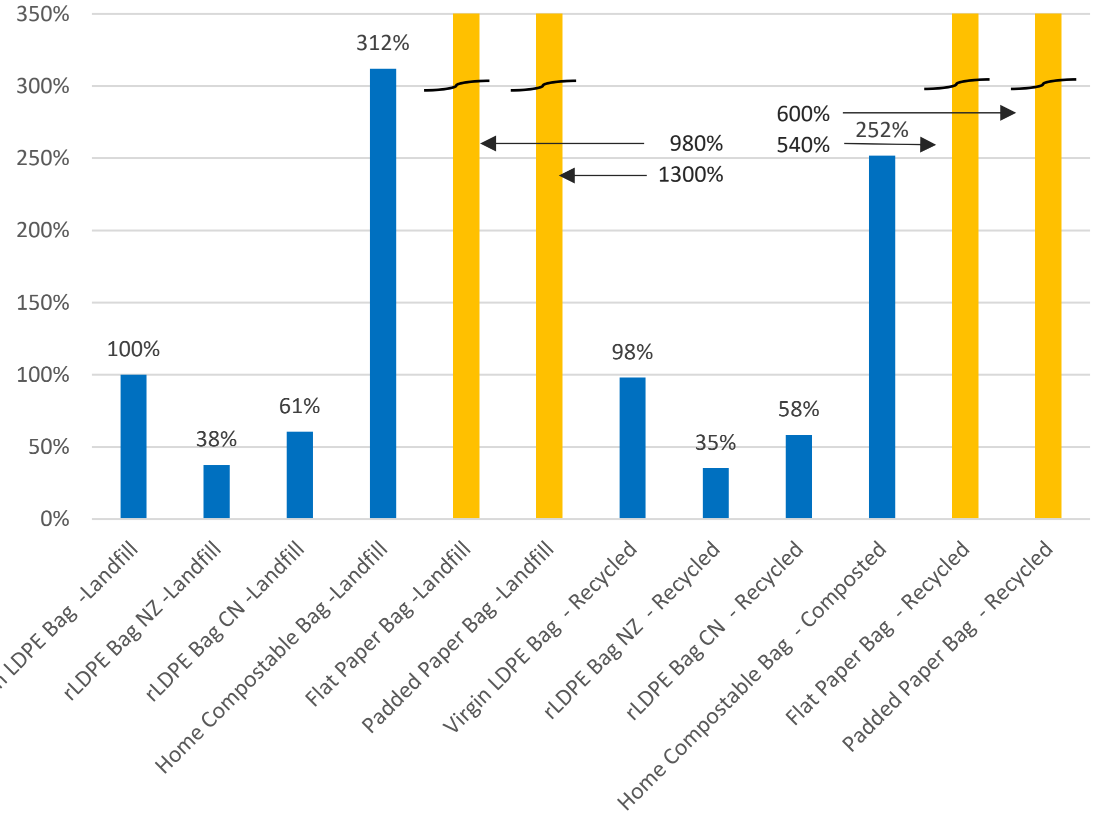


Figure 4-1: Relative GWP impact for each courier bag compared to the virgin LDPE bag

Figure 4-1 displays the relative GWP, measured in carbon dioxide equivalent emissions ($kgCO_2$-eq.), for each courier bag when compared to the virgin LDPE bag. The scale of Figure 4-1 has been limited to a maximum of 350% of the virgin LDPE bag, landfilled at end-of-life, for ease of interpreting the comparative performance of the best courier bag alternatives. The impacts from the paper bags, under both end-of-life scenarios, exceed the 350% limit and have been highlighted orange; their impacts can be found in Table 4-1. For a breakdown of the Figure 4-1 impacts into the three main life cycle stages – manufacturing, transport and end-of-life – please refer to the executive summary.

Table 4-2 quantifies the benefits gained by New Zealand Post if they were to switch to the recycled LDPE courier bag, since it is the highest performing bag. The benefits have been compared to the remaining investigated bags and is with respect to reductions in GWP. Multiple scenarios are given to show how the reductions in GWP change depending on the compared scenarios. As discussed in section 4.3.2, the most appropriate end-of-life allocation method has been deemed to be the cut-off method. Therefore, if the courier bags were switched from virgin LDPE to New Zealand manufactured rLDPE a global warming potential reduction of at least 2.6 times could be claimed.

Table 4-2: Relative GWP reductions compared to the rLDPE Bag (NZ)

Comparative Product	Cut off (landfilled)	Cut off (recycled)	Substitution method (landfilled)	Substitution method (recycled)
Virgin LDPE Bag	2.6	2.7	1.3	1.8
Recycled LDPE Bag CN	1.6	1.6	1.1	1.4
Bioplastic Bag	8.3	7.1	4.0	8.6
Flat Paper Bag	26.1	16.9	12.8	21.9
Padded Paper Bag	34.6	15.3	16.4	19.6

*All comparisons utilise the same end-of-life allocation method for consistency

4.1.1. Remaining indicators

Due to the many indicators included within this study, a traffic light system has been implemented to address the remaining indicators, as shown in Table 4-3. Results are presented as a percentage relative to the impacts for the virgin LDPE bag, landfilled at end-of-life to allow for easy interpretation across a broad range of results. To increase readability, any values with an impact less than the virgin LDPE bag has green text, those with a value of between 100% and 130% in orange text and greater than 130% in red text. A breakdown of the absolute results for the indicators below can be found in Annex D.

From Table 4-3, there are only two indicators where the New Zealand manufactured rLDPE bag is not the best performing bag (along with MCI, as shown in the previous section). These indicators are non-hazardous waste disposed and net use of fresh water.

In the instance of non-hazardous waste disposed, the rLDPE bag has an impact of 105% when landfilled in comparison to the virgin LDPE bag. The difference in performance is due to the increased mass of the bag necessary to account for any decrease in performance resulting from recycling the LDPE granulate.

Increased net use of fresh water is caused by the use of electricity from the New Zealand grid for producing recycled plastic. This electricity has a significant share of hydroelectric generation, resulting in greater water consumption through evaporation. Importantly, the impact of this increased water consumption relative to local water scarcity – as measured by the Water Scarcity Footprint – is lower than for the conventional LDPE bag. Put another way, the rLDPE bag manufactured in New Zealand consumes more water than the conventional LDPE bag, but the impact of this water consumption is lower due to water being less scarce in New Zealand (on average) than in China.

Table 4-3: Results of remaining indicators

	Landfilled at end-of-life					Recycled at end-of-life					
Indicator	**rLDPE Bag (NZ)**	**rLDPE Bag (CN)**	**Home Comp. Bag**	**Flat Paper Bag**	**Padded Paper Bag**	**Virgin LDPE Bag**	**rLDPE Bag (NZ)**	**rLDPE Bag (CN)**	**Home Comp. Bag**	**Flat Paper Bag**	**Padded Paper Bag**
Human toxicity, total	45%	52%	1152%	915%	962%	91%	36%	42%	1144%	871%	876%
Acidification potential of land and water	35%	36%	100%	69%	81%	99%	34%	35%	98%	60%	64%
Eutrophication potential	45%	56%	731%	467%	470%	88%	32%	43%	723%	427%	391%
Photochemical ozone formation potential	34%	47%	139%	266%	308%	99%	33%	45%	127%	219%	215%
Abiotic depletion potential – elements	69%	73%	357%	838%	739%	99%	67%	72%	356%	830%	723%
Abiotic depletion potential – fossil fuels	32%	40%	127%	136%	154%	99%	30%	39%	126%	129%	141%
Non-renewable primary energy as energy carrier	32%	41%	128%	144%	160%	99%	30%	40%	127%	138%	147%
Total primary energy demand from renewable and non renewable resources	42%	44%	158%	395%	356%	99%	40%	43%	157%	388%	343%
Water scarcity footprint	47%	57%	1621%	229%	288%	100%	47%	57%	1617%	213%	257%
Hazardous waste disposed	77%	87%	204%	4614%	3437%	94%	71%	81%	202%	4600%	3409%
Non-hazardous waste disposed	105%	105%	6%	176%	328%	2%	3%	3%	13%	19%	17%
Net use of fresh water	134%	67%	1372%	415%	410%	100%	134%	67%	1367%	397%	373%

4.2. Hotspot Analysis

Hotspot analysis has been conducted to identify the processes that contribute to significant impacts for global warming potential and human toxicity. Only processes that contribute ≥0.1% of the impacts are included in Table 4-4 to Table 4-7 for ease of readability. Processes that contribute ≥5% are highlighted in orange, while processes that contribute ≥2% are highlighted in yellow. Processes that contribute <0.01% yet are included due to having impacts of ≥0.1% in another scenario are greyed out to ease readability.

Further detail per impact category is discussed in the following sections.

4.2.1. Global Warming Potential

While the raw materials used to create the various courier bags vary greatly, they are consistently seen to be one of the leading hotspots for GWP. The raw materials contribute a larger proportion of the emissions when the bags are recycled at end-of-life as recycling leads to fewer emissions than landfilling for all courier bags. However, end-of-life remains a hotspot for the home compostable bag as composting releases the carbon embodied within the product which is derived largely from fossil fuels.

When landfilled, the plastic products which are relatively inert show few resulting emissions. However, the paper and home compostable bags, which can degrade, show a significant release of emissions when placed in landfill. The high emissions from landfilling are due to the production of methane which occurs when the products break down in an anaerobic environment to produce methane, a greenhouse gas approximately 25-30 times more potent than carbon dioxide over a 100-year time horizon.

Electricity is seen to be a hotspot for the plastic products due to the melting of granulate before the compounding and extrusion processes. The significance of electricity for the overall impacts varies between products and depends mainly on the electrical grid mix and the number of melting stages which occur. Electricity in China or Australia has a higher level of carbon dioxide emissions per kWh than New Zealand electricity due to renewable electricity comprising a smaller proportion of their national grids. The higher carbon dioxide emissions result in a higher impact occurring for the same process when comparing production in New Zealand to the alternative locations.

While the inclusion of recycled LDPE reduces the impacts associated with raw material extraction, it does lead to an increase in electricity consumption due to the additional melting stage within the recycling process, described in section 3.1.2. This is seen in the NZ made recycled LDPE bag where electricity is the second largest source of emissions. For the recycled LDPE bag manufactured in China, electricity consumption is the leading source of emissions due to the more carbon intensive electrical grid.

4.2.2. Human Toxicity Potential

Overall, the human toxicity of the products is predominantly due to the manufacture of virgin synthetic material and electricity production. With a trend similar to the relation between GWP and location of generation, electricity sourced from regions with a higher dependence on fossil fuels has a higher human toxicity than electricity from regions such as New Zealand which utilise more renewable sources.

Virgin LDPE is a leading source of human toxicity within the plastic bags which is to be expected due to the various stages of refining and processing required to turn crude oil into LDPE. For the paper bags, the majority of the human toxicity is a result of the EVA hotmelt adhesive used to seal the flap of the bag.

The main source of human toxicity within the home compostable bag is the PET proxy for PBAT used in Ecoflex and Ecovio. The validity of this proxy along with the impacts of utilising different proxy materials instead of PET are investigated further in a scenario analysis in section 4.4.

4.2.3. Material Circularity Indicator

The results of the material circulatory indicators are all as expected. Bags which include recycled material and those which can be most effectively recycled at end-of-life performed best. Only the LDPE and paper are assumed to be able to be recycled with components such as the adhesive and pigment being lost. All biological materials are assumed to be from regenerative sources and therefore perform better than virgin materials from non-renewable sources such as the virgin LDPE. While the home compostable bag utilises some biogenic material, the main component – Ecoflex – is a fossil fuel derived product.

It is important to note the MCI results are presented using the default recycling efficiencies from the updated version of the MCI tool released by James Goddin of Hoskins Circular (formerly of Granta Design and co-creator of the original MCI tool) in 2020 (Goddin, 2020). This newer version incorporates biological materials (which were excluded from the original 2015 release) following a methodology update made in 2019. Importantly, these default recycling efficiencies are low (22% for plastics and 45% for metals). That said, they are broadly reflective of whole-system recycling efficiencies for municipal recycling systems similar to those used in New Zealand, as evidenced by the Australian Packaging Covenant Organisation's *Packaging Material Flow Analysis 2018* (Madden & Florin, 2019). This article found a full-system recovery rate of 32% for plastics and 54% for metals, excluding losses from the recycling process itself. If recycling losses were included, the full-system recycling rate would fall below 30% for plastics and below 50% for metals, which would give values close to those in the updated MCI tool.

The relevance of the above paragraph for New Zealand Post is that the circularity of a recycling system greatly depends on the effectiveness of the system itself. If New Zealand Post were to set up its own system collecting its own bags, it is likely that it could dramatically increase this whole-system recycling efficiency.

Table 4-4: Life cycle hotspot analysis for Global Warming Potential of products landfilled at end-of-life (kg CO_2-eq.)

	Virgin LDPE Bag -Landfill	Recycled LDPE Bag NZ -Landfill	Recycled LDPE Bag CN -Landfill	Home Compostable Bag - Landfill	Flat Paper Bag - Landfill	Padded Paper Bag -Landfill
Adhesive	0.00%	0.00%	0.00%	0.00%	7.34%	5.53%
Cornstarch	0.00%	0.00%	0.00%	10.71%	0.00%	0.00%
Ecoflex	0.00%	0.00%	0.00%	22.83%	0.00%	0.00%
Ecovio	0.00%	0.00%	0.00%	11.38%	0.00%	0.00%
Electricity	19.36%	22.98%	51.98%	9.10%	1.60%	2.39%
Virgin LDPE	68.08%	34.65%	21.47%	0.00%	0.00%	0.00%
Newspaper	0.00%	0.00%	0.00%	0.00%	0.00%	0.28%
Paper	0.00%	0.00%	0.00%	0.00%	47.79%	28.60%
Colouring Pigment	2.19%	6.07%	3.76%	1.10%	0.00%	0.00%
Recycled LDPE	0.00%	1.89%	0.97%	0.00%	0.00%	0.00%
Newspaper Shredding	0.00%	0.00%	0.00%	0.00%	0.00%	2.09%
Thermal Energy	0.44%	7.69%	5.26%	0.19%	0.00%	0.00%
Sealing Strip	2.15%	5.72%	3.55%	0.92%	0.73%	0.55%
Transport	0.62%	1.70%	1.05%	0.29%	0.49%	0.66%
Secondary Packaging	2.89%	7.70%	4.77%	0.97%	0.37%	0.58%
Tertiary Packaging	2.16%	5.76%	3.57%	1.35%	2.67%	0.95%
Produced Waste	0.00%	0.00%	0.00%	2.52%	0.00%	0.00%
End-of-life	2.10%	5.82%	3.60%	38.65%	39.02%	58.36%
Sum of the above	**99.99%**	**99.99%**	**99.99%**	**100.00%**	**100.00%**	**100.00%**
Total	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**
Absolute Values (kg CO_2-eq.)	**1.78E-02**	**6.68E-03**	**1.08E-02**	**5.55E-02**	**1.75E-01**	**2.32E-01**

Table 4-5: Life cycle hotspot analysis for Global Warming Potential of products recycled at end-of-life (kg CO_2-eq.)

	Virgin LDPE Bag - Recycled	Recycled LDPE Bag NZ - Recycled	Recycled LDPE Bag CN - Recycled	Home Compostable Bag - Composted	Flat Paper Bag - Recycled	Padded Paper Bag - Recycled
Adhesive	0.00%	0.00%	0.00%	0.00%	12.02%	13.27%
Cornstarch	0.00%	0.00%	0.00%	13.27%	0.00%	0.00%
Ecoflex	0.00%	0.00%	0.00%	28.29%	0.00%	0.00%
Ecovio	0.00%	0.00%	0.00%	14.10%	0.00%	0.00%
Electricity	19.77%	24.35%	53.86%	11.28%	2.62%	5.73%
Virgin LDPE	69.49%	36.72%	22.25%	0.00%	0.00%	0.00%
Newspaper	0.00%	0.00%	0.00%	0.00%	0.00%	0.66%
Paper	0.00%	0.00%	0.00%	0.00%	78.31%	68.57%
Colouring Pigment	2.23%	6.43%	3.89%	1.36%	0.00%	0.00%
Recycled LDPE	0.00%	2.01%	1.01%	0.00%	0.00%	0.00%
Newspaper Shredding	0.00%	0.00%	0.00%	0.00%	0.00%	5.01%
Thermal Energy	0.45%	8.15%	5.45%	0.23%	0.00%	0.00%
Sealing Strip	2.19%	6.07%	3.67%	1.14%	1.19%	1.31%
Transport	0.63%	1.80%	1.09%	0.36%	0.80%	1.59%
Secondary Packaging	2.95%	8.16%	4.94%	1.20%	0.60%	1.39%
Tertiary Packaging	2.21%	6.11%	3.70%	1.68%	4.38%	2.29%
Produced Waste	0.00%	0.00%	0.00%	3.13%	0.00%	0.00%
End-of-life	0.07%	0.19%	0.12%	23.95%	0.08%	0.17%
Sum of the above	**99.99%**	**99.98%**	**99.99%**	**100.00%**	**100.00%**	**100.00%**
Total	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**
Absolute Values (kg CO_2-eq.)	**1.74E-02**	**6.30E-03**	**1.04E-02**	**4.48E-02**	**1.07E-01**	**9.67E-02**

Table 4-6: Life cycle hotspot analysis for total Human Toxicity Potential of products landfilled at end-of-life (CTUh)

