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**Abstract** It is the overarching aim of the circular economy to maintain the value of products, materials, and resources for as long as possible, and the re-use of packaging can play an important role in achieving this. Nevertheless, reliable information about reusable packaging in Europe is lacking. To address such a gap, this paper proposes a methodology to collect data on packaging re-use, aimed at carrying out some preliminary assessment. This methodology can be applied in different geographical contexts (i.e., in different countries) and allows the creation of an inventory of comparable data for legislative compliance and statistical purposes. The suggested methodology has been applied to the Italian context, as a case study, resulting in a qualitative and quantitative assessment of the practice of packaging re-use in Italy. The emerged criticalities and limitations are finally discussed, and recommendations are given to get reliable and representative data.

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**Keywords (separated by '-')** Re-use - Rotation - Packaging - Circular economy - Italy

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## Packaging re-use: a starting point for its quantification

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### Abstract

It is the overarching aim of the circular economy to maintain the value of products, materials, and resources for as long as possible, and the re-use of packaging can play an important role in achieving this. Nevertheless, reliable information about reusable packaging in Europe is lacking. To address such a gap, this paper proposes a methodology to collect data on packaging re-use, aimed at carrying out some preliminary assessment. This methodology can be applied in different geographical contexts (i.e., in different countries) and allows the creation of an inventory of comparable data for legislative compliance and statistical purposes. The suggested methodology has been applied to the Italian context, as a case study, resulting in a qualitative and quantitative assessment of the practice of packaging re-use in Italy. The emerged criticalities and limitations are finally discussed, and recommendations are given to get reliable and representative data.

**Keywords** Re-use · Rotation · Packaging · Circular economy · Italy

### Introduction

The transition to a more circular economy, where the value of products, materials, and resources is maintained for as long as possible, and the generation of waste is minimized, is an essential contribution to the EU's efforts to develop a sustainable, low carbon, resource efficient, and competitive economy [1].

Re-use means any operation by which products or components are used again for the same purpose for which they were conceived [2]. Packaging means all products used for the containment, protection, handling, delivery, and presentation of goods, from raw materials to processed goods, from the producer to the user or the consumer [3]. Despite packaging re-use playing a central role in the circular economy as a waste prevention activity [1], systematic quantitative information is lacking at the EU level, with specific data

about reusable packaging not being reported in EU-statistics (such as Eurostat). Golding [4] and Tsiliyannis [5] report some examples and data on re-use practices in Europe. However, they are not up-to-date, being referred to the end of the 1990s. A similar situation is observed in Italy. The only data about packaging re-use in Italy currently published refer to the number of annual rotating packaging items [6, 7], but they are very preliminary, and affected by uncertainty and simplification.

For what concerns the scientific literature, some efforts were devoted to the identification of a method to evaluate the performance of packaging re-use systems. Several proposals were put forward, such as the number of rotation and the re-use ratio considered by the international standard prCEN/TR 1450:2004 [8], the maximum re-use lifetime [9], and the total number of trips [10], until the more complex combined re-use/recycling rate index proposed by Tsiliyannis [9]. Particular attention was also given to the social aspects that lead to increased re-use behavior, such as knowledge and communication in favor of re-use, social norms, and availability of reusable packaging [11].

The lack of data about packaging re-use is a very critical point also in the framework of the new proposals of amending Directive 2008/98/EC on waste [12] and of amending Directive 94/62/EC on packaging and packaging waste [13], where one of the proposed actions is to increase the

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58 preparing for re-use and recycling targets for packaging  
59 waste, and the proposed calculation method includes both  
60 the municipal waste prepared for re-use as well as the re-  
61 used products and components.

62 The aim of this paper is twofold: to propose a methodol-  
63 ogy to collect data on packaging re-use that can be applied  
64 in different contexts to make them comparable for legislative  
65 compliance and statistical purposes; to apply such meth-  
66 odology to Italy, resulting in a qualitative and quantitative  
67 assessment. The emerged criticalities and limitations are  
68 finally discussed. It is our ambition, with the present work,  
69 to pave the road to similar assessments in other European  
70 Member States, to integrate the data on packaging recycling  
71 and recovery with those on re-use and have a more robust  
72 picture of this practice in the overall Europe.

