Author(s): Keränen, J. and Ervasti, I.

Title: Amounts of non-fibrous components in recovered paper

Year: 2014

Version: Post print

Please cite the original version:

Keränen, J. and Ervasti, I., 2014. Amounts of non-fibrous components in recovered paper. Resources, Conservation and Recycling 92, 151-157. DOI: 10.1016/j.resconrec.2014.09.010

Amounts of non-fibrous components in recovered paper

Keränen, Janne T[1], Ervasti, Ilpo[2]

1 Senior Scientist, Ph. D., Microkatu 1, Kuopio, P.O.Box 1199, FI-70211, Kuopio, Finland, Tel +358 20 722 2714, fax +358207222080, Email: janne.keranen@vtt.fi

2 M.Sc., Doctoral student, Aalto University, Industrial Engineering and Management, Otaniementie 17, 02150 Espoo, Finland, Tel. +358 500 184684, Email: ilervasti@gmail.com

Abstract

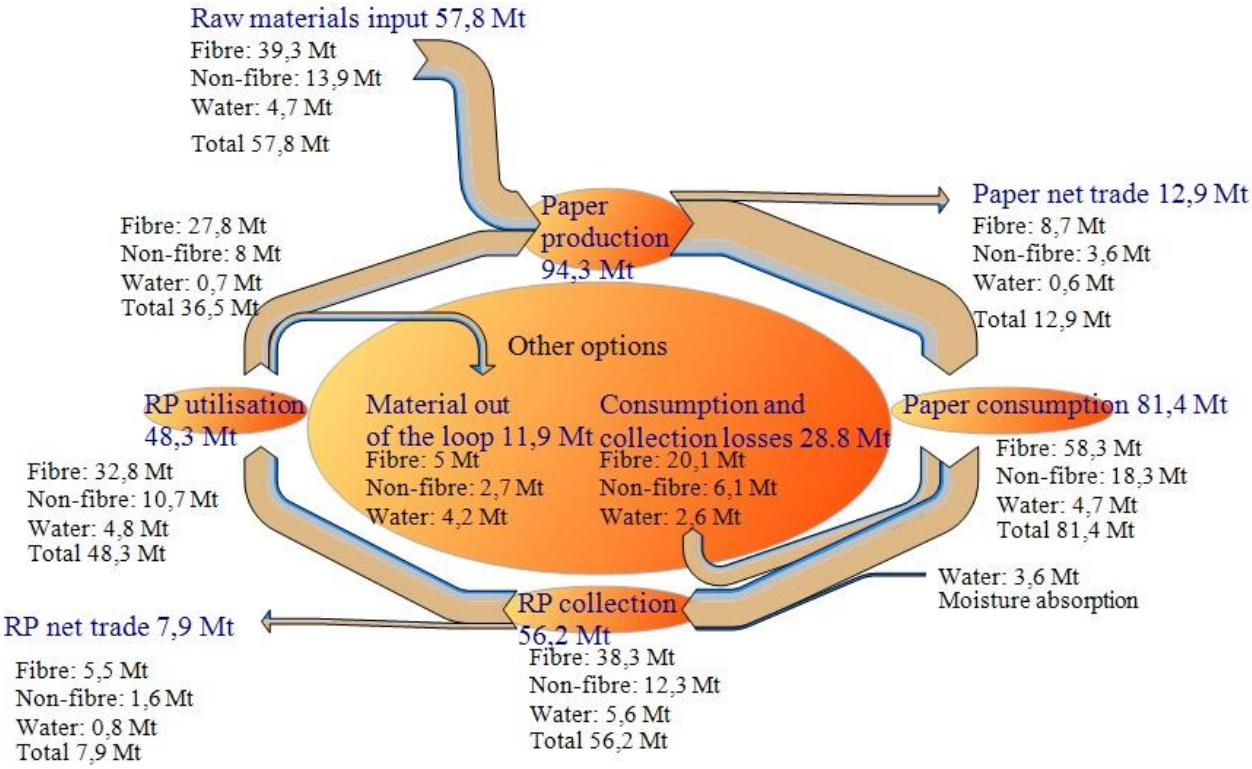
Paper and board recycling is now a central issue in papermaking. Understanding of material flows, as a part of the total production chain, as well as, fibrous and non-fibrous component flows needs further clarification. These flows are studied at a European level, with special focus on Germany and Sweden. Non-fibrous components are discussed in terms of a material which hampers the processing of paper and board. Resource-efficiency improvements, in conjunction with economic benefits, are sought and recycling has been able to fulfil both of these. The main drivers to maximize the use of recovered paper in paper and board manufacturing, have been improved over the last decades. These drivers are cost, environmental image and good technical properties to be used as raw material.

The increased recycling rate has reduced the quality of the collected paper, produced recycled paper, and replaced virgin pulp. Also, recycling as a process, like deinking, produces large amounts of waste material that has challenges to find proper utilization. These problem areas are addressed in this paper, too.

One focus area in the analysis of statistical information is an estimation of the share of non-fibrous components and fibre volumes of paper in Europe (EU) for the year 2010.

Keywords: recycling; recovery; fibre; non-fibre components

Graphical abstract



Graphical abstract: Fibre, non-fibre-components and water material flow of Europe (EU) in 2010.

1. Introduction

Paper and board products consist of four main components, namely mechanical and/or chemical wood pulp, recycled fibres, non-fibrous components (minerals and

additives) and water. Minerals, often called fillers, and additives here are referred to as non-fibrous components. The recycling rate in Europe (CEPI countries) has increased from 40.3% (1991) to 70.4% with paper production of 95 million tons (in 2011) [5, 20, 22]. Globally consumption of recovered paper was 228 million tons when paper and board production was 400 million tons (in 2011), giving recovered paper utilization rate 57% [22]. On a volume basis, recovered paper is the most important raw material for the paper and board industry. Paper and board can be recycled many times [30].

