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The true cost of cardboard cartons

Prepared for: CHEP Australia

About the authors

The **Institute for Sustainable Futures (ISF)** is a transdisciplinary research and policy institute at the University of Technology Sydney with over 100 research staff and students. Since 1997, ISF has been working collaboratively with governments, businesses, organisations and communities to create change towards sustainable futures. Our work in Australia and around the world aims to protect and enhance the environment, human wellbeing and social equity. We do this by developing transformative ideas into strategies that deliver impact and have a strong record of achievement in advancing circular economy and resource stewardship initiatives.

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Glossary

APCO	Australian Packaging Covenant Organisation
CHEP	Commonwealth Handling Equipment Pool
RPC	Reusable Plastic Container
SCC	Single-Use Cardboard Carton
OH&S	Occupation Health and Safety
FECA	Full Economic Cost Accounting

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Key Findings

This briefing paper presents the findings of a study into the differences between single-use (corrugated) cardboard cartons/boxes (SCCs) and reusable plastic crates (RPCs) in terms of the true direct economic costs (i.e. total costs along the supply chain), with a focus on fresh produce for retail.

The study was conducted as a general comparison between a typical SCC and a typical RPC. For RPCs we used the CHEP Reusable Plastic Container as a reference product. For SCCs we used sales quotes from VISY and Orora.

Characteristic benefits of SCCs and RPCs

The following list of benefits represents both generic and unique properties of typical SCC and RPC designs on the market.

Single-use cardboard cartons (SCCs):

- Relatively light weight
- Inexpensive to manufacture
- Can be made from recycled content
- Recyclable at end-of-life
- External surfaces can be printed for marketing purposes
- The dimensions of the boxes are fully customisable
- Can be erected by hand or machine and some designs are compatible with automated crate erectors.

Reusable plastic crates (RPCs)[1]:

- Designed to be stackable when in transit or on display
- Some designs are nestable
- Some designs allow for either or both horizontal and vertical stacking
- Some designs are compatible for layer picking
- Some designs can be folded when empty for optimised storage and transport
- Can be erected by hand or machine and some designs are compatible with automated crate erectors
- Resistant to ambient temperatures and physical impact
- Provide structural integrity and strength for product protection
- Standardised (allowing for more efficient packing)
- Good ventilation that facilitates airflow improving the shelf-life of produce
- Can be used in chilled (non-frozen) environments
- Can be used directly for display in a retail environment
- Compatible with high hygiene requirements
- Reusable over its lifespan
- Recyclable at end-of-life, and
- Can be made from recycled material (see breakout box).[2]

[1] Features may vary by manufacturer
[2] While there are no legal requirement preventing recycled material from being used in food grade packaging, The Australian Standard

Typical differences between SCCs and RPCs

Single-Use Cardboard Cartons	**Reusable Plastic Crates**
• Designed to be used once and then baled for recycling. • On average the initial purchase price is lower and does not include costs of end-of-life management. • Damaged boxes are not repairable. • Generally recyclable (unless significantly contaminated); waxed and some mixed-use cartons are not. In Australia, an estimated 62% of SCCs are recycled at end-of-life, the rest is landfilled. • Cardboard fibre can only be recycled up to five times to maintain structural integrity.	• Designed for multiple reuse, with an assumed life-cycle of 100 trips and at least five years. • The average upfront lease price per trip is slightly higher than the purchase of an SCC. Price includes return logistics (once the container is received at a distributed centre) cleaning and end-of-life management. • Some designs allow repairability. • The plastic is recyclable. • The plastic used in RPC manufacture could be made from recycled materials. In Australia, there is no legal requirement or standard that prevents recycled materials from being used for food grade packaging.

Recycled content used for food grade packaging

There is no legal requirement that prevents recycled material from being used for packaging that comes into direct contact with food. While the Australian standard (2070:1999 Plastics materials for food contact use) states that post-consumer recycled material cannot be used in direct contact with food, this is a voluntary, non-binding standard, without legal force and was prepared only as a guide for industry. In addition, the Australia New Zealand Food Standards Code which does have legal authority and carries more weight as a guidance document allows for the use of recycled content when correct processes are followed. The 2016 Food Standards Code clarifies that recycled and reused materials can be used for food packaging applications provided they are suitable for the intended use and will not contaminate food. While the code raises concerns about contaminants in the source of material ; the degradation of packaging due to reuse; and cleaning and sanitising processes, it makes specific note that packaging processes can be constructed to prevent contaminants from migrating into food.

In 2014 The Australian Packaging Covenant Organisation (APCO) published a report that addressed the misconception that recycled material could not be used in food grade packaging[1]. While Standards Australia has not stated an intent to review AS 2070:1999 it has been assessed as an 'aged standard' which requires review.

The Australia New Zealand Food Standards Code
http://www.foodstandards.gov.au/code/Pages/default.aspx

Australian Standard 2070:1999 Plastics materials for food contact use
https://www.saiglobal.com/PDFTemp/Previews/OSH/As/as2000/2000/2070.pdf.

APCO report on recycled materials in food contact applications
https://www.australianpackagingassessment.com.au/wp-content/uploads/2017/11/Recycled-material-in-food-contact-applications.pdf)

Functional unit of analysis

The functional unit for this comparative analysis is one crate undertaking a single trip through the supply chain. For an SCC it includes all direct costs from the initial purchase price through to final costs of recycling and/or disposal. The functional unit for an RPC is a single unit trip through the supply chain. A single trip begins when the crate is leased by the first user and ends when it is either reused, recycled or disposed. The cost of reusing, recycling or disposing of SCCs or RPCs are incorporated into the overall unit costs and are based on national averages for Australia.

Cost comparison results

- The major cost of an RPC is the lease fee, which includes the material cost, return logistics and cleaning, and end-of-life management. This is larger than the material and end-of-life costs for SCCs.
- The major costs for SCCs are related to externalities like product waste and tertiary packaging (e.g. plastic shrink wrap / pallet wrap), which are all greater than for RPCs. RPCs also tend to have lower associated handling/labour costs than SCCs.
- The full economic unit cost of an RPC used in Australia is estimated to range between $7.08 and $9.56 per unit trip.
- The full economic unit cost of a SCC used in Australia is estimated to range between $10.00 and $16.35 per unit trip.
- On average, RPCs offer a saving $4.85 which is 58% less expensive than SCCs for shipping fresh produce when all direct economic costs are considered for both options.
- The end-of-life disposal costs and revenue generated from selling corrugated cardboard for recycling is inconsequential and only changes the economic costs and benefits by less than 1%.[3]
- The full economic cost of RPCs is more certain because of the smaller range between the low and high cost estimates as evidenced by the fact that RPCs have fewer external costs and all major costs are determined upfront as part of the lease price.
- SCCs have significant 'hidden' costs (such as damage to fresh produce, increased labour costs and produce with a shorter shelf-life). These hidden costs add an extra $7.90 to the true cost of an SCC compared to just $0.52 for an RPC.
- For RPCs the most substantial cost is the lease price estimated range between $1.20 and $1.80 per trip, while for SCCs the most substantial cost is product damage costing between $1.17 and $4.88 per trip.

Using a full economic cost approach, we estimate that a typical supply chain using SCCs making the switch to RPCs could save a maximum of $9.27 per container. On average we estimate the cost savings across the entire supply chain to be about 58% or $4.85 per container. This represents a cost saving that is over three times the

[3] It is worth noting that this excludes the indirect environmental costs as an LCA was not conducted for this research

original unit cost of the SCC. These savings are driven primarily through reductions in product damage (51%), extending the shelf life of products (14%), labour cost savings (10%), less tertiary packaging (4%), more efficient transport (1%), less damaged packaging (1%) and a reduction in disposal costs (1%).

Figure 1 shows a mean cost saving of 58% or $4.85 for switching from SCCs to RPCs using the mid-point of the range between the two estimates.

Figure 1: Comparison of full economic costs per unit trip across the supply chain