	Current LDPE Bag -Landfill	Recycled LDPE Bag NZ -Landfill	Recycled LDPE Bag CN -Landfill	Home Compostable Bag - Landfill	Flat Paper Bag - Landfill	Padded Paper Bag -Landfill
Adhesive	0.00%	0.00%	0.00%	0.00%	73.77%	70.14%
Cornstarch	0.00%	0.00%	0.00%	1.10%	0.00%	0.00%
Ecoflex	0.00%	0.00%	0.00%	61.29%	0.00%	0.00%
Ecovio	0.00%	0.00%	0.00%	33.79%	0.00%	0.00%
Electricity	5.25%	5.51%	16.47%	0.67%	0.84%	1.59%
Virgin LDPE	65.53%	27.66%	24.15%	0.00%	0.00%	0.00%
Newspaper	0.00%	0.00%	0.00%	0.00%	0.00%	0.06%
Paper	0.00%	0.00%	0.00%	0.00%	5.93%	4.48%
Colouring Pigment	1.12%	2.57%	2.24%	0.15%	0.00%	0.00%
Recycled LDPE	0.00%	1.42%	1.21%	0.00%	0.00%	0.00%
Newspaper Shredding	0.00%	0.00%	0.00%	0.00%	0.00%	1.39%
Thermal Energy	0.09%	0.18%	1.19%	0.00%	0.00%	0.00%
Sealing Strip	12.77%	28.22%	24.64%	1.48%	10.42%	9.91%
Transport	0.10%	0.22%	0.20%	0.01%	0.08%	0.14%
Secondary Packaging	3.49%	7.72%	6.74%	0.32%	0.48%	0.95%
Tertiary Packaging	2.60%	5.74%	5.01%	0.39%	3.71%	2.35%
Produced Waste	0.00%	0.00%	0.00%	0.06%	0.00%	0.00%
End-of-life	9.04%	20.76%	18.12%	0.75%	4.76%	8.98%
Sum of the above	**99.99%**	**100.00%**	**99.98%**	**100.00%**	**100.00%**	**100.00%**
Total	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**
Absolute Values (CTUh)	**2.36E-09**	**1.07E-09**	**1.22E-09**	**2.72E-08**	**2.16E-08**	**2.27E-08**

Table 4-7: Life cycle hotspot analysis for total Human Toxicity Potential of products recycled at end-of-life (CTUh)

	Virgin LDPE Bag - Recycled	Recycled LDPE Bag NZ - Recycled	Recycled LDPE Bag CN - Recycled	Home Compostable Bag - Composted	Flat Paper Bag - Recycled	Padded Paper Bag - Recycled
Adhesive	0.00%	0.00%	0.00%	0.00%	77.45%	77.05%
Cornstarch	0.00%	0.00%	0.00%	1.11%	0.00%	0.00%
Ecoflex	0.00%	0.00%	0.00%	61.74%	0.00%	0.00%
Ecovio	0.00%	0.00%	0.00%	34.04%	0.00%	0.00%
Electricity	5.77%	6.96%	20.11%	0.67%	0.89%	1.75%
Virgin LDPE	72.04%	34.89%	29.48%	0.00%	0.00%	0.00%
Paper	0.00%	0.00%	0.00%	0.00%	6.23%	4.92%
Colouring Pigment	1.23%	3.24%	2.74%	0.15%	0.00%	0.00%
Recycled LDPE	0.00%	1.79%	1.48%	0.00%	0.00%	0.00%
Newspaper Shredding	0.00%	0.00%	0.00%	0.00%	0.00%	1.53%
Thermal Energy	0.09%	0.22%	1.46%	0.00%	0.00%	0.00%
Sealing Strip	14.04%	35.60%	30.09%	1.49%	10.94%	10.88%
Transport	0.11%	0.28%	0.24%	0.01%	0.09%	0.16%
Secondary Packaging	3.84%	9.73%	8.23%	0.32%	0.50%	1.04%
Tertiary Packaging	2.86%	7.25%	6.12%	0.39%	3.89%	2.58%
End-of-life	0.01%	0.03%	0.03%	0.01%	0.01%	0.02%
Sum of the above	**99.99%**	**99.99%**	**99.97%**	**99.94%**	**100.00%**	**99.93%**
Total	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**
Absolute Values (CTUh)	**2.15E-09**	**8.47E-10**	**1.00E-09**	**2.70E-08**	**2.06E-08**	**2.07E-08**

Table 4-8: Life cycle hotspot analysis for Acidification Potential of products landfilled at end-of-life (kg SO_2-eq.)

	Virgin LDPE Bag -Landfill	Recycled LDPE Bag NZ -Landfill	Recycled LDPE Bag CN -Landfill	Home Compostable Bag - Landfill	Flat Paper Bag - Landfill	Padded Paper Bag -Landfill
Adhesive	0.00%	0.00%	0.00%	0.00%	18.58%	15.77%
Cornstarch	0.00%	0.00%	0.00%	45.88%	0.00%	0.00%
Ecoflex	0.00%	0.00%	0.00%	23.21%	0.00%	0.00%
Ecovio	0.00%	0.00%	0.00%	6.25%	0.00%	0.00%
Electricity	5.44%	22.15%	24.86%	7.99%	5.45%	9.17%
Virgin LDPE	84.72%	46.31%	45.51%	0.00%	0.00%	0.00%
Newspaper	0.00%	0.00%	0.00%	0.00%	0.00%	1.09%
Paper	0.00%	0.00%	0.00%	0.00%	45.40%	30.58%
Colouring Pigment	7.85%	23.37%	22.97%	12.31%	0.00%	0.00%
Recycled LDPE	0.00%	1.42%	0.36%	0.00%	0.00%	0.00%
Newspaper Shredding	0.00%	0.00%	0.00%	0.00%	0.00%	8.02%
Thermal Energy	0.04%	1.10%	0.74%	0.08%	0.00%	0.00%
Sealing Strip	0.27%	0.78%	0.77%	0.37%	3.30%	2.80%
Transport	0.19%	0.56%	0.55%	0.28%	2.15%	3.24%
Secondary Packaging	0.34%	0.99%	0.97%	0.36%	0.62%	1.11%
Tertiary Packaging	0.62%	1.76%	1.73%	1.06%	11.65%	6.58%
Produced Waste	0.00%	0.00%	0.00%	0.11%	0.00%	0.00%
End-of-life	0.52%	1.55%	1.52%	2.11%	12.85%	21.63%
Sum of the above	**100.00%**	**100.00%**	**99.99%**	**100.00%**	**100.00%**	**100.00%**
Total	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**
Absolute Values (kg SO_2-eq.)	**1.86E-04**	**6.49E-05**	**6.60E-05**	**1.85E-04**	**1.28E-04**	**1.51E-04**

Table 4-9: Life cycle hotspot analysis for Acidification Potential of products recycled at end-of-life (kg SO_2-eq.)

	Virgin LDPE Bag - Recycled	Recycled LDPE Bag NZ - Recycled	Recycled LDPE Bag CN - Recycled	Home Compostable Bag - Composted	Flat Paper Bag - Recycled	Padded Paper Bag - Recycled
Adhesive	0.00%	0.00%	0.00%	0.00%	21.28%	20.07%
Cornstarch	0.00%	0.00%	0.00%	46.84%	0.00%	0.00%
Ecoflex	0.00%	0.00%	0.00%	23.70%	0.00%	0.00%
Ecovio	0.00%	0.00%	0.00%	6.39%	0.00%	0.00%
Electricity	5.46%	22.49%	25.23%	8.16%	6.24%	11.67%
Virgin LDPE	85.16%	47.02%	46.20%	0.00%	0.00%	0.00%
Newspaper	0.00%	0.00%	0.00%	0.00%	0.00%	1.39%
Paper	0.00%	0.00%	0.00%	0.00%	52.02%	38.91%
Colouring Pigment	7.89%	23.73%	23.32%	12.57%	0.00%	0.00%
Recycled LDPE	0.00%	1.44%	0.37%	0.00%	0.00%	0.00%
Newspaper Shredding	0.00%	0.00%	0.00%	0.00%	0.00%	10.21%
Thermal Energy	0.04%	1.12%	0.75%	0.08%	0.00%	0.00%
Sealing Strip	0.27%	0.79%	0.78%	0.37%	3.78%	3.56%
Transport	0.19%	0.57%	0.56%	0.28%	2.47%	4.13%
Secondary Packaging	0.35%	1.00%	0.98%	0.37%	0.71%	1.41%
Tertiary Packaging	0.62%	1.79%	1.76%	1.08%	13.34%	8.37%
Produced Waste	0.00%	0.00%	0.00%	0.11%	0.00%	0.00%
End-of-life	0.01%	0.04%	0.04%	0.05%	0.15%	0.28%
Sum of the above	**100.00%**	**100.00%**	**99.99%**	**100.00%**	**100.00%**	**100.00%**
Total	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**
Absolute Values (kg SO_2-eq.)	**1.85E-04**	**6.39E-05**	**6.51E-05**	**1.81E-04**	**1.12E-04**	**1.19E-04**

Table 4-10: Life cycle hotspot analysis for Eutrophication Potential of products landfilled at end-of-life (kg PO_4^{3-}-eq.)

	Virgin LDPE Bag - Landfill	Recycled LDPE Bag NZ -Landfill	Recycled LDPE Bag CN -Landfill	Home Compostable Bag - Landfill	Flat Paper Bag - Landfill	Padded Paper Bag -Landfill
Adhesive	0.00%	0.00%	0.00%	0.00%	29.26%	29.04%
Cornstarch	0.00%	0.00%	0.00%	77.18%	0.00%	0.00%
Ecoflex	0.00%	0.00%	0.00%	6.18%	0.00%	0.00%
Ecovio	0.00%	0.00%	0.00%	11.05%	0.00%	0.00%
Electricity	11.81%	13.72%	34.27%	2.37%	1.44%	2.83%
Virgin LDPE	67.77%	28.96%	23.10%	0.00%	0.00%	0.00%
Newspaper	0.00%	0.00%	0.00%	0.00%	0.00%	0.97%
Paper	0.00%	0.00%	0.00%	0.00%	46.57%	36.67%
Colouring Pigment	1.72%	4.01%	3.20%	0.37%	0.00%	0.00%
Recycled LDPE	0.00%	6.00%	3.12%	0.00%	0.00%	0.00%
Newspaper Shredding	0.00%	0.00%	0.00%	0.00%	0.00%	2.47%
Thermal Energy	0.18%	4.78%	2.37%	0.06%	0.00%	0.00%
Sealing Strip	0.86%	1.93%	1.54%	0.16%	2.96%	2.94%
Transport	0.74%	1.71%	1.36%	0.15%	1.24%	2.20%
Secondary Packaging	1.11%	2.49%	1.99%	0.16%	0.30%	0.62%
Tertiary Packaging	3.59%	8.03%	6.41%	0.91%	9.64%	5.34%
End-of-life	12.20%	28.36%	22.63%	1.36%	8.60%	16.93%
Sum of the above	**100.00%**	**99.99%**	**99.99%**	**99.94%**	**100.00%**	**100.00%**
Total	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**
Absolute Values (kg PO_4^{3-}- eq.)	**8.14E-06**	**3.64E-06**	**4.56E-06**	**5.95E-05**	**3.80E-05**	**3.83E-05**

Table 4-11: Life cycle hotspot analysis for Eutrophication Potential of products recycled at end-of-life (kg PO_4^{3-}-eq.)

	Virgin LDPE Bag - Recycled	Recycled LDPE Bag NZ - Recycled	Recycled LDPE Bag CN - Recycled	Home Compostable Bag - Composted	Flat Paper Bag - Recycled	Padded Paper Bag - Recycled
Adhesive	0.00%	0.00%	0.00%	0.00%	31.98%	34.88%
Cornstarch	0.00%	0.00%	0.00%	78.03%	0.00%	0.00%
Ecoflex	0.00%	0.00%	0.00%	6.25%	0.00%	0.00%
Ecovio	0.00%	0.00%	0.00%	11.17%	0.00%	0.00%
Electricity	13.44%	19.11%	44.23%	2.40%	1.57%	3.39%
Virgin LDPE	77.13%	40.34%	29.81%	0.00%	0.00%	0.00%
Newspaper	0.00%	0.00%	0.00%	0.00%	0.00%	1.16%
Paper	0.00%	0.00%	0.00%	0.00%	50.90%	44.04%
Colouring Pigment	1.96%	5.59%	4.13%	0.37%	0.00%	0.00%
Recycled LDPE	0.00%	8.36%	4.03%	0.00%	0.00%	0.00%
Newspaper Shredding	0.00%	0.00%	0.00%	0.00%	0.00%	2.97%
Thermal Energy	0.21%	6.66%	3.06%	0.06%	0.00%	0.00%
Sealing Strip	0.98%	2.69%	1.99%	0.16%	3.24%	3.53%
Transport	0.84%	2.38%	1.76%	0.15%	1.36%	2.64%
Secondary Packaging	1.27%	3.47%	2.57%	0.16%	0.33%	0.74%
Tertiary Packaging	4.09%	11.19%	8.27%	0.92%	10.53%	6.42%
End-of-life	0.07%	0.20%	0.14%	0.28%	0.10%	0.22%
Sum of the above	**99.99%**	**99.99%**	**99.99%**	**99.94%**	**100.00%**	**100.00%**
Total	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**
Absolute Values (kg PO_4^{3-}- eq.)	**7.15E-06**	**2.61E-06**	**3.54E-06**	**5.88E-05**	**3.48E-05**	**3.19E-05**

Table 4-12: Life cycle hotspot analysis for Photochemical Ozone Formation Potential of products landfilled at end-of-life (kg NOx-eq.)

	Virgin LDPE Bag -Landfill	Recycled LDPE Bag NZ -Landfill	Recycled LDPE Bag CN -Landfill	Home Compostable Bag - Landfill	Flat Paper Bag - Landfill	Padded Paper Bag -Landfill
Adhesive	0.00%	0.00%	0.00%	0.00%	11.52%	9.95%
Cornstarch	0.00%	0.00%	0.00%	17.66%	0.00%	0.00%
Ecoflex	0.00%	0.00%	0.00%	39.30%	0.00%	0.00%
Ecovio	0.00%	0.00%	0.00%	12.45%	0.00%	0.00%
Electricity	12.82%	18.49%	44.66%	13.57%	2.93%	5.02%
Virgin LDPE	78.51%	43.59%	32.13%	0.00%	0.00%	0.00%
Newspaper	0.00%	0.00%	0.00%	0.00%	0.00%	1.77%
Paper	0.00%	0.00%	0.00%	0.00%	48.13%	32.99%
Colouring Pigment	1.81%	5.46%	4.02%	2.04%	0.00%	0.00%
Recycled LDPE	0.00%	5.29%	1.45%	0.00%	0.00%	0.00%
Newspaper Shredding	0.00%	0.00%	0.00%	0.00%	0.00%	4.39%
Thermal Energy	0.22%	7.61%	3.31%	0.38%	0.00%	0.00%
Sealing Strip	0.77%	2.23%	1.64%	0.74%	3.24%	2.80%
Transport	0.88%	2.66%	1.96%	0.93%	2.60%	4.01%
Secondary Packaging	0.93%	2.71%	2.00%	0.70%	0.44%	0.79%
Tertiary Packaging	2.71%	7.87%	5.80%	3.34%	13.26%	7.62%
Produced Waste	0.00%	0.00%	0.00%	0.38%	0.00%	0.00%
End-of-life	1.36%	4.09%	3.02%	8.50%	17.89%	30.65%
Sum of the above	**100.00%**	**99.99%**	**99.99%**	**100.00%**	**100.00%**	**100.00%**
Total	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**
Absolute Values (kg NOx-eq.)	**5.11E-05**	**1.76E-05**	**2.38E-05**	**7.08E-05**	**1.36E-04**	**1.57E-04**

Table 4-13: Life cycle hotspot analysis for Photochemical Ozone Formation Potential of products recycled at end-of-life (kg NOx-eq.)

	Virgin LDPE Bag - Recycled	Recycled LDPE Bag NZ - Recycled	Recycled LDPE Bag CN - Recycled	Home Compostable Bag - Composted	Flat Paper Bag - Recycled	Padded Paper Bag - Recycled
Adhesive	0.00%	0.00%	0.00%	0.00%	13.99%	14.28%
Cornstarch	0.00%	0.00%	0.00%	19.28%	0.00%	0.00%
Ecoflex	0.00%	0.00%	0.00%	42.89%	0.00%	0.00%
Ecovio	0.00%	0.00%	0.00%	13.59%	0.00%	0.00%
Electricity	12.99%	19.24%	45.97%	14.81%	3.56%	7.20%
Virgin LDPE	79.53%	45.34%	33.07%	0.00%	0.00%	0.00%
Newspaper	0.00%	0.00%	0.00%	0.00%	0.00%	2.54%
Paper	0.00%	0.00%	0.00%	0.00%	58.47%	47.35%
Colouring Pigment	1.83%	5.68%	4.14%	2.22%	0.00%	0.00%
Recycled LDPE	0.00%	5.50%	1.49%	0.00%	0.00%	0.00%
Newspaper Shredding	0.00%	0.00%	0.00%	0.00%	0.00%	6.30%
Thermal Energy	0.22%	7.92%	3.41%	0.41%	0.00%	0.00%
Sealing Strip	0.78%	2.32%	1.69%	0.81%	3.94%	4.02%
Transport	0.89%	2.76%	2.02%	1.02%	3.16%	5.76%
Secondary Packaging	0.94%	2.82%	2.05%	0.77%	0.53%	1.13%
Tertiary Packaging	2.74%	8.19%	5.97%	3.65%	16.11%	10.94%
Produced Waste	0.00%	0.00%	0.00%	0.42%	0.00%	0.00%
End-of-life	0.07%	0.23%	0.16%	0.13%	0.24%	0.48%
Sum of the above	**99.99%**	**99.99%**	**99.99%**	**100.00%**	**100.00%**	**100.00%**
Total	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**
Absolute Values (kg NOx-eq.)	**5.04E-05**	**1.69E-05**	**2.32E-05**	**6.49E-05**	**1.12E-04**	**1.10E-04**

Table 4-14: Life cycle hotspot analysis for Abiotic Depletion Potential (Elements) of products landfilled at end-of-life (kg Sb-eq.)