In papermaking, the economy of production is essential and this is improved by using recycled paper to save costs. Recovered paper is also technically, a good enough raw material in comparison to virgin fibre, but cheaper. It is easy to handle, which also makes it a large global trade commodity, for example China imported 28 million tons of recovered paper in 2011 mainly from the US and Europe [22]. The global end uses of recovered paper include containerboards (50%), carton boards (13-14%) newsprint (12-13%) tissue paper (7-8%) and printing/writing papers (6%). [5, 10].

In western world after the Second World War the discourse of recycling started to grow, though recycling had been a daily routine from the beginning of the century [25]. As part of the growing discourse, the industry became a stakeholder and adopted some recycling schemes. These recycling schemes made it possible to acquire the collected materials at stable prices reducing overall raw material costs [25]. In practice the price stability is quite hard to achieve. For example the price of imported recovered old corrugated containers (OCC) in China has fluctuated from

$80/t (2009) to $270/t (2011) and for old newspapers (ONP) $100/t and $260/t, respectively [29]. Recovered paper prices tend to fluctuate accordingly, globally.

In the recycling chain there are different agents, consumers, collectors and producers. A typical paper and board recycling chain in Europe is as follows [5] (Figure 1):

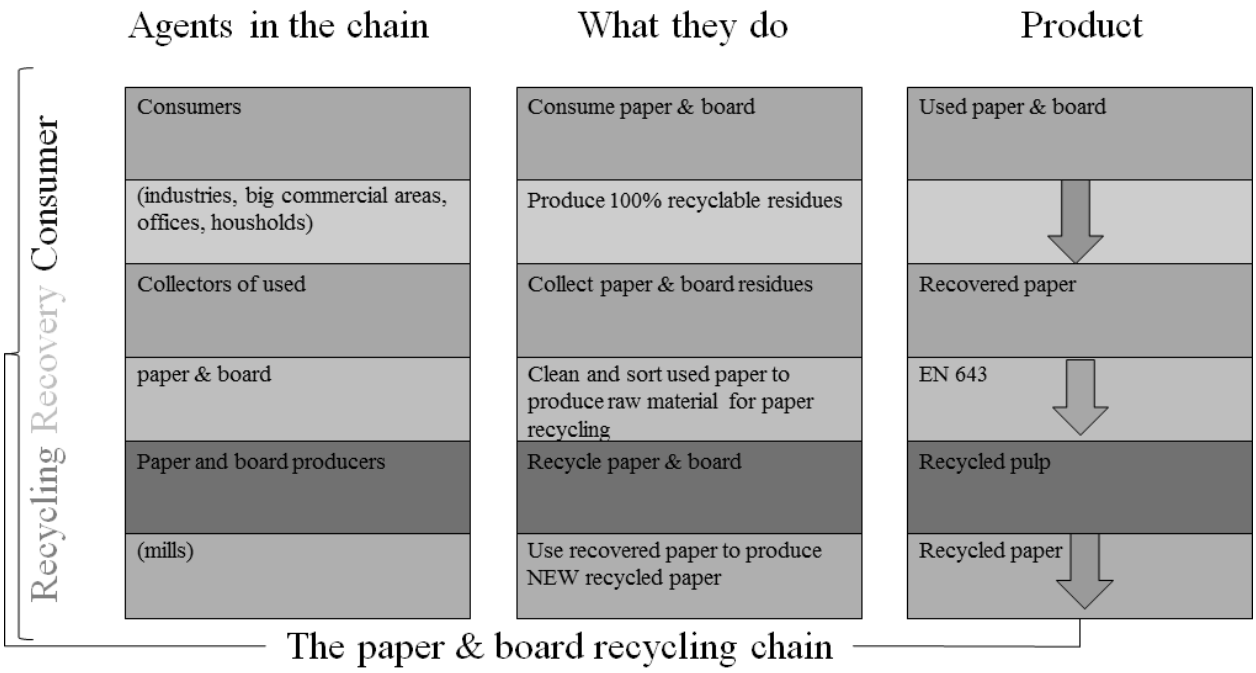


Figure 1. Typical paper & board recycling chain.

Consumers, including industry like converting and printing, households, offices and commercial areas, produce the collection potential in the form of used paper and board. Collection and sorting of recovered paper by collectors and traders is then made according to EN 643 (2013) in Europe. In practice this guideline distinguishes a total of 95 trade grades which can be divided into 5 different statistical recovered paper grades. On the other hand CEPI groups different recovered paper grades into 4 main statistical groups. These are mixed grades (Mixed), **o**ld **c**orrugated **c**ontainers

(OCC), **o**ld **n**ews**p**apers / **o**ld **m**a**g**azines (ONP/OMG) and **h**igh **g**rades and **p**ulp **s**ubstitutes (HG&PS). After the collection and sorting, these materials are used by paper and board producers to produce new paper and board. The quality of the materials varies greatly. For example OCC has a limited amount of printing ink and other impurities whereas certain board grades are hydrophobic and can contain reducing agents like polyethylene.

In the revised version of EN 643 (2013) the following major changes to previous version of EN 643 (2002) were made: 1) Recovered Paper & Board is now called Paper and Board for Recycling 2) Prohibited materials has now zero tolerance and 3) Total unwanted material has now a maximum tolerance level (maximum of 0.5% to 3% depending on grade) which includes already non-paper components. [7]

Recovered paper for recycling is defined in the revised EN 643 as "natural fibre-based paper and board suitable for recycling; consisting of paper and board in any shape or product made predominantly from paper and board, which may include other constituents that cannot be removed by dry sorting, such as coatings, laminates, spiral bindings, etc. [7]

The purpose of this study is to increase the understanding of the role of non-fibre components and fibres in the paper industry raw material flows at a European level by taking into account true effects of recycling. Special focus will be put on Germany and Sweden.

