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CHAOS IN TERMINOLOGY RELATED TO MATERIAL RECYCLING IN PAPER INDUSTRY

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The objective of this thesis is to increase understanding of the multiple uses of different terms related to paper industry material recycling.

Use of terms related to material recycling in paper and board industry is in chaos. Generally accepted, uniform definitions of terms are missing. Material recycling rate cannot be calculated univocally due to great number of different definitions. Often, different terms are being used for the same matter; and often, the same term is being used to refer to different matters.

Additionally, at present there is no reliable framework in use to describe paper industry material flows unequivocally. Consequently for example it is not possible to compare geographical regions with each other reliably.

There is a need to develop a new, uniform framework and a corresponding terminology to describe and quantify paper industry material flows. This new framework could help to better describe, understand, and manage regional and global paper industry material flows uniformly. A univocal framework and uniform terminology is necessary in order to estimate the future raw material demand and in order to compare different regions with each other.

When developing a new framework for paper industry material flows, special attention should be paid to material recycling, which plays an increasingly important role in paper manufacturing.

In this thesis a comprehensive review of extant terms and frameworks was carried out. An extensive table of terms as well as a list of existing frameworks is presented. Different definitions of terms used in the literature and selected frameworks are compared.

Preliminary suggestions for the development of a uniform recycling framework and clarifying the recycling terminology are provided.

Keywords: Recovered paper, waste paper, paper recycling, recycling rate, recovery, terminology, paper industry	Publishing language: English

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Tämän lisensiaattityön päämääränä on lisätä ymmärrystä paperiteollisuuden materiaalikierrätykseen liittyvien termien moninaisesta käytöstä.

Materiaalin kierrätystä koskevien termien käyttö paperi- ja kartonkiteollisuudessa on kaaoksessa. Yleisesti hyväksyttyjä termejä ja määritelmiä ei ole olemassa. Materiaalin kierrätysastetta ei voida laskea yksiselitteisesti, sillä käytössä on suuri määrä erilaisia määritelmiä. Samasta asiasta käytetään usein eri termiä. Toisaalta, sama termi voi tarkoittaa useita eri asioita.

Tällä hetkellä ei ole olemassa myöskään yhtenäistä mallia, jolla kuvattaisiin paperi- ja kartonkiteollisuuden materiaalivirtoja yksiselitteisesti. Tämän vuoksi on mahdotonta verrata eri maantieteellisiä alueita ja niiden materiaalivirtoja keskenään luotettavasti.

On tarpeellista kehittää uusi, yhdenmukainen malli ja siihen liittyvä terminologia. Tätä uutta ja yhtenäistä terminologiaa käyttämällä pitäisi pystyä kuvaamaan ja kvantifioimaan paperiteollisuuden materiaalivirtoja yhdenmukaisesti niin alueellisesti kuin maailmanlaajuisestikin. Yhtenäinen materiaalivirtoja kuvaava malli ja siihen liittyvä yhdenmukainen terminologia ovat välttämättömiä laadittaessa tulevia materiaalivirtoja koskevia ennusteita ja verrattaessa eri alueita keskenään.

Uuden materiaalivirtamallin kehittämisessä erityistä huomiota tulee kiinnittää materiaalin kierrätykseen, koska kierrätysmateriaalin osuus on yhä suurempi paperinvalmistuksessa.

Tässä lisensiaattitutkimuksessa tutkittiin laajalti paperiteollisuuden materiaalikierrätykseen liittyvien termien käyttöä ja määritelmiä. Lisäksi tutkittiin valittujen mallien käyttöä paperiteollisuuden materiaalivirtojen kuvaajina.

Tässä lisensiaattityössä annetaan myös alustavia ehdotuksia uuden yhtenäisen materiaalikiertoa kuvaavan mallin luomiseksi ja siihen liittyvän terminologian kehittämiseksi.

Asiasanat: Keräyspaperi, jätepaperi, paperin kierrätys, kierrätysaste, keräys, terminologia, paperiteollisuus	Julkaisukieli: Englanti

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Preface

The original objective of the author of this thesis was to use quantitative methods in comparing values of selected terms related to *paper recycling* like *collection rate, recycling rate, utilization rate* and *paper consumption* with each other. The idea was to quantify selected terms defined and taking into account different regions and different times as well as to track trends and reasons behind them.

However, already at the planning phase of the data collection, it became obvious that the intended work was not possible to be carried out due to lack of common terminology. The same term had different meanings depending on author, region and time. Furthermore, different terms had the same meaning. It became apparent that it was impossible to build reliable time series of the available data which would enable comparisons of different regions with each other. Comparisons were impossible because there is no common, global terminological system related to paper recycling.

After identification of the fact that several terms were defined differently by several sources, the project took on a totally new direction. The new task of the author was to compare different paper recycling related terms with each other by taking into account different authors, different regions and the period in question. In this respect, the quantitative approach changed to a qualitative approach. Also a hermeneutic research strategy was adopted.

The European Union uses recycling rate to indicate material recycling activity in different industry sectors. Material recycling targets have been set by the European Union as well as different industry organizations like the Federation of the European Paper Industries (CEPI). In this study, special attention paid to clarify, whether it is possible to define paper industry recycling rate reliably by using presently available definitions.

During the study process it the author identified chaos in terminology related to paper recycling. In this thesis the author gives some concrete suggestions about how to start solving this chaotic situation. A new material flow framework called “the wheel of fiber” is introduced.

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CHAOS IN TERMINOLOGY RELATED TO MATERIAL RECYCLING IN PAPER INDUSTRY

1. Introduction and background

The use of terms related to material recycling in the paper and paperboard industry is in chaos. A basic prerequisite for 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 obscure, misunderstandings can occur, or the messages may not be understood at all by the receiver. Every field of society and 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).

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). Easily understandable and robust indicators are essential in improving measuring of resource-efficiency, underscoring the importance of consistent definitions related to resource-efficiency between nations, business sectors and disciplines. However, such standardization is challenging in practise.

To be able to define and quantify resource flow related terms and material flow related terms reliably, it is necessary to form a clear picture about the material itself, and how the material flow systems work. It is also important to understand which stages are essential, what their mutual relations are, how the material flows between stages and how to quantify the stages and the flows as well as their relations.

Yet at present, it is difficult to define uniformly the paper and board industry material flows. There is no global system to uniformly define paper industry *material recycling* related different terms. Food and Agriculture Organization (FAO), a global organization, has a list of terms and their definitions, but they are not generally in use.

The chaos in the use of terms related to paper industry material recycling is so severe that it is difficult, for example, to compare different literature sources with each other. 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, attention has increasingly been paid to reducing *waste*, to the effective utilization of raw materials, to material recycling, and to the disposal of waste. Findings derived from studying paper industry material flows can be applied to other recycling sectors, too.

In this study, special attention has been paid to different terms which have been used both in the literature sources and the identified paper industry material flow frameworks. These terms may consist of several different words like *recovered paper recycling rate*. For this reason all terms used have been denoted in italics.

1.1. Study objective

The objective of this thesis is to increase understanding of the multiple uses of different terms related to paper industry material recycling. In this thesis a comprehensive review was conducted about the use and definitions of different terms and material flow frameworks relating to paper industry material recycling. This thesis identifies and analyzes different paper industry material flow systems by taking into account relevant input and output flows and main stages as well as *material recycling*. This is done by utilizing presently used paper industry material flow frameworks. Their structures, terminology used, definitions and capabilities to describe material flows are analyzed. This thesis criticizes the presently used several different paper recycling related terminological systems and gives improvement suggestions to find a solution for this situation as seen appropriate by the author.

In cases where definitions of terms differ by source, this thesis describes how the definitions differ in different geographical regions and how the definitions of terms may have changed over the course of time. Special emphasis in the literature review will be given to publications by industry associations and organizations producing statistics in the field as well as to scientific research reports.

1.2. The state of the art

Even the most common terms in the field of paper recycling are generally used without uniform definitions in the existing literature. For example, in many cases terms like *recovered paper, waste paper, recycled fiber (fibre*), and *recycled paper* have been used interchangeably, whereas in other sources the very same terms have been deliberately used to make a difference between materials in different stages of the recycling chain.

Many of the general level frameworks paying attention to the importance of input and output flows do not pay enough attention to *material recycling* which plays a key role in sectors like the paper industry. In the literature review, 64 sources that included definitions of different terms were identified. Additionally, 10 different paper industry related frameworks were identified.

This thesis gives a contribution to the scientific community by identifying that paper recycling related terminology is in chaos. This thesis gives useful advice to organize this chaos. Additionally, this thesis points out new ideas which should be researched further.

1.2.1. Importance of material recycling in the paper and board industry

Recovered paper is globally the most important raw material for the paper and board industry by volume, globally (Ristola, 2012). *Recovered paper* is a technically good and environmentally sound raw material and an important global trade commodity.

The global consumption of *recovered paper* was 221 million tons in 2010. During the same year, *paper and board production* was 394 million tons (Magnaghi, 2011). In accordance the *global recovered paper utilization rate* was 56%. Here, the definition for *recovered paper utilization rate* provided by the Federation of European Paper Industries (CEPI) is used. According to this definition, *recovered paper utilization rate* is the ratio of *recovered paper utilization* and *paper production*.

According to the European Waste Directive, separate collections for materials like paper, metal, plastic, wood, and glass need to be arranged by 2015 and a *recycling rate* of 50% for *household waste* needs to be achieved throughout Europe by 2020 (Directive 2008/98/EC).

Additionally, the European paper and board industry, together with several stakeholders, has published three different voluntary declarations on *paper recycling* with specific deadlines and *recycling rate* targets. (ERPA, 2000; ERPC, 2006; ERPC, 2011)

Recycling targets mean that there has to be a methodology to reliably calculate *recycling rates* for paper and other recyclables. The European Parliament and Council Waste Framework Directive (2008) view *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.

Quantitative description of the European use of different raw materials gives a good overall picture about the importance and the role of different raw materials in paper production. In paper manufacturing, the *raw material utilization* in CEPI countries (members of the Federation of the European Paper Industries) was 104.7 million tons in 2012 (CEPI, 2013a). This volume consists of different raw materials as shown in table 1.

Table 1. Utilization of different raw materials within the European (CEPI countries) paper industry in 2012

Material	**Million tons**	**Share, percent**
recovered paper	46.8	44.7
wood pulp	41.9	40.0
pulp other than wood	0.4	0.4
calcium carbonates	8.8	8.4
clays	3.6	3.4
starches	1.8	1.7
other non-fibrous materials	1.4	1.4
total raw material	104.7	100.0

Note: CEPI countries include: Austria, Belgium, Czech Republic, Finland, France, Germany, Hungary, Italy, the Netherlands, Norway, Poland, Portugal, Romania, Slovak Republic, Slovenia, Spain, Sweden and the United Kingdom

The total paper production in CEPI countries was 92.1 million tons and *recovered paper utilization* 46.8 million tons in 2012. Thus, the corresponding *recovered paper utilization rate* was 50.8%.

The total *recovered paper utilization* in CEPI countries represents 96.5% of the total European (EU 27 + Norway and Switzerland) *recovered paper utilization*. That is why it can be stated that CEPI countries as a region can be used to represent the European situation quite reliably (CEPI, 2011; Indufor 2013).

Europe exports more *recovered paper* than imports. In 2012, the European net exports of *recovered paper* totaled about 9 million tons (CEPI, 2013a). This represents 16% of the total European *recovered paper collection*. This material is not used in Europe but according to the presently used definition, it is included in the European recycling (CEPI, 2013a).

Different paper grades and thus the collected different *recovered paper* grades may consist of varying shares of *virgin pulp* (wood pulp from several different wood species and pulp from other plants), *recovered paper* as well as *non-fibrous materials* including minerals and additives like calcium carbonate and clay.

According to Faul (2012), the *recovered paper collection rates* in Europe are already close to maximum levels and globally, the *recovered paper* supply / demand balance is expected to tighten in the future. Ringman (2010) states that *recovered paper* is the most important source of fiber for paper manufacturing in Europe. That is why it is necessary to try to utilize the *paper collection potential* well in *material recycling*. According to the European Waste Directive, material recycling is favoured in comparison to energy production. However, it is possible that increasing volumes of *recovered paper* will be used for energy purposes in the future.

1.2.2. Use of terms

In this thesis, the word *term* covers all of the different stages in the material flow of the paper and board industry, from fiber material itself to *recycling*. For example, *old newspapers*, *old corrugated containers (OCC)*, *recovered paper*, *RP*, *recovered paper recycling*, *recovery*, *recycling rate*, and *waste paper* are all considered as terms. This thesis concentrates on paper industry sector related material flows. In this thesis the term *paper* covers both paper and paperboard.

American English is used in this article. In accordance, when the original source has used British English, the spelling of words has been changed to American English. For example, if the original

term in a British English statistics has been *recycled fibre*, the spelling in this article has been changed to *recycled fiber*. Terms themselves may consist of one or several words. That is why, to help readers to separate terms from the rest of the text, the terms have been written in *italics*.

Several organizations and authors have published their own frameworks and in most cases call them with names of their own. These frameworks have been called for example *accounts, diagrams, models, charts, material flow accounts (MFA)* and *substance flow analysis (SFA).* Additionally specific names have been given to the frameworks used. For example, the European Recovered Paper Council (ERPC, 2013) calls its framework *consumers who discard paper*. In this thesis, the term *framework* is used to cover all different names used for the *material recycling chain* by different sources.

The basic parameters for the word *definition*, according to Webster's (1994) are as follows:

1) the act of defining or making definite or clear
2) the formal statement of meaning or significance of a word, phrase etc.
3) condition of being definite.

1.2.3. Paper recycling related terms and definitions

Readers may find it quite difficult to understand the messages correctly if different writers use different terms for the same matter. It can be equally difficult for the reader to form a clear picture about the matter if different writers use the same terms for different matters.

In this thesis, the author selected different terms which are used to represent different stages of the paper *recycling chain* (Ervasti and Kauranen, 2011). The *paper recycling chain* consists of five main stages, namely *paper and paperboard production, paper and paperboard consumption, recovered paper collection, recovered paper utilization for paper manufacturing* and *other recovered paper options.* Main *paper recycling* related terms which are used in this thesis are as follows:

- The term *paper production* is generally in use globally and it represents *production of paper* and *production of paperboard* combined
- The term *paper consumption* represents *consumption of paper* and *consumption of paperboard* combined. This term is used globally and it is usually calculated through *paper production* and *net trade*

- The term *recovered paper* is used for material which is *collected (used) paper* and processed in accordance with any regional or global *recovered paper* classification system. There are a great number of other terms used for *recovered paper*, but this term was selected for several reasons. It describes the material well and the term is used by several organizations like Australian Council of Recyclers (ACOR), American Forest and Paper Association (AF&PA), European Cooperation in Science and Technology (COST E48), FAO, Paper Recycling Association of South Africa (PRASA) and Japanese Paper Recycling Promotion Centre (PRPC). European organizations like the Confederation of European Paper Industries (CEPI), European Recovered Paper Council (ERPC) and the European Committee for Standardization (CEN / EN 643) have used the term *recovered paper*. However, since 2011 these European organizations have replaced the term *recovered paper* with the term *paper for recycling*
- The term *collection* is used by several organizations like AF&PA, CEPI, ERPA, FAO, COST E48, PRPC and CEN / EN 643. It can refer both to the *collection process* itself where material is retrieved from a source or to statistical *collection* which is usually calculated through *recovered paper utilization* in a region and *net trade of recovered paper*. In this thesis, the term *collection* refers to the statistical *collection* if not otherwise mentioned. The term *recovery* is used, for example, in the USA and Japan in place of *collection*
- The term *utilization* refers to *recovered paper,* which is used as raw material in *paper and paperboard manufacturing*. The term refers to both mill scale use and regional (statistical) use. It is a generally used term, globally
- Mainly in Europe, the term *recycling* is used in place of the term *collection*. In other regions the term recycling is not used in this meaning, but to refer to *material recycling* in general
- The term *other options* refers to *recovered paper* use for other end uses than *paper manufacturing*, including also its energy use. This term also includes the volume of *not collected* and *disposed paper*.

1.3. Material flows

Describing industry material flows is essential. This is necessary to be able to analyze and forecast demand and trade of different fiber raw materials. Detailed description of material makes it possible to compare the amounts of different raw materials in the framework with each other.

1.3.1. Regional material flows

The world is changing rapidly and regional differences occur. Also, supply and demand and their balances of different raw materials change. The standard of living in Asian economies and especially in China is expected to grow faster than in Western economies. This increases demand for raw materials in Asia.

A lot of work has been done amongst the whole society including policy makers and non-governmental organisations to develop frameworks for the supply side of environmental accounting (Waller-Hunter, 2000). Attention has been paid to developing practical frameworks including accounting tools for natural resources like water, forests and energy. In accordance, availability of statistical data and sophisticated accounting and indicator systems are needed at national and international level. An important and widely used framework called Material Flow Account (MFA) has been seen as a tool to provide relevant, analytically sound and measurable indicators for decision makers at different levels.

For example, OECD (2004) uses several different terms related to material flows. OECD material flows and related indicators concentrate mainly on the national and macro-economic level. Priority is suggested to be given to the measurement of direct flows of materials physically entering a national economy for further use in the production or consumption processes. Development of economy-wide material flow terms covering the whole material flow chain is being suggested (OECD, 2004). In order to serve both analytical and communication purposes uniform definitions for key terms are needed. According to OECD (2004), it is necessary to all parties involved to agree upon a consistent terminology, building on a common language and understanding of the related concepts.

The development work concentrates mainly on input material flows that are easier to measure than the output material flows. Additionally, measurement of secondary, i.e. recycled or reused material flows is seen as highly relevant (OECD, 2004). This, however is expected to require long term measurement and methodological efforts (OECD, 2004). This development work can be done, for example, by countries that wish to establish more detailed sector or substance specific accounts. Progress can be achieved through specific national efforts, case studies in collaboration with countries sharing common interests or other forms of co-operation. There are natural variations

between different material sectors. Different flow accounts for different materials are needed (OECD, 2004).

1.3.2. Paper industry material flows

Different elements in paper industry material flows include *virgin fiber, recovered paper, non-fibrous components* like *fillers* and *coating pigments* as well as the final product, *paper*.

In different frameworks, stages between the flows are identified and described. Frameworks describing paper industry material flows should be built so that different stages and flows could be quantified uniformly in different geographical regions. Definitions of terms and the quantification of material in all of the stages and flows should be done so that the relations between the stages and flows in the framework could be defined uniformly in different regions. For example, the term *collection rate* is calculated with the following formula: *(recovered paper collection) / (paper consumption)*. Both *recovered paper collection* and *paper consumption* are terms defining different stages in a framework. If a uniform framework could be developed and adopted, it would be possible to link regional frameworks with each other and form a global, aggregate framework.

2. Study methodology

2.1. Qualitative research approach

This thesis uses a qualitative research approach. Different players set questions and interpret matters by using their own point of view and understanding. The same matter can be described in many ways. The starting point in qualitative research is the description of the actual situation. A basic assumption is that the reality is complicated (Hirsjärvi S. et al., 1996). It has to be taken into account in research that reality cannot be cut into pieces randomly. Different occurrences may have mutual relations. In qualitative research, the study phenomenon should be studied holistically. Generally, in qualitative research the aim is to find and reveal facts rather than verify existing claims.

This thesis utilizes exploratory research approach. This approach can be used if the problem or research field is not defined clearly. Exploratory research often uses material from available literature, focus groups and case studies. When the purpose of the study is to learn more about the phenomenon or to get a new insight into it in order to develop hypothesis or to formulate a more

precise problem, exploratory study approach is useful. Exploratory research is useful in gaining experience while formulating relevant hypothesis for more definite research.

The study hypothesis of this thesis includes two main steps. Firstly, to show that the terminological system related to paper recycling is in chaos. Secondly, study whether it is possible to give suggestions how to solve the identified chaos in terminology.

A comprehensive literature review was carried out to get a detailed picture about the used terminology and used material frameworks. The existence of chaos was illustrated by analyzing the FAO terminology. This case test shows that it is not possible to unambiguously define terms used by FAO by using the present terminological system. The main reason for this situation is that there are several different terminological systems which use different terms and different definitions.

Two material frameworks were introduced. The first is the Ervasti and Kauranen (2011) "wheel of fiber" framework which describes material recycling at a general level. The second is the Ervasti "five stage material framework" which is based on the Ervasti and Kauranen framework but describes paper industry material recycling more detailed. In addition, components from several different paper industry material frameworks were adopted. The Ervasti five stage framework was tested successfully with ten different paper industry material frameworks. Even the test of the CEPI (2013a) framework, which is the most complex among the tested frameworks, was carried out successfully. All stages and flows of the CEPI framework can be defined by using the five stage framework.

In this thesis the researcher gathered observations about different paper recycling related terms and then made generalizations related to the terms themselves and the use of terms in different contexts.

In this thesis, two approach categories of qualitative research have been utilized. These are descriptive research and document analysis. The descriptive research approach aims to collect available data about the study issue by describing and explaining the phenomenon without changing its contents. Even though the main purpose is to describe the phenomenon, the descriptive approach may include also some analysis. Document analysis means analysis of such

study data which can be identified from written and literate sources. History research belongs clearly to this category.

According to Patton (1990), typical characteristics of qualitative research include:

- research is comprehensive data collection by nature
- use of inductive analysis. The aim is to reveal unexpected matters. That is why the starting point is not to test theories or hypotheses but detailed and multilateral inspection of collected material (data)
- sources of data are selected appropriately, not by using random sampling
- research plan may change during the study process
- different cases should be understood to be unique and material should be interpreted accordingly.

This thesis also utilizes the quantitative research approach. In some cases, value for term A was defined with a formula: (term B) / (term C). By comparing different calculation formulas presented in different sources it could be seen that different terms used by different sources or at different times essentially have the same meaning because they were calculated by using the same formula. Additionally, if two matters defined with different terms in different statistics have the same quantitative value over several consecutive years they could be defined to mean the same matter. In parallel, the same term used by different sources and at different times may mean different matters.

In data collection, several different sources were identified. Many cited sources have published their own material recycling frameworks and used terms of their own related to different materials, stages and flows. In this respect, this thesis can be regarded to be a case study.

Normally, as a research method case study is used in many situations to increase knowledge of individual, group, organizational, social, political and related phenomena. Case study methodology has been adopted especially in psychology, sociology, political science, anthropology and also in economics (Yin, 2009). In studies concerning economics, industry structure or the economy of a city may be studied. In this thesis, the cases are individual frameworks. Each framework has its own structure of stages, flows and terms used. Variations between different analyzed frameworks were identified. However, this study does not explain why these variations exist. For example, industrial structure, local practices, history and influence of subjective behavior affect the formation of different frameworks.

This thesis does not conclude why terms are used as they are. In this respect, this thesis can, in fact, be regarded as a pre-case study for possible future case studies. Varying use of terms in different regions identified in this thesis indicate that different regional use of terms occur. This means that there should be different groups and organizations which use terms differently for some reasons. Yin (2009) states that the researcher needs sufficient access to the potential data, whether to interview people, review documents or records or make observations in the field. If more than one single case is available, the researcher should choose the cases that most likely illuminate the research field. This thesis does not give a clear answer to why the terms vary. However, the findings of this thesis offer a good base for further studies about the reasons for the varying use of terms and different frameworks.

According to Churchill (1987), a research process should include six stages as follows:

- problem formulation
- determination of research design
- design of data collection and methods
- sampling and data collection
- analyzing data
- preparing a research report

This thesis presents an explorative literature review of paper industry recycling related definitions of terms used by different sources. Additionally, several different frameworks related to paper recycling were identified and analyzed. Thus, the literature review includes sources covering terminology, frameworks or both.

2.2. Study structure

The study structure of this thesis presented in Figure 1 shows the study process including the objective, problem formulation and data collection. After this the data was analyzed and main findings and conclusions were drawn. Finally, study findings and conclusions were compared with the study objective.

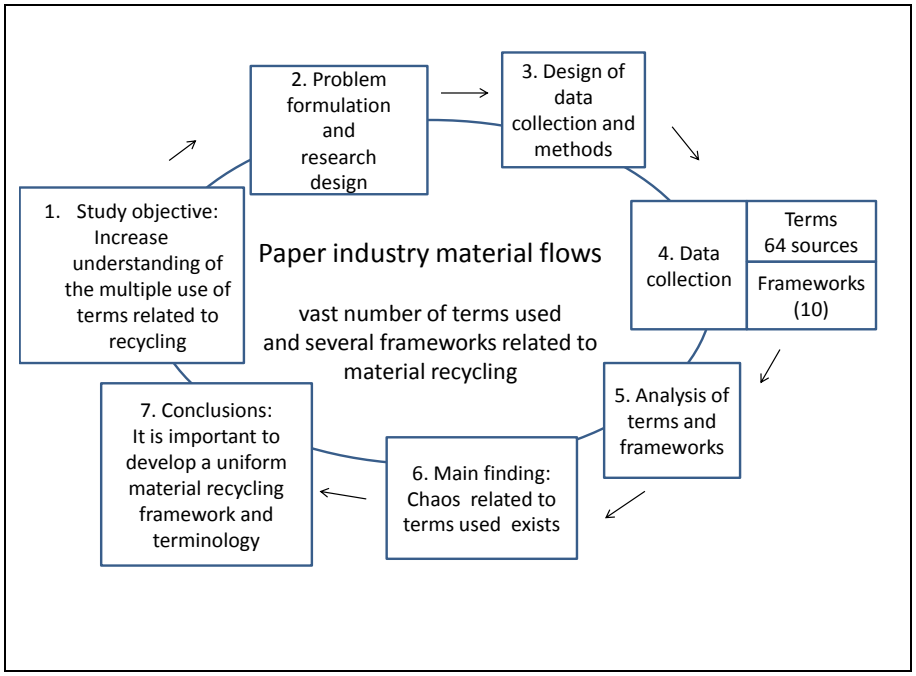

Figure 1. Structure of the thesis

2.2.1. Study objective and study structure

The structure of the study has to be in line with the study objective. To be able to increase understanding of the multiple uses of different terms, data collection methods, data collection and data analysis has to be designed accordingly. Additionally, main findings and conclusions have to comparable with the study objective.

2.2.2. Problem formulation and research design

At this stage, the study objective was used as a guideline in planning different stages of the study. The Patton (1990) characteristics for qualitative research were taken into account. Only after this, was it possible to design data collection and research methods used.

2.2.3. Design of data collection and methods

After the problem formulation, at the design stage of data collection several sources were identified and relevant written sources were selected and used. A detailed literature review was carried out. Major literature databases were searched using the following key words: *recovered paper*, *waste paper*, *recycled fiber (or fibre)*, *collected paper*, *recovered paper*, *de-inking*, *recycled paper*, *paper recovery*, and *recycling*.

The following searching engines, databases and organizations were used in identifying and collecting material for the thesis research: Aalto University library services, Ask.com, Bing, Google, Google Scholar, Infomine, Start page, Yahoo News, and Yahoo Search.

Numerous journal articles, conference proceedings, books, statistics, definitions and research reports were identified as a result of the literature searches. In addition, publications by industry associations and companies in the field of the paper and board industry as well as publications by other organizations producing statistics in the field were separately collected. The reference lists of the publications included in the literature study were reviewed in order to identify additional sources. In terms of geographical regions, the main emphasis was given to Europe, the U.S. and Japan.

2.2.4. Data collection

The total number of sources is 74. Within them, 10 different frameworks were identified. Use of terms and their definitions were analyzed in all of the sources.

Referred sources include several different international and regional organizations whose publications were cited during the research process. These organizations are shown in Table 2. In this table the geographic coverage of each of the organizations is shown. For example, AF&PA, EPA and ISRI are American organizations.

Table 2. Different referred organizations and their geographical coverage.

