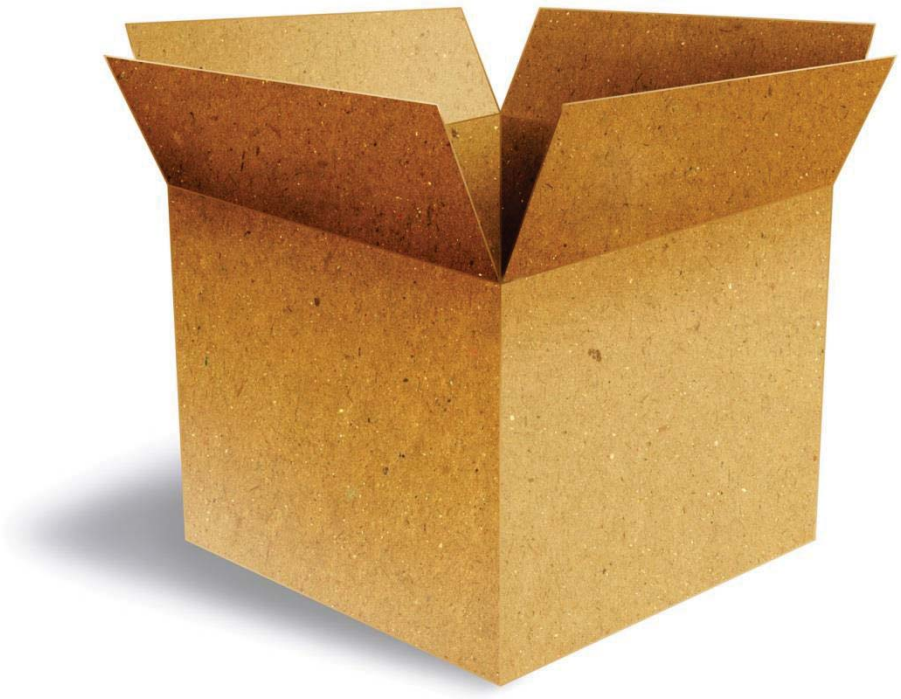
Final Report

Paper and Card Flow 2020



A review of the quantity of paper and card packaging being placed on the market and recycled in 2014 with projections to 2020.

Project code: PMP005-001
Research date: July – November 2015 **Date:** June 2016

WRAP's vision is a world in which resources are used sustainably.

Our mission is to accelerate the move to a sustainable resource-efficient economy through re-inventing how we design, produce and sell products; re-thinking how we use and consume products; and re-defining what is possible through re-use and recycling.

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valpak

Front cover photography: Cardboard Box

Executive Summary

Background

This project was commissioned by WRAP and carried out by Valpak Consulting, with support from the Confederation of Paper Industries (CPI) and a dedicated Steering Group of industry experts. The objective was to review the quantity of paper and card packaging being placed on the market (POM) and recycled in the UK in 2014. The project also projected future POM figures and recycling rates to 2020.

The method to achieve this was primary and secondary research with engagement of the stakeholder Steering Group. The group comprised Defra, the Environment Agency (EA), ACE UK, BPIF Cartons, CPI, DS Smith, Paper and Board Association, Paper Pak, POYRY, Professional Publishers Association, Recycling Association, Valpak, and WRAP.

Project Key Conclusions: POM 2014 and Future Projections

- The project's final best estimate of UK paper and card packaging POM for 2014 is **4,749k tonnes**: an increase of 862k tonnes from the current estimate for 2014 of 3,887k tonnes.
    - This POM figure is the most robust estimate that could be derived, using a variety of the most authoritative data, including industry estimates, Valpak data and publicly available data.
    - 1,966k tonnes of the POM estimate (41%) has a higher degree of uncertainty than the other 59% of the tonnage, based on the availability of data. Details of the confidence level in this data are provided in section 5.2.3.2 and further in Appendix VI.
    - The final POM estimate is corroborated by data from the CPI combined with estimations of empty imported packaging. In addition to this, the Steering Group were supportive of the methodology and data used as being the best available. The project recommends however further composition analysis within the manufacturing sector to increase the robustness of the data. See section 10.3 for more details.
- Non-obligated or unregistered flow for paper and card packaging accounted for 21% of POM in 2014 – higher than for any other packaging material.
- The projected trend between 2014 and 2020 in obligated paper and card packaging POM is zero growth. This does not consider non-obligated flow, which the Steering Group consider could increase, however the project could not identify any data to robustly support this view.

Project Key Conclusions: Recycling 2014 and Future Projections

- Using the new POM figure of 4,749k tonnes, the UK achieved a 73% recycling rate in 2014 with 3,470k tonnes of paper and card packaging being recycled by accredited reprocessors or exported.
- There was an estimated 367k tonnes of unaccredited paper and card packaging reprocessing in 2014 (10% of total recycling).
- Auto regression projects the recycling rate could rise to 82% by 2020 (if there had been no protocol EN023 update), but applying the revised EA Protocol EN023, updated prior to publication of this report and applicable from 2016, suggests the

recycling rate could rise to 85%[1], although stakeholders predict some tapering off by 2020.

- All scenarios (tapered and auto regression), with and without the amendment to EA protocol being applied, are projected to exceed the Directive 94/62/EC[2] target (60%) currently in place up to 2020 for paper and card packaging.

Project Recommendations

- EA Protocol EN023 for mixed paper and card requires updating. This protocol dates back to 1998 and stated 12.5% of mixed paper and card is packaging, but the market has changed considerably since then and more packaging is now present in the waste stream. . At the time of this analysis the regulators had agreed an interim change to 23% (from 12.5%) with effect from 1st January 2016. Guidance from the Steering Group suggests this is still too low and a further review is recommended.
- Further surveying of manufacturing waste to establish the manufacturing packaging: non-packaging ratio is required. This was identified by the project as a particular area of data uncertainty.
- A large proportion (21%) of paper and card packaging was identified as not being declared under the Packaging Regulations, a review of elements of the Regulations is required to capture more non-obligated or unregistered tonnage. Section 10.3 of this report provides further details.
- If all reprocessors became accredited for recycling activities, this could have increased the number of PRNs/PERNs generated for recycling by up to 367k tonnes in 2014.
- Further work is needed to enhance packaging waste data exchange with industry and policy makers, and develop novel tools, to reduce uncertainty in packaging waste tonnage estimates and better streamline flow methodologies.

Data Sources

The amount of paper and card packaging POM was calculated using the following methods and data sources:

- Consumer: Packaging used in the consumer sector was estimated using retail sector sales data and packaging usage.
- Non-consumer: Packaging used in the non-consumer sector was determined from data from a number of sources, including surveys of retail back of store, published reports and protocols.

Data Uncertainties and Appropriate Confidence in Estimates

The data presented in this report intends to represent the best estimate possible, given the available data. However, owing to uncertainties inherent in many of the data sources and assumptions used, it is important to caveat the robustness of the estimates. Appendix III includes an assessment of the uncertainty and robustness of the estimates.

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[1] *See section 7.2.1 for details*

[2] *European Parliament and Council Directive 94/62/EC of 20 December 1994 on packaging and packaging waste: http://eur-lex.europa.eu/legal-content/EN/ALL/?uri=celex:31994L0062 - note there have been a number of amendments to the Directive. Directive 2004/12/EC of the European Parliament and of the Council of 11 February 2004 added a number of targets, including the 60% target mentioned here. A consolidated version of the Directive can be found using the link in this footnote*

Contents

Figures

Glossary

CA – Civic amenity
C&I – Commercial and Industrial
CPI – Confederation of Paper Industries
C&D – Construction and demolition
EA – Environment Agency
EfW – Energy from Waste
EPIC – Environmental Product Information Centre
GDP – Gross Domestic Product
HWRC – Household waste recycling centre
k – Thousand
kt – Thousand tonnes
LA – Local authority
NPWD – National Packaging Waste Database
POM – Placed on the market
Primary Packaging – Any packaging that the customer will take home, remove and throw away e.g. aluminium can, plastic bottle
PRN – Packaging Recovery Note
PERN – Packaging Export Recovery Note
RDF – Refuse Derived Fuel
RTP – Returnable Transit Packaging
Secondary Packaging – Inner packaging used to transport or display goods to/in store, usually cardboard boxes or shelf-ready packaging
SEPA – Scottish Environment Protection Agency
Transit/Tertiary Packaging – Any transit packaging e.g. pallets, shrink wrap, staples or strapping
WDF – Waste Data Flow

Acknowledgements

Valpak Limited and WRAP would like to thank the following organisations for their contribution to the Paper and Card Flow 2020 project:

- ACE UK;
- Advisory Committee on Packaging (ACP)
- BPIF Cartons;
- Confederation of Paper Industries;
- DS Smith;
- Environment Agency;
- Paper and Board Association;
- Paper Pak;
- POYRY;
- Professional Publishers Association; and
- Recycling Association.

1.0 Introduction

1.1 Background and Existing Data

It is important to ensure that the estimates being used by Defra for its packaging policy work are as accurate as possible. To support Defra, this report focuses on reviewing the estimates of UK paper and card packaging POM[3] and the associated compliance implications. Accurate and robust assessments of current and future UK paper and card packaging flows are vital to help inform the setting of UK business targets and also the UK negotiating position in the acceptance of any possible future targets. The devolved administrations of Scotland, Wales and Northern Ireland are also interested in the outcome of this research.

The existing Defra estimate for 2014 is 3,887k tonnes of paper and card packaging POM. The PackFlow[4] project and industry assessment formed the basis for this estimate in 2008. PackFlow derived estimates of the growth in paper and card packaging (and other packaging materials) from a variety of quantitative and qualitative sources including dialogue with key stakeholders. The objective of Paper and Card Flow 2020 is to provide an updated baseline estimate of paper and card packaging POM and recycled/recovered.

1.2 Project Objectives

Paper and Card Flow 2020 had the following key objectives:

- Undertake a critical review of methodologies used in the previous three flow reports, Glass Flow[5], Plastic Flow[6] and Metal Flow[7] in order to develop a 'best in class' method for use for any packaging material, including paper and card packaging;
- Assemble a steering group to provide expertise and insights, and guide the project;
- Estimate the amount of paper and card packaging POM and recycled/recovered by format and stream for 2014;
- Project POM and recycling rates to 2020;
- Quantify the amount of paper and card packaging recycled but not PRNd/PERNd (unaccredited recycling);
- Assess potential compliance to 2017/20 with Packaging Regulation targets; and
- Produce a final report and slide set detailing the project findings and assumptions.

2.0 Flow Project Methodology Review

2.1 Rationale

Each of the flow projects undertaken by Valpak and WRAP has considered a number of methodologies in order to determine the most suitable to be used to assess the amount of material POM, these include;

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[3] *Paper and card packaging POM means all household and non-household paper and card packaging used around products within the UK.*

[4] *http://www.valpak.co.uk/Libraries/Environmental_Consulting_Documents/PackFlow_2017_Final_Report_09_11_12.sflb.ashx*

[5] *http://www.wrap.org.uk/content/glassflow-2012-report-0*

[6] *http://www.wrap.org.uk/content/plastic-packaging-market-study-plastic-flow-2014-0*

[7] *http://www.wrap.org.uk/content/metal-packaging-market-study-metal-flow-2014*

- Bottom up approach – estimating the POM by sector, such as grocery retail (using Valpak Environmental Product Information Centre [EPIC] data[8]), wider retail, commercial & industrial, construction & demolition, agricultural and other key sectors using published secondary sources;
- Net Pack Fill – uses data from the National Packaging Waste Database (NPWD) to calculate the obligated tonnage POM. This is then added to an estimate of the unobligated/free-rider tonnage; and
- Top down approach – using UK Trade Info data and other statistics from trade associations.

Additionally, Valpak and WRAP have used separate methodologies and datasets to assess recycling levels for each material, such as Waste Data Flow (WDF), NPWD, published waste composition reports, Valpak surveys and those conducted by trade associations as part of the projects, and Valpak internal data.

Due to the varying approaches used and in particular the Government's desire to have one 'best in class' methodology that can be used for any packaging material and updated annually, the project commenced with a review of each of these methodologies to consider the advantages and disadvantages of each.

2.2 Methodology

Adrian Hawkes, Policy Director at Valpak, undertook the critical review of the methodologies used in Glass Flow, Plastic Flow and Metal Flow to identify the advantages and disadvantages of each and propose a 'best in class' approach.

2.3 Best in class approach

The detailed review of each method can be found in Appendix I of this report, which provides the advantages and disadvantages of each methodology. The review's recommendations have informed the following 'best in class' method statement for packaging flow and recycling calculations.

2.3.1 Method Statement: POM

A: Adopt the following Net Pack Fill formula using data reported on the NPWD to calculate the tonnage of obligated packaging POM. Elements of this calculation should be cross-checked or replaced by producer data, where more comprehensive estimates are available[9], for example from Trade Associations.

Net Pack Fill	=	**Packing/Filling** table 1 - pack/filling	+	**Imports** table 3A - imported for the purpose of selling	+	**Imports** table 3B - packaging removed from around imports	-	**Exports** table 2A + table 2B – pack/filling

[8] *EPIC is Valpak's database of packaging weights, covering over 800,000 products, predominately relating to the grocery sector.*
[9] *For example where they include both obligated and non-obligated production data*

B: Make an assessment of the proportion of non-obligated tonnage of packaging POM and add this as a percentage to the tonnage calculated in step A. This can be calculated using one of the following methods:
- Production data and industry data-based estimates;
- Primary research including sampling or comparisons with schemes in other countries which have no or a much lower de-minimis. Once cost and scope of this work is determined consider whether feasible to carry this out and how it could be funded.

C: All data should then be cross-checked with other available sources. These can also be used to provide estimates of stream and format splits where required, although actual data reporting on NPWD will be necessary to do this more accurately. Sources that may be available include:
- Valpak EPIC data relating to grocery packaging sales;
- Valpak compliance data relating to non-grocery retail sales;
- Published reports; and
- Trade association and expert knowledge or data.

2.3.2 Method Statement: Recycling

A: Use NPWD total recycled figures for an accredited recycling tonnage (PRNs and PERNs generated).

B: Add an estimate of unaccredited recycling to the tonnage calculated in step A. This should be estimated annually due to the variations in the PRN market. This can be calculated using one of the following methods:
- Use of PRN prices and accreditation costs to assess an economic cut-off for registration combine with market knowledge of reprocessors not raising PRNs/PERNs to estimate the tonnage that may be recycled with no PRN/PERN raised.

C: Assess the benefits of carrying out a reprocessor/exporter survey across all materials (see AluPro[10]). This would involve contacting all reprocessors/exporters not accredited to raise PRNs/PERNs and understanding the tonnages they handle[11]. All data should then be cross-checked with other available sources to check whether it improves the overall confidence in the reprocessing estimate. These can also be used to estimate stream and format splits where required. Sources that may be available include:
- Local Authority collection data, such as Waste Data Flow (WDF)12;
- Published reports;
- Valpak data on back of store collections at supermarkets; and
- Trade Association and expert knowledge or data.

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[10] http://www.packagingnews.co.uk/news/environment/alupro-study-reveals-additional-uk-recycling-rate-18-04-2016

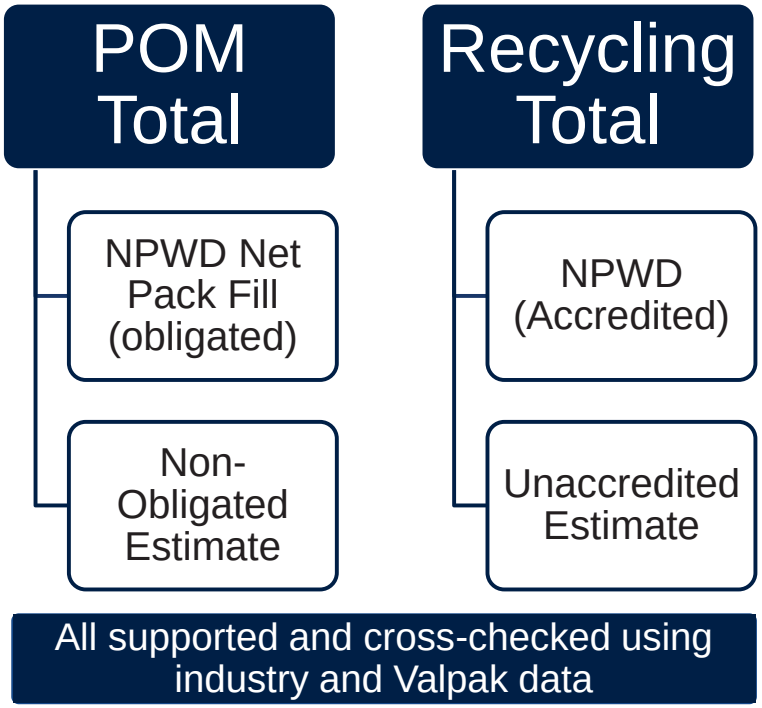
[11] This has not been done as part of this work.

[12] WDF data is generally deemed to report tonnage of materials collected for recycling, however due to contamination not all of the materials collected will necessarily be recycled. However, in the absence of other data this is the only source available. If possible, it should be reviewed and scaled down to reflect tonnages that were actually recycled/reprocessed rather than collected. This is the case for Plastics, where a separate annual survey is conducted by Recoup.

2.3.3 Methodology: Overview

An overview of the proposed 'best in class' methodology is provided in the diagram below.

