GUIDELINE DOCUMENT:

ECO-DESIGN FOR RECYCLING:

CRITERIA FOR SUSTAINABILITY

DECEMBER 2014

Sustainability Assessment

Contents

1. Introduction

The purpose of this guideline document is to portray how sustainability can be understood in the context of life cycle of paper products like for example graphic products and packaging. This document will primarily focus on the sustainability of end-of-life phase of paper products – especially regarding the stock preparation of the recycling process.

The document comprises of the following parts:

Definitions – where recycling, sustainability and life cycle relevant definitions are presented,

Sustainability assessment – introduction about sustainability, life cycle, life cycle thinking, impact assessment and how it can be understood in paper products context.

Impact assessment of recycling of paper products – description of relevant parameters of recycling depending on the recyclability laboratory results of graphic and packaging paper products and their environmental impacts for the calculation of the end of life phase of LCA.

Sustainability calculator – description of the web based tool that translates the recyclability parameters into specific environmental emissions and carbon footprint score.

2. Definitions

Environmental impact[1] **–** any change to the environment, whether adverse or beneficial, wholly or partially resulting from and organization's activities, products or services.

Deinkability – Removal of ink and/or toner from a printed product to a high extent by means of a deinking process. This shall restore as well as possible the optical properties of the unprinted product.

Recyclability – Design, manufacturing and converting of paper- and board-based products in such a way as to enable a high quality recycling of fibres and minerals in a manufacturing process in compliance – where appropriate – with current standards in the Community: as a minimum, recyclability requires that sufficient information is exchanged for appropriate risk management and safe re-use of fibres.

Recycling parameters – Test parameters measured in the Laboratory test method for the evaluation of deinkability/recyclability of paper products.

Unit process[1] **–** smallest portion of a product system for which data are collected when performing a life cycle assessment

Product system[1] **–** collection of materially and energetically unit processes which perform one or more defined functions

Life Cycle[1] **–** consecutive and interlinked stages of a product system, from raw material acquisition or generation of natural resources to the final disposal

Life Cycle Assessment[1] **–** compilation and evaluation of the inputs, outputs and the potential environmental impact of a product system throughout its life cycle

Life Cycle impact assessment LCIA[1] **–** phase of life cycle assessment aimed at understanding and evaluating the magnitude and significance of the potential environmental impacts of a product system

Impact category – class representing environmental issues of concern into which LCA results may be assigned[1]

Carbon Footprint – the amount of greenhouse gases and specifically carbon dioxide emitted by something (as a person's activities or a product's manufacture and transport) during a given period

Sustainability – The use of resources without jeopardizing the ability of future generation to do so as well - in other words ensuring that today's growth does not jeopardize the growth possibilities of future generations. Sustainable development comprises of three elements – economic, social and environmental - which have to be considered in equal measure at the political level. The strategy for sustainable development, adopted in 2001 and amended in 2005, is complemented inter alia by the principle of integrating environmental concerns with European policies which impact on the environment.

3. Sustainability Assessment: general aspects

[1] ISO 14050:2009 – Environmental management – Vocabulary

Activities of environmental organisations, higher level of society environmental awareness, increasing legal requirements and last but not least the development of knowledge concerning impacts of many products on the environment, have led to the creation of various methods of evaluating the impact of products and services on nature. An example of such successfully industrially implemented method, that is directed at identifying and reducing the negative impacts on the environment, is called *Life Cycle Assessment* (LCA).

LCA allows to track life cycle of the product since its production up to the stage of recovery or disposal of waste, and seems to be a natural extension of both the strategy for waste management and environmental management systems.

The LCA methodology can be used for the assessment of products, selected production processes, services, companies operations and management and even whole economies. LCA allows the assessment of aspects and environmental impacts resulting from all stages of life cycle, including:

- natural resources acquisition and processing,
- manufacturing,
- distribution,
- transportation,
- use,
- re-use,
- recycling and other recovery methods,
- final disposal of waste.

International Standard Organization (ISO) defines LCA as a technique of identifying environmental aspects and potential impacts associated with the product assessment. LCA according to ISO should follow these four steps:

- identification of the purpose and the scope of research,
- inventory of inputs and outputs in the product system,
- potential environmental impacts associated with inputs and outputs of the system assessment,
- interpretation of results.

