Evaluation of recycling and allocation methods for paper

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SCA
Global Hygiene Category
Environment & Product Safety

Göteborg
April 2014

The Swedish Life Cycle Center report no 2014:1

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0 The work with evaluating the allocation methods

The work to evaluate different allocation methods was undertaken as a project by SCA, who wanted to get at deeper understanding on the effects of these methods. The gained knowledge was used as input to CEPI and the European Commission’s pilot project on Product Footprinting in 2011. Also some direct contacts were taken with the Commision’s LCA experts, who also had the possibility to use the tool developed for the purpose of evaluating the allocation methods.

Further, a workshop at the Swedish Lifecycle Center was held in June 2013. The workshop, which gathered some 15 LCA experts, was highly appreciated as the approach with a complete review and the possibility to test all methods not had been presented before. The participants could here test the allocation methods with input of their own company specific data and for a number of different scenarios.

1 Purpose

Different allocation methods for recycling are documented in various standards and guidance documents for life cycle calculations of products. In this report a majority of these methods have been evaluated. The main purpose of the work has been to understand, compare and evaluate the allocation methods, and to be able to have a position on what method should be preferred for pulp and paper business in different situations (e.g. internal decision making or external communication). The choice of allocation method is important because different methods can lead to different results and conclusions. When these are used as bases for decisions or comparisons it is important with fair judgements without discredits of the alternatives.

2 Introduction

When a specific product system in a life cycle study needs to share some inputs or outputs with another product system, an allocation of the shared processes has to be done. The allocation methods can be either closed loop systems, i.e. the material is used in the same product system, or open loop systems where the material can be used for other products. According to the ISO standards for life cycle assessments, ISO 14040 and ISO 14044, the allocation shall be done according to clearly stated procedures and shall be documented and explained. The recycling of fibers for pulp and papermaking is a typical case for allocation in an open loop system. In such a case the questions are how to share the burdens and benefits respectively of the material production from virgin sources or secondary material and the waste handling including the collection of paper for recycling. Numerous guiding documents exist, both as international standards as well as other global or regional guidelines.

This report documents the findings and conclusions from a project performed to provide an increased knowledge regarding different allocation methods applicable for paper. The driver was to have a common understanding within the Confederation of European Paper Industries (CEPI) on preferred allocation methods for the business and for different possible situations.

During 2011, CEPI participated in a pilot regarding the development of product footprint category rules (PFCR) in the framework of the European Commission's work on product environmental footprinting (PEF). In relation to the PEF, a new allocation method was proposed by EC. This is however only one example of when our industry may be forced to use different allocation methods or to have a position regarding preferred methods.

Table 1 shows the methods selected with the objective to understand, compare and evaluate different allocation methods.

Table 1 Recycling and allocation methods under review

Type of method	Open loop	Closed loop
Attributional	GHG Protocol (Recycled content)	GHG Protocol (closed loop approximation)
	PAS 2050 (Recycled content)	PAS 2050 (closed loop approximation)
	PCR Tissue (Fibre loss compensation)	
	ISO/TS 14067 open loop	ISO/TS 14067 closed loop
	AFNOR BP X30-323 open loop	AFNOR BP X30-323 closed loop
	ILCD for attributional LCA, market value > 0	
	ILCD for attributional LCA, market value < 0	
Consequential	ILCD for consequential LCA	
For all situations	PFCR for paper	
	PEF June 2012	
	PEF April 2013	

The aim was to test the behaviour and mechanisms of the methods using relevant industry data but also to evaluate the applicability of the methods and to assess them against the general ISO recommendations as well as the European Commissions' objectives for recycling methods to use. Advantages and disadvantages of the methods were identified. The main focus was put on the methods proposed by the European Commission in the ILCD handbook and the PEF Guide [1, 2] and on methods relevant for paper products.

An overview of the methods that were reviewed is given in Table 1, and in total 15 methods were included.

3 Methodology

First an inventory of relevant methods was compiled. All recycling methods presented in the various standards or guidelines were then evaluated following a common approach. As a first step, we worked through the methods to have a common understanding within the project group as often the method descriptions were not clear or fully transparent. For all methods, a short written description was compiled.

The formula with the notations used in the reference document was documented. Sometimes, the formula had to be interpreted from text or pictures. A description of all methods is included in Annex I. The methods were translated into the same notation. Table 2 shows the parameters and variables used in common notation for all the methods, when applicable.

Table 2 Parameters and variables in common notation

Variable/ Parameter	Description	Comment
Variables and parameters used in all methods		
E	Total environmental impacts of life cycle under study	
E_V	Environmental impacts of primary material production (virgin pulp)	Could be any impact category, e.g. kg CO_2e/t
E_R	Environmental impacts of secondary material production (pulp from recovered paper)	Could be any impact category, e.g. kg CO_2e/t
E_P	Environmental impacts of papermaking process (paper machine and converting)	Could be any impact category, e.g. kg CO_2e/t
E_W	Environmental impacts of waste handling other than recycling (incineration & landfilling)	Could be any impact category, e.g. kg CO_2e/t
r_1	Proportion of secondary material input	0 % to 100 %
r_2	Proportion of material recycled after use	0 % to 100 %
Variables and parameters used in only some methods		
E_{REOL}	Environmental impacts of average recycling process of sector (pulp from recovered paper)	Could be any impact category, e.g. kg CO_2e/t
E_{CRED}	Credit for energy recovery	Could be any impact category, e.g. kg CO_2e/t
q	Quality degradation between secondary and primary fibres	Only used in some methods
r	Average recycling rate, e.g. national average	Only used in some methods, overrules r_1 and/or r_2
r_{EN}	National energy recovery rate for raw materials	Only used in some methods
f	Fibre loss in deinking process	Only used in some methods

An Excel tool was created that allows the testing of the formulas by entering values for all parameters in table 2, and the results are then calculated for all methods. The tool was reviewed by the Institut für Energie- und Umweltforschung Heidelberg and also sent out to CEPI Environmental Data Management Issue Group members for review. Each method has been tested using a base case with the same data, scenarios and assumptions. The various methods were analysed with respect to their behaviour, e.g. what happens when the recycled content of a product increases, what happens when recycling after use increases. The underlying mechanisms were identified and described.

In the base case, the values shown in Table 3 and representing different parts of the life cycle have been used for modelling (proxy for global warming). The proportion of secondary material input (r_1) and the proportion of material recycled after use (r_2) have been set to 0 %, 50 %, and 100 %, respectively. Nine scenarios were thus modelled in the base case.

Table 3 Values of parameters and variables in the base case

Variable/ Parameter	Description	Value (examples used for calculation, kg CO2e/t)
Variables and parameters used in all methods		
E_V	Environmental impacts of primary material production (virgin pulp)	600
E_R	Environmental impacts of secondary material production (pulp from recovered paper)	300
E_P	Environmental impacts of papermaking process (paper machine and converting)	1500
E_W	Environmental impacts of waste handling other than material recycling (incineration & landfilling)	500
Variables and parameters used in only some methods		

E_{REOL}	Environmental impacts of average recycling process of sector (pulp from recovered paper)	300
E_{CRED}	Credit for energy recovery	20
q	Quality degradation between secondary and primary fibres	50 %
r	Average recycling rate, e.g. national average	70 %
r_{EN}	National energy recovery rate for raw materials	0 %
f	Fibre loss in deinking process	15 %

Sensitivity analyses were performed for a better understanding of mechanisms. This included variations for different values (e.g. the quality factor q was set to 75 % instead of 50 %) but also to test values that represented other types of environmental impacts than global warming.

One part of the evaluation was to analyse the methods based on the European Commission's "point of view" on recycling methods. Based on personal contacts and presentations from EC staff, the method should [3]:

Criteria as expressed by European Commission on recycling methods
Give incentives for use of recycled material
Give incentives for collection for recycling
Show potential difference between products on the shelf

Our basic belief is that the method should steer towards the lowest environmental impact without discredits of other alternatives. Thus, the first two criteria of the EC need to be adjusted with the following;

Industry's criteria for recycling methods
To give incentives for use of recycled material should only be done as long as the recycling process (including collection) has lower impact than the virgin process;
To give incentives for collection for recycling should only be done as long as the recycling process (including collection) has lower impact than the virgin process and the impacts from waste are greater than zero;

Other included criteria to be used for the evaluation are based on our industry's perspective:

- Which values have to be agreed upon?
- What are the opportunities to improve the product life cycle?
- Applicability
- Is re-pulping seen as part of the material production or as part of end of life?
- Are both impacts from virgin production and final waste shared between all life cycles using the fibres (if sharing the burden between life cycles).

4 Results

4.1 Results of the base case scenarios

When calculating the results, we found that many methods are difficult to understand due to unclear descriptions or missing formulas. While we have done our best to interpret those methods, still some results have to be treated with care. The results of the base case scenarios for all methods are shown in Figure 1 and some different patterns can clearly be seen. With the same input data, one can come to different conclusions regarding which option (e.g. high virgin or high recycled content) being the best one from an environmental point of view. However, also similarities can be seen amongst the methods.

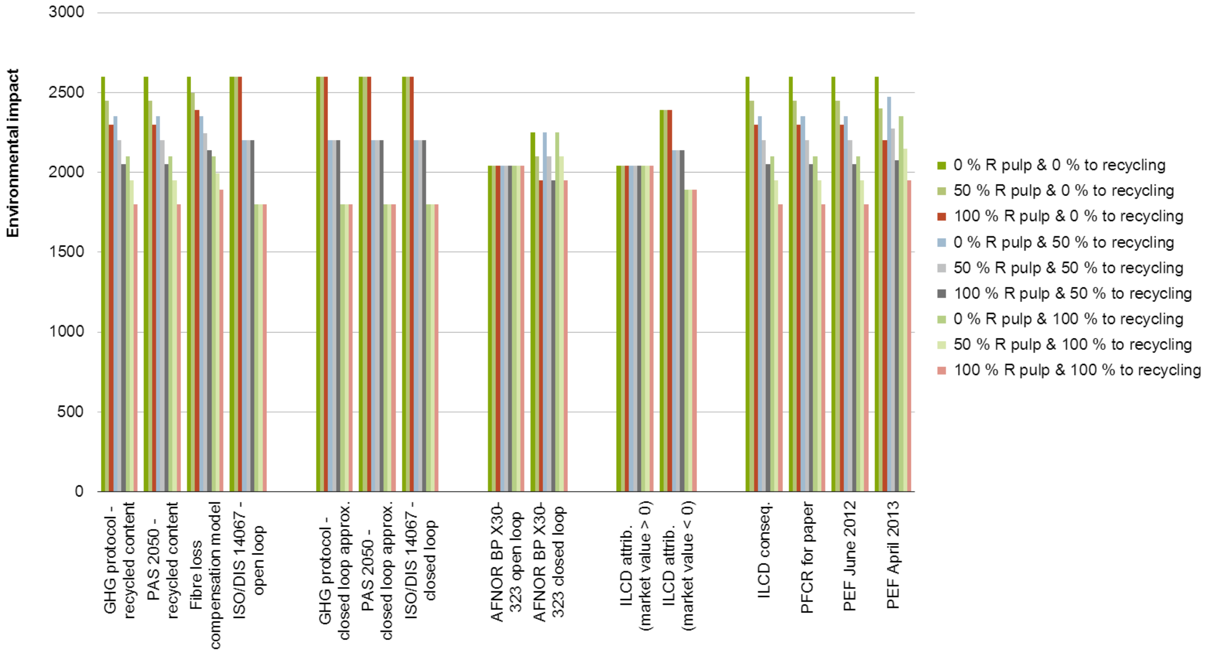

Figure 1 Results for the base case scenarios

In addition to the results overview, we have selected some scenarios of the base case as an example to explain detailed results. Figure 2 shows the result for a scenario where the product is made from 100 % virgin primary material and is not recycled after use. The majority of the methods (e.g. cut-off methods, PCR for tissue, ILCD consequential) show similar results with the full accounting of the virgin production (600), 0 for re-pulping, and 500 for waste.

