Zero Waste Cardboard Technology to Support Product Stewardship

Aharon Arakel, Bithi Roy, Rubick Arakel, Warwick Madden

Pact Renewables Pty Ltd, Sydney, Australia

Abstract

The principles of sustainability, as a core measure for reducing the adverse impacts of climate change, are now acknowledged globally. To reduce waste and reliance on landfilling and incineration, the concept of “take-back” (also expressed as “Reverse Logistics”, “Extended Product/Producer Responsibility” and “Product Stewardship”) is now increasingly being accepted by manufacturing industries and implemented in many jurisdictions, on a voluntary basis or through enactment.

This paper discusses the lifecycle issues associated with application of current product stewardship approaches to sustainable management of paper and cardboard packaging waste. We also provide an example of how technology-based innovation can simplify the application of reverse logistics to achieve tangible paper/cardboard product stewardship. The technology example presented herein involves direct use of waste paper/cardboard in manufacturing of a variety of industrial products and consumer goods that at the end of their useful life can be placed in soil to degrade and provide conditioning effects. By doing so, no waste is generated and reliance on landfilling or incineration of such waste paper/cardboard is avoided. However, as the challenge of waste paper/cardboard is complex and growing other zero waste technologies are also needed for uptake of the best fit options by industry and governments, and to promote product stewardship, design thinking and active engagement of the consumers.

Keywords

Waste paper and cardboard, Product Stewardship, Extended Producer Responsibility, Reverse Logistics, CtP technology

1 Introduction

The adverse impacts of climate change have accelerated the global search for sustainable use of resources and activities to reduce the impacts and preserve limited resources. This search for ethical sustainable governance (ESG) is reflected by numerous recent consumer surveys, that show over one third of consumers are willing to purchase environmentally friendly products. Sustainability is not just another buzzword as in the case of manufacturing of industrial products and consumer goods it requires implementation of reverse logistics for all manufacturers due to the growing environmental concerns, legislation, corporate social responsibility and sustainable competitiveness. Reverse logistics refers to the sequence of activities required to collect the product used by a consumer for the purpose of reuse, repair, re-manufacture, recycle or disposal. Reverse logistics has been expressed in different ways in different jurisdictions including the “take-back” concept, “Extended Product Responsibility” (EPR in U.S.A.) or “Product Stewardship” in Australia, ranging in enforcement from a voluntary basis to enacted laws. A careful review of relevant literature shows that although reverse logistics is still in an evolutionary phase, in fact the product take-back concept, initially developed in Germany and Japan in the early 1990’s, has now evolved globally into a broader initiative known as “Extended Producer Responsibility” (EPR). EPR is a policy concept in which a producer’s physical and/or financial responsibility for a product is extended to the post-consumer phase of the product’s life-cycle (e.g., EU Directive, 2018). EPR policies include take-back mandates, as in Germany, but other types of protocols and instruments may also fall under the EPR umbrella, such as “product stewardship”, a voluntary based EPR concept in Australia.

Accordingly, despite their contentious nature, “take-back” or EPR laws and initiatives were first enacted in Germany in 1991 under the so-called product “take-back” law and known as Packaging Ordinance. This required packaging manufacturers and distributors to take back packaging from consumers and ensure that a specified percentage of it is recycled. The law was facilitated by manufacturers and distributors meeting their obligations by joining a “producer responsibility organization” which handles collection and arranges for recycling (PALMER AND WELLS, 2002).

Faced with packaging waste making up between 20 to 30 percent of the total weight of the municipal solid waste stream (TANAKA, 1998; CLEAN JAPAN CENTRE, 2001), Japan was another early adopter of EPR by enacting *The Container and Packaging Recycling Law* in 1995. This law enforces manufacturers to be responsible for meeting phased-in recycling rate targets for glass and PET bottles, followed by targets for paper and plastic containers and packaging. The Japanese refer to the targets as “voluntary” and as in the Netherlands, local government in Japan maintains responsibility for collection of packaging waste and return to industry responsible for paying for recycling. Since then, many European countries have mandated EPR programs under the EU Directives (2018) or their own directives for many consumer goods.