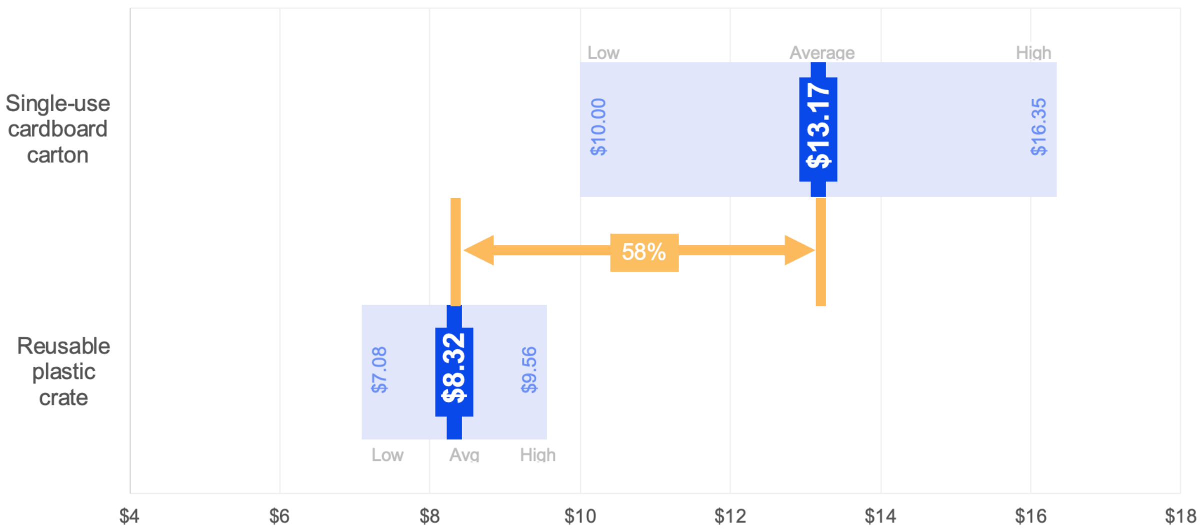


Figure 2: Comparison of low and high savings by crate type per unit trip

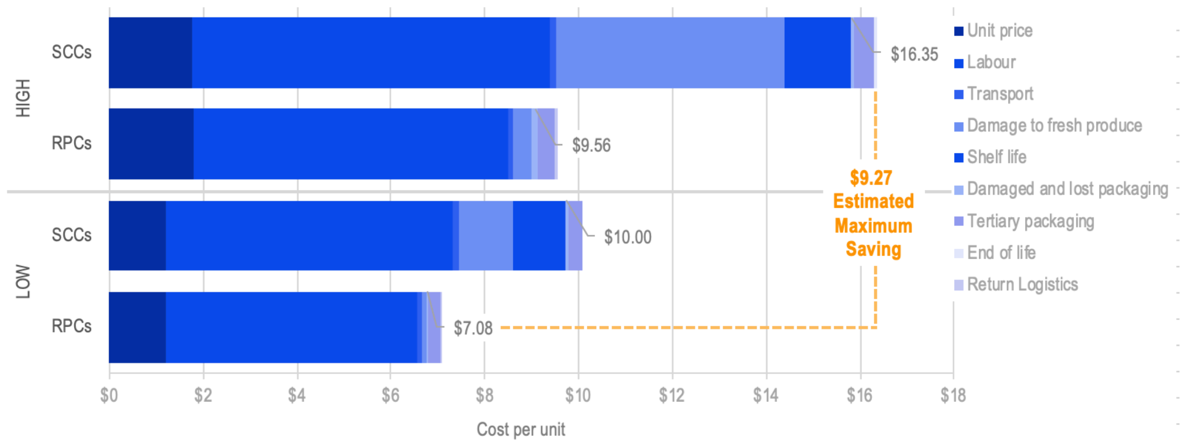


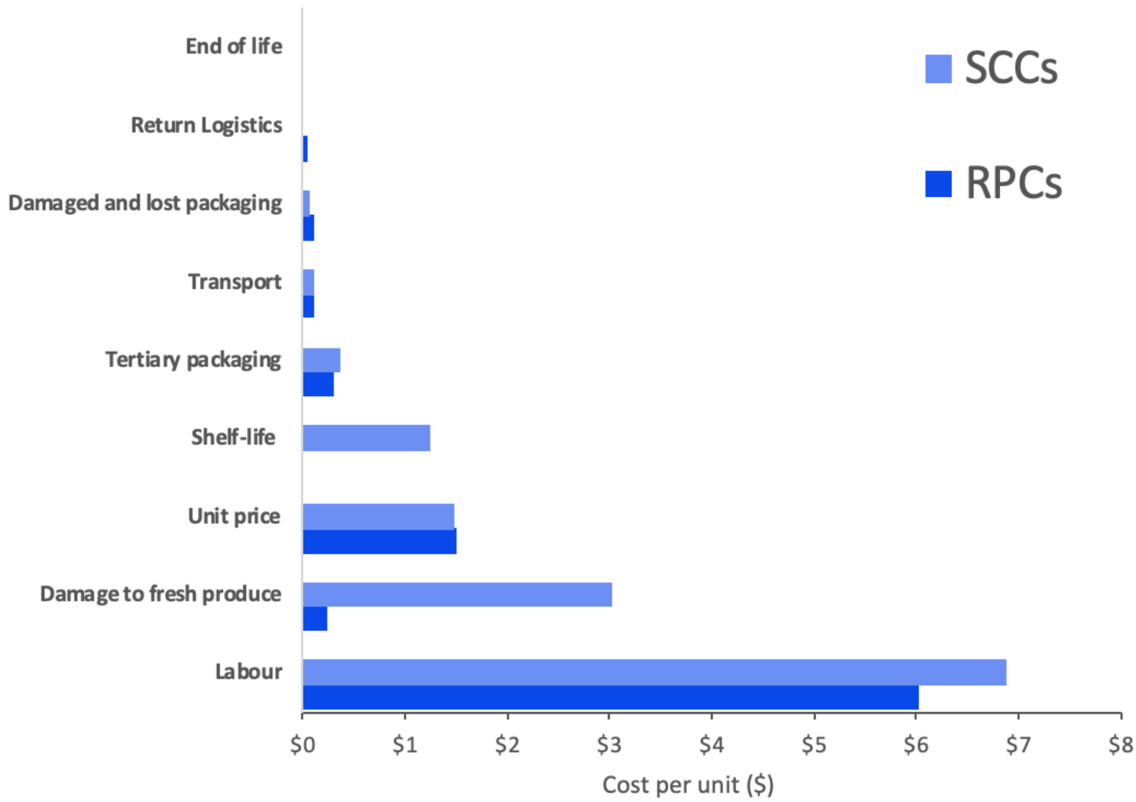
Table 1: High and low economic costs for RPCs and SCCs

	RPC[1]		SCC[2]	
	Low	High	Low	High
Unit price[3]	$1.20	$1.80	$1.21	$1.75
Transport	$0.11	$0.12	$0.11	$0.12
Labour	$5.36	$6.66	$6.12	$7.65
Damage to fresh produce	$0.08	$0.39	$1.17	$4.88
Reduced shelf-life of fresh produce[4]	$0.00	$0.01	$1.11	$1.39
Damaged and/or lost packaging	$0.06	$0.14	$0.05	$0.07
Tertiary packaging	$0.24	$0.36	$0.29	$0.43
End of life[5]	$0.00	$0.01	($0.07)[6]	$0.05
Return logistics	$0.04	$0.06	$0.00	$0.00
Total Costs	**$7.08**	**$9.56**	**$10.00**	**$16.35**

[1] The prices shown for RPCs are generally applicable across the range of RPC products
[2] The prices for SCCs are estimated for four typical produce-type cartons as shown in Table 5.
[3] Unit price represents the price of purchasing one SCC or the price of leasing one RPC for one trip through the supply chain
[4] Reduced shelf-life calculations were benchmarked against RPCs
[5] End-of life costs were allocated across the entire life of the container.
[6] This shows a cost benefit (revenue) of $0.07 per SCC because used corrugated cardboard can be sold thus generating income.

In Figure 3 the estimated economic cost differentials at different positions in the supply chain are listed from lowest cost to highest cost. The estimated average economic cost is represented by the coloured bar. Damage to fresh produce, shelf-life and labour costs are shown to have the highest cost differential with SCC costing an average additional $2.78, $1.25, and $0.80 per trip respectively when compared on a like for like basis with RPCs.

Figure 3: Economic cost differences per unit trip by cost category



Market projections for corrugated cardboard cartons

The demand for corrugated paperboard manufacturing in Australia is anticipated to remain subdued over the next five years. Imports from low-cost imported corrugated cardboard are expected to increase, putting downward pressure on supply prices and profit margins. Industry revenue will be supported by improvements in productivity and upgrades to existing mills (IbisWorld, 2018). Several operators are expected to sell-off and lease back their assets, freeing up capital to invest in new machinery. This will have short term impacts on profitability due to rent costs, but in the long term this is expected to support higher margins due to higher automation and lower reliance on labour. Large players are expected to develop innovative product offerings to help defend against substitutes and differentiate themselves from competitors. The intensification of competition is expected to further consolidate some of the smaller players in the industry (IbisWorld, 2018).

Table 2: Forecast price for SCC

Market Forecast ($AUS)	2016	2017	2018	2019	2020	2021	2022
Average Value per Tonne	$2,384	$2,394	$2,452	$2,501	$2,564	$2,621	$2,681
Average change in value	-0.70%	0.40%	2.40%	2.00%	2.50%	2.20%	2.32%
Average value per SCC	$1.19	$1.20	$1.23	$1.25	$1.28	$1.31	$1.34

* $2016
Source: RISI, Inc. (North American Data)

The forecast price of recycled cardboard

In Australia, the majority of reprocessing (sorting and bailing) of corrugated cardboard occurs on the east coast of NSW, Queensland and Victoria and is then exported. The new ban on recycled imports to China has had a serious impact on the recycled export market for corrugated cardboard. In 2016 around 62%[4] of cardboard was recycled in Australia and around 30%[5] of the cardboard that was recycled was sent to china. Between mid-2016 and mid-2018 the price of recycled baled old corrugated cardboard cartons fluctuated between $180-$250 / tonne.

4 https://www.environment.gov.au/system/files/resources/d075c9bc-45b3-4ac0-a8f2-6494c7d1fa0d/files/national-waste-report-2016.pdf
5 https://blueenvironment.com.au/wp-content/uploads/2018/05/Exports-of-recyclables-from-Aust-to-China-v2.pdf

Introduction

The choice of packaging is often determined by the upfront unit cost and potentially, the disposal cost. However, these costs do not represent the true cost of a packaging choice. This research aims to explore the true costs of packaging by taking a full economic cost approach, exploring all costs associated with different packaging alternatives across the supply chain.

Although several previous studies have conducted a comparative Life Cycle Assessment of reusable versus disposable containers in the fresh produce sector (Accorsi et al, 2014; Albrecht et al., 2013a; Carre, 2010; S. P. Singh, Chonhenchob, & Singh, 2006) we were not able to find any peer reviewed studies that adopted a comparative economic cost approach across the full supply chain.

Many companies have a very poor understanding of their full packaging costs, including the labour and fuel costs of packing and distribution, labour costs of unpacking, packaging waste disposal costs and the costs of wasted or spoiled product due to inadequate packaging systems (K. Verghese & Lewis, 2007).

Organisations that do not measure the hidden costs of packaging could be losing millions of dollars each year in lost revenue. In addition, businesses that do not understand the losses caused by poor packaging will be reluctant to adopt an alternative packaging system.

This research provides a first attempt at estimating the true costs across the entire supply chain for single-use cardboard cartons (SCCs) and reusable plastic crates (RPCs) in Australia. As each business is different and has unique characteristics it is not possible to provide precise estimates on the quantity of savings that a specific organisation may receive. This is because factors like produce type, transportation distance, existing infrastructure and labour costs have a material impact on overall packaging costs. In order to make this research relevant, reasonable assumptions are made for a typical business faced with a genuine choice between SCCs and RPCs within their supply chain. Where important, all assumptions have been explicitly stated with supporting evidence justifying the numbers used.

Both the peer reviewed academic literature (Albrecht et al., 2013b; Chonhenchob & Singh, 2003a, 2005; Koskela, Dahlbo, Judl, Korhonen, & Niininen, 2014a; Kye, Lee, & Lee, 2013; Levi, Cortesi, Vezzoli, & Salvia, 2011; Menesatti et al., 2012) and industry literature (Lindsay Whiffen, 2018; Reusable Transport Packaging, 2018; StopWaste, 2007) suggest that RPCs offer a number of cost-saving opportunities across the supply chain, which make up for the increased costs involved in leasing the crates, return logistics and cleaning.

These savings include:

- lower labour costs
- reduced product damage
- lower inventory costs
- lower shipping costs (due to stackability/'cube efficiency' inside vehicles)
- fewer workers' compensation claims due to better ergonomic design
- lower annual waste disposal costs.

Background

Packaging in the fresh food sector

Fresh food supply chains are an important and necessary support function in any economy. Packaging plays a critical role in shaping the overall sustainability of fresh food supply chains and contributes to both direct and indirect costs of operation through materials, handling, transportation and storage. Packaging significantly reduces food waste through product protection and improves worker safety through more ergonomic designs. Furthermore, packaging can influence the overall carbon footprint through optimum use of packaging materials, transport efficiency and design for the extended life of the packaged product.

Types of packaging

Primary packaging (sometimes called consumer or retail packaging) is the packaging used to contain and protect a product. Primary packaging also includes any packaging given to consumers at point of sale (e.g. retail bag, tissue paper etc), and all packaging delivered to consumers with on-line sales (e.g. bag, cushioning, box etc).