Some methods also show impacts from re-pulping. This is due to the fact that in those cases the recycled content is overruled by the national average rate of recycling (set to 70 % in the base case scenario). A third group of methods including the BPX 30-323 methods shows lower waste impacts which is due to the fact that r overrules the amount of material recycled after use assuming that this takes place.

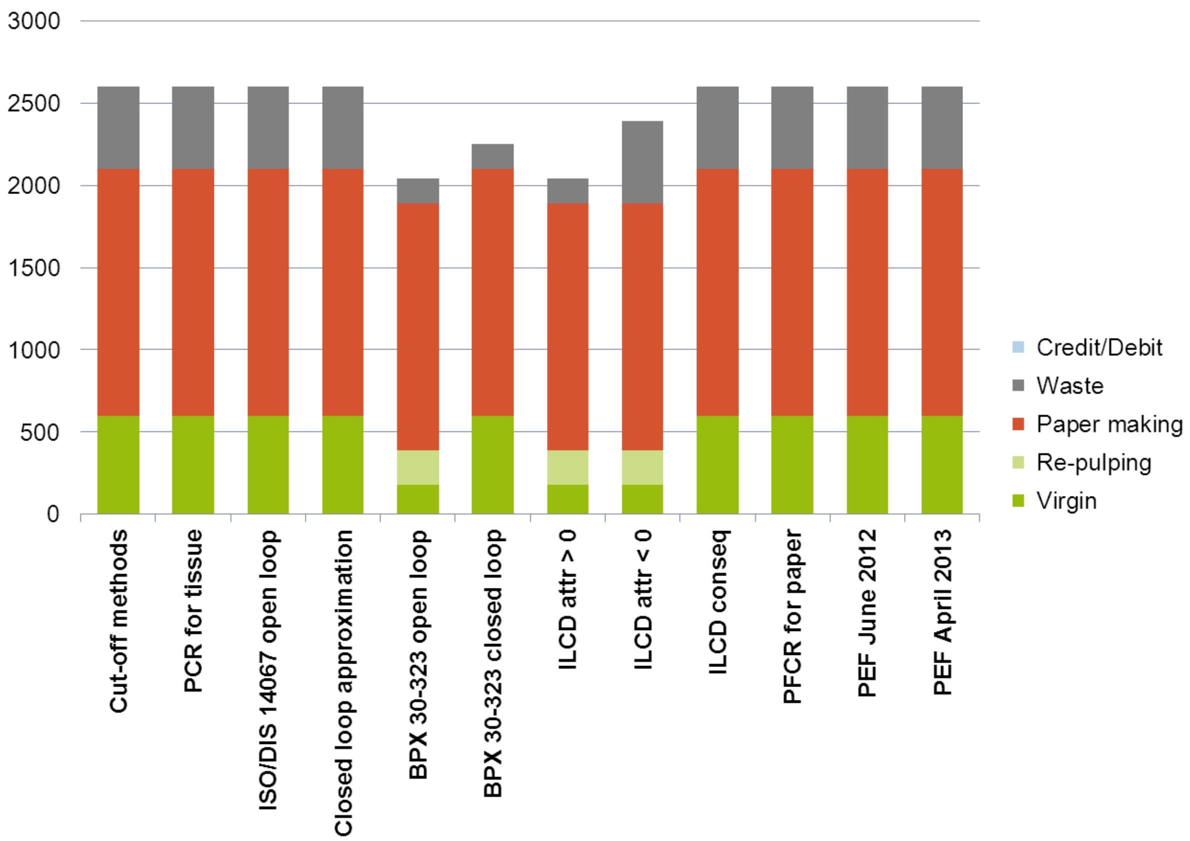

Figure 2 Results for a scenario with 100 % virgin content and 0 % recycling after use

Figure 3 shows the results for a scenario where a product is made from 100 % recycled material and is not recycled after use. As we can see, almost all methods behave differently now. Some of the methods (e.g. cut-off methods, BPX 30-323 closed loop) show no impacts from virgin material production, 300 for re-pulping and 500 for waste. Again, some methods have lower impacts from waste due to r overruling the amount of recycling after use and impacts from virgin production since r overrules the recycled content.

The PEF April 2013 method gives a net credit due to the fact that 50% of the impacts from waste handling are attributed to the previous user of the fibres. This method also has lowest impacts from re-pulping since again only 50 % of the re-pulping are allocated to the product. Interestingly, the ILCD consequential and the PFCR for paper do not account any impacts from raw material acquisition (neither virgin nor re.-pulping) as this is captured in the debit part.

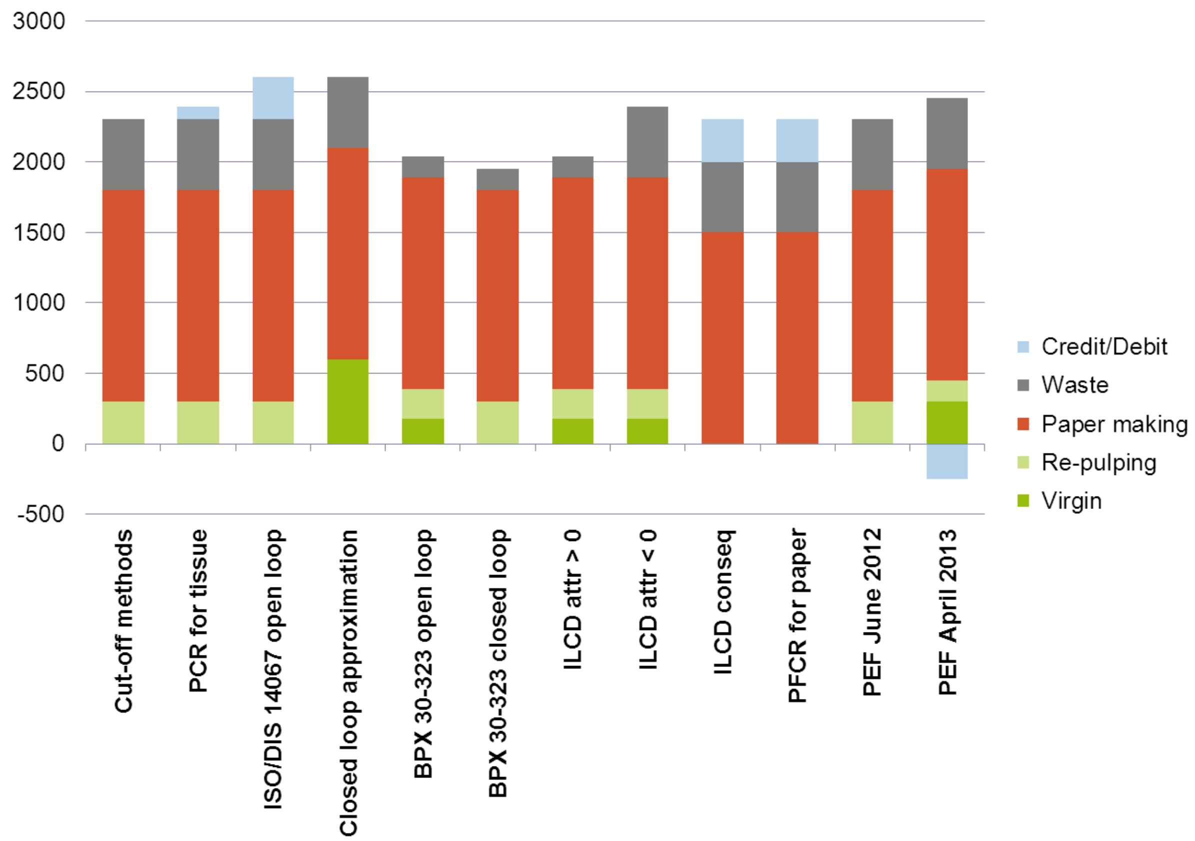

Figure 3 Results for a scenario with 100 % recycled content and 0 % recycling after use

In Figure 4, the results for a scenario with 100 % recycling after use is shown. The product is composed of 50 % virgin and 50 % recycled content. What can be seen is that in most methods, no impacts from waste appear.

In some of the methods as the BPX 30-323 methods there are waste impacts due to the fact that the national average rate of recycling overrules recycling after use. In the PEF April 2013 method, the waste impacts are shared (we have still to carry 50 % although our product is recycled since it will go to waste finally).

In other methods, credits for the substitution of primary virgin material can be seen (e.g. ISO/TS 14067 open loop, ILCD consequential methods). When we look at the raw material acquisition, results vary between 300 and 600. In the case of the BPX 30-323 and the ILCD attributional methods, the use of secondary material is again overruled by the national average rate of recycling.

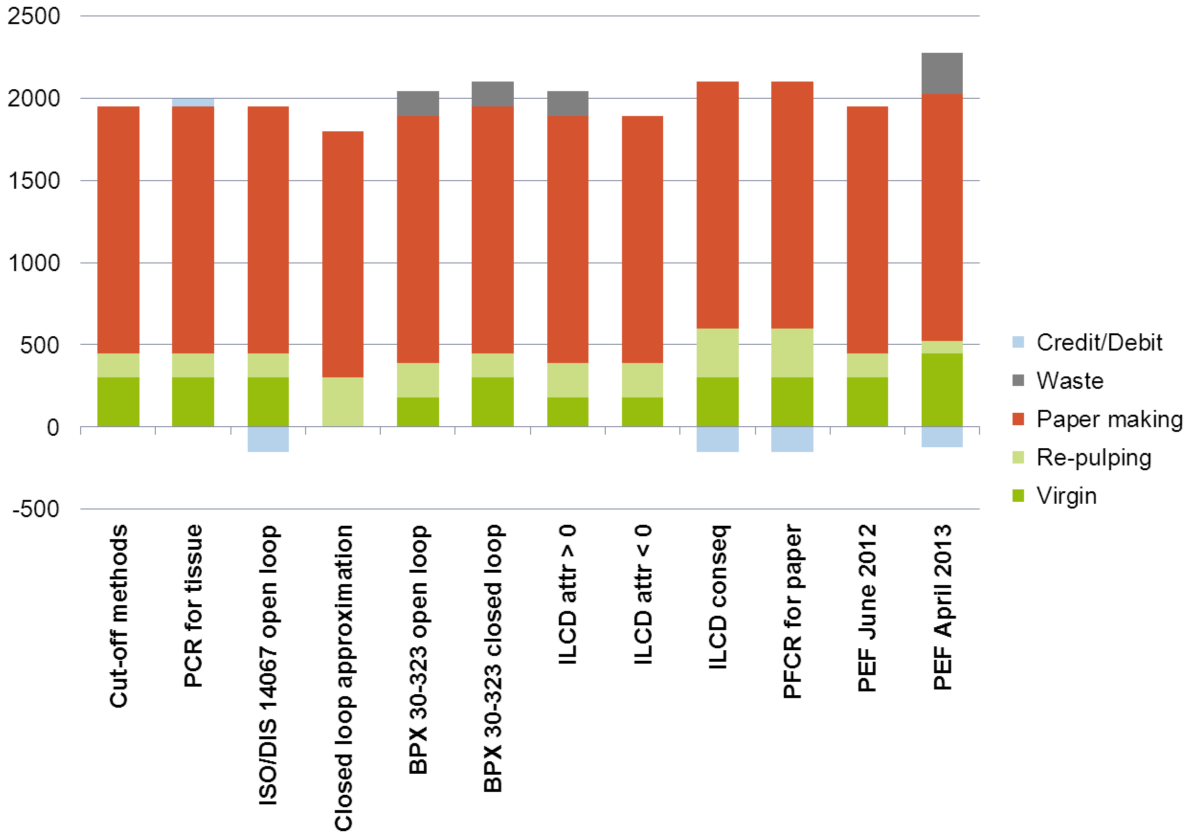

Figure 4 Results for a scenario with 50 % virgin content and 100 % recycling after use

4.2 Sensitivity analyses

Different sensitivity analyses have been performed including:

- Variations of the allocation or quality factor;
- Energy recovery with credit assuming an energy recovery rate of 20%;
- Lower impacts for virgin material than for re-pulping and high credit for waste;
- Values for other impact categories were used, such as land use.