LCA relates to complex interactions between a product and the environment. Main categories of environmental impacts require taking into consideration human health, usage of natural resources and the quality of the ecosystems.

LCA method, allows to define the methodology of effective resource management, according to both the environmental and economic aspects. It is therefore a powerful tool in developing solutions to reduce consumption of natural resources and energy while maintaining a sufficient supply of goods and services. Additionally LCA can be used to evaluate differences of environmental impacts in used technology and modelled or existing alternatives. Future LCA applications will be integrated with other decision making supporting tools in every situation where environmental issues are important. The availability and scope of information to be assessed in LCA is still growing, which gives the possibility to extend LCA on new products and application areas. Also together with the increasing amount of information that is available about processes, LCA will be more and more precise. LCA can lead to implementation of optimal environmental solutions and elimination of unfavourable processes from the point of view of sustainability.

Potential area of further development of the LCA methodology is an integration of LCA with other environment management methods. Most environment management tools neglect many indirect environmental aspects that can be supplemented with LCA. If we want to develop a LCA method as a tool for quantifying of direct and indirect environmental aspects and potential influence exerted in the whole lifecycle of products, some classification of data collection process is necessary. Another crucial question concerns the development of agreed methodology of data availability. Both methodologies and data are becoming better documented, which proves, that together with the development of ISO norms according LCA standards, future development of LCA method will be even more standardized than before[2,3].

Every single product has a specific impact on the environment, and its life cycle is often long and complicated. For that reason it is important to minimize the environmental impact in all phases of product's life cycle, especially in phases where this impact is greatest, and take action in the most efficient way[4].

Very recently the European Commission has launched an initiative called *Single Market for Green Products* with the objective to simplify and standardize the principles for communicating environmental performance. The new approach establishes two methods to measure environmental performance throughout the lifecycle: the Product Environmental Footprint (PEF) and the Organisation Environmental Footprint (OEF). LCA will be the main instrument used for measurement in these new methods.

When looking specifically at packaging products, life cycle includes the production of feedstock materials, production of packaging materials, production of packaging, packing/filling, packaging use and disposal scenarios. Figure 1 presents typical packaging life cycle in details:

[2] Rebitzer G. et al. ‚*Life cycle assessment, Part 1: Framework, goal and scope definition, inventory analysis, and applications*', Environment International 30. **2004** pp. 701-720.
[3] Pennington D.W. et al., *Life cycle assessment Part 2: Current impact assessment practice*', Environment International 30. **2004** pp. 721-739.
[4] ISO 14040:2006 Environmental management -- Life cycle assessment -- Principles and framework