### 73 Data collection method

74 In this chapter, we present our proposal of a method to col-  
75 lect data on reusable packaging.

### 76 Creation of the inventory

77 The first step is the creation of the inventory for the geo-  
78 graphical context under study. To this aim, the following  
79 actions should be performed (Fig. 1):

- 80 1. Identification of the reusable packaging.
- 81 2. Qualitative characterization. For each type of packaging,  
82 one should collect information about:
  - 83 • the material (steel, aluminum, cardboard, wood, plas-  
84 tic, and glass),

- the business application (“business to business”— 85  
B2B—or “business to consumer”—B2C—mar- 86  
kets), 87
  - the need of reconditioning and the type of recondi- 88  
tioning process, 89
  - the sector of use, 90
  - the main basic characteristics (such as the average 91  
size and/or average weight), 92
  - the type of service on which it is managed (e.g., 93  
rental vs. purchase), 94
  - if it is a primary or secondary or tertiary packag- 95  
ing. 96
3. Quantitative characterization. For each type of identified 97  
packaging, data about the following parameters should 98  
be collected, typically on an annual basis: 99
    - population: the total number (or weight) of items 100  
[8]; it can be assumed as the material stock avail- 101  
able, 102
    - number of rotations: the number of times the packag- 103  
ing is used before it is sent to disposal/recycling [8], 104
    - rotated packaging: the population multiplied by the 105  
number of rotations; it can be assumed as the mate- 106  
rial flow, 107
    - newly manufactured packaging, 108
    - prepared for re-use packaging, 109
    - overall lifetime: the average age of the packaging [4]. 110

111 Depending on the type of packaging, a rotation may  
112 take place with or without any operation of recondi-  
113 tioning. Moreover, the rotation may happen before or after the  
114 product has become waste (the latter implying a “prepar-  
115 ing for re-use” activity as defined in the Directive 2008/98/  
116 EC). The amount of prepared for re-use packaging refers to  
117 those types of packaging that have become waste and then  
118 enter again the market as a product after a preparing for  
119 re-use process (i.e., checking, cleaning, or repairing opera-  
120 tions). The data about the newly manufactured packaging  
121 usually comprehend both the reusable and the single-use  
122 packaging; therefore, an effort must be done in the estima-  
123 tion of the amount of reusable packaging out of the total.

124 If the population is not directly available, it can be calcu-  
125 lated in two different ways, according to the data availability:

1. 
$$\frac{\text{rotated packaging}}{\text{number of rotations}}$$
 126

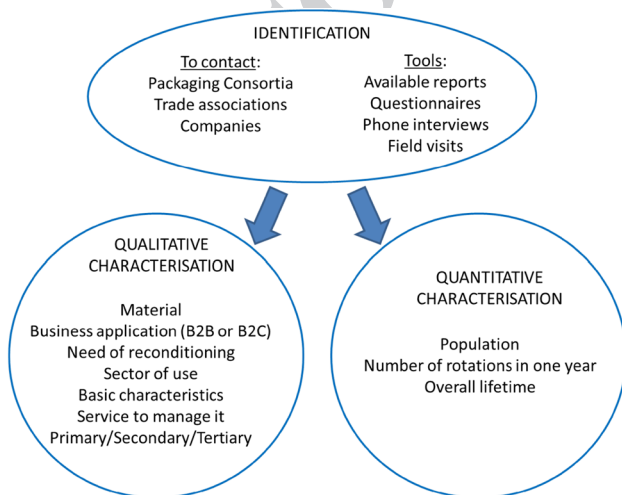


Fig. 1 Suggested procedure for the data collection

$$2. \frac{\text{newly reusable manufactured packaging} + \text{prepared for re-use packaging}}{\text{number of rotations}}$$

The collection of such data allows the creation of an inventory about the practice of packaging re-use in a certain geographical context and to highlight temporal trends, i.e., types of packaging that were re-used in the past but are not anymore, as well as newly introduced types of reusable packaging.

## Sources of information

Different sources of information can be used to collect the inventory data.

It is advised to contact, first of all, the national consortia for packaging and material recycling, if existing, as well as the specific trade associations, to check which data are already available about reusable packaging. For those types of packaging that are not monitored at all, it is necessary to identify the companies that produce or utilize them. These companies should be contacted through mail surveys or by phone interview. The right identification of the companies to contact is of primary importance to collect reliable information. For such a reason, we suggest to identify these companies in cooperation with the local network for packaging and material recycling or the trade associations that should have a good knowledge of the market. For example, for those packages which target a specific sector of usage (e.g., the plastic bottle carriers), it should be quite easy to identify and thus interview both the companies that produce and those which utilize the packages. For other types of packaging that can be used in several sectors (e.g., the plastic pallets), the identification of all possible users is much more difficult. In this case, the producers and the traders should be interviewed.

The minimum number of companies to interview can be defined by means of Cochran's sample size formula, as suggest by Bartlett et al. [14]. The sample size can be calculated as  $(t^2 \times s^2) / d^2$ , where  $t$  is the  $t$  value corresponding to the accepted level of risk that true margin of error may exceed the acceptable one (the so-called alpha level),  $s$  is the estimate of the standard deviation (continuous data) or the variance (categorical data) in the population, and  $d$  is the acceptable margin of error for the mean estimation. The result of the formula must be then divided by the expected response rate, which can be really low in the case of mail survey (20% can be regarded as a good response rate in industrial mail surveys, based on the experiences of Raeley [15]). The main problem of the application of Cochran's formula is the estimation of the population variance, which is a priori unknown in most of the cases and cannot be calculated a posteriori. When the variance of the population cannot be

estimated, an alternative to Cochran's formula is to define the minimum percentage of answers. This can be done on the basis of the sales volume and/or of the number of companies. We suggest assuming representative only the data from those questionnaires/interviews which were answered by a percentage of companies greater than 20% [15] and covering at least 50% of the market in terms of company turnover. These targets should guarantee the representativeness of the collected data, avoiding to accept as representative of the whole investigated sector data provided by many companies but of small dimension or, on the contrary, by a few big companies covering most of the market.

