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Title: A global comprehensive review of literature related to paper recycling: A pressing need for a uniform system of terms and definitions

Year: 2016

Version: Post print

Please cite the original version:

Ervasti, I., Miranda, R. and Kauranen, I., 2016. A global comprehensive review of literature related to paper recycling: A pressing need for a uniform system of terms and definitions. Waste Management 48, 64-71. DOI: 10.1016/j.wasman.2015.11.020

A GLOBAL, COMPREHENSIVE REVIEW OF LITERATURE RELATED TO PAPER RECYCLING: A PRESSING NEED FOR A UNIFORM SYSTEM OF TERMS AND DEFINITIONS

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ABSTRACT

A global, comprehensive review of terms and definitions related to *paper recycling* was conducted in this article. Terms and definitions related to *paper recycling* have varied in the course of time. Different terms and different definitions for the same thing are being used in different geographical regions and by different organizations. Definitions are different based on varying conceptions of *waste paper* as a *raw material*. Definitions of how to make various calculations related to *paper recycling activity* are inconsistent. Even such fundamental basic definitions like how to calculate *recycling rate* and *paper consumption* are not uniform.

It could be concluded that there is no uniform system of terms and definitions related to paper recycling and the implications of this deficiency are profound. For example, it is difficult to reliably compare with each other statistics from different times and from different geographical regions. It is not possible to measure if targets for recycling activities are met if the terms describing the targets are not uniformly defined. In cases of reporting data for

recycling targets, the lack of uniform terminology can, for example, impede the necessary transparency between different stakeholders and may allow for deception. The authors conclude there is a pressing need to develop a uniform system of terms and definition for terms related to *paper recycling*.

Keywords: *paper recycling; paper recovery; recycling rate; recovered paper; terminology; household waste*.

1. INTRODUCTION

Material recycling has become a global issue. New means have already been adopted and still need to be adopted in order to obtain more value from resources that have been taken from nature. Increasing material recycling has positive environmental effects. It reduces emissions and increases sustainability in raw material use.

The waste management hierarchy is the guiding principle in most waste management policies. It establishes an order of preference for action to reduce and manage wastes where recycling is a key element. Accordingly, recycling targets for different *packaging materials* and *household waste* have been set around the world.

Recovered paper is one of the best managed *secondary materials*, boasting high *recovery* and *recycling rates* around the world. *Recovered paper* is both a technically and environmentally sound raw material and an important global trade commodity. Globally,

recovered paper is the most important raw material for the paper and board industry by volume (Ristola, 2012).

This article concentrates on issues related to paper recycling and analyses different terms and definitions related to *paper recycling*. In this study, special attention is paid to different terms that have been used in the existing literature sources. These terms may consist of several different words, such as *recovered paper* and *recycling rate*. For this reason, all of the terms used here have been denoted in italics.

Many terms can be used to define the same product. In the literature, terms like *discarded paper, paper for recycling, paper stock, refuse paper, recovered paper, scrap paper, secondary paper, used paper* and *waste paper* have been used to define the same product. In addition, the term *paper* often refers to both *paper* and *paperboard*.

The most common terms have varied over the course of time and between regions. The use of terms has also varied along with the changing conception of *waste paper*: it has gone from being considered a *waste to be disposed of* to being considered an important raw material for *paper production*. In the past, experts typically used the terms *waste paper, scrap paper* or *refuse paper*, whereas in recent years *recovered paper* and *paper for recycling* have become the most popular terms. Figure 1 shows the relative importance of different recovered paper terms based on a bibliographic search in the Web of Science database. While the term *waste paper* appeared approximately 80–90% of the time during the years 1971–1990, this share decreased to approximately 70% in the years 1991–2000 and to 60% in the years 2001–2010. This decrease took place parallel to the increased use of the terms *used paper* and *recovered*

paper. During the years 2001–2010, the latter two terms represented approximately 15% and 20% of all related terms, respectively. The fourth most commonly used term is *stock paper*: it appeared at a fairly constant rate of 5–10% during the whole period under study. Other related terms appeared much less frequently in the scientific literature.

[Figure 1 about here]

A basic prerequisite for any communication is that the parties involved use the same definitions for terms. If the sender does not use the same definition as the receiver, then communication becomes obscured, misunderstandings can occur or the message may not be understood at all by the receiver. Every field of science needs to build a systematic terminology with generally accepted, uniform definitions for terms. Guidelines for building such a systematic terminology have been discussed, for example, by de Keizer and Abu-Hanna (2000), Christensen (2006), Van de Ven (2007) and Locke and Golden-Biddle (1997). In this article, only one term is used for the same material. This is done for the very reason of avoiding obscured communication. For example, the term *recovered paper* was chosen from among the many parallel terms that have been used for the same material. *Recovered paper* is a generally accepted term. According to the European Recovered Paper Council (2006), *recovered paper* is "*used paper and board* separately collected and in general processed according to the European Standard List of *Recovered Paper and Board*". One should note that the term *paper* here includes *paper and board* and is, thus, equal to *total paper*.