	Virgin LDPE Bag -Landfill	Recycled LDPE Bag NZ -Landfill	Recycled LDPE Bag CN -Landfill	Home Compostable Bag - Landfill	Flat Paper Bag - Landfill	Padded Paper Bag -Landfill
Adhesive	0.00%	0.00%	0.00%	0.00%	26.94%	30.56%
Cornstarch	0.00%	0.00%	0.00%	6.46%	0.00%	0.00%
Ecoflex	0.00%	0.00%	0.00%	14.77%	0.00%	0.00%
Ecovio	0.00%	0.00%	0.00%	56.02%	0.00%	0.00%
Electricity	5.70%	8.82%	12.63%	2.34%	0.11%	0.25%
Virgin LDPE	44.67%	12.37%	11.63%	0.00%	0.00%	0.00%
Paper	0.00%	0.00%	0.00%	0.00%	31.78%	28.60%
Colouring Pigment	11.17%	16.83%	15.83%	4.89%	0.00%	0.00%
Recycled LDPE	0.00%	5.80%	5.44%	0.00%	0.00%	0.00%
Newspaper Shredding	0.00%	0.00%	0.00%	0.00%	0.00%	0.22%
Thermal Energy	0.23%	0.68%	2.25%	0.02%	0.00%	0.00%
Sealing Strip	22.33%	32.37%	30.45%	8.37%	22.82%	25.89%
Secondary Packaging	3.16%	4.58%	4.31%	0.93%	0.47%	1.12%
Tertiary Packaging	11.21%	16.25%	15.29%	5.72%	16.90%	11.16%
End-of-life	1.49%	2.24%	2.11%	0.44%	0.95%	2.13%
Sum of the above	**99.96%**	**99.95%**	**99.95%**	**99.95%**	**99.97%**	**99.91%**
Total	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**
Absolute Values (kg Sb-eq.)	**4.54E-09**	**3.13E-09**	**3.33E-09**	**1.62E-08**	**3.81E-08**	**3.36E-08**

Table 4-15: Life cycle hotspot analysis for Abiotic Depletion Potential (Elements) of products recycled at end-of-life (kg Sb-eq.)

	Virgin LDPE Bag - Recycled	Recycled LDPE Bag NZ - Recycled	Recycled LDPE Bag CN - Recycled	Home Compostable Bag - Composted	Flat Paper Bag - Recycled	Padded Paper Bag - Recycled
Adhesive	0.00%	0.00%	0.00%	0.00%	27.20%	31.22%
Cornstarch	0.00%	0.00%	0.00%	6.49%	0.00%	0.00%
Ecoflex	0.00%	0.00%	0.00%	14.83%	0.00%	0.00%
Ecovio	0.00%	0.00%	0.00%	56.27%	0.00%	0.00%
Electricity	5.78%	9.02%	12.90%	2.35%	0.11%	0.25%
Virgin LDPE	45.34%	12.65%	11.88%	0.00%	0.00%	0.00%
Paper	0.00%	0.00%	0.00%	0.00%	32.08%	29.22%
Colouring Pigment	11.34%	17.22%	16.17%	4.91%	0.00%	0.00%
Recycled LDPE	0.00%	5.93%	5.56%	0.00%	0.00%	0.00%
Newspaper Shredding	0.00%	0.00%	0.00%	0.00%	0.00%	0.22%
Thermal Energy	0.23%	0.70%	2.30%	0.02%	0.00%	0.00%
Sealing Strip	22.67%	33.11%	31.11%	8.40%	23.04%	26.45%
Secondary Packaging	3.21%	4.69%	4.40%	0.93%	0.48%	1.14%
Tertiary Packaging	11.38%	16.63%	15.62%	5.74%	17.06%	11.40%
End-of-life	0.00%	0.01%	0.00%	0.01%	0.00%	0.01%
Sum of the above	**99.96%**	**99.95%**	**99.95%**	**99.95%**	**99.97%**	**99.91%**
Total	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**
Absolute Values (kg Sb-eq.)	**4.47E-09**	**3.06E-09**	**3.26E-09**	**1.61E-08**	**3.77E-08**	**3.28E-08**

Table 4-16: Life cycle hotspot analysis for Abiotic Depletion Potential (Fossil fuels) of products landfilled at end-of-life (MJ)

	Virgin LDPE Bag -Landfill	Recycled LDPE Bag NZ -Landfill	Recycled LDPE Bag CN -Landfill	Home Compostable Bag - Landfill	Flat Paper Bag - Landfill	Padded Paper Bag -Landfill
Adhesive	0.00%	0.00%	0.00%	0.00%	44.23%	39.04%
Cornstarch	0.00%	0.00%	0.00%	10.29%	0.00%	0.00%
Ecoflex	0.00%	0.00%	0.00%	53.37%	0.00%	0.00%
Ecovio	0.00%	0.00%	0.00%	17.21%	0.00%	0.00%
Electricity	7.64%	12.03%	30.77%	8.79%	4.64%	8.13%
Virgin LDPE	82.27%	49.79%	38.91%	0.00%	0.00%	0.00%
Newspaper	0.00%	0.00%	0.00%	0.00%	0.00%	1.30%
Paper	0.00%	0.00%	0.00%	0.00%	28.88%	20.22%
Colouring Pigment	1.06%	3.49%	2.73%	1.30%	0.00%	0.00%
Recycled LDPE	0.00%	1.11%	0.73%	0.00%	0.00%	0.00%
Newspaper Shredding	0.00%	0.00%	0.00%	0.00%	0.00%	7.11%
Thermal Energy	0.28%	5.67%	5.06%	0.28%	0.00%	0.00%
Sealing Strip	2.42%	7.67%	6.00%	2.54%	2.51%	2.22%
Transport	0.34%	1.11%	0.87%	0.39%	1.95%	3.10%
Secondary Packaging	3.74%	11.84%	9.25%	3.06%	3.45%	6.36%
Tertiary Packaging	1.05%	3.31%	2.59%	1.62%	9.31%	3.76%
End-of-life	1.20%	3.94%	3.08%	1.05%	5.01%	8.77%
Sum of the above	**99.99%**	**99.96%**	**99.97%**	**99.90%**	**100.00%**	**100.00%**
Total	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**
Absolute Values (MJ)	**4.49E-01**	**1.42E-01**	**1.81E-01**	**5.72E-01**	**6.08E-01**	**6.89E-01**

Table 4-17: Life cycle hotspot analysis for Abiotic Depletion Potential (Fossil fuels) of products recycled at end-of-life (MJ)

	Virgin LDPE Bag - Recycled	Recycled LDPE Bag NZ - Recycled	Recycled LDPE Bag CN - Recycled	Home Compostable Bag - Composted	Flat Paper Bag - Recycled	Padded Paper Bag - Recycled
Adhesive	0.00%	0.00%	0.00%	0.00%	46.47%	42.63%
Cornstarch	0.00%	0.00%	0.00%	10.37%	0.00%	0.00%
Ecoflex	0.00%	0.00%	0.00%	53.78%	0.00%	0.00%
Ecovio	0.00%	0.00%	0.00%	17.34%	0.00%	0.00%
Electricity	7.73%	12.51%	31.71%	8.86%	4.88%	8.87%
Virgin LDPE	83.23%	51.76%	40.11%	0.00%	0.00%	0.00%
Newspaper	0.00%	0.00%	0.00%	0.00%	0.00%	1.42%
Paper	0.00%	0.00%	0.00%	0.00%	30.34%	22.08%
Colouring Pigment	1.07%	3.63%	2.81%	1.31%	0.00%	0.00%
Recycled LDPE	0.00%	1.16%	0.75%	0.00%	0.00%	0.00%
Newspaper Shredding	0.00%	0.00%	0.00%	0.00%	0.00%	7.76%
Thermal Energy	0.29%	5.89%	5.21%	0.28%	0.00%	0.00%
Sealing Strip	2.45%	7.98%	6.18%	2.56%	2.64%	2.42%
Transport	0.34%	1.16%	0.90%	0.39%	2.05%	3.39%
Secondary Packaging	3.78%	12.31%	9.54%	3.09%	3.62%	6.94%
Tertiary Packaging	1.06%	3.45%	2.67%	1.63%	9.78%	4.11%
End-of-life	0.04%	0.12%	0.10%	0.29%	0.20%	0.37%
Sum of the above	**99.99%**	**99.96%**	**99.97%**	**99.90%**	**100.00%**	**100.00%**
Total	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**
Absolute Values (MJ)	**4.43E-01**	**1.36E-01**	**1.76E-01**	**5.67E-01**	**5.79E-01**	**6.31E-01**

Table 4-18: Life cycle hotspot analysis for Primary Energy Demand (Non-renewable) of products landfilled at end-of-life (MJ)

	Virgin LDPE Bag -Landfill	Recycled LDPE Bag NZ -Landfill	Recycled LDPE Bag CN -Landfill	Home Compostable Bag - Landfill	Flat Paper Bag - Landfill	Padded Paper Bag -Landfill
Adhesive	0.00%	0.00%	0.00%	0.00%	42.54%	38.23%
Cornstarch	0.00%	0.00%	0.00%	10.24%	0.00%	0.00%
Ecoflex	0.00%	0.00%	0.00%	52.73%	0.00%	0.00%
Ecovio	0.00%	0.00%	0.00%	17.45%	0.00%	0.00%
Electricity	7.91%	11.88%	31.43%	9.07%	4.32%	7.70%
Virgin LDPE	81.79%	49.38%	38.16%	0.00%	0.00%	0.00%
Paper	0.00%	0.00%	0.00%	0.00%	31.34%	22.35%
Colouring Pigment	1.06%	3.48%	2.69%	1.29%	0.00%	0.00%
Recycled LDPE	0.00%	1.16%	0.76%	0.00%	0.00%	0.00%
Newspaper Shredding	0.00%	0.00%	0.00%	0.00%	0.00%	6.73%
Sealing Strip	2.48%	7.85%	6.07%	2.60%	2.68%	2.41%
Secondary Packaging	3.80%	12.02%	9.29%	3.11%	3.30%	6.20%
Tertiary Packaging	1.11%	3.51%	2.71%	1.71%	9.28%	3.79%
End-of-life	1.22%	4.00%	3.09%	1.05%	4.73%	8.43%
Sum of the above	**99.37%**	**93.28%**	**94.19%**	**99.24%**	**98.18%**	**95.83%**
Total	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**
Absolute Values (MJ)	**4.54E-01**	**1.44E-01**	**1.86E-01**	**5.81E-01**	**6.54E-01**	**7.28E-01**

Table 4-19: Life cycle hotspot analysis for Primary Energy Demand (Non-renewable) of products recycled at end-of-life (MJ)

	Virgin LDPE Bag - Recycled	Recycled LDPE Bag NZ - Recycled	Recycled LDPE Bag CN - Recycled	Home Compostable Bag - Composted	Flat Paper Bag - Recycled	Padded Paper Bag - Recycled
Adhesive	0.00%	0.00%	0.00%	0.00%	44.57%	41.60%
Cornstarch	0.00%	0.00%	0.00%	10.32%	0.00%	0.00%
Ecoflex	0.00%	0.00%	0.00%	53.14%	0.00%	0.00%
Ecovio	0.00%	0.00%	0.00%	17.59%	0.00%	0.00%
Electricity	8.01%	12.36%	32.40%	9.14%	4.52%	8.38%
Virgin LDPE	82.76%	51.37%	39.34%	0.00%	0.00%	0.00%
Paper	0.00%	0.00%	0.00%	0.00%	32.83%	24.32%
Colouring Pigment	1.07%	3.62%	2.77%	1.30%	0.00%	0.00%
Recycled LDPE	0.00%	1.21%	0.78%	0.00%	0.00%	0.00%
Newspaper Shredding	0.00%	0.00%	0.00%	0.00%	0.00%	7.33%
Sealing Strip	2.51%	8.17%	6.26%	2.62%	2.81%	2.62%
Secondary Packaging	3.85%	12.51%	9.58%	3.13%	3.46%	6.75%
Tertiary Packaging	1.12%	3.65%	2.79%	1.73%	9.72%	4.12%
End-of-life	0.04%	0.12%	0.09%	0.28%	0.19%	0.35%
Sum of the above	**99.36%**	**93.01%**	**94.01%**	**99.24%**	**98.10%**	**95.46%**
Total	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**
Absolute Values (MJ)	**4.48E-01**	**1.38E-01**	**1.80E-01**	**5.77E-01**	**6.24E-01**	**6.69E-01**

Table 4-20 Life cycle hotspot analysis for Primary Energy Demand (total renewable and non-renewable) of products landfilled at end-of-life (MJ)

	Virgin LDPE Bag -Landfill	Recycled LDPE Bag NZ -Landfill	Recycled LDPE Bag CN -Landfill	Home Compostable Bag - Landfill	Flat Paper Bag - Landfill	Padded Paper Bag -Landfill
Adhesive	0.00%	0.00%	0.00%	0.00%	18.48%	20.47%
Cornstarch	0.00%	0.00%	0.00%	19.76%	0.00%	0.00%
Ecoflex	0.00%	0.00%	0.00%	40.55%	0.00%	0.00%
Ecovio	0.00%	0.00%	0.00%	20.09%	0.00%	0.00%
Electricity	8.92%	29.10%	32.84%	8.27%	1.58%	3.48%
Virgin LDPE	78.43%	36.01%	33.90%	0.00%	0.00%	0.00%
Paper	0.00%	0.00%	0.00%	0.00%	61.98%	54.47%
Colouring Pigment	1.08%	2.70%	2.54%	1.07%	0.00%	0.00%
Recycled LDPE	0.00%	0.90%	0.72%	0.00%	0.00%	0.00%
Newspaper Shredding	0.00%	0.00%	0.00%	0.00%	0.00%	3.04%
Sealing Strip	2.58%	6.19%	5.83%	2.18%	4.02%	4.46%
Secondary Packaging	3.84%	9.23%	8.69%	2.54%	1.22%	2.81%
Tertiary Packaging	3.34%	8.03%	7.56%	4.09%	10.32%	5.60%
End-of-life	1.22%	3.04%	2.86%	0.87%	1.77%	3.89%
Sum of the above	**99.41%**	**95.21%**	**94.95%**	**99.42%**	**99.38%**	**98.23%**
Total	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**
Absolute Values (MJ)	**4.85E-01**	**2.02E-01**	**2.14E-01**	**7.67E-01**	**1.91E+00**	**1.73E+00**

Table 4-21: Life cycle hotspot analysis for Primary Energy Demand (total renewable and non-renewable) of products recycled at end-of-life (MJ)

	Virgin LDPE Bag - Recycled	Recycled LDPE Bag NZ - Recycled	Recycled LDPE Bag CN - Recycled	Home Compostable Bag - Composted	Flat Paper Bag - Recycled	Padded Paper Bag - Recycled
Adhesive	0.00%	0.00%	0.00%	0.00%	18.80%	21.27%
Cornstarch	0.00%	0.00%	0.00%	19.89%	0.00%	0.00%
Ecoflex	0.00%	0.00%	0.00%	40.82%	0.00%	0.00%
Ecovio	0.00%	0.00%	0.00%	20.22%	0.00%	0.00%
Electricity	9.03%	29.98%	33.78%	8.33%	1.61%	3.62%
Virgin LDPE	79.37%	37.11%	34.88%	0.00%	0.00%	0.00%
Paper	0.00%	0.00%	0.00%	0.00%	63.06%	56.60%
Colouring Pigment	1.09%	2.78%	2.61%	1.07%	0.00%	0.00%
Recycled LDPE	0.00%	0.92%	0.74%	0.00%	0.00%	0.00%
Newspaper Shredding	0.00%	0.00%	0.00%	0.00%	0.00%	3.16%
Sealing Strip	2.61%	6.38%	6.00%	2.19%	4.09%	4.63%
Secondary Packaging	3.89%	9.51%	8.94%	2.55%	1.24%	2.92%
Tertiary Packaging	3.38%	8.27%	7.78%	4.11%	10.50%	5.82%
End-of-life	0.03%	0.09%	0.08%	0.22%	0.06%	0.14%
Sum of the above	**99.40%**	**95.06%**	**94.81%**	**99.42%**	**99.36%**	**98.16%**
Total	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**
Absolute Values (MJ)	**4.79E-01**	**1.96E-01**	**2.08E-01**	**7.62E-01**	**1.88E+00**	**1.66E+00**

Table 4-22: Life cycle hotspot analysis for Water Scarcity Footprint of products landfilled at end-of-life (m^3)

	Virgin LDPE Bag -Landfill	Recycled LDPE Bag NZ -Landfill	Recycled LDPE Bag CN -Landfill	Home Compostable Bag - Landfill	Flat Paper Bag - Landfill	Padded Paper Bag -Landfill
Adhesive	0.00%	0.00%	0.00%	0.00%	3.10%	2.46%
Cornstarch	0.00%	0.00%	0.00%	93.40%	0.00%	0.00%
Ecoflex	0.00%	0.00%	0.00%	4.03%	0.00%	0.00%
Ecovio	0.00%	0.00%	0.00%	0.29%	0.00%	0.00%
Electricity	33.09%	92.49%	93.81%	2.99%	14.27%	22.46%
Virgin LDPE	77.77%	31.56%	25.90%	0.00%	0.00%	0.00%
Paper	0.00%	0.00%	0.00%	0.00%	55.06%	34.69%
Colouring Pigment	-14.30%	-31.61%	-25.94%	-1.38%	0.00%	0.00%
Recycled LDPE	0.00%	0.22%	0.17%	0.00%	0.00%	0.00%
Newspaper Shredding	0.00%	0.00%	0.00%	0.00%	0.00%	19.64%
Sealing Strip	0.38%	0.81%	0.66%	0.03%	3.68%	2.92%
Secondary Packaging	-0.04%	-0.08%	-0.06%	0.00%	-0.02%	-0.03%
Tertiary Packaging	3.15%	6.70%	5.50%	0.37%	16.97%	6.90%
End-of-life	-0.08%	-0.17%	-0.14%	0.26%	6.87%	10.81%
Sum of the above	**99.97%**	**99.93%**	**99.91%**	**99.99%**	**99.93%**	**99.86%**
Total	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**
Absolute Values (m^3)	**3.47E-03**	**1.63E-03**	**1.99E-03**	**5.63E-02**	**7.94E-03**	**1.00E-02**

