LCA Methodology

Open-Loop Recycling: Criteria for Allocation Procedures

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Abstract

If the aim of an LCA is to support decisions or to generate and evaluate ideas for future decisions, the allocation procedure should generally be effect-oriented rather than cause-oriented. It is important that the procedure be acceptable to decision makers expected to use the LCA results. It is also an advantage if the procedure is easy to apply. Applicability appears to be in conflict with accurate reflection of effect-oriented causalities. To make LCA a more efficient tool for decision support, a range of feasible allocation procedures that reflect the consequences of inflows and outflows of cascade materials is required.

Keywords: Allocation procedures; cascade materials; environment, decision making; inventory analysis; LCA, tool for decision support; Life Cycle Assessment (LCA), applications; methodology, LCA; open loop recycling; recycling, open loop; system boundaries; systems analysis

1 Introduction

This paper deals with quantitative, environmental life-cycle assessment (LCA) as described elsewhere (*e.g.* GUINÉE *et al.* 1993a, 1993b). The methodological principles presented and discussed in this paper are also applicable to both semi-quantitative and qualitative LCAs.

In the LCA context, allocation can be defined as the act of assigning the environmental impacts of a system to the functions of that system in proportionate shares. We define the allocation *procedure* as a procedure used to deal with allocation problems. Possible allocation procedures include methods for allocating as well as methods for avoiding allocation, *e.g.* through expansion of system boundaries.

The allocation problem occurs when an LCA includes multi-functional processes. It also occurs in open-loop recycling, *i.e.* when recycling results in material or energy being used in more than one product. This paper deals with open-loop recycling of material (referred to below as cascade material). The principles are also applicable to energy recycling.

The Society of Environmental Toxicology and Chemistry (SETAC) made an early statement that it is important to "use a logical approach, consistent with the study goal" when dealing with allocation in open-loop recycling (SETAC 1993). Many different allocation procedures have been suggested (HUPPES and SCHNEIDER 1994, KLÖPFFER 1996). Several criteria have also been proposed for good allocation procedures. At the European Workshop on Allocation in LCA, it was concluded that allocation must, whenever possible, be based on causal relationships (CLIFT 1994). HEIJUNGS (1994) even claims that causality should be the guiding principle for LCA as a whole. KLÖPFFER (1996), on the other hand, states that "solutions have to be found which guarantee a fair distribution of the burdens and are feasible within the framework of an LCA".

Significant progress on harmonisation and standardisation has been made within SETAC and the International Standardisation Organisation (ISO). In a recent draft, ISO (1996) suggests a ranking order of allocation procedures which should be used when information is not available on how many times the cascade material is recycled:

1. Allocation should be avoided or minimised wherever possible. This may be achieved by subdividing the unit process into two or more sub-processes, or by expanding the system boundaries so that inputs, outputs and recycles remain within the system.
2. Where allocation cannot be avoided, the allocation should be based on the way in which the inputs and outputs are changed by quantitative changes in the products or functions delivered by the system.
3. Where such a relationship cannot be used as the basis for allocation, the allocation should be based on economic relationships.

This ranking order corresponds well to the ranking order recommended by the SETAC-Europe Working Group on Life Cycle Inventory Analysis (CLIFT 1996). The ranking order does not refer to the goal of the study.

In this paper, we build upon the early SETAC criterion that the procedure should be consistent with the study goal. Our aim is to investigate how such a consistency can be ob-

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tained. We discuss what properties are important in the allocation procedure in order to obtain the consistency. We also discuss what allocation procedures have these properties. The aim is to indicate what type of allocation procedures are appropriate for different study goals.

Before solutions can be discussed, we need to describe the allocation problem in further detail. We also need to distinguish between different kinds of causal relationships.

2 Further Definition of the Allocation Problem

2.1 System level

There are at least three different system levels at which allocation in open-loop recycling can be dealt with (→ *Fig. 1*):

- The recycling process. This can be considered a multi-function process which supplies waste management for upstream products and material for downstream products (HUPPES 1994). In **Figure 1**, process R1 supplies waste management for P1 and material for P2.
- The product life cycle investigated. This is a multi-function system which supplies the function(s) of the product as well as waste management for upstream products and/ or material for downstream products. The life cycle of P2 supplies the function(s) of P2, waste management for P1 and material for P3.
- The cascade or material life cycle. This is also a multi-function system which supplies the functions of all products in the cascade (P1, P2 and P3).