Resource efficiency is one of the important challenges faced at present by the European Union (EU) and other geographical communities. Resource-efficient utilization of raw materials is needed for sustainable growth (EC, 2013). In order to reach these targets, easily understandable and robust frameworks to describe material flows are necessary. Such material flow frameworks are a basis when resource efficiency is measured between nations, by various business sectors and disciplines, and over time. A useful framework requires that terms related to material flows are uniformly defined. Also material flows must be quantified reliably at all points in the framework.

Prior studies do not use the definitions concerning *paper recycling* in a uniform manner. The lack of uniform definitions has many negative consequences. In fact, it is difficult to even describe the paper industry materials and their flows without more precise definitions. The official *collection rate* and *utilization rate* do not accurately describe *fibre recycling*; they only provide an average picture of *paper fibre rotation* (Bajpai, 2014). Furthermore, it is difficult, for example, to compare different studies due to the inconsistent use of terms. Consistent definitions do not exist even for such fundamental definitions as *recycling of paper* and *paper consumption*.

Material recycling in general plays an important role in different sectors of society. Due to concerns about the environment, climate change and the optimal utilization of natural resources, much attention has increasingly been paid to shifting waste management up the waste hierarchy. Under Article 4 of the European Union's Waste Framework Directive (Waste Framework Directive 2008/98/EC), the European waste hierarchy lays out the preferred waste management practices, from most to the least preferred, in the following

order: waste *prevention, re-use, material recycling* (including composting), *energy recovery* and *disposal*.

The Waste Framework Directive (2008) views *recovered paper* as a valuable raw material that needs to be *recycled*. This directive makes a clear distinction between *recycling* and *recovery*. According to the directive, the term *recovery* includes, in addition to *material recycling*, *energy recovery* as well. In the waste hierarchy, however, *material recycling* is favoured over *recovery*. Furthermore, *energy recovery* (incineration) is favoured over disposal (landfilling). This hierarchy is supported by life cycle assessments (LCAs) carried out by, for example, Schmidt et al. (2007) and Villanueva and Wenzel (2007). These studies point out that from a global warming perspective as well, increasing the amount of *recycling* is preferable to increasing incineration. In the Waste Framework Directive, *composting* is also considered to be *material recycling*. As with incineration, when paper is composted it disappears from the *paper recycling chain*. The *composting* option should be an option only when *paper material* is not suitable for recycling, for example when the paper material has been soiled with food (Monte et al., 2009).

According to the Waste Framework Directive (2008), *separate collections* for materials like *paper, metal, plastic, wood* and *glass* need to be arranged by the end of 2015 and a *recycling rate* of 50% needs to be achieved by 2020 for *municipal waste* (Waste Framework Directive, 2008). In a new proposal for harmonizing all European legislation pertaining to waste issues, an even more ambitious recycling target of 70% for *municipal waste* is being considered by 2030 (EC, 2014).

In addition to the Waste Framework Directive, the European paper industry, together with several stakeholders, has launched three different voluntary declarations on *paper recycling* with specific deadlines and *recycling rate* targets (ERPA, 2000; ERPC, 2006; 2011). The first declaration set a 56% *recycling target* for the period 2000–2005, while the second declaration (2006–2010) set a target of 66% and the third declaration (2011-2015) established a 70% *recycling target.*

If recycling *targets* are made mandatory, then there has to be a way to reliably calculate *recycling rates* for the materials in question, like *household waste* and *paper*. Such calculations should be applicable even when considering voluntary commitments. The EC has stated that the reliable reporting of statistical data concerning waste management is paramount in order to efficiently implement and ensure a level playing field between the Member States (EC, 2014).

The contribution of this study is not only theoretical but of practical significance, both for people working in the field and people carrying out studies related to paper recycling. A detailed description of industry material flows and a corresponding uniform terminology is essential, for example, for analyzing and forecasting demand, for establishing recycling targets by policy makers, as well as for analyzing the trade of different materials. Without a uniform terminological system it is not possible to compare reliably the raw material use and recycling activities of different industry sectors in different geographical regions and between different times. As the world is rapidly becoming more globalized, the interrelationships between the production of products, the use of materials, and the generation of waste are becoming increasingly more complex and geographically dispersed. The need

for a uniform terminological system is becoming ever more pressing.