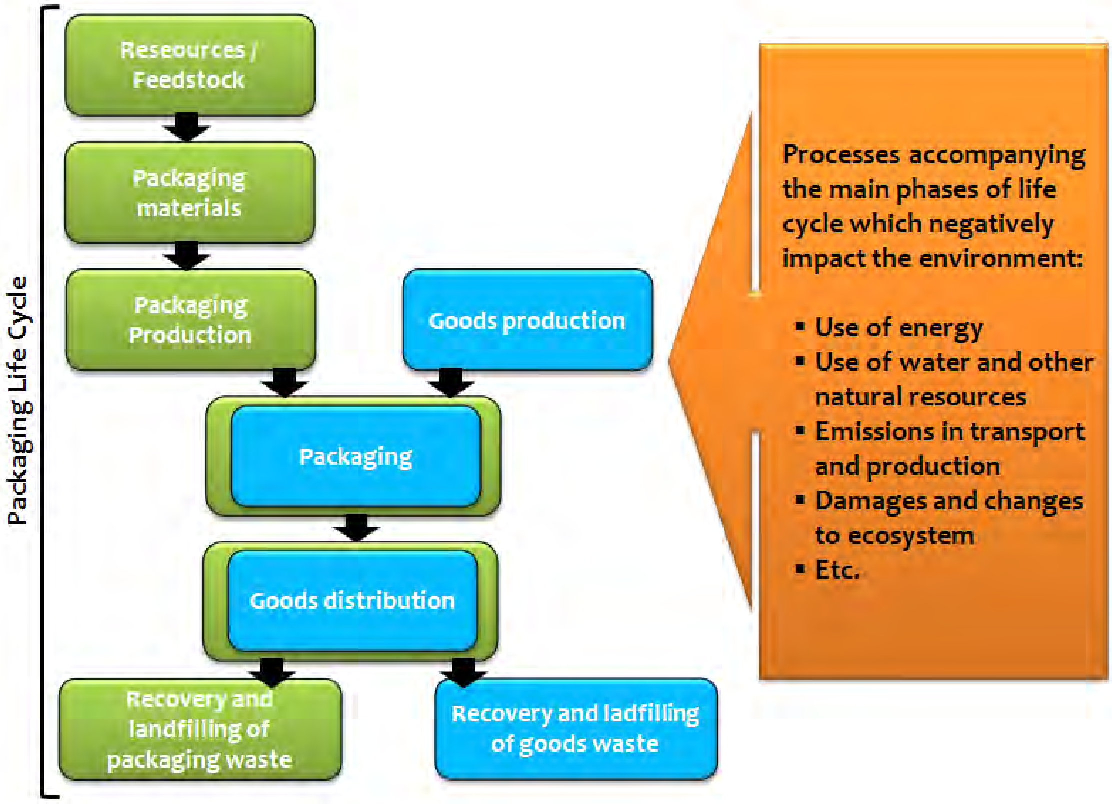

Figure 1: Main phases of life cycle in the example of packaging considering stages when the packaging should be seen together with the goods.

A similar approach should be considered for graphic paper products, taking into consideration all the processes from the pulp feedstock production to the end of life disposal scenario.

Collection of data for LCA of paper products should take into consideration principles set in ISO 14044[5]. It includes procedures for collecting data and calculations leading to the determination of the quantity of materials and energy introduced to the unit processes (input) and leaving the processes (output). These inputs and outputs may include resources use and related emissions to air, water and soil.

Generally, the relevant Impact categories for the life cycle of paper products are the ones connected to the processes of:

- Paper production
- Paper converting
- Paper finishing (printing/varnishing/embossing etc.)
- End-of-life options – paper recycling.

[5] ISO 14044:2006 Environmental management -- Life cycle assessment -- Requirements and guidelines

As an example when using one of the most common calculation method (ReCiPe) among the 18 impact categories addressed , three shall be considered the most important for the analysis of graphic and packaging paper products:

- Agricultural and urban land occupation (in particular for Paper Production process)

The amount of either agricultural land or urban land occupied for a certain time. The unit is m^2*yr.

- Natural land transformation (in particular for Paper Production process)

The amount of natural land transformed and occupied for a certain time. The unit is m^2*yr.

- Fossil fuel and minerals depletion (for all the processes)

Giving the assumption that most of the paper products are recyclable, in the present guidelines special attention is given to the parameters affecting the quality of the new product and their effect on the most relevant impact categories mentioned above. In the paper recycling process, the stock preparation of the pulp is mostly affected by the nature of the converted graphic or packaging product that enter the gate of the recycling process. From this point of view the most relevant impact parameters for the LCA studies are the ones related to energy consumption and waste production. For the graphic products the use of chemicals is also related to the deinking process.

4. Impact assessment of recycling of paper products

Eco-design and manufacturing solutions of paper products affect different parameters of the recycling process for the pulp stock preparation and production of new paper products. This can lead to limitations in the possibility of recycling or different levels and efficiency of the recycling process, affecting the environmental performances of the process itself, for instance in terms of emissions or energy consumptions.

Different approaches for the assessment of the end of life recycling of paper based products can be considered, depending on the goal and scope of the study and on the product system evaluated.

If the scope is mainly the screening impact assessment of different disposal scenarios related to different products - for instance: paper recycling versus incineration, or recycling in different recycling loops, like the effect of downgrading from a higher quality recycling loop to a lower quality recycling loop - the study should assess the possible effect of material recovery in a close loop approach. This happens when a product or a part of the product material can be recycled at the end of life in the same production loop, for producing the same paper grade as the original product. This option enables the reduction of the amount of the new raw material required for the manufacturing of new products, with a general positive effect in most of the impact categories of the LCA.

These important issues where demonstrated in two screening LCA performed in EcoPaperLoop, one study regarding newspapers with different printing solutions and one study regarding packaging paper shoppers with different composition and design solutions. The case studies were chosen as example, because the main scope was to compare the effect of different recycling destinations or disposal scenarios of the products.