This paper deals with open-loop recycling on the cascade level. The relevance of different system levels is discussed at the end of the paper.

2.2 Allocation at the cascade level

Allocation at the cascade level means allocating the environmental impact of all processes in the cascade. Many of these are clearly associated with one product only, *e.g.* the production, distribution, use and re-use of the product. However, virgin material production and final waste management are associated with all products in the cascade since they are necessary for all products containing material. From the above, it is clear that recycling processes are also associated with more than one product.

To our knowledge there is consensus in the LCA community that the impacts of processes associated with one product only should be allocated to that product. This means that the problem is reduced to allocation of impacts from virgin material production (V1 in *Fig. 1*), recycling (R1 and R2) and final waste management (W3). In the following, V1, R1, R2 and W3 are used to denote the environmental impacts of these processes.

3 Causal Relationships

As stated above, it has been proposed that allocation should be based on causal relationships, if possible. A closer inspection reveals that there are at least two categories of causal relationships on which allocation can be based (→ *Fig. 2*):

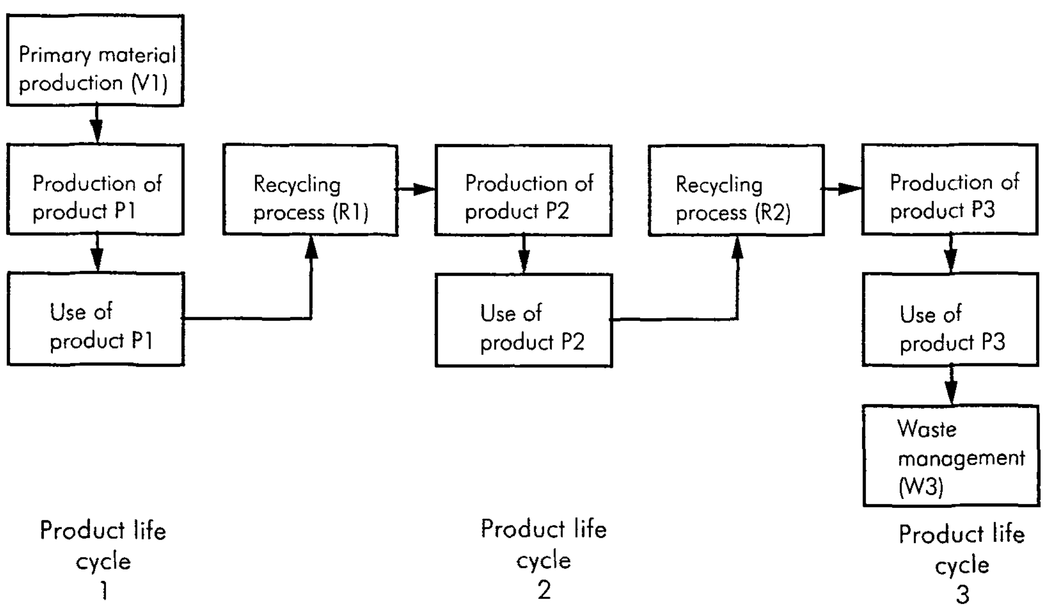

Fig. 1: Simplified illustration of the processes and material flows in an idealised cascade. All material in P1 is recycled into P2. All material in P2 is recycled into P3. P2 and P3 are produced from this recycled material only. The material in P3 is not recycled after use

- Cause-oriented: the relationship between the investigated system and its causes.
- Effect-oriented: the relationship between the investigated system and its effects.

		Investigated		
causes	→	system	→	effects
	cause-oriented causality		effect-oriented causality	

Fig. 2: Illustration of two different types of causal relationships which can be used as a basis for allocation

Huppes (1994) suggests that allocation should be based on gross sales value since the economic proceeds are the cause of the investigated process: products are produced because producers expect others to be willing to pay for them. This is an example of allocation based on a causality that is oriented towards the cause of the system.

When a product life cycle delivers recycled material, the demand for virgin material may be reduced in other product life cycles. Effects of the investigated product on other life cycles can be included in the LCA through expansion of system boundaries (Tillman *et al.* 1994). This is an example of a procedure based on effect-oriented causalities.