Finally, field visits at selected plants should be organized, to focus on specific situations of interest (for example, to collect detailed information and data about the reconditioning processes).

Based on the data source for the main quantitative parameters, we suggest classifying the packages in three groups:

- A. packaging directly monitored by the local consortia for packaging and material recycling or trade associations;
- B. packaging for which the population can be calculated on the basis of a combination of information from companies and from the local consortia for packaging and material recycling or trade associations;
- C. packaging not monitored by the local consortia for packaging and material recycling or trade associations and for which data come directly from companies collected through questionnaires and/or interviews.

## Updating of the information

Some recommendations can be given to update the information over the years for the three groups of packaging (A, B, and C) identified in "Sources of information".

For packaging belonging to group A, quantitative data should be acquired each year by the local consortium for packaging and material recycling or the trade associations that monitor them.

For packaging belonging to group B, data coming from the local network for packaging and material recycling or the trade associations should be updated every year. Parametric or specific data acquired from companies (excluded those data regarding selling volume) could instead be assumed constant for a certain number of years (say for example three). Then an update of these parameters is also recommended.

219 For packaging belonging to group C, quantitative data  
220 are collected through questionnaires/interviews. Since this  
221 activity is very time consuming and expensive, we suggest  
222 to update the information every 2–3 years.

## 223 Application of the proposed method 224 to the Italian context

**AQ1** 225 The methodology described in “Data collection method”  
226 was applied to the Italian context.

## 227 Sources of information

228 First of all, we identified reports of relevance for the study,  
229 drafted by the Italian network on packaging and material  
230 recycling, i.e., Conai. Conai is the Italian National Pack-  
231 aging Consortium, a private non-profit organization estab-  
232 lished in 1997 with the aim of promoting separate collection,  
233 sorting, recycling, and recovery of packaging waste in Italy  
234 [16]. Conai co-ordinates the activities of the six Material  
235 Consortia: *RICREA* for steel, *CiAl* for aluminum, *Comieco*  
236 for paper, *Rilegno* for wood, *Corepla* for plastic, and *CoReVe*  
237 for glass [16]. Thanks to the information provided by the  
238 Material Consortia and those gathered by web searches, the  
239 main trade associations involved with reusable packaging  
240 were identified and contacted: FIRI (the federation of bar-  
241 rels reconditioning plants), ANFIMA (the national associa-  
242 tion of manufacturers of metal packaging), Assogastecnici  
243 (the national association of industrial and medical gases),  
244 Assogasliquidi (the national association of liquefied petro-  
245 leum gases), EURepack (the European Reusable Packaging  
246 and Reverse Logistics Consortium), Assobirra (the national  
247 association of beers producers and maltsters); Assobibe (the  
248 national association of the soft drink producers), and Fed-  
249 erdistribuzione (the national federation of the retail distribu-  
250 tion sector).

251 Moreover, five questionnaires were prepared (Supple-  
252 mentary material section 1) with the aim to collect repre-  
253 sentative information regarding some reusable packages  
254 not directly monitored by the respective material consortia.  
255 The contacted companies were selected in collabora-  
256 tion with the material consortia and the trade association.  
257 As Cochran’s sample size formula was not applicable, the  
258 minimum percentage of answer to consider representative  
259 the collected data was calculated on the basis of the num-  
260 ber of companies and their turnover. The first questionnaire  
261 (*QUEST wood*) has targeted two types of wooden reusable  
262 packaging (wooden collars and collapsible boxes), and it  
263 was sent to the 154 companies affiliated with *Rilegno*, which  
264 represents almost the whole Italian sector of producers and  
265 traders of such types of packaging. The choice to send the

questionnaire to the producers, instead of the users, was due  
to the technical impossibility to identify all the users of the  
investigated packages. The second questionnaire (*QUEST steel*)  
was devoted to three types of steel reusable packaging  
(pallets, bins and containers, barrels for cooking oil) and was  
sent to the 406 companies affiliated with *RICREA*, which  
represents almost the whole sector of producers and traders  
of such packages. The third questionnaire (*QUEST retail*)  
was prepared to get information about some types of pack-  
aging re-used in the large-scale retail trade (durable bags,  
containers for detergents, and reusable cardboard boxes),  
and it was sent to 34 companies affiliated with “Federdis-  
tribuzione”. The fourth questionnaire investigates the wood  
pallets (*QUEST pallet*) and was sent to 60 companies that,  
according to Conai, have the ownership of the pallets and  
to the first 206 largest companies affiliated with Conai and  
that are potential users of the pallets. The fifth question-  
naire (*QUEST layer pads*) investigates the polypropylene  
(PP) layer pads and was sent to 274 companies identified  
by Conai as the potential national producers, to 58 compa-  
nies identified by Conai as the possible users (including the  
glassmakers), and to 332 companies identified by Conai as  
the Italian bottlers of beers and water (other possible users  
of the PP layer pads).