2. Materials & methods

Several statistical resources from Eurostat trade statistics [13, 15], FAO [10], Indufor [31], Trade Commission [28], Customs [14], CEPI [2-4, 19-21], were used. Some of the statistics were compiled by the authors. The numbers shown in the model (e.g. Figure 3) in European level are sums of individual EU-countries. To show the differences among countries in Europe, some of statistical figures from Germany and Sweden are shown separately. Long time series for EU-Europe are not used in all contexts; the country structure of EU has changed in time. In long time series, like in the introduction, CEPI-region has been used to represent European development. Use of CEPI-Europe statistics and EU-Europe statistics have been indicated in the text. In cases where EU time series are used, the EU consists of 27 countries in all years, even though they were not officially EU members in the past.

In the model, paper consists of fibre, non-fibre and water components. The furnish of paper is divided into newsprint printing and writing grades, tissue, containerboard, carton board and other paper and board grades. During paper consumption and collection the material absorbs moisture. Then recovered paper consists of absorbed moisture (and other contaminants that are in the non-fibrous component). The furnish of recovered paper is divided into old newsprint and old magazines (ONP/OMP), old corrugated containerboards (OCC), high grades and pulp substitutes (HG&PS) and mixed grades (Mixed). Collection volume is calculated by summing up European utilisation and net trade (i.e. consumption minus collection), and this made it possible to calculate other end use options.

3. Results

Waste is material that cannot be used and remains such until its threat to environment of human health is removed [15]. All industrial operations produce some waste and consume energy. Waste handling and recycling are topics that are bound together very closely. Larger proportions of material flows are recycled as new novel methods to utilize them are discovered. The EU's sustainable development strategy [27] identifies waste prevention and management as one of its top priorities. According to the European Waste Framework Directive (Directive 2008/98/EC), separate collections for materials like paper, wood, plastic, metal and glass need to be arranged by the end of 2014 and a recycling rate of 50% for municipal waste needs to be achieved by 2020 throughout Europe. The objective is to decouple the generation of waste from economic growth to reduce the pressures of waste on the environment [8]. Frost & Sullivan states [11] that in the EU countries there are some important topics that industrial operators needs to face. The first topic to face is the need for a strong regulatory framework setup by the EU, which includes also evolving legislative framework in individual countries as well, as mentioned above. Waste management needs more advanced and integrated solutions, which under current economic conditions and regional variation in trends are quite challenging to achieve. The variation of waste management inside European Union is quite large. For example the share of municipal waste to landfilling varies between 0-100% [13, 17]. Other growing options for municipal waste handling are recycling or composting and incineration. A group of countries with large paper, cardboard & wood waste proportion of above 15% can be noticed, and these countries are Sweden, Slovenia,

Finland, Latvia and Austria. Special focus on utilization of these wastes should be made within these countries. The large proportion of waste generated in the pulp and paper industry arises from non-organic materials, such as non-fibre components including both minerals and additives. These proportions cannot be reused economically using current technology, but these quantities are included in the statistics of recovered paper while the material moves in the chain.

Recovered paper collection rates usually increase with increasing income, ageing and per capita paper consumption [18], arising from better collection systems, but also being part of everyday practices of people. However the most effective reason to effect the collection achieved is the level of people's awareness of environmental issues [23]. Urbanization has also positive effect on recycled paper collection rate, but also level of waste produced [16, 26]. Alternative uses of collected paper play an important role in this field, where legislation set the rules. Waste collection operations are created based on legislation and if they are profitable, new systems will be used in large scale. As always, collection volumes need to be sufficient, in order to be able to be economically feasible.

Generally, waste generation should be minimised, by maximising the reuse and recycling of products and materials [1]. The papermaking processes utilises recycled material streams to produce pulp, paper and board. During the processing of materials energy is needed and part of energetic material resources is used to produce energy.

Each phase of the process chain produces some waste. A noticeable amount of non-fibre components is being separated from the main material flow during sorting and pulp manufacturing. Some of this non-fibre component material ends up as waste and part is being reused and returned into the production. The increasing recycling rate increases also the non-fibre components content in the process.

Recovered paper flow is divided into 4 main grades in this study. In practise it is not possible to analyse the availability of all the 95 trade grade classes as given in EN 643 (2013), because such statistics simply do not exist. To illustrate the possible upcoming challenges in the fibre processing chain, approximation of the use of different materials was made for Europe (EU) for 2010 and this is shown in Figure 2. This approach reveals the possible upcoming challenge of control of non-fibre components when the recycling rate increases. Figure 3 illustrates that there is substantial amount (in average 23% of the raw material) of non-fibre material already in the material loop at the paper production stage. The share of this non-fibre material varies depending on the stage of the chain. This material does not improve the product quality, and increases costs of recycling. If the producer of virgin paper reduces the use of non-fibre components to improve material recyclability, the benefits are gained by other operators in the chain by recycling the material. Virgin pulp based paper producer's costs are only increasing with this action instead.