4.3 Evaluation against suggested criteria

The results of the sensitivity analyses have been used together with the results of the base case to evaluate the methods against the suggested criteria (Section 3).

The methods have been evaluated for different factors: one being the behaviour when input parameters change. For example, if the environmental impacts from the use of secondary material (ER) are lower than the impacts from the use of virgin material (EV), there shall be an incentive to have a high value for the share of recycled content. Thus, in Table 4, the second column should have a “Yes” and the second column a “No”. A shading in green colour indicates that the methods behave according to the criteria or that they score well while a red shading indicates a behaviour in contrast to our criteria, i.e. the more green colour there is for a method, the more the actual method is fulfilling the criteria.

Table 4 Evaluation matrix of all recycling methods

Method	Rewards recycled content when ER < EV	Rewards recycled content when ER > EV	Rewards collection when ER < EV and EW > 0	Rewards collection when ER > EV and EW > 0	Show difference on shelf	Values to be agreed	Improvements in company leads to better results	Comments
Cut-off (recycled content)	Yes	No	Yes	Yes (lower impact from waste)	Yes (also differences related to recycled content)	n.a.	E_V, E_R, E_P, E_W, r_1, r_2	Easy to understand, transparent
PCR for tissue	Yes	No	Yes			E_V		
ISO/TS 14067 open loop	Depends on allocation factor	No	Yes			E_V, r_2, a		Strange behaviour, with debit, not easy to understand
Cut-off (closed loop)	No	No	Yes	Yes (when reduced impact from waste > increase from material production)	Limited (only differences in EP show)	E_V, E_R, r2	E_P, E_W	Easy to understand
ISO/TS 14067 closed loop	No	No	Yes					
AFNOR BPX 30-323 open loop	No	No	No	No	Yes (but not differences related to recycled content)	E_{CRED}, r, r_{EN}	E_V, E_R, E_P, E_W	Difficult to understand, is more a closed loop method
AFNOR BPX 30-323 closed loop	No	No	No	No	Yes (also differences related to recycled content)	r	E_V, E_R, E_P, E_W, r_1	Difficult to understand, is more a open loop method
ILCD attributional (m.v. > 0)	No	No	No	No	Yes (but not differences related to recycled content)	E_V, E_R, r	E_V, E_R, E_P, E_W	Not robust against changes in market price which means that the choice of allocation might depend on person and time
ILCD attributional (m.v. < 0)	No	No	Yes	Yes (when reduced impact from waste > increase from material production)		r	E_V, E_R, E_P, E_W, r_2	
ILCD consequential and PFCR for paper	Yes	Yes	Depends on q		Yes (also differences related to recycled content)	E_V, E_R, r_2, q	E_V, E_P, E_W, r_1	Difficult to understand, many values to be agreed upon
PEF June 2012	Yes	No				E_V, E_{REOL}, E_{CRED}, r_2, q	E_V, E_P, E_W, r_1	
PEF April 2013	Yes	No	Yes (if q>0)	Yes (if q>0)		E_V, E_{REOL}, E_W, E_{CRED}, r_2, q	E_V, E_P, E_R, E_W, r_1	

5 Conclusions

5.1 General findings

In many cases, it was difficult to apply the methods in practise as it was difficult to interpret them. Often, no formulas were given and definitions of individual parameters were insufficient. Hence, one main finding of the study is that many methods as described in literature are difficult to understand and not transparent enough.

Another conclusion is that all allocation methods, intentionally or unintentionally, include value choices. Using different methods will in most cases lead to different results on product life cycle level and also to different conclusions regarding possible choices in product development as well as on what life cycle stages that is of importance.

None of the reviewed methods are "perfect" and good to use in all cases. They all have advantages and disadvantages. However, some of the methods seem more suitable than others to use for the paper business in internal decision-making as well as in external communication. We have also identified some factors to be aware of and/or that needs to be clarified when using the different methods.

For many of the suggested methods there is a need of agreement on values to use. Preferably this is done when defining product specific rules such as PCR and PEFCR.

5.2 How to choose?

As described in section 3, all allocation methods have been evaluated against a set of pre-defined criteria, based on the views of the European Commission as well as on criteria from our industry sector.

Evaluation criteria
1. As long as the recycling process (including collection) has lower impact than the virgin process it should give incentives for use of recycled material
2. As long as the recycling process (including collection) has lower impact than the virgin process and the impacts from waste are greater than zero it should give incentives for collection for recycling
3. It should give incentives to improve the product life cycle i.e., • no general data to agree upon for internal processes • re-pulping should be part of the material production, not end-of-life
4. Impacts from virgin production and final waste should be shared between all life cycles using the fibres (if sharing the burden between life cycles).
5. Should show potential difference on shelf

The recycling and allocation methods under review can be grouped based on some common characteristics.

Table 5 shows what methods that are considered to belong in what group. In some cases the same method belongs to more than one of the above identified groups.

Table 5 Grouping of recycling and allocation methods under review

Method	Cut-off methods (Criteria 4 not fulfilled)	Methods using credits / debits to share burden	Methods with "wrong behaviour" (Criteria 1 and/or 2 not fulfilled)	Methods with re-pulping part of end of life (Criteria 3 not fulfilled)	Methods with general data to agree upon (Criteria 3 not fulfilled)
GHG Protocol (Recycled content)	X				
PAS 2050 (Recycled content)	X				
PCR Tissue	X	X			
ISO/TS 14067 open loop		X			
AFNOR BP X30-323 open loop	X		X		X
GHG Protocol (closed loop approx.)	X		X	X	
PAS 2050 (closed loop approx.)	X		X	X	
ISO/TS 14067 closed loop	X		X	X	
AFNOR BP X30-323 closed loop	X	X	X		X
ILCD for attrib. LCA, m.v. > 0		X	X		X
ILCD for attrib. LCA, m.v. < 0		X	X		X
ILCD for consequential LCA		X	(X)		
PFCR for paper		X	(X)		
PEF June 2012		X	(X)		
PEF April 2013		X[1)]			

1) Also waste burdens shared

5.3 Methods to be avoided

From our point of view the following methods should be clearly avoided:

- BPX 30-323 open loop & closed loop;
- GHG Protocol & PAS 2050 closed loop approximation;
- ISO/TS 14067 closed loop;
- ILCD attributional methods.

The reason for excluding methods where recycling is seen to be part of end of life is that improvements in the re-pulping process under our own control will not show up. The closed loop methods also only give incentives for increasing the collection rate and not for increasing the recycled content. We would like the methods we use to encourage recycled content as long as the recycling process has lower impact than a virgin process.

Methods using a lot of generic values give no or low incentives for improvement and will also show no or too little difference on shelf. Own improvements will not be visible in the results.

5.4 Preferred methods

Based on our point of view the following methods should be preferred:

- GHG Protocol & PAS 2050 open loop (recycled content);
- ISO/TS 14067 open loop;

- PEF method April 2013.

From our perspective the cut-off methods with open loop approach would be the first choice to use. They are easy to apply, easy to understand and seem to give enough incentives both for collection to recycling and to increase recycled content (as long as the recycling process has lower impact than the virgin process). The downside with the cut-off methods is that normally no sharing of burdens between life cycles is done. Virgin production and waste is not shared at all between the life cycles.

Concerning the ISO/TS 14067 open loop method, a strange behaviour could be observed as the allocation factor seems to work counterproductive which has to be carefully checked.

The main reason for having methods that share burdens between life cycles as second choice only are mainly that using credits and debits gives a greater complexity. This means a higher dependence on generic data, less parts of internal improvements showing up in results but also that it is more difficult to understand and predict the outcome when using such methods. When using methods including credits and debits special attention needs to be paid to choice of allocation and also to the choice of generic data when needed. Methods like the PEF method April 2013 which shares not only the burdens from virgin production but also from waste should be preferred in this case.

Annex

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Annex A Description of the individual methods

A.1 Attributional methods

A.1.1 GHG Protocol (recycled content)

Method description

The method proposed in the GHG protocol is a strict attributional cut-off method which means that only the life-cycle of the product is included. Each life cycle carries the impact that occurs within its life cycle. The method is recommended to be used in open loop situations that include recycled material inputs and outputs. The repulping process is seen as part of material acquisition: “The recycled content method allocates the recycling process emissions and removals to the life cycle that uses the recycled material” [4, p.73].

No credits for recycling after use are allowed: “The recycled content method does not include attributable processes due to recovered material output” [4]. No debit for using recycled fibres is given. No formula is given in the description, but only a figure is given to describe the principle. Equation 1 shows the formula from the interpretation of the document written in common notation.

Equation 1

$$E = (1 - r_1) * E_V + r_1 * E_R + E_P + (1 - r_2) * E_W$$

The system boundaries of the GHG Protocol (recycled content) method are shown in Figure 5. Again, the strict attributional cut-off method can be seen.

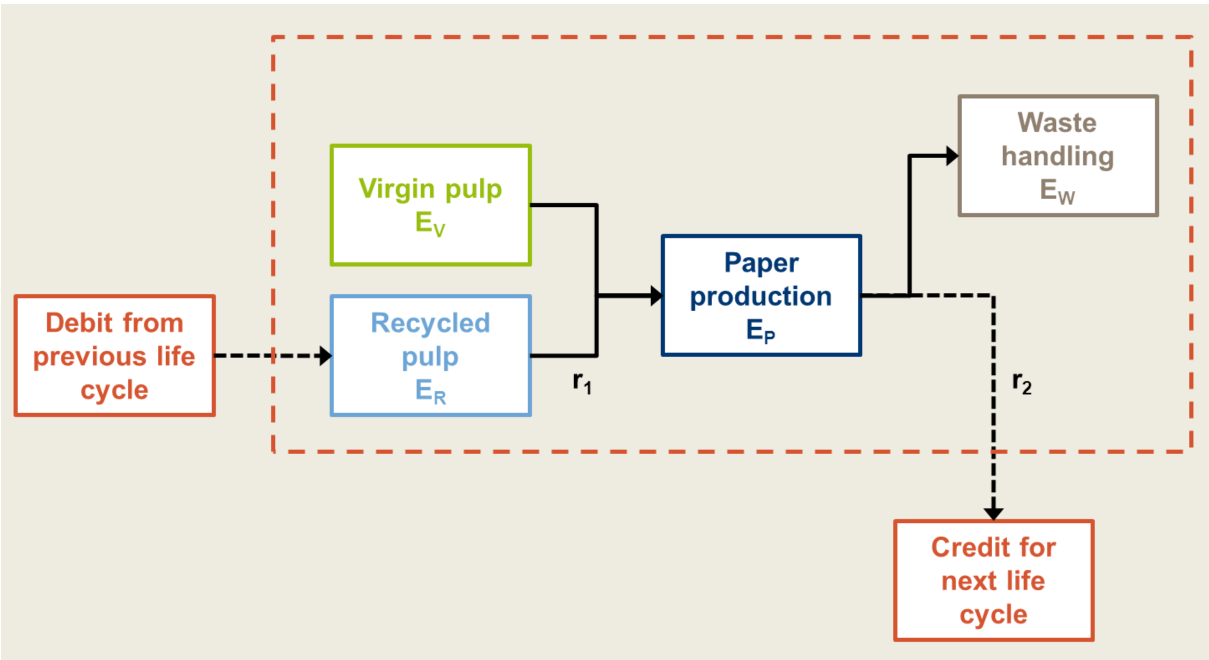

Figure 5 System boundaries for the GHG Protocol (recycled content) method

Results & findings

In the base case, when the ER is smaller than EV, the environmental burdens decrease when more secondary material is used in the product (Table 6). Recycling after use is preferable as the emissions from waste are avoided (if E_W is greater than zero).