Figure 1 'Best in Class' Method Overview



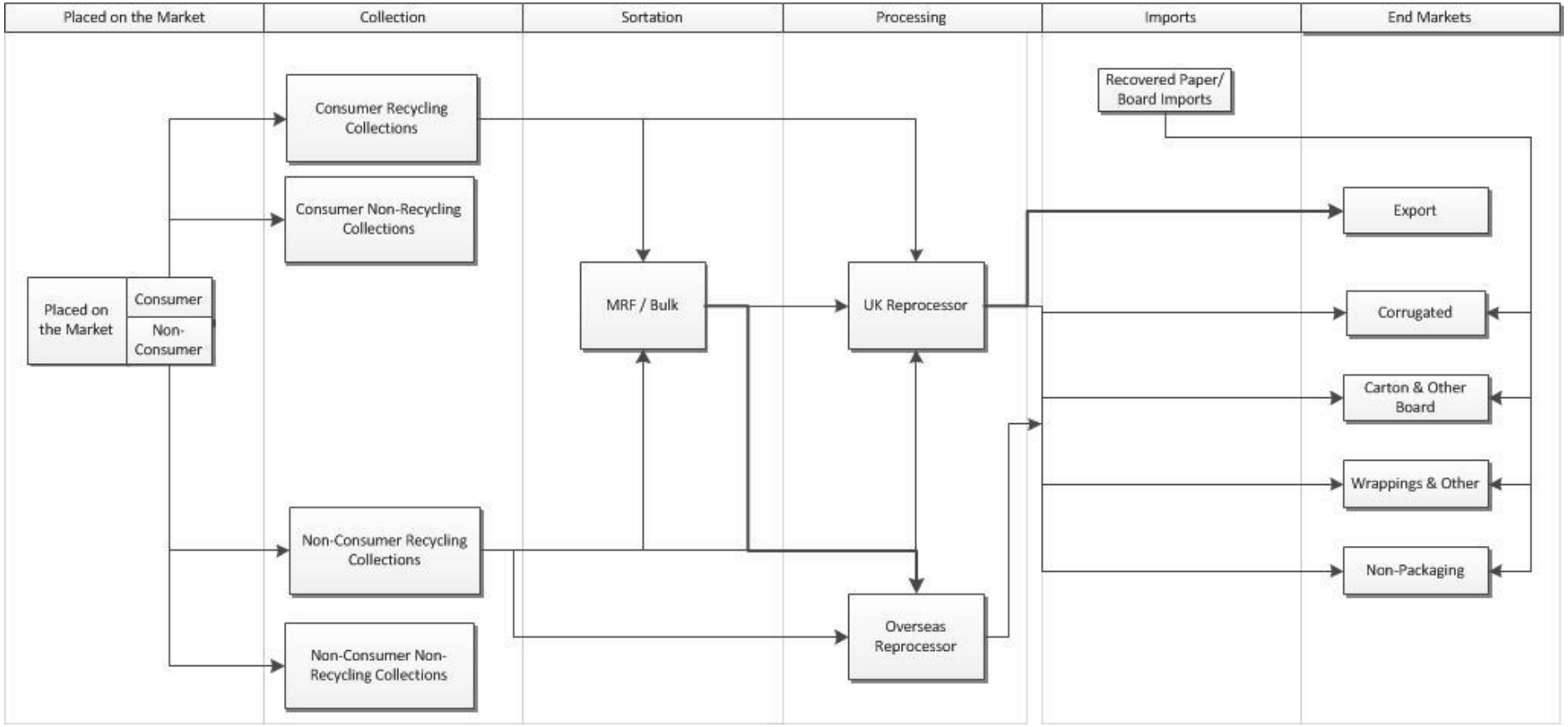
3.0 Paper and Card Packaging Supply Chain

This section of the report provides an overview of how paper and card packaging flows on and off the UK market through consumption, collection, sorting and reprocessing to final end market destinations. This section is important in setting the scene for the development of the paper and card packaging flow model and outlines the structure used.

3.1 Supply Chain Map

A map of the paper and card packaging supply chain is provided in **Error! Reference source not found.**. This is accompanied by a summary of each of the key formats and streams used within this report.

Figure 2 Paper and Card Packaging Supply Chain Map[13]



[13] *Each stage is explained in the following sections.*

3.2 Placed on the Market (POM)

POM refers to the flow of new paper and card packaging onto the UK market. Consumption of goods using paper and card as packaging can occur both in the consumer (in the home and on the move) and non-consumer (by business) streams.

Paper and card packaging typically enters the market in the following formats, which have been adopted for the purposes of this report;

- Corrugated board – used widely as secondary packaging and include Kraftliner and test liners. They are made by a conversion process in which three layers of paper (or paperboard) are corrugated during the process and the outer layers (liners) are glued to the peaks[14].
- Carton and other board – used as solid board cases and graphic board. Generally scores, folds, bends without splitting and has good printability. Widely used for food packaging, pharmaceuticals and other end-uses requiring a high quality, fast running print.
- Liquid beverage cartons – often called beverage cartons or Tetrapak (although other brands exist), these multi-layered cartons generally include paper, plastic and aluminium but tend to be categorised as paper and card due to this being the principal material by weight[15]. They are widely used to package fresh food and drinks, as cups, and increasingly used in the ambient aisle.[16]
- Other – all other forms of paper and card packaging such as wrappings, paper, shredded paper fillers and mouldings.

3.3 Collection

The next stage in the supply chain once waste paper and card packaging is generated is its collection. When waste paper and card packaging is generated, it is either collected within the general waste stream and sent for disposal (typically landfill or Refuse Derived Fuel [RDF]) or is collected for recycling, which is the key focus of this study.

3.4 Materials Recovery Facility (MRF)/Bulking Facility

One of the next steps in the supply chain following the collection of waste paper and card packaging is the MRF/bulking stage.

At a MRF/bulking facility, paper and card is typically sorted from other recyclate materials such as plastics and metals (if collected co-mingled), and then stored and

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[14] CPI 2014: Descriptions of Paper and Board Fact Sheet: http://www.paper.org.uk/information/factsheets/descriptions.pdf

[15] The EA definitions of composite and multi-layered packaging are defined in, the 'Agreed position and technical interpretations – producer responsibility for packaging '. Composite packaging is: 'multi-layered sheets of dissimilar materials which are bonded together and cannot be separated by hand', such as laminated paperboard, whereas multi-material packaging is: 'packages constructed of assembled components of different material', such as a blister pack made from cardboard and plastic and can be separated by hand. Within the technical interpretations guidance, the packaging weight for laminate packaging 'should be recorded under the predominant material by weight', compared to multi-material packaging weights, which should be recorded separately, by the different component materials.

[16] Ambient (shelf-stable) food can be safely stored at room temperature in a sealed container. This includes foods that would normally be stored refrigerated but which have been processed so that they can be stored at room temperature.

bulked until a sufficient quantity is achieved, at which point it will be transported to the next stage. If collected separately then no further sorting may be necessary and it is bulked ready for transporting.

The vast majority of Commercial & Industrial (C&I) paper and card waste is collected by paper merchants.

Once the paper and card leaves this stage of the supply chain it is typically sent to a paper and card recycler/reprocessor for rocessing or will be sent direct to export.

3.5 Sorting

This stage represents the reprocessing of paper and card packaging, where it is subject to a variety of processes including sorting and baling in order for it to be used as recycled content for further packaging or other uses.

3.6 Imports

A small quantity of waste paper and card packaging is believed to be imported into the UK for reprocessing. In this case a PRN should not be raised on the material as it is not UK waste.

3.7 End Markets

At the reprocessor, the paper and card packaging can either be processed into a product that can be directly used as recycled content or it can be exported outside of the UK for reprocessing. Alternatively it will be sent to RDF.

4.0 Paper and Card Packaging POM: Net Pack Fill

This section of the report is a review of the total paper and card packaging POM in the UK in 2014, based on the data stored on NPWD, as reported to the EA by obligated organisations.

The 2014 UK flow of paper and card packaging was calculated using the packaging weights reported to the EA by registered producers and publicly available on the NPWD website[17]. The calculation used is shown below:

Net Pack Fill	=	**Packing/Filling** table 1 - pack/filling	+	**Imports** table 3A - imported for the purpose of selling	+	**Imports** table 3B - packaging removed from around imports	-	**Exports** table 2A + table 2B – pack/filling

This methodology takes the weight reported at the *packing* stage of the supply chain as opposed to the *selling* stage of the supply chain. This was used as it is believed by

[17] https://npwd.environment-agency.gov.uk/

stakeholders[18] that there would be fewer unobligated packers in comparison to unobligated sellers, due to the likely size of the businesses. In addition raw material manufacturing include process losses, i.e. not everything manufactured will be converted or pack/filled. Using this method, the total obligated paper and card packaging tonnage in 2014 is **3,747k tonnes** (as shown in Figure 3).[19]

Figure 3 Net Pack Fill Results 2014

	Paper and Card
Table 1 Pack/Fill (UK pack/filling)	2,369kt
Imports	
3A Selling (filled imports)	1,240kt
3B (packaging removed from imports)	566kt
Total	**4,175kt**
2A P/F (direct exports)	410kt
2B P/F (third party exports)	18kt
Total Exported	**428kt**
Net Pack/Fill	**3,747kt**

This method does not account for paper and card packaging that is non-obligated or handled by unregistered producers, which is likely to include the following:

- Non-obligated producers – those below the registration thresholds of 50 tonnes of packaging or £2 million turnover per annum;
- Internal use packaging;
- Those obligated to register but not doing so (such as free riders); and
- Illegal importers.[20]

Estimating the amount of paper and card that is not obligated under the regulations was deemed to be very difficult by the stakeholders involved in the project. It is anticipated that it could be a significant volume, particularly relating to imported goods by mainly smaller and medium sized businesses. However, as this could not be quantified, further estimates of the paper and card packaging POM were assessed using other sources, as detailed in the following sections.

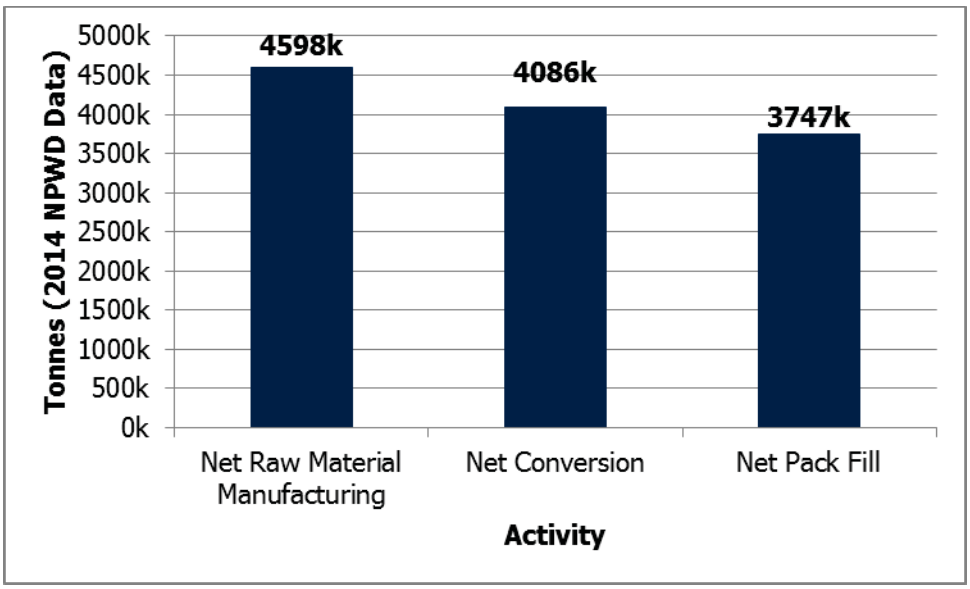
4.1 Data Verification

In order to confirm levels of confidence in the net pack fill calculations, checks were made using the data within the producer packaging data tables in the NPWD. The net calculation was applied to other activity lines of the tables: raw material manufacturing and conversion, in addition to pack/filling[21]. The aim was to sense check the results of

[18] *No data is available to support this.*
[19] *Accurate at the time of reporting (5th November 2015). Resubmissions can occur up to December 2015 (for 2014 sales data) and therefore a final figure will not be available until early 2016. However based on previous years' experiences it is unlikely this figure will vary significantly (typically +/- 5%).*
[20] *Those importing goods illegally*
[21] *See appendix II for further details on activity lines.*

applying the calculation to the other activities performed by companies. The results are shown in Figure 4.

Figure 4 'Net' Producer Data Table Calculations 2014[22]



Appendix III provides a detailed assessment of relative levels of confidence in the data.

5.0 Paper and Card Packaging POM: Industry and Other Data

As noted above, it was not possible for a non-obligated and unregistered paper and card packaging estimate to be generated given the limited amount of data. As a result, in order to estimate a total tonnage of paper and card packaging POM the flow was split into different elements in order to attempt to build a picture from the bottom up. The key elements were as follows:

- Consumer
- Non-consumer
  - Agricultural
  - Construction and Demolition (C&D)
  - Commercial and Industrial (C&I)
    - Hospitality
    - Retail
    - Manufacturing

It should be noted that packaging is considered paper and card if paper and card is the predominant material by weight in a composite.[23]

[22] *As reported on 5th November 2015.*

[23] *The EA definitions of composite and multi-layered packaging are defined in, the 'Agreed position and technical interpretations – producer responsibility for packaging[23]'. Composite packaging is: 'multi-layered sheets of dissimilar materials which are bonded together and cannot be separated by hand', such as laminated paperboard, whereas multi-material packaging is: 'packages constructed of assembled components of different material', such as a blister pack made from cardboard and plastic and can be separated by hand. Within the technical interpretations guidance, the packaging weight for laminate packaging 'should be*

5.1 Consumer

5.1.1 Grocery Retail

In order to estimate the amount of packaging POM by the grocery retail market, Valpak's EPIC database[24] was used to provide data on annual sales and packaging weights for all relevant products packaged in paper and card. This was taken from a selection of Valpak's supermarket clients representing a cross-section of grocery retailers in the UK. Using volume market share information from Kantar World Panel (not publicly available) for these supermarkets, which represented 53.1% of the grocery retail market by volume for 2014[25], the resulting quantity of paper and card packaging was scaled up to provide an estimate for the UK grocery retail market. An assumption has been made therefore that the paper and card packaging profile of the supermarkets for which data was available is representative of those not included. It is the opinion of the project team that packaging is similar in those supermarkets that are not included in this dataset. Based on brand advertising by low-cost supermarkets, we have assumed that the only difference between them and traditional supermarkets are in product pricing, there is nothing to suggest that product and therefore products packaging varies between them. This suggests no format switching for products[26]. The paper and card packaging in the grocery retail sector was estimated to be **578k tonnes in 2014**.

This estimate was cross referenced with aggregated EA data to check the validity of the EPIC data for grocery retail. The data provided by the EA was 2014 paper and card quantities reported in table 1 selling from NPWD for all the major grocery retailers[27]. Details of this are provided in Appendix IV. This shows that there is a 12% difference between the EA and EPIC data[28]; however, as the project team was able to view Valpak-held data and interrogate it on a product level[29], for the purpose of grocery sector analysis this was selected for use.[30]

Appendix III provides a detailed assessment of relative levels of confidence in the data.

5.1.2 Total Retail (Including Non-grocery)

To scale up the grocery retail result to represent total UK retail, including non-grocery retail, retail sales data as reported by the Office of National Statistics (ONS) for 2014 was

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recorded under the predominant material by weight', compared to multi-material packaging weights, which should be recorded separately, by the different component materials.

[24] The database is based on information collected direct from suppliers as well as information sourced internally, meaning that it holds a wide coverage of information across multiple product ranges. Product specific data collection is completed through site visits, supplier mailings and weighing in-house (purchasing product and collecting used product from staff). All data goes through a comprehensive checking process on receipt and is stored in Valpak's bespoke software Environmental Product Information Centre (EPIC). Over 800,000 supermarket products are recorded in EPIC.

[25] A sample of over 50% is very robust statistically

[26] No other information was made available to the project team

[27] The figure does not include free-riders or non-obligated producers.

[28] EA estimate being higher

[29] Due to increased granularity and visibility, as well as the known inclusion of non-grocery items sold by grocery retailers in the data reported to the EA.

[30] NPWD is the only place where all reported obligated producer data can be viewed, so when looking at the UK in its entirety NPWD can be used. In the case of consumer data, it is possible for Valpak to see specific customers' product and sales data, and scale up using market share, therefore Valpak held data is used.

used. This shows that the proportion of grocery spend of total UK retail spend was 45.5% in 2014.[31]

However, simply scaling up on the basis of market share was not considered robust, since it was likely that packaging usage within both sub-sectors differed. Therefore, paper and card packaging used by the grocery sector and other retail sectors was analysed using data reported by Valpak's membership[32]. Analysis involved the following key stages:

- Identification of grocery and non-grocery retail members;
- Gathering of company reported data and information; and
- Calculation of paper and card packaging tonnage per billion pound turnover for grocery and non-grocery retailers representing 17% of reported obligated tonnage of paper and card packaging in 2014 (across all producers).[33]

The method used assumes the packaging profile of those retailers within the sample is representative of those not in the sample.