The most important evidence of the studies, to be used as general indication, is that from the environmental point of view it is important not only that a paper product is recyclable (instead of a final disposal), but, that it is recyclable within the same recycling loop. This allows for accounting of a possible saving of raw material of a similar grade.

On the other hand, if the scope of the LCA is the assessment of different levels of recyclability in a similar quality recycling loop - for instance: graphic products recyclable in the graphic paper loop but with different levels of deinkability or packaging products recyclable in the same loop but with different recycling results - it is necessary to provide quantitative relations between different levels of recyclability, obtained from laboratory results and related environmental impacts to be used for the calculation of end-of-life phase of the LCA.

This is an innovative aspect that was deeply studied in the EcoPaperLoop project and integrated in the impact assessment methodology for the characterization of the recycling scenario. The approach is similar for graphic paper products and paper packaging, even if different recycling parameters should be taken into account and different environmental parameters are affected.

4.1 Graphic paper products:

Recycling of graphic products is normally performed by using an alkaline flotation deinking process, for the separation of the detached ink particles from the pulp, thus enabling the reuse of fibres for the production of new graphic paper with the proper required optical properties.

Deinking results are affected by different manufacturing features and design solutions of the printed products, e.g. type of paper and inks used, printing technology, post-treatments.

The most significant deinking parameters to be taken into account for the environmental assessment are the **luminosity** and the **dirt speck** content of deinked pulp. These parameters can be assessed for individual products using the standard laboratory method INGEDE Method 11:2012[6].

These two parameters are the most important quality indicators for the deinked pulp, when the desired quality is not achieved, some additional operation in the recycling process are needed, thus increasing the overall environmental impact of the production.

Considering a standard deinking plant, it is assumed that additional operations are needed to achieve the necessary deinked pulp quality when luminosity and/or dirt speck content of deinked pulp do not match the average acceptable range. Conversely, some operations can be avoided when these parameters are better than the acceptable range of results.

If the luminosity of a tested product is lower than the average value for the category, the luminosity should be increased. There are different options depending on specific plants, but generally the most common action is to increase the chemical dosage → high chemicals consumption.

If the luminosity of a tested product is higher than the average value for the category, a possible reduction of the deinking process can be assumed, e.g. a simplification of the flotation loop → less energy consumption.

In the case of dirt speck content higher than the average value for the category, there are different options for decreasing this value depending on specific plants, but generally the actions with their related environmental impacts are:

i) to increase the energy for the dispersion stage → high energy consumption.

ii) to add an additional dispersion stage → high energy consumption

The most important environmental impacts for printed graphic products are the ones related to **chemicals** and **electricity consumption**, which affect the selected impact categories for LCA.

Quantitative variations in the chemicals and electricity consumption with respect to luminosity and dirt speck results were studied in EcoPaperLoop and validated in a LCA study regarding the comparison of different magazines, with different levels of deinkability. The specified values for

[6] INGEDE Method 11 : 2012. Assessment of print product recyclability- Deinkability test.

each parameter are reported in Annex 1: "Graphic paper products, recycling parameters and environmental emissions to be considered for the recycling scenario".

This validated methodology can be integrated and used in the impact assessment of the recycling process of the LCA.

4.2 Packaging paper products:

In the production of packaging using paper for recycling, the stock preparation is normally performed in water without the aid of chemical additives. The main steps are the separation of plastic or metal parts, adhesives and all the other non-paper unwanted components from the pulp, thus enabling the reuse of fibres for the production of new packaging paper with proper quality and mechanical properties.

Recyclability results are affected by different manufacturing features and design solutions of the paper based packaging products, e.g. type of paper used, plastic or foil lamination, surface treatments like coating, varnish or wax application, additives used in the stock preparation, type and amount of adhesives.

The most significant recycling parameters selected for the scope of this study are the **coarse rejects** separated during the cleaning of pulp and the **macrosticky** content of recycled pulp. These parameters can be assessed for individual products using the standard laboratory method EcoPaperLoop Leaflet 1: July 2014.[7].

Coarse rejects and macrosticky content are the most important process and quality indicators for the recycled pulp and if their level is too high, some additional operations in the recycling process are needed and/or more waste is produced, thus increasing the overall environmental impact of the production.

Based on a standard packaging paper technology plant production, it was assumed which additional operations are needed in the stock preparation when coarse rejects and/or sticky results are over the standard average acceptable range or potential avoidable operations when they are lower than the average acceptable values.