Table 6 GHG Protocol (recycled content) results for the base case scenarios

Scenario	r1	r2	Virgin material	Recycled material	Paper making	Waste	Debit	Credit	Total
1	0 %	0 %	600	0	1500	500	n.a.	n.a.	2600
2	50 %	0 %	300	150	1500	500	n.a.	n.a.	2450
3	100 %	0 %	0	300	1500	500	n.a.	n.a.	2300
4	0 %	50 %	600	0	1500	250	n.a.	n.a.	2350
5	50 %	50 %	300	150	1500	250	n.a.	n.a.	2200
6	100 %	50 %	0	300	1500	250	n.a.	n.a.	2050
7	0 %	100 %	600	0	1500	0	n.a.	n.a.	2100
8	50 %	100 %	300	150	1500	0	n.a.	n.a.	1950
9	100 %	100 %	0	300	1500	0	n.a.	n.a.	1800

In general, the method is transparent and allows using primary data. No agreement on values for credits, debits, or recycling rate, is needed. The method is transparent and easy to understand. No double counting occurs.

A.1.2 PAS 2050 (recycled content)

The method that is described in the PAS 2050 is exactly the same as the GHG Protocol (recycled content) method [5] but the PAS document includes a formula in the description.

A.1.1 PCR for tissue (fibre loss compensation)

Method description

The method included in the PCR for tissue is based on a cut-off method [6]. The only difference is that a compensation for fibre losses in the de-inking process (in the case of recycled fibres) shall be given: “an additional process shall be added for compensating for actual fibre loss in de-inking process”.

The general rules in the EPD system do not allow for credits and debits. No formula is given in the description. Equation 2 shows the formula from the interpretation of the document written in common notation. In addition to the parameters shown in Section 0, a parameter for fibre loss f has to be included, giving the percentage of fibre loss in the de-inking process.

Equation 2

$$E = (1-r)*E_V + r_1*E_R + E_P + (1-r_2)*E_W + r_1*f*E_V$$

The system boundaries of the PCR for tissue (fibre loss compensation) method are shown in Figure 6. Both credits and debits are not included. The additional process for compensating fibre loss, however, has to be included.

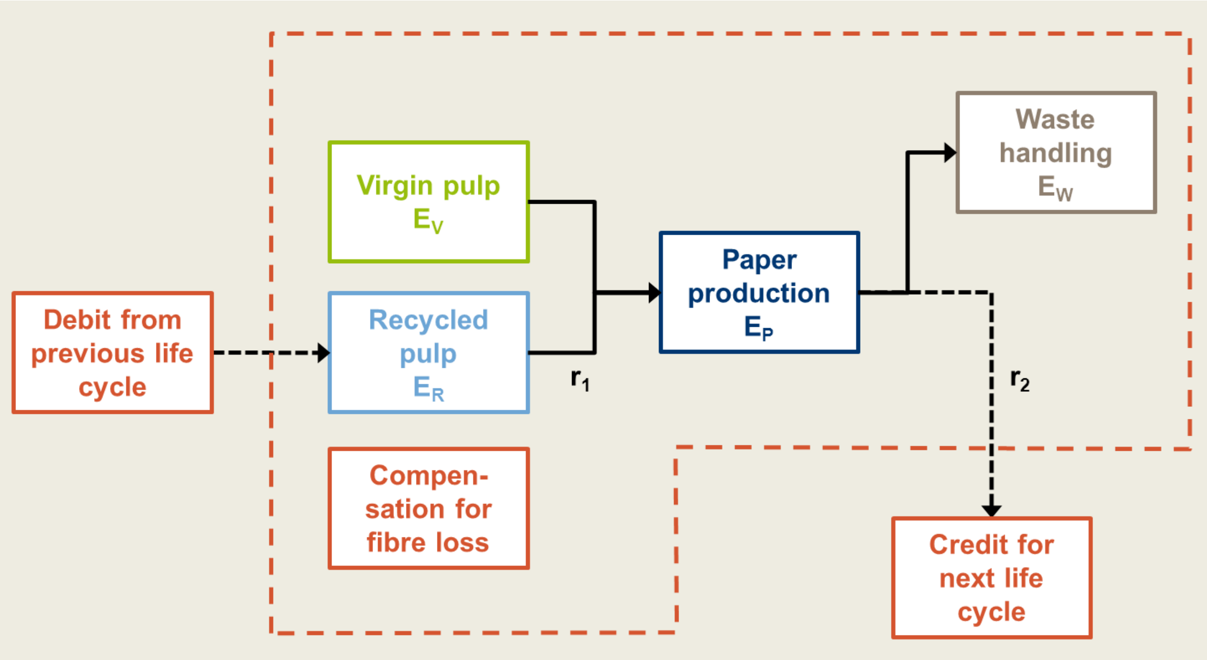

Figure 6 **System boundaries for the PCR for tissue (fibre loss compensation) method**

Results & findings

Results are similar to the cut-off methods. In the base case, when the ER is smaller than EV, the environmental burdens decrease when more secondary material is used (Table 7). Recycling after use is preferable as the emissions from waste are avoided (if E_W is greater than zero). The debit that occurs is very small as the fibre loss was set to 5 % in this example.

In this method, primary data shall be used. For the fibre loss compensation, values for E_V have to be defined. The method is transparent and easy to understand. No double counting occurs.

Table 7 **PCR for tissue (fibre loss compensation) results for the base case scenarios**

Scenario	r1	r2	Virgin material	Recycled material	Paper making	Waste	Debit	Credit	Total
1	0 %	0 %	600	0	1500	500	0.	n.a.	2600
2	50 %	0 %	300	150	1500	500	15	n.a.	2465
3	100 %	0 %	0	300	1500	500	30	n.a.	2330
4	0 %	50 %	600	0	1500	250	0.	n.a.	2350
5	50 %	50 %	300	150	1500	250	15	n.a.	2215
6	100 %	50 %	0	300	1500	250	30	n.a.	2080
7	0 %	100 %	600	0	1500	0	0.	n.a.	2100
8	50 %	100 %	300	150	1500	0	15	n.a.	1965
9	100 %	100 %	0	300	1500	0	30	n.a.	1830

A.1.2 ISO/TS 14067 open loop

Method description

The method proposed in the international standard on carbon footprint of products (ISO/TS 14067) is based on the cut-off methods. The repulping process is seen as part of material acquisition [7]. In addition, a credit is given when the material is recycled after use, i.e. when someone else can use secondary material instead of primary material. An allocation factor "a" has to be applied here (based on e.g. monetary or quality-related characteristics), which means that a full credit has to be given if the allocation factor is 100 %. A debit is also included in the formula, meaning that one has to pay the burden of the initial virgin production. This also has to take an allocation factor into account (Equation 3).

Equation 3

$$E = (1 - r)* E_V + r_1 * E_R + E_P + (1 - r_2) * E_W - a * r_2 * E_V + a * r_1 * E_V$$

In Figure 7, an attempt is made to show the system boundaries and processes that are included in the formula.

Results & findings

In the base case, when the quality is 50 % and the effort of repulping is 50 % of primary production, there is no increase in environmental burdens when r_1 increases (Table 8). If recycling after use is increasing, the burden from waste treatment is reduced but at the same time, a credit has to be given.

Table 8 ISO/TS 14067 open loop results for the base case scenarios

Scenario	r1	r2	Virgin material	Recycled material	Paper making	Waste	Debit	Credit	Total
1	0 %	0 %	600	0	1500	500	0	0	2600
2	50 %	0 %	300	150	1500	500	150	0	2600
3	100 %	0 %	0	300	1500	500	300	0	2600
4	0 %	50 %	600	0	1500	250	0	-300	2200
5	50 %	50 %	300	150	1500	250	150	-300	2200
6	100 %	50 %	0	300	1500	250	300	-300	2200
7	0 %	100 %	600	0	1500	0	0	-600	1800
8	50 %	100 %	300	150	1500	0	150	-600	1800
9	100 %	100 %	0	300	1500	0	300	-699	1800

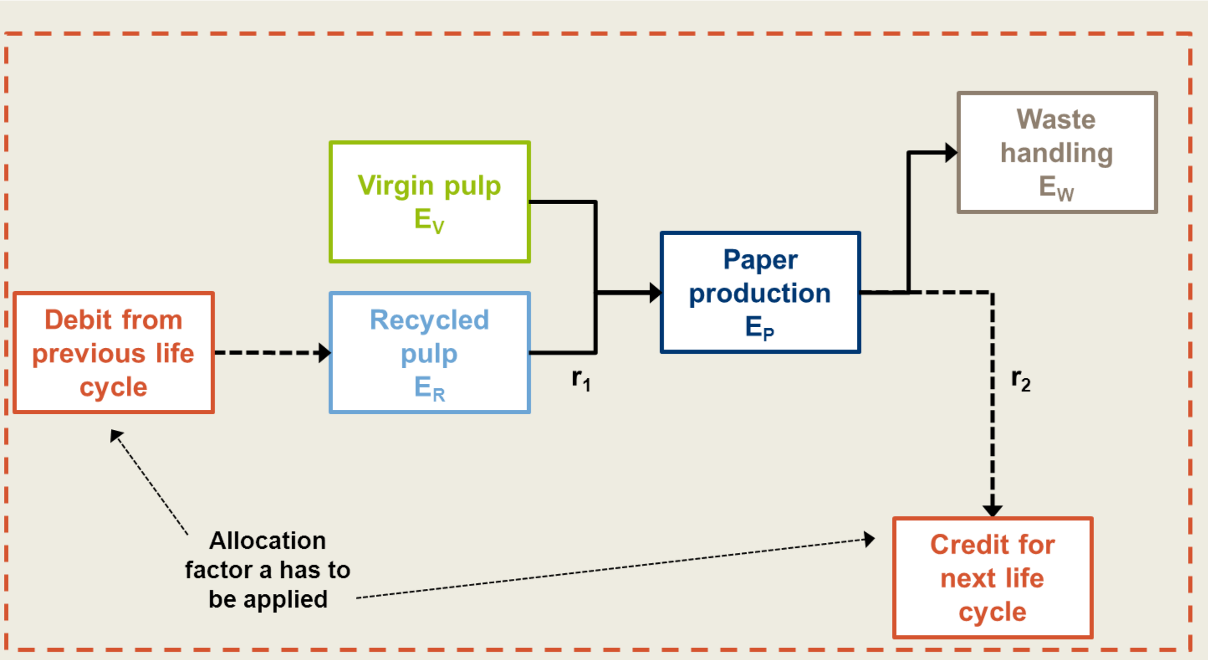

Figure 7 System boundaries for the ISO/TS 14067 open loop method

If primary and secondary material production have the same impacts and the allocation factor is 100 % then the total impacts increase if more recycled content is used (e.g. first three rows in Table 9). This is right: Assuming the quality to be equal, there should be no effort for repulping, meaning that if one has additional burdens from the repulping, this makes no sense.