Therefore, the following steps were taken to estimate total retail paper and card packaging consumption in the consumer (retail) sector in 2014:

- Total grocery paper and card packaging flow was 578k tonnes (see section 5.1.1);
- Proportion of grocery spend of total retail spend in the UK was 45.5% in 2014[34];
- Total retail paper and card packaging flow, assuming like for like packaging was 1,270k tonnes;
- Non-grocery paper and card packaging tonnes/£bn turnover is 122% of grocery paper and card packaging tonnes/£bn turnover[35]; and
- Therefore, applying 122% to the difference in tonnage between grocery (578k tonnes) and total retail (1,270k tonnes) means total retail paper and card packaging flow in 2014 was **1,423k tonnes**.

To allow for a targeted approach when analysing implications of flow on recycling, the breakdown of this estimate into formats of corrugated, carton and other board, liquid beverage cartons and other packaging was derived by analysing data within the Valpak EPIC database for grocery and non-grocery retailers, as provided in Figure 5.

[31] *http://www.ons.gov.uk/ons/publications/re-reference-tables.html?edition=tcm%3A77-324908*

[32] *Valpak membership represents approximately 46% of all obligated companies, by obligation. The entire NPWD database was considered for analysis; however, for confidentiality reasons it was not possible to gain access to NPWD to conduct the same analysis on the complete dataset.*

[33] *Assuming this is a random sample, the sample size allows 99% confidence that it represents the population as a whole with an error margin of 0.16%. However the population is of obligated producers only, therefore a further assumption is made that non-obligated companies see the same difference, since no packaging data is available to cover them.*

[34] *http://www.ons.gov.uk/ons/publications/re-reference-tables.html?edition=tcm%3A77-324908*

[35] *Appendix V provides results of sensitivity analysis on this result. The result was deemed reasonable by stakeholders.*

Figure 5 Grocery and Non-Grocery Consumer Packaging by Format[36]

	Grocery Proportion	Non-Grocery Proportion	Total Retail
Retail Corrugated	4%	46.5%	418kt
Retail Carton and Other Board	74%	41.5%	779kt
Retail Liquid Beverage Cartons	8%	0%	48kt
Retail Other	14%	12%	178kt

Appendix III provides a detailed assessment of relative levels of confidence in the data.

5.2 Non-consumer

In order to avoid duplication between consumer and non-consumer packaging, i.e. including packaging within the non-consumer sector that has already been included in the consumer sector, waste production is assessed in the bottom-up method[37] for the non-consumer sector.

The non-consumer sector is broken down into sub-sectors:

- C&D;
- Agricultural; and
- C&I.

5.2.1 Construction & Demolition

To quantify paper and card packaging consumption within the construction industry, secondary data was used.

Research commissioned by the Green Construction Board[38] (GCB) estimates that 289k tonnes of packaging (all materials) arose in the UK construction sector in 2009.

To estimate the paper and card proportion, a WRAP report[39], was used. This study audited the waste produced by 25 construction sites for a one week period, and concluded that the average amount per week of packaging waste produced was 5.27 tonnes; 1.3 tonnes of this was paper and card packaging. This suggests that 25% of packaging waste produced in the sector is paper and card.

Applying 25% to the GCB's estimate of 289k tonnes, suggests that **71k tonnes** of paper and card packaging waste was generated in the construction sector in 2009.[40]

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[36] *Based on data held in Valpak's EPIC database relating to grocery and non-grocery primary packaging. It should be noted that the Steering Group did identify that the non-grocery tonnage of corrugated may be too low and carton board too high. However, no further data could be provided to verify this and the final overall splits by format for POM were accepted by the Group.*

[37] *It is assumed that waste production is equal to POM in this case. An example would be where retailer sales is included within consumer but retail back of store waste within the non-consumer sector.*

[38] *Unpublished data provided by WRAP*

[39] *http://www2.wrap.org.uk/downloads/ConstructionSitePackagingWaste.250ebeab.1592.pdf - Establish Tonnages, and Cost Effectiveness of Collection, of Construction Site Packaging Waste, 2005 - latest available data. It is not believed by the project team that packaging usage in the industry has changed significantly over the last 10 years.*

[40] *Due to there being a low confidence in the correct metric to use to scale to 2014 this has not been done.*

Appendix III provides a detailed assessment of relative levels of confidence in the data.

5.2.2 Agricultural

For paper and card packaging in the agricultural sector, the EA's Agricultural Waste Survey from 2003 was used[41]. The total paper and card packaging reported by the EA was **10k tonnes[42].** Unfortunately no comparative representative estimates were available to cross-check this tonnage.

Appendix III provides a detailed assessment of relative levels of confidence in the data.

5.2.3 Commercial & Industrial

For the purposes of this work, the commercial and industrial sectors were broken down into three key sub-sectors:

- Hospitality;
- Manufacturing and other; and
- Retail back of store.

5.2.3.1 Hospitality

Hospitality paper and card packaging is that which is 'household-type', but includes both primary and secondary packaging that is consumed in pubs, cafés, hospitals etc. It is generally similar in type as that consumed at home, but may not be collected by a local authority for recycling or disposal, and may include some non-household type packaging such as large boxes.

Estimates for the quantity of paper and card packaging POM by the hospitality sector were derived from sales and packaging data for the cash and carry industry[43]. Market share information for the companies included in the sample was used to scale up the tonnage to represent the whole of UK cash and carry, resulting in a tonnage of ~45k tonnes.

This was used alongside estimates from the Institute of Grocery Distribution (IGD[44]); the IGD categorises the wholesale sector into three sub-sectors[45]:

- Cash and carry wholesalers;
- Delivered grocery wholesalers; and
- Delivered foodservice wholesalers.

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[41] *Agricultural Waste Survey 2003, Environment Agency. This is the most recent data relating to paper and card packaging in the agricultural sector.*

[42] *Due to lack of data on light-weighting in the sector and low confidence in the correct metric to use to scale to 2014 (e.g. GVA vs farm output tonnage) this has not been done,*

[43] *Valpak's EPIC database holds sales data and packaging weights information for clients signed up for the fully managed service*

[44] *http://www.igd.com/*

[45] *http://www.igd.com/Research/Retail/Wholesaling-and-foodservice/4114/UK-Wholesale-Market-Overview/*

Since delivered grocery wholesalers' products go to retailers and are therefore captured in section 5.2.3.3, cash and carry wholesalers and delivered foodservice wholesalers were the focus of this section. The IGD stated that in 2011 cash and carry accounted for 42% of the three sub-sectors and 'delivered foodservice' 24%[46]; therefore by excluding 'delivered grocery wholesalers', cash and carry accounts for 64% of the remaining two sub-sectors[47]. Using this proportion and the total tonnage for cash and carry for the UK of ~45k tonnes means a total tonnage estimate for the sector of **~70k tonnes**.

Appendix III provides a detailed assessment of relative levels of confidence in the data.

5.2.3.2 Manufacturing & Other

The last large scale project that aimed to estimate the volume of waste within the manufacturing sector was the C&I Waste Survey in 2009[48]. There are limitations to this data because it is based on 2009 statistics and only includes an analysis of the C&I sector in England. It also includes non-packaging streams and as such requires assumptions to be applied to the data in order to provide an estimate of packaging tonnages. However as this is the best and most recent dataset available to the project team it has not been possible to cross-check the results with any other sources.

The following sub-sectors were used in the survey:

- Food, drink & tobacco;
- Textiles/wood/paper/publishing;
- Power and utilities;
- Chemicals/non-metallic minerals manufacturing;
- Metals manufacturing;
- Machinery & equipment (other manufacturing);
- Retail and wholesale[49];
- Transport & storage; and
- Other services e.g. publishing activities, programming and broadcasting activities.

Work completed for the Chartered Institution of Wastes Management (CIWM) in 2013: "Commercial and Industrial Waste in the UK and Republic of Ireland"[50], highlights that C&I waste arisings equate to 82% of the overall waste arisings in the UK for this sector. This proportion was used to scale up the survey's data relating to England only to represent the UK[51].

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[46] http://www.igd.com/Research/Retail/Wholesaling-and-foodservice/4114/UK-Wholesale-Market-Overview/

[47] *Cash and carry wholesalers and delivered foodservice wholesalers*

[48] http://archive.defra.gov.uk/evidence/statistics/environment/waste/documents/commercial-industrial-waste101216.pdf

[49] *As retail is covered separately in section 5.2.3.3 Retailer Back of Store, this element of the Retail and Wholesale sector needed to be excluded within the manufacturing tonnage. This was carried out by assuming that the retail sector represents 60% of the tonnage handled, leaving 40% of the tonnage within the estimate to represent the Wholesale sector. This split was based on economic output data from The Retail Industry: Statistics and Policy Briefing Document 2015 (House of Commons), available here* http://researchbriefings.files.parliament.uk/documents/SN06186/SN06186.pdf

[50] http://www.ricardo-aea.com/cms/commercial-and-industrial-waste-arisings-management-and-capacity-gaps/

[51] *As no other data is available specific to other areas of the UK*

Finally the data included both packaging and non-packaging paper and card. As no EA protocol exists for non-consumer paper and card waste only[52] data from two composition analyses were taken. Primarily, a quality assessment undertaken by WRAP[53] was used to estimate how much of the sector's paper and card waste was packaging. This indicates that approximately 27% of this waste is packaging. It should be noted that this study is 13 years old therefore this percentage could be different by now, however this was the best available data at the time of analysis

This was used for all sub-sectors apart from Wholesale and Transport and Storage. For these two sectors, composition analysis relating to the motor, retail and wholesale sector[54] was used to estimate how much of the manufacturing sector's paper and card waste was packaging. This indicates that approximately 40% of this waste is packaging[55].

Therefore, it is estimated that the quantity of paper and card packaging POM from the manufacturing sector was **1,966k tonnes** in 2014 as shown in Figure 6. This assumes that C&I paper and card waste arisings stood at a broadly similar level to waste arisings in 2009, when the survey was conducted. No comparative representative estimates were available to cross-check this tonnage for 2014. As this makes up almost half of the overall POM, the project recommends waste composition analysis in the manufacturing sector to increase the availability and robustness of data for the sector.

Figure 6 Manufacturing Sector Non-Consumer Paper and Card Packaging

Business Sector	England Paper and Card Waste (k tonnes)	England Paper and Card Packaging Waste (k tonnes)	UK Paper and Card Packaging (k tonnes)
Food, drink & tobacco *(Pkg 27%)*	182	49	60
Textiles / wood / paper / publishing *(Pkg 27%)*	1,369	370	451
Power & utilities *(Pkg 27%)*	10	3	3
Chemicals / non-metallic minerals manufacture *(Pkg 27%)*	155	42	51
Metal manufacturing *(Pkg 27%)*	50	13	16
Machinery & equipment (other manufacture) *(Pkg 27%)*	225	61	74
Wholesale *(Pkg 40%)*	1,218	487	594
Transport & Storage *(Pkg 40%)*	477	191	233
Other Services *(Pkg 27%)*	1,471	396	483
Total	**5,158**	**1,612**	**1,966**

The caveats around the use of the C&I survey and around the additional assumptions needed to draw specific paper and card packaging estimates, together with the lack of

[52] The EA's protocol around paper and card packaging relates to both consumer and non-consumer waste and indicates that 12.5% of mixed paper and card should be packaging (although the steering group believe this is too low and are currently sampling to provide an updated protocol). However, as most 'mixed paper and card' waste comes from the consumer stream it was deemed too low for use when applying specially to the non-consumer stream.

[53] WRAP 2003: Assessment of Quality Arising from Existing Paper Collection Methods against European Recovered Paper Grades listed in BS EN 643

[54] http://www.wrap.org.uk/sites/files/wrap/The%20compostion%20of%20waste%20from%20three%20sectors%20in%20Scotland.pdf

[55] The value of 40% being packaging was provided with confidence intervals in the original study and as such sensitivity analysis around these values has been undertaken in Appendix VI. No other data is available that could be used to check that using this composition analysis is valid for the entire sector.

data available for meaningful sense-checks, suggest some concern over the robustness of this estimate. This is worth noting as the manufacturing estimate forms a significant proportion of the total paper and card POM[56]. See Appendix III for a more detailed assessment of relative levels of confidence in the data.

5.2.3.3 Retailer Back of Store

The quantity of paper and card packaging discarded by grocery and non-grocery retailers at back of store was derived from Valpak surveying retailers, as part of this project, covering over 47% of the market, during June-July 2015. Data was scaled up to UK level using market share information, provided by Kantar World Panel data. The final figure for retail back of store was **1,209k tonnes** of paper and card packaging.

Appendix III provides a detailed assessment of relative levels of confidence in the data.

5.2.4 Non-Consumer Waste by Format

Based on data available relating to secondary and transit packaging in Valpak's EPIC database[57] and that published relating to the hospitality waste in WRAP report 'Waste in the UK Hospitality and Food Service Sector, 2011[58]', it was possible to assess the breakdown of the non-consumer paper and card POM estimate into formats of corrugated, carton and other board, liquid beverage cartons and other packaging. This identified 89% of non-consumer waste as corrugated, 4% as carton and other board, a negligible proportion as liquid beverage cartons and 6% as other packaging.

[56] *See Appendix VI for sensitivity analysis*

[57] *Which is broken down into packaging type against individual product lines which can be combined with sales data*

[58] *http://www.wrap.org.uk/content/overview-waste-hospitality-and-food-service-sector*

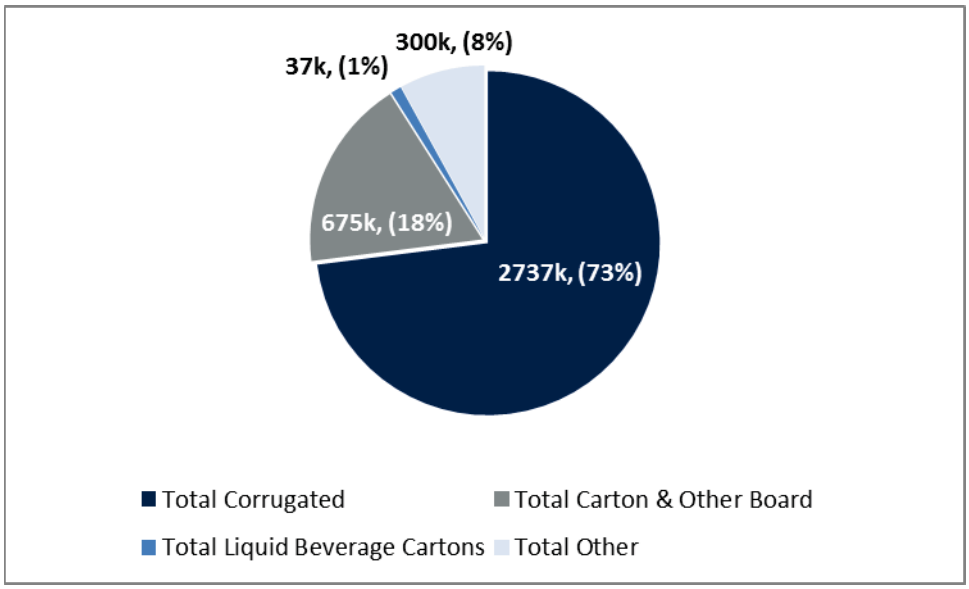
6.0 Results: Final Project Estimate of Paper and Card Packaging POM in 2014

The final project estimate for paper and card packaging POM in 2014 is 4,749k tonnes.
The final paper and card packaging POM figure is derived from a combination of data sources for each of the key consumer and non-consumer sectors.

The final project estimate for paper and card packaging POM in the consumer sector is 1,423k tonnes
This estimate is derived from primary data alongside reliable market share data.
The final project estimate for paper and card packaging POM in the non-consumer sector is 3,326k tonnes
This estimate is derived from data from a combination of sources covering both primary data for the retail back of store sector and secondary data for the C&D, hospitality, agriculture and manufacturing sectors.

The final project estimate of paper and card packaging POM by type is 2,737 tonnes (73%) corrugated, 675k tonnes (18%) carton and other board, 37k tonnes (1%) liquid beverage cartons and 300k tonnes (8%) other packaging
This estimate has primarily been derived from data from Valpak's EPIC database relating to retail packaging both sold to the consumer and disposed of back of store. This has then been adapted using secondary research and data from the CPI to cover the wider non-consumer sectors. This is summarised in the pie chart below.

Figure 7 Final Project Estimates of Paper and Card Packaging Tonnes POM by Type in 2014



An overview of the final project estimates for paper and card packaging POM in 2014 is provided in Figure 8.

Figure 8 Final Project Estimates of Paper and Card POM in 2014

	Total (k tonnes)
Grocery Retail	578
Non-grocery Retail	845
Total Consumer	**1,423**
Construction & Demolition	71
Agricultural	10
Commercial & Industrial[59]	3,245
Total Non-consumer	**3,326**
Total POM	**4,749**

Sense Checking of Results

The final project estimate of 4,749k tonnes POM has been verified using a combination of CPI and wider Valpak data. A CPI estimate of corrugated board supplied to UK pack/fillers[60] was made available for the project. This however did not include filled imported products and as such this had to be estimated and included. To achieve this, the CPI and Valpak's EPIC database for grocery and non-grocery sales identified that approximately 50% of paper and board packaging is imported filled. Based on this, it was possible to estimate that just over 3,800k tonnes of corrugated board was POM in 2014. In addition to this, the CPI estimate that in total (including filled imports) just over 1,000k tonnes of carton and other board and 50k tonnes of other paper and card packaging was used in the UK. This results in an estimate of around 5,100k tonnes, which is 7% higher than the Paper & Card Flow POM estimate[61]. The Steering Group was supportive of this methodology and conclusion.