In the United States, there has been resistance to wholesale adoption of the EPR approach as the focus on producer responsibility has been contested by U.S. business interests who consider the idea of replacing the decentralized solid waste collection and recycling system, that already exists in the U.S. as a duplication. This system is a centralised mandatory system in which producers are responsible for collection and recycling their products at end-of-useful life. Despite this, the U.S. Environmental Protection Agency, some state governments and industry groups have commenced supporting some of the ideas behind the EPR concept. There have been some shifts in the U.S. packaging industry groups who have traditionally opposed to mandated producer funding of recycling, towards supporting the EPR concept by means of engaging on the legislative front and support of recycling funding provided that the programs are set up in specific ways and meet certain requirements at the state level. These shifts are partly driven in response to recycling markets being recently thrown into turmoil in the wake of China's *National Sword policy*, which has driven a renewed focus by policymakers, at both the state and federal levels, on trying to stabilize the economics of materials recovery. For example, in a distinct shift from its previous position, in October 2020, Ameripen, a group representing several large U.S companies across the packaging-material spectrum, adopted a new internal policy on how the group would engage on the legislative front when it comes to recycling funding (AMERIPEN, 2021).

Product stewardship is relatively new in Australia, but in the wake of National Sword policy, it is becoming a major concern for state and federal governments as well as communities. Although sporadic, the efforts with product stewardship in Australia has so far reduced the environmental and human health impacts of selected waste streams generated by automotive, electronic, beverage and agricultural industries. In response to the slow progress with industry uptake, the establishment of a national centre of excellence for product stewardship was announced recently (PRODUCT STEWARDSHIP CENTRE OF EXCELLENCE, AUSTRALIA; 2020) to promote collaboration between industry and community groups.

As indicated earlier, the progress with reverse logistics is still is an evolving phase because of the issues related to adoption, implementation, forecasting product performance, outsourcing, networking from a secondary market perspective, and disposition decisions are yet to be thoroughly examined. One drawback hindering a broad-based adoption and implementation of reverse logistics relates to poor application of the reverse logistics concept, as defined presently, to certain waste categories due to the lack of technical solutions for product wastes having short recycling loops which leads to their eventual disposal in landfills or incinerators at the end of their useful life. For example, in contrast to wastes made from glass and plastic with long recycling loops (28-30 rounds), recycling of waste paper/cardboard is problematic because of short loops (2 recycling loops for high quality packaging boxes and up to 8 recycling loops for low quality egg cartons and beverage trays). A compounding problem with paper/cardboard waste is the high lifecycle cost associated with disposing cardboard waste at the end of its useful life, due to its low value and bulky nature.

In the context of reverse logistics, the challenge of waste paper/cardboard has been exacerbated with the exponential increase in the amount of cardboard packaging waste generated through increased online purchasing of consumer goods and prepared food due to the global Covid-19, that ultimately all need sustainable disposal solution. To move forward, innovation is needed to drive product stewardship for waste paper/cardboard in tandem with other waste categories in order to achieve global progress with impactful outcomes.

In this paper, we discuss lifecycle issues associated with current approaches to reverse logistics and the challenges in applying these approaches to addressing the product stewardship challenge for the ever-mounting paper/cardboard-based packaging waste. We also provide an overview of how technology-based innovation can drive reverse logistics to achieve waste paper/cardboard product stewardship. The technology presented herein involves the direct use of waste paper/cardboard for the manufacture of a variety of industrial products and consumer goods that, at the end of their useful life, allow degradation once placed in soil and provide conditioning effects. By doing so, landfilling or incineration of such waste is avoided.

In the following sections, the terms EPR, product stewardship and reverse logistics are used interchangeably, as their concepts are compatible with each other.