The important functions of primary packaging include the protection and preservation of the product and marketing to consumers. Primary packaging for food must meet certain standards related to hygiene and health. Not all products are sold in consumer packaging, for example, fresh produce is often sold loose (unpackaged) in which case it would be called distribution packaging becomes the primary packaging.

Secondary packaging is any additional packaging layers that contain the primary packs during distribution and for displaying the product on the shop floor. Secondary packaging is designed to facilitate sales, prevent theft and provide further marketing to consumers, and can enclose a single product, or multiple products. Thus, secondary packaging can be taken home by the end consumer or it can be left in the shop. Examples include cartons, corrugated cardboard boxes and plastic crates. Secondary packaging is often removed by the retailer when stacking produce on the shelves although boxes and crates are increasingly being designed for retail or shelf display.

Tertiary packaging is used to transport boxes/crates in bulk and is rarely seen by the final consumer. It is used to ship goods in bulk from one point to the next, such as from the farm or factory to the final destination. Examples include wooden/plastic pallets and stretch wrap.

Business-to-business or distribution packaging is packaging used to transport products between organisations and includes a wide range of packaging types such as bulk bins, crates, pallets and other protective material. The emphasis for business-to-business packaging is on containment protection and transport efficiency.

While consumer packaging represents approximately 70-80% of the value of packaging (BIS Shrapnel 1999, DTI et al. 2003) the remaining 20-30% of business-to-business packaging is still significant in terms of cost and environmental impact.

The focus of this research is on business-to-business packaging (specifically corrugated cardboard cartons and plastic crates) which are predominantly distribution packaging.

Single-use cardboard cartons (SCCs)

Cardboard cartons used for food transportation typically consist of three layers of cardboard. In the centre there is a corrugated layer, which is lined on either side by thinner layers of flat cardboard. This formation can be repeated to create thicker, stronger boxes with double or triple corrugation (also called "fluting"). The denser and thicker the fluting the stronger the box.

The inner layer of cardboard fluting is typically made of recycled fibre. The liners on either side may also be sourced from recycled material such as old cardboard or paper. The lining on the inside of a box is made from short fibres and is therefore sourced from hardwood trees or from recycled paper – it has a rougher surface.

Single layer

Double layer

Source: Mesa Carton Corrugate6

The outside layer of a box has a smoother surface to allow for printing and depending on the application might have a polyethylene or wax coating to improve water resistance. This paper is typically sourced from long fibre softwood trees and is called "Kraft" paper. Kraft paper is used to make the fluting in the centre of the cardboard. To create the fluting, rolls of paper are fed in to a corrugated roller machine, then glue is applied to adhere the test and Kraft paper. The cardboard material then goes through a process of being trimmed and cut to size for box formation. Glue is most often used in box assembly and is considered more hygienic for food, however, stitching and staples can also be used[7]

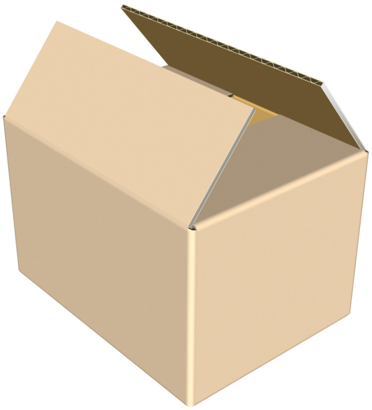
Cardboard cartons are used for transporting beverages, dairy goods, fruit and fresh produce, meat, and packaged food[8]. They are also used to transport household electronic appliances, cigarettes, cosmetics, pharmaceuticals, medical instruments, automotive components and for shipping container packaging[9,10]. However, food and beverages are the largest market for business SCCs[11].

Various types and sizes of cardboard cartons are used for fresh fruit and vegetables, including the classic regular slotted container (RSC) which is the most common type of cardboard cartons consisting of flaps that are all the same length. Half slotted containers with lids, bulk bins and produce trays which can be used to display food in a retail setting (see Figure 4).

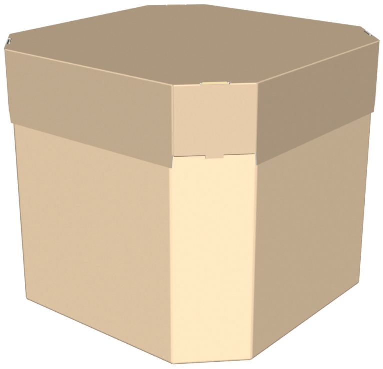
[6] http://cartoncorrugado.cl/index.php/2018/04/20/conceptos-clave/
[7] https://www.themanufacturer.com/articles/how-a-cardboard-box-is-made/
[8] https://www.visy.com.au/product-view/#rsc
[9] https://www.futuremarketinsights.com/reports/corrugated-boxes-market
[10] https://www.grandviewresearch.com/industry-analysis/cardboard-box-container-market
[11] https://www.futuremarketinsights.com/reports/corrugated-boxes-market

Figure 4: Cardboard container types

(i) Regular slotted container

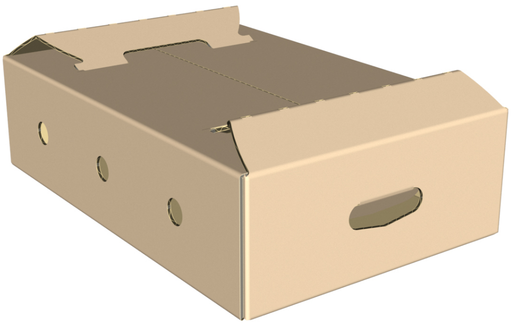


(ii) Bulk bin



(iii) Half slotted container Inners / Outers

(iv) Self-lock top/bottom



(v) Produce tray

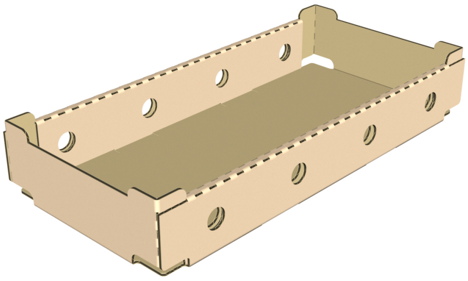


Image source: VISY

Reusable plastic containers (RPCs)

Similar to cardboard cartons, RPCs are used for the transportation of fresh produce through the supply chain from farm-gate to the retail shop floor. RPCs have been available on the market since the 1980s and have continued to grow and gain significant market presence over this time. RPCs are produced by extrusion or injection-moulding methods and are generally made from high density polyethylene (HDPE) or polypropylene (PP).

The sectors that most use RPCs are the fresh food sector and quick service restaurant sector.

RPCs have several innovative practical features that improve their overall functional performance, that is they can be designed to be nestable, stackable and some are even collapsible.

Figure 5: Reusable plastic containers (source: CHEP)

Image source: CHEP

Advantages and disadvantages of SCCs and RPCs

Single use corrugated cardboard cartons (SCCs)

On a per unit basis, cardboard cartons tend to be the cheapest form of distribution packaging on a per unit basis. Cardboard cartons are lightweight and can be stacked and folded when not in use, meaning they can occupy less storage space when not being used. Cardboard cartons can be printed with company names and logos and used for marketing purposes. They are also often viewed as an environmentally friendly option as uncoated cartons are biodegradable and are typically made with recycled and recyclable material.

Cardboard cartons are useful for transporting food as they are generally chemically stable. However, it was noted during our expert consultation that chemical migration has been an issue for some recycled cardboard containers previously. One key disadvantage of cardboard cartons is that they are only fit for purpose for one trip through the supply chain and therefore not as durable or water resistant as plastic which can face issues with regard to liquid leakage[12]. Cardboard cartons impacted by water ingress lose their structural integrity and are typically disposed[13]. There are also limits on the number of times that corrugated cardboard can be recycled before the integrity of the material is compromised (Albrecht et al., 2013a).

Reusable plastic crates (RPCs)

Because plastic crates are rigid and generally moulded to ergonomic specifications, they can be much easier to handle than alternatives. This potentially reduces insurance costs for workers with arm and back injuries and is therefore a better option from an occupational health and safety (OH&S) perspective. Plastic crates are strong enough to handle heavy loads of fruits and vegetables, unlike cardboard cartons which are limited in their design capacity to carry a heavy weight.

For some fruits and vegetables there is a need for a more water-resistant container to keep food fresh over a longer period of time. The circulation of air is also important for fruits and vegetables. A vented plastic crate means the product will stay fresh for longer. The rigidity of the HDPE plastic and uniformity means that they are effective at stacking and therefore take up less floor space in a factory, in storage or in a transportation. This can reduce shipping and storage costs substantially. Because of their durability they can be cleaned and then returned to the distribution network.

In some circumstances the produce is picked and loaded directly into the crates and stays there until it is sold on the shop floor. For example, a number of major retailers in Australia have implemented a supply chain solution where fruits and vegetables are sold directly out of plastic crates on the shop floor. The innovation of the folding plastic crate helps with the storage of crates when not needed and provides a readily available stock of crates when needed. Plastic crates are easy to clean with high-pressure water. RPCs have high UV resistance and therefore are not damaged by the sun and rain allowing them to be stored in open areas. They can also withstand freezing temperatures allowing produce to be picked and stored directly in freezers without the need to reload them into suitable containers for freezing. Plastic crates are also resistant to bacteria and fungi, making them ideal for the transportation of fresh produce.

In summary, RPCs offer packaging material cost savings, reduced labour for loading and unloading, reduced insurance and OH&S costs, reduced storage needs for empty containers due to more efficient packing, reduced transportation costs and reduction in damaged produce (Verghese et al, 2013).

High level comparison

	Single-use cardboard cartons	Reusable plastic crates
Upfront unit cost	★★★	★★
Lightweight	★★★	★
Strength	★	★★★
Crush-proof	★	★★★
Durability	★★	★★★

[12] https://www.grandviewresearch.com/industry-analysis/cardboard-box-container-market
[13] https://www.grandviewresearch.com/industry-analysis/cardboard-box-container-market

Reusable	★	★★★
Recyclable	★★★	★★★
Stackable	★	★★★
Storage efficiency	★	★★★
Operational Health and Safety Performance	★★	★★★
Protection from Bacteria and Fungi*	★	★★★
Protection of produce	★	★★★
Weather proof	★	★★★
Ergonomic design	★	★★★
Printed designs	★★★	★
Use of recycled materials	★★	★★

Assumes RPCs are washed and sanitised after use

While distribution packaging is generally fit for purpose, the alternatives have different strengths and weaknesses.

Supporting the shift to a circular economy

A truly circular economy goes beyond recycling materials at end-of-life to redesign systems of production, distribution and consumption such that products, components and materials are kept circulating in use for as long as possible, according to an expanded waste hierarchy that prioritises longevity, reuse, repair, reassembly and remanufacturing over recycling (Karli Verghese, Lewis, & Fitzpatrick, 2012).