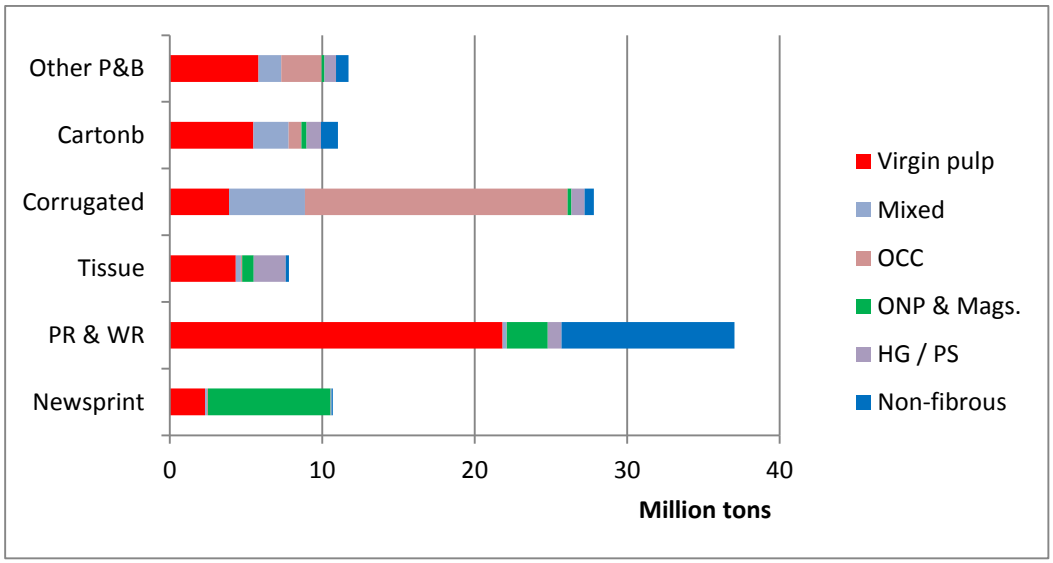


Figure 2. European (EU) paper raw material use by paper grade and by recovered paper grade in 2010, data from Indufor [31].

Implication of this is that development actions are aimed towards increasing the use of non-fibre components in the virgin paper and board production to save costs. Increasing use of non-fibre components leads to increased difficulties in the later stages of the processing chain in recycled pulp manufacturing. These challenges are likely to increase in the future. These issues need to be tackled by users of recovered paper producing (recycled) paper. A limited amount of development work has been done from recycling perspective of non-fibre components. One important question to overcome is, how much non-fibre components can there be in the final product? If the existing non-paper component share trend continues non-paper content maybe over half of weight in graphic paper in 2020. [?] This may be quite challenging for processes and holistic development actions may be required to overcome this challenge.

There are several alternatives to consider:

1. Developing the pulp and paper manufacturing process so that material stream with high non-paper components contents in recovered paper can be tolerated. On the other hand, in tissue manufacturing the share of non-fibre components has to be minimized.

2. Removal of the excess non-paper components produces more waste with environmental and economic impacts. In reality this will not happen, unless some changes for pricing of recovered paper and paper itself can be made simultaneously. Developing different end products from removed material would reduce waste generation. The user of recovered paper pays also for the non-fibre components when using recovered paper. This problem is two-fold: Firstly, the paper producer pays for non-fibre components in the recovered paper and secondly he has to pay more for the disposal of increasing amount of process waste. For example, changing the pricing from ton to square meter –base (would make this change) could be one possible solution. In practise this change would require(s) a new mind-set through the value chain., (because it benefits all.)

3. Develop legislation towards sustainability. As an example: Can part of the taxes of products be based on the amount of potential future waste, like non-fibre components?

   Firstly two options can be considered at the company level, but a societal dimension is required in the last option.

At the European (EU) level the four major components, namely virgin fibre, recycled fibre, non-fibre components and water materials flow in paper industry as shown in 2010 (Figure 3). The material flow system consists of five main stages and related flows [32].

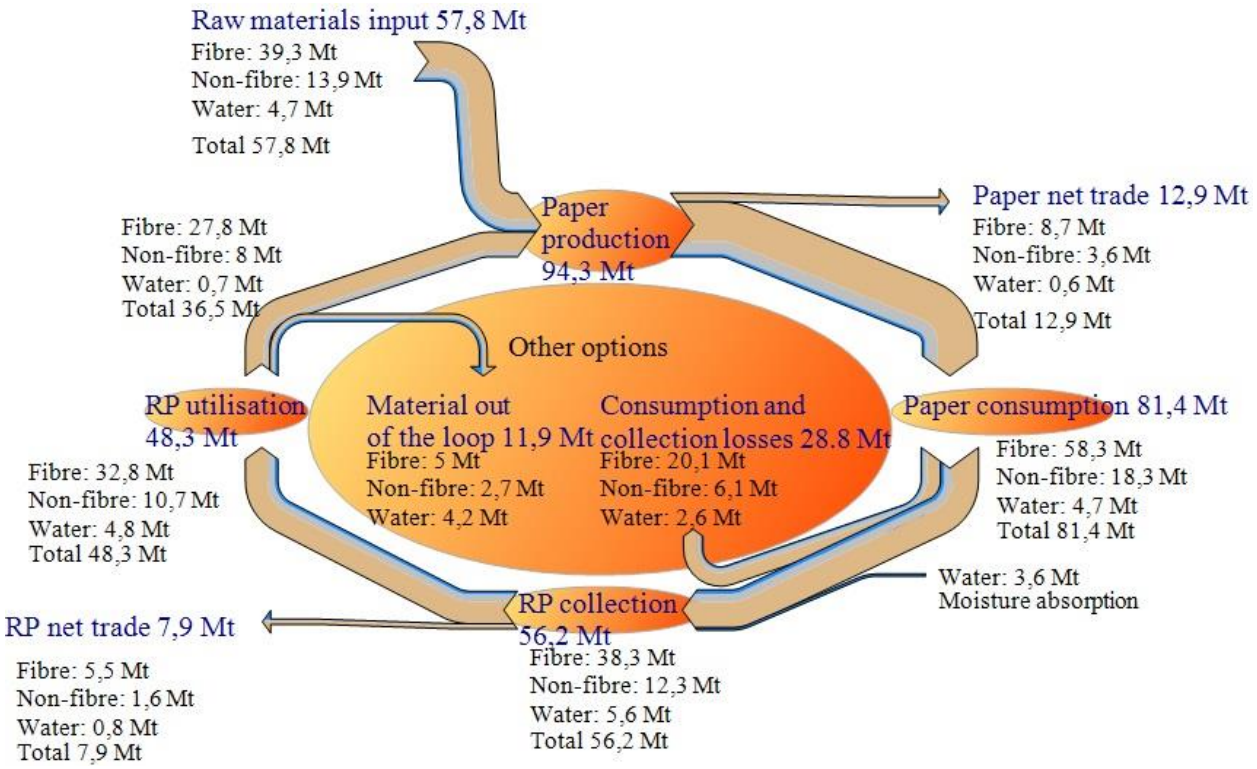


Figure 3. Fibre, non-fibre-components and water material flow of Europe (EU) in 2010 based on Ervasti and Kauranen –model [32].