Region / Country	**Organization**
Global	BIR, FAO, IEA, OECD, PPI
America	AF&PA, EPA, ISRI
Europe	CEN, CEPI, COST E48, EEA, ERPA, ERPC, EcoPaperloop, Eurostat, FEFCO
Australia	ACOR, AuRPS
Austria, Europe	Hamburger (company)
Finland, Europe	FOEX, Indufor (company), TSK, UPM (company)
Germany, Europe	Ingede, VDP
Japan	PRPC, Nippon Paper group (company)
India	Kirpa Impex (company)
Russia	Gost
South Africa	PRASA
United Kingdom	HSE

Used abbreviations:

ACOR, Australian Council of Recyclers
AF&PA, American Forest & paper Association
AuRPS, Australian recovered paper specifications
BIR, Bureau International Recycling
CEN, European Committee for Standardization
CEPI, Confederation of European Paper Industries
COST, European Cooperation in Science and Technology
EcoPaperloop, Eco Design for the Enhancement of Central Europe Paper Based Product Recycling Loop. EU project
EEA, European Environment Agency
EPA, Environment protection Agency
ERPA, European Recovered Paper Association
ERPC, European Recovered Paper Council
Eurostat, The statistical office of the European Union
FAO, Food and Agricultural Organization of the United nations
FEFCO, The European Federation of Corrugated Board manufacturers
FOEX, FOEX Indexes, a private company to provide price indexes, Finland
Gost, National standards of the Russian Federation and CIS countries
HSE, Health and Safety Executive, United Kingdom
IEA, International Energy Agency
Ingede, International Association of the Deinking Industry
ISRI, Institute of Scrap Recycling Industries, the USA
OECD, The Organization for Economic Co-operation and development
PPI, Pulp and Paper International magazine
PRASA, paper recycling association of South Africa
PRPC, Paper Recycling Promotion Center, Japan
TSK, The Finnish terminology centre
VDP, Verband Deutscher Papierfabriken e.V., Germany

It has to be noted that the geographical coverage of an organization can be wider than indicated in the table. For example, American recovered paper grade classifications (ISRI) are in use also in the importing countries (Kirpa Impex, 2013).

2.2.4.1. Data collection related to frameworks

Ten different frameworks related to paper industry material flows were identified and analyzed detailed. Four of the frameworks were published by researchers and six were published by organizations. In this thesis only the word framework is used although in the original sources the authors had named them with different words like the paper system, *recovered paper* balance, *paper recycling* loop, material flow and fiber flow chart.

> Material flows and different stages of the frameworks were compared with each other. The stages of the different frameworks were not necessarily comparable with each other. The identified stages of the different frameworks were grouped into five main stages, which are common for all frameworks. For example, there is a great variation between definitions and terms used concerning the stage *paper consumption*. This five stage framework is based on Ervasti and Kauranen wheel of fiber framework which identifies five main stages: *paper consumption, recovered paper collection, recovered paper utilization, paper production* and *other options* (Ervasti and Kauranen, 2011). *Other options* refers to *recovered paper use for other end uses than paper manufacturing*, including also its *energy use*. This term also includes the volume of *not collected* and *disposed paper*.

2.2.4.2. Data collection related to terms

Out of the 64 sources related to terms, 34 were journal articles, conference proceedings, and doctoral dissertations. The combined number of publications by industry associations, official standardization organizations, companies, and groups compiling statistics was 30. Additionally, 10 of the sources were frameworks related to paper industry material flows. In essence, the weight of statistics in the study is greater than their number would indicate because statistical sources usually include data from a range of years.

Each document was carefully scrutinized in order to pick out from the text any definitions of terms related to recycling in the paper and board industry. In many cases, the sources did not provide any

definitions for the related terms that had been used. In such cases, the author of this thesis used his best judgment in order to establish what definition the source had used. In some cases, the definitions for the terms that had been used could be determined by making calculations from the statistical material given in the source. In many cases, however, it was not possible to figure out what definition had been used for the terms in question.

2.2.5. Analysis of collected data

At the analysis phase, all data from the literature review, including the definitions from the different sources, were compared with each other. If differences in the definitions were discovered, reasons for these differences were analyzed. Special emphasis was given to detect if the differences were associated with the geographical region, the organization providing the definition, or the time period. Hundreds of different terms related to *recycling* were identified. Examples of identified terms related to paper recycling are presented in this thesis. The most commonly used terms and their definitions were listed and sorted according to source.

2.2.6. Main findings - identification of chaos in the use of terms

After the analysis phase, it was obvious that the use of terms is in chaos in paper and board industry. The reason for this conclusion is the lack of generally accepted definitions of terms and the lack of a uniform framework. Different sources seem to use and define paper recycling related terms according to their own needs and purposes. Great regional differences appear. Definitions of terms had also changed in the course of time.

2.2.7. Conclusions - building relations between terms and frameworks

After identifying the chaotic situation related to terms and frameworks in paper and board industry, the writer of this thesis compared different frameworks and used terms with each other. This work was done by grouping different stages of the frameworks analyzed by using the Ervasti and Kauranen five stage framework (Ervasti and Kauranen, 2011). By using this framework as basis it was possible to classify stages, flows and terms of different frameworks uniformly. Based on the results of this thesis, several ideas for future research are suggested.

3. Review of the usage of paper recycling related terminology in literature

3.1. Terminology and communication

3.1.1. General issues related to terminologies

In all research we have to determine what we know about the matter. According to the Webster's Encyclopedic Unabridged Dictionary of the English Language (1994), the word "term" means, first, a word or group of words serving as the specific name of something, especially in a specialized field like atomic physics. Second, it refers to any word or group of words considered to be a member of a particular construction or utterance.

According to de Keizer and Abu-Hanna (2000), a terminological system should support communication between the domain stakeholders. In this respect, ambiguity, vagueness and redundancy should be avoided when developing a terminological system.

Christensen (2006) points out that researchers should first observe the phenomena and carefully describe and measure what they see. If this is not possible, they will face problems in improving theory because they will not be able to agree on the nature of the phenomena. Van de Ven (2007) states that research knowledge is often communicated in a form that does not facilitate its proper transfer. This knowledge transfer problem limits the use of research knowledge for science and practice. He adds that all facts, observations, and data are theory-laden and embedded in language. Locke and Golden-Biddle (1997) claim that a key act in assigning meaning to different rhetorical practices involves explicating details of the language, such as the use of a particular word.

3.1.2. Terminological inconsistencies

The lack of generally accepted, uniform definitions for terms is not foreign to other fields either. For example, quite understandably in medicine, major problems have been encountered when different terms have been used for the same disease or when the same term has been used for different diseases. An example from medicine provides evidence that something can be done to help solve the complicated but important problem of missing uniform definitions within a particular field. Jennette et al. (1994) discuss a case where a committee of clinicians and pathologists from six countries was established to reach a consensus on the names used for some of the most common forms of non-infectious systemic vasculitis and to construct root definitions

for the so-named vasculitides. A great effort was made to adopt terms and definitions that were already widely accepted, especially those advocated in published articles concerning approaches to establishing a vasculitis nomenclature. Finally, a modified nominal group process was used to reach unanimous consensus on the definitions of selected, most common terms related to vasculitis.

3.1.3. Terminology and time

In various texts related to *recycling* in the paper and board industry, the terms *waste paper* and *recovery* were used to define *recovered paper* and *collection*. In fact, the use of the term *waste paper recovery* was more common in the past than in recent years. The European terminological system established by the European Recovered Paper Council (ERPC, 2006) does not define the term *waste paper recovery* any more. The ERPC definitions can be considered semi-official definitions in Europe.

In 2006, the European Commission (EC, 2006) defined *waste* to mean any substance or object which the holder discards, intends to discard or is required to discard. In this respect the commission wanted to clearly distinguish between *waste* and *recyclable material*.

Based on the European terminological systems established by the ERPC, if a text has been written after 2006, the term *recovered paper recycling* should be used instead of *recovered paper collection* a term that was generally in use before the year 2006. According to the European terminological system established by the ERPC (2006), the definition for *recycling* includes both the *utilization* and *net trade of recovered paper*. The European terminological system established by the ERPC was changed again in 2011 and the corresponding term, based on the revised terminological system, is *recycling of paper for recycling*. Consequently, the terms *waste paper recovery*, *recovered paper collection*, *recovered paper recycling*, and *recycling of paper for recycling* all refer to the same matter but these different terms have been used in Europe at different periods of time.

3.1.4. Terminology and different regions

The issues of terminological inconsistencies between different regions are complicated and thus comparisons between different regions are difficult. In Europe, the changes made for terms and their definitions have been connected to the terminological integration taking place within the

European Federation of Paper Industries (CEPI) and the European Union. In some other regions, individual countries like the USA and in Japan have had their own separate terminological systems, which are not completely consistent with other corresponding systems. The terminological systems established by the American Forest and Paper Association (AF&PA) and the Japanese Paper Recycling Promotion Center (PRPC) can be considered semi-official terminological systems in their own regions. These terminological systems do not provide, a definition of *paper recycling*; instead, they use the term *paper recovery*, which is close to the European definition for *paper collection* before the year 2006 (CEPI Annual statistics 2004; 2005) and *paper recycling* after 2006 (ERPC, 2006). The American definition and the Japanese definition have not been changed over the course of time, unlike the corresponding European definition.

3.1.5. Different recovered paper grade classification systems

3.1.5.1. Recovered paper classification systems

Definitions of different *recovered paper* grades vary considerably depending on the organization devising the definition. There are differences in the name of the grade, the code of the grade (number and letter), as well as the specification and detailed definition of the grade. In trade it is important that both the seller and the buyer talk about the same product. That is why different organizations have created classification systems to define different products. For example, the European list of standard grades of *paper and board for recycling* (EN 643, 2013) and the American PS-2009 (ISRI, 2009) define different *recovered paper* grades by taking into account following issues, which usually define the final trade grade. Some of these issues are optional and may vary depending on the classification system:

- original paper grade like *newsprint* or *corrugated containers*
- degree of converting or printing like *printed / unprinted*
- source like households or offices
- mixture of different *recovered paper* grades in the mass
- share of *unwanted materials* like *non-paper components*
- suitability for certain end use like *de-inking*

Additionally, classification systems may take into consideration issues such as the amount of *prohibited materials*, moisture and age of the product.

In general, *recycled materials* have always some degree of contamination and the quality of the material may decrease with each *recycling stage* (Castro et al., 2007). These quality losses cannot be measured by mass balances.

For example, Australian Recovered Paper Specifications (AuRPS), EN 643 (2013), Institute of Scrap Recycling Industries (ISRI) guidelines of Paper Stock (PS-2009) and Paper Recycling Association of South Africa (PRASA), Hamburger Containerboard, and Kirpa Impex have given a certain percentage value for *non-permitted and prohibitive materials* as well as for *outthrows* and moisture content in their *recovered paper* specifications.

The share of unusable material in *collected paper* increases together with the collection activity. According to Miranda et al. (2011), the unusable material content of paper from selective collection in Spain increased during the period 2005 – 2008, from 5.5% to 8.7%. The main reasons for this development are the increased collection activity, which rose from 58.5% to 68.6% and the more active paper collection from household sources. It is important to take this issue into account if, for example, the *recycling* calculation, analysis and use of terms is extended to different *recovered paper* grades, too (Ervasti & Kauranen, 2011).

Before being processed and used as raw material in paper manufacturing *recovered paper* has to fulfill quality requirements which are defined by industry organizations, official bodies like the above mentioned European classification systems (EN 643 2002; 2013), Australian (AuRPS, 2002), American Institute of Scrap Recycling Industries (ISRI, 2009), South African (PRASA, 2009) or individual companies like Hamburger Containerboard (2013). This means that the material pick-up, sorting and transportation must be arranged so that the quality requirements of different *recovered paper grades* can be achieved.

The statistical term *recovered paper collection* is calculated by using the following formula: *utilization* + *exports* – *imports* (CEPI Annual statistics, 2005). This means that *recovered paper*, at this stage, has to fulfill defined quality requirements (EN 643, 2002) after the *sorting process*. However, the term *recovered paper collection* can also refer to the action where *waste material* is retrieved and transported from sources like households. In this context terms like *retrieve* or *pick-up* could be used instead of *collection* to avoid confusion.

3.1.5.2. The American recovered paper classification system

The Institute of Scrap Recycling Industries (ISRI) has published the American Guidelines for *Paper Stock* – PS, which presents standard lists of *recovered paper* grades for the USA for domestic and export transactions. ISRI (2009) divides *recovered paper* (*paper stock for repulping*) in PS-2009 into 51 standard grades and 34 special grades for export transactions.

The American guidelines for *paper stock* (ISRI, 2009) state that the share of *outhrows* plus *prohibitive materials* may not exceed a certain percentage share in *recovered paper*. This percentage share varies between 1.0% and 5.0% depending on *recovered paper grade*. *Outhrows* consists of *papers* that are so manufactured or treated that they are unsuitable for consumption as the grade specified. *Prohibitive materials* include any materials which, given their presence in a package of *paper stock,* poses a risk of damage to the equipment or make the material unusable as the grade specified. A material can be classified as an *outhrow* in one grade and as a *prohibitive material* in another grade. *Carbon paper*, for instance, is *unsuitable* in *mixed paper* and is therefore classified as an *outhrow*; whereas it is *unusable* in *white ledger* and is classified as a *prohibitive material*.

In most *recovered paper* grades, the maximum total share of *outhrows* and *prohibitive materials* should be between 2.0% and 3.0%. The share of these materials is given separately for each *recovered paper* grade. Depending on the year, the terms and definitions in the guideline have changed to meet the demands of *recovered paper* market. For example in the PS-2009 the grade 44 (computer printout – CPP) was a main grade, but in the PS-2013 it is regarded to be specialty grade 36-S.

3.1.5.3. The European recovered paper classification system

In Europe, *recovered paper* has been divided into 57 different trade grades based on the List of Standard Grades of *Recovered Paper and Board* (EN 643, 2002), which defines each *recovered paper grade*. For example, *recovered paper grades* can be defined by their original *paper* grade, by their level of converting and source, as well as by what they contain and do not contain. The total *recovered paper* volume is, in fact, the sum of individual *recovered paper* grades. The revised EN 643 (2013) identifies 95 individual grades of *paper and board for recycling*.

The European recovered paper classification system EN 643 (2002) does not mention the share of *non-paper components* and total *unwanted material*. However, the revised EN 643 (2013) defines the share of *non-paper components* and total *unwanted material* for different *recovered paper* grades. The limits for non-paper components vary depending on the recovered paper grade. The maximum share of *non-paper components* is between 0.25% - 1.5% and total *unwanted material* between 0.5% - 3.0%, depending on the recovered paper grade.

The EN 643 (2002) and its *recovered paper* grade definitions for individual grades, is generally in use in *recovered paper* trade to assist industry professionals, organizations and individuals in buying and selling. The individual grades are grouped into bigger aggregate groups containing several different individual trade grades of *recovered paper*. The EN 643 (2002; 2013) groups the trade grades of recovered paper into five main groups. An important issue in the European grouping of individual *recovered paper* grades is that CEPI groups the same individual *recovered paper* grades into four main groups.

Table 3 and Table 4 show that in a defined region like in Europe, the same individual *recovered paper* grades can be classified differently depending on the end use purpose and the organization giving the definition. The numbers and names of the groups and individual *recovered paper grades* based on the European List of Standard List of Recovered Paper and Board (EN 643) grouping are shown in Table 3. Grade codes in Table 3 refer to codes defined in the EN 643 (2002).

Table 3. Standard grades of recovered paper in Europe divided into groups according to EN 643 (2002)

Group number	**Group name**	**Individual recovered paper grades in the group**
group 1	*ordinary grades*	*1.01, 1.02, 1.03, 1.04, 1.05, 1.06, 1.07, 1.08, 1.09, 1.10, 1.11,*
group 2	*medium grades*	*2.01,2.02, 2,03, 2.04 (2.03.01), 2.04 (2.04.01), 2.05, 2.06, 2.07, 2.08, 2.09, 2.10, 2.11, 2.12*
group 3	*high grades*	*3.01, 3.02, 3.03, 3.04, 3.05, 3.06, 3.07, 3.08, 3.09, 3.10, 3.11, 3.12, 3.13, 3.14, 3.15 (3.15.01), 3.16, 3.17, 3.18 (3.18.01), 3.19*
group 4	*kraft grades*	*4.01 (4.01.01, 4.01.02), 4.02, 4.03, 4.04 (4.04.01), 4.05 (4.05.01), 4.06, 4.07, 4.08*
group 5	*special grades*	*5.01, 5.02, 5.03, 5.04, 5.05, 5.06, 5.07*

The Federation of European Paper Industries (CEPI) has a grouping system of its own. It divides individual *recovered paper* grades into different groups. The CEPI system has four statistical groups and *recovered paper* grades are divided into these groups as shown in Table 4 (CEPI Special recycling statistics, 2006).

Table 4. Standard grades of recovered paper in Europe by EN 643 (2002) divided into statistical groups by using the CEPI grouping system.

Group name	**Individual recovered paper grades in the group**
mixed grades	*1.01, 1.02, 1.03, 5.01, 5.02, 5.03, 5.05*
corrugated and kraft	*1.04, 1.05, 4.01, 4.02, 4.03, 4.04, 4.05, 4.06, 4.07, 4.08, 5.04*
newspapers and magazines	*1.06, 1.07, 1.08, 1.09, 1.10, 1.11, 2.01, 2.02*
high grades	*2.03, 2.04, 2.05, 2.06, 2.07, 2.08, 2.09, 2.10, 2.11, 2.12, 3.01, 3.02, 3.03, 3.04, 3.05, 3.06, 3.07, 3.08, 3.09, 3.10, 3.11, 3.12, 3.13, 3.14, 3.15, 3.16, 3.17, 3.18, 3.19. 5.06, 5.07*

As can be seen by comparing Table 3 and Table 4, the two *recovered paper* grade grouping systems differs greatly from each other, even though the same EN 643(2002) grades have been used to define the individual grades. The CEPI grouping, which is based on the original paper grades, is close to the grouping systems of the USA, Japan and FAO. In these systems, different *recovered paper* grades are grouped into four statistical groups. It can be noted that the new revised European EN 643 (2013) grouping includes many additional *recovered paper grades* compared to the old EN 643 (2002). This means that the group classifications have to be revised both by CEPI and EN 643. A probable reason for these different grouping systems is that the EN 643 system concentrates on the trade material point of view and CEPI stresses the technical end use possibility of the *recovered paper grades* by taking into account the paper industry view.

At the moment, the *recovered paper grades* have been standardized for Europe according to the above-mentioned standard (EN 643, 2002, 2013). Before the establishment of the first version of the European Standard List of Recovered Paper and Board in 1999, many European countries had their own lists and definitions for *recovered paper grades*. Some of these country specific standards are still in use today, to some extent. The first European list of Standard Grades of Recovered Paper was published by Bureau of International Recycling (BIR) and CEPI, (1999).

3.1.5.4. Comparison of different recovered paper classification systems

The European Standard List of *Recovered Paper and Board* (EN 643) as well as other corresponding lists developed by other organizations assists traders, companies and individuals in buying and selling material intended for use as raw material. This is done by defining different *recovered paper grades*. Some of the organizations outside Europe have also grouped individual *recovered paper grades* into statistical groups.

Several geographical regions and countries as well as different organizations have their own *recovered paper* classification systems. Their contents are close to each other but are not the same. For this thesis, 14 different classification systems were identified. AF&PA, ISRI (PS-2009) and CEPI have published lists for *recovered paper* grades. In Europe CEN has published two times, in 2002 and in 2013, a list of Standard Grades of *Recovered Paper*. In Eurostat trade statistics, *recovered paper* is divided into four *recovered paper grades*. FAO divides *recovered paper* also into four grades. The Japanese Paper Recycling Promotion Center (PRPC) has published its own *recovered paper* list of *recovered paper* grades for Japan. Russia (GOST 7933, TU 5422-004-47975996-2003), the Australian Recovered Paper Specifications (AuRPS), and the Paper Recycling Association of South Africa (PRASA, 2013) also have their own *recovered paper*, *paper stock*, or *waste paper* grade classification systems. Additionally, companies like the Austrian company Hamburger Containerboard and the Indian company Kirpa Pulp & Paper Impex have published their own *recovered paper* classification lists.

Table 5 shows how selected organizations divide *recovered paper* into different grades. The number of *recovered paper* grades related to these classification systems is also shown in the table. The organizations mentioned have detailed lists and definitions describing *recovered paper grades*.

Table 5. Examples of the number of recovered paper grades and groups for trade and statistical purposes by different organizations.

Organization	**Region / Country**	**Number of recovered paper grades**
AF&PA, 2008	USA	33 *paper stock grades*, divided into 5 statistical groups and further into 4 groups by combining *pulp substitutes* and *high grade de-inking grades* into one group
AuRPS, 2002	Australia	15 *recovered paper* grades
CEPI, 2006a	Europe	57 *recovered paper* grades divided into 4 groups
EN 643, 2002	Europe	57 standard grades, divided into 5 groups
EN 643, 2013	Europe	95 standard grades, divided into 5 groups
Eurostat trade statistics, 2012	Europe	4 *recovered paper* grades and 1 recovered paper based pulp
FAO, 2010	Global	4 *recovered paper* grades
GOST 7933 (Russia)	Russia	20 *recovered paper* grades
Hamburger, 2013	Europe	12 *recovered paper* grades
Kirpa, 2013	India	*recovered paper* is divided into 16, 31, 46 or 55 different grades depending on the geographical origin of the material
PRASA, 2009	South Africa	16 *recovered paper* grades
PRPC, 2005	Japan	29 grades, divided into 9 statistical groups, 5 export grades and 4 *recovery grades*
PRPC, 2010	Japan	26 grades, divided into 9 statistical groups, 5 export grades and 4 *recovery grades*
PS-2009 (ISRI)	USA	51 standard grades of *paper stock* and 34 special grades

Several organizations mentioned in the Table 5 give limits for the maximum share of prohibitive materials, outhrows, non-paper components, garbage or total unwanted materials. Such organizations include: AuRPS, EN 643 (2013), Hamburger, Kirpa, PRASA, GOST 7933 and PS-2009 (ISRI).

A conclusion can be drawn that globally, paper that has been *collected* and *sorted* so that it fulfills any generally accepted grade definition of any organization, like any one of the definitions mentioned above, can be called *recovered paper*. It is difficult to compare different grades of different organizations with each other. However, in several countries the individual *recovered*

paper grades of different organizations can be grouped into four main statistical groups so that these groups are comparable with each other. These groups are:

- *mixed grades*
- *old corrugated containers and kraft grades*
- *old newspapers and magazines*
- *high grade de-inking and pulp substitutes.*

3.1.6. Summary of different recovered paper related terms and their definitions

A number of 64 different sources which use terms related to paper recycling were cited for this thesis. These sources of the literature review are listed alphabetically based on the name of the author and shown in Table 6. The terms related to recycling in the paper and board industry are listed and the corresponding definitions used in the source items are provided. If no definition was provided in the particular source, "no definition" is marked. If it was possible to detect an implicit definition that was used in the source, then this implicit definition is indicated.

Table 6. Terms and definitions related to recycling in the paper and board industry.

Source	Term	Definition
Ackerman et al. (2010)	*recycled fiber*	paper industry raw material, no definition
	recycled pulp(s)	blends of different fibers and pigments
	R.P., RP	recovered paper
	RCF	refers to both recovered paper and recycled fiber, depending on the context
	DIP	de-inked pulp
	unsorted recovered paper	mixture of different paper grades including different types of plastics, etc.
	recycling rate	used together with the term recovery rate
AF&PA American Forest and Paper Association (2008)	*paper recovery*	domestic consumption of recovered paper + exports - imports
	recovered paper	paper stock consisting of several grades
	recovery rate	(total paper collected) / (new supply of paper and board)
	utilization rate	(recovered paper consumption) / (paper production)
	recycled paperboard	paperboard manufactured by using mainly recovered paper
	paper stock	recovered paper
	paper consumption	New Supply is equal with production plus imports less exports, excluding hard-pressed board (imports and exports include paper and paperboard-converted products)
	mixed, newspaper, corrugated, high grade de-inking, pulp substitutes	terms are different groups of recovered paper grades. These groups consist of individual recovered paper grades according to the Paper Stock Classification. For example, the group *newspaper* includes the following individual *recovered paper*

		grades: *coated ground wood* sections, *flyleaf shavings, ground wood computer printout, mixed ground wood shavings, old newspapers, over-issue news, publication blanks, special news de-ink quality, white blank news*
AuRPS (2002)	*recovered paper*	the specifications do not make a clear distinction between the terms *recovered paper, waste paper, and recycled fiber*. The terms have been used interchangeably. *Recovered paper* consists of 15 individual grades and a quality comparison has been made with Institute of Scrap Recycling Industries (ISRI).
Barrio (2006)	*recycling rate (for packaging material)*	(B+C)/A. Where A = packaging placed on the market in Western Europe ((=*packaging waste* arised) = (*consumption* of packaging materials) + (*converting losses*) + ((additional other materials) + (net trade of *filled packaging*)); B = *material recycling = collection of recovered paper packaging* = (*utilization)* + (net exports); C = *organic recycling* and use for other purposes.
	recycling	*reprocessing* in a production process for the *waste materials* for the original purpose or for other purposes, including *organic recycling* but excluding *energy recovery*
Berlund and Söderholm (2003)	*waste paper recovery rate(RR)*	RR= ((*WP cons*) + (*WP ex – WP im))* / (*PB cons*)). Where WP cons is *waste paper consumption, WP* ex is *waste paper* exports, WP im is *waste paper* imports and *PB cons* is *paper and board consumption*
	waste paper utilization rate(UR)	(*WP consumption)/(PB production*) Where *WP consumption* is *waste paper consumption* and *PB production* is *paper and board production*
	waste paper recycling	no definition
BIR (2013)	*recovered paper*	no actual definition, but different sources, such as industry, business, and households, as well as corresponding grades are sources of *recovered paper*
	recycling of paper	consists of a series of stages, including *sorting, baling, shredding, washing, bleaching, pressing*, and *rolling*. The stages may vary depending on the type of *paper* and its degree of deterioration
	recovered fiber	produced by using *recovered paper* as raw material
	paper recovery	refers to *material recycling*. The definition excludes landfill and incineration for the purposes of *energy recovery*
	not collectable and /or not recyclable	estimated at 15–20% of the *total paper consumption*. Consists, for example, of *cigarette paper, wall papers, tissue papers*, and *archives*
Blanco (2005)	*RP, recovery paper*	no definition, context refers to *recovered paper*
	recycling rate	no definition
	collection rate	no definition
	recycled paper	no definition, context refers *to recovered paper*
Bobu et al. (2010)	*recovered paper (RP),*	EN 643 defines the quality of the *recovered paper and board* grades most commonly traded in Europe
	recycled pulp	produced after *RP processing*, including *pulping, screening*, and *cleaning*
	recovering of used p & b products	a stage in the *recovering* and *recycling loop* between *p & b converting* and *preparation of recycled fiber pulp* by *processing of recovered paper*
	used / recovered b & b	refers to *recovered paper*
Byström and Lönnstedt (1995)	*recovery rate*	no definition
	utilization rate	no definition
	recycled fiber	no definition
	waste paper	no definition