Table 4-23: Life cycle hotspot analysis for Water Scarcity Footprint of products recycled at end-of-life (m^3)

	Virgin LDPE Bag - Recycled	Recycled LDPE Bag NZ - Recycled	Recycled LDPE Bag CN - Recycled	Home Compostable Bag - Composted	Flat Paper Bag - Recycled	Padded Paper Bag - Recycled
Adhesive	0.00%	0.00%	0.00%	0.00%	3.33%	2.76%
Cornstarch	0.00%	0.00%	0.00%	93.64%	0.00%	0.00%
Ecoflex	0.00%	0.00%	0.00%	4.04%	0.00%	0.00%
Ecovio	0.00%	0.00%	0.00%	0.29%	0.00%	0.00%
Electricity	33.06%	92.33%	93.68%	3.00%	15.32%	25.18%
Virgin LDPE	77.70%	31.51%	25.86%	0.00%	0.00%	0.00%
Paper	0.00%	0.00%	0.00%	0.00%	59.12%	38.89%
Colouring Pigment	-14.29%	-31.55%	-25.90%	-1.38%	0.00%	0.00%
Recycled LDPE	0.00%	0.22%	0.17%	0.00%	0.00%	0.00%
Newspaper Shredding	0.00%	0.00%	0.00%	0.00%	0.00%	22.02%
Sealing Strip	0.38%	0.81%	0.66%	0.03%	3.95%	3.28%
Secondary Packaging	-0.04%	-0.08%	-0.06%	0.00%	-0.02%	-0.04%
Tertiary Packaging	3.15%	6.69%	5.49%	0.37%	18.22%	7.74%
End-of-life	0.00%	0.00%	0.00%	0.00%	0.01%	0.01%
Sum of the above	**99.97%**	**99.93%**	**99.91%**	**99.99%**	**99.92%**	**99.84%**
Total	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**
Absolute Values (m^3)	**3.48E-03**	**1.64E-03**	**1.99E-03**	**5.62E-02**	**7.40E-03**	**8.92E-03**

Table 4-24: Life cycle hotspot analysis for Hazardous Waste Disposed of products landfilled at end-of-life (kg)

	Virgin LDPE Bag -Landfill	Recycled LDPE Bag NZ -Landfill	Recycled LDPE Bag CN -Landfill	Home Compostable Bag - Landfill	Flat Paper Bag - Landfill	Padded Paper Bag -Landfill
Adhesive	0.00%	0.00%	0.00%	0.00%	-5.55%	-7.45%
Cornstarch	0.00%	0.00%	0.00%	3.71%	0.00%	0.00%
Ecoflex	0.00%	0.00%	0.00%	10.41%	0.00%	0.00%
Ecovio	0.00%	0.00%	0.00%	19.17%	0.00%	0.00%
Electricity	7.63%	2.51%	14.18%	5.48%	0.00%	0.01%
Virgin LDPE	22.95%	5.70%	5.01%	0.00%	0.00%	0.00%
Paper	0.00%	0.00%	0.00%	0.00%	84.74%	90.26%
Colouring Pigment	0.56%	0.75%	0.66%	0.43%	0.00%	0.00%
Recycled LDPE	0.00%	0.46%	0.40%	0.00%	0.00%	0.00%
Thermal Energy	0.10%	0.83%	0.86%	0.06%	0.00%	0.00%
Sealing Strip	2.72%	3.54%	3.11%	1.78%	5.21%	7.00%
Secondary Packaging	1.58%	2.05%	1.80%	0.81%	0.04%	0.12%
Tertiary Packaging	58.41%	75.97%	66.78%	56.67%	15.24%	9.22%
Produced Waste	0.00%	0.00%	0.00%	0.11%	0.00%	0.00%
End-of-life	6.03%	8.14%	7.16%	1.35%	0.30%	0.81%
Sum of the above	**99.97%**	**99.96%**	**99.96%**	**99.98%**	**100.00%**	**99.98%**
Total	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**
Absolute Values (kg)	**3.25E-10**	**2.50E-10**	**2.84E-10**	**6.64E-10**	**1.50E-08**	**1.12E-08**

Table 4-25: Life cycle hotspot analysis for Hazardous Waste Disposed of products recycled at end-of-life (kg)

	Virgin LDPE Bag - Recycled	Recycled LDPE Bag NZ - Recycled	Recycled LDPE Bag CN - Recycled	Home Compostable Bag - Composted	Flat Paper Bag - Recycled	Padded Paper Bag - Recycled
Adhesive	0.00%	0.00%	0.00%	0.00%	-5.56%	-7.51%
Cornstarch	0.00%	0.00%	0.00%	3.76%	0.00%	0.00%
Ecoflex	0.00%	0.00%	0.00%	10.55%	0.00%	0.00%
Ecovio	0.00%	0.00%	0.00%	19.43%	0.00%	0.00%
Electricity	8.12%	2.74%	15.27%	5.55%	0.00%	0.01%
Virgin LDPE	24.42%	6.20%	5.40%	0.00%	0.00%	0.00%
Paper	0.00%	0.00%	0.00%	0.00%	85.00%	91.00%
Colouring Pigment	0.59%	0.82%	0.71%	0.43%	0.00%	0.00%
Recycled LDPE	0.00%	0.50%	0.43%	0.00%	0.00%	0.00%
Thermal Energy	0.11%	0.90%	0.93%	0.06%	0.00%	0.00%
Sealing Strip	2.90%	3.86%	3.35%	1.81%	5.23%	7.06%
Secondary Packaging	1.68%	2.23%	1.94%	0.82%	0.04%	0.12%
Tertiary Packaging	62.15%	82.70%	71.92%	57.44%	15.28%	9.30%
Produced Waste	0.00%	0.00%	0.00%	0.11%	0.00%	0.00%
End-of-life	0.00%	0.00%	0.00%	0.02%	0.00%	0.00%
Sum of the above	**99.97%**	**99.96%**	**99.96%**	**99.98%**	**100.00%**	**99.98%**
Total	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**
Absolute Values (kg)	**3.06E-10**	**2.30E-10**	**2.64E-10**	**6.55E-10**	**1.50E-08**	**1.11E-08**

Table 4-26: Life cycle hotspot analysis for Non-hazardous Waste Disposed of products landfilled at end-of-life (kg)

	Virgin LDPE Bag -Landfill	Recycled LDPE Bag NZ -Landfill	Recycled LDPE Bag CN -Landfill	Home Compostable Bag - Landfill	Flat Paper Bag - Landfill	Padded Paper Bag -Landfill
Adhesive	0.00%	0.00%	0.00%	0.00%	2.81%	1.51%
Cornstarch	0.00%	0.00%	0.00%	10.52%	0.00%	0.00%
Ecoflex	0.00%	0.00%	0.00%	62.07%	0.00%	0.00%
Ecovio	0.00%	0.00%	0.00%	60.19%	0.00%	0.00%
Electricity	0.29%	0.15%	0.45%	7.10%	0.06%	0.06%
Virgin LDPE	1.21%	0.22%	0.22%	0.00%	0.00%	0.00%
Paper	0.00%	0.00%	0.00%	0.00%	4.14%	1.77%
Colouring Pigment	0.08%	0.08%	0.08%	2.07%	0.00%	0.00%
Recycled LDPE	0.00%	1.84%	1.83%	0.00%	0.00%	0.00%
Newspaper Shredding	0.00%	0.00%	0.00%	0.00%	0.00%	0.05%
Thermal Energy	0.01%	0.02%	0.04%	0.08%	0.00%	0.00%
Sealing Strip	0.23%	0.22%	0.22%	5.26%	1.14%	0.61%
Secondary Packaging	0.08%	0.08%	0.08%	1.46%	0.06%	0.07%
Tertiary Packaging	0.38%	0.36%	0.36%	10.63%	2.84%	1.06%
Produced Waste	0.00%	0.00%	0.00%	59.30%	0.00%	0.00%
End-of-life	97.72%	97.03%	96.72%	-118.71%	88.95%	94.86%
Sum of the above	**100.00%**	**100.00%**	**100.00%**	**99.98%**	**100.00%**	**100.00%**
Total	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**
Absolute Values (kg)	**5.27E-03**	**5.52E-03**	**5.53E-03**	**3.13E-04**	**9.30E-03**	**1.73E-02**

Table 4-27: Life cycle hotspot analysis for Non-hazardous Waste Disposed of products recycled at end-of-life (kg)

	Virgin LDPE Bag - Recycled	Recycled LDPE Bag NZ - Recycled	Recycled LDPE Bag CN - Recycled	Home Compostable Bag - Composted	Flat Paper Bag - Recycled	Padded Paper Bag - Recycled
Adhesive	0.00%	0.00%	0.00%	0.00%	25.47%	29.44%
Cornstarch	0.00%	0.00%	0.00%	4.81%	0.00%	0.00%
Ecoflex	0.00%	0.00%	0.00%	28.38%	0.00%	0.00%
Ecovio	0.00%	0.00%	0.00%	27.52%	0.00%	0.00%
Electricity	12.62%	4.95%	13.61%	3.25%	0.52%	1.19%
Virgin LDPE	53.15%	7.44%	6.73%	0.00%	0.00%	0.00%
Paper	0.00%	0.00%	0.00%	0.00%	37.46%	34.35%
Colouring Pigment	3.45%	2.63%	2.38%	0.95%	0.00%	0.00%
Recycled LDPE	0.00%	61.81%	55.93%	0.00%	0.00%	0.00%
Newspaper Shredding	0.00%	0.00%	0.00%	0.00%	0.00%	1.04%
Thermal Energy	0.23%	0.78%	1.10%	0.03%	0.00%	0.00%
Sealing Strip	10.25%	7.51%	6.79%	2.41%	10.30%	11.91%
Secondary Packaging	3.65%	2.67%	2.42%	0.67%	0.53%	1.29%
Tertiary Packaging	16.62%	12.18%	11.02%	4.86%	25.68%	20.70%
Produced Waste	0.00%	0.00%	0.00%	27.11%	0.00%	0.00%
End-of-life	0.00%	0.00%	0.00%	0.01%	0.00%	0.01%
Sum of the above	**99.97%**	**99.98%**	**99.98%**	**99.99%**	**99.97%**	**99.92%**
Total	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**
Absolute Values (kg)	**1.20E-04**	**1.64E-04**	**1.81E-04**	**6.85E-04**	**1.03E-03**	**8.89E-04**

Table 4-28: Life cycle hotspot analysis for Net Use of Fresh Water of products landfilled at end-of-life (kg)

	Virgin LDPE Bag -Landfill	Recycled LDPE Bag NZ -Landfill	Recycled LDPE Bag CN -Landfill	Home Compostable Bag - Landfill	Flat Paper Bag - Landfill	Padded Paper Bag -Landfill
Adhesive	0.00%	0.00%	0.00%	0.00%	30.92%	31.30%
Cornstarch	0.00%	0.00%	0.00%	88.70%	0.00%	0.00%
Ecoflex	0.00%	0.00%	0.00%	3.91%	0.00%	0.00%
Ecovio	0.00%	0.00%	0.00%	2.85%	0.00%	0.00%
Electricity	26.74%	82.52%	64.97%	2.86%	3.72%	7.46%
Virgin LDPE	61.90%	8.82%	17.67%	0.00%	0.00%	0.00%
Paper	0.00%	0.00%	0.00%	0.00%	40.32%	32.37%
Colouring Pigment	1.78%	1.39%	2.77%	0.20%	0.00%	0.00%
Recycled LDPE	0.00%	0.12%	0.23%	0.00%	0.00%	0.00%
Newspaper Shredding	0.00%	0.00%	0.00%	0.00%	0.00%	6.53%
Sealing Strip	1.65%	1.23%	2.47%	0.16%	3.09%	3.13%
Secondary Packaging	2.19%	1.63%	3.27%	0.17%	0.66%	1.39%
Tertiary Packaging	5.65%	4.22%	8.45%	0.79%	16.75%	8.70%
End-of-life	0.07%	0.05%	0.10%	0.35%	4.51%	9.05%
Sum of the above	**99.98%**	**99.98%**	**99.94%**	**99.98%**	**99.97%**	**99.93%**
Total	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**
Absolute Values (L)	**1.02E-01**	**1.36E-01**	**6.81E-02**	**1.40E+00**	**4.23E-01**	**4.18E-01**

Table 4-29: Life cycle hotspot analysis for Net Use of Fresh Water of products recycled at end-of-life (kg)

	Virgin LDPE Bag - Recycled	Recycled LDPE Bag NZ - Recycled	Recycled LDPE Bag CN - Recycled	Home Compostable Bag - Composted	Flat Paper Bag - Recycled	Padded Paper Bag - Recycled
Adhesive	0.00%	0.00%	0.00%	0.00%	32.38%	34.41%
Cornstarch	0.00%	0.00%	0.00%	89.01%	0.00%	0.00%
Ecoflex	0.00%	0.00%	0.00%	3.92%	0.00%	0.00%
Ecovio	0.00%	0.00%	0.00%	2.86%	0.00%	0.00%
Electricity	26.75%	82.56%	65.04%	2.87%	3.89%	8.20%
Virgin LDPE	61.94%	8.83%	17.69%	0.00%	0.00%	0.00%
Paper	0.00%	0.00%	0.00%	0.00%	42.22%	35.59%
Colouring Pigment	1.79%	1.39%	2.78%	0.20%	0.00%	0.00%
Recycled LDPE	0.00%	0.12%	0.23%	0.00%	0.00%	0.00%
Newspaper Shredding	0.00%	0.00%	0.00%	0.00%	0.00%	7.17%
Sealing Strip	1.65%	1.23%	2.47%	0.16%	3.24%	3.44%
Secondary Packaging	2.19%	1.63%	3.27%	0.17%	0.69%	1.53%
Tertiary Packaging	5.65%	4.22%	8.45%	0.79%	17.54%	9.56%
End-of-life	0.00%	0.00%	0.00%	0.00%	0.00%	0.01%
Sum of the above	**99.98%**	**99.98%**	**99.94%**	**99.98%**	**99.97%**	**99.93%**
Total	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**
Absolute Values (L)	**1.02E-01**	**1.36E-01**	**6.81E-02**	**1.39E+00**	**4.04E-01**	**3.80E-01**

4.3. Sensitivity Analysis

The baseline scenario for this study has been defined to best reflect the most realistic situation for the packaging systems. To account for areas of uncertainty and different methodological choices, several scenario analyses have been carried out.

4.3.1. New Zealand's Electricity Grid Mix

A sensitivity analysis has been conducted to determine how the impacts of the products may change with the annual variation of New Zealand's grid mix. The inclusion of the annual national electricity generation quantities was completed by taking information of New Zealand's electricity grid composition from the Ministry of Business, Innovation and Employment (MBIE, 2020) and then constructing new datasets for the annual grid mixes. Due to the inclusion of additional modelling changes, the original 2016 electricity grid mix provided by Sphera is seen as the most reliable dataset.

The sensitivity analysis of the electricity grid mix was only conducted on the New Zealand made rLDPE courier bag as this is the bag where the New Zealand electricity grid mix has the highest contribution to its overall impacts. Therefore, any change in impacts seen for the New Zealand made rLDPE bag will be lower for the other courier bags. The electricity sensitivity analysis also only looks at the changing GWP impacts as this has been deemed the most important indicator for the study.

As seen below in Figure 4-2, the changes to the overall GWP for the rLDPE courier bag landfilled at end-of-life can vary by up to +5.6%, relative to the 2016 New Zealand national electricity grid mix used in this analysis. The results of the sensitivity analysis show that 2016 was a good year for the New Zealand grid and that the impacts of the rLDPE courier bag are slightly sensitive to annual changes in the electricity grid. However, as the difference between the 2016 and 2019 years is only 2.3%, the 2016 electricity data provided by Sphera is seen as appropriate for use is this study.

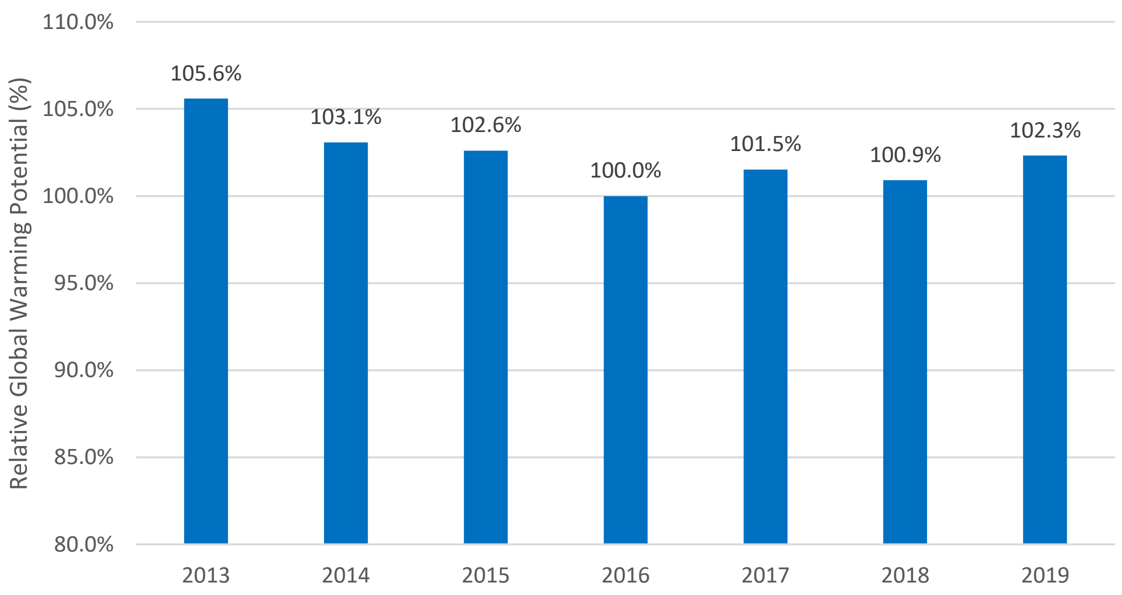


Figure 4-2: New Zealand electricity sensitivity analysis results for rLDPE courier bag, relative to 2016

4.3.2. End-of-Life Allocation Method

The baseline scenario in this report uses the cut-off method for allocation of recycled materials between product life cycles. This means that the impacts of previous and future uses of recycled materials are not considered within the system boundary. The analysis in this section applies the substitution approach instead. As a general rule, the cut-off method favours products with high recycled content irrespective of the recycling rate at end-of-life, whereas the substitution method penalises products that do not produce enough recycled content at end-of-life to manufacture themselves again (i.e., products are penalised if they have a net deficit of recycled content over the full product life cycle).