Coarse rejects: (i) If the coarse reject CR of a tested product is higher than the average, an additional amount of reject is accounted as waste production to be disposed, (ii) If the measured value for the coarse reject is lower than the average, a minor amount of reject is accounted as recycling waste to be disposed.

High levels of macrostickies in the pulp stock are determined by the presence of high amount of un-soluble adhesive particles below a certain particle size, which are potentially difficult to be separated in standard fine screen units.

[7] EcoPaperLoop Leaflet : July 2014. Recyclability Test for Packaging Products.

In order to decrease the amount of macrostickies, there are few options and generally it can be limited to operations intended to better separate the adhesive particles or disperse them if they have small size:

i) to add more effort in the screening stage → higher electricity consumption in the process.

ii) to add a dispersion step → higher electricity consumption in the process.

If the product has macrostickies lower than the average level, a possible reduction of the energy for the screening and/or dispersion stage can be assumed → less energy consumption.

The most important environmental impacts for packaging products recycling are the ones related to **waste production** and **electricity consumption**, which affect the selected impact categories for LCA.

Quantitative variations in the waste and electricity consumption with respect to coarse reject and macrosticky results were studied in EcoPaperLoop and validated in a LCA study regarding the comparison of different packaging board, with different levels of recyclability. The specified values for each parameters are reported in Annex 2: “Packaging paper products, recycling parameters and environmental emissions to be considered for the recycling scenario”.

This validated methodology can be integrated and used in the impact assessment of the recycling process of the LCA.

5. Sustainability calculator

The validated methodology explained in the previous chapter and the quantitative relations between recycling parameters and environmental impacts, in terms of calculation functions, were implemented in a Sustainability Calculator tool, which is a free calculator software available on the web.

The Sustainability Calculator is intended as a tool for paper and packaging producers, converters, brand-owners and final users of paper and packaging products. The scope is to enhance the environmental sustainability of paper base products, starting from the analysis of the recycling performances.

The Sustainability Calculator enables to quantify the most important environmental indicators related to the recycling behaviour and solutions of paper products. The requested inputs are the deinking and recycling parameters obtained in laboratory tests, according the international test methods previously mentioned. The outputs of the calculator are the values of chemicals and electricity consumption for the standard deinking of the tested graphic product and the values of waste production and electricity consumption for the standard recycling of the tested packaging product.

In addition, the carbon footprint of the deinking/recycling process is calculated, according to IPCC 2013 GWP100 and reported as CO_2 equivalent emission per functional unit of paper products.

Data and results are representative of the average situation of the considered product categories and recycling options, according to the most updated sector and literature information.

GUIDELINE DOCUMENT:
ECO-DESIGN FOR RECYCLING: CRITERIA FOR SUSTAINABILITY

ANNEX 1

Graphic paper products, recycling parameters, and environmental emissions to be considered for the recycling scenario in LCA

In the following tables are reported the most relevant deinking parameters (luminosity and dirt speck content) affecting the quality of deinked pulp and the related environmental emission (chemicals and electricity consumption), for the three most important graphic product categories (newspapers, uncoated magazines and coated magazines).

Table 1. Offset newspapers. Luminosity versus electricity and chemicals.
N1 and N2 are linear functions for the correlation of the luminosity, from the low limit to the average, and chemicals consumption.
N3 is a linear function for the correlation of the luminosity, from the average to the high limit, and electricity consumption.

OFFSET NEWSPAPERS (including Flyers)	Luminosity (Y)				
	Y < 33,5	Low limit: Y = 33,5	Average: Y = 53,0	High limit: Y = 72,5	Y > 72,5
energy consumption, electricity, kWh/kg pulp	Poor deinkable, the most sustainable option is to improve the design of the product	**constant = 0,300**	**0,300 (N3)**	**0,270 (N3)**	**constant = 0,270**
deinking chemicals consumption, g/kg pulp		**13 g/kg NaOH (N1) 40 g/kg silicate (N2)**	**5 g/kg NaOH (N1) 10 g/kg silicate (N2)**	**constant = 5 g/kg NaOH 10 g/kg Silicate**	**constant = 5 g/kg NaOH 10 g/kg Silicate**

Table 2. Uncoated magazines. Luminosity versus electricity and chemicals.
U1 and U2 are linear functions for the correlation of the luminosity, from the low limit to the average, and chemicals consumption.
U3 is a linear function for the correlation of the luminosity, from the average to the high limit, and electricity consumption.