Pooling systems of reusable plastic crates represent one of these innovative distribution systems supporting a more circular economy. Pooling involves the central ownership of a product (such as business-to-business packaging) which is then shared with users along the supply chain. In this model, responsibility for the packaging is retained by a single owner, providing an incentive to maintain and protect the value of the packaging. The pooling model eliminates the need for customers to purchase and manage their own equipment. This reduces costs, simplifies operations and reduces waste. By sharing reusable assets and extending the lifespan of products, the circular economy model helps companies transport, store and sell fresh produce more sustainability and efficiently.

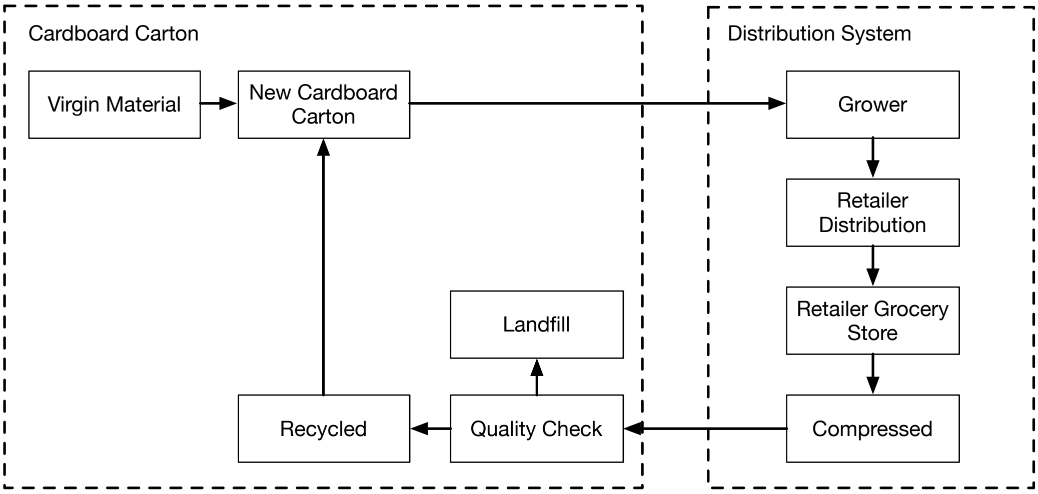
The packaging distribution system

Single-use cardboard cartons (SCCs) are produced using a mix of virgin and recycled fibres and are designed for single-use. The vast majority of SCCs used for business-to-business distribution are used only once, with an estimated 70% being recycled and 30% going to landfill[14], incinerated or taken home by customers for reuse. Empty SCCs are designed to be transported and stored flat. Damaged boxes are not repairable and must be disposed of. Standard cardboard cartons are

[14] https://www.environment.gov.au/system/files/resources/d075c9bc-45b3-4ac0-a8f2-6494c7d1fa0d/files/national-waste-report-2016.pdf

recyclable unless they have a heavy wax or polymer coating, are excessively contaminated with product waste or have liquid damage.

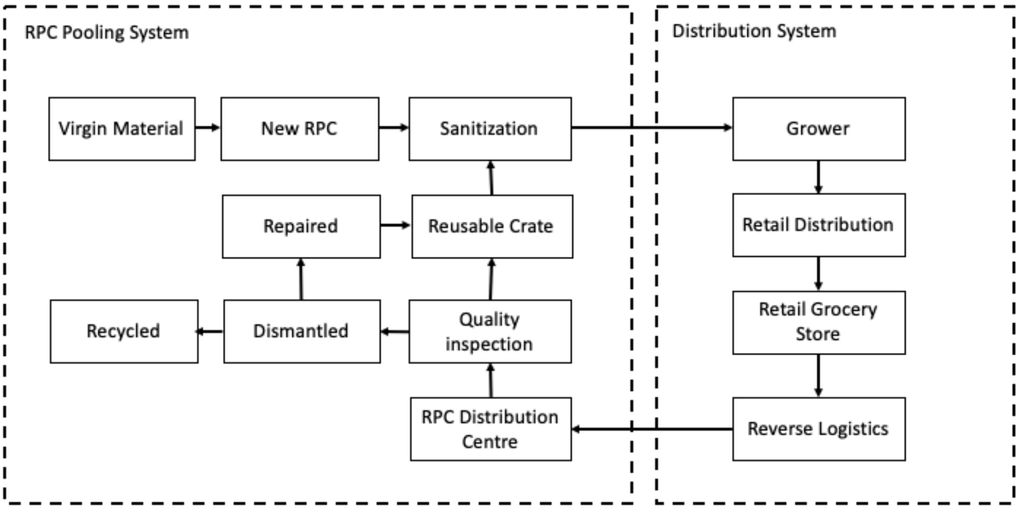
Figure 6: Typical single-use cardboard carton lifecycle



RPCs are designed to be used multiple times. For this study we assume that RPCs are used an average of 100 times and have a life of about five years or more. This assumption is based on information taken from the literature and from the interviews. RPCs are designed to be stackable, nestable or collapsible for transport, delivery and storage. Some designs also allow for repairability. All RPCs are recyclable.

In Australia crates cannot be recycled back into new food grade crates due to Australian voluntary food safety standards (2070:1999 Plastics materials for food contact use) that requires all packaging that is used in direct contact with food be made from virgin material.[15]

Figure 7: Reusable plastic crate lifecycle



[15] https://www.australianpackagingassessment.com.au/wp-content/uploads/2017/11/Recycled-material-in-food-contact-applications.pdf

Container packaging market in Australia

Market overview

Growth in the Australian packaging market has gradually slowed over the last several years and this trend is likely to continue into the future (MarketLine, 2018). The Australian packaging market had total revenue of $12.8 billion in 2017 and represents a combined annual growth rate of 3.8% between 2013 and 2017. In comparison the Japanese and Chinese markets grew at 7.2% and 3.9% respectively and are worth $127 billion and $147 billion in 2017 (Marketline, 2018).

One factor affecting growth over the last five years has been the changing behaviour of consumers who are becoming more conscious of waste. Consumers are choosing to recycle and reuse, and manufacturers are being encouraged to use less packaging and get rid of non-essential packaging material (Marketline, 2018). This trend is an opportunity for CHEP to continue to position its reusable plastic crate division as being a more sustainable alternative to corrugated cardboard.

Growth in the value of the packaging market in Australia is forecast to slow, with an anticipated annual growth rate of 3.4% for the five year period from 2017 to 2022, which will drive total market value to $15.1 billion by the end of 2022 (Marketline, 2018).

Market projections for corrugated cardboard container manufacturing in Australia

The paper and cardboard sector is a relatively mature industry in Australia and is therefore reasonably consolidated. Orora and Visy exhibit major market share concentration and represent a significant portion of industry revenue benefiting from economies of scale and vertical integration in their supply chain. Both Orora and Visy are expected to maintain their strong market position over the next five years.

The corrugated cardboard sector has an annual total revenue of $2.8b of which $2.2m are from exports with annual profits of $250m. The corrugated cardboard sector imports $67.5m of product from China (70%), Taiwan (6%), Indonesia (4.3%), Vietnam (3.8%) and other countries (16%). Between 2013-18 the annual growth of the corrugated cardboard sector was just 0.4% and is predicted to growth by 1.0% per annum over the next five years (Marketline, 2018).

Consumption of paper and paperboard for manufacturing corrugated containers in Australia reached a second successive annual record of 1,330 kt in 2016-17, 8.6% above the previous year. The drivers included increased food transportation, including exports, and rising e-commerce deliveries (Department of the Environment and Energy, 2018)[16].

External drivers

Demand for local agriculture products is expected to decline over the next period owing to an increase in imports. The proliferation of online shopping and growing demand from fast food and takeaway services has boosted demand for customised

[16] IndustryEdge, Assessment of Australian recycling infrastructure and 2016-17 exports to China – paper and paperboard, in Department of the Environment and Energy (2018), Analysis of Austrlaia's municipal recycling infrastructure capacity

SCC over the past five years. Customised packaging often attracts higher prices, which has supported industry revenue and lifted the profitability of the sector over the period. In addition, SCCs are often used to transport and store construction materials and so rising activity in the construction sector over the past five years has supported demand for corrugated cardboard manufacturing (IbisWorld, 2018).

Competition from RPCs has remained strong over the past five years. This trend has restricted major players in the corrugated cardboard industry from increasing prices. Over the past decade, Australian supermarkets have increasingly substituted SCCs with RPCs. Now, most major retailers in Australia are using plastic packaging for transferring and storing fresh fruits and vegetables in their supply chains (IbisWorld, 2018).

The Australian dollar has depreciated over the past five years. Despite this, import growth in general has remained strong and industry exports have fallen. Australian-made products are often uncompetitive in foreign markets compared with those that are produced locally with lower overheads and labour costs. Further restricting exports is a 7.5% tariff on Australian corrugated paperboard exports to China, the industry's largest trading partner (IbisWorld, 2018).

Carbon emissions

In July 2014 the federal government repealed the carbon tax. In its place the Australian government passed 'Direct Action' legislation which included $2.5 billion of grants to the country's largest polluters to help them cut down carbon emissions. As the production of corrugated cardboard produces significant emissions, this initiative will likely benefit any operators that receive part of this grant within the next five years (IbisWorld, 2018).

Industry outlook

The demand for corrugated paperboard manufacturing in Australia is anticipated to remain subdued over the next five years. This is due to intensified import penetration, price competition between the two largest players and substitution with reusable plastic crates. Imports of lower-cost corrugated cardboard are expected to increase, putting downward pressure on prices and profit margins. Industry revenue should be supported by improvements in productivity and upgrades to existing mills (IbisWorld, 2018).

Several operators are expected to sell-off and lease back their assets, freeing up capital to invest in new machinery. This will have short term impacts on profitability due to rent costs, but in the long term this is expected to support higher margins due to higher automation and lower reliance on labour. Large players are expected to develop innovative product offerings to help defend against substitutes and differentiate themselves from competitors. The intensification of competition is expected to further consolidate some of the smaller players in the industry (IbisWorld, 2018).

The future price of recycled cardboard

In Australia, the majority of reprocessing (sorting and bailing) of corrugated cardboard occurs on the east coast of New South Wales, Queensland and Victoria and is then exported overseas. The introduction of new restrictions on waste imports to China has had a serious impact on the export market for baled corrugated containers collected from households and businesses. Between mid-2016 and mid-2018 the price of corrugated cardboard has fluctuated between $180-$250/tonne. Table 3 shows the historical and forecast price of corrugated cardboard for the next five years. We estimate the future price of recycled paper/board will range between $150-$300 per tonne by 2022.