2 The challenge

Figure 1 is a schematic example of the conventional approach to reverse logistics proposed for various waste categories (SRIVASTAVA, 2008; ZIELINSKA, 2020). As shown, raw material from recycling of waste is used for production and distribution of new industrial products and consumer goods. In this scenario, the packaging waste from delivered industrial products and consumer goods is recycled through options of (a) repair/reuse, renovation and distribution, or (b) disassembly, service and distribution, or (c) regeneration and production, or (d) recycling of the waste paper/cardboard to produce raw material for manufacturing new packaging products.

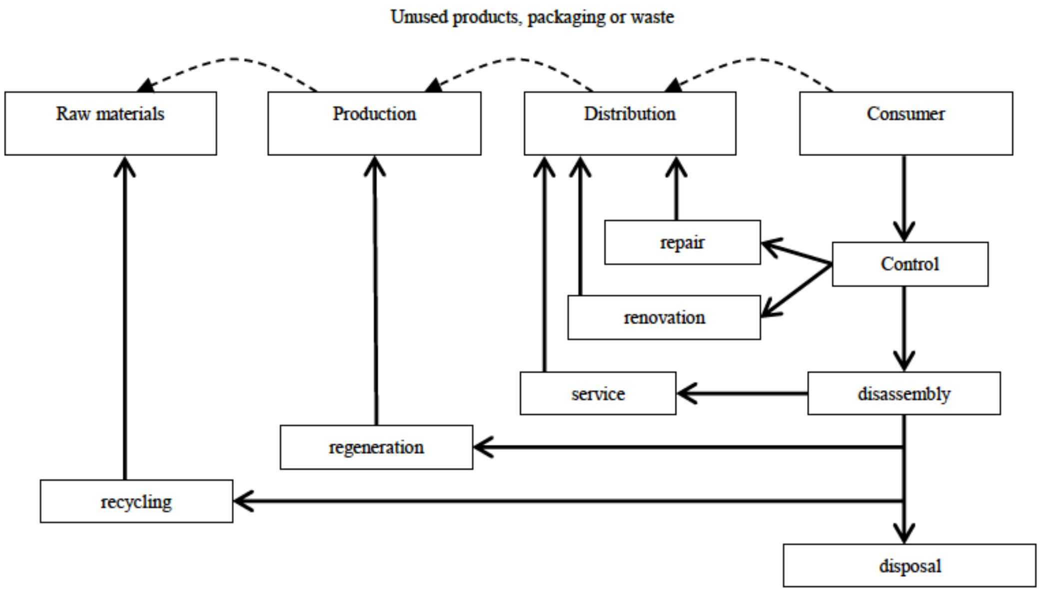

Figure 1 An example reverse logistics scheme used in this paper for discussing lifecycle aspects of paper/cardboard as related to product stewardship (Source: Zielinska, 2020; adopted from Srivastava S.K 2008).

As indicated earlier, these options although relevant to most other waste categories, cannot be adopted satisfactorily for the waste paper/cardboard category as:

- option (a) is not applicable because the quality of cardboard packaging material by simply repair/reuse/renovation will be the lower than a new cardboard packaging material;

- option (b) is also not feasible because of the damage caused to cardboard material during disassembly/dismantling;

- option (c) is also not applicable because inability to regenerate the packaging product after disassembly;

- option (d) although possible is limited to a few recycling loops and will incur substantial life cycle costs.

It should be immediately noted, that whereas option (d) might offer some scope, in practice, the end product of this option is reached just after a few recycling loops, and is commonly in the form of low quality products (e.g. egg cartons and beverage trays) and ultimately end up in landfills.

3 Proposed approach for addressing the challenge

Considering the above constraints, new approaches are needed to address the key issues related to waste paper/cardboard management (i.e., to avoid landfilling and incineration). The new approaches should offer solutions for two fundamental challenges, namely:

- how to achieve zero waste discharge?
- how to make the solution attractive to Industry by producing products from waste paper/cardboard with lower life cycle costs?