UNCOATED MAGAZINES (including flyers)	Luminosity (Y)				
	Y < 52,0	Low limit: Y = 52,0	Average: Y = 68,0	High limit: Y = 83,0	Y > 83,0
energy consumption, electricity, kWh/kg pulp	Poor deinkable, the most sustainable option is to improve the design of the product	constant = 0,300	0,300 (U3)	0,270 (U3)	constant = 0,270
deinking chemicals consumption, g/kg pulp		13 g/kg NaOH (U1) 40 g/kg silicate (U2)	5 g/kg NaOH (U1) 10 g/kg silicate (U2)	constant = 5 g/kg NaOH 10 g/kg Silicate	constant = 5 g/kg NaOH 10 g/kg Silicate

Table 3. Coated magazines. Luminosity versus electricity and chemicals.
C1 and C2 are linear functions for the correlation of the luminosity, from the low limit to the average, and chemicals consumption.
C3 is a linear function for the correlation of the luminosity, from the average to the high limit, and electricity consumption.

COATED MAGAZINES (including flyers)	Luminosity (Y)				
	Y < 52,0	Low limit: Y = 52,0	Average: Y = 73,5	High limit: Y = 87,0	Y > 87,0
energy consumption, electricity, kWh/kg pulp	Poor deinkable, the most sustainable option is to improve the design of the product	constant = 0,300	0,300 (C3)	0,270 (C3)	constant = 0,270
deinking chemicals consumption, g/kg pulp		13 g/kg NaOH (C1) 40 g/kg silicate (C2)	5 g/kg NaOH (C1) 10 g/kg silicate (C2)	constant = 5 g/kg NaOH 10 g/kg Silicate	constant = 5 g/kg NaOH 10 g/kg Silicate

Table 4. Offset newspapers. Dirt Specks versus electricity and chemicals.
N4 is a linear function for the correlation of the dirt speck content, from the average to the high limit, and electricity consumption.

OFFSET NEWSPAPERS (including Flyers)	Dirt specks (A_{50}), mm^2/m^2			
	Low limit: $A_{50} = 0$	Average: $A_{50} = 630$	High limit: $A_{50} = 3000$	$A_{50} > 3000$
energy consumption, electricity, kWh/kg pulp	constant = 0,300	0,300 (N4)	0,340 (N4)	Poor deinkable, the most sustainable option is to improve the design of the product
deinking chemicals consumption, g/kg pulp	-	-	-	

Table 5. Uncoated magazines. Dirt Specks versus electricity and chemicals.
U4 is a linear function for the correlation of the Dirt Specks content, from the Average to the High Limit, and electricity consumption.

UNCOATED MAGAZINES (including flyers)	Dirt specks (A_{250}), mm^2/m^2			
	Low limit: $A_{50} = 0$	Average: $A_{50} = 190$	High limit: $A_{50} = 1500$	$A_{250} > 1500$
energy consumption, electricity, kWh/kg pulp	constant = 0,300	0,300 (U4)	0,340 (U4)	Poor deinkable, the most sustainable option is to improve the design of the product
deinking chemicals consumption, g/kg pulp	-	-	-	

Table 6. Coated magazines. Dirt specks versus electricity and chemicals.
C4 is a linear function for the correlation of the dirt speck content, from the average to the high limit, and electricity consumption.

COATED MAGAZINES (including flyers)	Dirt specks (A_{250}), mm^2/m^2			
	Low limit: A_{50} = 0	Average: A_{50} = 290	High limit: A_{50} = 2000	A_{250} > 2000
energy consumption, electricity, kWh/kg pulp	constant = 0,300	0,300 (C4)	0,340 (C4)	Poor deinkable, the most sustainable option is to improve the design of the product
deinking chemicals consumption, g/kg pulp	-	-	-	

References:

Definition of the limits and average values for the deinking parameters luminosity and dirt specks:

- INGEDE Database of printed products. INGEDE, International Association of the Deinking Industry.