Table 3: Forecast price for SCC ($AUS)

Market Forecast	2016	2017	2018	2019	2020	2021	2022
Average Value per Tonne	$2,384	$2,394	$2,452	$2,501	$2,564	$2,621	$2,681
Average change in value	-0.70%	0.40%	2.40%	2.00%	2.50%	2.20%	2.32%
Real crate value per tonne	$2,407	$2,343	$2,338	$2,317	$2,270	$2,302	$2,296
Real change in value	0.30%	-2.70%	-0.20%	-0.90%	-0.30%	-0.30%	-0.30%
Average value per SCC	$1.19	$1.20	$1.23	$1.25	$1.28	$1.31	$1.34
Real average value per SCC	$1.20	$1.17	$1.17	$1.16	$1.13	$1.15	$1.15

** $2016*
Source: RISI, Inc. (North American Data)

Cost Comparison and Modelling

Approach and method to estimating functional unit costs

In order to compare RPCs with SCCs in a fair and consistent manner the direct economic costs incurred by each packaging crate were estimated for a single trip through the supply chain. Cost modelling was therefore completed on a like-for-like single trip basis. Uncertainty in different costs were represented by upper and lower estimates to provide bounds on the likely costs.

Full Economic Cost Accounting (FECA)

The full costs of packaging are not limited to purchase and disposal costs, but include material and production costs, packaging and filling costs, cost of distribution and transportation, handling/labour, OH&S and product damage costs, all along the supply chain (see Table 4). In order to understand these costs this study implemented the Full Economic Cost Accounting (FECA) method to determine the total costs of SCCs compared to RPCs across the whole supply chain. This is different to a typical financial analysis because it includes costs incurred by each entity at each point in the supply chain (e.g. growers, distributors, retailers, packaging manufacturers etc) that are either directly or indirectly associated with the use of each type of packaging.

System boundaries

To understand and estimate the full economic costs across the entire supply chain for both SCCs and RPCs it is important to determine the boundaries of the study prior to conducting any analysis. All major costs associated with each packaging type are shown in Table 4, and any other costs that are not directly caused by or attributable to a particular packaging type are considered external to this study or outside the boundary of analysis (see Table 4).).

Table 4: Economic cost categories for business to business packaging

Cost category	Description	Source
Unit price	SCC: The unit price of purchasing a new corrugated cardboard box	Estimated from market data and live quotes.
	RPC: The unit price of leasing an RPC for one trip through supply chain	Data provided by CHEP
Labour costs	The unit cost of labour associated with packing, lifting and loading one packaging unit at every stage in the supply chain i.e. at the farm, in the packing shed, warehouse and at retail.	Estimated from peer reviewed literature and supported through interviews.

Transport costs	The unit cost of transporting one packaging unit from farm gate to final retailer.	Estimated from bottom up calculations and compared with literature.
Product damage	The total cost of any product damage across the supply chain per packaging unit.	Estimated from peer reviewed literature and calculations.
Packaging damage and/or missing RPCs	The total cost of damaged packaging that requires replacement per packaging unit.	Data provided from interviews and grey literature.
Tertiary packaging	The total cost of tertiary packaging per packaging unit at each point in the supply chain.	Estimated from literature and own calculations.
Disposal costs	The unit cost of disposal (N.B. this excludes the cost of storage prior to disposal)	Market data and interviews
Recycling costs	The unit cost of recycling is considered as virgin material and therefore included in the cost of purchasing a SCC.	Included in the unit price of purchasing a SCC.
Cleaning costs	The cost of cleaning RPCs is considered to be included in the hire purchase cost of the RPC.	Included in the unit price of hiring an RPC
Storage costs	Storage costs for empty containers are excluded from this analysis due to the difficulty in quantifying these costs. Storage costs are considered to be lower for RPCs.	Storage costs are excluded from this analysis.

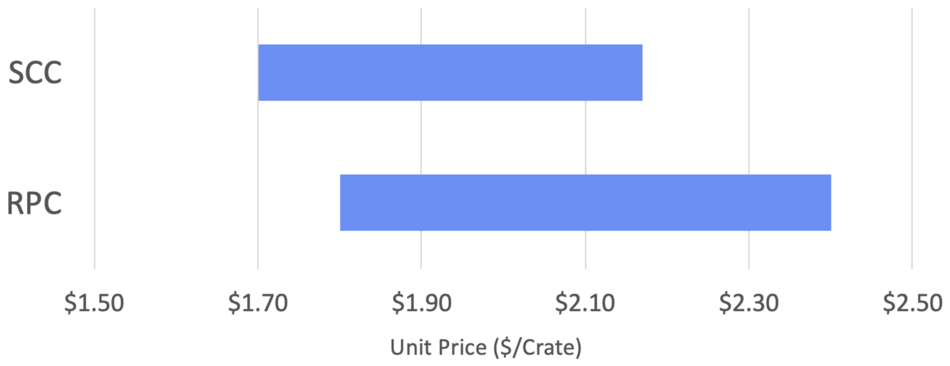
Unit prices

The unit price is the current market price that is paid for a container to package and transport a single crate of fresh produce once through the supply chain from farm-gate to retailer. For a single-use corrugated cardboard carton (SCC) this is the price paid to purchase the unit outright. For a reusable plastic crate (RPC) it is the price paid by an business to lease a single RPC.

A typical cardboard carton is only used once before it is crushed and disposed or recycled. The number of times an RPC is used varies considerably, but literature suggests a single RPC can be used anywhere between 70 (Accorsi et al., 2014) and 250 times (Koskela, Dahlbo, Judl, Korhonen, & Niininen, 2014b). Each RPC can also be used for up to five years before being finally dismantled, disposed or recycled (StopWaste, 2007).

Although the cost of producing a single RPC is much higher than producing an SCC, all material and manufacturing costs for the production of a single RPC can be apportioned over the entire life of the crate, reducing cost per unit trip substantially. When a like-for-like comparison of the unit price between SCCs and RPCs is made based on current economic market data, there is a large overlap in prices, and very little difference in the upfront unit price per packaging container for a single trip.

Figure 8: Range in unit price for each packaging type per single trip



The unit price of a single-use cardboard carton (SCC)

For a SCC the costs incorporated in the unit price include the virgin or recycled materials required to manufacture the carton, manufacturing costs (which includes the amortised cost of manufacturing plant and equipment), logistics, transport (to the point of collection) and any other administrative overheads. As an SCC is generally only used once for transporting fresh produce before it is either disposed or recycled all material and manufacturing costs associated with production are allocated to a single trip. For this study, the two major SCC manufacturers, Orora and Visy, were asked to provide a quote for cardboard container prices. Based on these requests for quotes, the typical market price paid for an SCC in Australia range from $1.23 and $1.70 depending on the capacity and quality of the box being manufactured. Table 5 shows how the unit prices differ by dimension and capacity for corrugated cardboard cartons.

Table 5: Unit price for different SCC carton types and quantities

	Dimensions	Capacity	Tare Weight	Unit Price		
				2,000	5,000	6,000
Orora						
Wholesale Carton	560 x 370 x 170	10-12kg	500g	$1.27	$1.23	$1.21
Visy						
Tomato Carton (base + lid)	263 x 266 x 190	8-10kg	360g	$1.40	$1.35	$1.30
Wholesale Carton	550 x 360 x 165	8-10 kg	500g	$1.30	$1.25	$1.20
Apple Carton	550 x 360 x 165	10-12 kg	500g	$1.75	$1.70	$1.65

The unit price of a reusable plastic rate (RPC)

The costs incorporated in the lease price of an RPC differ substantially from the unit price of a SCC. Typical costs included in the lease price of an RPC include the capital cost of purchasing the unit amortised on a pro-rata basis over the entire life of the RPC (e.g. the number of trips through the supply chain). The upfront capital cost of the RPC includes the virgin or recycled materials and the manufacturing costs (which include the amortised cost of manufacturing plant and equipment to make the crate). The lease price also includes allowance for logistics, inventory management, transport costs (to the point of collection) and any other administrative overheads. Once the RPC has completed its journey through the supply chain from farm-gate to retailer, the crate needs to be returned to a local distribution centre (LDC) and this is typically the responsibility of the final retailer.

Once a crate is returned to an LDC there are additional costs associated with return logistics, transport, cleaning, inspection, maintenance and preparing the crate for the next trip through the supply chain. All these costs are included in the lease price of the RPC as an upfront cost. The technical details for three different RPC capacities available from CHEP are shown in Table 6 while the range of lease prices are shown in **Error! Reference source not found.**.

Table 6: Technical details for CHEP Reusable Plastic Containers

	Expanded Dimensions (mm)	Folded Height (mm)	Weight / Capacity	Tare Weight
CHEP RPC				
Small crate	577 x 385 x 120	25	6kg / 22L	1.22kg
Medium crate	577 x 385 x 177	25	13kg / 34L	1.58kg
Large crate	577 x 385 x 245	25	16kg / 48 L	1.95kg

The unit lease cost for each RPC consists of three main cost categories, these are issue costs, hire costs and transport cost. The *issue cost* includes the capital cost of manufacturing or replacing old units, the *hire cost* includes the logistic costs, cleaning costs and a daily charge, while *transport costs* include the cost of transporting the item from the LDCs to the point of collection. As seen in **Error! Reference source not found.** the cost of leasing a single RPC ranges from $1.20 to $1.80[11].

Labour costs

In order to arrive at an estimate for the difference in costs between RPCs and SCCs we reviewed the literature for previous time-based studies. Time-Driven Activity Based Costing (TD-ABC) was determined to be the most appropriate methodology for this analysis. The TD-ABC method applies a time-based approach to measure the different packaging related activities in the major labour driven tasks of the fresh produce supply chain. Direct time studies fit this application due to the repetitive nature of the activities involved (J. Singh, Shani, Femal, & Deif, 2016).

The journey of fresh produce within retail supply chains involves numerous logistics processes, with each involving several activities. In the study chosen for this comparison, there were twenty-three main activities which included order picking at distribution centres; breakdown and storage of received pallet loads at retail; disposing of one-way packaging and returning reusables. For each category tasks were identified and labour times were measured[17] (J. Singh et al., 2016).

Appendix 2 provides a summary of the Average Cycle Times (ACT) for each of the different packaging activities for SCCs and RPCs. The lower and upper bounds for labour costs for both SCCs and RPCs in Australia per unit have been estimated by assuming average hourly labour costs of between $20 and $25 per hour. Based on the TD-ABC study, provides estimates on labour costs for both SCCs and RPCs. (Table 7). It is clear from this table, that labour costs are a significant proportion of

[17] The students t-distribution was used to calculate the sample size and the required number observations which was estimated to be approximately 1,800. This gave a confidence level of 95% and a margin of error of $\alpha = 0.05$.

the full economic costs associated with transporting one unit of fresh produce through the supply chain. The difference in labour costs between SCCs and RPCs is estimated to be between 12% and 15%. Thus, based on this study, RPCs are shown to save up to 15% in labour costs when compared on a like for like basis with SCCs. It is worth noting that this result was taken from one study, and further TD-ABC based studies should be completed to validate these results.