2. TERMINOLOGY RELATED TO PAPER RECYCLING

As there is no generally accepted, uniform global system of definitions for terms related to *paper recycling*, the authors of this article suggest that all authors should always define such terms when they use them in their texts and statistics. Even such commonly used basic terms as *collection rate, recovery rate, recycling rate* and *utilization rate* have different definitions depending on the source (Holik, 2006).

To demonstrate the extent to which researchers and organizations define the same terms differently, the authors of this article prepared a list of different definitions for a selected group of term, Table 1, Table 2 and Table 3. The term *recycling rate* was selected for closer study. The main reason for selecting *recycling rate* is that both the European Commission and European paper industry have given exact *recycling rate targets* for the coming years. *Recycling rate* is the relation between *material recycled* and *recycling potential.*

Other commonly used terms, such as *collection rate, recovery rate* and *utilization rate*, were not selected for detailed analysis in this study. There are several reasons for taking this decision. First, *collection rate* was not included for closer study because, since 2006, both *collection rate* and *recycling rate* have been considered equivalent in the European definitions and all previous statistics have been modified accordingly (ERPA, 2003; ERPC, 2006). Additionally, *recovery rate* was not included in the comparisons because its use may

cause confusion. *Recovery* is defined differently in the United States (AF&PA, 2008) and in Europe (ERPA, 2000). In the United States, the term *recovery* includes only *collection*, whereas in Europe *recovery* includes all of the following: *re-use, material recycling, composting* and *energy recovery* as well as all *material exports* used for similar purposes. Additionally, it should be noted that the American Forest and Paper Association (AF&PA) does not use the term *collection rate* but instead the term *recovery rate*.

Utilization rate was not selected for closer study, either. The definitions for *utilization rate* are quite similar in different regions. The definition used in North America (AF&PA, 2008) and in Europe (CEPI, 2009) is the same: (*recovered paper utilization rate*) = *(recovered paper utilization as raw material in paper production*) / (*paper production*). In Japan, *utilization rate* is calculated slightly differently using the following formula (PRPC, 2013; Nippon Paper Group, 2013): (*recovered paper utilization rate*) = (*recovered paper consumption*) / (*consumption of fibre stock for paper and board*). In the Japanese calculation, the denominator is *consumption of fibre material*, whereas in Europe and in the United States it is *paper production.*

Even though the term *utilization rate* is usually defined uniformly throughout the world, it was not included in the comparisons of terms because the term itself is not appropriate when comparing recycling activities in different regions. The term *utilization rate* relates more closely to the industry structure of a region than to a region's activity with respect to recycling (COST E48, 2010). The Nordic Countries (Sweden, Finland, Norway), for example, have a very efficient paper recycling system. The *recycling rates* in these countries are among the highest in Europe (70–80%), but at the same time the *utilization rates* in the Nordic Countries

are the lowest in Europe (5-30%). The reason for this anomaly is that most of the paper industry in the Nordic Countries is based on *virgin fibre*.

Furthermore, perhaps surprisingly, *utilization rates* do not vary between 0% and 100%, but values exceeding 100% are also possible! There are three reasons for why this is possible. First, there are moisture differences between raw materials and the final products. Second, material losses occur during the sorting and the pulp and paper manufacturing processes. Third, countries that import *recovered paper* are in a position to achieve high *utilization rates* even with low local *collection activity*. Based on the calculation methodology defined by the European Recovered Paper Council (2006), the *utilization of imported recovered paper* reduces the *recycling rate* because the volume has already been taken into account in the exporting country. Thus, countries with a high *utilization rate* can have a *low collection rate* and a low *recycling rate,* respectively.

3. DEFINING PAPER RECYCLING RATE

Recycling rate is used to indicate the level of *material recycling activity* in a particular region or in a particular country. The European Commission legislation as well as the European paper industry *recycling* declarations (ERPA, 2000; ERPC, 2006; ERPC, 2011) have set *recycling rate* targets for different materials.

Basically, *recycling rate* is a simple term. According to the European Recovered Paper Council's definition (ERPC, 2011), *paper recycling rate* is "the ratio between *recycling of used paper (recovered paper),* including *net trade of paper for recycling (recovered paper*)

and *paper consumption"*. Thus, *paper recycling rate* can be expressed via the following formula:

(paper recycling rate) = (paper recycling) / (paper consumption)