The method is not easy to understand. No double counting occurs. Primary data shall and can be used for most of the processes. However, an agreement on values for credits (E_V) is needed. Also, the allocation factor a has to be defined.

Table 9 ISO/TS 14067 open loop results for scenarios with same impacts from primary and secondary material production and the 100 % allocation

Scenario	r1	r2	Virgin material	Recycled material	Paper making	Waste	Debit	Credit	Total
1	0 %	0 %	600	0	1500	500	0	0	2600
2	50 %	0 %	300	300	1500	500	300	0	2900
3	100 %	0 %	0	600	1500	500	600	0	3200
4	0 %	50 %	600	0	1500	250	0	-300	2050
5	50 %	50 %	300	300	1500	250	300	-300	2350
6	100 %	50 %	0	600	1500	250	600	-300	2650
7	0 %	100 %	600	0	1500	0	0	-600	1500
8	50 %	100 %	300	300	1500	0	300	-600	1800
9	100 %	100 %	0	600	1500	0	600	-600	2100

A.1.3 AFNOR BP X30-323 open loop

Method description

The method proposed in the AFNOR repository of good practices BP X 30-323 for open loop systems allocates the impacts from recycling depending on the penetration rate of the recycled raw material in the raw materials market [8]. The method gives a credit for energy recovery at end-of-life. The new version of the reference (June 2011) has a slightly different formula but the calculations are basically the same.

Equation 4 shows the formula written in common notation. There is a common value r for r_1 and r_2 which has to be agreed on sector or sub-sector level. r_{EN} is the national energy recovery rate for materials and E_{CRED} is the credit for energy recovery from end of life.

Equation 4

$$E = (1-r) * E_V + r * E_R + E_P + (1 - r - r_{EN}) * E_W - r_{EN} * E_{CRED}$$

In Figure 8, an attempt is made to show the system boundaries and processes that are included in the formula. Interestingly, the open loop method proposed here looks like closed loop proposals according to other methods (e.g. GHG Protocol closed loop approximation).

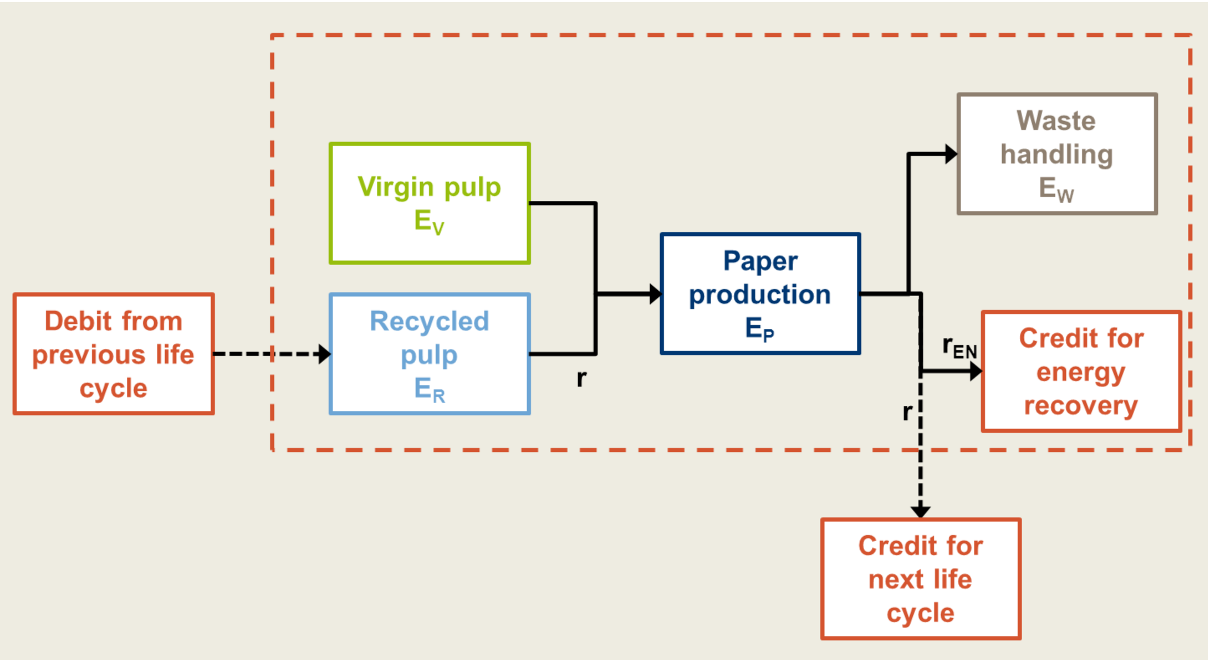

Figure 8 System boundaries for the AFNOR BP X30-323 open loop method

Results & findings

In the base case, the quality is 50 % and the effort of repulping is 50 % of primary production. r_{EN} has been assumed 20 % and r as 70 %. For E_{CRED}, a value of 20 was estimated. Basically, a change in r1 and r2 has no effect on the results, as national averages for r has to be used (Table 10).

Table 10 AFNOR BP X30-323 open loop results for the base case scenarios

Scenario	r1	r2	Virgin material	Recycled material	Paper making	Waste	Debit	Credit	Total
1	0 %	0 %	180	210	1500	50	-4	n.a.	1936
2	50 %	0 %	180	210	1500	50	-4	n.a.	1936
3	100 %	0 %	180	210	1500	50	-4	n.a.	1936
4	0 %	50 %	180	210	1500	50	-4	n.a.	1936
5	50 %	50 %	180	210	1500	50	-4	n.a.	1936
6	100 %	50 %	180	210	1500	50	-4	n.a.	1936
7	0 %	100 %	180	210	1500	50	-4	n.a.	1936
8	50 %	100 %	180	210	1500	50	-4	n.a.	1936
9	100 %	100 %	180	210	1500	50	-4	n.a.	1936

A.1.4 GHG Protocol (closed loop approximation)

Method description

The GHG protocol method for closed loop situations is a cut-off method and "accounts for the impact that end-of-life recycling has on the net virgin acquisition of a material. Its name derives from the assumption that the material being recycled is used to displace virgin material input with the same inherent properties" [4, p.71]. The description does not include a formula but a figure is given to describe the principle. Equation 5 shows the formula from the interpretation of the document written in common notation. The same parameter is used for recycled content and collection to recycling after use.

Equation 5

$$E = (1-r_2) * E_V + r_2 * E_R + E_P + (1-r_2) * E_W$$

The system boundaries of the GHG Protocol (closed loop approximation) method are shown in Figure 9. Again, the strict attributional cut-off method can be seen.

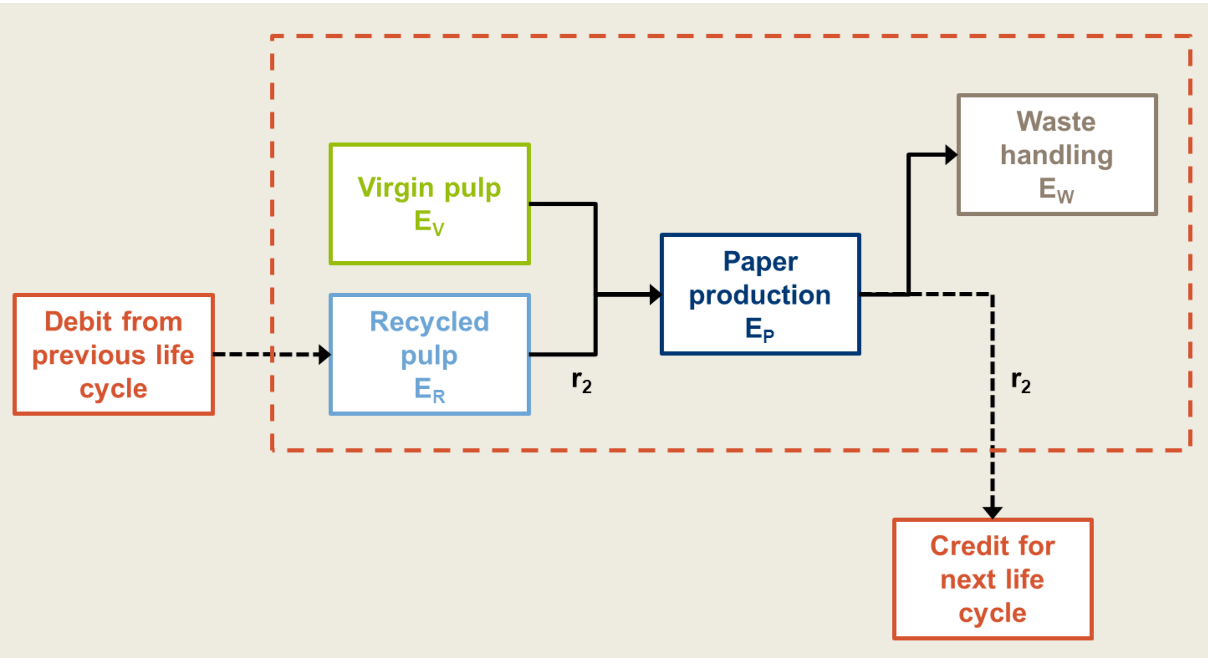

Figure 9 System boundaries for the GHG Protocol (closed loop approximation) method

Results & findings

In the base case, when the ER is smaller than EV, the environmental burdens decrease when more collection after recycling increased (Table 11). Recycling after use is preferable as the emissions from waste are avoided (if E_W is greater than zero).

In general, the method is transparent and allows using primary data. No agreement on values for credits or debits is needed. The method is transparent and easy to understand. No double counting occurs.

Table 11 GHG Protocol (recycled content) results for the base case scenarios

Scenario	r1	r2	Virgin material	Recycled material	Paper making	Waste	Debit	Credit	Total
1	0 %	0 %	600	0	1500	500	n.a.	n.a.	2600
2	50 %	0 %	600	0	1500	500	n.a.	n.a.	2600
3	100 %	0 %	600	0	1500	500	n.a.	n.a.	2600
4	0 %	50 %	300	150	1500	250	n.a.	n.a.	2200
5	50 %	50 %	300	150	1500	250	n.a.	n.a.	2200
6	100 %	50 %	300	150	1500	250	n.a.	n.a.	2200
7	0 %	100 %	0	300	1500	0	n.a.	n.a.	1800
8	50 %	100 %	0	300	1500	0	n.a.	n.a.	1800
9	100 %	100 %	0	300	1500	0	n.a.	n.a.	1800

A.1.5 PAS 2050 (closed loop approximation)

The closed loop method that is described in the PAS 2050 is exactly the same as the GHG Protocol (closed loop approximation) method [5].

A.1.6 ISO/TS 14067 closed loop

Method description

The method proposed in the international standard on carbon footprint of products (ISO/TS 14067) sees the repulping process as part of material acquisition [7]. The formula is the same than in the GHG protocol or PAS 2050 methods. However, one has first to account for the full burden of the initial virgin production. In addition, a credit is given when the material is recycled after use, i.e. when someone else can use secondary material instead of primary material. The term $(1-r_2) * EV$ is thus only split into two terms. Equation 6 shows the formula written in common notation.

Equation 6

$$E = E_V + r_2 * E_R + E_P + (1 - r_2) * E_W - r_2 * E_V$$

Figure 10shows the system boundaries and processes that are included in the formula.