The final project estimate of 4,749k was found to be 1,002k tonnes higher than data reported by obligated companies under the Packaging Waste Regulations (using the UK net pack fill calculation method). This suggests that non-obligated companies or tonnage (relating to the regulation thresholds and packaging definitions) or unregistered tonnage through free-riding, account for **1,002k tonnes (21%)** of paper and card packaging POM in the UK.

An equivalent calculation was made using the raw material manufacturing stage of the supply chain. Using this UK net raw material manufacturing calculation method suggests that non-obligated companies or tonnage (relating to the regulation thresholds and packaging definitions) or unregistered tonnage through free-riding at the raw material manufacturing stage, account for 151k tonnes (3%) of paper and card packaging in the

[59] *Total of hospitality, retail back of store and manufacturing and other combined.*
[60] *CPI market share for corrugated board supply up to UK pack filling is approximately 84%, which has been scaled up to represent 100% of the market.*
[61] *Although this is a high level estimate for cross checking purposes only, since the import % is estimates based on PBA and Valpak held data.*

UK. This is likely to be imported tonnage since all UK mills are registered under the regulations. It should be noted that this stage of the supply chain is not traditionally used for packaging handled analysis since the overall tonnage is likely to contain packaging that will subsequently be lost through process waste, or ultimately not be made into packaging. The results of the analysis support this hypothesis and hence the net pack fill approach.

It is important to stress that the net pack fill estimates are themselves open to the possibility of error because they rely on the robustness of the data that is submitted to NPWD. The NPWD data is widely recognised as being the best available for total obligated POM, as there is a legal obligation for companies to submit data that is as accurate as reasonably possible, it is then audited by the regulating body. This data is used by policy makers and their agencies.

The reported obligated flow of paper and card packaging and the project estimated flow of paper and card packaging are shown in Figure 9 alongside Defra's current flow estimate for 2014.

Figure 9 Reported Obligated Flow and Project Final Estimate of POM for 2014

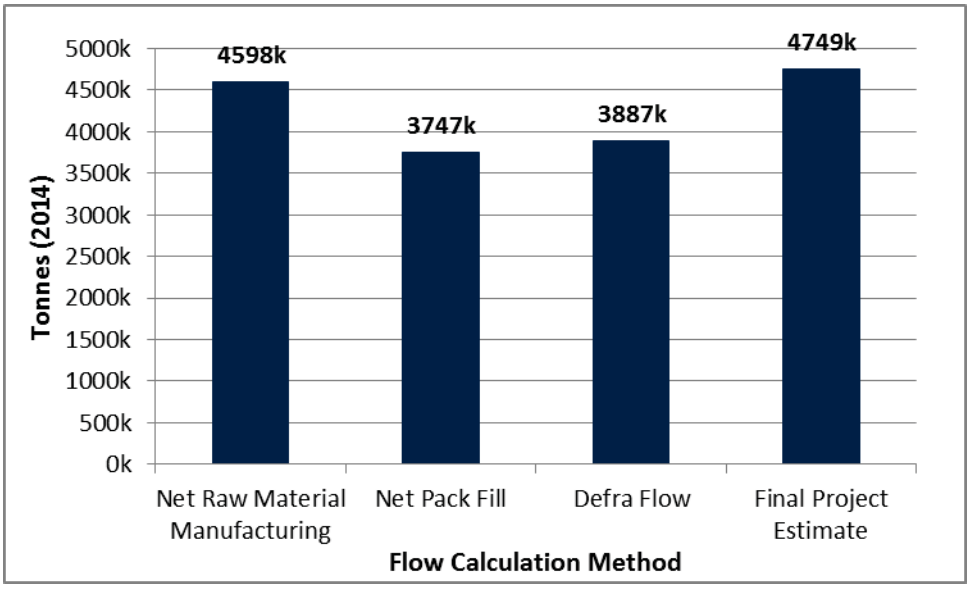
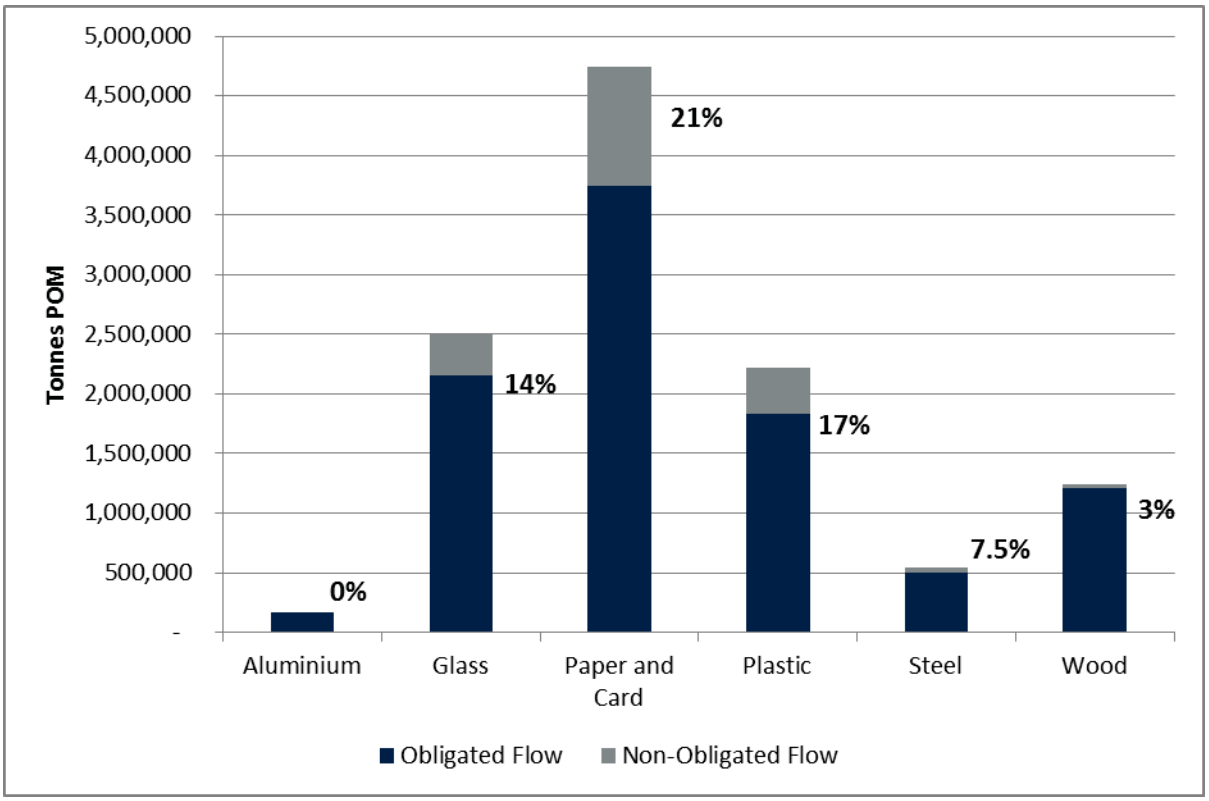


Figure 10 illustrates the obligated versus non-obligated flow for all reported materials using the pack fill part of the supply chain. All materials have undergone recent flow analysis apart from wood, which is underway at the time of reporting[62]. Although each packaging type is characterised by different market structures, the project results highlight that non-obligated flow for paper and card is higher than any other packaging material, with the next highest being plastic, estimated at 17%[63]. This is however

[62] *Metal Flow, which covers aluminium and steel has not been accepted by government at time of reporting. Wood Flow is currently underway and so the results have not fed into this project.*
[63] *The project stakeholders accepted this conclusion. The project team has made some suggestions as an explanation for the higher non-obligated proportion, however exactly where non-obligated is made up is not possible to verify.*

consistent with stakeholder views that a relatively large amount of paper and card packaging could be non-obligated or unreported, especially in comparison to other materials such as plastic. This is particularly related to imports, internet sales from small business that fall outside the regulations, and internal packaging handled. The latter two would both predominantly be corrugated secondary layer boxes for transporting items between one area of a business to another or to the end user in the case of internet sales.

Figure 10 Obligated Versus Non-Obligated POM for Packaging Materials



7.0 Collection and Reprocessing of Paper and Card Packaging in 2014

7.1 Introduction

This section of the report examines the levels of paper and card packaging waste collected and reprocessed within the UK or exported. The collections are split between local authorities (LAs) and C&I collections. In previous flow projects, the levels of collection have been assumed and highlighted to be equivalent to the levels of reprocessing; the data on LA recyclate collections (from Waste Data Flow [WDF]) being used as a proxy for household recycling and the number of PRNs being raised as the total recycling level. However, these figures do not account for unaccredited reprocessing[64] which has also been highlighted in previous flow reports. Therefore, this project has completed a separate analysis on this element of recycling in order to provide a more robust analysis overall.

7.2 Collections

When paper and card packaging is collected by LAs, and private collectors on behalf of LAs, it is generally collected from:

- Kerbside;
- Bring sites; and
- Household waste recycling centres (HWRCs) or civic amenity (CA) sites.

Collections data is submitted by the LAs to WDF. The collections of C&I paper and card are usually carried out by private waste management companies or paper and card recyclers.

7.2.1 Local Authority Collections

LA collections of paper and card packaging in the UK can be represented as follows:

Total UK Paper and Card Packaging Collected by Local Authorities	**=**	**Kerbside Collection[65]**	**+**	**Bring Site Collection**	**+**	**HWRC/CA Site Collection**

This data was extracted from WDF, and figures are reported based on the financial year 2013/14. This means there is some degree of inconsistency between the collection figures for April 2013 - March 2014 and the consumption figures for January 2014 - December 2014[66]. A summary of the UK LA paper and card packaging collections is shown in Figure 11.

[64] *That which is reprocessed or exported for reprocessing by a company that is not accredited/registered with the EA to raise PRNs/PERNs on packaging reprocessed/exported.*

[65] *Kerbside collections refer to local authority (or a waste management company on behalf of a local authority) collections from households*

[66] *At the time of writing 2013/14 was the most recent full set of WDF data available.*

Figure 11 Paper and Card Packaging WDF data 2013/14

	Total	Kerbside	Bring	CA
UK Total Paper and Card Packaging Collected	1,017kt	835kt	15kt	168kt

As shown in the table**, 1,017k tonnes** of paper and card packaging is reported on WDF by LAs as collected. However, much of the paper and card packaging collected is recorded by LAs as 'mixed paper and card' so includes a mixture of packaging and non-packaging materials. A protocol has been used to estimate the volume of packaging collected. The protocol is the same as that applied by accredited reprocessors/exporters to mixed paper and card waste to identify the number of PRNs/PERNs that can be raised. This is EA Protocol EN023 which, at the time of reporting, specified that 12.5% of mixed paper and card is packaging waste.

However, this protocol dates back to 1998 and therefore was in need of review. It was the opinion of the project's steering group that the proportion of packaging will have increased significantly based on a decline in newsprint sales and an increase in card flowing to households due to internet shopping for example.

Therefore prior to the publication of this report the EA accepted an interim update to the protocol from 12.5% to 23% during February 2016. Further sampling to be conducted during 2016 will aim to confirm this number, and could see it increase further. The results in this report are based on the original 12.5% EA protocol since the baseline year is 2014, however for future analysis, if using 2016 reprocessing data, the updated 23% should be applied.

The quantity of paper and card packaging collected in the UK at kerbside, bring sites and CA sites is shown in **Error! Reference source not found.** 12. No specific material splits on co-mingled collections at bring and CA sites were available, therefore the split of material separately collected at these collection sites[67] was applied to estimate proportion of co-mingled that is paper and card. This is also the methodology that was used for the existing PackFlow work, although it is clear there are issues with this as the type and relative proportion of each material at these sites can be very different by collection method: caution is required when interpreting and using these estimates. The majority of paper and card packaging collected by local authorities is collected at kerbside. It should also be noted that there may be a small quantity of C&I material collected through the household collection network due to businesses incorrectly using the collection receptacles. However, it is not possible to quantify this.

Figure 12 Local Authority Paper and Card Packaging Collected by Collection Method

Kerbside	Bring Sites	CA Sites

[67] *WDF data*

	Separate	Co-mingled	Separate	Co-mingled	Separate	Co-mingled
Paper and Card	160kt	675kt	13kt	2kt	153kt	15kt

7.2.2 C&I Collections

The amount of paper and card collected from C&I sources was estimated as follows:

Total UK Paper and Card Packaging Recycled	-	Local Authority Collections	=	Commercial & Industrial Collections

The total volume of materials recycled is taken from NPWD[68] and used as a proxy for the total tonnage collected. LA collections tonnages are taken from WDF, as per section 7.2.1. C&I collection tonnages are then calculated as the residual from the total quantity, which is reported as recycled on NPWD minus the WDF estimation. The estimate for C&I collections is shown in Figure 13[69].

The WDF collection figures will not equal the amount recycled, as many LAs do not robustly account for material rejected by the MRF during the sorting process. Therefore, for simplicity, by assuming that the total collected for recycling equals the total actually recycled, this calculation distorts the representation of contamination and non-target material, accounting for them all upfront (in this case, by default, within the C&I collections estimate). This means that C&I collections as reported here are implicitly underestimated by the combined, unknown level of contamination and non-target material.

It is also important to note that the NPWD figures only cover obligated waste recycled by accredited agents, and so do not include tonnages recycled without a PRN/PERN being generated.

Figure 13 C&I Paper and Card Collections

Paper and Card NPWD data (2014)	3,470kt
Paper and Card Local Authority Collections (2013/14)	1,017kt
Paper and Card C&I Collections	2,453kt

Based on the data reported in Figure 13 and the conclusions around consumer and non-consumer paper and card packaging POM made earlier in the report, it is possible to

[68] http://npwd.environment-agency.gov.uk/Public/PublicSummaryData.aspx

[69] *There is a time difference between the NPWD figures (calendar year 2014) and the local authority figures (2013/14 financial year); however, this was the best available data.*

estimate that 71% of consumer paper and card packaging was recycled in 2014 and 64% of non-consumer paper and card packaging.

7.3 Reprocessing of Paper and Card Packaging

This section of the report examines the level of paper and card packaging recycling within the UK and that which is exported. This is different from the material that is collected because it specifically examines the material that is successfully reprocessed. Reprocessing is where the process results in the creation of a new product from recovered paper and card packaging material.

In order to calculate the level of paper and card reprocessing that is taking place, the reprocessing activity was split into two categories:

- Accredited Reprocessing; and
- Unaccredited Reprocessing.

The accredited reprocessing was estimated from NPWD data using the quantity of PRNs (UK reprocessing) and PERNs (exported for reprocessing) issued. An estimation was made of the level of unaccredited reprocessing based on data provided by the CPI.

7.3.1 Accredited Reprocessing

The total tonnage reprocessed for paper and card is taken from NPWD[70], and is shown in Figure 14 each year from 2008 to 2014.

Figure 14 Total Accredited Paper and Card Packaging Recycling/Exports

	Total PRNs/PERNs
2008	3,063kt
2009	3,152kt
2010	3,103kt
2011	3,239kt
2012	3,328kt
2013	3,459kt
2014	3,470kt

The quantity of paper and card packaging recycling has been steadily increasing from 2008 until 2014, with the exception of 2010 where a decline of 49k tonnes was seen which is believed to be related to the economic downturn, but was followed by an increase in 2011 of 136k tonnes.

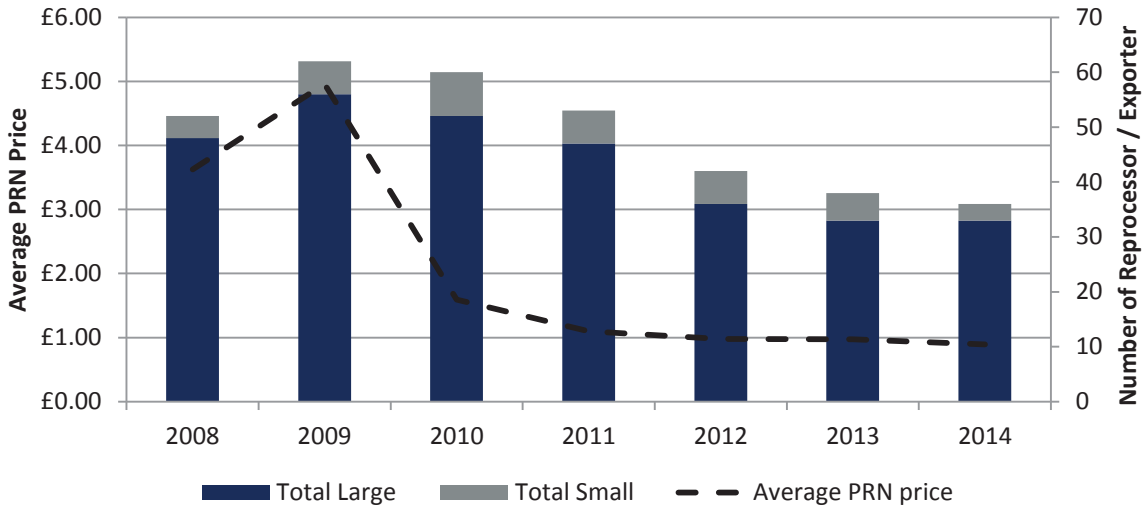
[70] http://npwd.environment-agency.gov.uk/Public/PublicSummaryData.aspx

7.3.2 Unaccredited Reprocessing

The stakeholder discussion highlighted a belief that there is a level of unaccredited paper and card reprocessing happening within the UK and via exporters.