For those reusable packages with a limited market (for  
example, the aluminum gas cylinders for CO<sub>2</sub>, the steel  
barrels for food products, and the wood rent pallets), we  
preferred to carry out phone interviews instead of ques-  
tionnaires (see supplementary material section 2 for more  
details). As for the questionnaires, the selection of the com-  
panies to contact was performed with the cooperation of the  
material consortia or the trade associations.

Finally, field visits at selected plants allowed to collect  
detailed information and data about the reconditioning  
processes of three types of packaging: barrels for chemical  
and petrochemical products, collapsible crates and mini-  
bins for fruits and vegetables, and returnable glass bottles.  
These were chosen based on the complexity of the pro-  
cess that might imply an important environmental impact,  
e.g., due to the use of chemicals or because it is energy- or  
water-intensive.

## Results

### Identification of types of re-used packaging and qualitative characterization

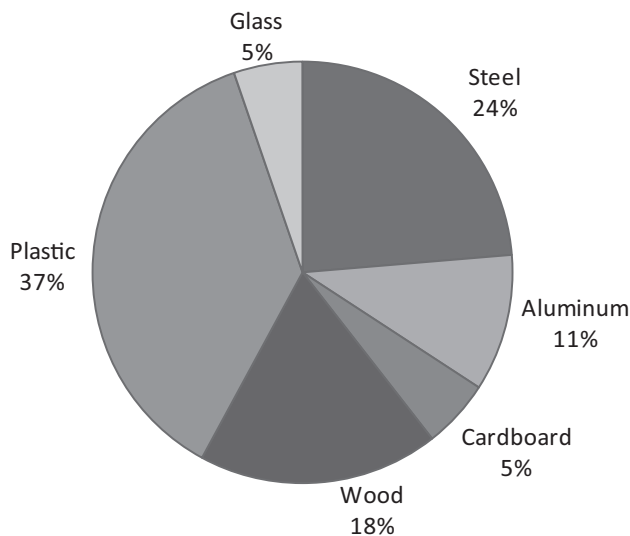
Table 1 shows all the types of packaging re-used in Italy that  
were identified during the survey. Supplementary material  
(sections 3 and 4) discusses them in detail.

Figure 2 shows the percentage composition of the types  
of packaging identified in the analysis in terms of material  
(i.e., steel, aluminum, cardboard, wood, plastic, and glass).

**Table 1** Types of packaging identified in the survey

Material	Types of packaging
Steel	Barrels for chemical and petrochemical products, barrels for food products, barrels for beer, barrels for cooking oil, cages of IBCs, pallets of IBCs, other pallets, gas cylinders, bins and containers
Aluminum	Pallets, gas cylinders for CO <sub>2</sub> , other gas cylinders, dewars
Cardboard	Octabins, boxes
Wood	Pallets, collars, reels, collapsible boxes, non-collapsible boxes, cages, platforms
Plastic	Bottles of IBCs, drums, pallets of IBCs, other pallets, collapsible crates and mini-bins for fruits and vegetables, bottle carriers, polypropylene layer pads, containers for detergents, big bottles for water, pallet boxes, durable bags, octabins, collars, bins
Glass	Bottles for water and soft drinks, bottles for beer

IBC's intermediate bulk containers



**Fig. 2** Percentage distribution of the types of packaging identified in the analysis in terms of material

316 Out of 38 types of re-used packaging, most of them are made  
 317 of plastic (14, i.e., 37%), followed by steel with 9 types (i.e.,  
 318 24%) and wood with 7 types (i.e., 18%).

319 Regarding the current trends, we found that wooden  
 320 boxes that used to be re-used in the fruit and vegetable sector  
 321 are nowadays a single-use packaging, for sanitary reasons.  
 322 Moreover, plastic octabins and plastic collars are two recent  
 323 types of reusable packaging that can replace cardboard  
 324 octabins and wooden collars, respectively.

325 Plastic bags are used only in the B2C market. Five types  
 326 of packaging (i.e., steel gas cylinders, gas cylinder for CO<sub>2</sub>,  
 327 other gas cylinders in aluminum, glass bottles for water and  
 328 soft drinks, and bottle carriers) are used both in the B2B  
 329 and in the B2C markets. All the others are used only in the  
 330 B2B market.