Figure 4-3 and Figure 4-4, below, show there is some change to the absolute impacts for the different courier bags, as was expected. These changes in impacts are most prevalent in the courier bags which utilise the highest percentage of recycled material and when the courier bags are recycled at end-of-life. While the sensitivity analysis shows there are changes across the products, in no instance does the order of preference change for GWP. As such, the current cut-off end-of-life methodology is deemed appropriate and the conclusion that the New Zealand manufactured recycled LDPE courier bag has the lowest carbon footprint of all courier bags in this study holds true.

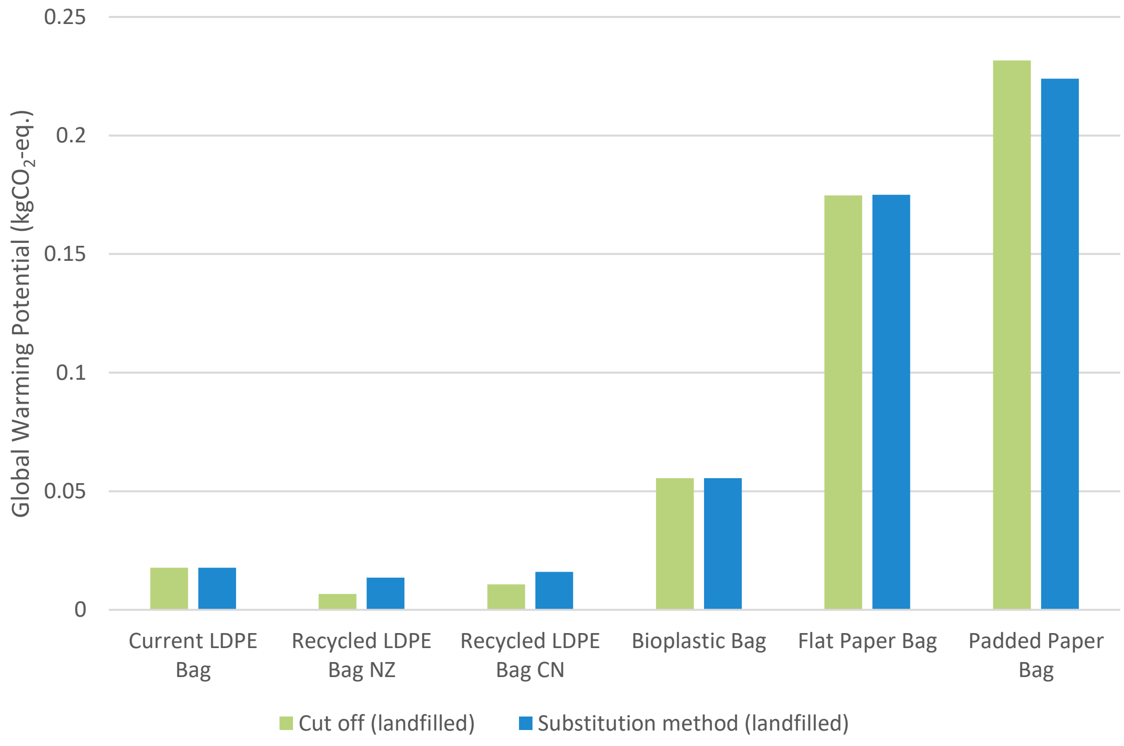


Figure 4-3: Comparison of GWP depending on end-of-life allocation method – landfilled

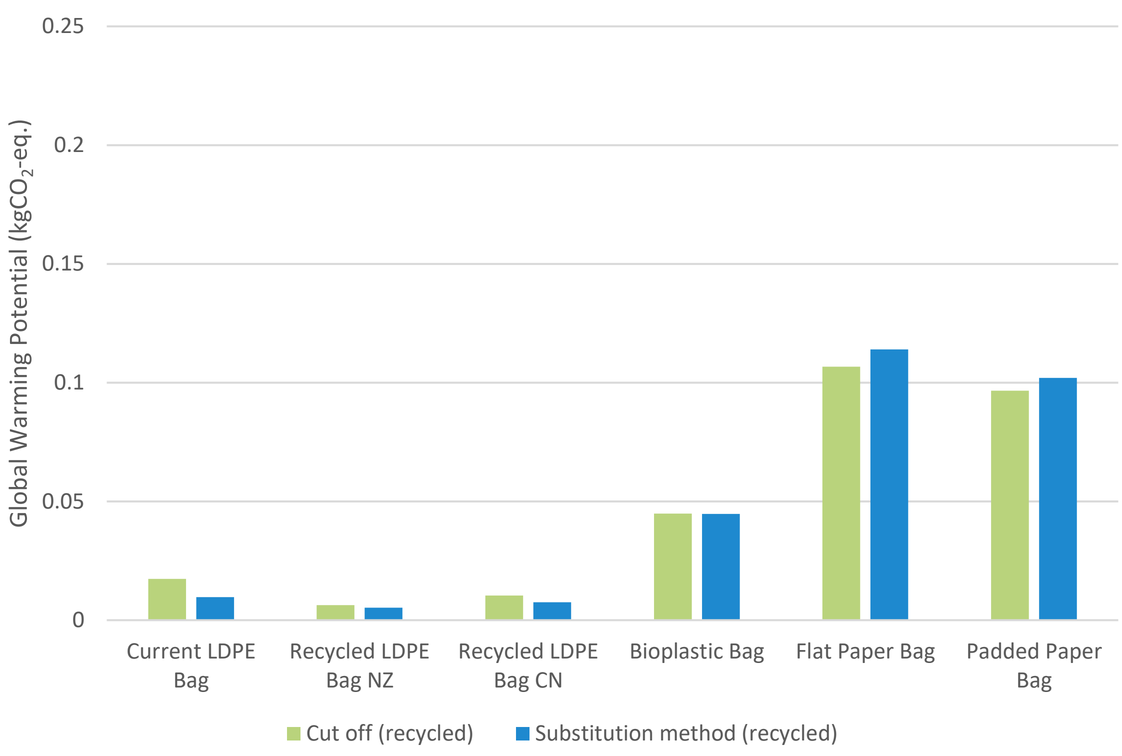


Figure 4-4: Comparison of GWP depending on end-of-life allocation method – recycled or composted

4.4. Scenario Analysis

As there was no dataset available within the GaBi Databases for polybutylene adipate terephthalate (PBAT), which is commonly produced under the trade name Ecoflex, this report uses polyethylene terephthalate (PET) as a proxy. PBAT is also blended with polylactic acid (PLA) to form Ecovio. PET was chosen as the proxy for PBAT as they are both fossil fuel derived polymers produced using dimethyl terephthalate (DMT), making PET the most similar chemical available within the GaBi Database.

An analysis was conducted to test the results of the home compostable bag against the proxy used to model the Ecoflex and Ecovio. The possible alternative proxies for PBAT are listed below in Table 4-30.

Table 4-30: Potential proxies for PBAT

Chemical	Feedstock	Compostable?
PBAT	Fossil fuels	Yes
PET	Fossil fuels	No
Polybutylene Succinate (PBS)	Biomass	Yes
Polylactic Acid (PLA)	Biomass	Yes
Nylon 6,6	Fossil fuels	No
ABS	Fossil fuels	No

To assess how the potential impacts of the home compostable bag change with the proxy selected for PBAT, the results for both GWP and human toxicity were calculated for all options.

Figure 4-5 and Figure 4-6 display the impacts of the investigation for GWP and human toxicity, respectively.

The Global Warming Potential for the home compostable bag is seen to vary from 54-78 g CO_2-eq/bag as the PBAT proxy is changed – a significant variation. However, given that the GWP of the home compostable bag is significantly larger than that for the other plastic bags, the variations within the home compostable bag do not change the conclusions of this study. None of the PBAT proxy scenarios change the performance of the compostable bag to be better or worse than a competing product.

Since identifying the courier bag with the lowest GWP is the main intention of the study, the use of PET as a proxy for PBAT is considered sufficient.

Due to the results for human toxicity having a high uncertainty (section 2.6), comments are made on the relative impacts of the different materials, but quantitative comparisons are deliberately limited. As seen in Figure 4-6, the different PBAT proxies have a large impact on the overall human toxicity of the home compostable bag.

For PLA and PBS, the source of human toxicity from the chemicals is due to releases of heavy metals such as zinc, mercury and lead to agricultural soil. For the remaining fossil fuel based chemicals, the human toxicity is a result of the possible release of mercury to air and both arsenic and chromium to fresh water. As mentioned above, although the proxy for PBAT chosen can greatly vary the overall human toxicity of the home compostable bag, due to GWP being the headline indicator of this study, the proxy is considered sufficient.

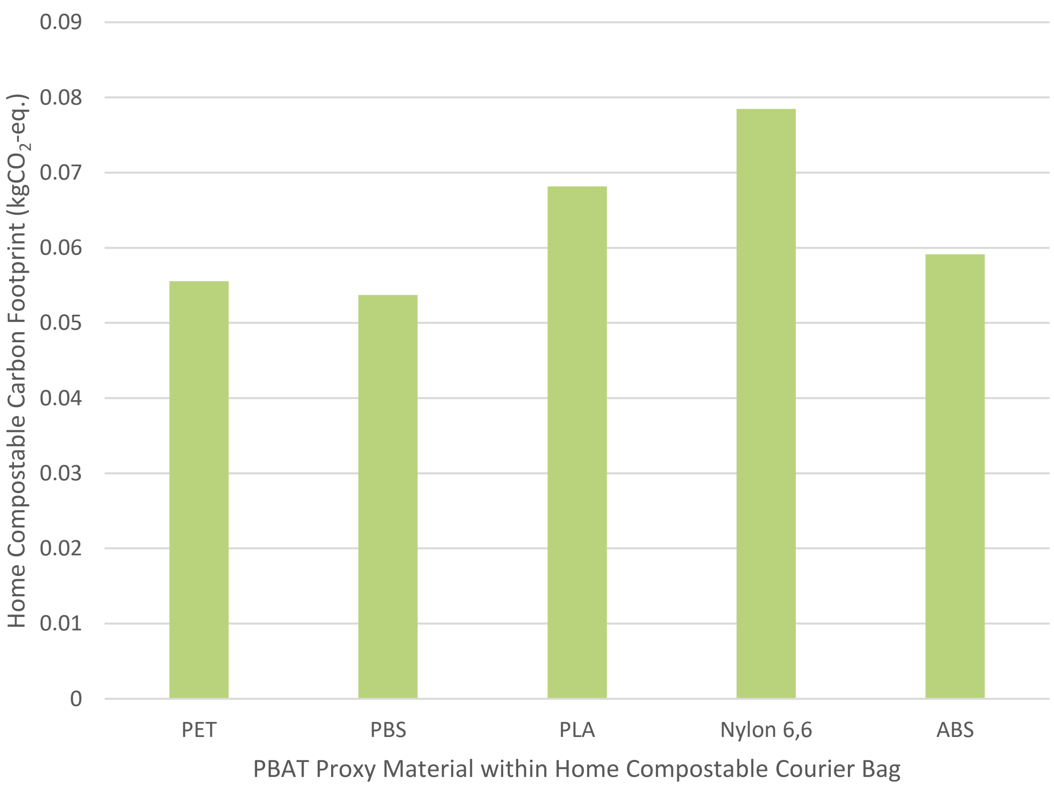


Figure 4-5: Global Warming Potential of home compostable bag as PBAT material changes

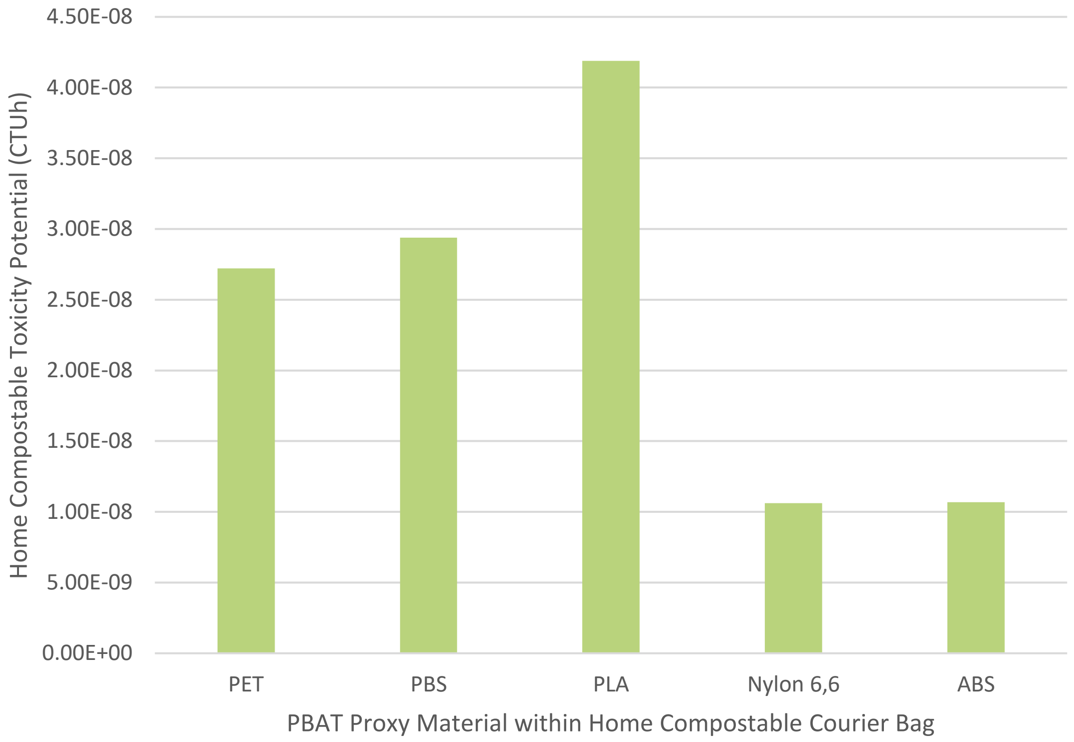


Figure 4-6: Human Toxicity Potential of home compostable bag as PBAT material changes

Table 4-31: Difference in home compostable bag impacts arising from choice of PBAT proxy

Chemical	Absolute Difference to GWP ($kgCO_{2\text{-eq.}}$)	Relative Difference to GWP (%)	Absolute Difference to HTP (CTUh)	Relative Difference to HTP (%)
PBAT	NA	NA	NA	NA
PET	0.00E+00	0%	0.00E+00	0%
Polybutylene Succinate (PBS)	-4.49E-03	-8%	3.80E-09	15%
Polylactic Acid (PLA)	9.94E-03	17%	1.63E-08	64%
Nylon 6,6	2.03E-02	35%	-1.50E-08	-59%
ABS	9.17E-04	2%	-1.49E-08	-58%

5. Interpretation

5.1. Identification of Relevant Findings

The LCIA results and hotspot analysis show:

- Courier bags manufactured in New Zealand from 80% recycled LDPE have the lowest Global Warming Potential and Human Toxicity Potential of all options considered within this study. Overall, the 80% recycled LDPE courier bags have the lowest impacts across all environmental indicators included within this study, except for non-hazardous waste disposed and net use of fresh water. Importantly, both indicators are inventory indicators and do not consider potential environmental impacts. When impacts are considered (e.g. Water Scarcity Footprint instead of net use of water), the New Zealand made recycled LDPE bags perform best.
- The raw materials are the main source of impact for bags made from virgin sources.
- The location of recycling is the main determining factor for the performance of recycled materials, due primarily to that location's energy mix.
- Landfilling is a high impact process for bags which can degrade, but not very significant for inert plastic bags.

Scenario analysis shows:

- The performance of the home compostable bag does depend on the material used as a proxy for Ecoflex (and Ecovio) due to no suitable secondary data being available for this material in the GaBi Databases. However, the conclusions of this study do not change with any of the four alternatives considered.
- Annual fluctuations in New Zealand's annual electrical grid mix have no significant implications for the overall impacts of the products.

5.2. Assumptions and Limitations

A number of assumptions were made in this study, as described in sections 2 and 3. Where possible, a conservative approach has been applied, including proxies rather than cutting off elements where there was uncertainty. The minor flows which were excluded from the study using cut-off criteria are assumed to have negligible impact on the outcome of the study.

Landfilling has been identified as a leading source of emissions for bags which can degrade. As discussed previously, landfilling emissions arise due to the production and subsequent release of methane to the atmosphere. As the methane capture rate will vary from landfill to landfill, the absolute emissions will depend on where the user disposes of their courier bag. However, as the products which can degrade have higher impacts than the LDPE bags before landfill impacts are considered, the methane capture rate will not alter the conclusions of this study.