Table 7: Labour costs based on Average Cycle Times

Summary of economic costs	SCC	RPC
Minutes	18.4	16.1
Hours	0.31	0.27
Total Cost – LOW ($20/hour)	$6.12	$5.36
Total Cost – HIGH ($25/hour)	$7.65	$6.66

Transport costs

Transport costs were estimated on a full-economic cost basis considering all costs associated with transporting crates from farm-gate to final retail store. For RPCs the transport costs associated with return logistics were also taken into account. These costs therefore include the capital cost of the truck, maintenance costs, as well as driver and financing costs. Accurate estimates for each of these costs was achieved by using the online tool FreightMetrics[18]. This tool includes up to date information on the costs of running a range of different truck types under various input assumptions. For this analysis we assume the truck type is a Single Curtain Sider which is a typical semi-trailer used to transport fresh produce in Australia. The full economic analysis for estimating transport costs can be found in the Appendix.

Once the average transport cost was determined we estimated the efficiency of packing the truck and the total quantity of produce being shipped for both SCCs and RPCs. Estimating packaging efficiency is highly dependent on the type of produce being shipped and the dimensions of the primary packaging used - if any. Because of the range of fresh produce being packed and their specific packaging requirements and dimensions, there is a lot of uncertainty in estimating average packing efficiency. Packaging logistics optimisation is a complex field of research that often requires the development of customised optimisation models. For these reasons it is difficult to get concrete estimates of truck packing efficiency for both SCCs and RPCs.

The literature on this subject is also inconclusive and either assumes that there is no difference in packing efficiency between RPCs and SCCs or that RPCs have a slight packing efficiency advantage. Studies where the same volume/weight of produce can be transported with both SCCs and RPCs include Albrecht et al., (2013) and StopWaste (2007). Studies where RPCs have higher packing efficiency include Koskela et al., (2014) Franklin Associates (2017) and Menesatti et al., (2012). In studies where RPCs have higher packing efficiency these savings range from between 5% to 10% when compared to SCCs.

From the interviews conducted we also received mixed reports on the packing efficiency of trucks. One participant claimed that RPCs provided improved packaging efficiency because RPCs had consistent dimensions and the crate stacking

[18] http://www.freightmetrics.com.au/

mechanism on the CHEP Reusable Plastic Container meant that crates could be stacked higher and therefore more crates could be loaded per truck.

Another interviewee had the opposite experience and noted that they were able to pack SCCs more efficiently owing to the fact that the SCC had been designed and manufactured to perfectly fit their pre-packaged produce (in this case it was pre-packaged tomatoes) and that there was a slight gap at the top of each fully loaded RPC. The end result was that when using SCCs they were able to get one more layer containers on the truck compared to RPCs. This is an example where an existing product-packaging system has been adapted to RPCs without re-designing the whole product-packaging system, resulting in overall inefficiencies. This inefficiency could be avoided by redesigning the primary packaging of the tomatoes to fit the dimensions of the RPC container, thus improving overall transport efficiency. For this study we assume that the whole product packaging system is optimised and therefore some gain in transport efficiency is realised. For these reasons and for the purposes of this study we assume that RPCs have an overall beneficial packing efficiency of 5%[19] over SCCs when the whole packaging-system is designed to support the RPC with the packing features that RPCs bring.

Based on the dimensions of the single sided curtain truck as shown in Figure 9, the dimensions of a standard pallet (1165mm x 1165mm) and the dimensions of a 34L CHEP foldable container, we estimate that each truck can carry 44 pallets. This assumes that each truck can carry 11 x 2 x 2 pallets and each pallet can carry 42 CHEP 34L open containers. Figure 9 gives the dimensions of the truck used for this analysis.

Figure 9: Truck dimensions

Table 8 summarises the calculation used to estimate transport costs. The upper and lower bounds of the transport cost estimates were represented by a difference in the fuel price represented by the high and low price of fuel over the last five years [20]. We assume a total distance of 100km is travelled between farm gate and final retailer, although this is likely to be an underestimate.

This analysis showed that transport costs are not a major differentiating factor between the two packaging systems and represent a small overall cost. However, if distances are increased and produce is shipped interstate then transport costs would represent 10% of overall unit packaging expenses on a full economic costing basis.

[19] 5% is an approximation and the true packing efficiency could range from as little as 1% to over 10%.
[20] Australian Institute of Petrolium www.aip.com.au

Table 8: Summary of transport costs per trip

Transport Costs	Low	High	Units
Price of Diesel	$1.50	$1.75	$/litre
Assumed distance travelled	100	100	km
Total cost of operating a truck (includes fuel)	$2.06	$2.18	$/km
Cost of transporting truckload	$206	$218	trip
RPC truck packing efficiency	100%	100%	%
SCC truck packing efficiency	95%	95%	%
RPCs per pallet (assumes full truck)	42	42	pallets/truck
Pallets per truck (assumes full truck)	44	44	pallets/truck
Crates per truck (RPC)	1848	1848	crates/truck
Crates per truck (SCC)	1756	1756	SCCs/truck
Transport cost per box (RPC)[21]	$0.11	$0.12	$/crate
Transport cost per box (SCC)	$0.12	$0.12	$/SCCs

Product damage

Product damage for the purposes of this study is any damage to fresh produce that occurs during distribution from the farm to final retailer. Any fresh produce that is disposed or considered unsellable by the final retailer is treated as an economic loss. In many situations companies are not aware of the significant costs to their business from wasted fresh produce (Karli Verghese, Lewis, Lockerey, & Williams, 2013; p34)

One of the benefits of RPCs for reducing product damage is they can be used as retail ready packaging – that is they can go straight onto the shop floor reducing double handling and the potential for damage.

In most modern developed markets such as Europe, North America and Australia, 9% of food waste occurs during the handling and storage stage of the value chain (Lipinski et al., 2013). Therefore, minimising loss through the supply chain is very important for reducing overall losses and reducing costs. In addition, physical or temperature related damage during distribution can lead to increased deterioration later in the value chain reducing the overall shelf-life – considered as a separate cost category in this analysis. Of all food types, fruits and vegetables comprise 44% of all food loss and waste in modern developed economies (Lipinski et al., 2013).

Previous studies have shown that RPCs are better at protecting fresh produce when compared directly with SCCs because they have a solid exterior structure preventing them from being damaged when dropped. They also have superior airflow characteristics keeping fresh produce cooler for longer. When RPCs are properly loaded and handled during distribution, one study showed that losses were reduced from a reported average product loss of 30% down to a loss of just 5% (Kitinoja, 2013). In one USAID project in Afghanistan, 1500 RPCs replaced a one-way alternative for tomato farmers reducing product losses from 50% to 5% (Kitinoja, 2013). One study that used cost-benefit analysis for the economic feasibility of RPCs

[21] Units are rounded to 3 decimal places owing to the similarity in transport costs.

for vegetable crops in Sri Lanka, Kitinjoja (2013) found that product losses were reduced by 25%.

Chonhenchob and Singh (2003) undertook a scientific study to compare product damage to mangoes by SCC and RPCs. Although RPCs are not presently used to transport mangoes in the Australian market, this case study uses an important and scientifically rigorous method to prove that RPCs are a superior product for preventing product damage. The results of this study showed that the knock-down style of RPCs with a single layer of fruit with cushioning was the best choice for both preventing bruising and improving the heat transfer within the crate, increasing the shelf-life of the produce. Singh et al., (2016) conducted a statistical study consisting of 1800 samples in North America that showed the overall damage to fresh produce decreased from 4.15% to 0.15% when using RPCs. The Fraunhofer Institute for Material Flow and Logistics at the University of Bonn (Fraunhofer, 2013) researched damage levels of product carried from grower to retail. The study reported single-use packaging had product damage of up to 20%, while the reusable system had close to 0% product damage.

Based on the interviews that ISF conducted, similar conclusions were found. One interviewee was able to confirm that since shifting to RPCs their product damage rates in their store alone had reduced by an estimated 5%. Based on the literature review and the interviews we conservatively estimate that product damage from SCCs range from 2% to 5% and product damage from RPCs ranges from 0.1% to 0.4%. These estimates were principally taken from Singh (2016) as this study was conducted in a developed market economy and used a large statistically significant sample to estimate product damage rates. For the purposes of this analysis we assume the retail value of fresh produce per packaging units is valued at between $6.00 and $7.50 per kg as representative of typical perishable high value fruits and vegetables (e.g. tomatoes, courgettes, nectarines, peaches, grapes etc). This leads to an upper product damage cost of $4.88 for each SCC unit, which is by far the largest economic cost of SCCs.

Table 9: Product damage costs

Product damage	Low	High	Units
SCC wasted product (low)	2%	5%	%
RPC wasted product (low)	0.1%	0.40%	%
Retail value of fresh produce	$6.00	$7.50	$/kg
Total box weight	13	13	kg
Total value of box	$78.00	$97.50	$/crate
SCC product damage cost	$1.17	$4.88	$/unit
RPC product damage	$0.08	$0.39	$/unit

Shelf life extension

Various studies have shown that RPCs provide extended shelf-life for fresh produce when compared to single-use systems (Chonhenchob & Singh, 2003b; Kitinoja, 2013; Lipinski et al., 2013; Menesatti et al., 2012; K. Verghese & Lewis, 2007). To estimate cost-savings from an extension of shelf-life of fresh produce, we used recently published data from an independent IFCO funded scientific study exploring the extension of shelf-life provided by RPC containers. The research was conducted by an independent fresh food consultancy, Dr Lippert Quality Management. The research involved conducting realistic tests on four common products – melons, tomatoes, mushrooms and grapes across the entire supply chain from grower to final consumer (Lippert, 2018). The researchers set up both chilled and ambient conditions and ran the test for 19 days, testing against a comprehensive list of criteria including weight loss, stem health, sugar and acidity levels, temperature and humidity, firmness, infection, rot/mould, colour, spoilage and appearance. The results from this study show that RPCs keep fresh produce in a better condition for longer, extending shelf life by up to four days. Table 10 provides a summary of the results from this scientific study, showing that melons and mushrooms have the longest shelf-life extension, while grapes and tomatoes have the shortest shelf-life extension.

Table 10: Example of fresh produce shelf-life extensions using RPCs

Fresh Produce	SCCs (days)	RPCs (days)	Difference (whole days)	Difference (%)
Melons	4	9	4.5	100%
Tomatoes	12	15	2.5	17%
Mushrooms	2	4	2	100%
Grapes	4	6	2	25%

In order to estimate the economic costs of the differences in shelf-life between RPCs and SCCs we need to estimate the total value of product life extension. This is estimated based on the average daily value of fresh produce (e.g. the total value of fresh produce per unit divided by the average number of shelf-life days for SCC). This value is then multiplied by the average supermarket loss estimates for fresh fruit and vegetables which was found to be approximately 12% (Jean, Wells, Actman, & Mickey, 2009). A summary of this calculation can be seen in Table 11. The upper and lower bounds of this calculation is driven by the value of fresh produce and the percentage of produce saved on the additional days of shelf-life. This calculation is only an approximation as it was difficult to find real data quantifying the value of product life extension for the fresh food sector.