	recycling, recovery	no definition
CEPI annual statistics 2006 and Special Recycling 2005 Statistics	*recycling rate*	(*recovered paper utilization*) /(*paper and board consumption*)
	recovered paper collection	(*utilization* + exports – imports) Note*: Utilization* includes *paper industry use* only
	paper consumption	(*domestic deliveries*) + (*imports from outside CEPI*). Some figures adjusted by using the following formula: (*consumption*) = (*production*) + (imports – exports)
	recovered paper utilization	use *of recovered paper* as raw material to produce *new products*
	R.P. and RP	*recovered paper*
	mixed grades, corrugated and kraft, newspapers & magazines, high grades	different groups of *recovered paper* grades. These groups consist of individual *recovered paper* grades according to the EN 643 European List of Standard Grades of Recovered Paper and Board. For example, *high grades consist of the following EN 643 recovered paper grades: 2.03, 2.04, 2.06, 2.07, 2,08, 2.09, 2.10, 2.11, 2.12, 3.01, 3.02, 3.03,3.04, 3.05, 3.06, 3.07, 3.08, 3.09, 3.10, 3.11, 3.12, 3.13, 3.14, 3.15, 3.16, 3.17, 3.18, 3.19, 5.06, 5.07*
CEPI annual statistics 2008	*utilization rate*	(*recovered paper utilization*) / *(paper and board production*)
	recycling rate	(*recovered paper utilization + net trade*)/ (*paper and board consumption*)
	non-collectable	*non-collectable paper and paperboard*. Represents about 8% of *product use*
COST E48 (2010)	*paper recycling*	the reprocessing of *recovered paper* in a production process either to produce *saleable paper* or to produce some other *saleable product*; typically this includes *composting* but excludes *energy recovery*
	recycling rate	the ratio between *RP used* for *recycling*, including *RP net trade*, and *paper and board consumption*
	recovery	same as ERPA (2000)
	recovered paper	same as ERPC (2006)
EPA Environmental Protection Agency (2012)	*postconsumer recovered fiber (paper)*	1) *paper, paperboard,* and *fibrous wastes* from retail stores and office buildings after they have passed through their end-usage phase as a consumer item. 2) all *paper, paperboard*, and *fibrous wastes* that enter and are *collected* from *municipal solid waste*
	recovered fiber	1) *postconsumer fiber*, as defined above. 2) *manufacturing wastes*, such as *dry paper and paperboard* and *waste generated after completion* of the *papermaking process*, like *cuttings* and *trimmings*, *envelope cuttings*, and other *waste* resulting from *printing, cutting,* and *other converting operations*. Includes also *re- pulped, finished paper*, and *paperboard from obsolete inventories* of paper manufacturers, merchants, wholesalers, dealers, printers, converters, or others.
	recycling rate	((*total recycled* (by weight)) / ((*total discarded* (by weight))+((*recycled* (by weight))
	paper stock	equivalent to *recovered paper* or *waste paper*
	collection	two main *collection methods*: *Single stream collection* and *sorted stream collection*
EN 643 (2002): The European List of Standard Grades of Recovered Paper and Board	*recovered paper and board*	no definition *for recovered paper* as such, but gives a general description of the *standard grades* by defining what they do and do not contain
	collection	no definition
	collected paper	no definition
	recycling	no definition
	recovery	no definition, but refers to *collection*

	recycled fiber	no definition
EN 643 (2013) "Paper and board – European list of standard grades of paper and board for recycling"	*paper and board for recycling*	a new term to replace *recovered paper*. *Natural fiber based paper and board* suitable for *recycling* and consisting of a) *paper and board in any shape*, and b) *products made predominately from paper and board*, which may include other constituents that cannot be removed by dry *sorting*, such as *coatings* and *laminates*, spiral bindings, etc.
	recovery	no definition but refers to *collection*
	recycling	no definition
	unwanted material (outthrows)	material not suitable for the *production of paper and board* including*: non-paper components*, paper and board not according to grade definition, paper and board detrimental to production and paper not *suitable for de-inking* (if applicable)
ERPA, European Declaration on Paper Recovery (2000)	*collection of paper and board*	*Separate collection* of *paper and paper products* from industrial and commercial outlets and from households and offices for -> recovery
	recovery	principle of *waste management policy*, including *re-use*, *material recycling*, *composting*, and -> *energy recovery* as well as exports for similar purposes
	recycling	reprocessing of *recovered paper* in a production process for an original purpose or for other purposes, including *composting* but excluding *energy recovery*
	recycling rate	the ratio between *recovered paper* used for *recycling* and *paper and board consumption*
ERPC, European Declaration on Paper Recycling (2006)	*collection of paper and board*	*Separate collection of paper and paper products* from industrial and commercial outlets and from households and offices for -> recovery
	recovered paper (RP)	*used paper and board separately collected* and in general processed according to EN 643
	recycling	*reprocessing of recovered paper* in a production process for *new paper and board*
	utilization	*use of recovered paper* in a paper mill while producing *recycled paper*
	recycling rate	the ratio of *recovered paper used for recycling*, including the *recovered paper net trade* and paper *and board consumption*
	waste	any substance or object that a holder discards or intends to discard or is required to discard
ERPC, European Declaration (2011)	*paper for recycling*	introduction of a new term to replace *recovered paper*
	collection of paper and board	*Separate collection of paper and paper products* from industrial and commercial outlets and from households and offices for -> *recycling.*
European Parliament and Council (1994)	*recycling*	*reprocessing* in a production process of the *waste materials* for their original purpose or for other purposes, including *organic recycling* but excluding *energy recovery*
	recovery	any of the applicable operations provided for in Annex II.B of Directive 75/442/EEC
	reuse	any operation by which packaging, which has been conceived and designed to accomplish within its life cycle a minimum number of trips or *rotations*, is *refilled* or used for the same purpose for which it was conceived, with or without the support of auxiliary products present on the market enabling the package to be *refilled*; such *re-used packaging* will become *packaging waste* when no longer subject to *re-use.* However, 2008/98/EC states that *re-use* means any operation by which products or components that are not *waste* are used again for the same purpose for which they were conceived
FAO (2010)	*waste paper net recovery rate*	(*waste paper collected for re-use*) /(*adjusted paper and paperboard consumption*)
	adjusted waste paper net recovery	(*the amount of waste paper collected*) / (*adjusted paper and paperboard*

	rate	*consumption from which the non-recoverable paper and paperboard is deduced*)
	recovered paper in fiber use rate	the amount of *recovered paper used for paper and paperboard* as a percentage of the *total fiber used for paper and paperboard*
	recovered paper utilization rate	(*recovered paper used for paper and board*) / (*paper and board production*)
FEFCO (2006)	*re-use*	any *recovery operations* by which products or components that have become *waste* and/or require prior reconditioning are used again for the same purpose for which they were originally conceived
GOST 7933 (2003)	*paper stock*	no definition
	broke of all kinds of newspapers	refers to *white newspaper* and *white trimmings*. Corresponds to EN 643, grades *3.14*, *2.03*, and *2.03.01*
Grace (1983)	*recovery*	technical term used for *fiber separation* during the alkaline *wood pulp* manufacturing process
Grossman (2009)	*RP recycling*	refers to COST E48 definition
	paper and board recycling	refers to COST E48 definition
	recovery	context refers to the *collection*: P&B is largely *recovered* through well-accepted and powerful *collection systems*
Göttsching et al. (1996)	*recovery*	context refers to the *collection*
	recycling	*utilization, processing* in paper industry within the observed country
	waste paper	no definition
	recycled paper	context refers to *paper* that is equal with, e.g. with *newsprint*
Halimi et al. (2006)	*recovered fibers*	refer to *fibers recovered* from *cotton waste*
Hamburger (2013)	*recovered paper*	*recovered paper* consists of several *recovered paper* grades. A detailed QM form consisting of 24 pages defines in detail what *recovered paper* may and may not include. It also defines the general conditions for acceptance of *recovered paper* (ARP).
Hamm (2010)	*recovered paper recycling*	to produce *recycled fiber pulp* for the manufacture of *paper and board*
Helander (2006)	*recovered paper*	consists of several grades
	paper and board collection rate	(*paper collection*) / (*total consumption of paper and board*)
HSE (2004)	*to recover*	the verb to *recover* is used in HSE's slogan "*recover paper safely*" and it refers to the *collection process*, *material handling*, like *baling* and transfer to specialist recycling sites for processing.
	sorting recovered paper	separating *recyclables* (*newspaper, card, pamphlets, and magazines (PAMS*)) from *unusable material*.
Huttunen and Pirttila(1998)	*RP*	*recovered paper*
	primary RP supply	refers to sources like households, converters, printers, and offices
	secondary RP supply	refers to RP merchants, waste management companies, municipalities, voluntary organizations, etc.
	demand for RP	refers to *paper and board* producers, the external market, incineration and other final uses
	de-inking grade	consists of *news, magazines and brochures* and those items mainly produced through a *sorting process* at sorting plants
	white wood-free grades	used as *pulp substitutes* and sourced mainly from *paper* refining plants and offices
ISRI PS-2009	*paper stock, stock*	*recovered paper*
	paper	*recovered paper*. However, in some cased the definition is not clear. For example,

		hard mixed paper (*HMP, grade no 3*) consists of a *clean, sorted mixture* of various *qualities of paper*
	outthrows	(*recovered*) *papers unsuitable for consumption* as grade-specified paper
	HMP,ONP, OIN, OMG,OCC ,DS OCC, DLK,KGB, WBN, CPO, CPB,SWS, HWS, HWEC, UOP, SOP, MCL, SWL, MWL, CBS, CGS	different abbreviations relate to individual recovered paper grades. For example, they can refer either to an *original paper grade*, like *over-issue newspapers* (*OIN*), to source, like *unsorted office paper* (*UOP*) and *mixed office waste* (*MOW*), or to raw material contents and the degree of converting, like *hard white shavings* (*HWS*), which consists of *shavings* or sheets of *unprinted, untreated white ground wood free paper*
ISRI (2013)	*recovered fiber*	*recovered paper and board*
Kaila (2010)	*recycling rate (packages)*	SFS-EN 13440. *Recycling / potential*
	recovery rate (packages)	(*Collection*) / (*potential*)
Kirpa Impex (2013)	*waste paper*	refer to a list of individual, *recovered, paper trade grades*
	pub blank	individual *recovered paper grade no. 24*, which consists of *baled, unprinted cuttings* or *sheets of white-coated, filled wood content paper*
Kleinau (1983)	*recovery*	technical term to describe the *separation of fibers* from the *paper material recovered during pulp manufacturing process.*
Klimek (2011)	*utilization rate*	D / A, where D = *waste paper utilization and A = paper production*
	recycling rate without trade	*D / B , where D = waste paper utilization and B = paper consumption*
	recycling rate including trade	C / B, where C = *waste paper collection and B = paper consumption*
Körkkö (2012)	*recovered paper stream*	contains all of the materials that became attached to the paper during its production and printing, e.g. *fibers, fiber fines, mineral fillers, printing ink, and adhesives*. In addition, a certain amount of extraneous matter, e.g. sand, glass, metal and plastic originating from the *recovered paper collection*, handling, and storing, are also present. A mixture of various types of paper in which, for example, the *ONP/OMG ratio* may vary.
Levlin (2008)	*recycling rate*	*recovered paper used for papermaking* , including utilization outside Europe
Levlin and Grossmann (2008)	*recycled pulp*	*fibrous raw material* created when using *recovered paper* as a raw material. Refers to the term *recycled fiber*.
	non-recoverable paper	Estimated as of 19% of *used paper*, meaning that only 81% of the *paper consumed* would be recoverable.
Lundmark (2001, 2002)	*waste paper utilization rate*	no definition
	wastepaper recovery	no definition
	paper recycling rate	no definition
	secondary paper, secondary fiber, scrap paper, recovered fiber	no definition, but according to the text context, the terms used refer to *recovered paper*
Lundmark and Nilsson (2001)	*recycling*	no definition
	wastepaper recovery	no definition
	recycling rate	no definition
	paper recovery	no definition

	recycling of waste paper	no definition
	recycling of paper	no definition
	recycled paper	no definition
	paper recycling	no definition
Mabee (1998)	*recovered fiber*	any fiber that is *recycled*, used more than once in the manufacturing of *paper* or a *board product*
	wastepaper recovery	no definition
	recycling of wastepaper	no definition
Moore (2006)	*recovery (cost)*	includes *collection* and *processing* (costs)
	collection rate	no definition
Miranda & Blanco (2010)	*recycling rate*	(*recovered paper utilization in the paper industry*) / (*paper consumption*)
	recovery	no definition
	collection rate	(*recovered paper collected*) /(*paper and board consumed*)
	utilization rate	(*recovered paper utilized in the paper industry*) / (*paper production*)
Nazhad (1994)	*recycled fiber*	a *pulp fiber* that has been rewetted from the dry state and made into paper at least once
	secondary fiber	*pulp recovered* from a *paper product* that has already served a commercial purpose. Secondary fiber may be obtained from an intermediate processor, such as a printer or converter, from a final user, such as a homeowner, of from its end destination: The municipal dump.
Nippon paper Group (2013)	*RP utilization rate*	the percentage of *recovered paper* in the raw materials that is used for making paper. *RP utilization rate* = (*recovered paper*) / (*recovered paper + other pulp*)
	recycled pulp	manufactured from *collected unused waste paper* after *sorting* and *collecting*
OECD/IEA (2007)	*paper recycling*	no definition
OECD (2010)	*recovery rate*	no definition
	recycling rate	no definition
	recovered paper pulp	*processed recovered paper*
	recovered fiber	*recovered paper*
Palmer et al. (1997)	*recycling*	refers to the market for the *recycled material*
	consumption of good	context refers to *collection potential*
	waste	*waste* that is disposed of
	waste (W = Q – R)	The amount of *waste disposed of*, W, is equal with the total consumption of good, Q, less the amount that is *recycled*, R
Pope Jim (1995)	*recovery rate*	(*recovered paper collected*) /(*new supply of paper and paperboard*) (AF&PA)
PRASA (2012)	*recovery of recyclable paper*	(*consumption of recycled paper* in South Africa) + (*recovered paper exports*) – (*recovered paper imports*)
	recycling rate	(*recovery of recyclable paper*) / (*recoverable paper*)
	recoverable paper	(*paper consumption*) – (*paper exported in agricultural products*) –(*paper unsuitable for recovery*)

PRPC Paper Recycling Promotion Center (2010)	*recovered paper*	*recovered paper*
	waste paper	*recovered paper*
	refuse paper	(*recovered paper*) *energy fraction*
	recovery	*recovery* = ((*recovered paper supply*) + (*shipments of de-inked market pulp* with 80% yield) – (*recovered paper imports*) + (*recovered paper exports*)) or (G+G'-E+F=H)
	recovery rate	*recovery* / *the balance* (*paper & board shipment + paper imports – paper exports*
	market DIP, market pulp	*market pulp* manufactured using *recovered paper* as the raw material
	fiber stock	*recovered paper + virgin pulp + de-inked pulp + other stock*
	corrugated containers, kraft browns, box board cuttings, old magazines, old news, hard white shavings, white GP containing shavings, printed woody paper quire, white and color ledger	different statistical groups of *recovered paper* grades. These groups consist of individual *recovered paper* grades based on the list of Japanese standard qualities of *recovered paper* provided by the PRPC. For example, *hard white shavings* consist of *white shavings* (Japanese: Jouhaku), *cream* (Japanese: Kuriimu Jouhaku), and *ruled-paper shavings* (Japanese: Keihaku)
	utilization rate	(*consumption of recovered paper*) / (*consumption of fiber stock for paper and paperboard*)
PP I (1998)	*recovery rate*	*waste paper recovery* divided by *paper and board consumption*
Putz (2010a, 2010b)	*recovered paper*	relates to *separately collected* and *processed material* according to EN 643
	collected paper	*paper and board from refuse sorting stations*, not suitable for use in paper industry
	post- consumer recovered paper	*recovered paper recovered* from retail stores, offices, and homes after these products have served their end-uses as consumer items and papers separated from *municipal solid waste*
	pre-consumer recovered paper	*paper and board material from manufacturing and converting proces*ses and *finished paper from obsolete inventories*
	recovery	includes tonnages in all stages of production and consumption, such as *material recycling in paper manufacturing* as well as *composting*, *incineration*, and *other treatments* (according to CEPI)
	available recovered paper potential	paper and board production usage – not collectable paper – net recovered paper export
Read (2008)	*recovery*	term used to equal with *collection*
Ristola (2012)	*recycled fiber, RCF*	two different definitions: 1. Prepared by using *waste paper* as raw material 2. Produced by using *recovered paper*
	recovered paper, RCP	*separately collected and sorted discarded paper*
	waste paper	*discarded paper*, sometimes used as synonym for *recovered paper (RCP*)
	discarded paper	*used or unused paper* that is no longer of use to consumers
	office waste	*discarded paper collected from offices*. Main grades are *mixed office waste* (*MOW*) and *sorted office waste (SOW*)
	MWP	*mixed waste paper*, *unsorted waste paper* usually *collected f*rom households
	ONP / OMG	*old newspapers and magazines*
Samakovlis (2004)	*recovery*	*waste paper consumption* minus imports plus exports of waste paper
	recovery level	no definition, but according to context refers to *collection*
	material recycling	no definition
	secondary fiber	no definition, but according to context refers to *recovered paper*
	recycled fiber , waste paper	no definition

Sukigara et al. (2003)	*recycled fiber*	refers to different *recycled fiber assemblies* made from sweaters (wool and a wool-blend assembly). The term refers to *discarded clothing*.
Tatsumi et al. (2000)	*waste paper*	*fiber* raw material source
	recovery and recovery rate	no definition
	recycled paper	raw material in paper manufacturing
	recycled pulp fiber suspension	*pulp manufactured from recovered paper*, before ink removal
Triantafyllou et al. (2006)	*recycled paper and board*	no definition
	recycled fiber materials	no definition
	recycled fiber-based materials	no definition
	recycled materials	no definition
TSK – The Finnish Terminology Centre, (1993)	*recovery*	synonym for *recycling* and *collection*
	recycled paper	*paper based on recycled fibers*
	waste paper collection	*paper reclaiming*
	recovery rate	in text *recovery* relates to *collection*
Villanueva et al. (2007)	*recycling*	refers to *material recycling*
	disposal and recovery	refer to EC Waste Framework Directive 75/442/EEC
Zhao (2012)	*Recovered paper, RCP*	*recovered paper*
	Paper collection rate	(*RCP collection*) / (*PAB consumption*)
	RCP usage rate	no definition
	Recovery rate	no definition
	Mixed collection of RCP	no definition, but text context relates to collection system, not to grade

Note: Source items from the literature study are listed alphabetically based on the last name of the author or the name of the organization

Table 6 shows that depending on the source there is great variation between different definitions concerning paper recycling related terms.

3.2. Frameworks

3.2.1. General

Generally, a framework to define material flows including *recycling* in paper industry reliably should include all stages which are needed to calculate the most common *recovered paper recycling* related terms by comparing them with each other. For example, the ratio between *recovered paper recycling* (*recovered paper utilization + recovered paper net trade*) and *paper consumption* is called the *recycling rate* (CEPI, 2013a) and the ratio between *recovered paper utilisation* and *paper production* is the *utilization rate* (CEPI, 2013a). Furthermore, the *collection rate* is the ratio between *recovered paper collection* and *paper consumption* (Miranda and Blanco,

2010). Consequently, *recovered paper recovery rate* is the ratio between *recovered paper recovery* and *paper consumption* (PRPC, 2012).

3.2.2. Concept of a framework

Material flow account (MFA) is one generally used term for a framework. It shows the amount of physical inputs into an economy, material accumulation in the economy and outputs to other economies or back to nature (Eurostat, 2001). In this context economy can be understood as an individual country or a geographical region. Any economy-wide MFA and balances as well as indicators derived from them provide information on the material and energy that enter into and leave from an economy (Eurostat, 2001). Eurostat uses the term economy for a country or for a geographical region. The material balance principle leads to the assumption that: total inputs = total outputs + net accumulation. All material flows have an origin and a destination. The sum of masses by origin must be equal to the sum of masses by destination. Matter changes and statistical errors occur during production and consumption processes when material changes form.

According to Friege et al. (1998), a material flow account is usually used for flows most relevant for national economy, but material flow account is also a general expression for all substance, material and product flows subject to documentation. For companies and authorities, the documentation and analysis of material flows is necessary in substance chains and material flow analysis. The data needed for a material flow account has to be documented by organizations. It is important to clearly define aggregated data which has to be collected by organizations like industry associations or state bodies.

3.2.3. The Eurostat framework

The Eurostat framework is called the economy-wide *material flow accounting (MFA) system*. It gives general guidelines about material flows within a regional system defining input and output flows as well as the region (economy) and the period of time. Several descriptions about general level material flow accounts were observed to form a picture about key issues related to material flow analysis. However, none of these general level material flow accounts, which are intended to be used for all materials, can be used as such to define the paper industry raw material flows in detail due to the specific nature of the sector where *material recycling* has a central role.

Eurostat (2001) published a framework called *general balance scheme.* It includes all relevant input and output flows. This general framework is shown in Figure 2. The framework includes indirect flows associated with imports and exports through the economy excluding water and air. Domestic extraction of materials can be further disaggregated into, for example, fossil fuels, metal ores, minerals, and biomass. Each of these broad material groups can further be subdivided into biomass, timber, agricultural harvest, etc.

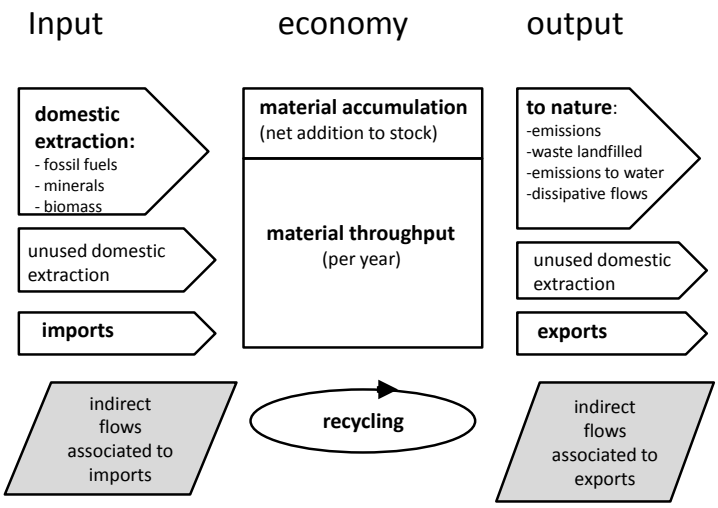

Figure 2. Framework for economy-wide material balance scheme (excluding air and water flows)
Source: Eurostat, 2001

In the Eurostat material balance scheme *recycling* is understood as a domestic material flow. However, in paper industry *recycling* is no more only a regional material flow. Millions of tons of *recovered paper* are exported from Europe to China. This is considered to be European recycling (ERPC, 2011).

By using the economy-wide material balance framework it is possible to derive input, consumption and output indicators. A complete material balance is difficult to achieve statistically. All material input and output flows are not observed systematically. Some data has to be estimated (Eurostat, 2001). When different flows are quantified, this is done for a certain period of time, normally a year. Material recycling is important as the target is to reuse the same material. Through recycling, considerable financial savings are possible (OECD, 2012).

3.2.4. What do frameworks define

A material flow account, which is one type of a framework, is used for material and energy balancing. The concept of material flow account is simply a model of the relationship between the environment and the economy. In such a framework, the economy is a subsystem inside the environment and is dependent on continuous throughput of material and energy (Behrens et al., 2007). Ayres et al. (1994) state, by using several examples, that it is possible to link material and energy flows with traditional economic variables. They also use the term *metabolism*. Generally, the term refers to the internal processes of a living organism which ingests materials to provide for its own maintenance, functions, growth and reproduction. At the most abstract level of description, the metabolism of industry is the whole integrated collection of physical processes that convert raw materials and energy, plus labor, into finished products and waste in a steady-state condition.

National level material flow accounts as well as projects to harmonise methodological approaches have been carried out by several scholars including Bringezu (1997) and Kleijn (2000). They have made major contributions in harmonizing material flow account methodologies. Bringezu (1997) argues that the material flow account approach can be used to reveal the quantity and structure of material throughput on a national or regional level. It is possible to derive material flow based indicators to support the planning and control of effective measures for materials management. Kleijn's (2000) central statement is that mass balances now constitute the most important basis for material flow accounts: ultimately, inflow is equal to outflow.

A material flow account is seen as an analytical instrument for integrated chain management, while another instrument, Substance Flow Analysis (SFA) can be seen as a part of a material flow account (Bovenkerk, 1997). Substance flow analysis is a specific kind of material flows, which deals for example with the analysis of flows of specific chemicals. This opinion is shared by van der Voet (2002), who argues that any economy can be viewed in terms of material flows. The first step in any material flow study is to define the system and divide it into subsystems. The next step is the quantification of the network. This requires identifying and collecting the relevant data. Additionally, spatial and functional demarcation, time horizon and material have to be defined.

Material flow account can be understood as a concept covering the analysis of bulk flows of specific materials such as paper, plastics, metal and glass through an economic system.

In material flow account and in substance flow analysis systems, it is essential that the volumes of the flows can be identified and measured. Bovenkerk (1997) stated that in the Dutch chlorine analysis, it was possible to focus on priority problems and achieve confidence in the possibility of placing the problem under control when the data set was accepted and 99% of the flows were known.
Beltran (1997) has paid attention to the fact that best available information about material flows should be reported periodically. In this context, he has not given any recommendations about the length of the period. The role of European Environment Agency is highlighted as an important player in supporting data collection and analysis.

Beltrán (1997) states that the European Environment Agency (EEA) expects material flow accounts to have an important role within the European Environmental Information System. In this respect, material flow account could provide important indicators, for example, for various stakeholders and serve as an early warning system by assisting with improving environmental trends and scenarios. This can be done by providing information on material flows and thus potential environmental impacts hidden in different products such as traded products. In the paper industry, detailed defining of the paper industry framework is an important matter. A great volume of packaging material travels together with traded goods imported from China to other geographical regions. At present these volumes are being recycled but not quantified transparently.

It is essential that there are reliable data and analysis methods to support decision making. This opinion is supported by Bovenkerk (1997), who states that in material flow-related analysis, finding a consensus on the data is an important pre-requisite for policy measures. If one set of data is accepted, there is no confusion about different data or about the fact that there is too many data. It is good if data from different sources match and if they can be used together. On the other hand, too much data may cause confusion. Additionally, according to Jänicke (1997), it is important that national material balances exist. Knowing annual material flows is the basis in sustainable development analysis. Time series are needed to evaluate long-term effects of material flows. It is important to start with data in material flow analysis to stimulate the policy of comprehensive long-term resource management.

3.2.5. Selected frameworks in the paper and board industry

3.2.5.1. General

Many organizations and scholars have developed and used frameworks to define the paper industry material flows and material recycling. In fact, in a paper industry framework, the input flows do not only turn into output flows but also output flows turn to input flows. When several regional frameworks are linked with each other with these material flows, they form a network of frameworks. In several traditional frameworks, generated waste is regarded as an output flow, but through material recycling it turns into an input flow. *Recovered paper*, which was formerly called *waste paper*, is part of the paper industry output flow in some countries. For example, the USA is an important *recovered paper exporter*. *Recovered paper* has turned into an important trade commodity. A great share of the Chinese paper industry raw material input consists of *imported recovered paper*. In fact, the Chinese paper industry could not function without imported *recovered paper*. About 61% of the Chinese paper industry fiber raw material was *recycled paper pulp* in 2011 (McClay, 2013). Additionally, according to Zhao (2013), over 40% of all *recovered paper* consumed in China was imported in 2012.

For this thesis, ten different frameworks related to paper recycling were identified. These frameworks are in use in different geographical regions by different organizations. All these frameworks are presented in the appendices.

Each of the sources calls its framework with a name of its own. The sources and names of their frameworks are shown in Table 7.

Table 7. Different paper and board industry material flow frameworks and their names

Source	**Name of the framework**
European Recovered Paper Council (ERPC, 2013)	*Paper recycling* – Who does what?
Villenueva et al. (2007)	The Paper System
Indufor (2013)	Wood raw-material flows within and between the EU forest-based industries subsectors
EcoPaperLoop (2014)	*Recovered Paper* Balance
CEPI (2013a)	The European Fiber Flow Chart
CEPI (2008)	*Paper Recycling* Loop
Schmidt et al (2007)	Paper Flow in Product System
PRPC (2010)	*Recovered Paper Generation* / Distribution route
Davidsdottir et al. (2005)	System Boundaries for *Pulp and Paper Production*
Pento (1994)	Material Flows of *Printing Papers* in Germany

In all of the frameworks, the structure includes several stages and flows. The stages and flows were quantified in four frameworks, namely in the CEPI (2013a), EcoPaperLoop (2014), PRPC (2010) and Schmidt et al. (2007) frameworks. On the other hand, in six frameworks the system definition was made on a general level only to give an overall picture about the system. Accordingly, stages or flows between the stages were not quantified in these frameworks. These frameworks include the CEPI (2008), ERPC (2013), Villanueva et al. (2007), Indufor (2013), Pento (1994) and Davidsdottir et al. (2005) frameworks.