Main stages and their corresponding flows (in million tons) of the loop are 1) Paper production 94.3 Mt, 2) Paper consumption 81.4 Mt, 3) RP (recovered paper) collection 56.2 Mt, 4) RP utilisation 48.3 Mt and 5) Other options (includes

consumption, (and) collection and process losses and material out of the loop) 40.7 Mt. A summary of the material flows is shown in Table 1.

Table 1. European (EU) paper industry material balances in 2010, values are in million tons.

Stage	Input/output	Fibre	Non-fibre	Water	Total	Total exit *)
Paper production stage (94.3)	recycled input	27.8	8	0.7	36.5	-
	virgin input	39.3	13.9	4.7	57.8	-
	total input	67.1	21.9	5.4	94.3	-
Paper net trade	material exits loop	8.7	3.6	0.6	12.9	12.9
Paper consumption stage (81.4)	to other options	20.1	6.1	2.6	28.8	28.8
	to collection	38.3	12.3	5.6	56.2	-3.6 **)
RP net trade	material exits loop	5.5	1.6	0.8	7.9	7.9
RP utilization stage (48.3)	to other options	5	2.7	4.2	11.9	(11.9) ***)
	to recycling	27.8	8	0.7	36.5	-

*) Total material exit from the paper recycling loop inside the region 57.8 Mt and it needs to be replaced with "virgin" material input

**) Absorbed water

***) This volume includes water which will be evaporated later

Possible differences found to other available statistics may be explained by the factor that simulation of loop balance was made after 8 iteration and stabilisation loops, which made the accuracy of simulation to approximately similar to accuracy of statistics.

The values of basic figures used for analysis in the Figure 3 are based on Indufor [31] working documents. The raw materials include different wood pulp grades,

recovered paper is divided into four main statistical grades as well as the non-fibre components. Additionally, it is assumed that recovered paper includes 10% moisture and paper includes 3-8% moisture, depending on the grade. The paper industry raw material furnishes were analyzed by paper and board grades for all EU 27 countries for 2010. Calculation of the balance for inputs of recovered paper in Figure 3 was made by 8 balancing iteration loops for amounts of fiber, non-paper components and water. Initial input of material flow was taken from all inputs with statistics in EU(-) 27 area including import and export for both paper and recovered paper.

The structure of the Figure 3 is based on Ervasti and Kauranen [32] model where the paper industry material flow was divided into five main stages: paper production, paper consumption, RP collection, RP utilization and other end uses (including RP utilization and production residues and consumption and collection losses).

Material changes form during the rotation loop in the chain. For example paper turns into recovered paper through collection and back to paper in the recovered paper utilization stage. At the collection stage different paper grades turn into four main statistical recovered paper grades. At the same time different materials in paper (fibres, non-fiber components and water) join the recovered paper flows. Due to different moisture level additional water is absorbed into the material at this stage. The principle of this metamorphosis where paper turns into recovered paper is shown in Figure 4. Due to sorting residues and the share of non-recyclable and non-collectable materials, part of the material flow ends up to other options.