331 Collapsible crates and mini-bins for fruits and vegetables  
 332 are managed only through a rental service. A rental service

exists also for wooden pallets, plastic pallets, and plastic 333  
 pallet boxes, even if these types of packaging can also be 334  
 sold to the users. 335

In terms of sector of use, we can distinguish between the 336  
 food and beverage sector, accounting for 39% of the total 337  
 types of packaging, and the other sectors, accounting for 338  
 68%. The sum is higher than 100% since some types of pack- 339  
 aging (e.g., the pallets) are used in both sectors. 340

A more complex picture arises when trying to distinguish 341  
 between primary and secondary/tertiary packaging. By bear- 342  
 ing in mind that primary packaging are those in direct con- 343  
 tact with the goods and destined to their final delivery, this 344  
 applies to most of aluminum and glass-based reusable pack- 345  
 aging. Wood is mostly used for secondary/tertiary packag- 346  
 ing, as well as paper. Plastic and steel showed a widespread 347  
 range of applications, including both primary and second- 348  
 ary/tertiary uses. 349

34% of the identified types of packaging always need a 350  
 reconditioning process before being re-used, whereas 47% 351  
 are generally re-used without any type of cleaning or repair- 352  
 ing process. For the remaining types of packaging (i.e., 353  
 18%), the actual need of reconditioning depends on the 354  
 conditions of the packaging after its use: this is the case, for 355  
 example, of wooden pallets or steel barrels for food products. 356

### Quantitative characterization 357

The identified reusable packages were classified on the 358  
 basis of the source of the main information, as suggested in 359  
 "Sources of information" (Table 2). 360

It was found that packaging re-use is scarcely controlled 361  
 by material consortia and trade associations: only 36.5% of 362  
 the identified types of packaging were included in group 363  
 A. This is due to a number of reasons, first of all the fact 364  
 that priority has been given so far to recycling and recov- 365  
 ery; the fact that re-use is an operation carried out at the 366  
 boundary between product and waste, with different formal 367

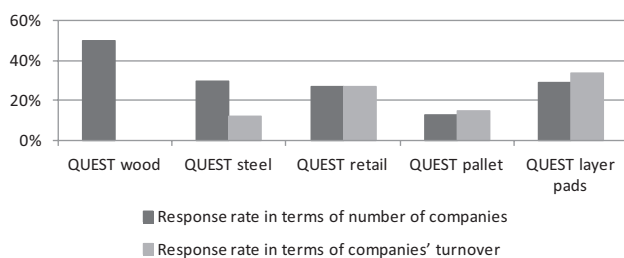


**Table 2** Subdivision of the reusable packaging types according to the source of data

Material	Packaging type	Data source <sup>a</sup>
Steel	Barrels for chemical and petrochemical products; cages and pallets of IBCs; barrels for food products; gas cylinders	A
	Barrels for beer	B
	Barrels for cooking oil; other pallets; bins and containers	C
Aluminum	Pallets; gas cylinders for CO <sub>2</sub> ; dewars	C
	Other gas cylinders	A
Cardboard	Octabin; boxes	C
Wood	Pallet (not rent); reels	A
	Rent pallet; collars; collapsible boxes; cages; platforms; non-collapsible boxes	C
Plastic	Drums; bottles and pallets of IBCs; collapsible crates and mini-bins for fruits and vegetables; pallet boxes (not rent)	A
	Bottle carriers	B
	Containers for detergents; big bottles for water; other pallets (not rent); durable bags; octabin; collars; bins; other pallets (rent); rent pallet boxes; polypropylene layer pads	C
Glass	Bottles for water and soft drinks; bottles for beer	A

IBC's intermediate bulk containers

<sup>a</sup>(A) Packaging monitored by consortia or associations; (B) packaging of which the authors have estimated the annual population on the basis of information available from consortia or associations; (C) packaging not monitored by consortia or associations and for which estimates were not feasible, i.e., packaging for which the data comes directly from companies



**Fig. 3** Response rate of the five questionnaires. For “QUEST wood”, data about the companies’ turnover were not available

368 recognitions also plays a role. Moreover, even when an  
369 attempt in monitoring the re-use is done, data are seldom  
370 published.

371 Most types of packaging were included in group C.  
372 Unfortunately, the response rate of questionnaires and  
373 phone interviews was lower than expected and not enough  
374 to consider the data robust and representative. In no case, the  
375 response rate based on the number of companies was greater  
376 than 20% and, at the same time, the response rate based  
377 on the companies’ turnover was greater than 50% (Fig. 3).  
378 Consequently, the data for the packaging belonging to group  
379 C are not reported.

380 Data collected for the groups A and B, together with the  
381 respective sources, are reported in Tables 3 and 4. They refer  
382 to year 2014, unless otherwise specified.