Even when the terms describing of the stages and the flows in the analyzed different frameworks were the same in these frameworks they do not necessarily mean the same matter. Additionally, the terms used of the stages and flows sometimes were called differently, even though they may mean the same matter.

Analysis of the selected ten frameworks leads to the conclusion that there is no generally accepted uniform framework which can be used to describe material flows including *recycling* within the paper industry. Especially, the existing frameworks do not solve the need that regional frameworks could be compared and combined with each other to form a usable network of flows globally.

Terms defining the different stages and flows as well as other *recycling* related terms vary considerably between different frameworks.

3.2.5.2. The European Recovered Paper Council (ERPC) framework

The ERPC (2013) framework (appendix 1) includes four different stages. Each of these stages consists of two main elements which are a) actor and process, b) product and status. The ERPC (2013) framework describes the different stages of the material flows and their order at general level.

The ERPC (2013) framework covers the whole *recycling chain* but it cannot be used as such to quantify the material volumes and their relations when material moves between different stages of the *recycling chain*. The ERPC (2013) framework can be understood to describe only the movement of an individual fiber between different stages of the framework without taking into account the continuous rotation nature of the recycling process, which is also highly dependent on continuous interaction with the outside environment. This means that material flows to outside (output) the system and flows of materials into (input) the system is not taken into account in the ERPC (2013) framework.

Additionally, ERPC (2013) indicates in its framework that converting paper products to new paper based products is a stage of its own. Thus, it is unclear for the readers to define where the *collection potential* really exists. In the framework, there is an additional stage, namely the consumer stage, between the converting stage and collection stage. It should be remembered that the printing and converting stage itself is an important source of *recovered paper* in the form of converting losses.

3.2.5.3. The Villanueva framework

Villanueva et al. (2007) carried out an extensive review of existing life cycle assessments on *paper and board waste* (Appendix 2). The objectives of the review were threefold: firstly to identify messages, secondly to identify key methodological issues of *paper waste* management life cycle assessments (LCAs), and thirdly to discuss about whether it is valid to use the life cycle assessment methodology to guide policy decisions on *paper waste*. To be able to explore

systematically several different life cycle assessments, a framework to cover the paper system was developed. Fifteen key system boundary issues divided into three stages were identified. The authors present a life-cycle diagram of the entire paper system and divide it into three main stages as follows:

- *raw materials / forestry stage,* which supplies wood raw material to sawmills
- *paper production stage,* which utilizes *virgin fiber material* and *recovered paper*. In this framework, *virgin fiber* comes only from sawmills to produce *virgin pulp* and *used paper* processing and includes both *domestic collection* and imported material. The *manufactured paper* was then traded internationally or used domestically. In this framework (Villanueva, 2007) there is no such stage which relates to *paper converting*
- *disposal / energy recovery stage,* which includes *domestically used paper* was not *collected* to be used domestically for *paper manufacturing* or traded internationally.

When defining the above mentioned stages, attention is paid mainly to LCA issues and the mentioned key system boundary issues which, in most cases pertain to energy-related matters.

In Villanueva et al.'s (2007) framework, there are two separate *fiber material* flows at the *paper production stage:* firstly for *virgin wood pulp* and secondly for *used paper processing* to be used as raw material. The system does not take into account the possibility that a mixture of *virgin pulp* and *recycled fiber* could be used as paper industry raw material. This is a clear weakness of the framework. In many cases, paper is manufactured by mixing *virgin pulp* and *recycled pulp*. This is the case especially in multiply paperboard manufacturing where top layers typically are *virgin pulp* based and middle layers consist mainly of *recycled pulp*.

Villanueva et al. (2007) use following sub-stages in their framework related to the first main stage, *raw material utilization*:

a) *virgin pulp for paper* (*chemical, mechanical, semi-chemical pulping*)

b) *recovered paper used for paper (re-pulping, de-inking*)

c) *utilization = collection + net trade of recovered paper (used paper processing = used paper collection and sorting – international trade of used paper*)

d) *recycled and de-inked pulp* used for paper

e) wood raw materials from forests is used to produce *wood pulp*.

3.2.5.4. The Indufor framework

The Indufor (2013) framework (appendix 3) covers material flows within and between the EU forest-based industries sub-sectors including all main sectors namely paper and paperboard, *wood pulp* and *recovered paper*, round wood and other wood biomass, sawn wood and wood-based panels as well as bio-energy at a general level without paying attention to volumes or the time frame.

The Indufor (2013) framework assumes also that the paper production stage and net trade of paper is equal with *paper consumption*. Additionally, after this the *recovered paper collection* and *net trade of recovered paper* lead to *recovered paper utilization*. Additionally, *other uses*, *energy use* and disposal stages have been identified.

3.2.5.5. The EcoPaperLoop framework

The EcoPaperLoop (2014) uses a framework (Appendix 4) called *Paper – Recovered Paper – Balance* to describe material flows related to *recycling* in the EU 27 area. In this framework the term *product use* includes additives and the term is used to describe *paper consumption.* This stage represents *recovered paper potential* after the volume of *not collectable paper waste* has been reduced. The framework introduces two additional paper consumption related terms and stages called the *theoretical recovered paper potential* and *available recovered paper potential*. The EcoPaperLoop (2014) framework includes four different terms related to *paper consumption*. In the framework, these different stages are defined with different terms. These stages are quantified in the framework. The different *paper consumption* related stages and their mutual relations can be expressed with calculation formulas as follows:

- ((*paper consumption*) + (*additives*)) = (*product use*)
- ((*product use*) – (*not collectable paper waste*)) = (*theoretical recovered paper potential*)
- ((*theoretical recovered paper potential*) – (*net recovered paper exports*)) = (*available recovered paper potential*)
- (*available recovered paper potential*) = ((*paper waste*) + (*recovered paper for material recycling within the region*))

3.2.5.6. The CEPI (2013a) framework

CEPI (2013a) uses in its annual statistics a framework called the European Flow Chart to cover the paper industry material flows within Europe. In this framework different stages and flows are quantified in metric tons. Flows from one stage to another are equal to the following stage or the sum of stages and flows.

In the CEPI (2013a) framework (Appendix 5) all stages and flows are quantified thoroughly. The *paper production* stage flows lead to both *paper net trade* and *paper consumption* stage which, is called the *market supply of paper*. This stage is first of the three *paper consumption* sub-stages and it is used as the collection potential when calculating the *recycling rate,* which is the ratio between the *recycling volume* and *market supply of paper*. From this stage, a flow, namely *collected from converting and printing,* exits the stage and the remaining material stage is termed the *market supply of converted products*. Additionally, there are two exit flows from this stage: a) *returns (unsold)* and b) *net direct traded converted products and trade of packaging material surrounding traded goods*. The following stage is termed the *product use*. In fact, all three stages mentioned can be regarded to define *paper consumption* but their calculation formulas differ from each other. Only the first stage termed the *market supply of paper* is used in the calculation of the *recycling rate*.

The CEPI (2013a) framework indicates that the *net trade of converted products*, the *net trade of packaging material surrounding traded goods (including manuals)* as well as the share of *non-collectable and non-recyclable paper* have an influence on the *collection potential* volume. The identification of these flows is important, but in the framework these flows have not really been taken into account because these trade volumes have been assumed to be in balance. Due to huge volume of packages surrounding imported goods, especially from Asia, Europe is, in fact, a net importer of packaging material.

The CEPI (2013a) fiber flow chart shows several different stages and corresponding flows but does not necessarily group them clearly. As mentioned earlier in this section, there are three different stages describing *paper consumption* and *collection potential*. Additionally, *recovered paper* flow used for *other recycling options* has been identified, but it has not been grouped with

recovered paper utilization within paper and board production and *recovered paper net trade*, even though all of them could be included in the *recycling option* (ERPA 2000).

3.2.5.7. The CEPI (2008) framework

CEPI has used also another framework to cover material flows and *recycling within the paper industry* (CEPI, 2008; Appendix 6). In this framework, the *paper recycling* was observed in the view of legislation. In this framework the main stages are identified at a general level but not quantified. Directions of material flows between stages, are indicated with arrows.

In the paper manufacturing stage the *virgin fiber flow* and the *recycled fiber flows* have been differentiated. Ink and additive injection during printing and converting is clearly identified forming the *paper consumption* stage called *product usage*. The framework clearly shows that after *collection* and *sorting*, before *pulping*, the collected material has to fulfill EN 643 definitions.

3.2.5.8. The Schmidt et al. framework

Schmidt et al (2007) studied whether it is better to *recycle paper* than to incinerate and landfill it from an environmental point of view. The study is a life cycle assessment (LCA) case study and it concerns the Danish consumption of paper in 1999. A mass flow system was introduced to define different stages and material flows related to Danish *paper consumption*.

Schmidt et al (2007) use the framework (appendix 7) to quantify material volume in different stages and flows. Main stages and flows have been quantified. To avoid possible errors related to moisture differences between the stages material amounts have been given in 100% dry solids. This is the only one of the analyzed frameworks to identify the moisture changes within the recycling chain and its possible effect to volume differences between the stages.

3.2.5.9. The PRPC framework

The Japanese PRPC (2010) framework (Appendix 8) covers different stages of *recycling* at a detailed level, including also the use of *recovered paper for de-inked market pulp production*. The main share of the stages and flows between the stages has been quantified. Special attention is paid

to defining different *recovered paper sources* and *collection* arrangements related to these sources. The PRPC (2010) framework also takes into account the *recovered paper utilization* in *market de-inked pulp* manufacturing and an average yield of 80% is used. This is the only framework of the frameworks that takes into account the possibility that *de-inked pulp* is imported from outside the country.

3.2.5.10. The Davidsdottir et al. framework

The Davidsdottir et al. (2005) framework (Appendix 9) describes paper industry material and energy processes and flows in the USA. For example, *wastepaper collection* and *paper production* are defined as processes, but in fact they can also be regarded as stages. Energy flows and their directions are taken into account. Stages and flows have been defined at a general level without quantifying them.

3.2.5.11. The Pento framework

The Pento (1994) framework (Appendix 10) covers the German printing paper material stages and flows. *Paper used* is divided into different paper grades. Material which is used by the end users after printing, form the *collection potential*. Printing houses as a source of printing residues for de-inking has been identified but this flow is not included in collection. Pento (1994) does not use the term *collection potential* but *paper from end users* leads to following stages: *long-life products*, *paper collection*, *land filling* and *incineration*. Stages and flows have not been quantified.

3.3. Possible sources of error

The high number of sources can be regarded as sufficient for giving a clear picture about the field, especially because the selected documents describe both different geographical regions and different years.

It is difficult to reliably quantify material flows and stages of all the different frameworks, to calculate the previously mentioned different activity rates related to *recovered paper recycling* and compare them with each other. Seven main categories of error sources related to both terminological definitions and to quantifying the material flows were identified:

- depending on time, region, author and framework, terms used may have a different definition and correspondingly a different calculation formula
- existence of material flows which are not identified or quantified
- terms which are used to indicate ratios between stages and flows like *recycling rate* do not necessarily represent what they are intended to represent
- lack of a uniform and generally accepted material flow framework related to paper recycling
- the material and moisture contents of the stock at different stages and flows within the framework may differ considerably depending on paper grade, region and time
- statistics and methods to quantify material flows and stages are not available, inaccurate or vary depending on source
- there are no reliable statistics about the *recovered paper recycling* outside the paper industry.

For example, the term *recovery* can have a totally different definition depending on the region. In Europe, *recovery* refers to the sum of *re-use, material recycling, energy recovery* as well as exports to similar purposes. Before 2007, the European *recycling* volume included only *recovered paper utilized* within the region but after that year *recovered paper* exported outside the region was also included in the European *recycling rate*.

In the USA (AF&PA, 2008) and Japan (PRPC, 2010), the term *recovery* is equal to the European term of *collection* (CEPI, 2005). It must be noted that in the PRPC framework in Japan (PRPC, 2010), 20% material losses in *de-inked market pulp production* have been included in the calculation formula. These losses have not been taken into account in the USA and Europe. However, the volume of this difference is very small, representing only about 0.2 % of the total Japanese *recovered paper collection.*

In *collection* and *recycling activity* calculations the *paper consumption* volume is assumed to represent the *recovered paper collection potential*. However, this assumption can be contested. The *consumption* figure definition varies depending on the framework used and it does not necessarily contain all the essential elements such as the *trade of converted products*, the *trade of packaging materials traded together with goods* and *added inks and additives during the printing and converting process*.

In regions and countries like Europe and the USA the *collection rate, recycling rate* and *recovery rate* can be said to be too high. These regions are net importers of *packaging materials traded with goods*. In fact, these *packages* are part of the collection potential but they are not included in the *paper consumption* volume which is the divisor in calculating the above mentioned volume. On the other hand, in countries like China, the *collection rate* is too low. The country is a net exporter of *packaging materials together with goods*. In calculation formulas, these volumes are included in the local *paper consumption* but, in fact, due to net exports they are not part of the local *collection potential.*

According to Zhao (2012), the Chinese net exports of *paper packaging material traded with goods* and *converted paper products* were 22 million tons in 2010. According to present calculation methods, this volume is included in the Chinese collection potential. If this volume were reduced from the Chinese *paper consumption,* as it should, the true Chinese *collection rate* in 2010 would be 57% instead of the official 44% (Zhao, 2012). These figures show the magnitudes of these material flows. A large share of the Chinese exports of goods goes to North America and Europe. This means that in these regions, the real *paper collection potential* is considerably higher than what the *paper consumption* statistics indicate.

Additionally, in some frameworks, *paper consumption* is the volume which is delivered to converters. In some frameworks, *paper consumption* volume includes converting and printing. In some other frameworks the *paper consumption* volume consists of the material which is used by the final consumers. All these stages are different in volume because, for example, due to *converting losses* and addition of *inks*, the weight of the material changes when moving inside certain individual *paper consumption* stages.

Moisture contents may change between different stages and flows in the framework. This may have an effect on material volume calculations. Papers after the production process and at the paper consumption stage tend to have a lower moisture content compared to *virgin fiber pulp* and *recovered paper* flows. According to FOEX (2013), and EN 643 (2002, 2013), the dryness of both *wood pulp* and *recovered paper* is calculated as 90% air dry and corresponding volumes are being calculated accordingly. In the USA (PS-2013), all exported *paper stock* must be packed air dry, which corresponds to moisture content of 12% or dryness of 88%.

On the other hand, the dryness of manufactured paper, 92 – 97% in average (UPM, 2011; Li et al. 2003) is considerably higher than in *recovered paper*. In spite of this fact, ratios between different stages are typically calculated, without taking into account the moisture difference (CEPI, 2013a) and (PRCP, 2010). For example, the recycling rate, which is the ratio between *recovered paper recycling* and *paper consumption*, does not give a reliable picture about the situation. In fact, *recovered paper* includes on average 4 - 6 percentage points more water than *paper consumed*, to which it is compared.

Additionally, *collected paper material* may include undesirable components like, plastics, dirt, wastes and other contaminants collected together with *paper products*. According to Miranda et al. (2012), the share of *unusable material in recovered paper* may vary between 5 and 20% depending on source, *collection activity* as well as on the *collection* and *sorting* system. In this respect *traded and used recovered paper* volume contains both *fibers* and *unsuitable materials*. Sometimes it is difficult to identify at which stage in the framework the material had been weighted and what the material consists of.

Some paper grades like *printing and writing grades* may include considerable share of *non-fiber components* like *fillers, coating pigments, inks, adhesives*, and *metal foil laminations* which are being absorbed to the product itself either in the production or in the converting stage. For example, when these *paper grades* are utilized after *collection* in the production of *tissue paper*, a main share of these *unwanted components* has to be removed from the mass, increasing the volume of *process losses*.

Paper matter is dual including both material in paper itself like *fillers*, which belongs to the structure of paper as well as *non-paper components* which join the material flow, e.g. during and after the paper consumption stage in converting. When weighting *recovered paper*, we do not know the shares of different components like *fillers, water, fibers* and *non-paper components* in the material.

It is misleading to compare the term *utilization rate* for total paper between regions and in time. The *utilization rate*, which is the ratio between the *total recovered paper utilization* and the *total paper production*, does not necessarily provide a good base for such comparisons. In Europe, for example, the average *recovered paper utilization rate* in printing and writing paper manufacturing

(excluding newsprint) was 11.0% and in *packaging materials (liner and fluting) manufacturing* 94.2% in 2012 (CEPI, 2013a). During the same year the *total recovered paper utilization rate* was 50.8%. The variation between individual countries and paper grades is even higher. For example, the total *recovered paper utilization rate* in the paper industry was 5.3 % in Finland and 14.2 % in Sweden. On the other end of the scale are countries like Hungary, with a *utilization rate* of 102.6 %, and United Kingdom where the average *utilization rate* was 86.8 % in 2012 (CEPI, 2013a). Thus the *utilization rate* reflects more the structure of the paper industry in a certain country or during a certain year rather than *recycling activity level* which can be reached by hard work.

As an example, a hypothetical example can be given. In a country with a total paper production of 1 million tons, there are two mills to produce paper: 500,000 tons of printing and writing paper and 500,000 tons of containerboard. By using the above mentioned European average *utilization rates* for different paper grades the printing and writing paper mill would use 55,000 tons of *recovered paper* (55,000 t / 500,000 t = 11%) and the containerboard mill would use 470,000 tons of *recovered paper* (470,000 tons / 500,000 tons = 94%). The average *recovered paper utilization rate* in the country would be 52.5% (525,000 tons / 1000,000 tons). If the printing and writing paper mill were closed and only the containerboard mill would continue, the *average utilization rate* would grow to 94%. This great change would only be a result of a structural change in the country. For this reason, countries with high printing and writing paper capacities tend to have low recovered paper utilization rates and countries with high packaging material capacity high utilization rates.

Reliability of data varies between countries and regions. For example, data collection methods vary. In Europe, in the USA and Japan the data collection is carried out transparently by local or global organizations like CEPI, AF&PA, PRPC and FAO. In many countries there are no such organizations which collect, combine and distribute data related to *paper recycling* transparently. In such cases, data from these countries is based on experts' opinions and estimation.

Significant measurement errors also occur in the trade statistics. For example according to the Eurostat trade statistics (2009), the Dutch exports of *recovered paper* to Belgium were 463,000 tons in 2008. However, according to the same source, the Belgian *recovered paper* imports from the Netherlands were 889,000 tons during the same year. Such disparities can be identified between other countries, too. There is, in fact, no reliable data source to define the *recovered*

paper trade between countries. This is an important matter because, for example, CEPI (2008) calculates the *recycling rate* by using the following formula: (*recovered paper utilization* + *recovered paper net trade*) / (*paper and board consumption*). In this formula the trade volume has an important role.

Furthermore, translation of terms and definitions from one language to another and different weight measurement systems (like the American short ton, which equal to 0.907 metric tons) are potential sources of errors.

Emission flows to nature have been included in most of the frameworks. In this thesis, these flows have been identified and grouped as waste disposal under the main stage *other options* which also include process losses, sorting of non-paper components at the *recovered paper utilization* stage. *Other options* include also *recovered paper use for other purposes* like for insulation and animal bedding. These flows do not have in a key role in the calculation of the *recycling activity*.

Moreover, it can be argued that the accuracy of the *recovered paper recycling* volume is misleading. In most frameworks, it includes *material utilization for paper industry end uses*, only excluding the *material use outside the paper industry sector***.** Only three out of the ten selected frameworks, namely the Villanueva et al. (2007), Indufor (2013) and CEPI (2013a) frameworks, indicate that *recovered paper* as material is also used outside the paper industry. This material use includes for example construction material production, molded products, animal bedding, insulation and composting. At present there is no reliable statistical system to quantify these volumes. For example, according to AF&PA, the *use of recovered paper* to other purposes varies between 4.8% and 7.4% of the *total recovered paper utilization*. In Europe this volume is estimated at 4 – 5% of *recovered paper utilization* (COST E48, 2010). Additionally, considerable volumes of *waste paper* and *recovered paper* are used for *energy recovery*. No reliable statistics about these volumes could be found. However, COST E48 (2010) states that in Europe the *recovered paper material use* outside the paper industry together with *energy recovery* would be about 8% of the collected volume.

3.4. Example of term definitions. Case: FAO

Global definitions are necessary. Food and Agriculture Organization (FAO) of the UN is a leading organization producing global *recovered paper* statistics. From 1997 to 2010, every third year, FAO published four sets of global statistics (*Recovered paper* data) about *recovered paper* (FAO,

1997; 2004; 2007; 2010). These publications include statistical data from 33 to 37 countries, depending on the publication year. FAO (2010) uses several term definitions related to *paper recycling* but the most interesting are definitions which belong to the group of terms relating to relations between terms or activity level.

The FAO statistical publication "*Recovered paper* data" includes four terms belonging to the group of terms indicating activity. The FAO (2010) definition states that (*waste paper net recovery rate*) = (*waste paper for re-use*) / (*adjusted paper and paperboard consumption*). This last term, *adjusted paper and board consumption* includes not only *paper and board consumption* but also the *net trade of converted paper and board products* but it excludes *printed materials*.

Additionally, FAO (2010) defines a second term called the *adjusted waste paper net recovery rate*, which is the ratio between amount of *waste paper collected* and the *adjusted paper and paperboard consumption* of which the *non-recoverable paper and board* are deducted.

The third term used by FAO is *recovered paper in fiber use rate* which is the ratio between the amount of *recovered paper* used for paper and paperboard and *total fiber used for paper and board.*

The FAO (2010) also defines a fourth term, *recovered paper utilization rate*. This is the ratio between the amount of *recovered paper used for paper and paperboard* and *paper and paperboard production*. This fourth term is widely in use in several organizations.

FAO's definitions are important. It is a recognized organization that frequently produces global recovered paper statistics called FAO, Recovered paper data. However, even though FAO is a global organization, three of its main terms among the above mentioned four, are not commonly in use: *net recovery rate, recovered paper in fiber use* and *adjusted waste paper net recovery rate*. There must be a reason for this, even though the definition of the *net recovery rate* underlines the importance of the real *collection potential* by taking into account the amount of *converted products*. The *adjusted waste paper net recovery rate* is even more accurate by taking into account also *non-recoverable paper and paperboard*. By comparing the use of *recovered paper* to the sum of *recovered paper* and *virgin fiber,* FAO points out that the share of *recovered paper* of the total *fiber use volume* provides a better picture about the *fiber use rate* than the commonly used

utilization rate, wherein *recovered paper utilization* (use) is compared to the *paper production*. The author of this thesis did not come up with any existing studies on why the definitions of the FAO are not widely in use.

In fact, FAO's definitions do not fulfill the parameters of a definition, since these definitions are not clear:

- in the FAO definitions there is no differentiation between terms *waste paper* and *recovered paper*. Both describe the same material in the statistics and in the survey questionnaire, which is used by FAO for data collection
- there is no differentiation between terms *recovery* and *collection*
- the term *re-use* is misleadingly used to define *recycling.*
- is very difficult to reliably quantify the *adjusted paper and paperboard consumption*
- it is difficult to reliably quantify *non-recoverable paper and paperboard*.
  In fact, these two above mentioned terms, *adjusted paper and board consumption* and *non-recoverable paper and board* are not quantified or not even included in the survey questionnaire with which the data is collected from different countries
- the aim of FAO in defining the term *recovered paper in fiber use* is to compare *recovered fiber used* volume to the *total use of fiber for paper production*. Due to confusion in the use of terms in the FAO term definitions, the term *recovered paper use* should not be compared to *total fiber* because *recovered paper* is used as raw material in *recycled fiber* production.

On the first page of the FAO publication, it is noted that "there is some misunderstanding in the definitions and readers are urged to use caution when interpreting data for some countries".

Two of the above mentioned terms which can be included in the group activity terms namely *waste paper net recovery rate* and *adjusted waste paper net recovery rate* are interesting. FAO itself is not able to quantify these two terms even though they are two first terms out of the four most important terms in the list of definition. FAO collects data for its publication by sending a questionnaire to individual countries. FAO does not collect and publish data which would make it even possible to quantify the above mentioned two terms. In this respect, it is no wonder that these, theoretically justified, terms indicating *recovery* activity are not generally in use.

Detailed analyses of definitions of terms by other organizations would also likely reveal similar inconsistencies. Further inconsistencies occur in the use of terms. A reason for such inconsistencies can be that not enough attention has been paid to having exact definitions of terms. Traditional regional terms have been used without consideration to their exact definitions and without comparing the definitions with corresponding definitions by other sources. There is no global, uniform terminological system. Regional organizations may change their definitions according to their own interests.

4. Results of the thesis

4.1. General

The author of this thesis points out that the analyses of the terms and their definitions have not been done to indicate correct or incorrect uses of the terms and their definitions by other authors or sources. Analyzes have been done to increase understanding about the multiple uses of different terms related to paper industry material recycling. Uniform terminological system is lacking. In cases where definitions were found to differ, the reasons for the differences are discussed. Despite the fact that different sources have used different definitions, it can be stated that in most cases the definitions provided for terms within the same source were used consistently.

4.2. Number of terms

When analyzing the documents in the field of *material recycling* in the paper and board industry, it was found that a large number of terms are in use. For example, the following relevant terms listed below, were identified:

> *Available recovered paper potential, box board cuttings, CBS, CGS, collected paper, collection, collection of paper and board, collection rate, consumption of goods, corrugated, corrugated and kraft, corrugated containers , CPB, CPO, de-inked pulp, de-inking grade, demand for high grades, DIP, discarded paper, DLK, DS OCC, fiber stock, hard white shavings, high grade de-inking, high grades, HMP, HWEC, KGB, kraft browns, market DIP, material recycling, MCL, mixed collection of RCP, RCP collection, RCP demand, RCP usage rate, mixed grades, MOW, MWL, MWP, newspapers and magazines, non-collectable, OCC, office waste, old magazines, old news, old newspaper, OIN, OMG, ONP, outthrows, paper, paper and board recycling, paper collection, paper collection rate, paper consumption, paper for recycling, paper recovery, paper recycling, paper recycling rate, paper stock, PFR, post-consumer recovered paper, pre-consumer recovered*

paper, printed woody paper quire, pub blank, pulp substitute, R.P., RCF, RCP, recovered fiber, recovered fibre, recovered paper (RP), recovered paper and board, recovered paper collection, recovered paper pulp, recovered paper recycling, recovered paper utilization, recovery, recovery (cost), recovery level, recovery paper, recovery rate, recovery rate (packages), recycled fiber, recycled fiber, recycled paper, recycled paperboard, recycled pulp, recycling, recycling of paper, recycling of waste paper, recycling rate, recycling rate (packages), refuse paper, RP, RP recycling, scrap paper, secondary fiber, secondary paper, SOP, stock, SWL, SWS, unsorted recovered paper, UOP,

utilization, utilization rate, waste, waste paper, waste paper collection, waste paper net recovery rate, waste paper recovery rate (RR), waste paper recycling, waste paper utilization rate, wastepaper recovery, WBN, white and color ledger, white GP containing shavings, and *white wood free grades.*

Obviously, the above list including a vast number of terms is not exhaustive, and additional relevant terms may be found in literature sources that were not chosen for this thesis. Many of the terms mentioned above are names or abbreviations of different *recovered paper grades*.

The number of identified individual *recovered paper grades* used by all of the organizations in this literature study is 445. Many of the organizations have given their own codes and abbreviations for *recovered paper grades*. If all the names, codes, and abbreviations are summed up, the total number of different terms related to individual *recovered paper grades* is close to 800. Additionally, many of the terms consist of several words like *recovered paper collection*, *recycling for paper for recycling, recovered paper recovery rate* and *waste paper utilization rate*. The combination of words increases the number of terms used to almost an endless figure.

4.3. Differences related to organization and region

Many organizations have published their own classification lists for individual *recovered paper grades*. The literature documents analyzed in this thesis include fourteen different organizations. Twelve of them were regional organizations and two were companies which have published their own classifications and definitions or lists for individual *recovered paper* grades. For example, in Europe *sorted graphic paper for de-inking* is also called *1.11, de-inking grade recovered paper*, or *sorted graphic paper for de-inking, D 39,* according to the old German VDP list, or simply *de-inking grade.*

There is no generally accepted system for comparing the above-mentioned *recovered paper* grades with one another. In many cases, trade between the seller and the buyer and quality requirements are based on mutual agreement and samples.