An analysis was completed on the number of large and small registered reprocessors or exporters for paper and card, from 2008 to 2014. This was plotted against the average PRN price across these years to ascertain the optimum PRN value to make it viable to become accredited. This is shown in Figure 15.

Figure 15 Reprocessor/Exporter Accreditations and PRN Price[71]



This appears to show a spike in the number of registered reprocessors and exporters when the PRN price was high in 2009, however following this, the price drops significantly from just under £5 per tonne in 2009 to just over £1.50 per tonne in 2010.

For other materials, it has been found that as the PRN price lowers a company will only register for accreditation if they handle a significant tonnage. In previous packaging flow projects[72] an assessment of accreditation costs (EA fees and internal administration costs) has helped the identfication of the tonnage of unaccredited recycling undertaken based on this economic benefit of raising PRNs. In the case of paper, this would be around 3kt of paper and card per registered company. It is known that companies on average handle in the region of 70kt to 95kt. Therefore this calculation method was not considered appropriate for paper and card packaging.

Therefore in order to estimate the tonnage of paper and card packaging that is reprocessed/exported but not PRNd/PERNd, data provided by the CPI was utilised[73], as shown in Figure 16. The CPI data gives total reprocessing activity, therefore by removing the accredited activity, it is estimated that **367k tonnes** or 10% of the total UK

[71] *Based on the number of active reprocessors/exporters reported on NPWD on 07/07/2015*

[72] *Metal Flow* http://www.wrap.org.uk/content/metal-packaging-market-study-metal-flow-2014 *and Glass Flow* http://www.wrap.org.uk/content/glassflow-2012-report-0

[73] *Based on CPI member activities, representing approximately 95% of the reprocessing market and scaled up to represent total UK activity and combined with data available from HMRC. Note this includes a very small volume of imported waste reprocessed in the UK which is not eligible for PRNs, however it is believed that due to the small tonnage concerned this would in reality have PRNs raised on it upon recycling and as such remains included within the data.*

reprocessing/exporting of paper and card packaging is undertaken by unaccredited companies.

Figure 16 Accredited and Estimated Unaccredited Reprocessing/Exporting

	UK Reprocessing/Exporting				
	Total	Accredited		Estimated Unaccredited	
Paper and Card	3,837kt	3,470kt	90%	367kt	10%

It should be noted that this data also involves calculations using EA Protocol EN023, specifying at the time of analysis that 12.5% of mixed paper and card recyclate is packaging waste.

7.4 Recovery

In addition to the tonnage of paper and card recycled, some material is also recovered through Energy from Waste (EfW). The total tonnage of accredited mixed packaging material (primarily paper and card, plastic and wood) recovered in this way is identifiable on NPWD and totalled 566k tonnes in 2014[74]. No composition analysis specifically related to the split of these packaging materials recovered in this way was available to identify the tonnage relating to paper and card only. Therefore an estimate was made by applying the ratio of paper and card PRN/PERNs raised to plastic and wood, which was calculated at 73%. As a result it is estimated that **416k tonnes** of paper and card packaging was recovered through accredited EfW[75].

8.0 Recycling & Recovery Rates

Throughout sections 4 to 7 of the report, estimates for paper and card packaging POM and recycled/recovered in 2014 have been made. As such Figure 17 shows the recycling and recovery rates calculated based on these estimates.

Figure 17 Paper and Card Packaging 2014 Recycling Rates

	POM	Accredited Recycling Rate	Total Accredited Recycling & Recovery Rate
Paper and Card	4,749kt	73%	82%

Based on the new estimate for paper and card packaging POM and the current reported recycling through PRNs/PERNs raised, it is believed that the recycling rate is 73% (or 81%

[74] http://npwd.environment-agency.gov.uk/Public/PublicSummaryData.aspx
[75] *Unaccredited recovery has not been included here since data was not available at the time of reporting.*

if unaccredited recycling is accounted for[76]). This is lower than the previous estimate of 89%, due to the increase in the volume of paper and card packaging believed to be POM. When the accredited recovery tonnage estimated through the generation of EfW PRNs is included the total recycling and recovery rate increases to 82%.

Using the POM estimated in this study would mean that the UK would have met its 2014 Packaging Regulation material specific policy intention for paper and card, which stands at 66.1% and the EU Packaging Directive target of 60%.

It should be noted that the recycling estimates used in Figure 17 were based on the EA Protocol EN023 which, at the time of analysis, specified that 12.5% of mixed paper and card recyclate is packaging waste. In early 2016, all four agencies agreed an interim 23% of mixed paper and card recyclate being packaging waste (applicable from 1st January 2016), with a view to review this position following detailed sampling at a later date. Therefore, Figure 18 illustrates the resulting recycling rate as a consequence of the additional PRNs/PERNs raised based on 23%, and also shows the resulting recycling rates of changing the protocol to either 30%, 40% or 50%[77] for 2014.

Figure 18 Paper and Card Packaging 2014 Recycling Rates Variations to the Mixed Paper & Card Protocol[78]

Protocol %	12.5%	23%	30%	40%	50%
Total Accredited Recycling	3470k	3595k	3679k	3799k	3918k
Additional PRNs Raised	0k	125k	209k	329k	448k
POM	4749k	4749k	4749k	4749k	4749k
Accredited Recycling Rate	73%	76%	77%	80%	83%

It is important therefore that this protocol be updated, based on rigorous sampling. As an example the increase of 329k tonnes of paper and card packaging seen by increasing the mixed paper and card protocol to 40% would be from the domestic waste stream, as this is where mixed collections are predominantly seen. This would have meant that additional PRN revenue of around £300,000[79] could have been generated and used to support recycling.

[76] *Not shown in Figure 17*

[77] *Estimates derived based on the views and initial sampling made available to the Steering Group. For the purpose of scenario analysis presented later in this report, 40% has been used as a mid-point and based on preliminary findings from sampling and initial stakeholder views.*

[78] *Based on substituting 12.5% for 23%, 30%, 40% or 50% for all sorted and unsorted mixed waste in 2014 as published on NPWD (accessed October 2015).*

9.0 Flow and Recycling Scenario Analysis

9.1 Introduction

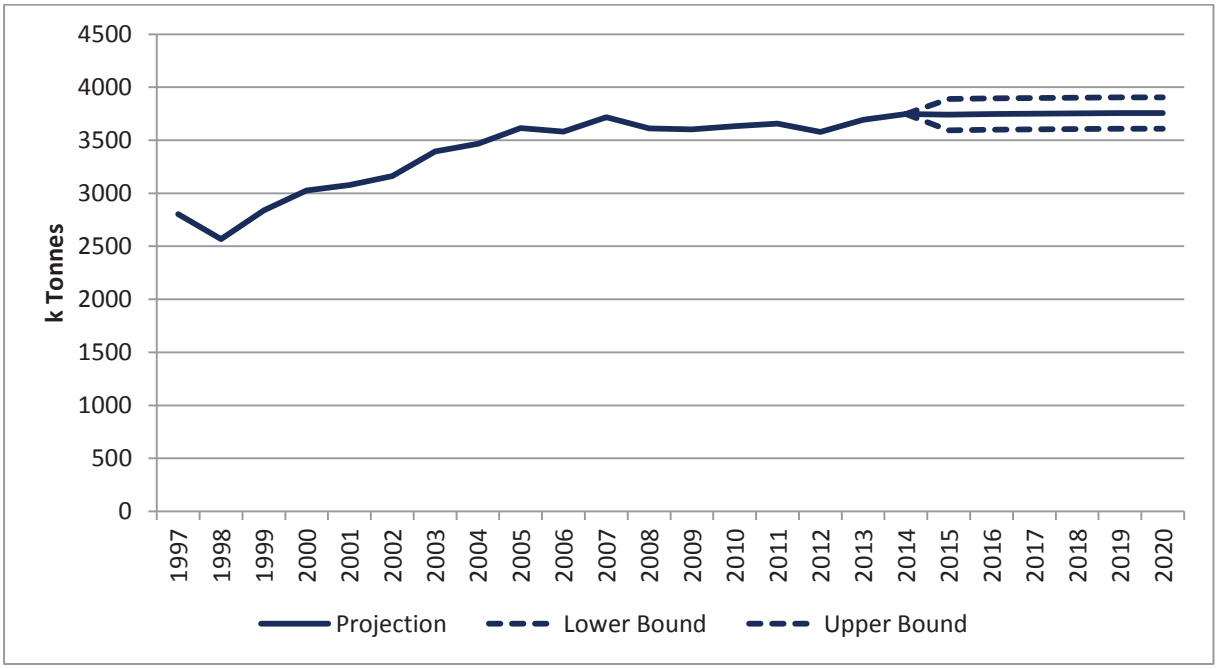
This section looks at the historical (1997 – 2014) POM and recycling figures for paper and card packaging in the UK and uses these to make projections to 2020.

9.2 POM Historic Analysis and Projections

A regression analysis using historical reported ('obligated') POM data was undertaken to help better predict future tonnages of paper and card packaging POM. This was made possible using the EA's packaging data from 1997 and the net pack fill calculation (as described in Section 3 of this report). Obligated POM is known not to represent the total tonnage of paper and card packaging flowing onto the UK market; however this is the only historic dataset available and therefore is used for projecting trends.

Figure 19 presents this 'obligated' data in a graphical format. It shows that there was an initial upward trend until 2007, before a slowing of the growth rate up to 2014 (the final year of actual reported data available). Some of the initial growth may have been partly due to legislative factors rather than just an increase in paper and card packaging POM from the same firms. For example, in 2000 the threshold for the Packaging Regulations changed from £5m to £2m per annum turnover, which resulted in an increase in the number of companies obligated to report their packaging handled data to the EA.

Figure 19 Paper and Card Historic Net Pack Fill and Projections



In order to project the obligated packaging data forward to 2020, a technique called linear auto regression was used. This method involves using past data trends to project POM until 2020. Details of the technique applied are described in Appendix VII of this report, with the results displayed in Figure 19.

There is uncertainty around the projections, and therefore a range was developed. Assuming a normal distribution and using a 95% confidence interval[80] a range was calculated and is shown in Figure 19 as the upper and lower bounds. This was determined using the regression standard error from the projection analysis.

The projections up to 2020 indicate flat growth in the tonnage of 'obligated' paper and card packaging POM. Implicit in this auto regression model is the assumption that past data is useful for future projections, and therefore that the wider economic climate will continue on or near current trends. There are a number of potential factors identified that could affect future POM, including GDP growth, light-weighting, raw material prices and the growth in internet sales. However, the Steering Group felt that the growth projected by the model was sensible and that actual POM was likely to fall within the bounds of the projection.

This study estimates that unobligated/unregistered packaging accounted for 21% in 2014 (as described in Section 6 of this report). It is very likely that this proportion of unobligated tonnage has grown over the years since 2008. A large increase in internet shopping and the off-shoring of some of the UK's manufacturing capacity in the past decade, with China and Eastern Europe providing low cost components and products for the burgeoning SME sector makes this at least plausible. However the project team and stakeholders have no data to support this opinion. There is no data to accurately project how the volume of business done via the internet will grow or the overseas procurement activities of UK manufacturing and retail sectors.

One factor affecting the projected trends for POM could be the light-weighting of corrugated boxes. The average base weight of containerboard used in corrugated boxes in the UK has fallen by approximately 15% in the past decade or so. Much of this opportunity is already taken as paper making technology reaches its limits, however, there may be additional market opportunities yet to be had i.e. it seems unlikely that the weight of board will get significantly lighter, but the number of businesses exploiting it could rise. It is the opinion of stakeholders that it is likely that this will have only a marginal impact upon the net volume of packaging on the market by 2020, although there is no data to support this.

As there is no data available to prove or quantify any of these assumptions on non-obligated packaging, projections are based on obligated flow only.

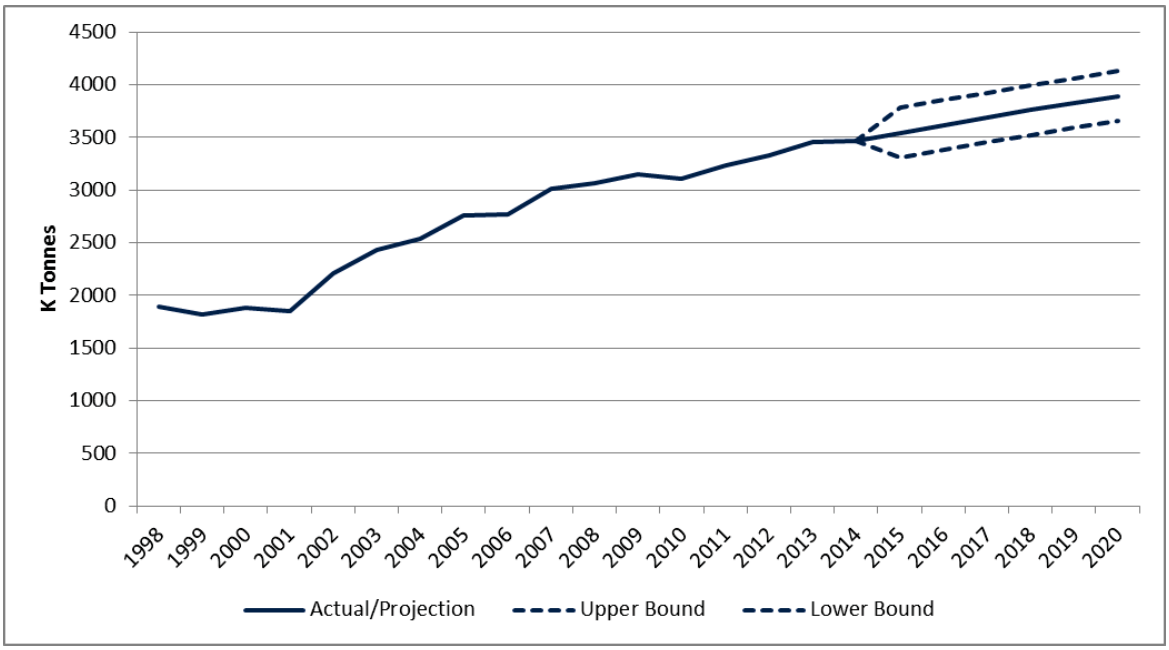
9.3 Recycling Rates Analysis and Projections

An analysis of historical recycling data was possible by using PRN/PERNs generated as an estimate of paper and card recycling rates (i.e. accredited recycling only). Data from 1998 to 2014 was used.

[80] *With a standard error of 75.38.*

In order to project future recycling rates to 2020, a technique called linear auto regression was used[81]. This uses past trends to generate projections of future values over the period 2015-2020. The results are displayed in Figure 20 and show that future recycling is projected to increase by 10% over the period[82]. As historic data has been used, it is important to note that the predicted tonnages illustrated in Figure 20 are based on the 12.5% of mixed papers being packaging.

Figure 20 Paper and Card Packaging Recycling Projections to 2020



Date sources: Actual = NPWD, Projected = Valpak

Implicit in this auto regression model is the assumption that past data is useful for future projections, and therefore that the wider economic climate will continue on or near current trends. However, the Steering Group felt that because paper and card recycling is already high following considerable growth in the past decade, future growth may taper off. As recycling rates increase, each additional percentage increase becomes progressively more difficult. There are a number of potential factors that the Steering Group identified that could mean that recycling diverts significantly from this projection, if there is a large change in trends over the next five years:

- GDP;
- Recycled price;
- Population growth / demographic;
- Legislation;
- Mill closures;
- Collection practices; and

[81] *The full details of the technique applied are described in Appendix VII of this report*

[82] *There is uncertainty around projections and therefore a range was developed around the recycled projection. The bounds were calculated using the standard method of a 95% confidence interval using the regression standard error. Therefore, it gives an indication of how large the errors made by using the regression could potentially be. Assuming a normal distribution and using a 95% confidence interval a range around the projections was calculated and is shown in Figure 21 as the upper and lower bounds.*

- Export markets.

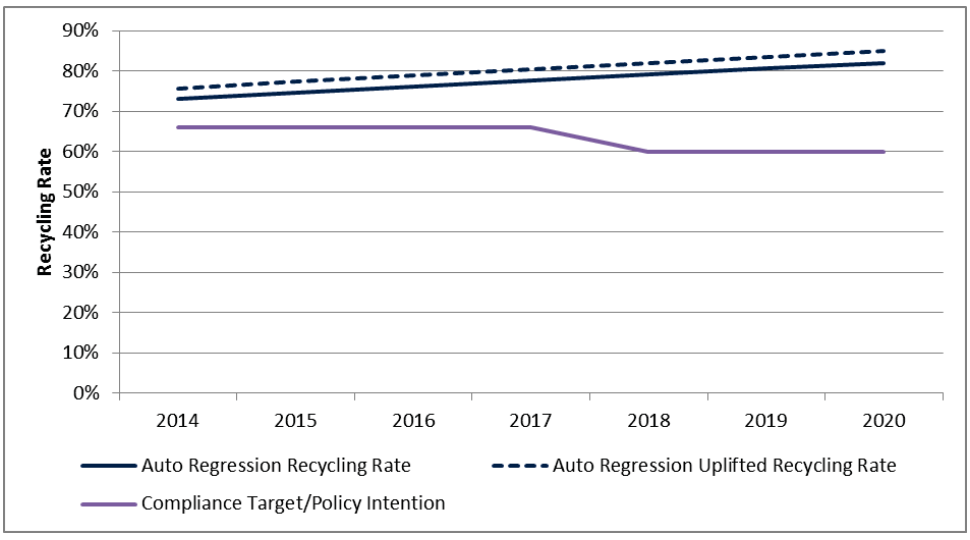
Some members of the Steering Group observed that UK markets are at capacity and the export market is stagnating, while others expressed the view that although the export market has been slow in recent months, China's imports of recovered paper from Europe have mounted a strong recovery in 2015, and are forecast by some commentators to remain strong in the medium term[83]. At present the UK is reliant on China. However, with China focusing on its own circular economy, and therefore moving to domestic sourced material with less need for imports, the UK should investigate other end markets including other European markets for the longer term. The global market for recycled paper is stable and there is demand for further recovered paper and card packaging.