The term *paper recycling* indicates the volume of *material recycling*, while *paper consumption* indicates the *material recycling potential*. When defining the method for calculating the *paper recycling rate*, one of the key issues to consider is how well the *recycling rate* actually defines *material recycling* all the way back to circulation. According to the Confederation of European Paper Industries' annual statistics (2011), the European *paper recycling rate* was close to 70% in 2010. However, Keränen and Ervasti (2014) found that only 41% of the *fibre* ending up as *paper produced* was *recycled fibre material*. Accordingly, the main share of *fibre*, approximately 59% of all *fibre*, ending up in *paper* throughout Europe in 2010 was *virgin fibre*. There are three reasons for the great difference between these two figures — namely, 70% and 41%. First, *recovered paper* includes a large share of *non-fibrous components*, like *minerals and additives.* In the paper recycling process, non-fibrous components are removed while at the same time some of the fiber is also lost. Second, the moisture content of *recovered paper* is higher than the moisture content of newly *produced paper*. Based on the two previous reasons, the process yields in *paper production* vary between 40 and 50% for *tissue* and *deinked market pulp* and between 90 and 95% in the case of *packaging papers* (Holik, 2006; BREF, 2001). Third, according to the European Recovered Paper Council's definition (2011), *recovered paper exports* from Europe are also considered a part of European *recycling*.

The European Recovered Paper Council (ERPC, 2006) defines *paper recycling* as consisting of "*reprocessed recovered paper* used in a production process into *new paper* in Europe and *exported recovered paper* to outside Europe". The material flow chain currently used by the European paper industry is incomplete. Some of the side flows, like *trade of packages traded with goods* and *material recycling for other uses outside the paper industry*, are missing from the model of the material flow chain. Additionally, the model is not complete because *recycling rate* takes into account material that is fed into the *recycled fibre manufacturing process*. It does not take into account the material that actually returns to circulation in the form of a *new product*. A share of material is lost as *pulping residues* and *rejects* during the different process stages. In this respect, only that part of the *recycled material* which is utilized during paper manufacturing really returns to circulation.

The two terms in the calculation formula for the *recycling rate*, namely *paper recycling* and *paper consumption*, will be analysed in detail next.

3.1. PAPER RECYCLING

Twelve different definitions for *paper recycling* are listed in Table 1. These definitions were extracted from the existing literature as part of an extensive literature review that covered altogether 64 studies. The differences between the existing definitions for the term *recycling* are significant. In addition, several studies in the literature review used the term *recycling* without defining it. The authors of the studies seemed to assume that the definition of this term is uniformly accepted, which, however, is not the case.

Table 1. Definitions for the term *recycling* used in the different studies

Source	**Definition of *recycling***
BIR, 2013	includes *sorting, baling, shredding, washing, bleaching, pressing* and *rolling*
COST E48, 2010; Grossmann, 2009	reprocessing of *recovered paper* in a production process either to produce *saleable paper* or to produce some other *saleable product*, typically including *composting* but excluding *energy recovery*
CEPI, 2013	*utilization of paper for recycling*, including *net trade of paper for recycling*
ERPA, 2000	reprocessing of *recovered paper* in a production process for the original purpose or for other purposes, including *composting* but excluding *energy recovery*
ERPC, 2006	reprocessing of *recovered paper* in a production process to form new paper and board
ERPC, 2011	reprocessing of *used paper* in a production process to form new paper and board
European Parliament and Council, 1994; Barrio, 2006	reprocessing in a production process of *waste materials* for the original purpose or for other purposes, including *organic recycling* but excluding *energy recovery*
Göttsching, 1996	*utilization, processing* in the paper industry within the observed country
Hamm, 2010	to produce *recycled fibre pulp* for the manufacture of *paper and board*
Levlin, 2008	*recovered paper used for papermaking*, including *utilization* outside Europe
Palmer, 1997	refers to *recycled material*
Villanueva et al., 2007	term *recycling* refers to *material recycling*

According to the European Recovered Paper Council (EPRC, 2011), *recycling* is the reprocessing of *used paper* in a production process to form *new paper*. It should be noted that this definition does not mention the place where the processing occurs. That is why *exported recovered paper* also falls under the *recycling* category in the exporting country. It can be assumed that the term *recycling* is equal to *utilization* and *collection* because at a global level all these terms have the same cumulative quantitative value.

It has to be noted that the term *recycling* is not used in either Japan or the United States. Instead, these countries use the term *recovery*. For example, in Japan *paper recovery* is defined as follows (PRPC, 2013):

(recovery) = (recovered paper supply) + (deinked market pulp) – (imports of recovered paper) + (exports of recovered paper)

In the United States, *paper recovery* is calculated as follows (AF&PA, 2008):

(recovery) = (consumption of recovered paper at paper and board mills) + (other uses of recovered paper) + (recovered paper exports) – (recovered paper imports)

In its European flow chart, the Confederation of European Paper Industries (2013) calculates the *collection of paper for recycling* as follows:

(collection of paper for recycling) = (utilization of paper for recycling within paper and board production) + (recovered paper exports) – (recovered paper imports)