While the padded paper envelope performed worse that the flat paper envelope across most indicators including Global Warming Potential, it should be noted that it is a functionally superior product and offers greater protection to goods stored within it.

As discussed in Chapter 4, the dataset used for modelling the kraft paper within the padded and flat courier bags has been modified to reflect the higher carbon footprint of the supplier. However, these changes have not been extended to cover the other indicators within this study due to a lack of data. As these changes should only increase the impacts of the paper bag, due to a higher dependence on fossil fuels in manufacturing, the current modelling is conservative as it reflects the best case scenario for the paper courier bags. Because both paper bags already perform worse than the recycled LDPE bag across nearly all indicators, the changes in impacts should not alter the conclusions of this study.

5.3. Data Quality Assessment

Inventory data quality is judged by its precision (measured, calculated or estimated), completeness (e.g., unreported emissions), consistency (degree of uniformity of the methodology applied) and representativeness (geographical, temporal, and technological).

To cover these requirements and to ensure reliable results, first-hand industry data in combination with consistent background LCA information from the GaBi 2020 database were used. The LCI datasets from the GaBi 2020 database are widely distributed and used with the GaBi 6 Software. The datasets have been used in LCA models worldwide in industrial and scientific applications in internal as well as in many critically reviewed and published studies. In the process of providing these datasets they are cross-checked with other databases and values from industry and science.

5.3.1. Precision and Completeness

- ✓ **Precision:** All material weights are based on measured data. All background data for manufacturing, transport and end-of-life are sourced from GaBi Databases with the documented precision.
- ✓ **Completeness:** Each foreground process was checked for mass balance and completeness of the emission inventory. Completeness of foreground unit process data is considered to be sufficient. All background data are sourced from GaBi databases with the documented completeness.

5.3.2. Consistency and Reproducibility

- ✓ **Consistency:** To ensure data consistency, all primary data were collected with the same level of detail, while all background data were sourced from the GaBi databases.
- ✓ **Reproducibility:** Reproducibility is supported as much as possible through the disclosure of input-output data, dataset choices, and modelling approaches in this report. Based on this information, any third party should be able to approximate the results of this study using the same data and modelling approaches.

5.3.3. Representativeness

- ✓ **Temporal:** All primary data were collected for the year 2020. All secondary data come from the GaBi 2020 databases and are representative of the years 2016-2019. As the study intended to compare the product systems for the reference year 2020, temporal representativeness is considered to be good.

- ✓ **Geographical:** All primary and secondary data were collected specific to the countries or regions under study. Where country-specific or region-specific data were unavailable, proxy data were used. Geographical representativeness is considered to be sufficient.
- ✓ **Technological:** All primary and secondary data were modelled to be specific to the technologies or technology mixes under study. Where technology-specific data were unavailable, proxy data were used. Technological representativeness is considered to be sufficient.
- ✓ **Equivalence:** All of the courier bags are designed to contain A5 sized goods and have been considered functionally suitable to replace the virgin LDPE courier bag by New Zealand Post as a prerequisite. Therefore, the different products within this study are considered to be appropriately equivalent, with the exception of the padded paper courier bag that is functionally superior.

5.4. Model Completeness and Consistency

5.4.1. Completeness

All relevant process steps for each product system were considered and modelled to represent each specific situation. The process chain is considered sufficiently complete and detailed with regards to the goal and scope of this study.

5.4.2. Consistency

All assumptions, methods and data are consistent with each other and with the study's goal and scope. Differences in background data quality were minimised by exclusively using LCI data from the GaBi 2020 databases. System boundaries, allocation rules, and impact assessment methods have been applied consistently throughout the study.

5.5. Conclusions, Limitations, and Recommendations

5.5.1. Conclusions

- The analysis shows the courier bag produced in NZ from recycled granulate is the highest performing product across the majority of the environmental indicators investigated in this study (12 out of 14) for both end-of-life treatment scenarios.
- The electricity grid utilised for the manufacturing processes is an important factor in determining the emissions of the recycled LDPE bags.
- Bags which are made from compostable materials have far higher life cycle emissions when placed in landfill at the end of their usable life. This is due to using largely fossil fuel derived plastic that is biodegradable.

5.5.2. Limitations

- Based on all the possible proxies investigated, it is likely the PBAT used within the home compostable bag will be a leading source of the bag's emissions. However, there is no reason to suggest the PBAT will perform better than the PET proxy used and so the conclusions drawn remain true.

- As discussed in Chapter 4, with the exception of GWP, the environmental impacts of the paper manufacturing have not been completely captured. However, as the impacts will be higher than currently modelled, there will be no changes to the conclusions made by this study.
- This study has been undertaken with the intention of identifying the possible environmental impacts for two different end-of-life treatment options potentially available to consumers. On average, a mixture of the two end-of-life treatment options will occur depending on the recycling recovery rates in the consumer's region. Varying recycling rates will produce real world impacts within the limits of the two sets of results provided; however, this is out of the scope of this study.

5.5.3. Recommendations

Based on the findings of this study, NZ Post should consider replacing its virgin LDPE courier bags with bags manufactured from recycled LDPE. Due to the lower emissions of the national electrical grid, it is also recommended that the bags be manufactured in New Zealand.

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List of Acronyms

CN	China
CML	Institute of Environmental Sciences at Leiden University
CO_2	Carbon Dioxide
$CO_{2\text{-eq}}$	Carbon Dioxide Equivalent
CTUh	Comparative Toxic Unit for Humans
DMT	Dimethyl Terephthalate
EoL	End-of-Life
EVA	Ethylene Vinyl Acetate
GaBi	Ganzheitliche Bilanzierung (German for holistic balancing)
GHG	Greenhouse Gas
GWP	Global Warming Potential
HTP	Human Toxicity Potential
IPCC	Intergovernmental Panel on Climate Change
ISO	International Organization for Standardization
LCA	Life Cycle Assessment
LCI	Life Cycle Inventory
LCIA	Life Cycle Impact Assessment
LDPE	Low Density Polyethylene
MCI	Material Circularity Indicator
NZ	New Zealand
PBAT	Polybutylene Adipate Terephthalate
PBS	Polybutylene Succinate
PET	Polyethylene Terephthalate
PLA	Polylactic Acid
PVA	Polyvinyl Acetate
rLDPE	Recycled Low Density Polyethylene
SETAC	Society of Environmental Toxicology and Chemistry
UNEP	United Nations Environmental Programme
VIC	Victoria

Glossary of Terms

Life cycle

A view of a product system as “consecutive and interlinked stages … from raw material acquisition or generation from natural resources to final disposal” (ISO 14040:2006, section 3.1). This includes all material and energy inputs as well as emissions to air, land and water.

Life Cycle Assessment (LCA)

“Compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle” (ISO 14040:2006, section 3.2)

Life Cycle Inventory (LCI)

“Phase of life cycle assessment involving the compilation and quantification of inputs and outputs for a product throughout its life cycle” (ISO 14040:2006, section 3.3)

Life Cycle Impact Assessment (LCIA)

“Phase of life cycle assessment aimed at understanding and evaluating the magnitude and significance of the potential environmental impacts for a product system throughout the life cycle of the product” (ISO 14040:2006, section 3.4)

Life cycle interpretation

“Phase of life cycle assessment in which the findings of either the inventory analysis or the impact assessment, or both, are evaluated in relation to the defined goal and scope in order to reach conclusions and recommendations” (ISO 14040:2006, section 3.5)

Environmental Product Declaration (EPD)

“Independently verified and registered document that communicates transparent and comparable information about the life-cycle environmental impact of products.”

Product Category Rule (PCR)

“Defines the rules and requirements for EPDs of a certain product category.”

Functional / Declared unit

“Quantified performance of a product system for use as a reference unit.” (ISO 14040:2006, section 3.20)

Functional unit = LCA/EPD covers entire life cycle “cradle to grave”.

Declared unit = LCA/EPD is not based on a full “cradle to grave” LCA, common in construction product EPDs.

Allocation

“Partitioning the input or output flows of a process or a product system between the product system under study and one or more other product systems” (ISO 14040:2006, section 3.17)

Foreground system

“Those processes of the system that are specific to it … and/or directly affected by decisions analysed in the study.” (JRC, 2010, 97) This typically includes first-tier suppliers, the manufacturer itself and any downstream life cycle stages where the manufacturer can exert significant influence. As a general rule, specific (primary) data should be used for the foreground system.

Background system

“Those processes, where due to the averaging effect across the suppliers, a homogenous market with average (or equivalent, generic data) can be assumed to appropriately represent the respective process … and/or those processes that are operated as part of the system but that are not under direct control or decisive influence of the producer of the good….” (JRC, 2010, 97-98) As a general rule, secondary data are appropriate for the background system, particularly where primary data are difficult to collect.

Closed-loop and open-loop allocation of recycled material

“An open-loop allocation procedure applies to open-loop product systems where the material is recycled into other product systems and the material undergoes a change to its inherent properties.”

“A closed-loop allocation procedure applies to closed-loop product systems. It also applies to open-loop product systems where no changes occur in the inherent properties of the recycled material. In such cases, the need for allocation is avoided since the use of secondary material displaces the use of virgin (primary) materials.”

(ISO 14044:2006, section 4.3.4.3.3)

Critical Review

“Process intended to ensure consistency between a life cycle assessment and the principles and requirements of the International Standards on life cycle assessment” (ISO 14044:2006, section 3.45).

Annex A Critical Review Statement

Critical Review Statement

Study	Life Cycle Assessment of Courier Bags for New Zealand Post Dated: 8 March 2021 Version: 1.7
Commissioner of the LCA study	New Zealand Post Level 12, New Zealand Post House 7 Waterloo Quay, Pipitea, Wellington 5045, New Zealand
Practitioners of the LCA study	Ben Riordan, Sustainability Engineer Jeff Vickers, Technical Director thinkstep Ltd 11 Rawhiti Road, Pukerua Bay Wellington 5026, New Zealand
Independent external expert reviewers (review panel)	Chairperson: Andrew D Moore, Life Cycle Logic (Australia) Helen Lewis, Helen Lewis Research (Australia) Kimberly Robertson, Catalyst® Ltd (New Zealand)

Scope of the Critical Review

The critical review process has been conducted following the international standards for life cycle assessment: Critical review processes and reviewer competencies ISO/TS 14071:2014.

The aim of the critical review process is to ensure that:

- The methods used to carry out the study followed the international standards:
    - ISO 14040:2006 International Organisation for Standardisation (ISO), Environmental management – Life cycle assessment – Principles and framework, Genève, Switzerland.
    - ISO 14044:2006 International Organisation for Standardisation (ISO), Environmental management – Life cycle assessment – Life Cycle Interpretation, Genève, Switzerland.
    - ISO 14067:2018 Greenhouse Gases — Carbon Footprint of Products — Requirements and Guidelines for Quantification. International Standard Organization (ISO), Genève, Switzerland.
- 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 report is transparent and consistent with the aims of the study

The critical review covered all aspects of the LCA, including data appropriateness and reasonability, calculation procedures, life cycle inventory, impact assessment methodologies, characterisation factors, calculated life cycle inventory and life cycle inventory analysis results, and interpretation.

Review process

The review was:

- Undertaken by a panel of interested parties
- Performed at the end of the study
- Performed on the report: 'Life Cycle Assessment of Courier Bags' for New Zealand Post (version 1.7, dated 8 March 2021).

The review included an assessment of the life cycle inventory model (as detailed in the report) and of the individual datasets (as detailed in the study report).

The study was reviewed according to the above scope. Reviewer comments were tabled; classified as general, technical or editorial; and provided to the study authors. All reviewer comments were addressed through the review process. For details of the review please refer to the critical review comments in Annex E Review Commentary section of the report.

General evaluation

The study is a comprehensive Life Cycle Assessment of New Zealand Post single-use courier bags. The scope of the study was found to be appropriate to achieve the stated goals. It included comprehensive sensitivity analysis of key assumptions and methodological choices to increase the confidence in the findings of the study. Overall, the study was performed in a professional manner.

Conclusions

The reviewers found the overall quality of the final version of the study to be of a very high standard. The study has been carried out in conformance with ISO 14040:2006, ISO 14044:2006 and ISO 14067:2018. The study is reported in a comprehensive manner and includes transparent documentation of the goal, scope, inventory data, modelling methodology, results and conclusions.

Independent external expert reviewers

[signature]	[signature]	[signature]
Andrew D Moore Principal Scientist 8/3/2021	Helen Lewis Principal 8/3/2021	Kimberly Robertson Consultant 8/3/2021

Annex B Confidential Data

Confidential details have been removed from this public report, but were provided to the review panel.

Annex C ISO 14067 Results

The results presented in the body of this report exclude biogenic carbon. The results presented in Table 6-2 follow ISO 14067 and include biogenic carbon, with withdrawals and emissions of biogenic carbon presented as a net “GWP100 Biotic” value below. As a result of slight differences in methodology within the GaBi software for each indicator, the total GWP below differs slightly from the body of this report.

Table 6-2: GWP100 results following ISO 14067

Scenario	ISO14067 GWP100, Total (kg CO_2 eq.)	ISO14067 GWP100, Aviation (kg CO_2 eq.)	ISO14067 GWP100, Biotic (kg CO_2 eq.)	ISO14067 GWP100, Fossil Fuels (kg CO_2 eq.)	ISO14067 GWP100, Land Use (kgCO_2 eq.)
Landfilled at end-of-life					
Virgin LDPE Bag	1.72E-02	7.31E-08	-5.84E-04	1.78E-02	1.01E-05
Recycled LDPE Bag NZ	6.09E-03	6.17E-08	-5.75E-04	6.66E-03	6.07E-06
Recycled LDPE Bag CN	1.02E-02	7.05E-08	-5.83E-04	1.08E-02	8.91E-06
Home Compostable Bag	4.79E-02	1.02E-07	1.10E-02	3.68E-02	1.37E-04
Flat Paper Bag	1.38E-01	8.65E-07	2.89E-02	1.09E-01	2.86E-04
Padded Paper Bag	2.39E-01	8.60E-07	1.38E-01	1.01E-01	2.56E-04
Recycled at end-of-life					
Virgin LDPE Bag	1.69E-02	7.27E-08	-5.73E-04	1.74E-02	9.84E-06
Recycled LDPE Bag NZ	5.72E-03	6.13E-08	-5.63E-04	6.28E-03	5.75E-06
Recycled LDPE Bag CN	9.82E-03	7.01E-08	-5.71E-04	1.04E-02	8.59E-06
Home Compostable Bag	3.85E-02	1.01E-07	-4.67E-03	4.30E-02	1.37E-04
Flat Paper Bag	4.10E-02	8.62E-07	-6.58E-02	1.07E-01	2.85E-04
Padded Paper Bag	4.65E-02	8.55E-07	-5.03E-02	9.65E-02	2.54E-04

Annex D Additional Indicators

Table 6-3: Remaining indicator potential impacts for landfilled courier bags

Indicator	Unit	Virgin LDPE Bag -Landfill	Recycled LDPE Bag NZ - Landfill	Recycled LDPE Bag CN - Landfill	Home Compostable Bag - Landfill	Flat Paper Bag - Landfill	Padded Paper Bag - Landfill
Human toxicity, total	CTUh	2.36E-09	1.07E-09	1.22E-09	2.72E-08	2.16E-08	2.27E-08
Acidification potential of land and water	kg SO_2-eq.	1.86E-04	6.49E-05	6.60E-05	1.85E-04	1.28E-04	1.51E-04
Eutrophication potential	kg PO_4^{3-}-eq.	8.14E-06	3.64E-06	4.56E-06	5.95E-05	3.80E-05	3.83E-05
Photochemical ozone formation potential	kg NOx-eq.	5.11E-05	1.76E-05	2.38E-05	7.08E-05	1.36E-04	1.57E-04
Abiotic depletion potential – elements	kg Sb-eq.	4.54E-09	3.13E-09	3.33E-09	1.62E-08	3.81E-08	3.36E-08
Abiotic depletion potential – fossil fuels	MJ	4.49E-01	1.42E-01	1.81E-01	5.72E-01	6.08E-01	6.89E-01
Primary energy demand from non-renewable resources	MJ	4.54E-01	1.44E-01	1.86E-01	5.81E-01	6.54E-01	7.28E-01
Total primary energy demand from renewable and non-renewable resources	MJ	4.85E-01	2.02E-01	2.14E-01	7.67E-01	1.91E+00	1.73E+00
Water scarcity footprint	kg	3.47E-03	1.63E-03	1.99E-03	5.63E-02	7.94E-03	1.00E-02
Hazardous waste disposed	kg	3.25E-10	2.50E-10	2.84E-10	6.64E-10	1.50E-08	1.12E-08
Non-hazardous waste disposed	kg	5.27E-03	5.52E-03	5.53E-03	3.13E-04	9.30E-03	1.73E-02
Net use of fresh water	L	1.02E-01	1.36E-01	6.81E-02	1.40E+00	4.23E-01	4.18E-01

Table 6-4: Remaining indicator potential impacts for recycled and composted courier bags

Indicator	Units	Virgin LDPE Bag - Recycled	Recycled LDPE Bag NZ - Recycled	Recycled LDPE Bag CN - Recycled	Home Compostable Bag - Composted	Flat Paper Bag - Recycled	Padded Paper Bag - Recycled
Human toxicity, total	CTUh	2.15E-09	8.47E-10	1.00E-09	2.70E-08	2.06E-08	2.07E-08
Acidification potential of land and water	kg SO_2-eq.	1.85E-04	6.39E-05	6.51E-05	1.81E-04	1.12E-04	1.19E-04
Eutrophication potential	kg PO_4^{3-}-eq.	7.15E-06	2.61E-06	3.54E-06	5.88E-05	3.48E-05	3.19E-05
Photochemical ozone formation potential	kg NOx-eq.	5.04E-05	1.69E-05	2.32E-05	6.49E-05	1.12E-04	1.10E-04
Abiotic depletion potential – elements	kg Sb-eq.	4.47E-09	3.06E-09	3.26E-09	1.61E-08	3.77E-08	3.28E-08
Abiotic depletion potential – fossil fuels	MJ	4.43E-01	1.36E-01	1.76E-01	5.67E-01	5.79E-01	6.31E-01
Primary energy demand from non-renewable resources	MJ	4.48E-01	1.38E-01	1.80E-01	5.77E-01	6.24E-01	6.69E-01
Total primary energy demand from renewable and non-renewable resources	MJ	4.79E-01	1.96E-01	2.08E-01	7.62E-01	1.88E+00	1.66E+00
Water scarcity footprint	kg	3.48E-03	1.64E-03	1.99E-03	5.62E-02	7.40E-03	8.92E-03
Hazardous waste disposed	kg	3.06E-10	2.30E-10	2.64E-10	6.55E-10	1.50E-08	1.11E-08
Non-hazardous waste disposed	kg	1.20E-04	1.64E-04	1.81E-04	6.85E-04	1.03E-03	8.89E-04
Net use of fresh water	L	1.02E-01	1.36E-01	6.81E-02	1.39E+00	4.04E-01	3.80E-01

Annex E Review Commentary

The dialogue between the reviewers and the LCA practitioner during the panel review has been transparently documented below in accordance with the critical review requirements of ISO 14044:2006 and ISO 14071:2014.