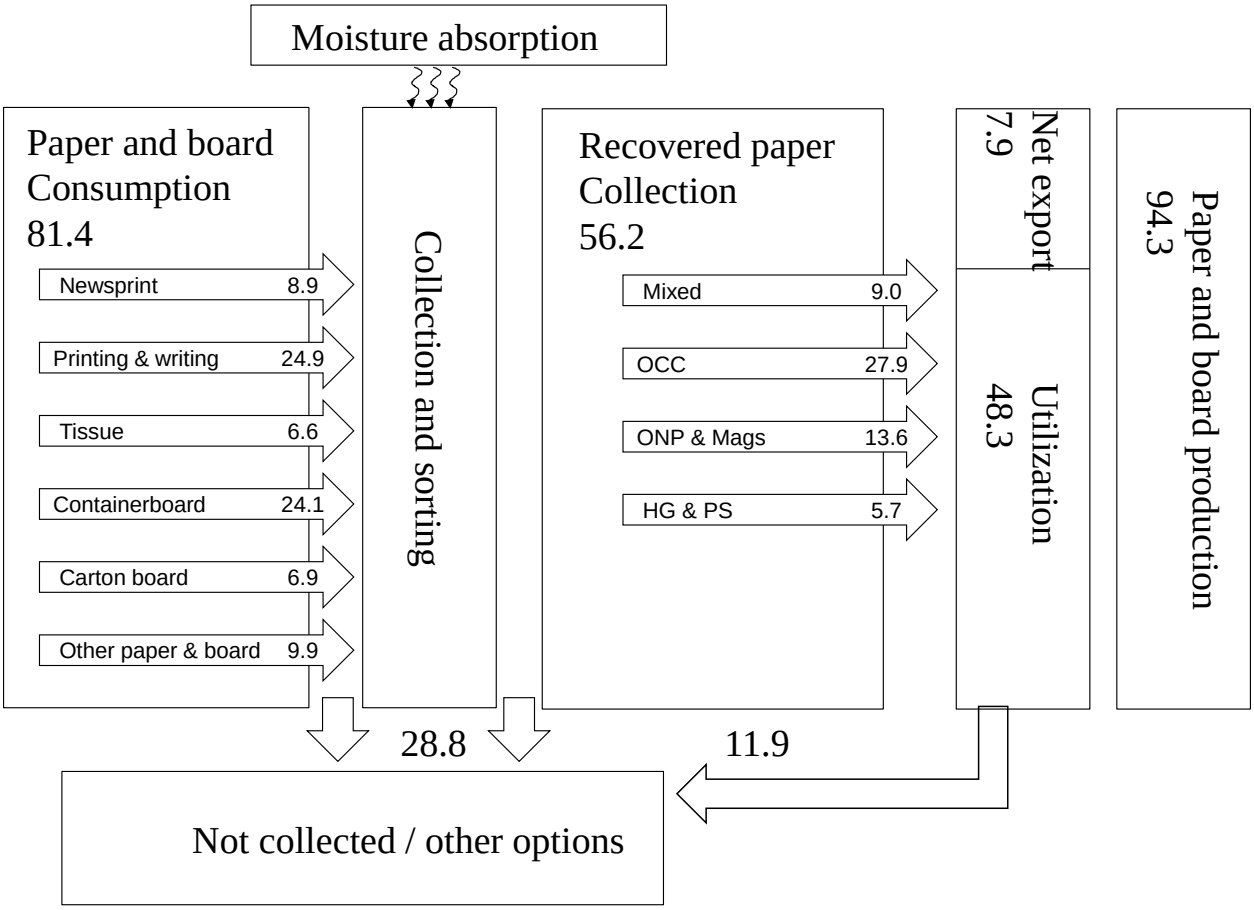


Figure 4. Europe (EU) in 2010. At collection stage different paper grades turn into different recovered paper grades to be utilized locally or to be exported to outside the region. In this model six different paper and board grades turn into four recovered paper grades. All values are in million tons (Mt).

3.1 Non-fibrous components contents

Non-fibrous components content in recovered paper has increased [5]. Historically there was a 0.3% increase of added non-fibre components content annually in paper & board; this in conjunction with increasing recycling rate increase of 1.8% annually, will increase development needs. This is due to both increased new non-fibrous components input at the paper production stage, but also increased fibre recycling

which include non-fibre components. The increase in recycling rate influences on the average non-fibre components content of paper & board especially in high grades. As one result, (more landfills) new means to get rid of the material are needed, (although they should be) while use of landfills should be avoided if no new means to recycle also non-fibrous components can be found. Part of this material flow is exported as paper, paperboard and recovered paper to outside the region making the disposal concern a global one. Most of non-fibrous components are in printing and writing paper grades, as shown in Figure 2. The consumption share of these grades decreases fastest and this changes the overall paper and board furnish and material flows. A comparison of two very different EU-countries (Sweden and Germany) is made in terms of paper and board production and collection. This difference has been shown in Figure 4???. The accumulation shows the total (virgin??) non-fibre components in each paper and board grade in year??. In Sweden, a large proportion of the paper produced is exported. However, some minor parts of the production are used inside Sweden, and estimate of the share of recycled non-fibre components use in Sweden was also made and shown in Figure 5. One interesting finding from statistics it is that it seems plausible that a new undocumented source of RP can be shown from a source of RP coming from OCC, which is considerably higher than fresh non-fibrous utilisation (both in Sweden and in Germany). We believe this arises from packages which are imported together with traded goods. Increasing internet trade is part of this flow. This finding requires further studies. In Germany most of the accumulation of the non-fibrous components is seen in corrugated containerboards, carton boards and wood-containing printing and writing papers. Especially in boards the non-

fibrous components reuse plays an important role and their origin varies. In wood-containing printing and writing papers non-fibrous components source is mainly from ONP/Mags –grades. Minerals and additives has a tendency to enrich in the loop as discussed earlier. The new waste directive with increasing recycling targets will increase production costs of some paper grades due to increasing disposal costs??, unless non-fibrous components cannot be recycled as raw material in the processing chain.

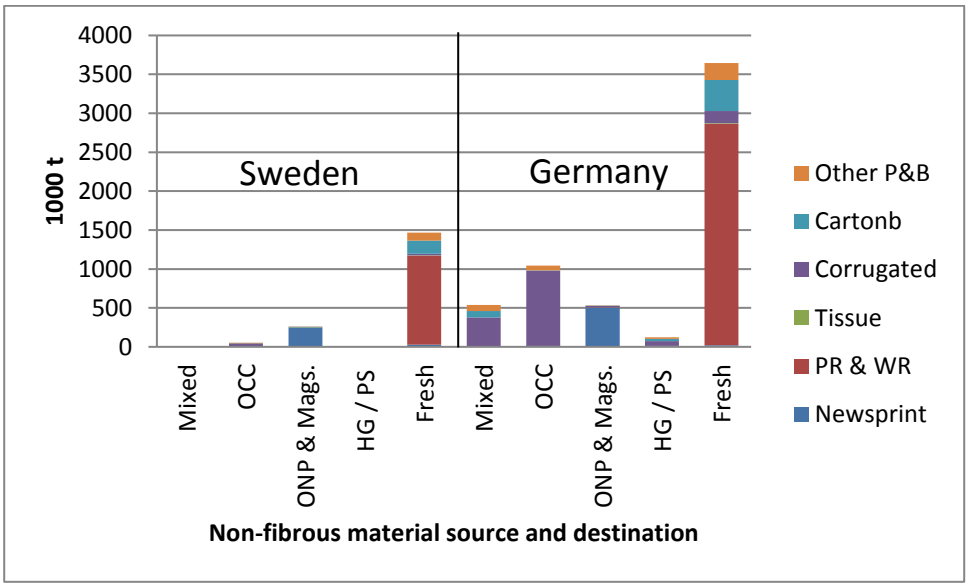


Figure 5. Comparison of non-fibre components in Sweden (SWE) and in Germany (GER) by (RP) source in 2010??. Fresh indicates non-recovered non-paper components, data from Indufor [31]. Miten tama laskettiin???

4. Discussion

Novel utilization methods for recovered paper and its components are required in order to reduce waste loads to landfills and intensifed recycling more and more beyond the current level. There is also increasing pressure to collect raw material

from households, as the other collecting sources (like supermarkets, industrial, converting and printing sources) are already well covered. The amount of non-fibrous components has direct effect on (landfill) waste amounts. (Landfill) Waste reduction options have to be taken into account, by reducing the amount of non-fibre components (usage) in the waste stream. To be able to develop these issues effectively it is essential to be able to describe the material flows reliably.