Results & findings

In the base case, when the ER is smaller than EV, the environmental burdens decrease when more collection after recycling increased (Table 12). Recycling after use is preferable as the emissions from waste are avoided (if E_W is greater than zero). The method basically leads to the same total as the GHG protocol or PAS 2050 methods, however, the results for the individual life cycle phases differ.

Table 12 ISO/TS 14067 closed loop results for the base case scenarios

Scenario	r1	r2	Virgin material	Recycled material	Paper making	Waste	Debit	Credit	Total
1	0 %	0 %	600	0	1500	500	n.a.	0	2600
2	50 %	0 %	600	0	1500	500	n.a.	0	2600
3	100 %	0 %	600	0	1500	500	n.a.	0	2600
4	0 %	50 %	600	150	1500	250	n.a.	-150	2200
5	50 %	50 %	600	150	1500	250	n.a.	-150	2200
6	100 %	50 %	600	150	1500	250	n.a.	-150	2200
7	0 %	100 %	600	300	1500	0	n.a.	-300	1800
8	50 %	100 %	600	300	1500	0	n.a.	-300	1800
9	100 %	100 %	600	300	1500	0	n.a.	-300	1800

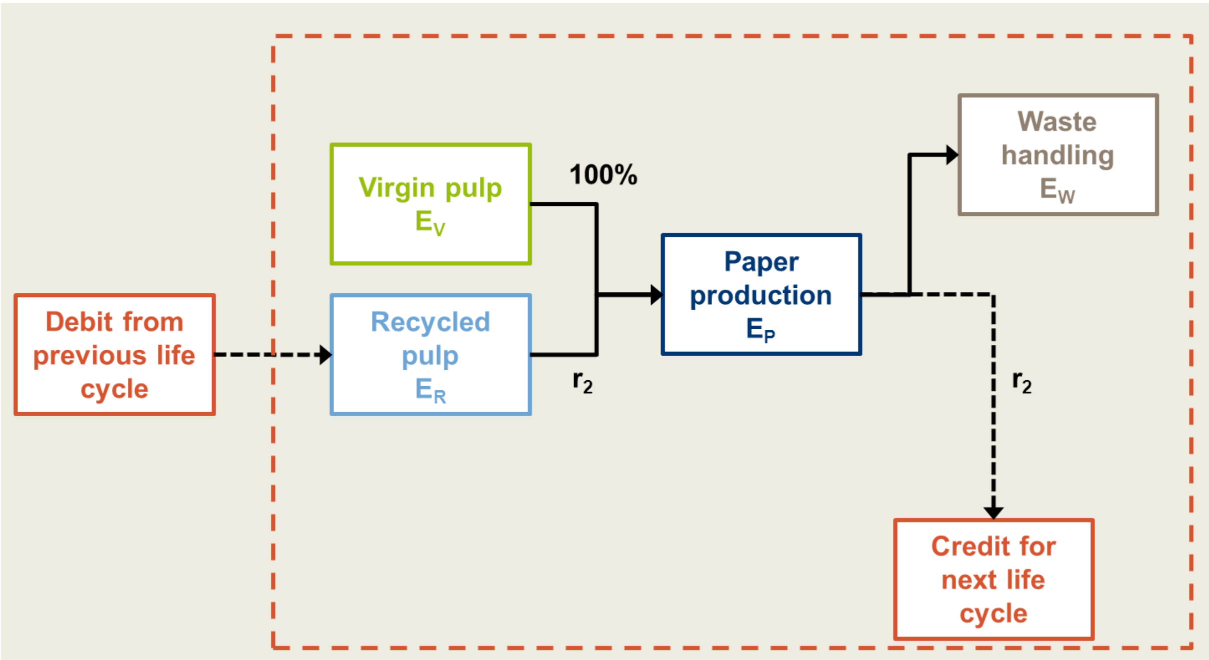

Figure 10 System boundaries for the ISO/TS 14067 closed loop method

In general, the method is transparent and allows using primary data. No agreement on values for credits or debits is needed. The method is transparent and easy to understand. No double counting occurs.

A.1.7 AFNOR BP X30-323 closed loop

Method description

The method proposed in the AFNOR repository of good practices BP X 30-323 for closed loop systems is shown in Equation 7 [8]. The standard especially mentions paper and carton as products the method should be used for. Instead of r_2, a national average of r has to be applied. The new version of the reference (June 2011) has a slightly different formula but the calculations are basically the same.

Equation 7

$$E = (1 - r_1) * E_V + r_1 * E_R + E_P + (1 - r) * E_W$$

Figure 11 shows the system boundaries and processes that are included in the formula. Interestingly, the closed loop method proposed here looks like open loop proposals according to other methods (e.g. GHG Protocol recycled content).

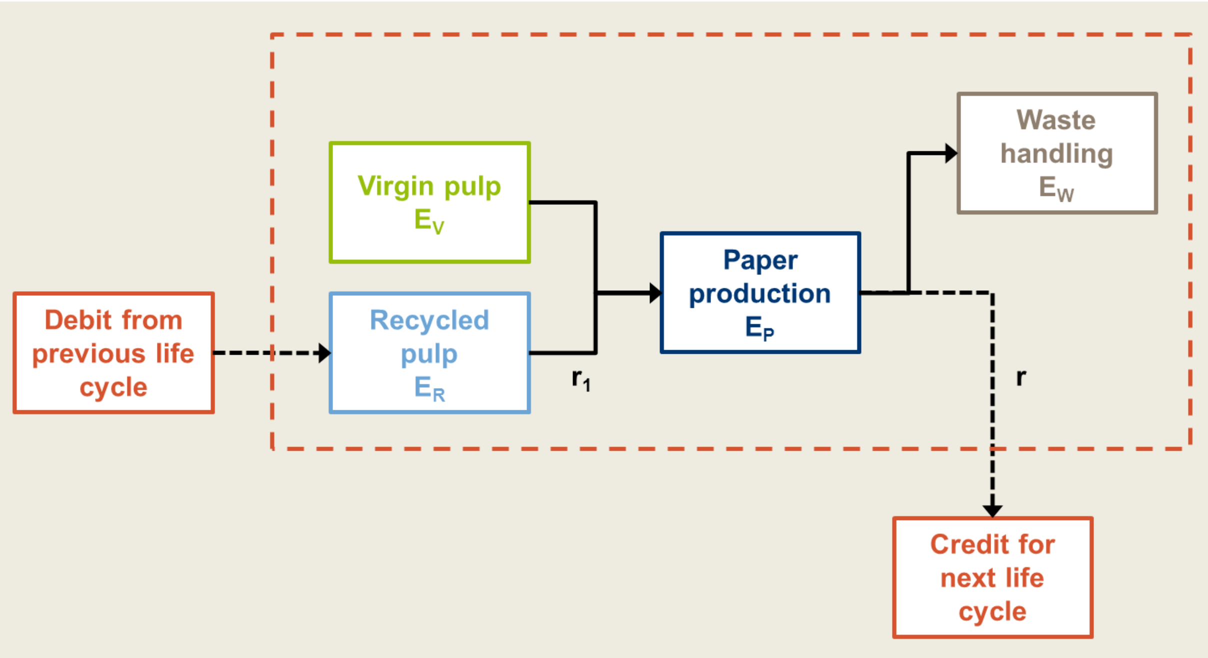

Figure 11 System boundaries for the AFNOR BP X30-323 closed loop method

Results & findings

In the base case, the quality is 50 % and the effort of repulping is 50 % of primary production. r has been assumed 70 % A change in r2 has thus no effect on the results, as the national average for r has to be used (Table 13). The recipe (recycled content) is thus taken into account. If any change in r_2 occurs, the results will not be influenced.

Table 13 AFNOR BP X30-323 closed loop results for the base case scenarios

Scenario	r1	r2	Virgin material	Recycled material	Paper making	Waste	Debit	Credit	Total
1	0 %	0 %	600	0	1500	150	n.a.	n.a.	2250
2	50 %	0 %	300	150	1500	150	n.a.	n.a.	2100
3	100 %	0 %	0	300	1500	150	n.a.	n.a.	1950
4	0 %	50 %	600	0	1500	150	n.a.	n.a.	2250
5	50 %	50 %	300	150	1500	150	n.a.	n.a.	2100
6	100 %	50 %	0	300	1500	150	n.a.	n.a.	1950
7	0 %	100 %	600	0	1500	150	n.a.	n.a.	2250
8	50 %	100 %	300	150	1500	150	n.a.	n.a.	2100
9	100 %	100 %	0	300	1500	150	n.a.	n.a.	1950

A.1.8 ILCD for attributional LCA (market value > 0)

Method description

The method proposed in the ILCD handbook for attributional modelling says that "it is appropriate to assign to both the system that generates the waste or end-of-life product and to the one that uses the secondary good the corresponding share of the inventory" [1]. The ILCD differentiates between cases where the market value of the waste or end-of-life product at its point of origin is above zero or below zero.

The method proposed in the handbook for a market value above zero is shown in Equation 8. Instead of r_1 and r_2, an average recycling rate r has to be applied. The philosophy behind this method is that, in case of a market value above 0, the impacts from both final waste treatment and virgin production are shared equally between all users of the fibres.

Equation 8

$$E = (1-r) * E_V + r * E_R + E_P + (1-r) * E_W$$

Figure 12 shows the system boundaries and processes that are included in the formula. Interestingly, the method proposed is similar to the AFNOR BP X30-323 open loop method.

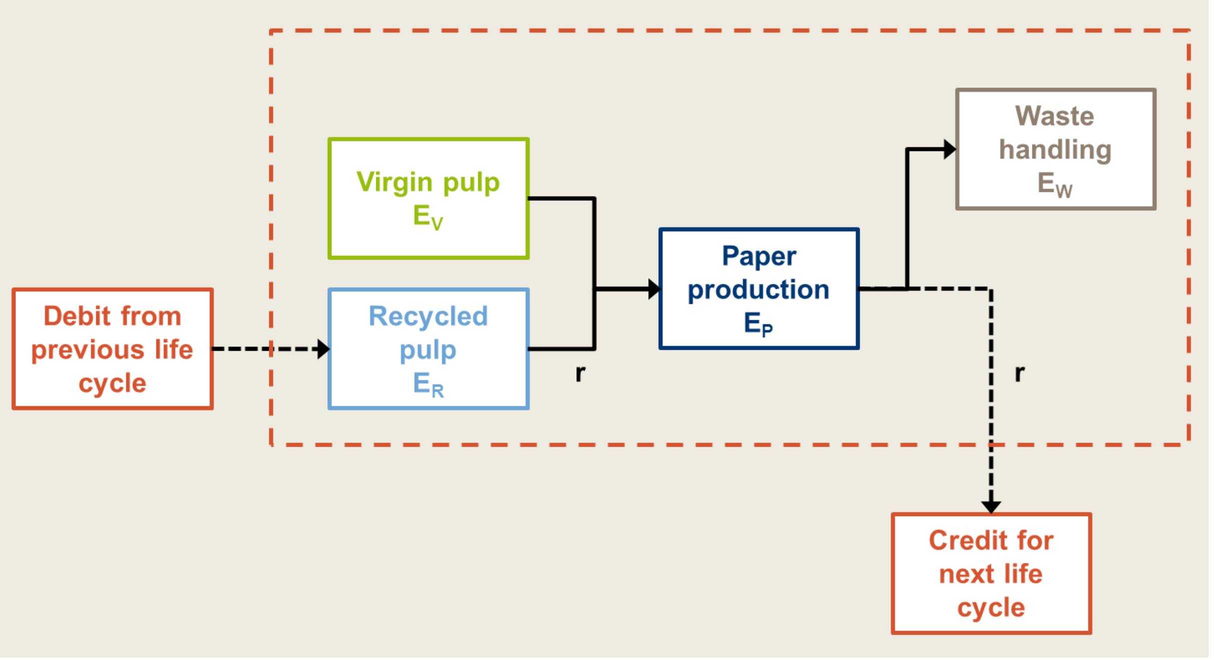

Figure 12 System boundaries for the ILCD for attributional LCA (market value > 0) method

Results & findings

In the base case, the quality is 50 % and the effort of repulping is 50 % of primary production. r has been assumed 70 %. A change in r_1 and r_2 has thus no effect on the results (Table 14).