The Confederation of European Paper Industries (2013) also proposes using the following formula:

(paper recycling) = (utilization of paper for recycling) + (net trade of paper for recycling)

The European Recovered Paper Council (2007) defines *utilization* as the "*use* of *recovered paper* in paper mills while processing *recycled paper"*. This definition takes no stand on where the *utilization* takes place. That is why the *use of exported recovered paper* in paper manufacturing abroad can be regarded as *utilization*. This is in parallel with *paper recycling*, as by definition *exported paper* is regarded as *recycled*. However, in practice *exported paper* is not always *recycled*. For example, shipments of low-quality *recovered paper* to China have been landfilled there because it would have been more expensive to ship the material back to the countries of origin. To avoid this, China implemented a "Green Fence" policy early in 2014. This policy was designed to keep *contaminated recycling materials* from crossing Chinese borders. The law forbids buying *recovered paper material* from abroad with a greater than 1.5% contamination rate or with moisture contents higher than 12%. If the contamination rate exceeds this value, the shipments are sent back, with the cost to be paid by the firm shipping the *paper material* to China. In Europe, similar environmental policies have been implemented. According to the European Commission (2014): "*Waste* exported from the Union for preparing for *re-use* or *recycling* shall only count towards the fulfilment of the targets laid down in Article 11(2) if the exporter can prove in compliance with Regulations EC No. 1013//2006 that the treatment outside the Union took place under conditions that are equivalent to the requirements of the relevant Union environmental

legislation." However, the appropriate treatment outside the Union can be difficult for the exporter to demonstrate.

By combining the above definitions, we can make the following claim with respect to volume:

(European recycling) = (European collection) = (Japanese recovery) = (American recovery, excluding uses of recovered paper outside the paper and board industry) = (European utilization, including both domestic utilization and net trade of recovered paper)

3.2. PAPER CONSUMPTION

Table 2 lists fourteen different definitions for *paper consumption* based on our analysis of the existing studies. *Paper consumption* is usually used to indicate the *recycling potential*. For example, Pento (1994), CEPI (2009), and Schmidt et al. (2007) have all posited that the *paper consumption* stage is the last stage after converting and printing and that it constitutes the *potential for recycling*. However, as there are several different definitions for the term *paper consumption*, it is difficult to unambiguously claim that *paper consumption* describes the *recycling potential*.

At this point, it is interesting to note that the *recycling potentia*l is significantly lower than the amount of *paper consumed* due to the amount of *non-recyclable paper* or *non-collectable paper*, i.e. *cigarette paper, wallpaper, tissue paper* and *archival papers*. Several different

studies estimate that these *paper grades* represent 15–20% of *total paper consumption* (CEPI, 2003; BIR, 2014).

Table 2. Definitions for the term *paper consumption* used in the different studies

Source	**Definition of *paper consumption***
AF&PA, 2008	*new supply* is equal to *paper production + paper imports – paper exports*, excluding *hard pressed board* but including *traded converted products*
ERPC, 2013 *)	*paper consumed* by consumers who discard paper
Villanueva et al., 2007*)	*(used paper & board) = (manufacture of paper & board) – (net trade)*
Indufor, 2013 *)	*(production) – (net trade, including converting (printing))*
EcoPaperLoop, 2014	*product usage - additives*
CEPI, 2013**)	four different definitions: 1. *(market supply paper & board) = (paper & board production) – (paper & board net trade)*. Calculated as*: (paper & board domestic deliveries) + (imports)* 2. *(converted market supply products) = (market supply paper & board) – (collected from converters & print)* 3. *(product use) = (market supply paper & board) – (net direct trade of converted products, including trade of packages surrounding traded goods and manuals)* 4. *(paper for recycling at end users) = (product use) – (net trade + returns)*
CEPI, 2008 *)	*(product usage) = (printing (publishing)) + (converting)*
Schmidt et al., 2007	*paper products, including converting (printing)*
PRPC, 2010	*(paper & board production) – (net trade of paper & board)*
Davidsdottir et al. 2005 *)	*paper and paperboard use and discard*

Pento, 1994 *)	*paper at end users*

Note:

*) These sources do not quantify the material flows.

**) The CEPI has used four different definitions to define *recycling potential (paper consumption)* in its European paper industry fibre flow chart. In calculating *recycling rate*, the CEPI uses definition 1 for the *recycling potential*.

3.3. PAPER RECYCLING RATE

As defined previously, the *recycling rate* is the ratio between *paper recycling* and *paper consumption. Paper consumption* is considered to be the *paper recycling potential*. As indicated above, there are many different definitions for both *paper recycling* and *paper consumption*. The fact that the various definitions for *paper recycling rate* can be combined in different ways opens up the possibility for an even greater number of potential definitions for *paper recycling rate* in the future. The present literature review confirms the fact that, indeed, definitions for *paper recycling rate* vary significantly. Table 3 highlights the different ways that various studies have defined *paper recycling rate*.