Figure 21 presents the projected recycling rates between 2015 and 2020 based on the linear auto regression (solid blue line). This analysis suggests that the recycling rate for paper and card packaging could reach 82% in 2020 if using the new project POM estimate but with no change to the EA protocol EN023). However taking into account the protocol change from 2016 and applying this to the predicted tonnages suggests a recycling rate of 85% (90% if the protocol was changed to 40% packaging[84]). All would comply with the current Directive target of 60%.

In 2014, the accredited recycling rate was 73%, meeting Defra's Policy intention of 66.1%, and compliant with the Directive Requirement of 60%.

Projections suggest compliance with the business targets up to 2017 and the original EU directive target of 60% up to 2020, as shown in Figure 21.

Figure 21 Paper and Card Packaging Recycling Rate Projections to 2020



[83] http://www.bir.org/news-press/latest-news/recent-bir-world-recycling-convention-2015-in-prague-paper-division-chinas-recovered-paper-demand-to-remain-sustained/ *viewed 06.11.2015*

[84] *As an example, further examples are provided in Figure 19*

Based on the suggestion from the Steering Group that recycling rates would begin to taper; a scenario analysis was considered in this study. For the purpose of this scenario, it was assumed that this tapering would lead to a capping at 80% recycling rate in 2020[85] (83% with updated EA protocol to 23% and 88% with updated protocol at 40%[86]). This scenario would see the UK meet both Defra's Policy intention to 2017 and the current Directive Requirements up to 2020.

The European Commission has proposed national packaging targets in its circular economy package. For paper and card packaging these have been set at 75% in 2025, and 85% in 2030. However, there are no specific targets for 2020, so the 60% target is assumed to remain.

[85] *As a scenario only.*
[86] *As an example, further examples are provided in Figure 19*

10.0 Conclusions and Recommendations

This section details the conclusions of the project and the areas recommended for further work.

10.1 Conclusions: Flow

The project's final best estimate of UK flow for 2014 is 4,749k tonnes: an increase of 862k tonnes from Defra's estimated flow figure

The most robust estimate that could be derived, using a variety of the most authoritative data, including industry estimates, Valpak data and publicly available data, suggests that the quantity of paper and card packaging POM in 2014 was 4,749k tonnes. This figure is 862k tonnes higher than the current Defra estimate of 3,887k tonnes for 2014.

It is important to note that 1,966k tonnes of the POM estimate (41%) has a higher degree of uncertainty than the other 59% of the tonnage, based on the availability of data. Details of the confidence level in this data are provided in section 5.2.3.2 and further in Appendix VI.

A CPI estimate of corrugated board supplied to UK pack/fillers[87] was made available for the project. This however did not include filled imported product and as such this had to be estimated and included. To achieve this, the CPI and Valpak's EPIC database for grocery and non-grocery sales identified that approximately 50% of paper and board packaging is imported filled. Based on this it was possible to estimate that just over 3,800k tonnes of corrugated board was POM in 2014. In addition to this the CPI estimate that in total (including filled imports) just over 1,000k tonnes of carton and other board and 50kt of other paper and card packaging was used in the UK. This results in an estimate of around 5,100k tonnes, which is 7% higher than the estimate above and therefore provides some verification[88]. The Steering Group for the project was supportive of the methodology underpinning the baseline POM estimate and conclusion.

Non-obligated or unregistered flow for paper and card packaging accounted for 21% of POM in 2014 – higher than any other packaging material

The final project estimate was found to be 1,002k tonnes higher than data reported by obligated companies under the Packaging Waste Regulations (using the UK net pack fill calculation method). This suggests that non-obligated companies or tonnage (relating to the Regulation thresholds and packaging definitions) or unregistered tonnage through free-riding, account for 1,002k tonnes (21%) of paper and card packaging in the UK.

Although each packaging type is characterised by different market structures, the project results highlight that the non-obligated/unregistered flow, as a proportion of total paper and card flow is higher than for any other packaging material, with the next

[87] *CPI market share for corrugated board supply up to UK pack filling is approximately 84%, which has been scaled up to represent 100% of the market.*

[88] *Although this is a high level estimate for cross checking purposes only, since the import % is estimates based on PBA and Valpak held data.*

highest being plastic, estimated at 17%. This is however consistent with stakeholder views that a relatively large amount of paper and card packaging could be non-obligated or unreported, particularly related to imports, internet sales and internal packaging handled, which are considered to be high for paper and card in comparison to other packaging materials.

The final project estimates of paper and card packaging POM by type are 2,737k tonnes (73%) corrugated, 675k tonnes (18%) carton and other board, 37k tonnes (1%) liquid beverage cartons and 300k tonnes (8%) other packaging

Using a combination of Valpak's EPIC database for retail packaging sold to consumers and disposed of back of store and that published in reports, the final project estimate by format has been made. This indicates that almost three quarters of paper and card packaging POM is corrugated.

There was significantly higher uncertainty around the final estimate for manufacturing POM

The final project estimate relating to manufacturing paper and card packaging is based on a C&I survey conducted for Defra in 2009, which considers both packaging and non-packaging together. There is significant uncertainty around what proportion of this material would be packaging and whilst the best available data has been used and agreed by the Steering Group to estimate this, this should still be viewed with some caution. This estimate makes up 41% of the total POM estimate.

The projected trend for obligated paper and card packaging POM between 2014 and 2020 is zero growth

Using an auto regression technique, which projects forward based on historical data, and using historic data for obligated flow, it is suggested that there will be zero growth in obligated paper and card packaging POM to 2020. This does not consider non-obligated flow, which for 2014 accounts for 21% of POM. It is very likely that this proportion of unobligated tonnage has grown over the years since 2008. A large increase in internet shopping and the off-shoring of much of the UK's manufacturing capacity in the past decade, with China and Eastern Europe providing low cost components and products for the growing SME sector makes this at least plausible. There is no reason to believe that the volume of business done via the internet will not continue to grow and nor that the UK manufacturing and retail sectors will continue to buy components and goods manufactured abroad. Much depends upon growth projections for the UK economy. As there is no data available to quantify any of these assumptions, projections are based on obligated flow only.

10.2 Conclusions: Recycling

Using the new POM figure of 4,749k tonnes, the UK achieved a 73% recycling rate in 2014

This is 16 percentage points lower than previously estimated.

There is an estimated 367k tonnes of unaccredited paper and card reprocessing

The project estimated some 367k tonnes of paper and card packaging that was reprocessed in 2014 did not have a PRN/PERN issued against it. This is 10% of total recycling (accredited and unaccredited).

By including the estimated unaccredited reprocessing, the recycling rate increases
The recycling rate for paper and card packaging increases to 81% if the level of unaccredited recycling is included.

Auto regression projects the recycling rate could rise to 82% (if there had been no protocol update), however taking into account the amended protocol, this rate could reach 85% in 2020, although stakeholders predict some tapering off by 2020.
Should past trends continue, the UK is projected to achieve an overall recycling rate of 82% in 2020 without an amendment to EA Protocol EN023. However having amended it to 23% in the interim, this changes it to 85%. If the protocol is updated further to 40%[89] the recycling rate could hit 90% in 2020. However the Steering Group predict that the rate of growth in recycling will be lower than in the past. This is because recycling rates for paper and card are already high and factors such as increased comingled collections mean that the quantity of paper and card suitable for recycling may not increase at the same rate as past growth.

All scenarios (tapered and auto regression), are projected to continue compliance with the Directive targets (60%) currently in place up to 2020.

10.3 Recommended Areas for Further Work

This study has concluded a significantly higher POM tonnage than previously estimated however a large proportion (41%) of the POM tonnage has a higher level of uncertainty than the remaining 59% of the tonnage. The result also suggests a 21% non-obligated proportion of packaging in 2014, which is higher than for any other packaging material. Both have implications for the current UK picture for paper and card recycling. The following recommendations are made with a focus on addressing the proportion of POM that is less certain and the large proportion of non-obligated packaging, as well as impacts of these on UK recycling rates.

EA Protocol EN023 for mixed paper and card requires updating
The project recommends that the 'mixed paper' recycling protocol (EA Protocol EN023) is reviewed and where necessary update as it has been identified as potentially too low. During this project it was updated to 23% as an interim measure, with further review proposed following detailed sampling.

Further surveying of manufacturing waste to establish manufacturing packaging: non-packaging ratios
There is uncertainty around the proportion of packaging to non-packaging paper and card within the manufacturing sector. This was highlighted as a key area of uncertainty when trying to construct the level of packaging being POM for paper and card. A

[89] *As an example.*

recommended way forward is to undertake composition analysis of waste from a range of manufacturing activities. This may be best achieved by working with trade associations relevant to the manufacturing sector.

Review elements of the Packaging Regulations to capture more non-obligated or unregistered tonnage

The project has estimated that 21% of paper and card packaging is currently not obligated or reported under the Packaging Regulations. Areas where amendments could be made to capture more of this non-obligated or unregistered tonnage include:

- Re-introducing the service provider clause. This was originally introduced to capture tonnage sold to small businesses by wholesalers and therefore not captured as the 'selling' organisation was too small to be obligated. A revised version of this clause could be re-introduced to capture this non-obligated tonnage by placing an obligation on the wholesaler.
- Clauses in the Regulations exist to capture tonnage handled by lessors and franchisors who do not necessarily perform pack filling and selling but are responsible for these activities and as such take on their packaging obligation. This could be extended to cover other organisations, for example businesses performing a "fulfilment service", who either do not perform the packaging activities or do not own the packaging but are responsible for the sales outlet and/or marketing function of the products sold. This business model has become increasingly popular for "online" sales.
- Investigate the potential for unobligated or unregistered tonnage to be supplied through increasing use of internet "marketplace" arrangements, particularly where products are supplied from other countries
- Currently, packaging used internally by an organisation (for example for transporting between or within sites) is exempt from the Regulations. This may be a significant volume for paper and card and therefore its inclusion within the obligated tonnage could be investigated further.
- In cases where the brand owner supplies packaging to contract packers free of charge (contract packing), the brand owner is responsible for the obligation. However, it is suspected that this may be overlooked by producers in many cases and as such could be a focus of compliance scheme or enforcement agency auditors to carry out checks and issue reminders.

The total quantity of non-obligated/unregistered paper and card packaging should also be reviewed going forward and a further study identifying in which sectors this tonnage is high undertaken.

Accreditation of all recycling activities

- If all companies in the UK performing recycling activities on packaging were to become accredited, this would ensure that PRNs were issued on more of the packaging material recycled, resulting in no unaccredited recycling and simpler compliance for the UK with regulatory targets. All reprocessors becoming accredited for recycling activities could increase the number of PRNs/PERNs generated for recycling, by up to 367k tonnes in 2014.

Improve packaging waste data exchange

- High volatility in recyclate prices and availability of international and domestic markets can put significant constraints on achieving increasingly challenging recovery and recycling targets, and sustaining profitability in the reprocessing sector. Policy makers and industry would benefit from the ability to update POM estimates and projections on a more frequent basis, to better adapt to these challenges. Further work is t needed to enhance packaging waste data exchange with industry and policy makers, and develop novel tools, to reduce uncertainty in packaging waste tonnage estimates and to streamline flow methodologies.

Appendix I Methodology Review Results

Method Used	Projects Used In	Report reference	POM or Recycling	Overview	Advantages	Disadvantages
Net Pack Fill	Plastics & metal	Plastics: Section 4, p.18 Metals: Section 3, p.17	POM	NPWD combined data form used to populate formula (T1 Pack/Fill + T3A sell (filled imports)+ T3B (removed from imports) - T2A (exports) - T2B (exports)) + non-obligated/free-rider estimate	Use of NPWD represents best available data as represents actual data and mandatory legal requirement to report. Using the pack/fill data set likely to be most representative as minimises exclusion of non obligated producers (better representation). Data reliable and well identified by most producers. Data available in public domain. Calculation of obligated tonnage flow is straight forward and quick.	NPWD does not record data from small or non-obligated producers or internal use packaging. Not clear if deductions are made for retailers who may export some of their stock for selling in other countries eg. Ireland - third party exports.
Net Pack Fill	Glass	Section 3, p.12	POM	NPWD combined data form with UK production, empty imports & direct exports data available from British Glass (Total Production + T3A filled imports + estimate of illegal filled imports + empty imports - direct exports - T2B (exports))	UK glass production data likely to be reliable, regularly produced and repeatable. Use of NPWD represents best available data as mandatory legal requirement to report. Calculation of obligated tonnage flow is straight forward and quick.	Production data set not public so reliant on British Glass. May be costly to repeat. Production data will be less accurate or not available in more deverse sectors or where no strong and representative Trade Body exists. Method not suitable where few players involved because of competition concerns. NPWD does not record data from small or non-obligated producers or internal use packaging.
Bottom Up Approach - Valpak EPIC	Plastics, glass and metal	Plastics: Section 2.2, p.9 Glass: Section 3.2, p.19 Metals: Section 2.2, p.7	POM	Estimating POM by sector - EPIC data used for food and non-food estimates by material including format and polymer and scaled up to UK	Good primary weight data and coverage can be checked. Good sector representation for grocery retailers. Scaling up to whole sector means non-obligated flow included.	Data not so representative for other sectors (non-grocery) and assumes those retailers included are representative. Requires access for repeatability to extensive databases and sales figures for major retailers.
Bottom Up Approach - Published Sources	Plastics, glass and metal	Plastics: Various: Section 2.3.1, 2.3.2, 2.3.3, p.11-15 Glass: Various: p.20, p.22 Metals: Various: p.10-13	POM	Estimating POM by sector - wider retail, commercial & industrial, construction & demolition, agricultural and other key sectors using published secondary sources	Includes non-obligated flow. Assume coverage and reliability of secondary sources (eg. Kantar) are reviewed.	Depends on accuracy and degree of representation of industry estimates. Considerable reliance on knowledge and experience of small number of individuals. May not be repeatable. Data purchase required and compilation method may not be transparent/validated.
EA data	Metal	Section 3.4.1, p.21	POM	Aggregated EA compliance data	Data covers whole national tonnage but only for named companies.	Highly manual exercise dependent on EA resource. Much more difficult for non-grocery to identify producers. Dependent on manually naming all producers in a sector. No detailed analysis possible as individual information not provided.
Top Down Approach - UK Trade Info/ProdCom	Glass and Metal	Metals: Section 4, p.25	POM	Trade info for exports and imports - Prodcom	Readily available and likely to be rapid to assemble. Can provide useful cross check/sanity check.	Not based on reliable or repeatable data sources. Difficult to reference or quantify accuracy. Prodcom only covers UK manufacturing and empty exports. Also does not specifically cover packaging and quantities are by tonnes of product or units, packaging has to be deduced.
Top Down Approach - Trade Association Data/ Industry Estimates	Plastics, glass	Plastics: Section 3, p.16 Glass: Section 3.2.1, p.13	POM	Various estimates from trade associations members or steering group members	Readily available and likely to be rapid to assemble. Can provide useful cross check/sanity check. Can be based on thorough survey of members but not universally so.	Not based on reliable or repeatable data sources. Difficult to reference or quantify accuracy. Variable quality and reliability depending on Trade Association processes. Representation and market share may be difficult to quantify.

Method Used	Projects Used In	Report reference	POM or Recycling	Overview	Advantages	Disadvantages
NPWD	Plastics, glass and metal	Plastics: Section 6.1.2, p.26 Glass: Section 4.2.2, p.27 Metals: Section 5.3, p.28	Recycling	Total recycled tonnages + estimate of that which is not PRN'd/accredited	Consists of actual reported data from accredited reprocessors and exporters and EA audited. Unaccredited reprocessing relatively straight forward in high entry cost materials with few players but more difficult for exporters and lower entry cost materials such as plastic.	Voluntary system so does not include all processors. Unaccredited tonnage varies significantly by year depending on market conditions so not repeatable - requires full survey each year. Reasonable estimate possible by using accreditation records and market knowledge. More detailed primary research required for detailed analysis.
WDF	Glass and Metal	Glass: Section 4, p.26 Metals: Section 5, p.26	Consumer Recycling	LA data on tonnages recycled	Routinely reported by LAs in WDF. Analysis relatively straight forward.	Accuracy wholly dependent on LA reporting accuracy. Provides collection figures which are bound to be higher than recycling. Difference difficult to estimate because of variability in reporting accuracy, collection method, etc. Impact of contamination in collections not quantified.
Recoup Plastics Report	Plastics	Section 6, p.25	Consumer Recycling	LA data on tonnages recycled	Based on thorough independent survey in addition to WDF. Validated.	Requires continuing support of external organisation to conduct and fund. Not independently validated as based on LA reports and discussions.
Published Reports	Plastics, glass and metal	Plastics: Section 6, p.25	Non-Consumer Recycling	Published waste composition reports eg. previously conducted, mainly for non-consumer recycling.	Easily accessible. Possible sense check.	Variable quality and accuracy. Can be years out of date, small sample size in some cases, insufficiently detailed. Depends on what is available - no new work done.
Valpak Internal Data	Plastics	Section 2.3.3.3, p.14	Non-Consumer (Grocery) Recycling	Data informally gathered from large grocery retailers	Reliable for those stores covered.	Limited to Valpak contacts who are willing to participate. Grocery only so whole market scaling up may be inaccurate.
Trade Associations	Plastics, glass	Plastics: Section 6.1.2, p.26	Recycling	Various estimates from trade associations members	Can be useful cross check.	Not really representative of whole market. May not cover export data depending on material and Trade Association coverage.