The amount of recovered paper has grown and will grow further (Figure 3????). In Europe the EC has set distinct binding targets and schedules and also the paper industry has committed to voluntary increases in recycling degree (3 voluntary declarations). (The recycling rate in CEPI has reached a high level (69% in 2010 [30]).) With increasing recycling rate, the paper quality may be compromised, as the (use) share of virgin fibre material is reduced. Unbalances in the recovered fibre grades may also occur due to increase of exported raw material net flow out of Europe. At the moment large amounts of collected paper is exported to outside Europe, mainly to China, in 2009 almost 13 million tons annually (Cepi, 2011) [5].

The European (CEPI) recovered paper utilization rate in paper production (is) was some 51% in 2011. However, the most often used indicators related to paper recycling, like utilization rate and recycling rate, tend to give a too optimistic picture about the recycling activity as the figure 3 indicates, while according to findings of this study, only about 41% of fibre used in paper production phase comes back to circulation (from recovered sources) through recycling in Europe (EU). Difference between utilization rate and recycling rate development in Europe (EU) during 1995-2012 is shown in Figure 6.

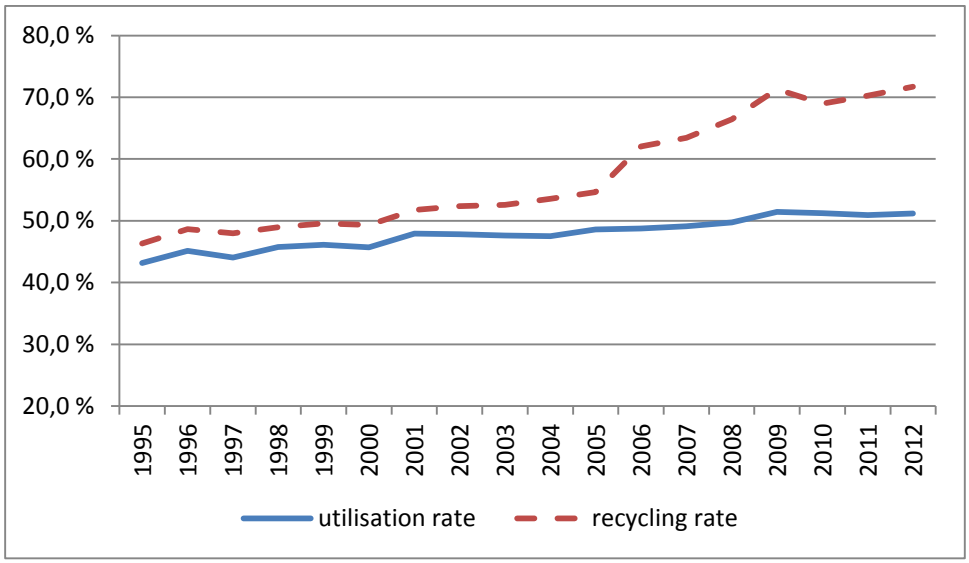


Figure 6. Utilisation rate and recycling rate in Europe during 1995-2012, data from CEPI and Indufor [5, 31].

However, recovered paper is used also for other purposes beyond the paper & board applications. Other alternatives like the uses in insulation materials and moulded products should be quantified, too. However, due to presently used calculation methodology, these volumes are not included in the present collection volume. Energy use, together with waste, is increasing, but according to definition, it is not recycling but recovery. Deinking of (fibre) produces large amounts of waste and residues. For example in tissue production the losses are 28-40% (in tissue production) [12]. New methods of (sorting and) recycling are needed to recycle this material instead (of loading it to landfills) of putting it into waste stream.

Deinking residues (waste) including minerals and additives can be reused for paper production, or reusing (the material) it in other uses. The cost of recycling and quality of collected (material) paper strongly depends on the smartness of the

collection and sorting methods, efficiency of transportation methods and logistics systems. A limited amount of research has been carried out in these areas [26]. A multi-scientific approach is needed to solve the questions of better sourcing and utilisation of recycled fibre material, where each operator's active participation can be a great opportunity. Agents (collectors, traders of paper products, designers) themselves need to set the game of play as an active actor in this field, remembering the legal limitations in each country. This makes it possible for them to outline the map of future actions needed to fulfil the game wanted. For some operators this requires investments, whereas some can benefit from the opportunities with minimal investments. Cooperation with different parties is essential to maximize the benefits.

Environmental impact of transport needs consideration as well. Some of the possible benefits arising from reduced use of non-fibrous components were shown???missä??. In addition to direct benefits from reduced need of transport (both recovered and produced paper and board). Reduced logistics cost may even be (the leading) an important reason (for reduction) when considering use of non-fibre components (use in the) paper and board in the future.

5. Conclusions

By dividing the paper industry material flows into four main material components, namely into virgin fibre, recovered paper, non-fibrous components and water, reliable description and comparison of the flows of each of these material groups in the paper recycling chain is possible. In our opinion this (approach) study is the first to show flows of fibre, water and non-fibrous components in the same figure. This

study (showed) identified a potential source of recovered fibre, which is possibly arising from e.g. internet orders that are packed and packages (recovered) collected. Mainly this was seen from analyses of non-fibrous components in Sweden and Germany. Also we showed that recycling of fibre and non-fibrous components is low, even though their defined (recovery) recycling rates are relatively high. The importance of fresh fibre input to papermaking is thus evident and perhaps greater than earlier considered.

Non-fibre components play an important role in paper manufacturing. If the use of non-fibre components in paper production increases as it has been done lately, the development of processes needs to be made. The increased use of non-fibre components has been one of the key components to save raw material costs at the paper production stage. If the non-fibrous components use is reduced actively, some savings from logistics and waste management can be obtained, but also business development needs to be made, for example considering change of sales from ton base to sqm-base. The non-fibre component flow is important to be understood while after the whole rotation chain only 36.5% of this material ends up back to paper production????. The remaining 63.5% of the European non-fiber material may be exported outside the region????.