Table 6-5: Dialogue between the reviewers and the LCA practitioner during the panel review

Initials of reviewer	Date of comment	Reference	Type	Reviewer question/comment and recommendation	Practitioner of LCA study response	Final approval
KR, ADM	29/10/2020	2.6 Selection of LCIA methodology and Impact categories	te	ISO14044:2006, section 4.4.5 requires: "An LCIA that is intended to be used in comparative assertions intended to be disclosed to the public shall employ a **sufficiently comprehensive set of category indicators**. The comparison shall be con-ducted category indicator by category indicator." The LCA standard requires a sufficiently comprehensive set of internationally accepted category indicators. It is recommended to add EP, AP, ODP, POCP, ADPE, ADPF, FW (and optionally waste indicators). Considering that the LDPE bags are produced from non-renewable fossil fuels it would be important to consider ADPE and APPF. The other alternative is to make the focus of the study the carbon footprints (and optionally include MCI), however, this would mean that comparative assertions of "environmental superiority" could not be made.	The scope has been expanded to a total of 14 relevant indicators.	OK
ADM	29/10/2020	List of Acronyms	ed	ILCD: International Reference Life Cycle Data System	Removed.	OK
ADM	29/10/2020	List of Acronyms	ed	Please revise the list of acronyms as it appears many acronyms are missing (e.g. rLDPE, CTUh, PBA, JRC, CN, NZ, UNEPSETAC, CO_2 , CO_2-eq, VIC, PET, PLA, DMT, PBS…)	Updated to include all acronyms.	OK
ADM	29/10/2020	Glossary	ed	Please revise and delete terms that are not relevant for this study e.g. EPD, PCR, declared unit)	Removed non-relevant terms.	OK

Initials of reviewer	Date of comment	Reference	Type	Reviewer question/comment and recommendation	Practitioner of LCA study response	Final approval
ADM	29/10/2020	Executive summary	ed	including the approximate external dimensions is too vague. Recommend deleting and including details in section 2. Scope of the Study	“approximately” removed. Specific parcel dimensions have been added.	OK
ADM	29/10/2020	Executive summary	ge	Please ensure the points relating to the inclusion of padded paper envelope considered in the Interpretation of results.	Have added a comment stating that the padded paper is functionally superior to flat paper and that this metric is not covered by the study.	OK
KR	22/10/2020	Executive summary, Pg 10	ge	Executive summary doesn’t include much information on human toxicity. Consider adding a paragraph on human toxicity results (and other impact categories to that may also be included).	The explanation of the indicators and their results has been kept short to prevent the executive summary becoming too long. GWP has been explained as it is the most important indicator with the descriptions and results for the remaining indicators found later in the report.	OK
ADM	29/10/2020	Executive summary and 2.3 system boundary	te	Is secondary (primary?) packaging included in the study? As the product itself is packaging, the product packaging should be considered primary packaging (e.g. the boxes the courier bags are packaged in). Please clarify, and if excluded, ensure the exclusion is sufficiently justified. **10/12/2020** The naming of the packaging layers certainly improves the readability of the study. Please revise the use of secondary and tertiary packaging to ensure that they are consistent (e.g. the packaging terms in the Key Material Flow tables in section 3.2.2 appear to be different from stated in section 2.1.1).	All relevant packaging layers are included in the study. A section explaining the packaging systems has been added. **3/12/2020** Updated naming of packaging layers. Secondary packaging is for grouping and display. Tertiary packaging is for transit (shipper boxes and pallets). **15/2/2021** Issue corrected.	OK

Initials of reviewer	Date of comment	Reference	Type	Reviewer question/comment and recommendation	Practitioner of LCA study response	Final approval
KR	22/10/2020	Executive summary, Pg 10	ge	Four alternative bags are included. Is there a reusable bag option? Could bags be designed for easy reuse? Eg resealed and new address sticker applied? Include information on why there is no reusable option included in analysis.	A statement has been added to address New Zealand Post's stance on the current suitability of reusable bags within New Zealand.	OK
ADM	29/10/2020	Executive summary	ge	The figures are presented with the same number of significant figures (following EPD convention), however, in this context it makes more sense to use the same number of decimal places (e.g. as the figures are for the same impact category). Consider revision.	Results presented to 4dp	OK
HL	23/11/20	Executive summary pg 18	ge	Suggest adding to last para – 'different end of life treatment methods **potentially** available to end consumers' as recycling and home composting not easily accessible by all consumers	"potentially" added to paragraph	OK
ADM	29/10/2020	1 Goal	te	Please address all of the ISO14044:2006, section 4.2.2 requirements for goal definition (e.g. the intended application, intended audience, whether the results are intended to be used in comparative assertions intended to be disclosed to the public)	Intended audience and scope of comparisons listed in goal of study	OK
ADM	29/10/2020	2.1 Product systems	ge	Please revise the description of the product systems and provide actual dimensions of the products in Table 2 to ensure the products are sufficiently described. It is also recommended to include product photos (where available). For example, are the bags designed to contain an A5 card/letter or are the external dimensions of the bag A5?	Description of products refined to convey they are intended to house A5 sized items. Photos or schematics have been added for further clarification of the product details.	OK
ADM	29/10/2020	2.1 Product systems	ed	The term "fossil" is used several times in the report in places where "fossil fuel" or non-renewable fossil fuel could be more appropriate. Consider revision. **22/11/2020** Some references to "fossil" remain. Recommend further revision for consistency.	Terms refined to "fossil fuel" where relevant. **27/1/2020** Have reviewed and amended missed terms	OK

Initials of reviewer	Date of comment	Reference	Type	Reviewer question/comment and recommendation	Practitioner of LCA study response	Final approval
KR, ADM	22/10/2020	Pg 14, table 2, Table 4, and Pg 52 Table 15	ge	Why does the rLDPE bag weigh less than the LDPE bag? Wouldn't they weigh the same to be functionally the same? Weights of LDPE and rLDPE bags provided in Table 2 are different to table 4 and table 15. Table 2 and 15 weights should be consistent and to the same decimal places. Please revise for consistency. **22/11/2020** The figures for the weights in Table 2 and Table 7are very slightly different to those in Table 49: Material mass and composition of courier bags. For example, the Recycled LDPE bag is 5.23g in Table 2 but the figures in Table 49 add up to 5.2g. Is there a reason for this difference? If not, I'd recommend revising for consistency, especially as the error range of the measurement is stated to be ±5% (which is 0.27g for the rLDPE bag).	This was a human error. The mass of rLDPE is 5.23g. Mass is slightly higher to account for the slight decrease in material strength as a result of the recycling process. Tables amended to use 2 decimal places. **27/11/2020** Table 49 (now table 50) has been revised to list component masses to 2 decimal places. Materials now add to respective bag masses.	OK
HL	23/10/2020	2.1 Product systems, Table 2	ge	The predominant materials for the home compostable bag should specify the polymers not (or in addition to) brand names, e.g. AAC/PBAT, PLA and corn starch	A statement has been added explaining the brand names for each of the polymers. The brand names have been used in order to present the results at the same level as the components used during manufacturing.	OK

Initials of reviewer	Date of comment	Reference	Type	Reviewer question/comment and recommendation	Practitioner of LCA study response	Final approval
ADM, KR	29/10/2020	2.2 Functional unit	te	Please revise the functional unit to ensure it is unambiguously defined (including units for comparison and performance characteristics). E.g. single use disposable, excludes goods contained within, include examples of typical packaged goods, define whether the bags are designed to take A5 or are A5 size, is adhesive to close the bags included/excluded, is there a weight range that the bags need to be able to hold?). Please see the NZ Post website for an example of the product details that (at minimum) would be needed to clearly define the product and it's function (https://www.nzpost.co.nz/shop/domestic-parcels/postage-included-bags/size-2-bag)	Have updated to be more specific.	OK
HL	23/11/20	2.2 Functional unit	ed	Fix typo in first para, i.e. reference to 'successful functioning ~~of the courier~~ of the courier bags'	Amended	OK
ADM	29/10/2020	2.3 system boundary	te	Is the transport to EoL included?	Yes, the impacts from which are included within the relevant end-of-life process.	OK
ADM	29/10/2020	2.4.1 Multi-output allocation	te	Does the allocation follow the requirements of ISO 14044:2006? Please revise the use of the word "generally".	Yes, it does comply. The term "generally" has been removed.	OK
ADM	29/10/2020	2.4.1 Multi-output allocation	te	Please include a complete reference to the GaBi database in the Reference section of the report and cross reference.	Changed from Gabi search page to Gabi 2020 LCI documentation page	OK

Initials of reviewer	Date of comment	Reference	Type	Reviewer question/comment and recommendation	Practitioner of LCA study response	Final approval
HL, KR, ADM	22/10/2020	2.4.2 End-of-life allocation Pg 15	te	Does the choice of the end-of-life allocation method affect the results? It is recommended to include this in the sensitivity analysis section. The comment about poor recovery rates does not apply to paper/cardboard bags. **26/11/2020** Please included this response/comment in section 5.5.2 Limitations of the study as actual average recycling rates will vary.	Yes, the chosen end-of-life scenario does affect the results. However, this study looks at the individual bags and the end-of-life options available to the consumer rather than the market average treatment and so no sensitivity analysis has been conducted. A comment has been added to the executive summary to explain the reasoning for utilising specific end-of-life treatments. **27/11/2020** A paragraph has been added to 5.5.2 which states the real world impacts will be somewhere in between the limits of the two sets of results provided.	OK

Initials of reviewer	Date of comment	Reference	Type	Reviewer question/comment and recommendation	Practitioner of LCA study response	Final approval
KR, HL	22/10/2020	2.4.2 End-of-life allocation Pg 15 and 3.1.5 End-of-life		It is not clear what recycling rates have been assumed for each material and whether or not these are realistic. LDPE consumer packaging is recycled at very low rates, through supermarket drop-off systems (in Australia would probably be around 1%). Love NZ Soft Plastics Recycling Scheme is currently only available in 5 regions in selected stores. Is NZ post considering setting up plastic courier bag recycling drop offs in stores? Paper is recycled at relatively high rates through kerbside or municipal drop-off. Include information on actual recycling rates in NZ for the various materials.	This study looks at the individual bags and the end-of-life treatment options available to the consumer rather than the market average treatment and the specific recycling rates have been excluded.	OK
ADM	29/10/2020	2.6 Selection of LCIA	te	It states that USEtox results should not be used for comparative assertions – if so why has this impact category been selected for this study if the goal of the study is to make comparative assertions?	Amended to detail that limitations in characterisation factors within the USEtox methodology means it should not be used for absolute assertions.	OK
HL	23/11/20	2.6 Pg 32 third para last line –	ed	Should say ‘**too** imprecise’	Amended	OK
ADM	29/10/2020	MCI	te	Please ensure the limitations of the MCI been adequately described and assessed. See https://www.researchgate.net/publication/320779652_TOWARDS_MEASURING_CIRCULARITY_AT_PRODUCT_LEVEL_-_METHODOLOGY_AND_APPLICATION_OF_MATERIAL_CIRCULARITY_INDICATOR	Have added a paragraph on the limitations of the MCI tool.	OK

Initials of reviewer	Date of comment	Reference	Type	Reviewer question/comment and recommendation	Practitioner of LCA study response	Final approval
ADM	29/10/2020	MCI, Table 4: Impact category descriptions	te	Please add the units for the MCI **26/11/2020** Please add “MCI score 0-1” to table 4 Units provide the context and scale of the measured quantity as well as establishing a common framework by which physical results are expressed. For MCI, the scale has been included (0-1), but the context and common framework still need to be added.	There are none. **27/11/2020** Have added “MCI score” beforehand for context	OK
ADM	29/10/2020	2.8 Data quality requirement	ge	The last dot point states that “the most representative industry-average data for all background processes” has been used which appears to contradict the statement in section 2.3.2 which states that “The data collected and assumptions made are intended to represent the packaging industries’ best practices in 2020”. Please revise.	Have revised the first statement for consistency. Both now state to be in line with best industry practices.	OK
ADM	29/10/2020	2.10	te	Please ensure the version of the GaBi database is fully referenced in the Reference section of the report and cross references used.	GaBi service pack 40 added to complete the reference.	OK
ADM	29/10/2020	2.11 Critical review	te	Please include full reference to ISO 14040:2006 and ISO 14044:2006.	Reference included.	OK
ADM	29/10/2020	2.11 Critical review	te	ISO14044:2006, section 6.3 requirement: “The review statement and review panel report, as well as comments of the expert and any responses to recommendations made by the reviewer or by the panel, **shall be included in the LCA report.”**	A copy of these comments made by the verifiers has been added to the report.	OK
ADM	29/10/2020	2.11 Critical review	te	Please identify the type of critical review as a “Critical review by a panel of interested parties”. as per ISO 14044:2006 section 6.	Done	OK
ADM	29/10/2020	3. LCI	te	Please ensure that all data sources are appropriately referenced, especially for the manufacturing descriptions and data.	Film extrusion process added and recycling process broken down into sub processes	OK

Initials of reviewer	Date of comment	Reference	Type	Reviewer question/comment and recommendation	Practitioner of LCA study response	Final approval
ADM	29/10/2020	3.1.1 Product composition, table 4	te	Please include the density property of the materials used (e.g. g/m^2) is included in Table 4.	As primary data was used wherever possible only the weight of the bags was recorded. We do not have accurate measurements for the grammage of the films.	OK
ADM	29/10/2020	3.1.1 Product composition, Table 4, and 2.2 Functional unit and 3.1.2 Manufacturing, Flat paper courier bags	te	It appears that the paper bags include adhesive for the user to close the bag but the LDPE and home compostable bags do not. Are the product systems equivalent to enable a valid comparison? The GWP results indicate that the adhesives contribute 5% to 14% for the paper bags, which is significant, and the HTP results are dominated by the adhesive (>70%) so it is really important to include the adhesive for the other systems. Please revise.	The mass of the adhesive and corresponding protective plastic seal has been separated out in the plastic bags for clarification.	OK
ADM	29/10/2020	3.1.2 Manufacturing	te	The pigments for virgin LDPE are identified as LDPE/titanium dioxide mix but the pigments for the other product systems are not identified. The hotspot results indicate that the contribution of the pigment can be >5% (Recycled LDPE Bag NZ – Recycled) Please revise so that all pigments are clearly stated.	The pigments are the same, this has been clarified. They all now refer to TiO2 as the pigment.	OK
ADM	29/10/2020	3.1.2 manufacturing, Figure 3 Virgin LDPE bag manufacturing stages	te	The second process box from the top is named "Plastic film extrusion to form bag…" As the bag is not formed at this step please revise heading for clarity.	Updated.	OK

Initials of reviewer	Date of comment	Reference	Type	Reviewer question/comment and recommendation	Practitioner of LCA study response	Final approval
KR	27/10/2020	3.1.2 manufacturing, Figure 3 Virgin LDPE bag manufacturing stages Figure 4	ge	Can the rLDPE bags and offcuts not be recycled again? Include explanation of why/why not.	The offcuts from the virgin and recycled LDPE bags can be recycled. According to New Zealand Post the home compostable bag offcuts cannot be recycled and are sent to landfill.	OK (Figure 4 updated to include reuse of production scrap)
ADM	29/10/2020	3.1.2 manufacturing, Figure 4 Recycled LDPE bag manufacturing stages	te	Please include in Figure 4 and the associated text whether the transport of the scrap to the washing and shredding has been included or excluded.	Transport is included and has been added to the figure	OK
ADM	29/10/2020	3.1.2 manufacturing, Home Compostable Courier bag	te	Please define “lower toughness” (e.g does it refer to tear resistance, overall durability etc?).	The description has been changed to “tear resistance”	OK
HL	23/10/2020	3.1.2 manufacturing, Home Compostable Courier bag p. 23	ge	Second paragraph – the details on the compounding stage may be correct but just checking. .Ecovio is already a compound of ecoflex (AAC/PBAT), PLA and sometimes corn starch. Is it accurate to say that ecovio is then compounded again with additional ecoflex and starch? As previously mentioned, I suggest detailing the polymer types contained in each brand name product	As above, brand names have been used to present results at the same level as the manufacturing components.	OK
HL	23/10/2020	3.1.2 manufacturing, Flat paper courier bags, p. 24	ed	Typo in first line (Victoria)	Updated	OK
ADM	29/10/2020	3.1.3 Distribution and 3.1.4 Use	te	Please include all references for distances used.	Updated with a comment in the paragraph prior to explain distances used.	OK