Table 3: Definitions for the term paper *recycling rate* used in the different studies

Source	**Definition of *paper recycling rate***
Ackerman et al., 2010	refers to *the recovery rate*
Barrio, 2006	(B+C) / A, where A = *packaging placed on the market*, B = *material recycling* and C = *organic recycling and use for other purposes*

CEPI Annual Statistics, 2006; Special Recycling Statistics, 2005 (CEPI definition up to 2006)	*(recovered paper utilization) / (paper and board consumption)*
CEPI, 2013 (CEPI definition since 2006)	*(utilization of paper for recycling + net trade of paper for recycling) / (market supply paper & board)**
EPA, 2012	*(total recycled by weight) / (total discarded and recycled by weight)*
ERPA, 2000	*the ratio between recovered paper utilized for recycling and paper and board consumption*
ERPC, 2006 and COST E48, 2010	*the ratio between RP (recovered paper) utilized for recycling, including RP net trade, and paper and board consumption*
Kaila, 2010	*(recycling) / (potential)*
Klimek, 2011	Klimek has proposed two different definitions for *recycling rate* 1. *(waste paper utilization) / (paper consumption, without trade)* 2. *(waste paper collection) / (paper consumption, including trade)*
Miranda & Blanco, 2010	*(RP utilization in paper industry) / (paper consumption)*
PRASA, 2012	*(recovered recyclable paper) / (recoverable paper)*

Note: *) Instead of the term *paper consumption*, the CEPI uses the term *market supply paper & board*.

The first important fact to take into account regarding these definitions is that the paper industry is not the only user of *recovered paper.* By definition, other uses outside the paper industry should be included in the *recycling volume* (ERPA, 2000). The AF&PA estimates that the *utilization of recovered paper* outside the paper industry in the United States represents between 4.8% and 7.4% of the *total recovered paper use* (COST E48, 2010). This volume includes end-use sectors, such as *paper used for construction purposes, moulded products, insulation, mailing bags* or *animal bedding*, to name just a few. In Europe, *recovered paper* is also used outside the paper industry. At present, this volume is not included in the *recycling volume* used in Europe. The main reason for not including it has to do with the fact that there is no reliable data on the *use of recovered paper* outside the paper industry. The CEPI estimates that in Europe, more than 8% of *collected paper* is used in other applications outside the paper industry, including *construction material, animal bedding, composting* and *energy purposes*. Because this figure includes energy use (which, according to current European definitions, is not *recycling), recovered paper recycling* for other end uses in Europe is significantly lower than 8%. For example, COST E48 (2010) has estimated that the figure is closer to 4–5%. In Japan, the official statistics suggest that only 1% of paper is used outside the paper industry (PRPC, 2014).

The European Declaration on Paper Recycling (ERPC, 2006; 2011) has chosen to define *recycling* differently than the ERPA (2000). The ERPC (2011) declaration states that the term *recycling* includes only the *reprocessing of used paper* in a production process into *new paper and board* plus the *net trade of recovered paper*. The ERPA (2000) definition for *recycling* also includes *other uses* outside the paper industry, including composting.

The authors of this study suggest that use of *recovered paper outside the paper industry* should be included in the *recycling volume*, as already occurs in the United States, where *recovered paper use outside the paper industry* is included in the *recovery* volume.

Furthermore, the *net trade of converted products*, the *net trade of packaging material surrounding traded goods* (including manuals) as well as *non-collectable and non-recyclable paper* all have an influence on the *recycling potential* volume (CEPI; 2013). This is indicated in the definition for *paper consumption* proposed by the CEPI (definition no. 4 in Table 2). While the three material flows mentioned above have been identified by CEPI, they have not been taken into account in *recycling* calculations because there is no generally accepted method to measure the volumes of these types of material flows.

The CEPI has assumed that the import and export volumes of *converted products* and the *packaging material surrounding traded goods* are in balance (CEPI, 2013). However this is just an assumption. In fact, Europe is a net importer of *packaging material* due to the huge volume of *packages surrounding imported goods*, especially those from Asia to Europe. Therefore, the *packages surrounding products* imported from Asia are part of the *recycling potential*. A recent study focusing on the China's true *collection rate* after adjusting the *exports of paper packaging materials* and *converted products* determined that 22 million (net) tonnes of *paper packaging and converted products* went overseas in 2010 (Zhao, 2012), which is approximately half the amount of *recovered paper collected* in China in the same year. Thus, the real apparent collection rate in China might be as high as 65% rather than the 45% reported in "official statistics" (data for 2013) (Zhao, 2014). This means that a tremendous share of China's *collection potential* is lost as *exported paper packages surrounding exported goods*.