The method assumes an indefinite numbers of recycling and equal quality of primary and recycled material. It is not robust against changes in market price which means that the choice of allocation might depend on person and time.

Table 14 ILCD for attributional LCA (market value > 0) results for the base case scenarios

Scenario	r1	r2	Virgin material	Recycled material	Paper making	Waste	Debit	Credit	Total
1	0 %	0 %	180	210	1500	50	n.a.	n.a.	2040
2	50 %	0 %	180	210	1500	50	n.a.	n.a.	2040
3	100 %	0 %	180	210	1500	50	n.a.	n.a.	2040
4	0 %	50 %	180	210	1500	50	n.a.	n.a.	2040
5	50 %	50 %	180	210	1500	50	n.a.	n.a.	2040
6	100 %	50 %	180	210	1500	50	n.a.	n.a.	2040
7	0 %	100 %	180	210	1500	50	n.a.	n.a.	2040
8	50 %	100 %	180	210	1500	50	n.a.	n.a.	2040
9	100 %	100 %	180	210	1500	50	n.a.	n.a.	2040

A.1.9 ILCD for attributional LCA (market value < 0)

Method description

The method for attributional LCA proposed in the ILCD handbook for attributional modelling in case of a market value of waste below zero allocates all waste treatment steps “to the first system that has generated the waste / end-of-life product” [1].

Equation 9 shows the formula of the method. Instead of r_1, an average recycling rate r has to be applied. The philosophy behind this method is that the impacts from virgin production are shared equally between all users of the fibres while the impacts from end-of-life treatment are fully assigned to the last user.

Equation 9

$$E = (1-r) * E_V + r * E_R + E_P + (1-r_2) * E_W$$

Figure 13shows the system boundaries and processes that are included in the formula.

Results & findings

In the base case, the quality is 50 % and the effort of repulping is 50 % of primary production. r has been assumed 70 %. A change in r_1 has thus no effect on the results (Table 15). This means that the actual recipe of the product will not show up. Environmental impacts decrease when waste treatment is avoided (in case E_W emissions are greater than zero). Neither credits nor debits are given.

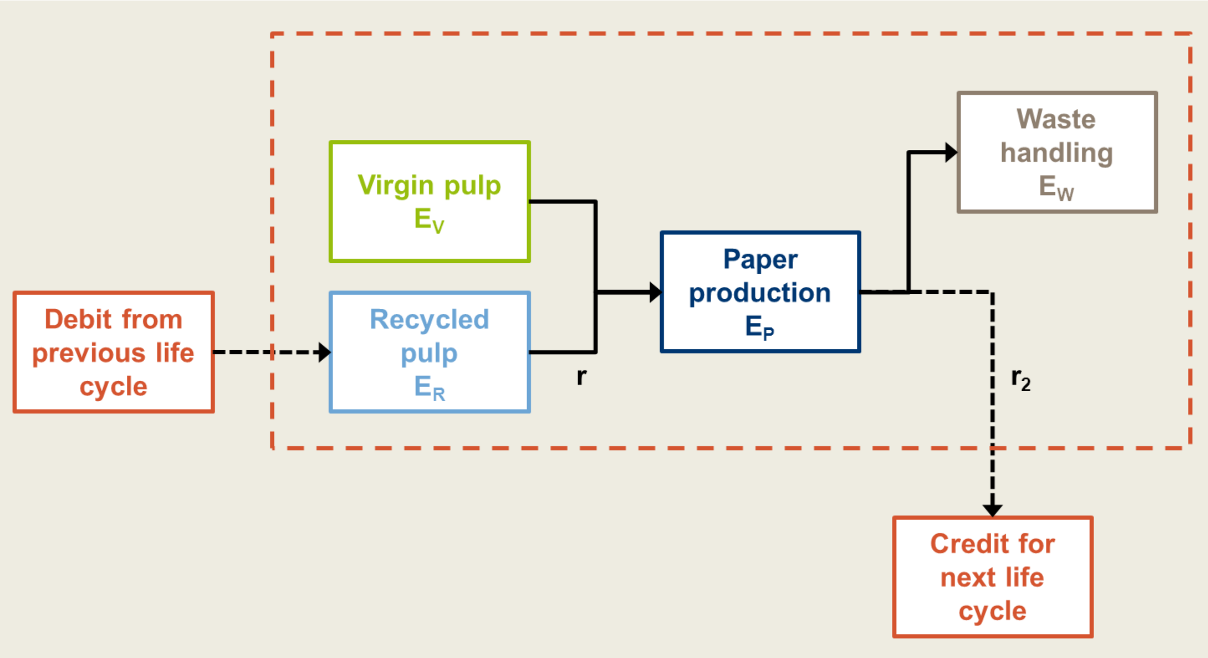

Figure 13 System boundaries for the ILCD for attributional LCA (market value < 0) method

Table 15 ILCD for attributional LCA (market value > 0) results for the base case scenarios

Scenario	r1	r2	Virgin material	Recycled material	Paper making	Waste	Debit	Credit	Total
1	0 %	0 %	180	210	1500	500	n.a.	n.a.	2390
2	50 %	0 %	180	210	1500	500	n.a.	n.a.	2390
3	100 %	0 %	180	210	1500	500	n.a.	n.a.	2390
4	0 %	50 %	180	210	1500	250	n.a.	n.a.	2140
5	50 %	50 %	180	210	1500	250	n.a.	n.a.	2140
6	100 %	50 %	180	210	1500	250	n.a.	n.a.	2140
7	0 %	100 %	180	210	1500	0	n.a.	n.a.	1890
8	50 %	100 %	180	210	1500	0	n.a.	n.a.	1890
9	100 %	100 %	180	210	1500	0	n.a.	n.a.	1890

It can be discussed, if waste paper ever has a market value below zero. It seems strange that the impacts of primary production and recycling are equally distributed to products along the life cycle while the waste management is not shared between the users depending on the market value.

A.2 Consequential methods

A.2.1 ILCD for consequential LCA

Method description

The consequential method according to the ILCD handbook gives a credit due to avoided primary production to the end-of-life product or waste according to the recycling rate [1]. The impacts from the recycling operations and the final waste treatment are fully allocated to the life cycle under consideration.

The method proposed is shown in Equation 10. If the user is actually a net source of fibres, a credit is given. In the opposite case (net drain of fibres from the system), a debit applies. Repulping is seen as part of the waste handling. The credit/debit takes the quality ratio between primary and secondary fibres into account by introducing the factor q. This means that a full credit has to be given if the quality of the secondary material is as high as the quality of the primary material. If the quality is zero after use, no credit is given.

Equation 10

$$E = (1-r_1)*E_V + r_2*E_R + E_P + (1-r_2)*E_W + (r_1 - r_2)*q*E_V$$

Figure 14 shows the system boundaries and processes that are included in the formula.

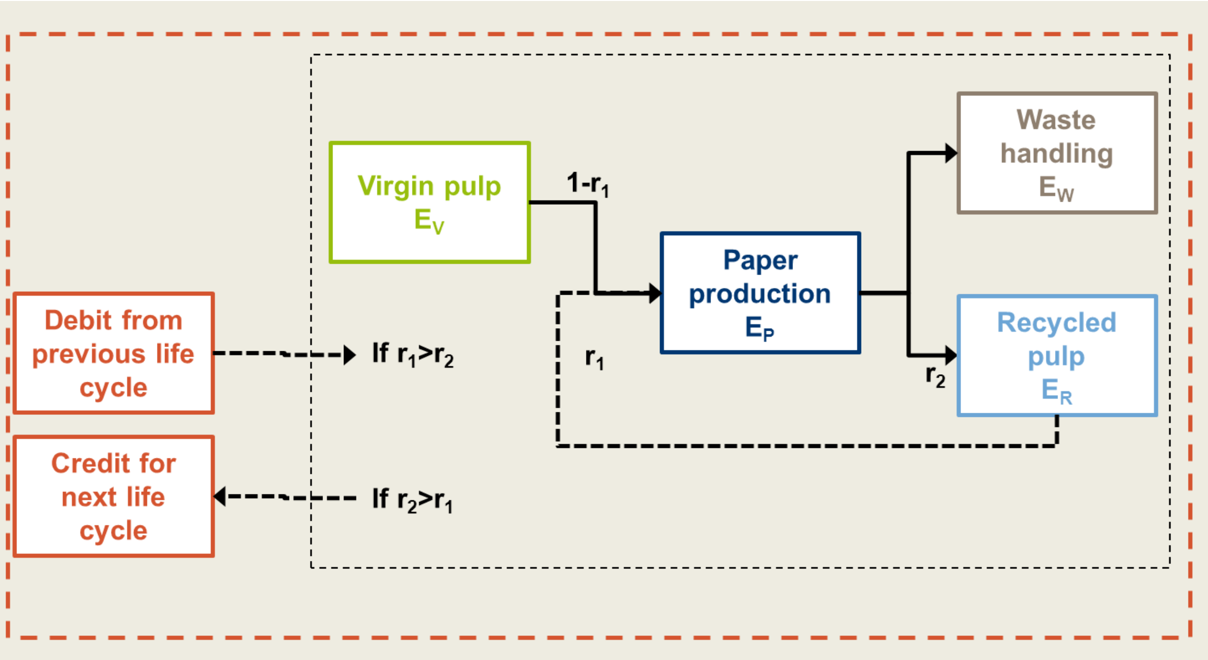

Figure 14 System boundaries for the ILCD consequential method

Results & findings

In the base case, the quality is 50 % and the effort of repulping is 50 % of primary production. If the recycled content of the product is increased, the impacts from E_R remain the same as E_R is now part of the waste and thus multiplied by r_2 (Table 16). Instead, the debit (from previous life) increases from 0 to 300. In case the collection to recycling increases, a credit is given. Environmental impacts decrease when waste treatment is avoided (in case E_W emissions are greater than zero) as in all other methods.

The problem in this case is that for the credits and debits, values have to be agreed upon. Also the quality factor q has to be defined. It is also a problem that ER is part of EOL and not part of the incoming material.

Table 16 ILCD for consequential LCA results for the base case scenarios

Scenario	r1	r2	Virgin material	Recycled material	Paper making	Waste	Debit	Credit	Total
1	0 %	0 %	600	0	1500	500	0	0.	2600
2	50 %	0 %	300	0	1500	500	150	0	2450
3	100 %	0 %	0	0	1500	500	300	0	2300
4	0 %	50 %	600	150	1500	250	0	-150	2350
5	50 %	50 %	300	150	1500	250	150	-150	2200
6	100 %	50 %	0	150	1500	250	300	-150	2050
7	0 %	100 %	600	300	1500	0	0	-300	2100
8	50 %	100 %	300	300	1500	0	150	-300	1950
9	100 %	100 %	0	300	1500	0	300	-300	1800

A.3 Methods intended for all situations

A.3.1 PFCR for paper

The method that is described in the PFCR for paper was taken from the PEF guide and is exactly the same as the ILCD consequential method [1, 9].