In the field of recycling within the paper and board industry, even the most fundamental terms having the words *recovery* or *recycling* in them do not have generally accepted, uniform definitions. For example, in the USA the definition provided by the American Forest and Paper Association (AF&PA, 2008) defines *recovery rate* as ratio between the *recovered paper collection* and the *new supply of paper*; whereas in Europe the definition provided by the Federation of European Paper Industries (CEPI, 2013a) defines *recycling rate* as follows: ((*paper for recycling utilization*) + (*net trade of recovered paper*)) / (*total paper consumption*). Based on their respective definitions in the USA and Europe, *new supply of paper and paper consumption* mean nearly the same thing. Thus, *recovery rate* as it is defined in the USA and *recycling rate* as it is defined in Europe mean the same thing, although the terms used are different. However, in 2006 CEPI changed its use of terms in its statistics: What is today defined as *recycling rate* (ERPC, 2011) was, according the definition provided prior to 2006 (ERPA, 2000), called *collection rate*. All in all, the three different terms, that are *recovery rate*, *collection rate*, and *recycling rate*, can mean the same thing depending on the geographical region, the organization providing the definition and the point in time that the term was used.

Similarly, even the term *recovery* itself has been defined differently in different regions. In Japan, the Japanese Paper Recycling Promotion Centre (PRPC, 2010) defines *recovered paper recovery (H)* as follows: (*recovered paper supply, G*) + (*shipments of de-inked market pulp with yield of 80%, G'*) – (*recovered paper imports, E*) + (*recovered paper exports, F'*). A formula is given to define the *recovery (H=G+G'-E+F)*, but this formula and the letters used in the formula only clarify different terms of the corresponding data table *"*trends in recovered paper recovery rate*"* inside the publication. In the PRPC (2010) framework the term *recovered paper shipment for mills* is used instead of *recovered paper supply*. In Europe, the European Recovered Paper Association (ERPA, 2000) defines *recovery* as a principle of waste management policy consisting of *re-use*, *material recycling*, *composting*, and *energy use* as well as exports to similar purposes. It can be mentioned that according to the definition by the European Recovered Paper Association (ERPA, 2000), *recycling of paper* consists of the *reprocessing of recovered paper* in a production process for its original purpose or for other purposes and *composting*, but it excludes *energy use*.

The American Forest and Paper Association (AF&PA, 2008) defines *recovery* as (*domestic consumption of recovered paper*) + (*exports of recovered paper*) – (*imports of recovered paper*). This is the same formula that CEPI used to calculate *recovered paper collection* in Europe prior to 2006. Since 2006, this formula has been used to define *recycling* in order to calculate the regional *recycling rate*.

4.4. Interchangeability of terms

The Finnish Technical Terminology Centre (TSK, 1993) states that the terms *recovery*, *recycling* and *collection* should be treated as synonyms. Göttsching et al. (1996) suggest that *recovery* is the same as *collection* and that *recycling* is the same as *utilization*. Presumably, terms like *recovery, collection* and *recycling* are not used interchangeably on a deliberate basis and relying on some pre-existing definitions; rather, interchangeable use occurs without paying attention to the definitions. Nevertheless, this can lead to ambiguous or incorrect communication. *Recovered paper recovery* in Europe is higher in volume than *recovered paper collection* or *recovered paper recycling* because *recovered paper recovery* also includes other uses of *recovered paper* outside the paper industry as well as *energy use*, whereas *recovered paper collection* and *recovered paper recycling* do not include *other uses for recovered paper* outside the paper industry nor *energy use* according to the European definitions quoted above. Furthermore, calculations based on the European definition for *recovered paper recovery* are even more inaccurate than other corresponding calculations because statistics of other possible *uses of recovered paper outside the paper industry* as well as *energy use* are relatively less accurate or even non-existent (Ervasti, 2008).

4.5. Term definition and time

The situation pertaining to European definitions and their comparability to definitions in other regions is ambiguous. Some terms that previously were included in the European lists of definitions are not listed there anymore. The latest lists of definitions in the European Declaration on Paper Recycling (ERPC, 2006, 2011) no longer include a definition for *recovery*. In the recent annual CEPI statistics, *recycling rate* and *utilization rate* are listed, but *collection rate*, which was included previously, has been omitted. Additionally, the European Declaration on Paper Recycling

for 2011–2015 (ERPC, 2011) claims that the term *recovered paper* is outdated and that *paper for recycling* should be used instead.

It is quite natural to drop some terms from the lists of definitions as times change. For instance, as *recycling* has become even more desirable ethically and *waste paper* or *recovered paper* growingly important as a source of raw material, several industry associations have dropped the use of the term *waste paper* in favor of *recovered paper* to avoid the material being associated with solid waste. Another trend has been that the export and import of *recovered paper* has increased on a global level and *recovered paper* has clearly established itself as an international trade commodity.

Also the grade definitions for *recovered paper grades* change in time. For example the European List of Standard Grades of Paper and Board for Recycling (EN 643, 2013) differ from the European List of Standard Grades of Recovered Paper and Board (EN 643, 2002). The number of individual grades has increased from 57 to 95. Additionally, new definitions like the share of *non-paper components* and *total unwanted materials* have been added for individual grades. This same development of change of grade descriptions is also occurring also in the USA. When comparing the Institute of Scrap Recycling Industries' (ISRI) Guidelines for Paper Stock PS-2013 with PS-2009 it can be noted that there are differences between 13 grades where either the name, definition, number code of the grade has been changed or the grade has been erased from the list. Grade definitions have also changed in Japan. When comparing the PRPC (2012) list of Japanese standard qualities of *recovered paper* with the corresponding list of the year 2005 (PRPC, 2005) many changes can be found: the total number of individual grades has been reduced from 29 to 26. At the same time the number codes of 20 different *recovered paper grades* has been changed.

4.6. Terms used and their definitions

4.6.1. Comparison of selected common terms

When terms do not have generally accepted, uniform definitions, the authors should clearly indicate what definitions they are using or what they mean when selecting a certain term, in order to avoid confusion. As there are different definitions for almost all *recycling* related terms, the author of this thesis suggests that all authors would always define the terms used in their texts and statistics.

To show how the same terms are defined differently by different authors and organizations making a comprehensive list of different definitions for selected terms, a comprehensive list was made. Terms *recycling* and *recycling rate* were selected for a closer look. *Collection rate* was not included for comparison because comparison of the American definitions (AF&PA, 2008) and European definitions (ERPC, 2006) shows that the definition for *collection rate* and *recycling rate* are the same. However, it should be noted that AF&PA does not use the term *collection rate* but the term *recovery rate*, instead. Additionally the *recovery rate* was not included in the comparison of terms as in the USA (AF&PA, 2008) and European (ERPC, 2006) *recovery rate* means a different thing. In the USA, the term refers to *collection* and in Europe it refers to *material recycling* including net trade and *energy recovery*.

Utilization rate is the ratio between *recovered paper consumption* and *paper production*. This definition is used in North America (AF&PA, 2008) and in Europe (CEPI, 2008). In Japan *utilization rate* is calculated differently (PRPC, 2012; Nippon Paper Group, 2013): (*utilization rate*) = (*recovered paper consumption*) / (*consumption of fiber stock for paper and board*).

Utilization rates exceeding 100% are possible. This can be explained with moisture differences between raw material and final products as well as material losses in the sorting process in the pulp and paper production. Additionally, imported *packaging material traded together with goods* has also an effect on the *utilization rate:* When this material is *collected* it is, in fact, included in the *collected volume* but it is not included in the *paper consumption*.

Even though the term *utilization rate* is defined almost uniformly, globally, it is not included in the comparison of terms in this section because the term itself is not appropriate when comparing different regions or periods of time. The term *utilization* relates more closely to industry structure rather than regions' activity with respect to recycling.

In the cited sources the terms *recovery* or *recovery rate* were used by 36 sources. A close reading of the context or definition demonstrates that in 18 cases, the sources in fact mean *collection*, based on how it is defined in the European CEPI annual and special *recycling* statistics prior to 2006. Four sources used the term *recovery* based on the European definition, and thus the authors were actually talking about *recycling* in combination with net trade, and incineration for *energy*

recovery. In three documents *re-use* was included in *recovery*. In two cases, the term *recovery* referred to the pulp manufacturing process. In some cases, the author of this thesis found that with *recovery* the source referred to *utilization, energy recovery, composting*, or to other transformation processes.

The cited sources defined different paper *recycling* related terms in many different ways. In fact, there were a vast number of definitions that differ from each other. The definitions of the selected sources were listed and compared with each other. Table 8 shows different paper recycling related terms and a number of different definitions related to these terms. For example, six different definitions for defining the term *collection* were identified. In this context, a different definition means that a definition really differs from another definition.

Table 8. Number of different definitions defining paper recycling related terms.

Term	**Number of different definitions**
Collection	6
Collection rate	3
Collected paper	3
Paper consumption	4
Recovered paper	18
Recovered fiber	5
Recovery	16
Recovery rate	9
Recycled fiber	7
Recycled paper	5
Recycled pulp	5
Recycling	11
Recycling rate	13
Reuse	3
Secondary fiber	2
Utilization	2
Utilization rate	7
Waste paper	7

In many cases, the cited sources used terms without defining them or without mentioning if they had used definitions of a certain organization or a certain author.

Two terms, namely *recycling* and *recycling rate* were selected for more detailed analysis to show that a term may have different definitions. *Recycling rate* is used to indicate the level of material recycling activity in a region or in a country. The European paper industry *recycling declarations* have set targets for *recycling rates*.

The term *recycling* or *recycling rate* was used by 36 of the cited sources. The term *recycling* was defined in 11 cases and *recycling rate* was defined in 13 cases. Those sources which did not define these terms seemed to assume that definitions of these terms are generally known.

When these terms were defined by the sources, the definitions used by these sources varied significantly. For example, the different sources defined *recycling* as presented in Table 9

Table 9. Definitions of the term recycling by different sources

Source	**Definition**
BIR, 2013	including 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
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
European Council 1994; Barrio, 2006	reprocessing in a production process for 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 fiber 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
Sukigara, 2003	recycling of fiber assemblies made from knitted sweaters and clothing
Villanueva et al., 2007	term recycling refers to material recycling

Text analysis plays an important role in defining terms. A good example of this is the defining of the term *recycling* in the European context. By combining different definitions of terms like *collection, recycling* and *utilization* from different sources, it can be shown that the definitions of different terms are sometimes the same. The following discussion illustrates this.

According to ERPC (2011), *recycling* is reprocessing of *used paper* in a production process into *new paper and board*. It should be noted that this definition does not mention the place of processing. ERPC (2005) defines *utilization* in the context of paper and board industries as use of *recovered paper* as raw material put into pulp at the paper mill. That is why it can be interpreted that *recycling* is equal to *utilization*. According to ERPC (2011), definition *recycling rate* is the ratio between *recycling of used paper* and *paper consumption.* Here the numerator includes, in addition, the *net trade of paper for recycling*. The total *utilization* (reprocessing) of *recovered paper* is the sum of *recovered paper utilized* domestically and exported from the region. This means that the exported volume of *recovered paper* is assumed to be *utilized* in the destination country. Thus, the total sum of *domestically utilized recovered paper* and *net traded volume of recovered paper utilized abroad* is equal to *recycling*.

Recovered paper collection (CEPI, 2013a) is the sum of *utilization of recovered paper* (domestically) and net exports. Thus, it is equal to *recycling*. In fact:

- *recycling = utilization*
- *recycling = collection*

This leads to the final conclusion that: *recycling = utilization = collection.* Also, the *recycling rate* and *collection rate* equal to each other because in both cases the divisor of the calculation formula, i.e. *paper consumption* is the same. However, the exact quantification of the *utilization rate* is more difficult while it is impossible to define which share of the exported *recovered paper* in the destination country is used for *paper production*.

In this context, the author of this thesis points out that it is not only important to define terms uniformly but also to select uniform symbols for the *paper recycling* related terms. This would make it easier to define ratios between terms in formulas.

The definitions concerning *recycling rate*, used by different sources vary significantly. The different sources defined *recycling rate* as presented in Table 10

Table 10: Definitions of the term recycling rate by different sources

Source	**Definition**
Ackerman et al., 2010	refers to the *recovery rate*
Barrio, 2006	(B+C) / A, where A = packages placed on the market, B = *material recycling* and C = *organic recycling* and use for other purposes
CEPI Annual Statistics, 2006; Special Recycling Statistics, 2005	(*recovered paper utilization*) / (*paper and board consumption*)
CEPI Annual Statistics, 2008	(*recovered paper utilization + net trade*) / (*paper and board consumption*)
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	*(waste paper utilization) / (paper consumption) w/o trade*
Klimek, 2011	*(waste paper collection) / (paper consumption) including trade*
Levlin (2008)	*recovered paper used for papermaking*, including utilization outside Europe
Miranda & Blanco, 2010	*(RP utilization in paper industry) / (paper consumption)*
PRASA, 2012	(*recovered recyclable paper) / (recoverable paper)*

Several of the sources use the term *recovery* to refer to different materials, such as *recovered paper, waste paper, paper and board, paper, packages*, and *recyclable paper*. By analyzing the context in which the term has been used, it can be argued that, for example, terms like *paper recovery, waste paper recovery*, and *paper and board recovery* mean the same.

There are two major organizations in North America (namely, AF&PA and ISRI) and one such organization in Japan referenced in this thesis that define terms related to *paper recycling*. Definitions given by these organizations have been stable over time, changing only infrequently.

Also, in these regions, definitions of names and codes of individual *recovered paper grades* have not been changed as often as in Europe. In Europe, there are several organizations and publications that define terms related to *paper recycling*. However, these European definitions of terms do not always match with definitions of the same terms given by other organizations in other regions. It also should be noted that definitions have been changed in course of time.

Terms like *recycled fiber* and *recovered fiber* are generally used to refer to *recovered paper*. However, some of the literature sources use these terms when referring to textile fibers, such as *recovered cotton fibers* (Halimi et al., 2006), *recycled wool, and recycled fiber assemblies made from clothing* (Sukigara et al., 2003).

4.6.2. Results related to material flows

4.6.2.1. General

Paper industry related material flows including *paper recycling* offer an interesting sector for material flow analysis. Fibers are part of the biomass flow and originate from forests and annual plants. After having been *utilized* for the first time to produce *paper* the fibers acquire a new life through *recycling*.

In this thesis *paper* and *recovered paper* related stages and flows have been described in detail, and the emphasis has been placed on the role of *recycling* in the material flows. *Recovered paper* is today the most important *fiber component* by volume in the paper industry. Nevertheless, continuous injection of *virgin fiber* and other materials into the system is necessary to replace the lost material.

In material flow frameworks ratios between different stages and flows can be identified and quantified. In paper industry related terms include terms like *recovered paper utilisation, recovered paper recycling, paper consumption* and *paper production.* In addition, there are terms that describe relationships between these basic terms. Such terms can be used, among other things to indicate material recycling activity level within the industry. For example, *recycling rate* is the ratio between *recovered paper recycling* and *paper consumption*.

A good framework should describe material flows uniformly in all geographical regions. The frameworks should capable of being joined together so that material flows between the frameworks use the same terms, definitions and they could be quantified uniformly. A good paper industry framework should be comprehensive and include material flows and trade of different materials like *wood pulp, paper, converted paper products, paper packages traded with goods, recovered paper* and *recycled fiber*.

When researching paper industry related material flows, it is difficult to use general frameworks, like, the Eurostat (2001) framework. For example, in Europe the paper and board industry *material recycling* plays a central role both domestically and internationally. In the Eurostat framework, little attention has been paid to this global nature of *recycling*. In Europe (EU 27 + Norway and Switzerland) the recovered *paper recycling rate* was 70% in 2011 (CEPI, 2013a). In the earlier presented Eurostat framework, *recycling* is seen mainly as a domestic issue.

In the general frameworks, there is generally a stated starting point for input material flows and *recycling* has a minor role in showing that only a certain share of the consumed material returns to circulation. The traditional frameworks do not clearly define what the exact sources and destinations of *recycled material* are.

The paper and board industry material flows including *recycling* cannot be analyzed only by examining the system in a linear form with a certain starting point, material throughput stages and output. There is no clear starting point and material source like there is in the case of an ore mine.

4.6.2.2. Framework and recycling

The paper and board industry material flow framework has to be understood as assuming the form of a circle or a wheel, whereby there is no exact starting point or end point. Material input and material output happen continuously at different stages of the framework as the material moves in the system. This circle can be divided into relevant main stages, each of which may have several sub-stages. There are also inflow streams and outflow streams of material which move between the stages. Additionally, these flows may also lead to outside the wheel (for example to another region) or flows can come from outside the wheel into the system.

In general, very little attention has been paid to the rotation speed of an individual fiber in the framework or to the fact that the same fiber may be included in the calculation several times before it exits the loop.

It is essential to approach the phenomenon by analyzing such frameworks which have been developed specially to take into account the characteristics of the paper and board industry material flows.

Even though the analyzed sources used different terms when describing different stages, the five main stages structure could be identified in all of the frameworks. Additionally, all selected frameworks except one, namely, the EcoPaperLoop (2014), takes the form of a wheel.

According to analysis of the frameworks, five common stages of material movement were identified. *Consumed paper* changes form to *waste paper* which then turns into *recovered paper* in collection and sorting. After collection *recovered paper* is utilized in *paper production*. *Other options* include *material use outside the paper industry*, *sorting residues* and *non-collected material.* Additionally, the *paper flow* consists of several different *paper grades* each having a raw material furnish of its own, including a different combination of *fibers and fillers*. The structures of all different frameworks can be grouped by using the identified five main stage approach shown in Figure 3. Arrows between the stages indicate material flows.

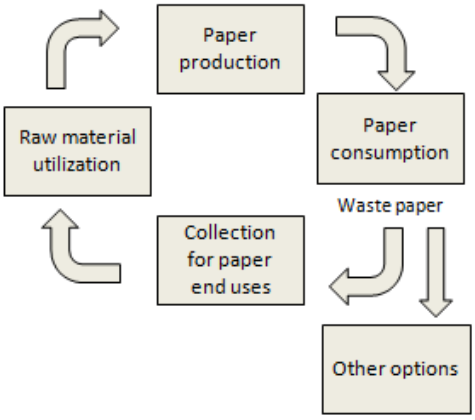

Figure 3. General description of the Ervasti and Kauranen “wheel of fiber”. Material recycling flow framework consisting of five main stages

Paper consumption which can be regarded as one of the main stages can further be divided into sub-stages identified in the analyzed frameworks as follows: *paper in rolls or sheets, converted products, packaging material with goods* and *paper at end users*.

Additionally, material contents related to fiber flows can be divided into four main fiber categories including *wood raw material, wood pulp, recovered paper* and *paper*. Additionally, considering these as the final products each of these categories can be divided into several grades.

For quantitative analyses, the stages and flows in the framework have to be quantified. The five stages which are common to the selected paper industry material flow frameworks presented in Figure 3 include:

- *raw material utilization* including *virgin fiber, recovered paper* and other raw materials in paper manufacturing
- *paper production*
- *paper consumption*
- *collection (or recycling) of recovered paper* including both *domestic utilization* and net trade
- *other options*. This includes all material flows except those which are being *collected* and *used for paper manufacturing* domestically or as exported. Other options include *recovered paper material use outside the paper industry, energy use, not collected paper* and *disposed paper*

For example, *paper produced* in Europe is *recycled* in both in Europe and outside Europe as *exported paper*, as *exported converted products* and as *exported packaging material* like *boxes exported with goods*. These different materials can be *collected* in the destination region. In order for material to flow and rotate continuously in a region, both the material input flows and output flows have to be in balance, in the long term.

Forests can be understood as a source of *wood fiber* and *paper consumption* can be understood to be the potential source for *waste paper*. *Waste paper* is then a source for *recovered paper*, which is used as raw material for *recycled fiber*. Finally, *recycled fiber* is used as raw material in *(recycled) paper production*.

4.6.3. Comparison of different frameworks

By comparing the selected frameworks by using the new five stage framework as a basis, considerable differences were found in relation to the stages themselves and as to their descriptions.

The identified fifth main stage of the new five stage framework is termed *other options* in this thesis. In the analyzed frameworks, the *other options* stage was not clearly identified and is not seen as part of the *recycling* chain but rather a means to define volume which exits the system. This fifth stage includes several different flows or sub-stages termed differently in different frameworks as shown in Table 11.

Table 11. Different flows included in the other options stage in different material flow frameworks

Framework	**Terms of flows in the other options stage**
ERPC 2013	other options stage is not identified
Villanueva, 2007	digestion / composting, incineration, landfilling
Indufor, 2013	disposal, other uses, bio-energy
EcoPaperLoop, 2014	sewerage, longliving products, landfilling, incineration
CEPI, 2013a	landfill disposal, used for other recycling options, composting, incineration, other treatments
CEPI, 2008	long term storage, disposal
Schmidt et al., 2007	incineration, landfill
PRPC, 2010	not recovered
Davidsdottir, 2005	incineration, landfill, energy recovery
Pento, 1994	long-life products, landfill, incineration

The suggested five stage framework takes into account different material flows, and using it makes it possible to unify the use of terms and pay special attention to the *recycling* nature of the material flows related to the paper industry. By grouping the stages and flows of the selected frameworks, the five stage approach could be used successfully as the basic framework. The *other options stage* can be an individual stage. It includes *recovered paper for other uses* and *composting*, which end uses, according to ERPA (2000), are material recycling options.

Collection rate, *recycling rate*, *recovery rate* and *utilization rate* used by recognized organizations can be defined by quantifying different stages and calculating ratios between them with each other. Appropriate formulas need to be used depending on the case.

The introduced five stage framework can be tested with regards to how well it can be used to calculate different regional activity related terms within the paper industry material flows by comparing different stages and material flows with each other.

When grouping the stages used in the different frameworks, the author of this thesis had to make a subjective judgment about the contents of each of these stages because the terms for different stages vary depending on the framework. An example related to one of the main stages, namely *paper consumption*, is given.

For example, according to Pento (1994), CEPI (2008), and Schmidt et al. (2007), the *paper collection potential* and *paper consumption* stage is the last stage after *converting and printing*. In fact, there are several different definitions for the term *paper consumption*. In this respect, it is difficult to unambiguously define that *paper consumption* related stage which would describe the collection potential reliably. The *paper consumption stage* is termed and defined differently in different frameworks as shown in Table 12.

Table 12. Descriptions and terms used to describe the paper consumption stage in different frameworks.

Framework	**Definition of *paper consumption* stage**
ERPC, 2013 *)	*consumers who discard paper*
Villanueva et al., 2007*)	*used paper / paperboard*
Indufor, 2013 *)	*paper consumption including converting (printing)*
EcoPaperLoop, 2014	*theoretical recovered paper potential*
CEPI, 2013a	*three different terms or sub-stages related to paper consumption*
CEPI, 2008 *)	*product use*
Schmidt et al., 2007	*paper products including converting (printing)*
PRPC, 2010	*paper consumption*
Davidsdottir et al. 2005 *)	*paper and paperboard use and discard*
Pento, 1994 *)	*paper at end users*

Note: *) in these frameworks the stages and material flows are not quantified

A rough division between the selected paper industry frameworks can be made by taking into account how the framework can be used to quantify material flows. In four, of the frameworks the material flows and stages are quantified.

In the traditional material flow accounts, the material flows usually start from the raw material sources or from the material *utilization* stage (Eurostat, 2001). However, for the paper industry material flow framework there is no clear starting stage and end stage due to the fact that material rotates in the system. That is why any stage like raw *material utilization, paper production* or *paper consumption* can be used as a starting point. In Villanueva (2007), CEPI (2008 and 2013), Schmidt et al (2007), PRPC (2010) and Pento (1994) frameworks the raw *material utilization in paper production* is the starting stage followed by *paper production, paper consumption, recovered paper collection* and *disposal*. On the other hand, ERPC (2013), Indufor (2013) and PaperLoop (2012) use *paper consumption* as the starting point as this stage describes the *recovered paper collection potential*. Additionally, according to Davidsdottir et al., *recovered paper collection* stage is the starting point.

When the author of this thesis defined the material starting point for the frameworks either numbering of the different stages used by the corresponding author or the order of the stages in the framework chart from the top to bottom was taken into account.

The relationship between the identified five main stages and stages from the analyzed frameworks is shown in Table 13, which is called "Grouping of stages of different frameworks base on the stage structure of the five stage framework". It should be noted that each main stage may consist of several sub-stages. Relevant issues identified in the analyzed frameworks have been mentioned under each main stage. An "*x*" in a column means that the corresponding stage could be identified in the selected frameworks.

At the raw material *utilization stage, recovered paper* is used to produce *recycled pulp* which is then used as raw material together with *wood pulp* in paper production. After this, *paper consumption* forms the *recovered paper collection potential*. Further, the *recovered paper collection stage* is in fact parallel with the *other options* stage. Material flows from the *paper consumption* stage to both *collection* stage and *utilization* stage. In this thesis the *other options* is not analyzed in detail.

A notable difference between the *Ervasti five stage framework* and the *Ervasti and Kauranen wheel of fiber framework* is that in the *five stage framework* material to *other options* comes also from the *recovered paper utilization stage*. This material flow has been identified by CEPI (2013a). Also Pento (1994) identified this material flow but claimed it to be *waste to landfills*. Additionally, the *Ervasti five stage framework* is more detailed in identifying and defining material stages and material flows.

Table 13 shows that all the stages and flows of the CEPI (2013a) framework can be grouped by using the introduced five stage framework. The same five main stage structure can be used to group terms and stages of all the selected paper industry related frameworks. Detailed description concerning these different paper industry material flow frameworks, identified recycling stages and terms used are shown in Table 13.

Table 13. Grouping of stages of different frameworks according to the stage structure of the Ervasti five stage material recycling framework.

Main stage	Sub-stage or flow used in different frameworks	ERPC (2013)	Ville-nueva (2007)	Indufor (2013)	EcoPaper Loop (2014)	CEPI (2013a)	CEPI (2008)	Schmidt et al (2007)	PRPC (2010)	Davids-dottir (2005)	Pento (1994)
raw material utilization	virgin fiber pulp used for paper		x	x		x	**x**	**x**	x	x	x
	recovered paper used for paper	x	x	x	x	x	**x**	**x**	x	x	x
	recovered paper utilization = collection - net trade, or collection = utilization + net trade		x	x		x		x	x	x	x
	Recovered paper used for recycled / de-inked pulp	x	x	x			x	x	x	x	x
	recycled / de-inked pulp used for paper		x	x			x		x	x	x
	non-fibrous materials used for paper					x		x			x
paper production	paper production	x	x	x	x	x	x	x	x	x	x
	- production of different paper grades		x			x					x
paper consumption	paper consumption		x	x	x	x	x	x	x		x
	-paper consumption by grade										x
	converting paper into paper products	x				x	x	x			x
	consumer / end user who discards paper	x				x				x	x
	consumption = product usage + additives				x			x			
	consumption = production + net trade		x	x		x			x		x
	product use				x	x	x			x	x
	theoretical recovered paper potential				x						
	non-collectable paper taken into account				x	x					
	ink and additive use in converting				x		x	x			
	available recovered paper potential				x						
	trade of packaging material included					x					
	trade of converted products included					x					x
recovered paper collection	recovered paper collection	x	x	x	x	x	x	x	x	x	x
	recovered paper sorting	x	x			x	x		x		
	fulfill recovered paper grade quality definition	x					x				
	collection from different sources or collection of different recovered paper grades					x	x		x		x
Other options	other recycling options			x		x				x	
	other recovery options		x	x		x					
	-energy recovery		x	x						x	
	-composting		x			x					
	-other treatments					x					
	long living products included				x		x				x
	land filling		x		x	x		x		x	x
	disposal			x		x	x				
	sewerage				x						
	incineration		x	x	x	x		x		x	x
	process losses in pulping					x					x
	not collected, non-collectable				x	x			x		x

Note: The letter x in the table indicates that the source in question has used the marked stage, flow or term in its framework.