Table 11: Product shelf-life extensions

Economic costs and assumptions	Low	High	Units
Retail value of fresh produce	$6.00	$7.50	$/kg
Max box weight	13	13	kg
Total retail value of product in a single container	$78.00	$97.50	$
Typical product shelf life (RPCs)	15	15	days
Typical product shelf life (SCCs)	12	12	days
Average shelf-life extension (RPCs)	2.5	2.5	days
Average daily product value per box (RPCs)	$3.71	$4.64	$/day
% of product disposed	12%	12%	%
Total value of additional days product shelf-life	$1.11	$1.39	$

Damaged or lost packaging

Damage to cardboard cartons is an expected consequence of the handling and distribution process. SCCs are designed for a single use, making them more prone to damage. First, SCCs are at risk of being crushed if they are dropped or handled and stacked incorrectly. Second, uncoated SCCs are not water-proof and once they get wet, their structural integrity is reduced, and it cannot be used reliably.

The causes of damage to SSC packaging in order of importance include: insufficiently robust boxes (64%), inadequate securing of loading units (20%) and other external factors (16%) (Fraunhofer, 2013).. In addition, when an SCCs is damaged, it is likely that the produce within the box will also be damaged. Any product that remains undamaged must also be transferred to a new SCC. The cost of replacing the SCC and the labour required to transfer the produce to another cardboard carton thus needs to be incorporated into the economic loss calculations.

RPCs also get damaged but much less frequently than SCCs owing to their more robust design. RPCs are designed to be reused many times and because they are typically made from HDPE they have significantly better structural integrity than SCCs when impacted. This means that when RPCs are dropped or stacked incorrectly, they are much less likely to fail and the produce they are holding is therefore less likely to get damaged. However, because RPCs are more valuable on a per unit basis, when one goes missing a fee is charged by the supplier to recover the cost of the lost crate. Based on information collected from interviews we assume that between 1 in 100 and 1 in 200 crates go missing as the upper and lower bounds for this calculation. We also assume that the value of an RPC ranges between $10 and $12.50.

Damage rates have been estimated based on evidence from the literature, which was also confirmed through our own independent interview process. The Fraunhofer Institute for Material Flow and Logistics (Fraunhofer, 2013) found that damage rates to SCCs during distribution occurred at a frequency of 0.88% at the warehouse and 3.32% during transportation and handling. This contrasts with RPCs with a damage rate of just 0.02% at the warehouse and 0.1% during transportation and handling. Table 12 lists the assumptions and data used to evaluate the economic cost of damaged or lost SCCs and RPCs.

Table 12: Lost and damaged cardboard cartons and plastic crates per trip

Economic costs and assumptions	Low	High	Units
Replacement cost of SCC	$1.21	$1.75	$/crate
Replacement cost of RPC	$10.00	$12.50	$/crate
Proportion RPCs damaged	0.10%	0.12%	%
Proportion of RPCs lost	0.50%	1.00%	%
Proportion SCCs damaged	4.0%	4.2%	%
Cost of damaged SCC	$0.05	$0.07	$/crate
Cost of damaged RPCs	$0.01	$0.02	$/crate
Cost of lost RPCs	$0.05	$0.13	$/crate
Total damaged SCC	$0.05	$0.07	$/crate
Total damaged or lost RPCs	$0.06	$0.14	$/crate

Tertiary packaging

In this research, tertiary packaging includes any additional packaging material used to protect and secure the cardboard cartons and plastic crates for transport and handling. This includes the pallet and the plastic stretch wrap. Both RPCs and SCCs require a pallet for shipping and as it is assumed for the purposes of this study that an equal number of cardboard cartons and plastic crates can be loaded on a pallet, so for both SCCs and RPCs the cost of the base pallet is equivalent. This may not always be the case depending on the type and size of containers being shipped.

Securing cardboard cartons to the pallet is generally achieved using plastic stretch film, as shown in Figure 10, and sometimes plastic strapping for heavier loads. RPCs have an interlocking stacking mechanism allowing them to be securely locked together on pallets, thus eliminating the need to use plastic stretch wrap or strapping.

From the interviews conducted we were advised that several retailers had a policy that plastic stretch wrapping was required on all inbound pallets, regardless of whether the crates had an interlocking stacking mechanism or not. Although the plastic film is very cheap, it is still single-use and although recyclable is often sent to landfill (N.B. most of the big retailers recycle at their distribution centres and most stores). For the purposes of this study, we assume that RPCs do not require as much plastic wrapping owing to the interlocking stacking mechanism but assume that all cardboard containers do require shrink wrapping.

Figure 10: RPC on pallets shrink wrapped with plastic film

Wrapping the average pallet consumes approximately five linear metres and about 500g of plastic. It takes an average of three mins to wrap and one min to unwrap an average pallet. Stretch wrap costs around $10 per roll and each roll can wrap approximately 10 pallets. The disposal cost for plastic wrap was estimated to be $0.0002 per container and because of the small cost was ignored for these calculations. Table 13 provides a summary of the tertiary packaging costs for SCCs and RPCs.

Table 13: Tertiary packaging costs

Economic costs and assumptions	Low	High	Unit
Labour cost	$20.00	$25.00	$/hour
Cost of stretch wrap per pallet	$0.80	$1.20	$/pallet
RPCs per pallet	42	42	RPC/pallet
Cost of stretch film per box	$0.02	$0.03	$/RPC
Time to wrap RPC	4	4	mins
Cost of manually wrapping pallet (per RPC)	$0.03	$0.04	$/RPC
Market price for a disposable pallet (1165 x 1165)	$10	$15	$/RPC
Cost of pallet per RPC	$0.24	$0.36	$/RPC
Total cost SCC	$0.29	$0.43	$/RPC
Total cost RPC	$0.24	$0.36	$/RPC

Return logistics and transportation costs

Return transportation costs are only relevant to RPCs as SCCs are recycled or disposed and not re-used. Once produce has been removed from the RPC they need to be returned to the nearest CHEP local distribution centre (service centre). The costs associated with returning RPCs back to the nearest distribution centre are typically incurred by the retailer and therefore needs to be included as part of this analysis.

Once an RPC has been returned to a service centre, CHEP is responsible for checking, cleaning and preparing the crate for the next cycle through the supply chain. As the CHEP RPCs are foldable it is possible to return up to three times as many folded RPCs per truck as were delivered as open RPCs. For this calculation we assume the upper and lower bounds for the number of RPCs returned ranges between two and three times the number of fully loaded open RPCs. We provide a lower estimate as it is likely retailers will want to return RPCs on a partially loaded truck to avoid paying the additional daily hire costs and wait to return a full load of RPCs. The same transport cost assumptions as provided in Appendix on transport costs are assumed for the return of RPCs. A summary of these costs is shown in Table 14.

Table 14: RPC return transport costs

Economic costs and assumptions	Low	High	
Distance travelled	100	100	km
Return factor multiple (multiples returned)	3	2	-
Crates per trip	5,544	3,696	crates/trip
Estimated cost per km	$2.06	$2.18	$/km
Estimated cost per trip	$206	$218	$/trip
Estimated cost per crate returned	$0.04	$0.06	$/crate

Disposal and recycling costs

For this analysis, disposal costs are more significant for SCCs as the majority of the costs for recycling and disposing of RPCs is incorporated in the unit lease price of the RPC. Owing to the typical business model of RPCs, the disposal costs are managed by operator and therefore these costs must be covered by the lease price. This is in contrast to SCCs where the cost of disposal is the responsibility of the final retailer. Using a market price of $500/tonne for HDPE recyclables and a raw material cost raw processed HDPE beads of $1500/tonne we estimate the processing and recycling cost of HDPE to be $1000/tonne. Each RPC weights 500g so the end of life cost of a single RPC is estimated to be $0.50. It is estimated that a single RPC is used on average 100 times before it reaches end-of-life. Therefore, the total end-of-life cost per unit-trip for an RPC is between $0.0 and $0.005.

Table 15: Economic end-of-life costs of RPCs

Economic costs and assumptions	Low	High	Units
Cost of sorted HDPE recyclables (a)	$200	$500	$/tonne
Cost of raw processed HDPE beads (b)	$800	$1500	$/tonne
Processing and logistic costs (b – a)	$600	$1000	$/tonne
Total weight of typical RPC	0.5	0.5	kg
End-of-life cost per unit	$0.3	$0.50	$/unit
Total trips per unit	80	100	trips
Net disposal costs per trip	**$0.004**	**$0.005**	**$/unit trip**

The disposal cost of SCC is born by the retailer. Current market prices to estimate disposal costs were provided by interviews and recently published market reports (Australian Packaging Covenant Organisation, 2018; Environment and Communications References Committee, 2018; Pickin & Randell, 2017).

The typical end-of-life costs for SCC were separated into the (i) costs and revenues from cardboard cartons that is recycled and (ii) the costs of disposing cardboard cartons to landfill. In Australia around 60% of cardboard cartons are recycled or used for energy recovery, the remaining 40% goes to landfill. In order to estimate the end of life costs for a typical SCC it was assumed that 60% of the net cost are is incurred from recycling and 40% from disposal to landfill. The various costs included in recycling and disposal to landfill are shown in Table 16

Table 16: Costs included in recycling and landfill of used cardboard

Included in the cost of recycling	Recycling costs	Landfill costs
Collecting, sorting baling of cardboard	yes	yes
Freight of cardboard inland	yes	yes
Shipping and export costs for recycling	yes	no
Landfill costs	no	yes
Revenue from selling cardboard for recycling	yes	no

Estimating the typical end of life costs for a cardboard crate are shown in Table 17. Costs shown in red and in brackets are positive cashflows from revenue. The main variables used to control the upper and lower bounds in this estimation are landfill levies and the revenue from selling recycled corrugated cardboard on the open spot market. Given the high price volatility of paper and cardboard on the international spot markets, we allow for a large range in the estimation of the lower and upper estimates for the export price. These were taken forecasts of the future price of recycled cardboard. As seen in Table 17 the end of life costs for typical SCC range from a positive revenue of $0.07 to a cost of $0.05 per crate.

Table 17: Typical end of life costs for SCC

Economic costs and assumptions	Low	High	Units
Collecting sorting of cardboard	$30	$40	$/tonne
Freight of cardboard inland	$15	$20	$/tonne
Percentage cardboard recycled	60%	60%	%
Percentage cardboard to landfill	40%	40%	%
Shipping and export for recycling	$15	$20	$/tonne
Cost of disposing cardboard to landfill	$50	$100	$/tonne
Revenue from selling recycled cardboard	$100	$350	$/tonne
Weight of box	0.5	0.5	kg
Total boxes per tonne	2000	2000	boxes / tonne
Disposal cost	$0.02	$0.03	$/crate
Recycling cost	$0.02	$0.02	$/crate
Total recycling revenue	($0.11)	($0.00)	$/crate
Net recycling cost	($0.09)	($0.02)	$/crate
Net disposal costs	**($0.07)**	**$0.05**	**$/crate**

What is clear from this analysis, is that the end-of-life costs for disposing or recycling cardboard containers is negligible when undertaking a full-economic cost analysis and contribute less than 1% of the total economic costs. In the following section we include market analysis for corrugated cardboard containers and five-year projections on the forecast price of corrugated cardboard.