Without active participation, either development of processes or legal framework the paper & board industry, especially in the graphic grades will face difficult operational actions (due to decreasing demand). Some of the operators may not be able to continue their operations with current level without heavy investments.

Number of operating companies has decreased by??30.9% (by years) and number of mills by 25.6% from (year) 2000 to (year) 2010 [5].

Ecologically and economically optimised utilisation of paper and board will be a natural outcome, when participation is active??? mitä tarkoitetaan. Some parts of paper and board collection could be even separated, especially for the grades with very high either low non-fibre components content., (where recovery of) High non-fibre content papers (would) could take an alternative route of utilisation in e.g. composites and other material end uses. An important question arising from this study is should the non-fibre components content of recovered paper be measured more closely? Due to exit of fibres from the material in different flows, the actual fibre amount back into the loop is considerably lower than the presently used term like recycling rate indicates.

Active participation of the paper and board recycling network in Europe is needed as initiator and as part of global corresponding network to solve the emerging issues discussed in this paper.

References:

1 Bartl, A. et al. Recycling Of Fibre Materials: doi: 10.1205/psep.04392 (2005)

2 CEPI Annual and Key statistics 2010: http://www.cepi.org/system/files/public/documents/publications/statistics/2010%20Key%20Statistics%20FINAL.pdf

3 CEPI annual statistics 2007

4 CEPI annual statistics 2008

5 CEPI, www.cepi.org (statistical resources, last accessed 10.1.2014).

6 European List of Standard Grades of Recovered Paper and Board, 2002 (EN 643)

7 European List of Standard Grades of Recovered Paper and Board, 2013 (EN 643) http://www.cepi.org/system/files/public/documents/publications/recycling/2013/CEPI_EN%20643_brochure_FINAL_0.pdf (last accessed 9.1.2014)

8 Eurostat (2010) Environmental Statistics and Accounts in Europe, Waste (Chapter 3). Available at: http://epp.eurostat.ec.europa.eu/portal/page/portal/waste/documents/Waste_Chapter_Flagship_Publication.pdf (accessed 3.11.2011).

9 Eurostat (2014): http://epp.eurostat.ec.europa.eu/portal/page/portal/waste/introduction/ (last accessed 10.1.2014)

10 FAO: pulp and paper capacities, 2009-2014 (ISSN 0255-7665): http://www.fao.org/docrep/012/i1666t/i1666t00.pdf (last accessed 10.1.2014)

11 Frost & Sullivan (2011): Growth Opportunities in the European Industrial Waste Management Services Market, June 2011.

12 Hamm U. (1999), Final fate of waste in recovered paper processing and non-recycled paper products. Papermaking Science and Technology, book 7, Recycled Fiber and Deinking, FAPET, Helsinki, Finland, 1999.

13 http://epp.eurostat.ec.europa.eu/portal/page/portal/environment/data/main_tables# (last accessed 10.1.2014)

14 http://epp.eurostat.ec.europa.eu/portal/page/portal/international_trade/publications/comext_dvd (last accessed 13.1.2014)

15 http://europa.eu/legislation_summaries/environment/waste_management/index_en.htm (last accessed 10.1.2014)

16 http://siteresources.worldbank.org/INTURBANDEVELOPMENT/Resources/336387-1334852610766/Chap3.pdf (last accessed 9.1.2014)

17 http://www.defra.gov.uk/statistics/environment/waste/ (last accessed 10.1.2014)

18 Hua, F. and Shinichi, T., (2012) Analysis of China's Current Waste Paper Collection Rate, Design for Innovative Value Towards a Sustainable Society, Proc. of EcoDesign 2011: 7th International Symposium on Environmentally Conscious Design and Inverse Manufacturing 2012, pp 853-856, ISBN: 978-94-007-3010-6

19 Key statistics 2009: http://www.cepi.org/system/files/public/documents/publications/statistics/Annual%20Statistics%202009.pdf

20 Key statistics 2011: http://www.cepi.org/system/files/public/documents/publications/statistics/Key%20Statistics%202011%20FINAL.pdf

21 Key statistics 2012: http://www.cepi.org/system/files/public/documents/publications/statistics/2013/Key%20Statistics%20Report%202012.pdf

22 Magnaghi G. (2013) Recovered Paper Market in 2011, BIR (Bureau International Recycling); 2013.

23 Miranda R, Blanco A. (2010) Environmental awareness and paper recycling. Cell Chem Technol. 2010;44(10):431–49.

24 Moilanen, A., et. al. (2000) Recycling and processing of ash from incineration of waste paper and deinking sludge for paper filler. Paperi ja puu - Paper and Timber, 2000. Vol. 82, No. 8, p. 546 – 552

25 Oldenziel, R. and Weber., H. (2013) Introduction: Reconsidering recycling, Contemporary European History, vol. 22, pp.347-370, 2013

26 Stawicki, B. and Read, B. (eds.), (2010) The future of paper recycling in Europe: Opportunities and limitations, (COST action 48, final report, "The Limits of paper recycling", 2010), available: http://www.cost-e48.net/10_9_publications/thebook.pdf (last accessed 10.1.2014)

27 The sustainable development strategy of the European Union (EU SDS), as revised in 2006, is a framework for a long-term vision of sustainability in which economic growth, social cohesion and environmental protection go hand in hand and are mutually supporting. See the communication from the Commission to the Council and the European Parliament 'On the review of the sustainable development strategy — A platform for action' (COM(2005) 658 final).

28 United States International Trade Commission (http://dataweb.usitc.gov/) (last accessed 10.1.2014)

29 Zhao H. (2012) Outlook for Recovered Paper Markets. RISI. October 2012.

30 Cepi sustainability report 2013

31 Indufor, (2013), Study on the wood raw material supply and demand for the EU wood processing industries, A11-04451, December 4, 2013

32 Ervasti I., Kauranen I. Unbundling the chaos: Revealing inconsistencies in paper recycling related terminology, Seminar paper, Doktoranden Treffen, TU-Dresden (Germany), 2011;