Appendix II Obligation Reporting Activity Lines

Figure 22 The EA's Data Form – Activity Descriptions

Activity	Description
Raw material manufacturing	Production of raw materials that will be made into packaging
Conversion	Conversion of raw materials into packaging
Packing/filling	Applying packaging to goods
Selling	Supplying packaging to an end user i.e. the company/person who removes the packaging

Appendix III Data Robustness

A robustness analysis was completed on the data sources used. This was developed to highlight the level of uncertainty for each data source by scoring the data sources on the evidence and agreement level from stakeholders. The results are shown in Figure 24, which has been constructed based on analysis completed for each project estimate. Questions were created relating to the evidence and agreement levels of the data used.

The tables thereafter provide a full breakdown for each project estimate. If the question is answered 'Yes' then a score of 3 is given, if 'No' then a score of 0. Where a partial score is given, a score 1 or 2 is made and a comment is added to justify this decision. An example of this is in Figure 31 where the NPWD net pack/fill data scores a partial score for coverage as the data misses unobligated tonnage.

Figure 23 Data Robustness Assessment Results

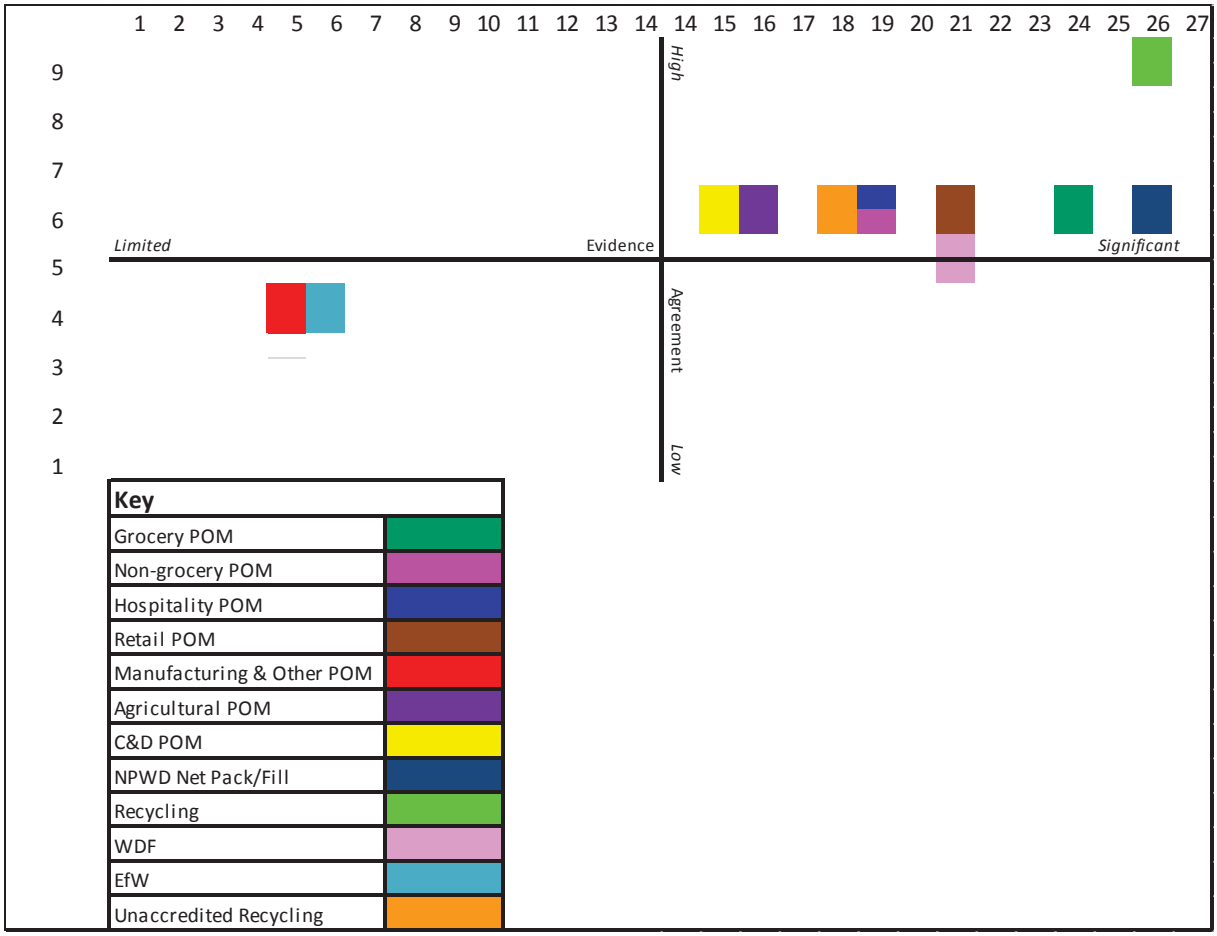


Figure 24 Data Robustness Assessment: Grocery POM

Evidence (Robustness and completeness, max 27):	Scoring		Evidence
Does the data cover the correct time-frame?	Y	3	
Does the data provide complete coverage?	Y	3	
Has the data been sourced from credible, up-to-date sources?	Y	3	
Is the underlying data reasonably free from concerns (e.g. official data from the ONS)?	Y	3	
Have the findings been independently peer-reviewed?	N	0	
Is the methodology/calculation reasonably free from concerns?	Y	3	
Have the methodology/calculations been independently checked (internally or externally)?	Y	3	
Is the quantitative evidence well rooted in a wider qualitative understanding of the issue?	Y	3	
Have the findings been sense-checked against credible alternative sources (incl. inconclusively)?	Y	3	Checked against EA reported Data
Total	**24**		
Degree of agreement around the findings (max 9):			
Does more than one data source confirm the findings (within +/- 5%)?	N	0	
Do the key stakeholders/experts actively agree with the findings?	Y	3	
Has feedback from the key stakeholders been incorporated in the reporting of findings?	Y	3	
Total	**6**		

Figure 25 Data Robustness Assessment: Non-grocery POM

Evidence (Robustness and completeness, max 27):	Scoring		Evidence
Does the data cover the correct time-frame?	Y	3	
Does the data provide complete coverage?	N	0	
Has the data been sourced from credible, up-to-date sources?	Y	3	ONS and Valpak member data
Is the underlying data reasonably free from concerns (e.g. official data from the ONS)?	with reservations	2	
Have the findings been independently peer-reviewed?	Y	3	
Is the methodology/calculation reasonably free from concerns?	with reservations	2	
Have the methodology/calculations been independently checked (internally or externally)?	Y	3	
Is the quantitative evidence well rooted in a wider qualitative understanding of the issue?	Y	3	
Have the findings been sense-checked against credible alternative sources (incl. inconclusively)?	N	0	
Total	**19**		
Degree of agreement around the findings (max 9):			
Does more than one data source confirm the findings (within +/- 5%)?	N	0	
Do the key stakeholders/experts actively agree with the findings?	Y	3	
Has feedback from the key stakeholders been incorporated in the reporting of findings?	Y	3	
Total	**6**		

Figure 26 Data Robustness Assessment: Hospitality POM

Evidence (Robustness and completeness, max 27):	Scoring		Evidence
Does the data cover the correct time-frame?	Y	3	
Does the data provide complete coverage?	yes with some reservations	2	
Has the data been sourced from credible, up-to-date sources?	Y	3	
Is the underlying data reasonably free from concerns (e.g. official data from the ONS)?	Y	3	
Have the findings been independently peer-reviewed?	N	0	
Is the methodology/calculation reasonably free from concerns?	yes with some reservations	2	
Have the methodology/calculations been independently checked (internally or externally)?	Y	3	
Is the quantitative evidence well rooted in a wider qualitative understanding of the issue?	Y	3	
Have the findings been sense-checked against credible alternative sources (incl. inconclusively)?	N	0	
Total	**19**		
Degree of agreement around the findings (max 9):			
Does more than one data source confirm the findings (within +/- 5%)?	N	0	
Do the key stakeholders/experts actively agree with the findings?	Y	3	
Has feedback from the key stakeholders been incorporated in the reporting of findings?	Y	3	
Total	**6**		

Figure 27 Data Robustness Assessment: Non-consumer Retail (Back of Store) POM

Evidence (Robustness and completeness, max 27):	Scoring		Evidence
Does the data cover the correct time-frame?	Y	3	
Does the data provide complete coverage?	Y	3	
Has the data been sourced from credible, up-to-date sources?	Y	3	
Is the underlying data reasonably free from concerns (e.g. official data from the ONS)?	Y	3	
Have the findings been independently peer-reviewed?	N	0	
Is the methodology/calculation reasonably free from concerns?	Y	3	
Have the methodology/calculations been independently checked (internally or externally)?	Y	3	
Is the quantitative evidence well rooted in a wider qualitative understanding of the issue?	Y	3	
Have the findings been sense-checked against credible alternative sources (incl. inconclusively)?	N	0	
Total	**21**		
Degree of agreement around the findings (max 9):			
Does more than one data source confirm the findings (within +/- 5%)?	N	0	
Do the key stakeholders/experts actively agree with the findings?	Y	3	
Has feedback from the key stakeholders been incorporated in the reporting of findings?	Y	3	
Total	**6**		

Figure 28 Data Robustness Assessment: Manufacturing and Other POM

Evidence (Robustness and completeness, max 27):	Scoring		Evidence
Does the data cover the correct time-frame?	N	0	
Does the data provide complete coverage?	N	0	
Has the data been sourced from credible, up-to-date sources?	more yes than no but equivocal	1	Credible source but not up-to-date
Is the underlying data reasonably free from concerns (e.g. official data from the ONS)?	N	0	Packaging is not key focus of the research - best available data only
Have the findings been independently peer-reviewed?	yes with some reservations	2	
Is the methodology/calculation reasonably free from concerns?	N	0	Packaging is not key focus of the research - best available data only
Have the methodology/calculations been independently checked (internally or externally)?	N	0	Packaging is not key focus of the research - best available data only
Is the quantitative evidence well rooted in a wider qualitative understanding of the issue?	more yes than no but equivocal	1	
Have the findings been sense-checked against credible alternative sources (incl. inconclusively)?	N	0	
Total	**4**		
Degree of agreement around the findings (max 9):			
Does more than one data source confirm the findings (within +/- 5%)?	N	0	
Do the key stakeholders/experts actively agree with the findings?	yes with some reservations	2	
Has feedback from the key stakeholders been incorporated in the reporting of findings?	Y	3	
Total	**5**		

Figure 29 Data Robustness Assessment: Agricultural POM

Evidence (Robustness and completeness, max 27):	Scoring		Evidence
Does the data cover the correct time-frame?	N	0	
Does the data provide complete coverage?	Y	3	
Has the data been sourced from credible, up-to-date sources?	with reservations	2	Credible source but not up-to-date
Is the underlying data reasonably free from concerns (e.g. official data from the ONS)?	Y	3	
Have the findings been independently peer-reviewed?	N	0	
Is the methodology/calculation reasonably free from concerns?	with reservations	2	Not possible to scale up or consider lightweighting
Have the methodology/calculations been independently checked (internally or externally)?	Y	3	
Is the quantitative evidence well rooted in a wider qualitative understanding of the issue?	Y	3	
Have the findings been sense-checked against credible alternative sources (incl. inconclusively)?	N	0	
Total	**16**		
Degree of agreement around the findings (max 9):			
Does more than one data source confirm the findings (within +/- 5%)?	N	0	
Do the key stakeholders/experts actively agree with the findings?	Y	3	
Has feedback from the key stakeholders been incorporated in the reporting of findings?	Y	3	
Total	**6**		

Figure 30 Data Robustness Assessment: Construction and Demolition POM

Evidence (Robustness and completeness, max 27):	Scoring		Evidence
Does the data cover the correct time-frame?	N	0	
Does the data provide complete coverage?	Y	3	
Has the data been sourced from credible, up-to-date sources?	most, not all	2	
Is the underlying data reasonably free from concerns (e.g. official data from the ONS)?	most, not all	2	
Have the findings been independently peer-reviewed?	N	0	
Is the methodology/calculation reasonably free from concerns?	most, not all	2	
Have the methodology/calculations been independently checked (internally or externally)?	Y	3	
Is the quantitative evidence well rooted in a wider qualitative understanding of the issue?	Y	3	
Have the findings been sense-checked against credible alternative sources (incl. inconclusively)?	N	0	
Total	**15**		
Degree of agreement around the findings (max 9):			
Does more than one data source confirm the findings (within +/- 5%)?	N	0	
Do the key stakeholders/experts actively agree with the findings?	Y	3	
Has feedback from the key stakeholders been incorporated in the reporting of findings?	Y	3	
Total	**6**		

Figure 31 Data Robustness Assessment: NPWD Net Pack Fill POM

Evidence (Robustness and completeness, max 27):	Scoring		Evidence
Does the data cover the correct time-frame?	Y	3	
Does the data provide complete coverage?	most, not all	2	Missing unobligated tonnages
Has the data been sourced from credible, up-to-date sources?	Y	3	The EA is an official data source
Is the underlying data reasonably free from concerns (e.g. official data from the ONS)?	Y	3	
Have the findings been independently peer-reviewed?	Y	3	By the EA
Is the methodology/calculation reasonably free from concerns?	Y	3	
Have the methodology/calculations been independently checked (internally or externally)?	Y	3	By the EA
Is the quantitative evidence well rooted in a wider qualitative understanding of the issue?	Y	3	
Have the findings been sense-checked against credible alternative sources (incl. inconclusively)?	Y	3	Against total flow and gap between obligated and non-obligated is reasonable
Total	**26**		
Degree of agreement around the findings (max 9):			
Does more than one data source confirm the findings (within +/- 5%)?	N	0	
Do the key stakeholders/experts actively agree with the findings?	Y	3	
Has feedback from the key stakeholders been incorporated in the reporting of findings?	Y	3	
Total	**6**		

Figure 32 Data Robustness Assessment: NPWD Recycling

Evidence (Robustness and completeness, max 27):	Scoring		Evidence
Does the data cover the correct time-frame?	Y	3	
Does the data provide complete coverage?	most, not all	2	Missing unaccredited
Has the data been sourced from credible, up-to-date sources?	Y	3	
Is the underlying data reasonably free from concerns (e.g. official data from the ONS)?	Y	3	
Have the findings been independently peer-reviewed?	Y	3	
Is the methodology/calculation reasonably free from concerns?	Y	3	
Have the methodology/calculations been independently checked (internally or externally)?	Y	3	
Is the quantitative evidence well rooted in a wider qualitative understanding of the issue?	Y	3	
Have the findings been sense-checked against credible alternative sources (incl. inconclusively)?	Y	3	CPI
Total	**26**		
Degree of agreement around the findings (max 9):			
Does more than one data source confirm the findings (within +/- 5%)?	Y	3	CPI
Do the key stakeholders/experts actively agree with the findings?	Y	3	
Has feedback from the key stakeholders been incorporated in the reporting of findings?	Y	3	
Total	**9**		

Figure 33 Data Robustness Assessment: WDF Recycling

Evidence (Robustness and completeness, max 27):	Scoring		Evidence
Does the data cover the correct time-frame?	Y	3	
Does the data provide complete coverage?	Y	3	
Has the data been sourced from credible, up-to-date sources?	yes with some reservations	2	
Is the underlying data reasonably free from concerns (e.g. official data from the ONS)?	yes with some reservations	2	
Have the findings been independently peer-reviewed?	Y	3	
Is the methodology/calculation reasonably free from concerns?	yes with some reservations	2	
Have the methodology/calculations been independently checked (internally or externally)?	Y	3	
Is the quantitative evidence well rooted in a wider qualitative understanding of the issue?	Y	3	
Have the findings been sense-checked against credible alternative sources (incl. inconclusively)?	N	0	
Total	**21**		
Degree of agreement around the findings (max 9):			
Does more than one data source confirm the findings (within +/- 5%)?	N	0	
Do the key stakeholders/experts actively agree with the findings?	yes with some reservations	2	
Has feedback from the key stakeholders been incorporated in the reporting of findings?	Y	3	
Total	**5**		

Figure 34 Data Robustness Assessment: EfW

Evidence (Robustness and completeness, max 27):	Scoring		Evidence
Does the data cover the correct time-frame?	Y	3	
Does the data provide complete coverage?	N	0	
Has the data been sourced from credible, up-to-date sources?	more yes than no but equivocal	1	
Is the underlying data reasonably free from concerns (e.g. official data from the ONS)?	N	0	
Have the findings been independently peer-reviewed?	N	0	
Is the methodology/calculation reasonably free from concerns?	N	0	
Have the methodology/calculations been independently checked (internally or externally)?	yes with some reservations	2	
Is the quantitative evidence well rooted in a wider qualitative understanding of the issue?	N	0	
Have the findings been sense-checked against credible alternative sources (incl. inconclusively)?	N	0	
Total	**6**		
Degree of agreement around the findings (max 9):			
Does more than one data source confirm the findings (within +/- 5%)?	N	0	
Do the key stakeholders/experts actively agree with the findings?	more yes than no but equivocal	1	
Has feedback from the key stakeholders been incorporated in the reporting of findings?	Y	3	
Total	**4**		

Figure 35 Data Robustness Assessment: Unaccredited Recycling

Evidence (Robustness and completeness, max 27):	Scoring		Evidence
Does the data cover the correct time-frame?	Y	3	
Does the data provide complete coverage?	Y	3	
Has the data been sourced from credible, up-to-date sources?	with some reservations	2	
Is the underlying data reasonably free from concerns (e.g. official data from the ONS)?	Y	3	
Have the findings been independently peer-reviewed?	N	0	
Is the methodology/calculation reasonably free from concerns?	more yes than no but equivocal	1	
Have the methodology/calculations been independently checked (internally or externally)?	Y	3	
Is the quantitative evidence well rooted in a wider qualitative understanding of the issue?	Y	3	
Have the findings been sense-checked against credible alternative sources (incl. inconclusively)?	N	0	
Total	**18**		
Degree of agreement around the findings (max 9):			
Does more than one data source confirm the findings (within +/- 5%)?	N	0	
Do the key stakeholders/experts actively agree with the findings?	Y	3	
Has feedback from the key stakeholders been incorporated in the reporting of findings?	Y	3	
Total	**6**		

Appendix IV Grocery Retail Cross Reference

To sense-check the validity of the EPIC data for grocery retail, Valpak requested aggregated data from the EA for selected retailers. Table 1 selling data were requested for paper and card packaging handled in 2014 (2014 sales) for the following retailers:

- Tesco;
- Asda;
- Sainsbury;
- Morrisons;
- Iceland;
- Co-Op;
- Boots;
- M&S;
- Aldi;
- Lidl;
- Nisa; and
- Musgrave (Budgens).