Initials of reviewer	Date of comment	Reference	Type	Reviewer question/comment and recommendation	Practitioner of LCA study response	Final approval
KR	27/10/2020	3.1.3 Distribution, Pg 27	ge	The text notes that home composting doesn't require transport at end of life but the transport distance given in Table 5 is the same for all options. Home composting should have a lower transport distance. Check distance assumption used for home composting and update results/table 5 as required. Or is table 5 only for transport from manufacture to NZ Post? Report notes 'The breakdown of the distribution distances across the various life stages are found in Table 5' which implies that Table 5 includes transport from manufacture to NZ Post; to customer; to end of life. Clarify what transport distance is include in table 5.	Table 5 is for the distribution of bags to the NZ Post facility. Header has been amended to display this more clearly. Have amended the reference to table 5 as well to clarify it is only for the transfer from manufacturers to NZ Post .	OK
KR	27/10/2020	3.1.3 Distribution, Table 5	ge	The table doesn't include transport distance for the LDPE bag. Add transport distance for the LDPE bag.	Added	OK
KR	24/11/20	3.1.5	ge	Transport distance for end of life is given as 25 km for material sent to landfill but isn't noted for recycling or home composting. Add end of life transport distance for all options.	A transport distance of 25km is stated in paragraph 9 of 3.1.5 for all recycled products. An additional sentence has been added to clarify that home composting has no transport associated with it due to the assumption the process occurring at the consumer's property.	OK
ADM	29/10/2020	3.1.5 End-of-life	te	What is the carbon content of the different materials which is used in the EoL modelling?	Have added the carbon content of the degradable portions of the two bags.	OK
ADM	29/10/2020	3.1.5 End-of-life	te	If only 49% of the paper bags degrade, is the 51% that remains included in the EoL model as sequestered carbon with a negative carbon footprint? Please clarify.	Correct. Have clarified in paragraph.	OK

Initials of reviewer	Date of comment	Reference	Type	Reviewer question/comment and recommendation	Practitioner of LCA study response	Final approval
ADM	29/10/2020	3.1.5 End-of-life, commercial windrow processes as a proxy for home composting	te	Andersen et al 2010 [1] and Ermolaev et al 2014 [2] appear to support the assumption that a commercial windrow process could be used as a conservative proxy for home composing, however, sufficient justification has not been provided in the text. Please revise to add justification for this key assumption. Also consider changing the “home” composting courier bag to “commercial” composting if this is what the dataset is for (even though these waste treatment methods may not be available in NZ).	Reference to Andersen added.	OK

[1] Andersen, Jacob Kragh, Alessio Boldrin, Thomas Højlund Christensen, and Charlotte Scheutz. 2010. ‘Greenhouse Gas Emissions from Home Composting of Organic Household Waste’. Waste Management 30 (12): 2475–2482.

[2] Ermolaev, Evgheni, Cecilia Sundberg, Mikael Pell, and Håkan Jönsson. 2014. ‘Greenhouse Gas Emissions from Home Composting in Practice’. Bioresource Technology 151 (January): 174–82. https://doi.org/10.1016/j.biortech.2013.10.049.

Initials of reviewer	Date of comment	Reference	Type	Reviewer question/comment and recommendation	Practitioner of LCA study response	Final approval
ADM	29/10/2020	3.1.5 End-of-life, commercial windrow processes	te	Please transparently document the parameters and details of the modelling associated with the UNSW Windrow composting dataset (e.g. transport distance for application of material, is the sequestered carbon included in the total etc). The EoL emissions for bioplastic bag composting seems higher than expected.	Transport distance of the finished compost is out of scope in this instance. The impacts of composting the bioplastic have been reviewed and appear correct. Approximately 2/3 of the impacts are due to the release of the fossil carbon within the product during composting. This will result in higher impacts compared to composting biogenic materials where there is sequestration during the growth of the material.	OK
HL, KR, ADM	27/10/2020	3.1.5 End-of-life, home composting rates	te	What is the home composting rates for similar items vs landfill rates? Should this be included in the sensitivity analysis?	Not relevant to the current study.	OK
ADM	29/10/2020	3.1.5 End-of-life,	te	What is the basis for the assumption in the sentence *"In the process of composting, 90% of the mass of the product is assumed to degrade and the remaining 10% sequestered as organic material."* Please justify or include a reference. If it is an assumption it should be investigated in the Sensitivity Analysis section.	Reference added.	OK

Initials of reviewer	Date of comment	Reference	Type	Reviewer question/comment and recommendation	Practitioner of LCA study response	Final approval
KR	27/10/2020	3.1.5 End-of-life, methane capture rates	te	Have you checked the NZ GHG inventory for NZ landfill methane capture rates? The GHG inventory notes that in 2018 68% of the CH generated was recovered from 25 landfills with gas recovery and these landfills account for 90% of waste disposed to landfills. This is substantially different from the Australian rate used in this study. Check the NZ GHG Inventory for landfill methane recovery rate and either update analysis with this rate or justify why an Australian rate is used.	We have included a methane recovery rate of 53% for NZ. A 53% capture rate has been calculated as a weighted average using information for the Ministry for the Environment for the proportion of landfills with methane recovery, the population they each serve and an assumed lifetime landfill gas collection effectiveness of 85%.	OK
KR	27/10/2020	3.2.1 Fuels and Energy, table 3	ge	NZ Electricity mix can vary annually largely due to changes in hydro and coal used for electricity, which can have a significant impact on GHG emissions. Why isn't the latest NZ grid mix data used (2019 data available on the MBIE website)? Given that the electricity was identified as a hotspot it would also make sense to include seasonal grid variation on the results.	Sensitivity study into the effects of the annual change of New Zealand's electrical grid has been added.	OK
KR	27/10/2020	Pg 30 Table 3 and 6	ed	Table numbers out of sequence. Please revise.	Tables updated	OK
HL	23/10/2020	4.22 and 4.3	ge	Statement that PBAT is used in Ecoflex and Ecovio. I thought Ecoflex was an Aliphatic Aromatic Copolyester (AAC) – is that the same as PBAT?	Ecoflex is the brand name of the product the New Zealand Post supplier uses. The chemical is PBAT.	OK
HL	23/10/2020	4.23	te	Should this para also acknowledge that ecoflex (AAC/PBAT) is made from a non-renewable source?	Explanatory note added to clarify the origin of Ecoflex/PBAT.	OK
HL	23/10/2020	5.2	ge	Should there be more discussion in here about the availability of recycling/composting systems in NZ for LDPE and the compostable bag?	Paragraph is deemed suitable as the recycling rates are out of scope of this study.	OK
HL	23/10/2020	5.5.1	te	Suggest replacing 'degradable' with 'compostable' to be more specific	Replaced.	OK

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HL	23/10/2020	5.5.3	ge	Suggest going even further with recommendation – NZ Post should ensure that consumers have convenient access to a recycling option for the LDPE bags, either through a take-bag scheme or support for Love NZ Soft Plastics Recycling.	Recycling the product at end of life has a rather minimal impact on the overall life cycle in the case of the rLDPE bag. The recommendations try to focus on the most impactful areas and so this has been excluded for now.	OK
ADM	30/10/2020	3.2.1 Fuels and Energy	te	As electricity source was identified as a hotspot, please document the grid mix shares in the report for transparency and completeness (for NZ, AU-VIC, and CN).	A breakdown of the electricity generation methods for each electricity grid mix utilised has been added.	OK
ADM	30/10/2020	3.2.2 Raw materials and processes, table 6	te	EU-28 kraft paper is used as a proxy for AU paper – is this should be considered in the interpretation of results. Please include.	Explanation added to describe how the EU-28 process was modified to represent data from the Australian paper manufacture (Opal)	OK
ADM	30/10/2020	3.2.2 Raw materials and processes, table 6	te	The caption for table 6 is “Key material and process datasets used in inventory analysis” – should it mean modelling and/or LCIA? Please revise.	Revised to modelling	OK
ADM	30/10/2020	3.2.2 Raw materials and processes, table 6 and 3.2.4 End-of-life Treatment, table 8	te	Why is the Landfill for wood products – (cut-off allocation) used as a proxy for landfill of home compostable and paper bags? Isn’t this a parameterised process that is adjusted to be representative for these products and therefore not a proxy as such?	The “landfill of wood products” process is a parameterised process that allows for the detailed modelling of degradation within a landfill and allows a high level of control for parameters such as material composition. As a result we believe it is a suitable method for modelling many different materials	OK

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ADM	30/10/2020	3.2.3 Transportation	ed	Should "…Australasia…" refer to "Australia"?	Term has been updated to "Australian"	OK
ADM	30/10/2020	3.2.3 Transportation	te	Were the default dataset parameters for the dataset used (e.g. payload, sulphur content of fuel, biogenic carbon content, driving shares by road type, capacity utilisation, DWT) Please clarify.	Have included an explanation. All values were default except for utilisation in the case of EoL transport	OK
ADM	30/10/2020	3.2.3 Transportation, table 7	te	Why are the proxy for fuels labelled as "Yes*" rather than "No*" ? If it is correctly labelled as "Yes*" then is this uncertainty considered in the interpretation of results?	It should be No* , have amended	OK
ADM	30/10/2020	3.2.4 End-of-life Treatment, table 8	te	There are two different datasets included in table 8 and table 6 for home composting. Please revise to clarify which one (AT or NZ) was used in the modelling.	Revised to one dataset with description.	OK
ADM	30/10/2020	4.1 Overall results, Figure 8 GWP	te	The data for the paper bags is presented in an unconventional format that could easily be misinterpreted. It is recommended to remove the "fade" on the results bars for the paper bags and instead insert break symbol and labels on the bars or simply remove the paper bags from the figure. **26/11/2020** As figures are often interpreted without the context of the supporting text it is important to ensure that the figures are not easily misinterpreted. Please add legend to the figure and labels to the orange bars to ensure the figure is not easily misinterpreted.	The fade has been removed and replaced with the bars in question being highlighted. A further comment has been added to ensure the results can be interpreted accurately. **26/11/2020** Break symbols and data labels have been added to the Figure.	OK
ADM	30/10/2020	4.2 Hotspot analysis	ed	The second sentence is contradictory – it says only results >0.1% are shown and also results <0.01% are greyed out. Please revise.	Explanation added as to how results less than the threshold can be included (they are above the threshold in another scenario).	OK
HL	23/11/2020	4.2.1 GWP	ed	Last sentence in first para appears to have missing words	Paragraph has been refined.	OK

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ADM	30/10/2020	4.2.3 MCI, second sentence	te	The details about recyclability of the products should be included previously in the end-of-life section of the report and not only in the LCIA results section.	In the previous sections it is detailed that one of the purposes of this study is to determine the impacts of individual end-of-life treatment scenarios available to the end user rather than what happens within to products with the market. As a result, the recyclability has not been covered as it is out of the scope of this study.	OK
ADM	30/10/2020	4.3 Scenario Analysis	ed	Third paragraph, first sentence has "To access…", appears it should be "To assess…"	Amended.	OK
ADM	30/10/2020	4.3 Scenario Analysis	te	It is important to include the relative changes to the results from the different PBAT proxies so that the overall difference can be demonstrated (without the reader having to do this themselves). Please include the results indicating the relative change (in addition to the absolute change).	Have added a table with the relative and absolute differences in results arising from the choice of PBAT proxy.	OK
ADM	30/10/2020	5.5.1 Conclusions	ge	The conclusion that the "location of manufacturing" is correct but to avoid potential misinterpretation (i.e. that this implies transport is a significant part) it is recommended to make it more specific (e.g. electricity emissions intensity of the location of manufacture).	Have revised to: *"The electricity grid utilised for the manufacturing processes is an important factor in determining the emissions of the recycled LDPE bags"*	OK
ADM	30/10/2020	5.5.3 Recommendations	ge	the comment relating to transport is not supported by the findings of the study. Recommend revision.	Have removed mentioning the reduction of transport	OK
ADM	30/10/2020	5.3.3 Representativeness, Geographical	te	Section 3.2 Background data indicates that some of the datasets were geographic proxies, some of which where it is expected that the choice of proxy would materially influence the results (e.g. EU-28 Kraft paper). Please revise statements in 5.3.3	Geographical representativeness changed to "sufficient".	OK

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ADM	29/10/2020		te	ISO14044:2006, section 4.2.3.3.3 requires: “Where the study is intended to be used in comparative assertions intended to be disclosed to the public, the final sensitivity analysis of the inputs and outputs data shall include the mass, energy and environmental significance criteria so that all inputs that cumulatively contribute more than a defined amount (e.g. percentage) to the total are included in the study.” Please include.	The finished bags were weighed and all mass is included. Materials may be modelled as a proxy but are included.	OK
ADM	29/10/2020	ISO14044:2006, section 4.3.3.2 Validation of data	te	Please include the mass and energy balances to document that the data quality requirements have been met.	Multiple mass and energy tables have been added for transparency.	OK

ADM	29/10/2020	ISO14044:2006, section 5.3 reporting requirements for comparative assertions	te	Please ensure that all of the ISO14044:2006, section 5.3 "Further reporting requirements for comparative assertions intended to be disclosed to the public" been met. The items highlighted using **<u>bold underline</u>** appear yet to be addressed. "5.3 Further reporting requirements for comparative assertion intended to be disclosed to the public 5.3.1 For LCA studies supporting comparative assertions intended to be disclosed to the public, the following issues shall also be addressed by the report in addition to those identified in 5.1 and 5.2: a) analysis of material and energy flows to justify their inclusion or exclusion; b) assessment of the precision, completeness and representativeness of data used; **<u>c) description of the equivalence of the systems being compared in accordance with 4.2.3.7;</u>** **<u>d) description of the critical review process;</u>** e) an evaluation of the completeness of the LCIA; **<u>f) a statement as to whether or not international acceptance exists for the selected category in-dicators and a justification for their use;</u>** **<u>g) an explanation for the scientific and technical validity and environmental relevance of the category indicators used in the study;</u>** **<u>h) the results of the uncertainty and sensitivity analyses;</u>**	All bags are considered by New Zealand Post to be functionally equivalent as they are all designed to hold the same sized bags. The critical review process has been described as being completed after the study.	OK

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				<u>i) evaluation of the significance of the differences found.</u>		
ADM	29/10/2020	ISO14044:2006, section 4.5.3.3 Sensitivity Checks and Appendix tables B9 to B13		Please ensure the Sensitivity Check requirements – for studies where comparative assertions have been made – are met. See ISO14044:2006, section 4.5.3.3 Sensitivity Checks and Appendix tables B9 to B13	Two additional sensitivity studies have been added to cover the annual change to NZ electricity grid mix and the chosen end-of-life allocation method used. The requirements are now considered to be met.	OK
ADM	26/11/2020	Key Material Flow tables, Table 12: Key material flows for the manufacturing of the current virgin LDPE courier bag, Table 14: Key material flows for the manufacturing of the home compostable courier bag, Table 15: Key material flows for the manufacturing of the flat paper courier bag,	te	The masses in the Key Material Flow tables do not balance or match the product masses in the other tables. Please revise the mass balances to ensure that they are balanced, and ensure that all of the tables with product masses match.	We made a small scaling error due to the mass of the sealing strip being included twice. This has now been corrected and all tables have been updated. The tables have also been extended to show packaging materials.	OK

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ADM	10/12/2020	5.1, Identification of Relevant Findings, second sentence	ed	Appears to be a word missing in the sentence… " Overall, the have the lowest impacts across all environmental indicators included within this study…" Please revise.	Corrected	OK
ADM	10/12/2020	5.1, Identification of Relevant Findings, Scenario analysis shows, second dot point	ed	Spelling of "signficant"	Corrected	OK
ADM	23/2/2021	Executive summary, paragraph 4	ge	The paragraph on the padded bag uses the LCA term "functionally superior" which is potentially misleading for "plain English" audiences. It is recommended to remove this term and revise the paragraph. It is recommended to follow the language for this paragraph in the previous version which seemed to be easier for non-LCA audiences to interpret and understand.	Reverted to previous wording for the last part of the paragraph. The "functionally superior" phrase has been removed.	OK
ADM	23/2/2021	Executive summary, The NZ-made recycled LDPE courier bag also performs the best across most other environmental indicators	te	As currently written, the paragraphs relating to non-hazardous waste appear unnecessarily alarmist. When read in the context of the EoL scenario for which these results are relevant (i.e. thrown in landfill) then the heavier bag (NZ-made rLDPE is 4% heavier than the virgin LDPE bag) obviously leads to more non-hazardous waste. Given that a cut-off approach was used would that mean that the recycled content of the NZ-made rLDPE bag would not be accounted for in the non-hazardous waste (e.g. as a credit for non-hazardous waste recycled)? It is recommended that this paragraph be revised.	This sentence intends to explain that the slightly greater waste is due to the heavier bag. It does not sound alarmist to my ear – it is intended simply as a statement of fact. The word "slightly" has been added in two additional places.	OK
ADM	23/2/2021	Executive summary, paragraph 5	ge	The first sentence of the paragraph that gives a reason for not investigating reusable bags is significantly different from the previous version of the report. It is recommending deleting the first sentence of this paragraph.	Sentence reworded to be closer to the previous version. The reasons remain the same as before.	OK
ADM	23/2/2021	Executive summary, paragraph 7	ed	Paragraphs 6 and 7 use different adjectives that could be confusing (e.g. lowest carbon footprint and highest performing). Consider revising for consistent use of adjectives to avoid potential confusion.	Agreed. Wording changed throughout to always use lowest impact.	OK

Initials of reviewer	Date of comment	Reference	Type	Reviewer question/comment and recommendation	Practitioner of LCA study response	Final approval
ADM	26/2/2021	Executive summary, paragraph 13	te	It might be worth changing the non-hazardous waste paragraph to read "up to 5% more" to account for this percentage only relating to the landfill (and not recycling) scenario .	Accepted. Wording changed.	OK

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