### 383 Estimation of packaging re-use in Italy

384 The application of the methodology proposed in Sect. 2  
385 to the Italian context would result in the estimation of the

re-using of packages in Italy. To do this, for each type of  
packaging, the “population” in 2014, i.e., the total number  
or weight of that packaging type in the whole re-use  
system, should be quantified.

Looking at Tables 3 and 4, one can realize that unfortunately  
for many types of packaging some information are missing  
and thus their population cannot be calculated. The types of  
packaging for which we were able to identify the population  
for year 2014 are as follows: steel gas cylinders for technical  
gases, other gas cylinders in aluminum, plastic collapsible  
crates and mini-bins for fruits and vegetables, glass bottles  
for water, glass bottles for beer, steel barrels for beer, and  
plastic bottle carriers. Indeed, for some of them, it was not  
possible to estimate both the mass and the number of items,  
because of the lack of specific information.

## 402 Discussion

The application of the proposed methodology to the Italian  
context allowed to draft a preliminary picture of packaging  
re-use in this country. The types of packaging that are  
re-used were identified along with qualitative information  
about their main basic characteristics, business application,  
the possible reconditioning process applied, and the type of  
service on which there are managed.

However, several critical issues were revealed, mainly  
associated with the difficulty to gather representative/reliable  
quantitative data:

**Table 3** Quantitative data for packaging belonging to group A (year 2014)

Material and type of packaging	Packaging prepared for re-use	Packaging newly manufactured	Rotated packaging	Population	Number of rotations; (overall lifetime)
Steel: barrels for chemical and petrochemical products	6527 t <sup>a</sup>				7 over a lifetime <sup>b</sup>
Steel: barrels for food products		12,000 t, of which 50% re-used <sup>c</sup>			2–5 over a lifetime <sup>c</sup>
Steel: cages of IBCs	7918 t <sup>a</sup>				
Steel: pallets of IBCs	2310 t <sup>a</sup>				
Steel: gas cylinders				7.2 million gas cylinders for technical gas (327,000 t) <sup>d</sup> 27.5 million gas cylinders for LPG gas (404,770 t) <sup>e</sup>	(overall lifetime > 50 years) <sup>d,e</sup>
Aluminum: other gas cylinders				800,000 pieces (34,640 t) <sup>d</sup>	(overall lifetime > 50 years) <sup>d</sup>
Wood: pallets (not rent)	647,251 t	1,245,784 t <sup>f,g</sup>			2.2–4.5 over a lifetime (overall lifetime of EPAL pallets: 5–6 years) <sup>f</sup>
Wood: reels		24,297 t of which 50% re-used <sup>f</sup>			From 0 to 6 over a lifetime <sup>h</sup>
Plastic: drums	1300 t <sup>a</sup>				
Plastic: bottles of IBCs	5765 t <sup>a</sup>				From 3 to 5 over a lifetime <sup>b</sup>
Plastic: pallets of IBCs	348 t <sup>a</sup>				
Plastic: collapsible crates and mini-bins for fruits and vegetables			280 million crates + 518,000 mini-bins <sup>i</sup>	41–48 million crates <sup>i</sup>	6–7 per year (overall lifetime: 5–20 years) <sup>i</sup>
Plastic: pallet boxes (not rent)					
Glass: bottles for water			190,933 t <sup>j</sup>	47,733 t <sup>j</sup>	3–5 per year 5–40 over a lifetime <sup>k</sup>
Glass: bottles for beer			31,725 t <sup>j</sup> 125 million bottles <sup>l</sup>	5288 t <sup>j</sup> 35.6 million bottles <sup>l</sup>	2–4 per year (overall lifetime: 5–7 years) <sup>k</sup>

<sup>a</sup>Data provided by Conai<sup>b</sup>Data provided by FIRI<sup>c</sup>Data provided by ANFIMA<sup>d</sup>Data provided by Assogastecnici<sup>e</sup>Data provided by Assogasliquidi. This value refers to the year 2013<sup>f</sup>Data provided by Rilegno<sup>g</sup>The percentage of reusable packaging is not known<sup>h</sup>Primary data resulting from the questionnaires and the phone interviews<sup>i</sup>Data provided by EURepack and some companies operating in the sector<sup>j</sup>Data provided by Co.Re.Ve.<sup>k</sup>Primary data resulting from the phone interviews<sup>l</sup>This value was calculated by the authors to add information to the data expressed in tons. It was calculated based on information about the sale of beer, the annual rotated bottles, and the number of rotations per year provided by Assobirra and Assobibe (personal communication) and referring to the two main brands which sell beer in re-used glass bottles in Italy. These data were then extended to the overall *Horeca* (Hotel/Restaurant/Café) sector (1,179,000 hl of beer sold in re-used glass bottles in the year 2014)