These retailers were deemed to represent 85% of the UK grocery retail market, based on Kantar World Panel data (not publicly available). As such the EA data was scaled up to represent 100% of the UK market and the table below shows this grocery retail estimate.

Figure 36 Aggregated EA Grocery Retail Packaging Handled (2014)

	Paper and Card (k tonnes)
Grocery Retail	656[90]

EPIC data was scaled up to account for the above retailers (using market share information by volume sales for the four supermarkets' data used, provided by Kantar). Figure 37, below, compares the scaled-up EA figures to the scaled-up EPIC data.

Figure 37 Aggregated Grocery Retail Packaging Handled (2013)

	Paper and Card (k tonnes)
EA Grocery Retail	656[91]
EPIC Grocery Retail	578
Difference	78 (12%)

[90] *As reported in July 2015*
[91] *As reported in July 2015*

Figure 37 shows the tonnage difference between the scaled up EA grocery retail and EPIC grocery retail tonnage. The EPIC grocery retail tonnage is 12% lower than the EA data, which is a relatively small difference but could be significant. However, as Valpak's EPIC data includes only grocery related items from the retailers covered, whereas the EA data includes non-grocery items as well, which are likely to have more packaging per item (as identified in the non-grocery analysis carried out for this project), this could be one reason for the variation and justification for using the Valpak data. Additionally, Valpak has great confidence in the data they collate and submit and have been doing so for ten years. The project team was not able to access the raw data from the EA and therefore was not able to assess the confidence levels for this data, as a result a greater level of confidence is held within the EPIC data than that provided from the EA and as such this data was selected for use within the project.

Appendix V Retail Sensitivity Analysis

In order to assess total retail flow, including non-grocery retailers, analysis was completed on paper and card packaging tonnes per £bn turnover. The result showed that non-grocery paper and card packaging tonnes/£bn turnover is 122% of grocery paper and card packaging tonnes/£bn turnover, based on the average for a number of retailers.

Sensitivity analysis has been carried out to establish the impact on total flow if this percentage was 5 percentage points lower or higher. If non-grocery paper and card packaging tonnes/£bn turnover was 117% of that used in the grocery sector, total flow would be 5,219k tonnes (-0.7% below the final project estimate) and if non-grocery paper and card packaging tonnes/£bn turnover was 127% of that used in the grocery sector, total flow would be 5,288k tonnes (+0.7% higher than the final project estimate).

However the retailers used in the calculation account for 17% of reported obligated tonnage of paper and card packaging in 2014; the sample size allows 99% confidence that it represents the population as a whole with an error margin of 0.16%.

Appendix VI Manufacturing Sensitivity Analysis

In order to assess total manufacturing flow, data from Defra's 2009 C&I survey[92] was used, which covered both packaging and non-packaging paper and card flow. This data is relatively old however this is the best available data at the time of reporting. Cross checks with other data was not possible for this sector.

In order to estimate the amount that was packaging for the purposes of the study a proportion of 27% was used[93] for all sectors with the exception of 'wholesale' and 'transport and storage'. WRAP's 2003 assessment does not state confidence intervals therefore no sensitivity analysis can be made. However, the 40% assigned to 'wholesale' and 'transport and storage' was derived from a Zero Waste Scotland report covering motor, retail and wholesale waste[94]. This proportion was provided with confidence intervals and as such these have been used to carry out sensitivity analysis to assess the impact this would have on the final project estimate for paper and card packaging POM. Again, this is the best available data for this sector.

Based on the original report, it is estimated that there is 95% confidence that the proportion of paper and card that is packaging would fall between 34% and 47%. This range has been applied to the sector data and results in a total manufacturing flow of between 1,842k tonnes and 2,110k tonnes. This would result in the total paper and card POM ranging from 4,623k tonnes (3% lower than the final project estimate) to 4,893k tonnes (3% higher than the final project estimate).

[92] http://archive.defra.gov.uk/evidence/statistics/environment/waste/documents/commercial-industrial-waste101216.pdf

[93] *Based on WRAP 2003: Assessment of Quality Arising from Existing Paper Collection Methods against European Recovered Paper Grades listed in BS EN 643 http://www.amec-ukenvironment.com/downloads/pp_686.pdf*

[94] http://www.wrap.org.uk/sites/files/wrap/The%20compostion%20of%20waste%20from%20three%20sectors%20in%20Scotland.pdf

Appendix VII Auto Regression

Introduction

Two regression analyses were carried out for this project – one studying changes in obligated Net Pack Fill (representing tonnage POM), and the other investigating the quantity of paper and card PRNs/PERNs generated over time as a proxy for paper and card recycling rates.

The observations on the time series made at date t are denoted Y_t and the total number of observations is denoted T. The interval between the observations, that is, the difference between t and t+1, is one year.

The value of Y in the previous period is called its *first lagged value* or, more simply, its *first lag*, and is denoted Y_{t-1}. Its p^{th} lagged value (or p^{th} lag) is its value at *p* periods, which is Y_{t-p}. Additionally, Y_{t+1} denotes the value of Y one period in the future.

Net Pack Fill

The data used in this report was the obligated NPWD calculated using the Net Pack Fill formula[95] tonnage, rounded to the nearest 1,000 tonnes. Data was available reaching back to 1997, allowing for 18 observations in the data set. This is relatively few data points for a regression model, but the availability of packaging data and the annual nature of its reporting means that these observations provided the best possible model.

The first hypothesis investigated in this analysis was that Net Pack Fill tonnage is closely related to past Net Pack Fill tonnage. This was decided upon after looking at the data graphically. To test whether this was the case, a correlation test using Excel's Data Analysis tool between Net Pack Fill and the previous period's Net Pack Fill was conducted. This produced a correlation value of 0.94, supporting our hypothesis that these variables are very closely (and positively) related.

As a result of this test, an autoregression model was used for analysis. This is a tool used to project the levels of future Net Pack Fill based on past trends. A simple auto regression with one lag is abbreviated to AR(1), and is represented as shown:

$$\mathbf{Y_t = \beta_0 + \beta_1 Y_{t-1} + \mu_t}$$

Where β_0 is the intercept, β_1 is the effect of past data on current data, and μ_t is the error term. The AR(1) therefore uses last period's value to estimate next period's value. We can include this information by introducing additional regressors into the OLS function which are also lags of Y_t. The p^{th} order autoregressive model represents Y_t as a function of *p* of its lagged values. The number of lags, *p*, included in an AR(p) model, is called the

[95] https://npwd.environment-agency.gov.uk/Public/PublicReports.aspx

order, or lag length, of the regression. The p^{th} order autoregressive model (the AR(p)) can be represented as below:

$$\mathbf{Y_t = \beta_0 + \beta_1 Y_{t-1} + \beta_2 Y_{t-2} + \ldots + \beta_P Y_{t-P} + \mu_P}$$

For this analysis, three autoregressions were calculated using $Y_{t-1,}$ Y_{t-2} and Y_{t-3} as the dependent variables, extending to another period in each model. The optimum number of lags, or the value of *p,* needs to be decided upon. The trade-off is as follows: too few lags or regressors is potentially omitting valuable data from the more distant lagged values. However, if there are too many, there will be more coefficient calculations than necessary, which, in turn, will introduce additional estimation error into the forecasts. The way the optimum *p* number is calculated is by minimizing an "information criterion". The Bayes information criterion (BIC) is a common tool, which can be calculated as follows:

$$\mathbf{BIC(p) = \ln ((SSR(p)) / T) + (p+1) \ln T / T}$$

The first term calculates the Sum of the Squared Residuals and so necessarily decreases (or at least does not increase) as lags are added. This is because, as more regressors are added, more (or at least not fewer) is explained by the model (i.e. R^2 will increase). The second term is the number of estimated regression coefficients (the number of lags, p, plus one for the intercept) multiplied by the factor (lnT)/T. This increases as the number of lags is added and so these two opposing forces allow us to choose the p value, which minimizes the BIC. Therefore, the BIC measures the trade-off qualitatively described earlier.

When running the OLS regression when a lag is added, it is likely one fewer year's data can be used when calculating a coefficient. This is because, when running a regression, the number of dependent variable observations needs to be the same as the number of observations for each regressor. Therefore, if one lag is added, there is one fewer observation, as the oldest year's data cannot have an equivalent for the previous year (assuming all observations are used in the first regression).
The Bayes Information Criteria results are as follows:

p	SSR(p)/T	ln(SSR(p)/T)	(p+1)ln(T)/T	BIC (p)
1	14637.15798	9.591318641	0.34657359	9.937892232
2	4924.669973	8.502012541	0.54161004	**9.043622581**
3	5030.975782	8.523369237	0.75401638	9.277385617

The results show that the lowest BIC value, and therefore the optimal lag model, is the two lag model. Therefore, an AR(2) model was used in the forecasting. We assume the Ordinary Least Squares assumptions hold, and use this model in our forecasting. The AR(2) general form can be seen below:

$$\mathbf{Y_t = \beta_0 + \beta_1 Y_{t-1} + \beta_2 Y_{t-2} + \mu_t}$$

The regression was run in excel and produced the following function for obligated Net Pack Fill:

$$Y_t = 822.0275701 + 0.628912844\ Y_{t-1} + 0.152770728\ Y_{t-2}$$

The regression had a standard error of 75.38110843. This equation was used to calculate future obligated net pack fill by plugging in numbers from the most recent periods. To calculate the bounds, the common method of a 95% confidence interval around each projection was calculated using the regression standard error. However, it is recognised that the bounds will become less certain as we stretch further into the future.

An implicit assumption in this auto regression model is that past data is useful to predict the future, and therefore the wider economic climate will continue on current trends. If this was to be the case, the coefficients in the equation would change, leading to Net Pack Fill following a different trajectory.

Valpak identified a number of potential factors that could reduce the accuracy of this model, if they changed significantly in their trend over the next five years:

- GDP
- Internet sales
- Packaging lightweighting
- Material switches in packaging
- Availability and cost of raw materials – virgin or recycled content
- Population

This uncertainty implicit in the model is one of the difficulties of forecasting. The model should therefore be considered in light of the assumptions that are implicit in its forecasts.

Paper and Card Recycling

The data used in this report for Paper Recycling was the number of paper and card PRNs/PERNs generated, rounded to the nearest 1,000. This represented a proxy for total paper and card recycling, and it is expected that it will capture the trends in the industry. Data was available reaching back to 1998, allowing for 17 observations in the data set. This is relatively few data points, but the length of the PRN system being in place and the annual nature of the reports means that these observations provide the best current model to predict future PRNs/PERNs raised.

The first hypothesis investigated in this analysis was that the number of PRN/PERNs raised are closely related to past PRN/PERNs raised. This was decided upon after consulting the data graphically. To test whether this was the case, a correlation test using Excel's Data Analysis tool between PRNs and the previous period's PRNs was conducted. This produced a correlation value of 0.98, supporting our hypothesis that these variables are very closely (and positively) related.

Following this test, an auto regression model was used for analysis. This is a tool used to project the levels of PRNs in the future based on past trends. The typical first order

regression is abbreviated to AR(1), with 1 representing the number of lags included, and is represented as shown:

$$\mathbf{Y_t = \beta_0 + \beta_1 Y_{t-1} + \mu_t}$$

Where β_0 is the intercept, β_1 is the effect of past data on current data, and μ_t is the error term. The AR(1) uses last period's value to predict the current period's value, but this is ignoring potentially important data in the more distant past. We can include this information by introducing additional regressors into the OLS function which are also lags of Y_t. The p^{th} order autoregressive model represents Y_t as a function of *p* of its lagged values. The number of lags, *p*, included in an AR(p) model, is called the order, or lag length, of the regression. The p^{th} order autoregressive model (the AR(p)) can be represented as below:

$$\mathbf{Y_t = \beta_0 + \beta_1 Y_{t-1} + \beta_2 Y_{t-2} + \ldots + \beta_P Y_{t-P} + \mu_P}$$

Three autoregressions were calculated using $Y_{t-1,}$ Y_{t-2} and Y_{t-3} as the dependent variables, extending to another period in each model. The optimum number of lags, or the value of *p,* needs to be decided upon. The trade-off is as follows: too few lags or regressors is potentially omitting valuable data from the more distant lagged values. However, if there are too many, there will be more coefficient calculations than necessary, which, in turn, will introduce additional estimation error into the forecasts. The way the optimum *p* number is calculated is by minimizing an "information criterion". The Bayes information criterion (BIC) is a common tool, which can be calculated as follows:

$$\mathbf{BIC(p) = \ln((SSR(p)) / T) + (p+1) \ln T / T}$$

The first term calculates the Sum of the Squared Residuals and so necessarily decreases (or at least does not increase) as lags are added. This is because, as more regressors are added, more (or at least not fewer) is explained by the model (i.e. R2 will increase). The second term is the number of estimated regression coefficients (the number of lags, p, plus one for the intercept) multiplied by the factor (lnT)/T. This increases as the number of lags is added and so these two opposing forces allow us to choose the p value, which minimizes the BIC. Therefore, the BIC measures the trade-off qualitatively described earlier.

When running the OLS regression when a lag is added, it is likely one fewer year's data can be used when calculating a coefficient. This is because, when running a regression, the number of dependent variable observations needs to be the same as the number of observations for each regressor. Therefore, if one lag is added, there is one fewer observation, as the oldest year's data cannot have an equivalent for the previous year (assuming all possible observations are used in the first regression).

The Bayes Information Criteria results are as follows:

p	SSR(p)/T	ln(SSR(p)/T)	(p+1)ln(T)/T	BIC
1	13504.99	9.51081423	0.36107336	**9.871887589**
2	11116.45	9.31618155	0.56551229	9.881693831

3	9323.77	9.14032234	0.78921519	9.929537529

The results show that the lowest BIC value, and therefore the optimal lag model, was the one lag model. Therefore, an AR(1) model was used in the forecasting. We assume the Ordinary Least Squares assumptions hold, and use this model in our forecasting. The general form AR(1) model can be seen below:

$$\mathbf{Y_t = \beta_0 + \beta_1 Y_{t-1} + \mu_t}$$

The regression was run in excel and produced the following function for obligated Net Pack Fill:

$$\mathbf{Y_t = 174.1982116 + 0.971514584\ Y_{t-1}}$$

The regression had a standard error of 120.2897662. This equation was used to calculate future obligated net pack fill by plugging in numbers from the most recent periods. To calculate the bounds, the common method of a 95% confidence interval around each projection was calculated using the regression standard error. However, it is recognised that the bounds will become less certain as we stretch further into the future.

An implicit assumption in this auto regression model is that past data is useful to predict the future, and therefore the wider economic climate will continue on current trends. If this was to be the case, the coefficients in the equation would change, leading to PRN tonnage following a different trajectory.

The steering group identified a number of potential factors that could reduce the accuracy of this model, and instead could lead to a tapering of recycling rates to 2020, if they changed significantly in their trend over the next five years:

- GDP
- Increased difficulty in increasing recycling rates as you near 100% (i.e. after you have reached the 'low hanging fruit'.)
- Social deprivation index
- Legislation changes
- Communication and engagement campaigns
- Population demographic
- Recyclate Price
- POM

This uncertainty implicit in the model is one of the difficulties of forecasting. The model should therefore be considered in light of the assumptions that are implicit in its forecasts.

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