With reference to Figure 1, one approach is using the dissembled waste paper/cardboard from any recycling loop and use it as part of a feedstock material for manufacture of industrial products and consumer goods that become degraded once placed in soil. This approach has been used by Pact Renewables Pty Ltd from the outset to develop a zero waste paper/cardboard technology which overcomes the constraints discussed earlier. The technology, known as CtP (cardboard-to-product), diagrammatically shown in Figure 2 and further described below, offers a low lifecycle cost option for applying reverse logistics for sustainable management of waste paper/cardboard and achieve impactful outcomes.

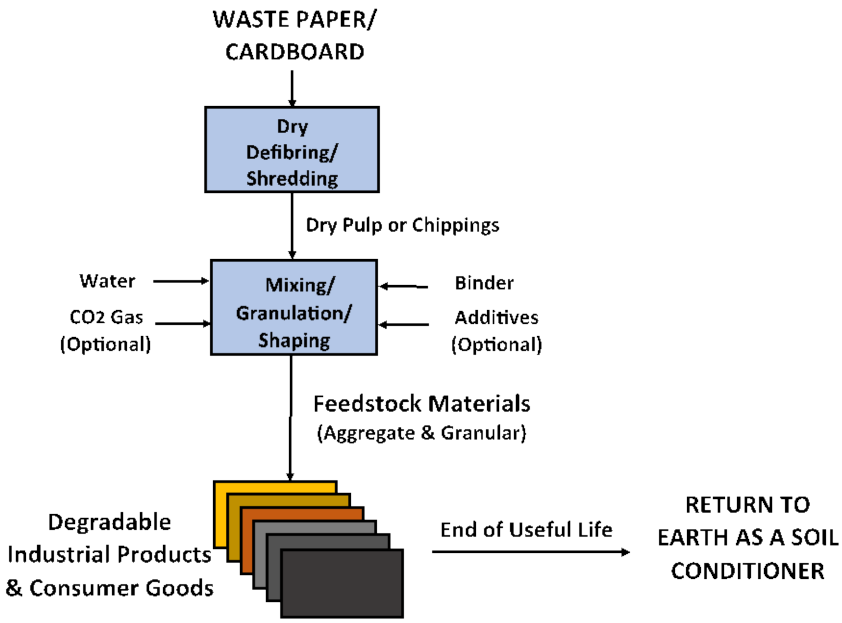

Figure 2 Schematic presentation of CtP zero waste technology, showing the key process steps leading to beneficial use of waste paper/cardboard to produce degradable products.

The technology behind the proposed approach is essentially comprised of two process components, namely, dry defibring of waste paper/cardboard and then mixing the defibred pulp with a proprietary mineral-based binder, water and selected additives in a vessel to produce degradable feedstock materials. The feedstock materials, from which the products and goods are produced are comprised of pulp/chippings, mineral-based binders (made of sulphates, carbonates and hydroxides of Ca, Mg and K), and optionally one or more degradable additives. The feedstock materials, in the form of either aggregate or granules, are used beneficially for producing industrial products and consumer goods using conventional equipment such as moulding machinery for the manufacture of agricultural containers. For some product streams, a conventional or a purpose-built agglomeration unit can be used to produce pebble and granular products of desired sizes, shapes, textural features and functionalities, according to end user requirements.

The amount of cardboard in the feedstock materials depends on the intended application area but generally can be up to 60% by weight of total feedstock material. Additives may include organic and inorganic fillers, pestcides, mineral nutrients, colourants and coating agents. A distinct advantage of the feedstock material of this technology is the ability to absorb and react with CO_2 gas in order to refine the minerology of the binders for producing end products with additional functionalities, such as improved water holding capacity and enhanced compressive strength.

Since the conception of the technology, numerous laboratory and field trials have been undertaken to assess the technology application to various industries and assessment of the performance of the products for target application areas. Table 1 provides a summary listing of currently identified application areas of the technology reflecting its attractiveness to sustainably address the paper/cardboard waste challenge. Furthermore, as the technology assessments progress, new application areas are being identified systematically assessed for product quality, functionalities and degradability.