3.4. METHODS USED TO DEFINE TERMS RELATED TO PAPER RECYCLING

When quantifying *paper recycling* and *paper consumption* volumes, special attention must be paid to the reliability of the data. For example, the European paper industry calculates the *paper recycling volume* by adding the regional *utilization of recovered paper* together with the *net trade of recovered paper* outside the region. The regional European *recovered paper utilization* volume is an aggregate figure that has been calculated by adding together the figures collected from various national paper industry associations. Additionally, *recovered paper trade* figures have been sourced from official sources like national statistical offices or the European statistical organization, Eurostat. We can assume that this data collection methodology is reliable and accurate.

With respect to data related to *paper recycling*, the means for collecting the data are well structured and planned. Annual data for Europe can be regarded as accurate, and it is possible to compare different countries with each other.

The field of *paper recycling* material flows includes a number of meaningful players, such as households, converters, printers, shops, collectors, municipalities, individuals, sorting stations, waste management companies, paper mills, landfills and incinerators, which are all part of the recycling chain. It is not possible to reliably define and quantify all of the numerous material flows between these different players and, accordingly, the implications of these flows for the *recycling chain*. To obtain an undistorted picture of the situation, the paper industry collects volume data on *recovered paper utilization* at predetermined points in the *recycling chain* and material flows at paper mills. In addition, it monitors the export

and import volumes of *recovered paper*. By adding together the *utilized volumes* and the *net traded volumes*, it is possible to calculate the *recycling volume*. If a country *utilizes*, for example, 100 tonnes of *recovered paper* in paper manufacturing in a certain year, and if the *net exports of recovered paper* in the same year in total is 15 tonnes, then that the *collection of recovered paper* would be 115 tonnes. Regional volumes can be calculated by adding together the corresponding volumes from individual countries in the region.

In the case of *household waste*, no general international standard has been adopted for defining *household waste* streams, their compositions and their volumes. For example, Dahlen and Lagerkvist (2008) have identified twenty different methods for *solid waste component* analysis based on physical sampling. Most of these methods concentrate on analysing the composition of *waste* at the household level or sampling from *waste collection* vehicles. Dahlen and Lagerkvist also identified several sources of sampling errors and concluded that it is not possible to reliably define and quantify the *household waste* streams at any defined point.

Pitard (1993) has identified several different sources of error for *waste* sampling when collecting and splitting solid samples. It is also difficult to identify and quantify material flows such as *paper collected by non-profit organizations, yard composting, illegal dumping* or *burning of waste* (Berg, 1993). Though the material flows not included in the *main waste* stream can be significant, it is difficult to quantify them. Dahlen et al. (2008) identified sixteen sources of error in official waste statistics. They emphasize that reliable waste generation and composting data is necessary to underpin waste management policies.

The authors of this present article stress that it is not easy to reliably define, for example, the European *household waste recycling rate* just by analysing samples of some of the material flows. Comprehensive and uniform methods for quantifying both the *recycled material* as well as the *recycling potential* at certain points of the *material flow* stream should be developed. Such methods would make it easier to compare different countries as well as different *recyclables* with each other. *Recycling rate* calculations developed for the paper industry can be applied when developing *recycling rate* calculations for other *recyclables* and *household waste*, too.

With respect to other important materials such as *packaging waste*, which also have mandatory *recycling targets* in Europe, there are many inconsistencies between the statistics from the different Member States. Experts have strongly recommended developing a solid statistic framework to improve the accuracy and comparability of the data (EUROPEN, 2014).

4. DISCUSSION OF RESULTS

It is important, globally, that such resources as raw materials, water and energy could be used responsibly. *Material recycling* is one of the key means to use natural resources in a sustainable manner. By increasing the level of *material recycling*, it is possible to reduce the amount of *virgin raw materials* consumed from nature and to save energy and water. Reduced energy consumption will make it easier to manage emissions into the air. Also, it will be possible to reduce the material volumes of landfills.

Our analyses of the terms related to *paper recycling* show that there is an inconsistency in the use of terms related to *paper recycling*. In fact, it can be claimed that the use of terms related to *paper recycling* is in chaos. In some cases, certain terms have been used interchangeably, whereas in other studies the very same terms have been used to point out differences between, for example, materials at different stages of the recycling chain. Additionally, in many studies the terms that have been used have not been defined at all, leaving the message ambiguous to the reader.