Only Schmidt et al. (2007) and Pento (1994) have paid attention to the fact that moisture of the material varies from one stage to another. The difference between energy recovery and incineration is not clear in all cases. Incineration as a means of *waste disposal* is possible also without *energy recovery*. Only CEPI (2013a) has taken into account the flow of *packages traded with goods* at the *paper consumption* stage and *recovered paper utilized* for other material uses outside the paper industry. Only CEPI (2013a) and Villenueva et al. (2007) have identified composting as an end use of *recovered paper or waste paper*, but both sources indicate that it is either a disposal or a recovery option. CEPI (2006) uses also another formula to calculate *paper consumption*, which is *(internal deliveries of paper) + (imports of paper from outside CEPI).*

Pento (1994) and Villenueva et al. (2007) have mentioned that *paper production* consists of different *paper grades*. Two frameworks, CEPI (2008) and Schmidt et al. (2007) state that inks and additives are added into the material flow during the converting process. Only CEPI (2013a) and Pento (1994) have taken into account the trade of *converted paper products* as an output flow at the paper consumption stage. ERPC (2013) and CEPI (2008) define that *collected recovered paper* has to fulfill a certain *recovered paper grade* quality definition (Both sources refer to the European EN 643). CEPI (2013a) and Pento (1994) have identified the material output flow as process losses at the raw material *utilization stage*. Use of terms to define different stages and flows varies greatly. For example 14 different terms and definitions related to the *paper consumption* stage alone were identified. No framework source mentioned the possibility of *non-paper component* input flow into the system at sources indicated by Miranda et al (2011). In its annual statistics, CEPI calculates paper consumption as follows: (*paper production*) + (imports of paper from other CEPI countries) + (imports from outside CEPI) – (exports to other CEPI countries) – (exports to outside CEPI). According to ERPC (2011) CEPI calculates *paper consumption* as follows: (internal deliveries into the defined region) + (imports from countries outside the defined region).

None of the analyzed frameworks have identified that in paper sorting some material in the form of sorting residues goes to other options. This fact is clearly indicated by Miranda et al. (2011).

4.6.4. Testing of the compatibility of the five stage material flow framework and the CEPI (2013a) framework

To test the usability and functionality of the five stage material flow framework, the author of this paper introduces how the different stages and flows of the CEPI (2013a) framework can be grouped by using the five main stage framework as a basis. The CEPI framework is widely in use in Europe.

The CEPI (2013a) framework is called *the European Fiber Flow Chart 2012*. The CEPI (2013a) framework was selected for this purpose as the framework has the highest number of stages, sub-stages and flows amongst the selected ten frameworks. Additionally, CEPI as an organization has done a lot of work in quantifying the stages and flows in its framework. The quantification is done by obtaining and combining data from official statistical sources like Eurostat and from national paper industry associations which collect data from local companies and aggregate it into country level data.

CEPI (2013a) calculates the two most important *recovered paper* related activity terms as follows by comparing selected stages with each other:

- *recycling rate = (collection of paper for recycling) / (market supply paper and board)*
- *utilization rate = (utilization of paper for recycling within paper and board production) / (paper and board production)*

In the above context, terms relate to introduced different framework stages as follows:

- *collection of paper for recycling* relates to the collection stage
- *market supply paper and board* refers to the paper consumption stage
- *utilization of paper for recycling* relates to the raw material utilization stage
- *paper and board production* relates to paper production stage.

A detailed description of the CEPI (2013a) framework is shown in Table 14. The five stage framework stage structure is used to group the different stages of the CEPI (2013a) framework.

Table 14. The CEPI framework "The European Fiber Flow Chart" reordered according to the five stage framework.

- **raw material utilization** (stage)
  - virgin pulp and non-fibrous material input
  - utilization of paper for recycling within paper and board production
    - process losses and non-paper usages (to other options)
- **paper production refer to paper and board production** (main stage)
    - paper and board net trade (to / from other regions)
- **paper consumption** (stage)
  - market supply paper and board
    - collection from converters and printers (to collection)
  - market supply converted products
    - net direct trade of converted products and packaging surrounding traded goods (to / from other regions)
    - returns, unsold (to collection)
  - product use
    - non-collectable (to other options)
    - paper for recycling at end users (to collection)
- **recovered paper collection** refer to collection of paper for recycling (stage)
  - collected and sorted
    - from different sources
      - households
      - offices
      - trade and industry
      - paper collection from converters and printers (see above)
      - collection of returns (see above)
    - collection of paper for recycling
      - (to regional utilization)
      - net trade of paper for recycling (to / from other regions)
- **other options** (main stage)
  - landfill, disposal
  - paper for recycling used for other recycling options
  - other recovery options
    - composting
    - incineration
    - other treatments

As a result of using the five stage approach to group the CEPI (2013a) framework, it can be said that all the stages of the CEPI framework could be grouped successfully. The CEPI (2013a) framework identifies that there is a material flow of *process losses* and *non-paper uses* between

the *recovered paper utilization* and *paper production*. Even though this flow is quantified in the framework, it is difficult to define how much fiber and moisture it contains. The *utilization rate* is calculated according to definition, as the ratio between *recovered paper utilization* and *paper production*.

In the CEPI (2013a) framework, the *paper consumption* stage follows the *paper production* stage. The difference between these two stages is the net trade flow of paper and board. In the CEPI framework there are four different sub-stages in the *paper consumption* main stage and the first of them termed *market supply of paper & board* is used to calculate the *recycling rate*. This sub-stage within the *paper consumption* main stage is quantified by summing domestic deliveries and imports. In most other regions the *paper consumption* is calculated by summing production and net trade of paper.

The CEPI (2013a) framework identifies several material flows which cannot be found from most of the other analyzed frameworks. These flows include for example the *net trade of converted products* and the *net trade of packages surrounding traded goods*. CEPI estimates these flows to be in balance by volume.

In its framework, CEPI (2013a) assumes that the share of *non-collectable paper* is about 8% of the product use. The existence of a flow called *non-recyclable material* is mentioned and quantified in the framework. The total volume of *non-collectable* and *non-recyclable* is estimated to be 19% of the total paper and board volume put on the market. Bureau of International Recycling (BIR, 2013) says that the share of such paper products, which are *non-collectable* and *non-recyclable* consist of for example cigarette papers, wall papers, tissue papers and archives, and the volume is estimated to be about 15 – 20% of the total paper consumption. According to ERPC (2003), 19% of paper products on the European market cannot be collected or recycled for technical reasons or because they are being used for permanent applications.

In the CEPI (2013a) framework, *composting* is included in the *recovery* option even though according to ERPA (2000), it is a *recycling* option. Additionally, the terminology which is used in the CEPI (2013a) framework differs from other frameworks. The CEPI (2013a) framework does not take into account moisture differences between different stages.

A reason hindering earlier development and implementation of a more reliable calculation methodology *for recycling* rate is that there are no reliable statistics available to indicate volumes for *traded packages* or *recovered paper recycling* for uses outside the paper industry and collection of this new data would be costly. However, due to increasing *recycling* activity and growing *recovered paper* trade, globally, development of a reliable calculation method for recycling is necessary.

4.7. Framework quantification

It is not enough that a certain material flow account or system can be described with a framework. To be able to compare different regions and, for example, their *recycling activities* with each other it is essential that both the stages and material flows can be quantified uniformly. This means that the same framework with its stages and flows as well same terms and their definition could be adopted in different regions. In this respect the five stage framework could be used as a starting point in developing a new, paper industry material flow framework.

5. Understanding and developing a terminology and recycling related framework

5.1. Guidelines for a new terminological system

Based on the previous analyses, it is obvious that the terminology used in the field of *recycling within the paper and board industry* does not fulfill the criteria of uniform definitions for terms, while many different definitions for several terms could be identified. How then should the terminological system be improved? A suggestion of a solution to this problematic situation this is given in this thesis. In this thesis, a preliminary suggestion is made for a new terminological system.

The suggestion for a new system is based on the *material recycling* chain, which refers to the material flow from paper that has already been used and that, after the collection and sorting process, is being treated as raw material for the *production of recycled paper*. Other points of departure for the new system include the fact that the existing terminological systems need to be altered so that the new system will be as consistent with the existing systems as possible, allowing for a smooth transition for users.

However, if more than one inconsistent terminological solution is used at the same time, then a decision needs to be made regarding what to include in the recommended new system. If the existing terminological system has some illogical patterns or misleading or even incorrect parts, then obviously it should not be part of the recommended new system. In developing a new terminological system, certain basic issues should be taken into account.

The material *recycling* chain varies depending on, for example, the country and the material. The new terminological system should be so general in nature that it covers all contexts. It should support reliability and validity in communication between all stakeholders. A sound terminological system should be unambiguous as a whole, there should not be any vaguely defined terms, and there should not be redundancy.

The first step in developing a uniform terminological system would include systematic detailed list of terms and their definitions. In this thesis, the word "term" refers to all the different stages of the paper and board industry, from raw *material utilization* to *recovered paper collection* and *recycling*. Different terms can be grouped roughly for example into eight groups as shown in Table 15.

Table 15. Different groups of terms and examples of corresponding terms

Term group	**Examples of terms in the group**
1. material related terms.	a) terms and abbreviations describing the material at general level: *recovered paper, waste paper, recycled fiber, recycled paper, RP, RCF, OMG, News, OCC*
	b) terms related to names of different trade grades of recovered paper. For example by EN 643, PS-2012, PRPC and AuRPS
2. statistical terms which relate to stage and flow. Terms can be quantified	*utilization, collection, recycling, consumption, export volume, production, shipment*
3. activity terms relate to relations between terms and activity level	*utilization rate, collection rate, recycling rate, (adjusted) waste paper net recovery rate, recovery rate*
4. terms which may have a different meaning and definition depending on region, organization and time	*recovery, waste paper, recycling. Additionally, for example in different regions and in their classification systems number "4" refers e.g. to different recovered paper grades including terms like heavy letters, mill wrappings, kraft grades, boxboard cuttings, tabulating cards and paper sacks*
5. different terms which may have the same meaning depending for example on region and time	a) (material) *recycled fiber - recycled paper - waste paper – recycled paper* b) (statistical & activity) *recovery- collection – recycling*
6. terms which refer to action or doing something	*recovery, collection, sorting, recycling*
7. terms which cannot be quantified or which are difficult to be quantified reliably	*recovery (in Europe), re-use, (adjusted) paper consumption, recovered paper use for other purposes outside paper industry, RP used for energy recovery, volumes related to individual recovered paper trade grades*
8. terms which relate to several of the above mentioned groups	*recovery* and *collection* may relate to action and different statistical terms

This thesis has identified that the same terms are defined in different ways and that there is a great variation in the use of different terms. The fact that the same term may occur in several term groups increases confusion. Systematic description and additional research work is needed to develop a new uniform terminological system related to paper recycling. In this development work it is important to first group different fields of terminological chaos by taking into account varying use of terms related, for example according, to the above list, (Table 15).

It is possible to carry out the grouping of terms by describing and comparing systematically the use of different individual terms and by taking into account variations which are dependent on the researcher, organization, region, and time. For example, the definition of a certain term may vary between different organizations and regions. Also, a term like *collection* can be understood to be a statistical term or it can relate to the pick-up action. Such separate uses of the same term can be confusing although it is not incorrect.

5.2. Material related recycling terms and stages of a recycling framework

Terms used for materials related to *recycling* have a close connection to the *recycling* framework. When material moves from a stage to another within the framework it changes form and terms used to define these materials should change accordingly. This issue can be illustrated by using an analogy from the paper and virgin wood pulp industry. In the pulp industry the material chain starts from forests and trees. After the trees have been cut they turn into timber or pulp wood. After the pulping process wood becomes *wood pulp,* which again is used as raw material in paper production. In the paper and *virgin wood pulp* industry, the above mentioned terms clearly define different materials.

The v*irgin fiber* analogy is illustrated in Figure 4, where the paper industry *virgin fiber* chain and *recycled fiber* chain are compared with each other. Both chains have been divided into different material stages and corresponding processes. It should be noted that the stage structure shown in Figure 4 is not the same as the stage structure presented in the recycling framework because Figure 4 describes the metamorphosis of the material itself. Figure 4 clearly illustrates that corresponding material to be compared, for example, with *virgin wood pulp* is not *recovered paper* but *recycled fiber* or *recycled pulp* like *de-inked pulp*. In this respect *recovered paper* is used as

raw material in *recycled fiber* production and it should be compared with wood raw material instead.

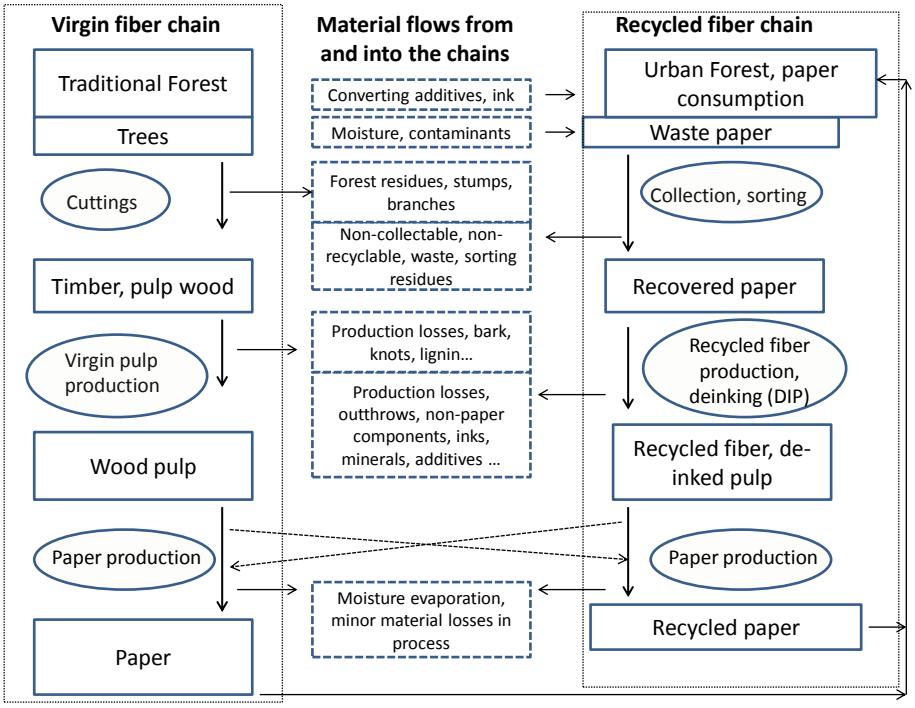

Figure 4. Comparison of two paper industry raw material chains and corresponding material flows within the chain (intra chain flows) as well as flows into the chain and out from the chain (inter chain flows).

Figure 4 indicates that there are two different main raw material chains feeding paper production. Firstly, the virgin fiber chain starts from the forest. After cutting, the material turns into *pulp wood* which is used as raw material in *wood pulp production*. *Wood pulp* is then used as raw material in paper production. After production, paper is converted, printed and consumed.

Secondly, *paper consumption* forms the potential for *waste paper*. After *sorting and collection*, material turns into *recovered paper*, which is then used as raw material in *recycled fiber production*. *Recycled pulp* is then used as raw material in *recycled paper production*, which after converting and printing is consumed by consumers. Figure 4 shows how different stages and corresponding material terms of the *virgin fiber* and *recycled fiber* chains should be compared:

- forest corresponds to *paper consumption*
- trees correspond to *waste paper*

- *timber* and *pulp wood* correspond to *recovered paper*
- *wood pulp* corresponds to *recycled pulp (recycled fiber)*
- *paper* corresponds to *recycled paper*

It is important to note that there is no actual difference between *paper* and *recycled paper*. In several paper grades *recovered paper* is used together with *virgin pulps* as raw material.

5.3. Identification of two different main types of material flow chains

5.3.1. General

When analyzing the terms identified for this thesis, an intriguing question appeared: Why does *waste paper* not occur in the five stage framework as a separate stage? One might surmise that terms like *waste* or *waste paper* refer to no physical product or stage in the framework that could be quantified easily. In fact, they cannot be quantified. Only when the term *waste paper* is used misleadingly to substitute for the term *recovered paper* can the material flow be quantified. With a closer look at material flows, in addition to the five stage framework within *paper recycling*, which has already been discussed in this thesis, another hidden framework can be identified. This hidden framework is related to the terms used, not to actual measurable material flows.

In this section the earlier introduced five stage framework is compared with a terminology-based framework. The new terminology-based framework must to be introduced. This framework does not relate to material flows but only to terms used. In this respect, a clear distinction has to be made between these two different frameworks. These frameworks are called:

- the five stage framework related to material flows
- the terminology based framework related to the terms used

Firstly, the five stage framework, related to material flows includes the following stages:

- *paper consumption*
- *recovered paper collection*
- *recovered paper utilization*
- *recycled paper production*
- *other options*

Secondly, the terminology-based framework includes the following stages which are closely related to the terms used:

- *paper consumption*
- *waste paper*
- *recovered paper collection*
- *recovered paper utilization*
- *paper production*

The main difference between these two frameworks is the *waste paper stage* in the terminology-based framework. In fact, in the five stage framework, a stage as *waste paper* does not exist. There is no reliable statistical data about the volume of *waste paper*. *Waste paper* is, in fact, a mixture of different *wastes* and *non-paper components* like *paper, plastics, metal, glass* and *other contaminants*. Also, the moisture contents of *waste paper* may vary considerably. For example, the *waste paper recovery rate* is the ratio between *waste paper collection* and *paper consumption.* Furthermore, *waste paper utilization rate* is the relation between *waste paper utilization* and *paper production*. In the literature, there appears a rich family of terms related to *waste paper.* The *waste paper stage* in the terminological framework is only an imaginary bundle of terms between the *paper consumption* stage and the *recovered paper collection* stage. The fact that the waste paper stage is understood to be a measurable stage is one important source of confusion in paper recycling terminology. The shares of the different types of wastes and recyclable materials may vary greatly depending on *region* and *source*. For example, *regio* relates to the country or to the geographic area, while *source* relates to sources like households, offices, converting and shops. Additionally, *waste paper is not* exported. Exports consist of different *recovered paper grades* which have been sorted out of *waste paper*.

5.3.2. The five stage material recycling framework

The first stage in the Ervasti five stage material recycling framework is the same as in the terminology-based framework, namely *paper consumption*. The second stage in the five stage framework defined in accordance with the definitions provided by, for example, the ERPC (2011), is *recovered paper*. For this stage only, material which is collected and sorted appropriately for material use is included. In addition, it can be assumed that the collected and sorted material has to fulfill quality requirements set for material suitable for processing. In practice, quality

requirements are set separately for different grades of *recovered paper*. Quality standard systems have been established separately for different geographical regions, like Europe, the USA, Japan, Australia, Russia, and South Africa, and, consequently, there exists no uniform standard accepted by all parties.

When the collected and sorted material fulfils the set requirements, then the material becomes a trade commodity, an individual *recovered paper trade grade*. Individual *recovered paper grades* are treated separately as commodities, and in order to quantify the total *recovered paper* volume the *recovered paper* volumes of all individual *recovered paper grades* need to be summed up.

It has to be stressed that *waste paper* belongs to no stage in the five stage material framework. It is not *paper*. On the other hand, it is not *recovered paper* while it does not fulfill the set criteria.

After the *collection stage*, there is the *recovered paper utilization* stage, where *recovered paper* is processed into *recycled fiber*. The next stage is the *paper production* stage during which *recycled fiber* is utilized in paper manufacturing.

Figure 5 illustrates that a term used has a connection to the stage where it appears. If the five stage framework were used all regional material flow frameworks could be joined with each other. An export flow of paper or recovered paper is an import flow in another region. These trade flows which tie different regions together relate to several product groups like: *wood pulp, paper, converted paper products, paper packages, recovered paper* and *recycled fiber*.

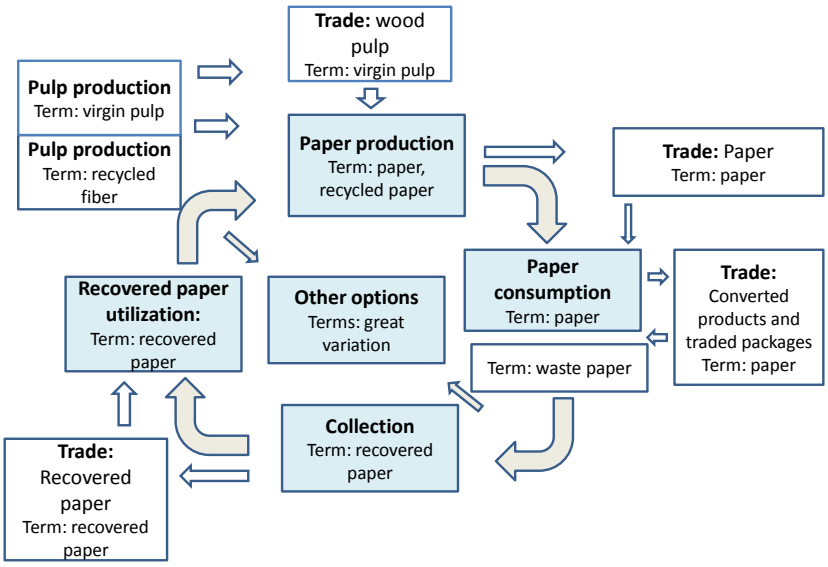

Figure 5. The Ervasti five stage material recycling framework and use of material related terms and their relations to different stages of the framework.

The material recycling related term change while material moves from a stage to the next in the chain. In this flow, the material changes form. The relation between recycling terms and stages in the recycling framework can be described as follows:

- the term paper is used at the *paper consumption* stage or when *paper* is traded. The *paper consumption*, possible contamination and mixing it with other wastes during and after the paper consumption stage forms a mixture of different materials which is called *waste paper*
- *recovered paper* is *collected* material which after sorting fulfills the definition of any generally accepted *recovered paper* classification system. *Recovered paper* is traded and utilized as raw material in *recycled fiber* or *recycled pulp production*
- in *recovered paper utilization*, *recycled fiber* is produced and it is used as raw material in paper production as such or mixed with other raw materials
- *paper production* uses *virgin pulp*, *recycled fiber* and other materials or their mixtures as raw material.

At present, terms related to *fiber material recycling* in the paper and board industry, such terms as *recycling rate*, *collection rate*, and *utilization rate*, are quantified for total *recovered paper* only. However, there are several different *recovered paper grades* that have their own specific end uses

as well as their own specific collection, sorting, and processing practices. R*ecovered paper* is generally divided into four groups or statistical grades: *Mixed grades, corrugated and kraft (OCC), newspapers and magazines*, and *high grades*. These statistical grades each consist of a group of individual *recovered paper trade grades*. The American AF&PA, European EN 643 and Japanese PRPC each have their own system for combining individual *recovered paper* grades into groups for the statistical grades. In the new terminological system, the terms could be extended to each recovered paper statistical grade level, too.

5.3.3. The terminology-based framework

The terminology-based framework is closely related to the material flow framework. Consequently, the terms which cover the initial terminological stages in the terminology-based framework are difficult to quantify. In this context the paper consumption stage is considered to be the first stage. The stages of the terminology-based framework are as follows:

- the first stage: *paper (consumed).* In the paper stage, terms relate to end products like newspaper*, printed matters converted products* and *boxes*. All these paper products consist of several different materials. For example, a *printed newspaper* consists of *paper(newsprint)* and *printing inks.*
- the second stage: *waste paper*. According to Bach et al. (2004), the total amount of *waste paper* is the sum of *paper collected separately in paper bins, paper from the bins of other separately collected waste categories*, paper that is part of the *residual waste*, and the amount of *paper moving on to some other sinks*, such as the *paper that is used for energy production or incinerated*. Additionally, *waste paper* contains different volumes of impurities, non-paper components and contaminants. *Waste paper* volume, which cannot be quantified reliably, sets an upper limit to the *collection potential*, but for many reasons the amount of *recovered paper* is smaller than the amount of *waste paper*. Some *waste paper* is *non-collectable*, such as *filter paper, cigarette paper* and many types of *tissue papers*. Some *waste paper* is *non-recyclable*; for example, due to the degree of converting, contamination, or mixing with other waste materials. A certain amount of *waste paper* is always lost when *waste paper* turns into *recovered paper* through the collection and sorting process.
- the third stage: *recovered paper.* This stage is closely related to the *recovered paper collection* stage and raw material utilization stage in the five stage framework.

- the fourth stage: *recycled fiber*. In the terminological framework this stage includes fibers after the *recovered paper* has been processing into *fiber* form again. In this stage, terms like *de-inked pulp, DIP and recycled pulp* are used.
- the fifth stage: *paper produced.* Paper is manufactured by using *recycled fiber* like *de-inked pulp as raw material*. The *paper* in question is termed, for example, *recycled paper*, *newsprint*, *liner*, *fluting* and *sanitary paper*. It should be noted that the terms related to the *paper produced* stage differ from the *paper consumption* stage terms. The terms relate merely to *printed and converted paper products*.

Terms defining the material itself change as the material moves through the material flow chain. The change of terms in the terminology-based framework is related to different stages and to different products as shown in Figure 6.

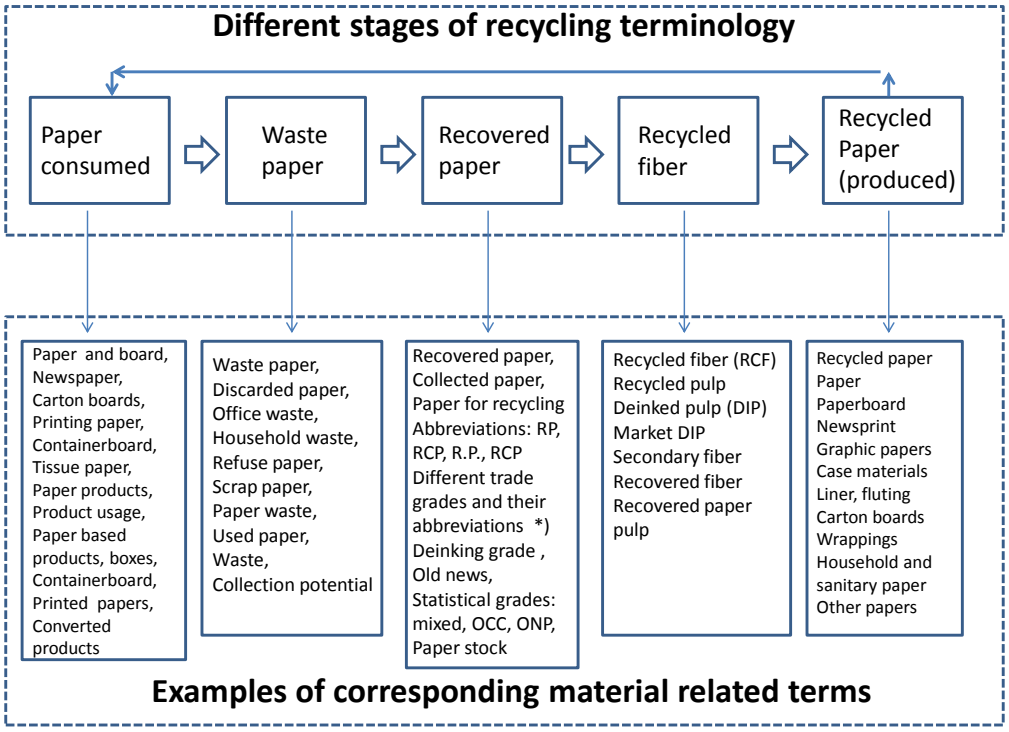

Figure 6. The terminology-based framework of paper recycling - different stages and examples of corresponding material related terms

Terms related to *paper produced* stage and *paper consumed* stage are close to each other. There are, however, some differences between terms used. Terms which relate to *paper consumed stage* are *converted products* or *printed products* which have been consumed either by printers,

converters or consumers. For example, terms like *newspaper*, *containerboard* and *boxes* relate to *paper consumed stage* and terms like *newsprint*, *case materials* and *fluting* relate to *paper produced stage*.

It should be noted that the number of different grades of *recovered paper* used by different organizations varies considerably. In most cases these organizations have their own names, abbreviations and codes for individual *recovered paper grades*.