Table 1 Summary list of identified application areas of feedstock materials produced by CtP technology using waste paper/cardboard

Application Area	**Product Types**
Agriculture and food production	• Containers for nursery/seedling, horticulture forestry, landscaping and mine site tailings vegetation, etc. horticultural, agricultural containers • Granular and sheet mulch • Granular soil conditioners for revegetating land divisions, decommissioned landfills, mine sites and brownfields, landscaping and commercial orchards, and garden watering and nutrient supply • Grow media for greenhouse/glasshouse farming

Odour control media	• Aggregate for odour reduction in poultries, piggeries, cattle farms, etc. • Aggregate for reduction of malodour from food consumption (household, restaurants, military, cafes, grocery stores, schools, hotels, cruise and cargo ships, hospitals, etc) and food waste management (including composting, garbage collection, waste management centres)
Goods packaging fillers	• Aggregate and granular fillers for goods packaging • Aggregate fillers for padded envelopes
Garden decoration and landscaping	• Colourful and nutritious granules and pebbles for home garden decoration and landscaping
Compost amendments from food waste	Granular compost amendments incorporating fruit /vegetable/fish/meat/dairy product waste generated by household and commercial food production operations

Figure 3 shows images of selected products containing waste paper/cardboard. Long-term field monitoring and laboratory assessments, using a combination of visual and microscopic observations, leachate analysis and mineralogical determination by X-Ray Diffraction methods have been performed to assess the degradability of various product streams. The results point to the effectiveness of the combined action of physical, geochemical and biological processes (e.g., plant root growth through the walls of the agricultural containers) in degrading and integrating the products in the receiving soils over a 6-12 months of placement in garden or forestry soil.

Figure 3 – Examples of products containing waste paper/cardboard. Viewing from left to right – a partially degraded agricultural container; packaging fillers for a consumer good package; and field trial of soil conditioners.

4 Benefits offered by the proposed technology solution

Aside from the economic and environmental benefits arising from using waste paper/cardboard as part of feedstock material formulations, as described earlier, CtP is potentially and enabling technology for the successful application of the principles of reverse logistics for sustainable management of waste paper/cardboard. Accordingly, this zero waste technology avoids landfilling and incineration of low value voluminous waste paper/cardboard by using it to manufacture products which degrade in soil at the end of their useful life.

Further, the products made from CtP technology incur low lifecycle costs and have functionalities similar or even better than the similar products available in markets thus making products using waste paper/cardboard commercially attractive for investments. Additionally, the technology is scalable and adaptable as an end of pipeline solution; hence, production operations using the technology can be located near industries/population centre where waste paper/cardboard is available in sufficient quantities to achieve the desired economies of scale.

Finally, the sustainability of the technology is further enhanced through use of widely available mineral resources in formulating the binders, utilising conventional mineral and food processing equipment.

5 Conclusions

Review of industry news and views and scientific literature point to a significant progress with Community understanding and industry recognition of the need for product stewardship, as related to plastic and glass waste streams. To some extent, this has been at the expense of a slower progress with addressing the challenge of waste paper/cardboard as indicated by the absence of any sustainable and cost effective solution and as a result the bulk of this major waste stream is still ending up in landfills or incinerated.

Paper/cardboard waste is voluminous, low value and being fibrous has a short recycling loop, therefore managing it in a way to avoid landfilling/incineration requires technology-based innovation that enable zero waste discharge. It is further highlighted herein that other technologies, such as the one exemplified in this paper, need to be developed and market tested before their uptake by industry and governments. A whole community engagement is also needed to support the best fit product stewardship schemes, promote product design thinking and drive the process of active consumer engagement for addressing the challenge of this difficult and largely forgotten waste stream.

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Author's address(es) *like this example:*

Dr Aharon Arakel
Pact Renewables Pty Ltd
P.O. Box 92
Thornleigh, NSW, 2120, Australia
Phone +61 29484 4274
E-Mail info@pactrenewables.com