**Table 4** Quantitative data for packaging types belonging to group B (year 2014)

Material and type of packaging	Rotated packaging	Population	Number of rotations; (overall lifetime)
Steel: barrels for beer	9.1 million barrels (84,800 t) <sup>a</sup>	2.8 million barrels (25,800 t) <sup>a</sup>	3.3 per year (overall lifetime: 10–30 years) <sup>b</sup>
Plastic: bottle carriers	13.4 million carriers for the beer sector <sup>c</sup>	Water sector: 39.6 million carriers <sup>d</sup> Beer sector: 3.7 million carriers <sup>c</sup>	Water sector: 20–30 over a lifetimes or 5–10 per year (overall lifetime: 2–3 years) <sup>e</sup> Beer sector: 2–5 per year (overall lifetime: 7–8 years) <sup>b</sup>

<sup>a</sup>This value was calculated by the authors starting from the information about the sale of beer, the rotated barrels, and the number of rotations per year provided by *Assobirra* (personal communication) and referring to the three main brands which sell beer in Italy (covering about 70% of the market). The result was then extended to the overall *Horeca* (Hotel/Restaurant/Café) sector (2,445,000 hl of beer sold in barrels in the year 2014)

<sup>b</sup>Data provided by Assobirra

<sup>c</sup>This value was calculated by the authors considering the hectolitres of beer sold in returnable glass bottles (i.e., 1,179,000 hl in 2014) and the average ratio "number of carriers/hl" provided by the two main brands which sell beer in Italy in returnable glass bottle

<sup>d</sup>This value was calculated by the authors on the basis of the population of returnable glass bottles for water in the *Horeca* sector in the year 2014 (personal communication with *Co.Re.Ve.*) and of the information about the ratio "number of carriers/number of bottles" provided by five Italian brands which sell water in returnable glass bottles

<sup>e</sup>Data resulting from the phone interviews

- 413 1. Only few types of re-used packages are monitored by the material consortia, and in particular those for which  
414 a discount in the recycling fee (i.e., the fee imposed on  
415 new purchases of packages for their future recycling)  
416 is granted when the re-use activity is demonstrated. In  
417 the absence of this economic incentive, the companies  
418 are not willing to provide information about their re-use  
419 activity to the material consortia. 441  
420  
421 2. The collaboration of the companies contacted by means  
422 of mail surveys or phone interviews was quite modest,  
423 resulting in low response rates. For some types of pack-  
424 aging, companies were not willing to provide informa-  
425 tion on their packaging population because it is con-  
426 sidered a sensitive data (this is the case, for example,  
427 of the pallet renting). In other cases, it was because the  
428 packaging re-use is not monitored within the company  
429 since, at the moment, it is not officially accounted as  
430 avoided waste production. 442  
431 3. The companies contacted by means of mail surveys were  
432 not always correctly identified (i.e., the company does  
433 not commercialize or use the investigated packaging),  
434 despite selection was performed in collaboration with  
435 the material consortia and the trade associations. 443  
436 4. For some types of packaging (for example, wood pallet),  
437 the reconditioning processes are often carried out before  
438 it has become waste. In such a situation, data on re-use  
439 are not included in official statistics and unlikely they  
440 can be gathered from companies. 444
5. In some cases, the companies formally classify their  
packaging as a general product (and not as a packag-  
ing), meaning that they are not obliged to provide any  
information to Conai. 445  
To achieve more reliable/representative data, it is thus  
necessary: 446
- 447 1. First of all, to promote the monitoring of the packaging  
448 re-use practice within the companies. As suggested by  
449 Golding [5], the mandatory registration of the produc-  
450 tion quantities should be introduced at the company level  
451 for each type of packaging. Moreover, the introduction  
452 of an indelible mark, on each reusable packaging part,  
453 reporting the production date and each following filling  
454 operation could help to track the number of rotation and  
455 the overall lifetime of the packaging. 447
  - 456 2. Second, to promote companies collaboration, by encour-  
457 aging them to share data about product flows and pack-  
458 aging re-use. This could be achieved by introducing  
459 some forms of incentives (e.g., in terms of discount in  
460 the recycling fee, as already happens for some types of  
461 packaging). Communication of data about packaging  
462 re-use should become a standard as already happens for  
463 material recycling and recovery. 448

464 **Conclusions**

465 Re-use of packaging can play a non-negligible role in  
466 increasing the lifetime of materials, preventing the amount  
467 of generated waste, and at the end reducing the need for final  
468 sinks. Still, such a role needs to be better and more robustly  
469 assessed quantitatively.

470 A methodology was then proposed to assess the packag-  
471 ing re-use activity to provide some uniform data to be used  
472 for statistical purposes, as well as for checking the legislative  
473 compliance on recycling set by the EU.