Occupation health and safety (OH&S) costs

Data on the costs associated with occupational health and safety OH&S were not available for this study and were therefore not included in the full costs. The literature on this subject provides some qualitative evidence suggesting RPCs may reduce OH&S costs owing to the improved ergonomic design of the RPCs, interlocking stacking system and the increased strength and sturdiness of stacked crates minimising the risk of accidents (Accorsi et al., 2014; S. P. Singh et al., 2006). As RPCs are designed with ergonomic handles, lifting and transporting the crates is also more manageable preventing sustained injuries over longer periods of time. These costs were not included in the economic cost calculations.

Conclusions

Using a full economic cost approach, we estimate that a typical supply chain using SCCs making the switch to RPCs could save between $2.92 and $9.27 per crate, as shown in Table 18.

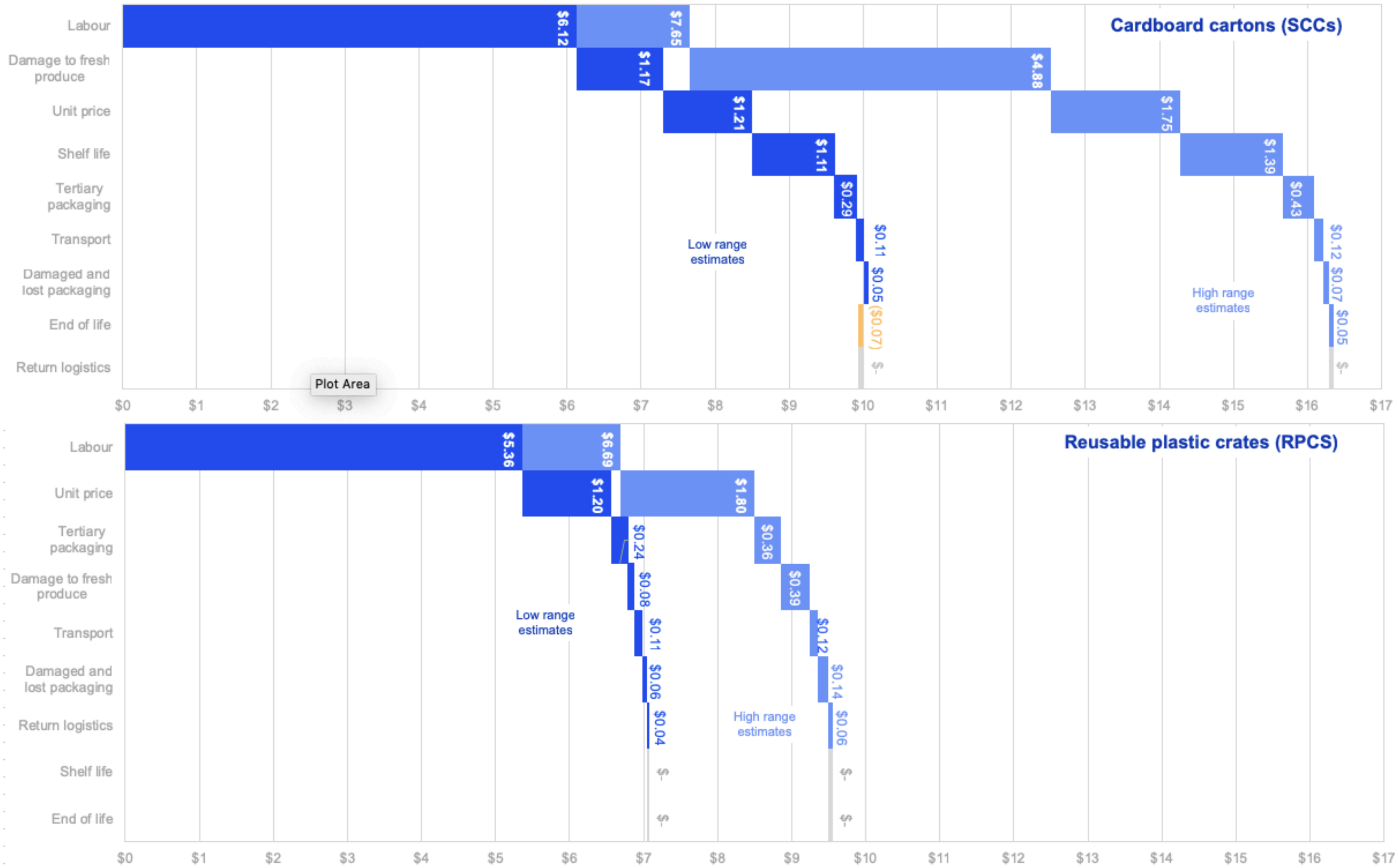
Table 18: High and low economic costs for RPCs and SCCs

	RPC*		SCC**	
	Low	High	Low	High
Unit cost	$1.20	$1.80	$1.21	$1.75
Transport	$0.11	$0.12	$0.11	$0.12
Labour	$5.36	$6.66	$6.12	$7.65
Damage to fresh produce	$0.08	$0.39	$1.17	$4.88
Reduced shelf-life of fresh produce	$0.01	$0.01	$1.11	$1.39
Damaged and/or lost packaging	$0.06	$0.14	$0.05	$0.07
Tertiary packaging	$0.24	$0.36	$0.29	$0.43
End of life costs	$0.00	$0.01	($0.07)	$0.05
Return logistics	$0.04	$0.06	$0.00	$0.00
Total cost	**$7.08**	**$9.56**	**$10.00**	**$16.35**
Saving	**$2.92**	**$9.27**		

* The prices shown for RPCs are generally applicable across the range of RPC products
** The prices for SCCs are estimated for four typical produce-type cartons as shown in Table 5.
† Reduced shelf-life calculations were benchmarked against RPCs
§ End-of life costs were allocated across the entire life of the container.

On average we estimate the cost savings across the entire supply chain to be approximately 58% or $4.85 per packaging crate. This represents a cost saving that is up to 3 times the original unit cost of SCCs. These savings are driven primarily through reductions in product damage (51%), extending the shelf life of products (14%), labour cost savings (10%), less tertiary packaging requirements (4%), more efficient transport (1%), less damaged packaging (1%) and a reduction in disposal costs (1%). A full comparison of the costs is shown in Figure 11 below.

Figure 11: Full cost comparison of SCCs and RPCs



Note: Categories organised from greatest to least cost based on low-range estimates.

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Appendix 1: Stakeholder Interviews

Participating stakeholders

Stakeholders invited to interview or provide data

Company	Supply chain stage	Invited	Participated
CHEP	Packaging and supply chain solutions supplier	✓	✓
Visy	Packaging supplier	✓	✓
Orora	Packaging supplier	✓	✓
ALDI	Retailer	✓	✓
Woolworths	Retailer	✓	Declined
Coles	Retailer	✓	Declined
Metcash	Distributer	✓	✓
Mitri Hydroponics	Producer	✓	✓
Corrigan	Producer	✓	Did not respond
Refrigerants Australia	Logistics	✓	Did not respond
SUEZ	End-of-life collector and management	✓	✓

Appendix 2: Labour Cycle Times

Order Picking for Retail at DC	SCC	RPC
Unloading of truck	46	40
Repacking (unit load)	102	77
Taking into stock (unit load)	97	30
Stock keeping (unit load)	73	66
Order picking (per container)	27	25
Securing unit load (unit load)	36	26
Loading mixed load carriers (unit load)	44	37
Providing Fresh Commodity at Retail	**SCC**	**RPC**
Unloading of truck (unit load)	87	85
Stocking / buffering goods (per container)	12	9
Order picking (per container)	4	3
Transportation to shelf (per cart)	25	22
Providing goods (hand stocking per container)	163	142
Transportation to back (per cart)	94	31
Folding and palletising RPC (per container)	-	6
Disposal of single use packaging (per case)	7	-
Pallet load / bale to truck (unit load)	42	92
Loading truck with empty containers (unit load)	75	75
Disposing one-way / returning returnables	**SCC**	**RPC**
Unloading of truck (unit load)	37	33
Physical reception of empty containers (unit load)	34	63
sort and palletise reusables (per container)	-	42
Securing unit load (unit load)	-	24
Sorting on-way packaging (unit load)	61	-
Providing reusables and one-way packaging for collection (unit load)	36	36
Total (seconds per container)	964	1102
Total (minutes per container)	16.06	18.36
Total (Hours)	0.27	0.31

Appendix 3: Transport Costs

Basic Truck Properties	Low	High	Unit
Type of Truck	Curtain Sider B-Double	Curtain Sider B-Double	
Net average Daily Delivery	24	24	Tonne
Current price of diesel	$1.50	$1.75	per litre
Less Fuel Rebate	$0.12	$0.12	per litre
Effective fuel price	$1.38	$1.63	per litre
Operational data			
Average vehicle burn rate	1.6	$2.10	km/litre
Distance travelled per day	750	750	km
Days per week	6	6	days per week
Weeks per year	46	46	accounting for holidays
Capital Cost - Truck	$276,210	$276,210	$
Vehicle Stamp Duty	$8,286	$8,286	$
Capital Cost Trailers	$81,406	$81,406	$
Trailer Stamp Duty	$2,442	$2,442	$
Miscellaneous	$15,000	$15,000	$
Principle	$368,344	$368,344	$
Balloon	25%	25%	%
interest Rate	9.50%	9.5%	%
Loan Period	5	5	years
Other fixed costs			
Insurance, Registration, Admin, Depot, Wages	$34,097	$34,097	per year
Wages	$278	$278	per day
Telecommunications, Admin staff	$2,545	$2,545	per month
Servicing	$2,000	$2,000	per year
Cost Summary	**Annual Costs**		
Fuel	$136,025	$160,668	$
Interest on truck finance	$24,061	$24,061	$
Depreciation	$25,000	$25,000	$
Fixed costs	$92,788	$92,788	$
Driver costs	$98,618	$98,618	$
Tyres (wear and tear)	$21,346	$21,346	$
Maintenance costs	$17,284	$17,284	$
Servicing costs	$10,695	$10,695	$
Total Annual Cost	**$425,790**	**$450,433**	
Distance travelled	207,000	207,000	km per year (average)
Service intervals	12	12	per year
Maintenance intervals	10	10	per year
Operating charge per day	$1,714.13	$1,813.34	per day
Estimated cost per km	$2.06	$2.18	per km