6. Discussion

The findings of this thesis clearly indicate that both the terminological system related to *paper recycling* and the several material frameworks which are presently used are not capable to unequivocally define material flows in paper industry and related terms.

One of the main reasons behind the terminological chaos related to material terms may be that *waste paper* has been understood to be a real material stage, instead of a general term describing loosely some indefinite material between *paper consumption* and *recovered paper collection* stages.

Additional efforts are needed to improve statistical systems to reliably quantify stages and flows which could be used to increase the credibility of the introduced five stage framework. This thesis suggests that a new uniform paper industry material framework should be created. The introduced five stage framework could be used as basis in this development work.
It would facilitate the definition of terms if at least those terms which are defined as ratios between other terms could be expressed with symbols and formulas uniformly. However, at present there is no commonly used system which would define uniformly symbols for different terms related to material recycling.

Many sources have used case specific symbols for selected terms. For example, Berlund and Söderholm (2003) have expressed ratios between terms with symbols and formulas. However, use of these very symbols and formulas cannot be recommended because the terms used are case specific. *Recovery rate* is expressed with formula: *RR = ((WP cons) + (WP ex –WP im)) / (PB*

cons). In this formula *RR = recovery rate, WP cons = waste paper consumption, WP ex = waste paper exports, WP im = waste paper imports and PB cons = paper and board consumption.*

The Japanese PRPC (2012) uses formula to calculate *recovery*:

H = (G + G' – E + F). In the PRPC (2012) formula *H = recovery, G = recovered paper supply, G' = deinked market pulp shipments, E = imports of recovered paper, and F = exports of recovered paper.*

Palmer et al (1997) use the formula:

(W = Q - R) to define *waste.* In Palmer's (1997) formula *Q = total consumption of goods, R = recycled volume* and *W = waste disposed*.

Klimek (2011) also uses formulas to define selected terms:

Utilization rate = D / A, recycling rate without trade = D / B and *recycling rate with trade = C / B.* In Klimek's (2011) formulas *A = paper production, B = paper consumption, C = waste paper collection* and *D = waste paper utilization*.

Barrio (2006) expresses *recycling rate* with the formula:

(B + C) / A. In Barrio's (2006) formula *A = packaging placed on the market, B = material recycling and C = organic recycling and use for other purposes*.

Additionally, CEPI (annual statistics, 2007) defines *utilization rate* with the formula:

(E / G). In this formula *E = total use of recovered paper* and *G = total paper production*.

These examples show that there are great variations both in formulas and symbols used when defining terms. In the future, it is important that different recycling related terms have defined and uniform symbols. This would make it easier for different players of this field to explain what they really mean when using different terms. In this thesis, no list of symbols is suggested with respect

to different terms. Defining symbols should be done together with the development of the terminological system.

However, creation and adaptation of a new terminology would create some problems. If a new terminology were introduced, this would make it difficult to build accurate time series. Collecting and combining data based on both new and old terminology is challenging.

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 (EU, 2008 and ERPA, 2000). At present, this volume is not included in *recycling* volume. There is no reliable data about this volume. Presently, the European Declaration on Paper Recycling (ERPC, 2006; 2011) has changed this definition and simply states that the term *recycling* includes only the *reprocessing of used paper* in a production process into *new paper and board* plus *net trade of recovered paper*. However, this thesis suggests that *other uses of recovered paper outside the paper industry* should be included in the *recycling* volume also in practice, not only in definitions. For example, terms like *recycling* which is not reliably defined, may include or may not include *packages traded together with goods*, *trade of converted paper products* as well as *other uses of recovered paper outside the paper industry*.

The paper industry, especially in Asian countries, has plans to increase *recovered paper-based paper production* considerably (Levlin & Grossmann, 2008). If the typical collection rate is 50% and process material losses per cycle is 20%, only low percentage of fibers will be recycled more than 3 times. The system needs a continuous influx of *virgin fibers* in order to keep the system running (Levlin & Grossmann, 2008). According to CEPI (2013b), paper can in theory be recycled up to six or seven times. The current average number of rounds, according to CEPI in Europe is 3.5. This figure is called *velocity*. *Velocity* means that in a period of time, the same fiber returns for another round of production (Ringman, 2014). *Velocity* is calculated with following formula:

Vt = 1 / (1-0.x); where 0.x = collection rate.

So, if the *collection rate* is for example 50%, the *velocity* value is 2. The opinion of the author of this thesis is that this figure is too optimistic. The formula does not fully take into account all material exits from the loop and material losses in different stages of the recycling chain.

In most countries which have records about *recovered paper use* and *material recycling* the *recovered paper utilization* volume for paper production is usually reliably quantified. However, it is not well known, how much of the *fiber in recovered paper stock* goes back to circulation in the paper production stage after the pulping process. The real fiber volume back to circulation is considerably lower than the utilization rate indicates. Three main reasons for this can be listed:

- moisture of recovered paper is on average 4 to 6 percentage points higher than in paper, to which it is compared with
- the share of unusable materials in recovered paper stock collected from households and sorted in material recovery facilities (MRFs) may vary between 5 to 20 percentage. In recovered paper classification systems like PS-2012, EN 643 and Kirpa Impex the allowed share of unwanted materials and outthrows varies between 1 to 10 percentage units.
- in recycled fiber pulping process, the losses may vary between 15 to 45 percentage. This figure of losses includes materials like rejects, sludge and inks. This high share of losses shown in this context refers to production of graphic papers and tissue papers.

This thesis points out that the existence of some material flows like *trade of packaging materials together with goods*, *recovered paper utilization outside the paper industry*, *trade of converted products* and *real fiber volume back to circulation* have been identified but they have not been quantified. To be able to achieve a clear picture about the level of *fiber recycling*, all identified material flows should also be quantified.

In addition to *paper recycling*, voluntary and compulsory material recycling targets for different materials, such as metals, glass, plastics, and wood, are being set for different regions. This means that there should be a generally accepted, uniform system of definitions of terms in other sectors of recycling than just *paper*. The results of this thesis indicate that a common framework and uniform terminology is necessary and it could be used for other recyclables, too. Different sectors can learn from each other when developing recycling terminology and recycling practices in general.

7. Validity, reliability and generalization

7.1. Validity

The validity of an assessment is the degree to what it measures what it is supposed to measure. Validity means the qualifications of the methodology used in the research (Scandura & Williams, 2000). Validity requires that theory, model and constructs used in the study match with reality. The basic criterion of validity is a rich and strong description about the study phenomenon (Merriam, 1988).

When judging the validity of this thesis, critical issues include selection of data sources, identification of term definitions, analysis methods and conclusions. In this respect, the selection of sources is in order because all of them are experts or organizations which have close relations with the paper industry. It was possible to identify several different paper industry recycling related terms and their definitions. In many cases, the terms were the same but their definitions were considerably different from each other. The validity can be considered to be quite good as the names of the compared terms are the same.

Two types of approach categories were used: descriptive research and document analysis. Listing of terms used, comparison of different frameworks and definitions can be regarded as a suitable means of analysis to fulfill the demands related to the study objective.

A comprehensive review of terms and frameworks which relate to paper industry recycling was conducted. This thesis identified a great number of different terms and several frameworks and their relationships. The traceability of definitions of terms used is provided to the reader.

Furthermore, all sources were carefully cited. Numerous direct citations and definitions of sources were used. This ensures that the subjective influence of the author is minimized. In this thesis the qualitative and quantitative material are connected successfully. Some terms can be demonstrated to be equal to each other by comparing their calculation formulas. For example, if the formula for two different terms is the same, these terms can be assumed to define the same matter.

The grouping of different stages of the analyzed frameworks proved to be successful. After disaggregation of different frameworks they were reconstructed by using their components

according to the selected five stage framework. All the components (terms, stages and material flows) could be grouped according to the selected framework. Some difficulties occurred because the terms used and stages of the analyzed frameworks varied greatly.

7.2. Reliability

Reliability means internal consistency and it measures the amount of error in the measurement of a construct. Measuring the same phenomenon with different variables can increase reliability (Scandura & Williams, 2000). Reliability also relates investigator bias (Yin, 2009). High reliability means that another researcher with same skills would presumably not affect the results and conclusions of the work. It is important to provide a complete, documented trail of what has been done. This is necessary in order to be able to replicate the study if so decided. This means that there is a study protocol and references to data sources. Calculations and comparisons must be transparent so that another researcher can repeat the process in case they want to see if they come up with same kind of results.

According to Kauranen et. al. (1992), one merit of a strong research paper is that the information has been obtained from many different sources; items from different sources have been compared critically; comparisons have also been made with the writer's own results and the comparisons have been made at an international level, whenever possible.

In this thesis, in data collection several relevant sources related to paper recycling were identified. Many of these sources are official and semi-official international or geographical organizations covering more than one country. Data collection had two main purposes: firstly, to identify sources which have used terms related to paper recycling, secondly, to identify frameworks which define paper industry fiber flows.

Data concerning the use of different recycling terms covers even more regions than in the case of the ten frameworks which cover Europe, North America and Japan. Out of the ten identified frameworks, eight of the frameworks define paper recycling-related material flows in Europe. One of the frameworks concerns North American and one framework concerns Japanese paper industry recycling. Even though the main share of the frameworks concentrates on Europe, the collected data can be regarded to represent paper recycling at general level. In addition, Australian, Indian,

South African and Russian sources were also referenced. Additionally, four global organizations, namely Bureau International Recycling (BIR), FAO, International Energy Agency (IEA) and OECD were referred.

Even though the used sources cover different regions and the total world quite well, there is however, a minor negative issue related to this matter: Chinese sources are missing. This is due to the fact that suitable Chinese sources could not be located.

In the analysis phase, the terms identified were listed in tables. This makes it possible for the reader to easily compare different uses of terms by different sources. At the analysis stage, frameworks were compared with each other and a short description of each of the frameworks was made. Additionally, when comparing the frameworks with each other, structures of each of the frameworks were analyzed in detail. All the stages and flows as well as terms used in the frameworks were restructured by using the five stage framework as a basic model. However, the five stage framework, which has been used as a model to represent a general framework in this thesis, may bring some subjectivity to the work. Nevertheless, earlier versions of this model framework have been introduced in literature and in conferences (COST E48, 2010; Ervasti and Kauranen, 2011).

The three above mentioned regions, namely Europe, North America, and Japan form a representative sample about the total global recovered paper collection. The share of Europe was 28%, the share of North America 23% (CEPI, 2013a) and the share of Japan was about 9% (PRPC, 2012) of the total global recovered paper collection in 2011. Accordingly, these regions correspond with 60% of the global recovered paper collection and give a clear global picture about the studied matter.

7.3. Generalization of results

Generalization means how well the results of the specific research are applicable to other contexts. Researchers can increase generalization by using different sources of information instead of using only one source when studying the same phenomenon (Scandura & Williams, 2000). Due to a great number of sources from different regions, it can be assumed that the conclusions of this thesis can be generalized. This is true especially when stating that there is a chaos in defining

different terms. However, most of the cited sources in this thesis cover Europe, and thus the generalization of the results in Europe can be significant. It has to be remembered that some of the terms can be regarded regional. For example, terms *like recycling* and *recycling rate* can be regarded to be European terms, while they are defined in Europe. In other geographical regions, these terms are used in general meaning only to describe material recycling.

Even though this thesis focuses on paper industry material flows, the results of the thesis can, at least partly be applicable to other industry sectors and other recyclable materials, too.

8. Conclusions

The objective of this thesis was to increase understanding of the multiple uses of different terms related to paper industry material recycling. This objective was approached by studying whether it is possible to define univocally terms related to paper recycling.

The study objective was achieved. The thesis increased understanding about the multiple uses of different terms related to paper industry material recycling. A comprehensive review about the use of and definitions of different terms and material flow frameworks related to paper industry material recycling was conducted.

The study hypothesis includes two main steps. Firstly, to show that the terminological system related to paper recycling is in chaos. Secondly, study whether it is possible to give suggestions how to solve the identified chaos in terminology. The results of this thesis indicate that both steps of the hypothesis can be confirmed. There is a chaos in terminology and it is possible to give suggestions about solving the identified chaos.

A comprehensive review of terms and frameworks which relate to paper industry material recycling was conducted. The study findings indicate that paper industry material recycling related terms *recycling* and *recycling rate* are not defined univocally in presently available different definitions. Firstly, there are a great number of different definitions defining the terms *recycling* and *recycling rate*. In this thesis 11 different definitions for *recycling* and 13 different definitions for *recycling rate* were identified. Secondly, none of these definitions took into account all

relevant material flows and stages related to material recycling which were identified when analyzing different paper industry material flow frameworks.

There is no uniform system to univocally define terms related to material recycling in paper industry. Definitions of terms vary depending on author, region and time. The findings of this thesis indicate that the use of terms and their definitions related to material is in chaos.

The findings of this thesis are based on a vast number of sources using recycling terms and ten different frameworks of their own were identified and analyzed. Even though these frameworks try to define the same matter, *paper industry material recycling*, great variations between them occur. At the same time there are several regional terminological systems in use. In addition to this, many authors misleadingly use terms from more than one discipline together with each other without mentioning it in the text. Surprisingly, even the most common terms in the field of paper recycling are generally used without uniform definitions.

Defining the terms *recycling* and *recycling rate* seems to be a European phenomenon. In Europe, these terms have several definitions depending on source. However, in other geographical regions term *recycling* refers to material recycling at a general level only. The term *recycling rate* is not in use outside Europe.

In data collection, special attention was placed on European sources, but also American, Japanese, Australian, Indian, South African and Russian sources were identified and referred.

Most of the analyzed frameworks cover only *total recovered paper*, without dividing this into individual grades. Additionally, only in four out of the ten identified frameworks different stages and material flows were quantified.

An extensive table of terms is presented in this thesis together with the definitions which have been used for these terms in the literature. The terms are listed in an all-inclusive manner. The different definitions provided in the literature can easily be compared with each other.

One reason for the terminological confusion is that earlier no actual difference was made between several terms related to material when it moves in the material chain. The use of the term *waste paper* has also caused confusion. When this term is used to define *recovered paper*, the different

material flows and stages can be quantified. However, if the term *waste paper* relates to waste material, the related material flows cannot be quantified reliably.

In the virgin wood pulp industry, there is a clear difference, for example, between terms like *tree*, *pulp wood*, *wood pulp* and *paper*. In *recycled fiber production* corresponding terms at different stages of the material chain like *paper, waste paper, recovered paper, recycled pulp* and *recycled paper* have not generally been understood to define different materials. Additionally, material related terms like *recovered paper* can be divided into hundreds individual *recovered paper grades*, by using classification systems of different organizations. Globally, these individual grades can be organized into four main groups, according to their technical quality.

A new global, functioning paper industry material flow framework is needed. Only after development of this kind of framework will it be possible to form a clear picture about the global material flows and recycling as well as their effect on regional and global material systems. A global material framework could be used to estimate the amount of needed virgin fiber input into the system globally in long term. Additionally, uniform system to define terms and quantify material flows reliably makes it possible to estimate and forecast paper industry related GHG emissions.

For understanding the multiple uses of different terms related to paper industry material recycling, a new material framework was introduced. This new Ervasti five stage material framework for paper recycling can be used in analyzing the presently utilized frameworks which are used by different organizations and researchers. This new five stage framework includes all those stages and material flows which could be found when analyzing the ten identified frameworks. The identified stages and material flows from the different frameworks were grouped according to the five stage framework stage structure. Even though the introduced five stage framework may not be perfect and it may involve some researcher-related subjective weaknesses, it can be used as the basis for developing a new uniform recycling framework. This framework can be used as a tool to quantify different stages and material flows related to paper industry. For example, by using this framework it is possible to calculate and forecast needed input values of virgin fibers in different countries, regions and also globally with different fiber recycling levels and different paper industry structures.

This thesis gives a contribution to the scientific community by identifying that paper recycling related terminology is in chaos. This thesis gives useful advice to organize this chaos. Additionally, this thesis points out new ideas which should be researched further.

This introduced framework could be used also as a foundation in developing a new terminology related to paper recycling. This thesis shows any terminology and a corresponding and the framework lean on each other.

9. Ideas for future research

This thesis suggests that it is important to have a universal, generally accepted material flow framework and a uniform terminology for paper industry material flows and recycling. For this development, a comprehensive study project is needed. This project should be supported by all stakeholders including industry, trade, authorities, environmental groups, researchers and consumers organizations. During the research process experiences and findings of this thesis can be used to support achieving the set targets of the research process:

- this thesis suggests that there is a research problem and research gap in this area
- now when a research gap has been identified a clear target for the research project should be defined and research design should be created accordingly
- the author of this thesis has concentrated in utilizing desk research sources like articles, definitions, statistics and regulations. It is important that when designing data collection for example for an actual case study also experts' opinions and interviews should be included
- in this thesis the collected data were analyzed only partially. For example when grouping individual recovered paper grades, only European (EN 643, 2002; 2013) grades were analyzed. In the future study process, all corresponding grade definitions of other regions should be analyzed and grouped in order to create a uniform, global recovered paper classification system.

Different stages of the development of a new uniform recycling framework suggested by the author of this thesis are shown in Figure 7.

Objective -> Problem formulation -> Data collection -> Data -analysis -> Findings -> Conclusions

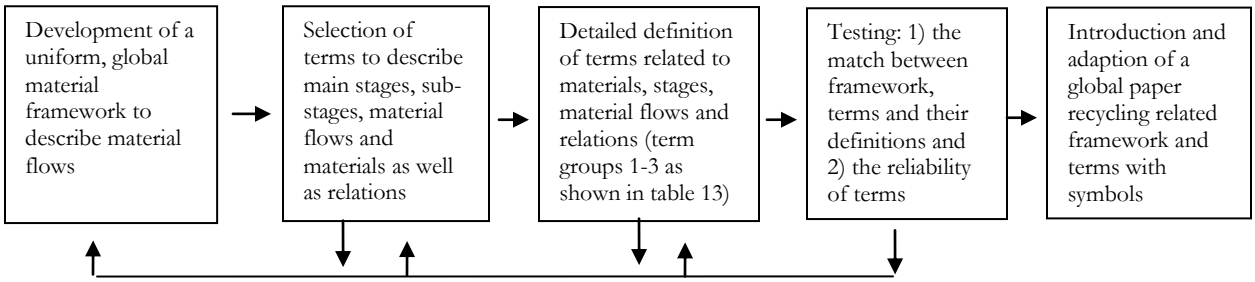

Figure 7. Steps which are essential when developing a new paper industry recycling framework

The introduced stages in developing a new uniform recycling framework loosely follow the general research stages (Churchill, 1987). Comprehension of the Churchill general study steps and the suggested framework development project steps are also presented in Figure 7.

A body of representatives from various stakeholders and geographical regions with in-depth insights into the field should be formed to devise a new and uniform framework for paper recycling and a uniform system for related terms including a list of recovered paper trade grades.

To be able to calculate reliably terms like recycling rate collection rate and utilization rate it is necessary to quantify reliably all of the stages and flows of the material framework. These issues should be studied in the future. Additionally, reliably methods to quantify the use of waste paper and recovered paper for energy production should be developed.

This thesis shows that the moisture contents of material may differ between different stages of the material flow. This has not been taken into account in recycling rate calculations. For accurate recycling rate calculations it is necessary have a reliable picture about the moisture contents of material at different stages of the framework.

Common abbreviations

ACOR	Australian Council of Recyclers
AF&PA	American Forest & Paper Association
ARP	Acceptance of recovered paper
AuRPS	Australian recovered paper specifications (ACOR)
BIR	Bureau International Recycling
CEPI	Confederation of European Paper Industries
CEN	European Committee for Standardization
COST	European Cooperation in Science and Technology. European intergovernmental network for cooperation in research
CTP	Centre Technigue du Papier – France
DIP	De-inked pulp
EC	European Commission
EcoPaperLoop	Eco Design for the Enhancement of Central Europe Paper Based Product Recycling Loop. Project funded by European Union regional development fund
EEA	European Environment Agency
EN 643	European list of standard grades of recovered paper
EPA	Environmental Protection Agency – United States
ERPA	European Recovered Association
ERPC	European Recovered paper Council
EU	European Union
Europe	As a statistical region consists of EU 27 + Norway and Switzerland
Eurostat	The statistical office of the European Union
FAO	Food and Agricultural Organization of the United Nations
FOEX	FOEX Indexes. A private company to provide price indexes
FEFCO	The European Federation of Corrugated Board Manufacturers
Framework	Term used to describe different MFAs and material flow diagrams
GOST	National standards of the Russian Federation and CIS countries
HSE	Health and Safety Executive – the United Kingdom
IEA	International Energy Agency
Ingede	International Association of the Deinking Industry

ISRI	Institute of Scrap Recycling Industries – United States
Kraft	Unbleached (sulphate) wood pulp
LCA	Life Cycle Assessment
MFA	Material flow account
MOW	Mixed office waste
MRF	Material recovery facility
Net trade	Product exports – product imports
OCC	Old corrugated containers
OECD	The Organization for Economic Co-operation and Development
ONP	Old newspapers
OMG	Old magazines
PB, PAB, P&B	Paper and board
Paper	Include paper and board
PPI	Pulp and Paper International - Magazine
PRASA	Paper recycling association of South Africa
PRPC	Paper Recycling Promotion Center - Japan
PTS	Papier Technische Stiftung - Germany
PS – 2009	Guidelines of Paper Stock (ISRI)
QM form	Quality monitoring form
RCF	Recycled fiber
RP, RCP, R.R.	Recovered paper
RR	Recovery rate
SFA	Substance flow analysis
SFS	Finnish standards association
SOW	Sorted office waste
TSK	The Finnish terminology centre
UN	United Nations
UPM	United paper Mills – private forest industry company
UR	Waste paper utilization rate
VDP	Verband Deutscher Papierfabriken e.V.
WP	Waste paper

Note: There are a great number of different abbreviations related to different recovered paper grades. All of these abbreviations are not shown in the above list. These abbreviations include for example following abbreviations: CBS, CGS, CPB, CPO, DLK, DLS, DS, HMP, HWEC, HWS, KGB, MCL, MOW, MWL, MWP, OIN, PFR, R.P., SOP, SWL, SWS, UOP, WBN, GP.

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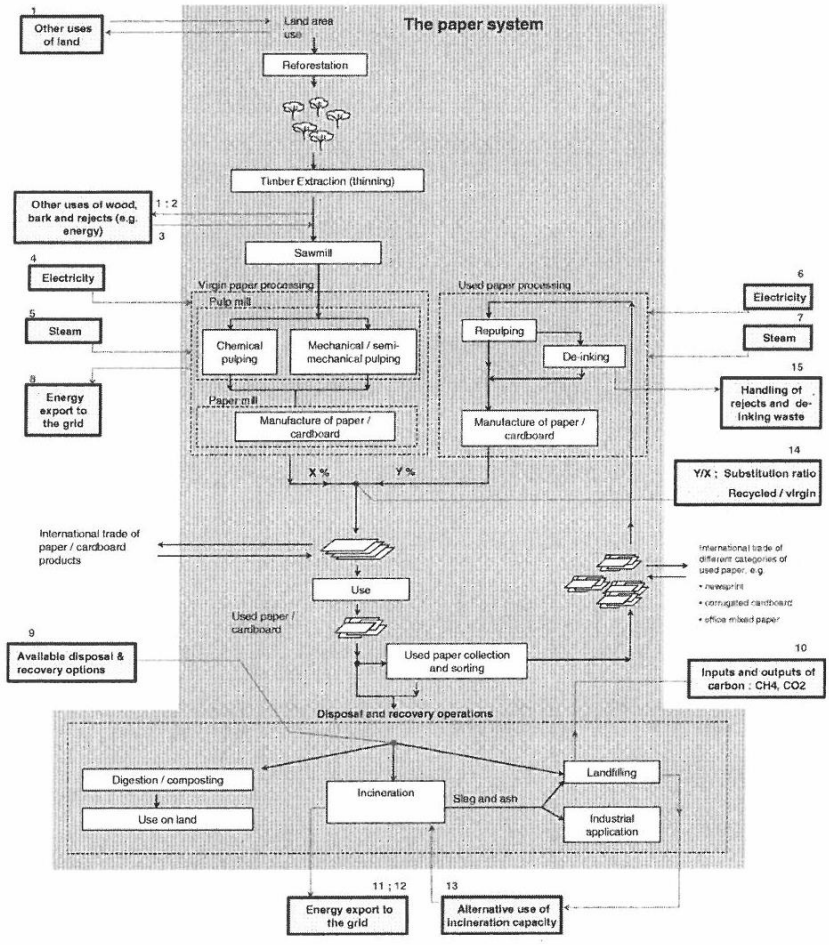
Appendix 1. ERPC, 2013 Framework

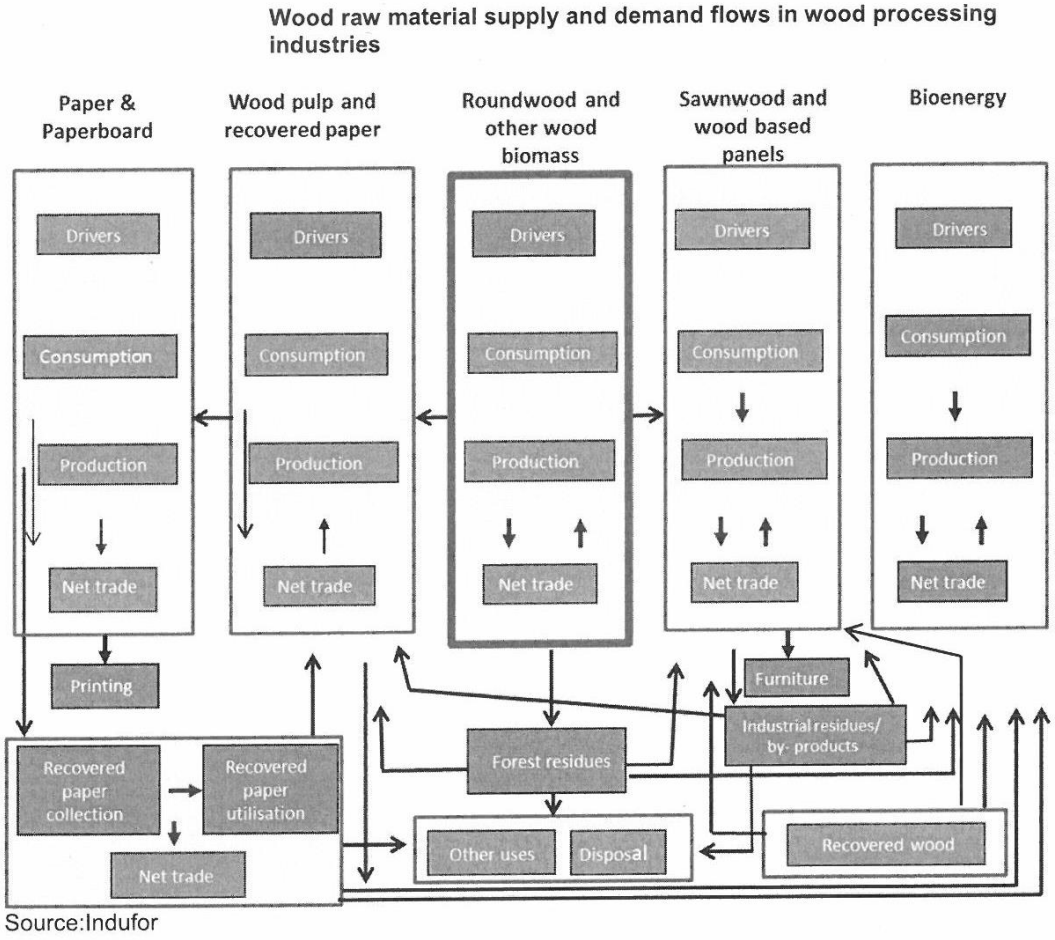
Appendix 2. Villanueva, 2007 Framework

A. Villanueva, H. Wenzel / Waste Management 27 (2007) S29–S46



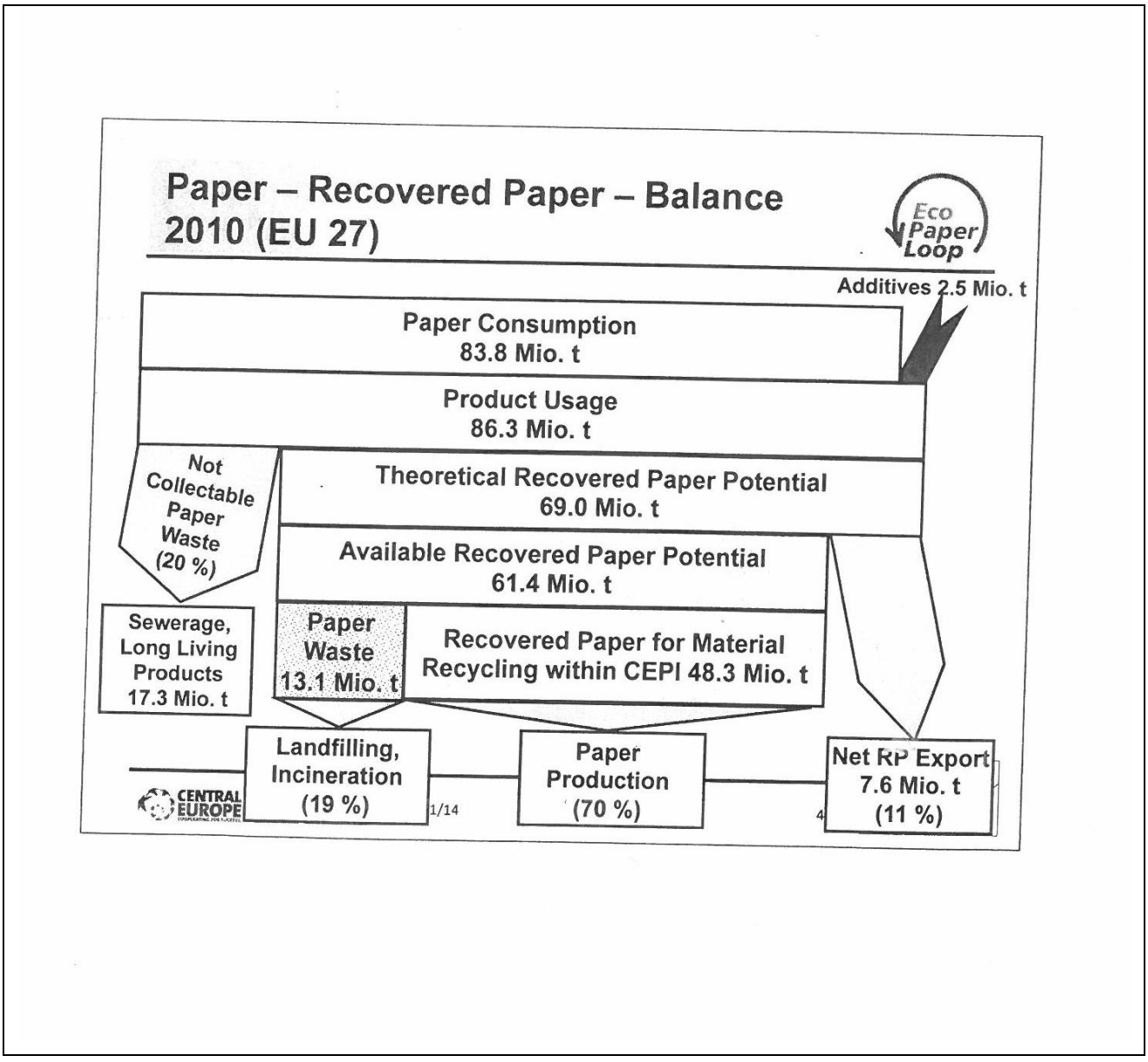
The paper system. The dotted boxes indicate the parts of the paper system that are important to define clearly and justify in a comparative LCA, in order to ensure that the systems defined are fully comparable.