474 The methodology was then applied to the Italian con-  
475 text, resulting in a preliminary qualitative and quantitative  
476 assessment of the practice of packaging re-use in Italy. In  
477 particular, we identified 38 types of packaging that are cur-  
478 rently re-used in the Italian territory. For each of them, we  
479 identified the constituent material, the market of use, the  
480 sector of use, the main basic characteristics (such as aver-  
481 age size and/or weight), the possible reconditioning process  
482 applied, and the type of service based on which is run (e.g.,  
483 rental). For what concerns the quantitative data, we have  
484 found many difficulties even trying to combine the infor-  
485 mation arising from different sources (i.e., official reports,  
486 web search, direct contacts with companies, interviews with  
487 experts, and field visits).

488 We have carried out the analysis for Italy, but it would  
489 be useful to perform a similar assessment also in the other  
490 European Member States, to integrate the data on recycling  
491 and recovery with those on packaging re-use and have a  
492 picture of this practice in the overall Europe. This is a very  
493 critical point in view, for example, of the new proposals  
494 of amending Directive 2008/98/EC on waste [12] and of  
495 amending Directive 94/62/EC on packaging and packaging  
496 waste [13]. One of the proposed actions is the increase of  
497 the preparing for re-use and recycling targets for packag-  
498 ing waste, and the proposed calculation method includes  
499 both the municipal waste prepared for re-used as well as the  
500 products and components prepared for re-use. As we real-  
501 ized with our analysis, these data are available only for a few  
502 types of packaging. More research is thus needed, together  
503 with the establishment of common rules on data collection,  
504 verification, and reporting.

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**References**

1. European Commission (2015) COM (2015) 614/2 Communication **AQ3** 3  
from the Commission to the European Parliament, the Council, 514  
the European Economic and Social Committee and the Commit- 515  
tee of the Regions: closing the loop—an EU action plan for the 516  
Circular Economy. [http://ec.europa.eu/environment/circular-economy/index\\_en.htm](http://ec.europa.eu/environment/circular-economy/index_en.htm) 517  
518
2. European Commission (2008) Directive 2008/98/EC of the Euro- 519  
pean Parliament and of the Council of 19 November 2008 on 520  
waste and repealing certain Directives. Off J Eur Union 521
3. European Commission (2004) Directive 2004/12/EC of the Euro- 522  
pean Parliament and of the Council of 11 February 2004 amend- 523  
ing Directive 94/62/EC on packaging and packaging waste. Off J 524  
Eur Union 18.2.2004, L 47 525
4. Golding A (1999) Reuse of primary packaging. Final report. Part 526  
I—main report. [http://ec.europa.eu/environment/waste/studies/](http://ec.europa.eu/environment/waste/studies/packaging/reuse_main.pdf)  
[packaging/reuse\\_main.pdf](http://ec.europa.eu/environment/waste/studies/packaging/reuse_main.pdf). Last access 20 Jan 2016 527  
528
5. Tsiliyannis CA (2005) A new rate index for environmental moni- 529  
toring of combined reuse/recycling packaging systems. Waste 530  
Manag Res 23:304–313 531
6. ISPRA (2014) Rapporto Rifiuti Urbani—Edizione 2014. [http://](http://www.isprambiente.gov.it/)  
[www.isprambiente.gov.it/](http://www.isprambiente.gov.it/) 532  
533
7. Conai (2013) Programma generale di prevenzione e di gestione 534  
degli imballaggi e dei rifiuti di imballaggio. Relazione generale 535  
consuntiva 2012. <http://www.conai.org/> 536
8. CEN (2004) prCEN/TR 14520. Packaging-Reuse-Methods for 537  
determining the number of trips or rotations 538
9. Tsiliyannis CA (2005) Parametric analysis of environmental per- 539  
formance of reused/recycling packaging. Environ Sci Technol 540  
39:9770–9777 541
10. Diakoulaki D, Papayannakis L (1994) Development of a criteria 542  
system for defining priorities in packaging recycling. MER 4th 543  
International Congress, Belgium 544
11. Badaber A, Ren J, Jones KO, Wang J (2016) A system dynamics 545  
approach for enhancing social behaviours regarding the reuse of 546  
packaging. Expert Syst Appl 46:417–425 547
12. European Commission (2015) COM(2015) 595 final, 2015/0275 548  
(COD) Proposal for a Directive of the European Parliament and 549  
of the Council amending Directive 2008/98/EC on waste 550
13. European Commission (2015) COM (2015) 596 final, 2015/0276 551  
(COD) Proposal for a Directive of the European Parliament and 552  
of the Council amending Directive 94/62/EC on packaging and 553  
packaging waste 554
14. Bartlett JE, Kotrlik JW, Higgins CC (2001) Organizational 555  
research: determining appropriate sample size in survey research. 556  
Inf Technol Learn Perform J 19:43–50 557
15. Raeley J (2012) Conducting research interviews. Manag Res Rev 558  
35:260–271 559
16. Conai (2015) Programma generale di prevenzione e di gestione 560  
degli imballaggi e dei rifiuti di imballaggio - Relazione generale 561  
consuntiva 2014. <http://www.conai.org/> 562

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