A.3.2 PEF June 2012

Method description

The JRC reconsidered the recycling method proposed in the PEF guide [2] after having received stakeholder comments. Rana Pant explained to one of the authors of this report a new proposal. This method has been under discussion but has not been included in the final PEF guide. The repulping is now again seen as part of the incoming material (Equation 11). The debit/credit term consists of two parts: First, a debit for the recycling process which can be interpreted as the impacts from the operations to but the material back into the condition that it can be used again. Second, a credit for the substitution of virgin fibres, weighted by a quality factor. Figure 15 shows the system boundaries and processes that are included in the formula.

Equation 11

$$E = (1-r_1) * E_V + r_1 * E_R + E_P + (1-r_2) * E_W + r_2 * (E_{REOL} - q * E_V)$$

Results & findings

In the base case, the quality is 50 % and the effort of repulping is 50 % of primary production. E_{REOL} has been assumed to be the same as E_R. Results of the base case are shown in Table 17. In this case, the credit and the debit term are the same and thus equalled out.

In a second case, a higher quality factor of 75 % was tested. Here, the credit increases compared to the base case which seems to be logic.

Table 17 PEF June 2012 results for the base case scenarios

Scenario	r1	r2	Virgin material	Recycled material	Paper making	Waste	Debit	Credit	Total
1	0 %	0 %	600	0	1500	500	0	0	2600
2	50 %	0 %	300	150	1500	500	0	0	2450
3	100 %	0 %	0	300	1500	500	0	0	2300
4	0 %	50 %	600	0	1500	250	150	-150	2350
5	50 %	50 %	300	150	1500	250	150	-150	2200
6	100 %	50 %	0	300	1500	250	150	-150	2050
7	0 %	100 %	600	0	1500	0	300	-300	2100
8	50 %	100 %	300	150	1500	0	300	-300	1950
9	100 %	100 %	0	300	1500	0	300	-300	1800

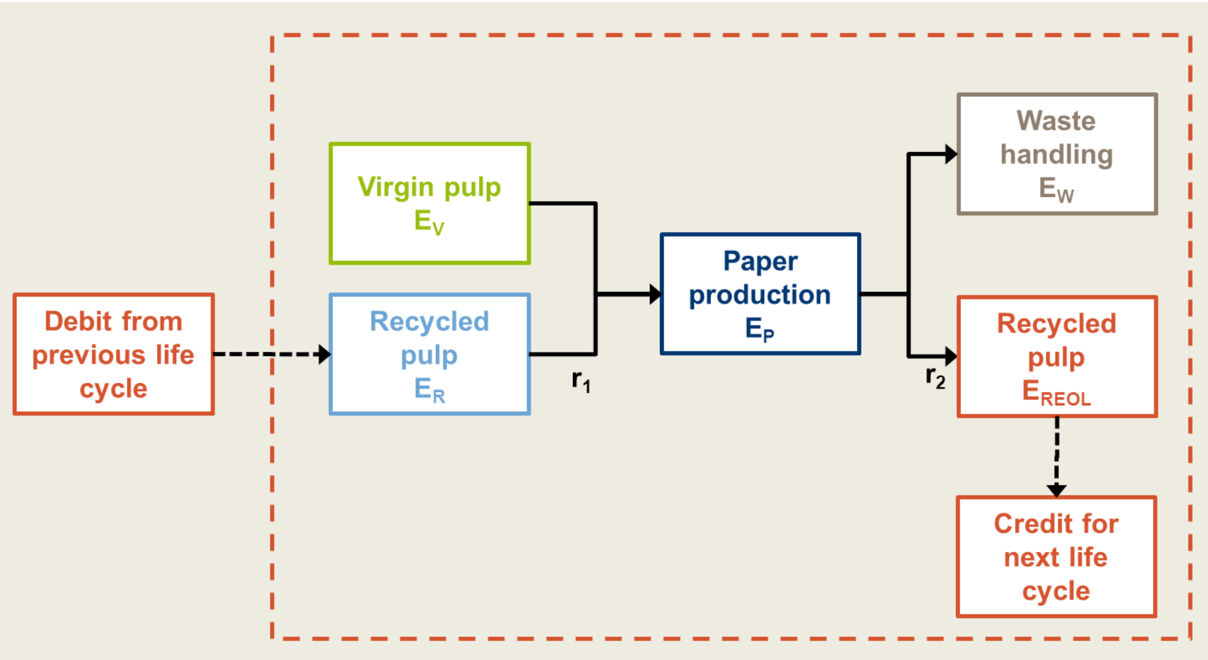

Figure 15 System boundaries for the PEF June 2012 method

Table 18 PEF June 2012 results for a case with q = 75 %

Scenario	r1	r2	Virgin material	Recycled material	Paper making	Waste	Debit	Credit	Total
1	0 %	0 %	600	0	1500	500	0	0	2600
2	50 %	0 %	300	150	1500	500	0	0	2450
3	100 %	0 %	0	300	1500	500	0	0	2300
4	0 %	50 %	600	0	1500	250	150	-225	2275
5	50 %	50 %	300	150	1500	250	150	-225	2125
6	100 %	50 %	0	300	1500	250	150	-225	1975
7	0 %	100 %	600	0	1500	0	300	-450	1950
8	50 %	100 %	300	150	1500	0	300	-450	1800
9	100 %	100 %	0	300	1500	0	300	-450	1650

The problem of the PEF June 2012 method is the double-counting of the impacts from ER (as incoming material and as part of EOL operations).

A.3.3 PEF April 2013

Method description

The method proposed in the final draft PEF guide is basically a 50/50 method [10]. The method is shown in Equation 12.

The repulping is now again seen as part of the incoming material. The debit/credit term consists of two parts: First, a debit for the recycling process which can be interpreted as the impacts from the operations to but the material back into the condition that it can be used again. Second, a credit for the substitution of virgin fibres, weighted by a quality factor. Figure 16 shows the system boundaries and processes that are included in the formula.

Equation 12

$$E = (1 - r_1/2) * E_V + r_1/2 * E_R + E_P + (1 - r_2/2 - r_{EN}) * E_W + r_2/2 * (E_{REOL} - E_V * q)$$
$$- r_{EN} * E_{CRED} - r_1/2 * E_W$$

Results & findings

In the base case, the quality is 50 % and the effort of repulping is 50 % of primary production. E_{REOL} has been assumed to be the same as E_R. r_{EN} has been assumed 20 % and r as 70 %. For E_{CRED}, a value of 20 was estimated (Section A.1.3). Results of the base case are shown in Table 19. In this case, the credit from energy recovery is 4 and the credit for waste ranges from 0 to 250 depending on r_1. The credit/debit term from recycling ($r_2/2* E_{REOL}-E_V*q$) is zero in the case of q = 50%. In a second case, a higher quality factor of 75 % was tested. Here, the credit/debit term from recycling now is a true credit (Table 20).

Table 19 PEF April 2013 results for the base case scenarios

Scenario	r1	r2	Virgin material	Recycled material	Paper making	Waste	Debit	Credit	Total
1	0 %	0 %	600	0	1500	500	0	-4	2496
2	50 %	0 %	450	75	1500	500	0	-129	2296
3	100 %	0 %	300	150	1500	500	0	-254	2096
4	0 %	50 %	600	0	1500	375	0	-42	2334
5	50 %	50 %	450	75	1500	375	0	-167	2134
6	100 %	50 %	300	150	1500	375	0	-292	1934
7	0 %	100 %	600	0	1500	250	0	-79	2171
8	50 %	100 %	450	75	1500	250	0	-204	1971
9	100 %	100 %	300	150	1500	250	0	-329	1771

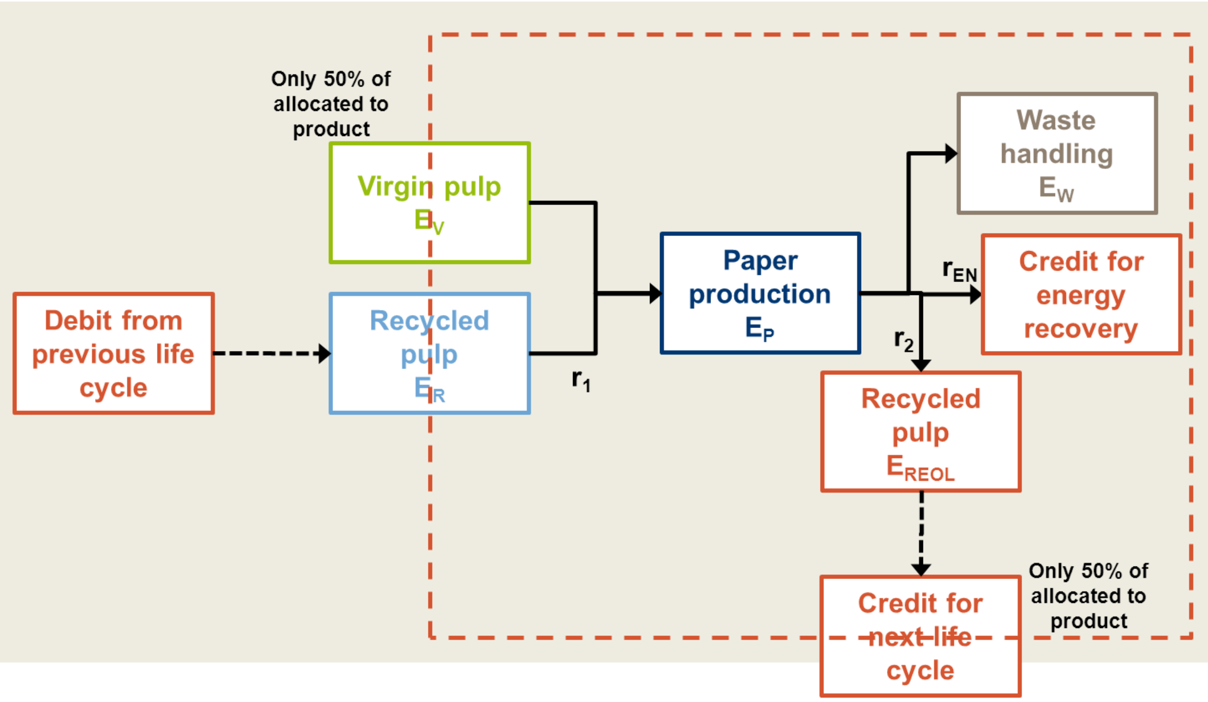

Figure 16 System boundaries for the PEF April 2013 method

Table 20 PEF April 2013 results for a case with q = 75 %

Scenario	r1	r2	Virgin material	Recycled material	Paper making	Waste	Debit	Credit	Total
1	0 %	0 %	600	0	1500	400	0	-4	2496
2	50 %	0 %	450	75	1500	400	0	-129	2296
3	100 %	0 %	300	150	1500	400	0	-254	2096
4	0 %	50 %	600	0	1500	275	0	-42	2334
5	50 %	50 %	450	75	1500	275	0	-167	2134
6	100 %	50 %	300	150	1500	275	0	-292	1934
7	0 %	100 %	600	0	1500	150	0	-79	2171
8	50 %	100 %	450	75	1500	150	0	-204	1971
9	100 %	100 %	300	150	1500	150	0	-329	1771

The problem of the PEF April 2013 method is the double-counting of the impacts when the product or material is used more than twice. The impacts from end of waste are also shared between the users of the materials which is good. However, E_W for credits has to be agreed upon. Due to the fact that waste impacts are shared, the incentives for collection to recycling are lower compared to other methods.

Annex B References

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