Appendix 3. Indufor, 2013 Framework

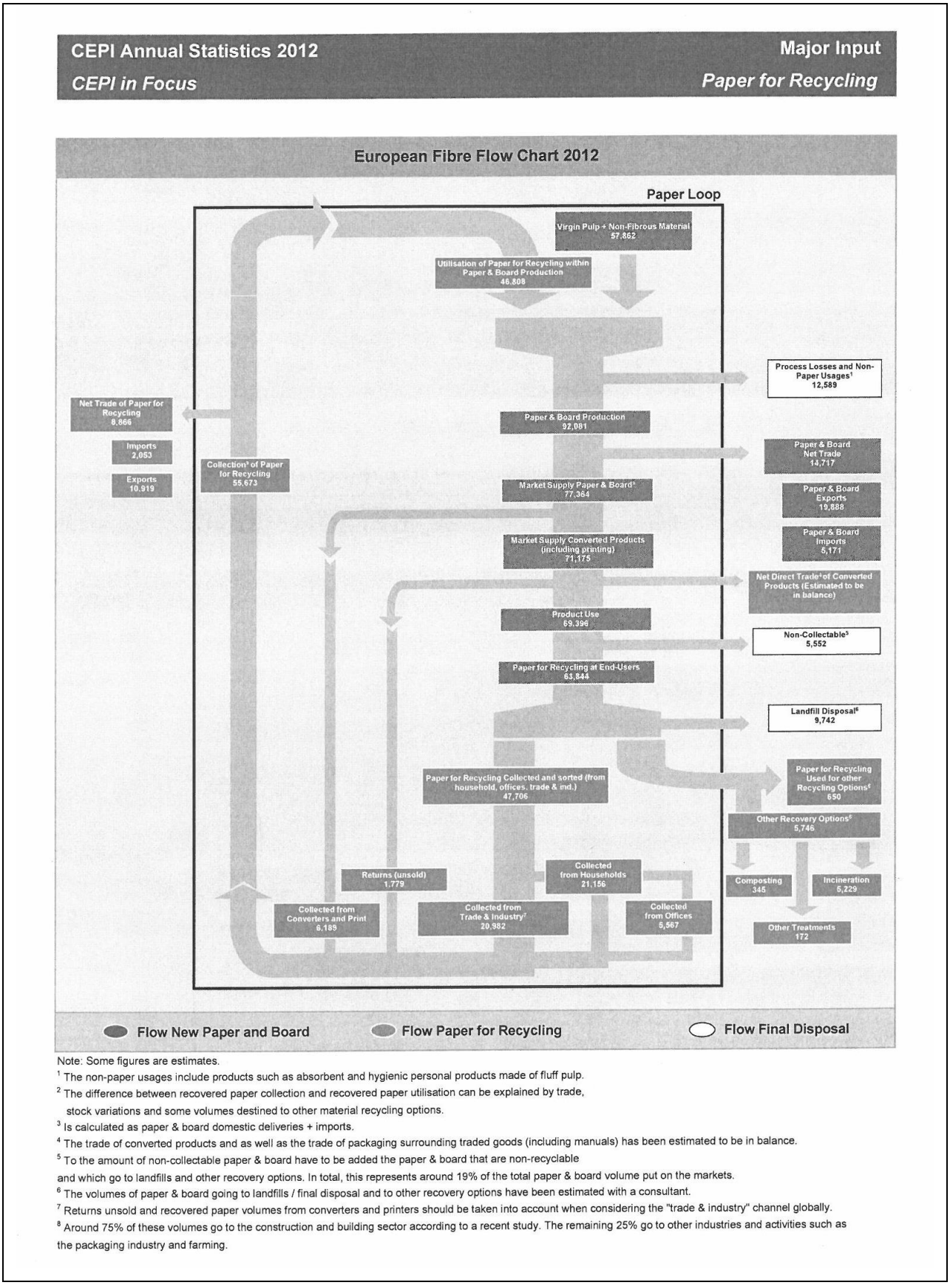


© INDUFOR: A11-04451 STUDY ON THE WOOD RAW MATERIAL SUPPLY AND DEMAND FOR THE EU WOOD-PROCESSING INDUSTRIES (ID 31848), December 4, 2013

Appendix 4. EcoPaperLoop, 2014 Framework



Appendix 5. CEPI, 2013a Framework



Note: Some figures are estimates.

[1] The non-paper usages include products such as absorbent and hygienic personal products made of fluff pulp.

[2] The difference between recovered paper collection and recovered paper utilisation can be explained by trade, stock variations and some volumes destined to other material recycling options.

[3] Is calculated as paper & board domestic deliveries + imports.

[4] The trade of converted products and as well as the trade of packaging surrounding traded goods (including manuals) has been estimated to be in balance.

[5] To the amount of non-collectable paper & board have to be added the paper & board that are non-recyclable and which go to landfills and other recovery options. In total, this represents around 19% of the total paper & board volume put on the markets.

[6] The volumes of paper & board going to landfills / final disposal and to other recovery options have been estimated with a consultant.

[7] Returns unsold and recovered paper volumes from converters and printers should be taken into account when considering the "trade & industry" channel globally.

[8] Around 75% of these volumes go to the construction and building sector according to a recent study. The remaining 25% go to other industries and activities such as the packaging industry and farming.

Appendix 6. CEPI, 2008 Framework

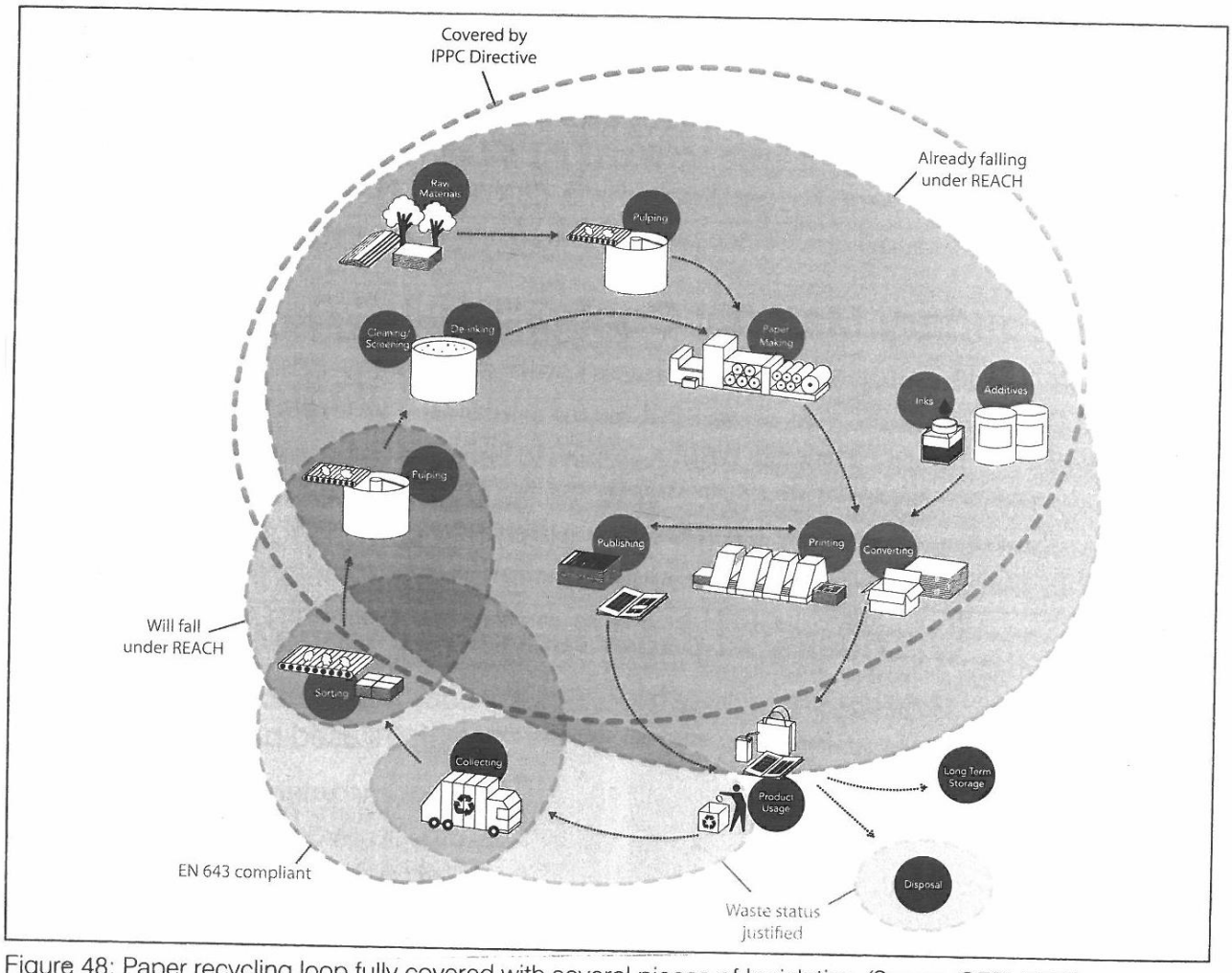


Figure 48: Paper recycling loop fully covered with several pieces of legislation *(Source CEPI 2008)*

Appendix 7. Schmidt et al., 2007 Framework

J.H. Schmidt et al. / Waste Management 27 (2007) 1519–1530

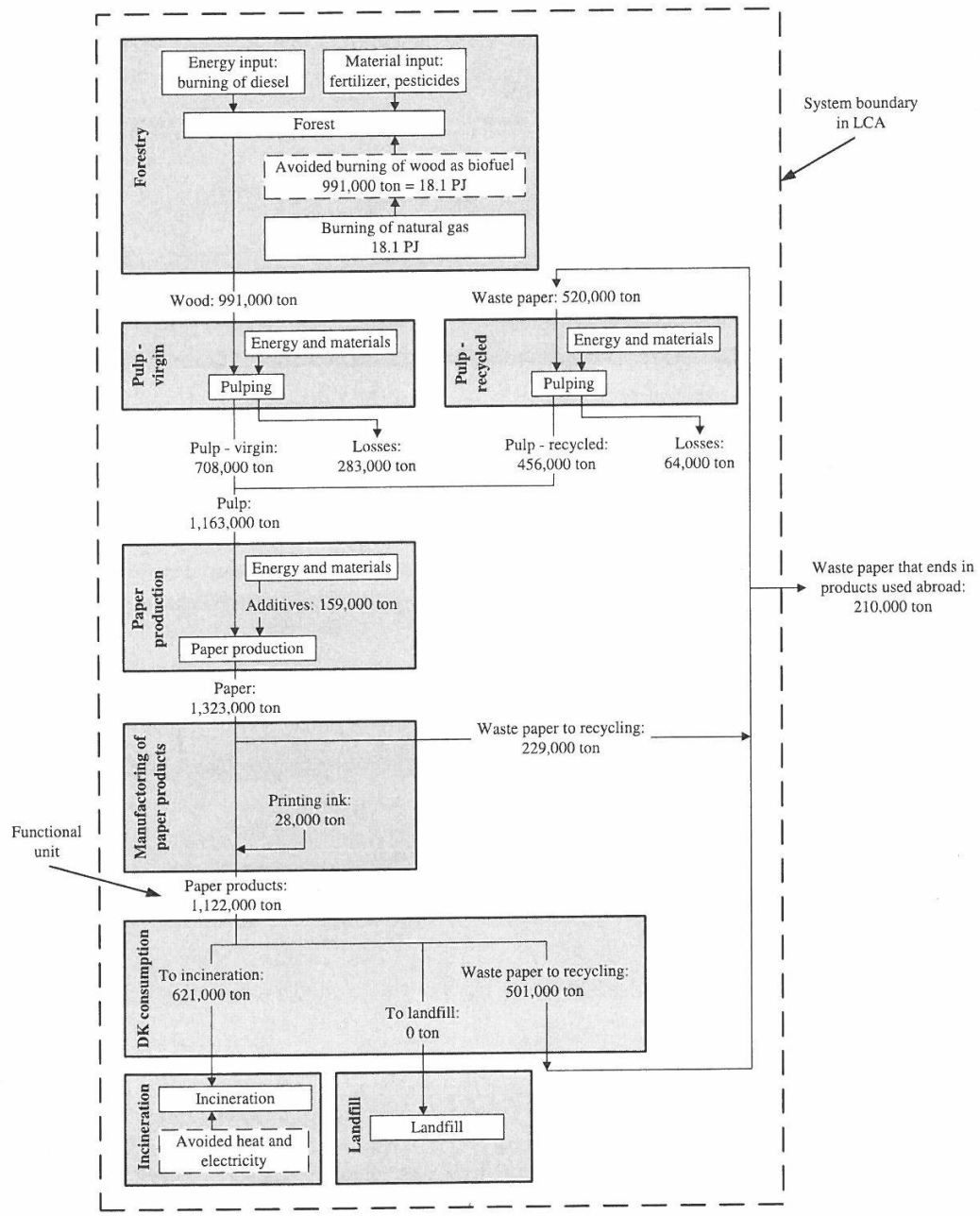
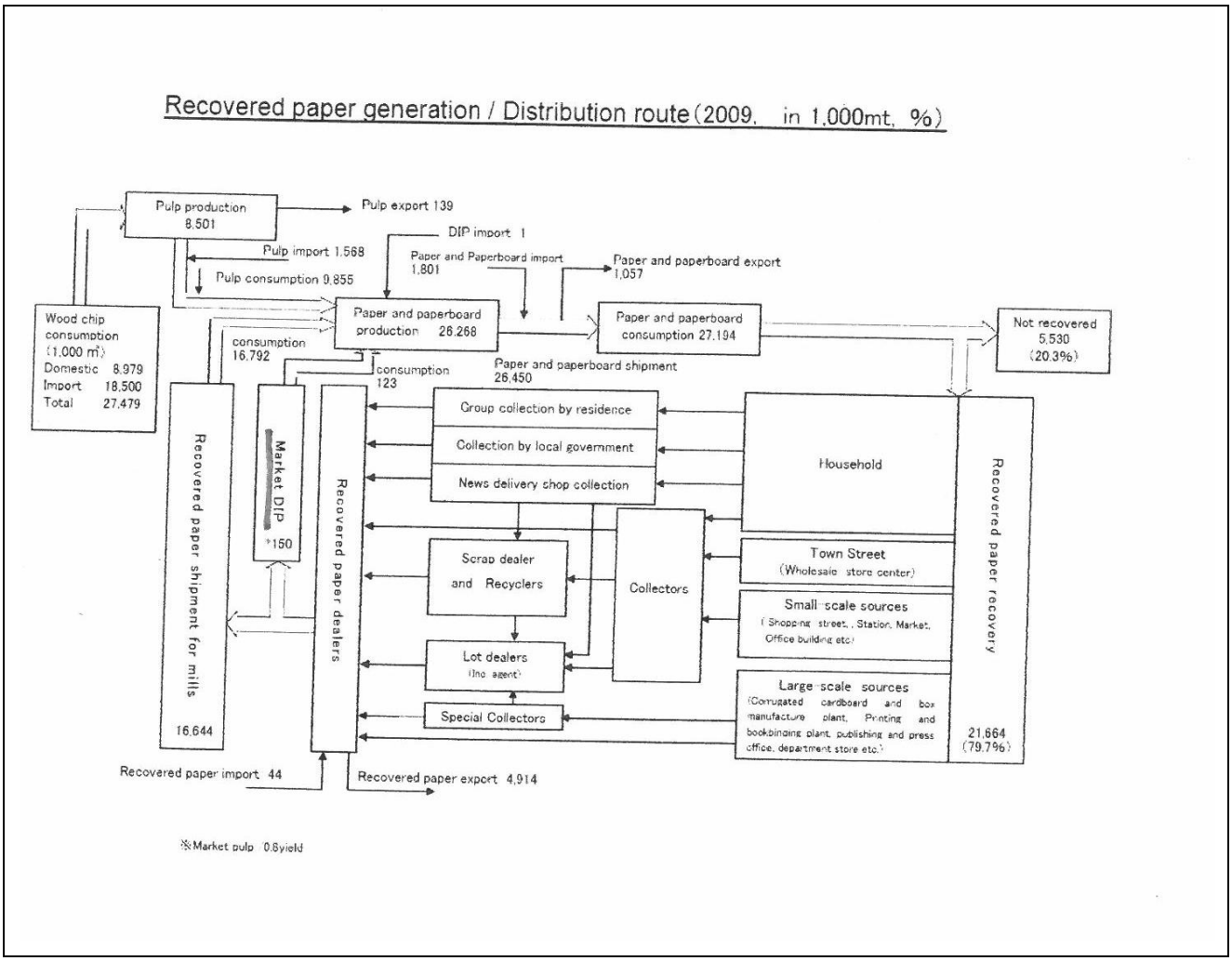


Fig. 1. Illustration of paper flow in product system in 1999 situation related to Danish consumption of paper. System boundaries and functional units are also specified. Grey boxes represent stages in the product life cycle and white boxes represent unit processes for which emission data are inventoried. Dotted white boxes represent avoided processes. All numbers given are in 100% dry solids (DS).

Appendix 8. PRPC (Paper Recycling Promotion Center, Japan), 2010 Framework



Appendix 9. Davidsdottir, 2005 Framework

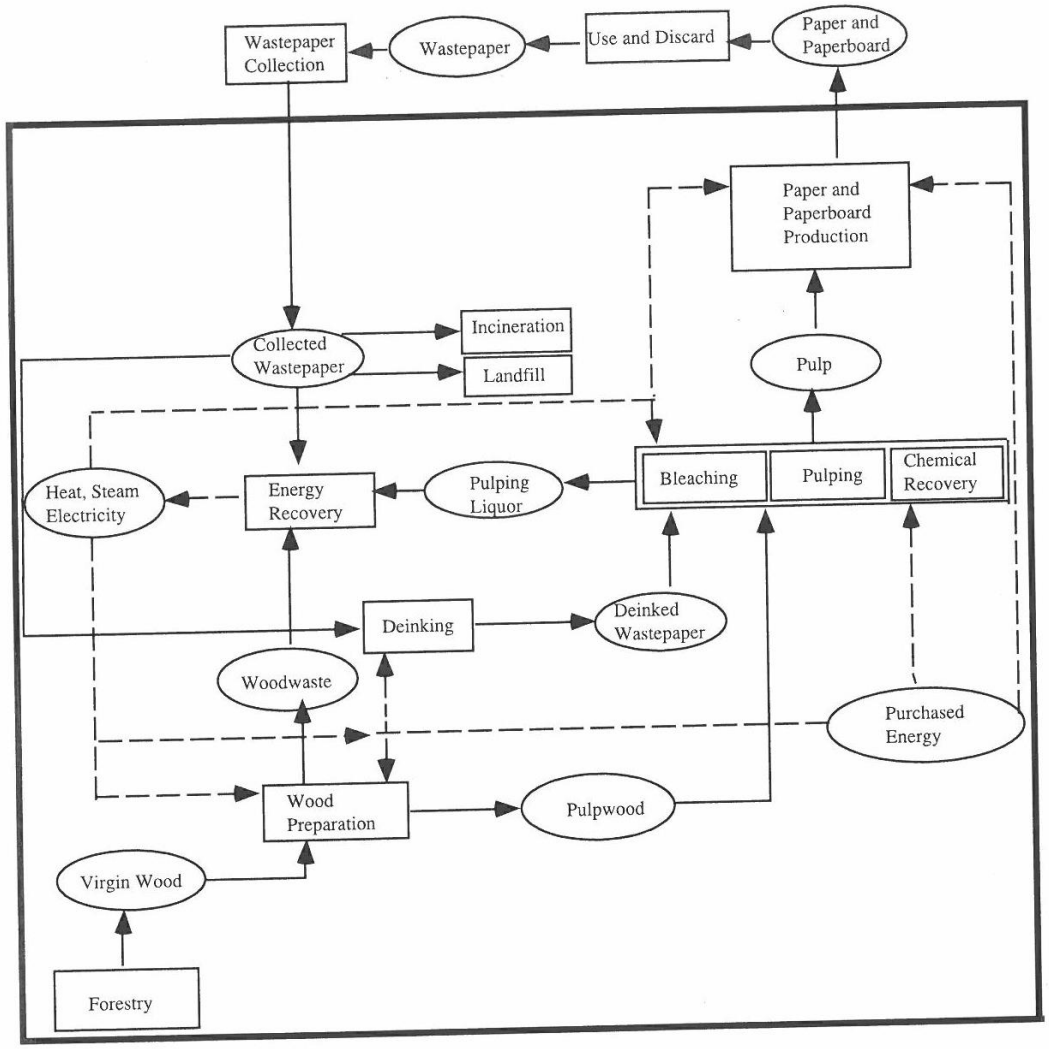
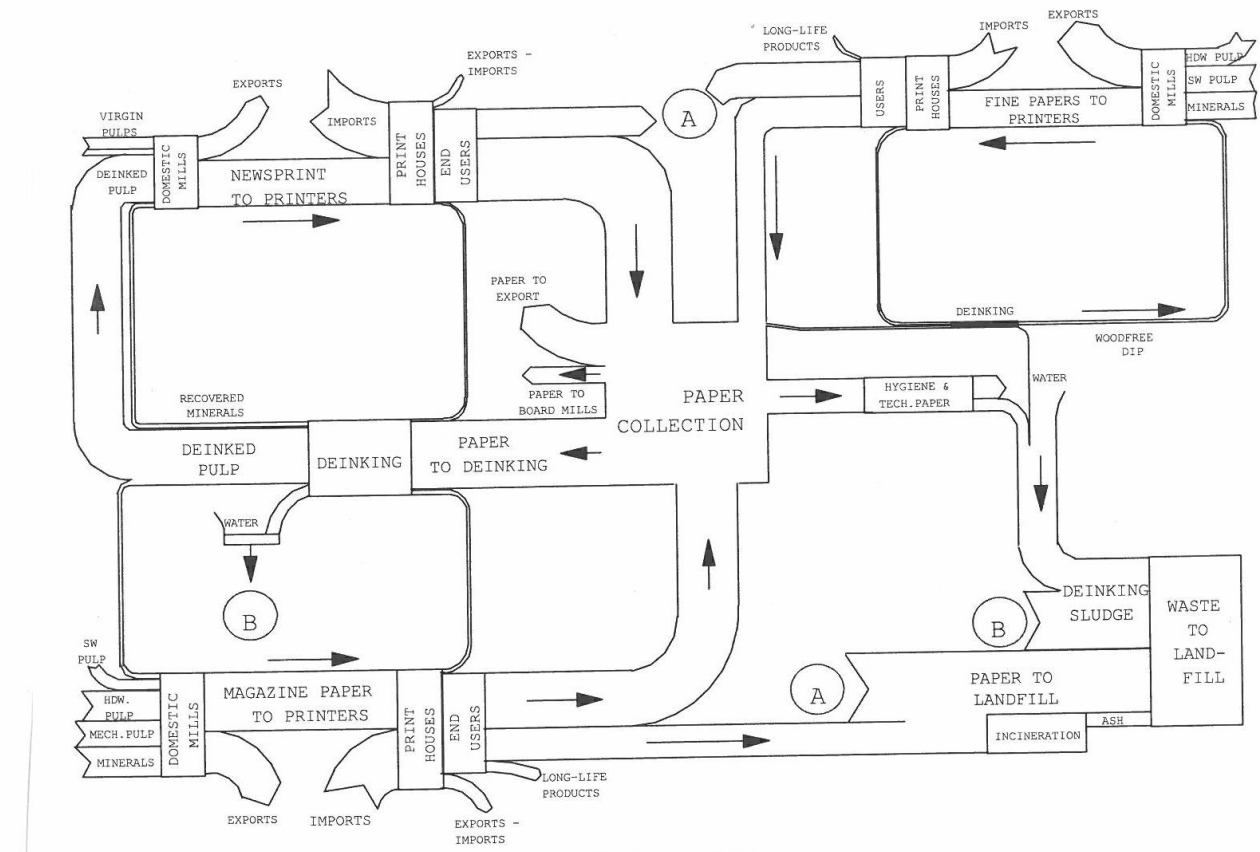


Figure 1 System boundaries for pulp and paper production.

Davidsdottir and Ruth, Regionalized Dynamic Model of the US Pulp and Paper Industry

Appendix 10. Pento, 1994 Framework



Material flows of printing papers in Germany in 1993 (Pento, 1994).