Definition of chemicals and energy consumption values:

- INGEDE, Information Package Deinking. **2010**.
- Holik H., in Recycled Fiber and Deinking, Papermaking Science and Technology, vol.7. **2000.**
- Holik H. revised by Samuel Schabel, in Recycled Fiber and Deinking, Papermaking Science and Technology, vol.7. **2010**.
- Holik H., Handbook of Paper and Board, Chapter 7 Unit Operations. **2013**.
- Blechschmidt J., Altpapier, Abwasserreinigung und Energienutzung. **2011**.

GUIDELINE DOCUMENT:
ECO-DESIGN FOR RECYCLING: CRITERIA FOR SUSTAINABILITY

ANNEX 2

Packaging paper products, recycling parameters, and environmental emissions to be considered for the recycling scenario in LCA

The following tables report the most relevant recycling parameters (coarse rejects and macrosticky content) affecting the quality of recycled pulp and the related environmental emission (waste production and electricity consumption), for the two most important packaging product categories (corrugated boxes and folding cartons).

Table 1. Corrugated Boxes. Coarse rejects content versus waste production.
CB1 is a linear function for the correlation of the coarse reject value, from the low limit to the high limit, and waste production.

CORRUGATED BOXES	Coarse rejects, CR %			
	Low limit: 0,0	High limit: 20,0	20,0 < CR < 30,0	CR ≥ 30,0
energy consumption, electricity, kWh / kg pulp	-	-	Tolerable recyclability, but needs design improvements and/or process adaptations	Not suitable for use in standard recycling processes, but can possibly be used in specialized processes
waste production kg waste / kg raw material	**0,0 (CB1)**	**0,2 (CB2)**		

Table 2. Folding Cartons. Coarse Rejects content versus waste production.
F1 is a linear function for the correlation of the coarse reject value, from the low limit to the high limit, and waste production.

FOLDING CARTONS	Coarse rejects, CR %			
	Low limit: 0,0	High limit: 20,0	20,0 < CR < 30,0	CR ≥ 30,0
energy consumption, electricity, kWh / kg pulp	-	-	Tolerable recyclability, but needs design improvements and/or process adaptations	Not suitable for use in standard recycling process, but can possibly be used in specialized processes
waste production kg waste / kg raw material	**0,0 (F1)**	**0,2 (F1)**		

Table 3. Corrugated Boxes. Macrosticky content versus electricity consumption.
CB2 is a linear function for the correlation of the macrosticky content, from the low limit to the average, and electricity consumption.
CB3 is a linear function for the correlation of the macrosticky content, from the average to the high limit, and electricity consumption.

CORRUGATED BOXES	Macrostickies <2000, MSA mm^2/kg				
	Low limit: 0	Average: 2600	High limit: 20000	20000 < MSA < 30000	MSA ≥ 30000
energy consumption, electricity, kWh / kg pulp	0,120 (CB2)	(CB2) 0,140 (CB3)	0,220 (CB3)	Tolerable recyclability , but need improved adhesive applications	Not suitable for use in any recycling process as individual product
waste production kg waste / kg raw material	-	-	-		

Table 4. Folding Cartons. Macrosticky content versus electricity consumption.
F2 is a linear function for the correlation of the macrosticky content, from the low limit to the average, and electricity consumption.
F3 is a linear function for the correlation of the macrosticky content, from the average to the high limit, and electricity consumption.

FOLDING CARTONS	Macrostickies <2000, MSA mm^2/kg				
	Low limit: 0	Average: 2400	High limit: 20000	MSA > 20000	MSA ≥ 30000
energy consumption, electricity, kWh / kg pulp	0,120 (F2)	(F2) 0,140 (F3)	0,220 (F3)	Tolerable recyclability , but need improved adhesive applications	Not suitable for use in any recycling process as individual product
waste production kg waste / kg raw material	-	-	-		

References:

Definition of the Limits and Average values for the recycling parameters coarse rejects and macrosticky content:

- EcoPaperLoop, Recyclability Database of packaging products.

Definition of waste production and energy consumption values:

- Holik H., in Recycled Fiber and Deinking, Papermaking Science and Technology, vol.7. **2000.**
- Holik H. revised by Samuel Schabel, in Recycled Fiber and Deinking, Papermaking Science and Technology, vol.7. **2010**.
- Holik H., Handbook of Paper and Board, Chapter 7 Unit Operations. **2013**.
- Blechschmidt J., Altpapier, Abwasserreinigung und Energienutzung. **2011**.