At present, there are no methods for reliably measuring *recycling rates* for *waste materials*. For example, the European paper industry has developed a functional methodology to collect data and calculate *paper recycling rates*. However, as this article shows, there is still much to be done when it comes to developing a reliable, internationally accepted, method for calculating the *recycling rate*. In particular, it will be challenging to calculate reliably how large a percentage of *fibre material* is returned to the *recycling chain* at various stages of the *recycling chain*.

Different terms for the same thing are used in different geographical regions. For example, the terms *paper recycling* and *paper recycling rate* are used only in Europe. In the United States, corresponding targets are set using the term *recovery rate*. Additionally, all these terms have several definitions depending on the source. In many geographical regions, the term *recycling* refers to *material recycling* at a general level only and *recycling rate* is not used in quantitative calculations.

Another interesting issue to consider is how different definitions can render different levels of achievement for *recycling rates* set that have been set as targets. For example, the CEPI changed its definition of *paper recycling* for Europe when the exports of *recovered paper* started to increase significantly. Prior to 2006, *recycling rate* was calculated as: (recycling rate) = 100 · *(recovered paper utilisation) / (total paper consumption)*. After 2006, *recycling rate* has also included the *net trade of recovered paper* and has been calculated as: (*recycling rate) = 100·((recovered paper utilisation + net trade) / (total paper consumption))*. In 2000, the difference between the two calculations was minor (49.8% vs. 51.8%). However, due to the increased amount of European *recovered paper exports* the difference in the year 2005 was almost 8.0 percentage points: (54.1% vs. 62.0%) and by 2010 about 10.0 percentage points 2010 (58.9% vs. 68.7%). After that, the difference has remained almost constant: the figures for 2013 were 62.2% vs. 71.7%.

Attention must also be paid to data collection. Data must be reliable and accurate. The European statistics for *paper recycling* kept by the CEPI can be regarded accurate. The data are based on industry statistics. The data cover total material volumes, such as recovered paper utilization by the whole paper industry within a particular region. Statistics of recycled paper flows are usually more accurate than statistics of other recycled material flows, such as household waste or packaging waste. In certain cases, more information of recycled material flows can be attained by analyses of sampled physical material flows or analyses of the contents of lorry loads.

In any *recycling activity*, attention must also be paid to the quality of the *recycled material*, not only to the volume. Efficient sorting of *recovered paper* is important. Comprehensive

sorting makes it possible to use the sorted material for higher grades of recycled paper. Thus, expensive *wood pulp grades* can be replaced with *recycled materials* in paper manufacturing.

The authors of this present study want to point out that it is not only important to define the terms related to *paper recycling* uniformly, but also to select uniform symbols for the terms related to *paper recycling*. Having uniform symbols would further make communication simpler and more accurate. In many fields of science, such universal global agreements of symbols have been established.

5. CONCLUSIONS

A global, comprehensive review of terms and definitions related to *paper recycling* was conducted in this article. The review revealed that

- Terms and definitions related to *paper recycling* have varied in the course of time.
- Different terms and different definitions for the same thing are being used in different geographical regions and by different organizations.
- Definitions are different based on varying conceptions of *waste paper* as a *raw material*.
- Definitions of how to make various calculations related to *paper recycling activity* are inconsistent.
- Even such fundamental basic definitions like how to calculate *recycling rate* are not uniform.

It can be concluded that there is no uniform system of terms and definitions related to paper recycling and the implications of this deficiency are profound. For example, it is difficult to

reliably compare with each other statistics from different times and from different geographical regions. It is not possible to measure if targets for recycling activities are met if the terms describing the targets are not uniformly defined. In cases of reporting data for recycling targets, the lack of uniform terminology can, for example, impede the necessary transparency between different stakeholders and may allow for deception.

In general, a basic prerequisite for any communication is that the parties involved use the same definitions for terms. If the sender does not use the same definition as the receiver, then communication becomes obscured, misunderstandings can occur or the message may not be understood at all by the receiver. Every field of science needs to build a systematic terminology with generally accepted, uniform definitions for terms. The authors conclude there is a pressing need to develop a uniform system of terms and definition for terms related to *paper recycling*.

The development of a uniform terminological system is very difficult in practice. A consensus between many countries and many organizations should be reached. An important first step was that, in this article a comprehensive review of the inconsistencies of the existing terminological system was made and that the negative implications of the inconsistencies was exposed in detail. The second step will be that a concrete proposal of a framework of paper recycling should be developed with a corresponding uniform system of related terminology. This will be the topic of a future publication from the same authors. The framework and the related terminological system will be exposed for thorough discussion in order to develop them further. Eventually, a consensus should be reached with the help of important professional organizations in the field.

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FIGURE CAPTIONS

Figure 1. Relative usage of the different terms related to recovered paper in the scientific literature (based on the Web of Science database).