4 Goals of the LCA

LCA can be used to support decisions regarding different products, raw materials, production processes, waste management processes etc. LCA can be used to generate and evaluate ideas for future decisions through identifying the most important environmental aspects (Lindfors *et al.* 1995) or improvement options for the life cycle. LCA can be used to generate knowledge about the life cycle of the product without the explicit aim of affecting decision-making. LCA can also be used for other goals which are beyond the scope of this paper, for example to:

- Test or demonstrate different LCA methods.
- Create a "green" image. Use the fact that LCAs are carried out to indicate that environmental issues are dealt with from a holistic perspective.
- Delay decisions by demanding that a comprehensive LCA is carried out before a decision is made or by using uncertainties in LCA results and discrepancies in LCA methods to show that the issue is more complicated than anticipated.
- Mislead authorities, customers and public opinion through the systematic use of LCA methods that favour a certain product or opinion.

The users of LCA results (decision-makers or others) may have different relations to the allocation procedure. If they are actively involved in the LCA, they may decide on the allocation procedure. If they are not involved in the LCA, they may still be informed about the allocation procedure and, ideally, about the motives for the procedure. In certain cases – e.g. when LCA results are used on an ecolabel which is used as a basis for consumer decisions – the decision makers may even be unaware of the fact that there is an allocation problem.

5 Criteria for the Choice of Allocation Procedures

5.1 Reflection of effect-oriented causality

In a well defined problem, the decision maker knows the outcome, or the outcome probabilities, of the available alternatives (Abelson and Levi 1985). Textbooks on decision theory (see *e.g.* Grubbström 1977) and corporate finance (*e.g.* Brealey and Myers 1984) are based on the recognition that information on the consequences of available alternatives is necessary to make a rational decision. This recognition can be applied to LCA: to be an efficient support for a decision, LCA results should reflect the environmental consequences of that decision. If the decision affects inflows or outflows of cascade material, the LCA results should reflect the consequences of these changes. Using the terminology above, the allocation procedure should be based on effect-oriented causal relationships.

To generate and evaluate good ideas for future decisions, LCA results should indicate the importance of different improvement options. This means that the consequences of different actions should be indicated. If the most important environmental improvements are obtained through increased use of recycled material, this should be reflected in the LCA results. Consequently, it is an advantage if the allocation procedure is based on effect-oriented causal relationships.

The effect-oriented criterion is not relevant for dealing with inflows and outflows of cascade material which are unaffected by the decision(s) supported by the LCA. Neither is it relevant if the LCA is carried out without the aim of affecting decisions. As an example, consider an LCA carried out to support a choice between raw materials for a product. The packaging used for the product is unaffected by this choice of raw material. If the packaging is recycled after use, the effect-oriented criterion does not apply to the choice of allocation procedure for the recycling.

5.2 Acceptability

The results of an LCA are only effective in a decision situation when the decision makers feel that the results are relevant. This requires the use of allocation procedures in the study which are acceptable to the decision makers (if it is known to them). The animated debate concerning allocation indicates that acceptability is an important criterion. This does not imply that decision makers should be allowed to arbitrarily chose allocation procedures that confirm their prejudices. In fact, such procedures are probably not efficient for investigating what options are the best for the environment. Instead, acceptability can (and we believe it should) be obtained through explaining the motives for the choice of allocation procedure. A strong motive can be that the procedure is well founded on physical and/or social sciences. Another strong motive can be that the procedure is widely accepted among LCA experts. Such an acceptance can be reflected in, for instance, recommendations from ISO (or SETAC or an other important body). The acceptability is also likely to be enhanced if the procedure is well established in practise.

If the users of LCA results cannot be informed about the motives for the allocation procedure, the procedure is more easily accepted when it is intuitively reasonable or fair. If the users can be informed, it is more easily accepted when the procedure and its motives are easy to communicate and understand.

5.3 Applicability

Regardless of the goal of the LCA, the allocation procedure must be feasible. LCA practitioners have an interest in the allocation procedure being readily applicable. The commissioning party of an LCA also has an interest in reducing the cost and time demands related to the LCA. This means it is an advantage if the amount of information needed for the allocation procedure is small and the necessary data are easy to collect and interpret.

Applicability is especially important when the LCA is focused not only on recycling but on other aspects of the life cycle as well, such as when the study goal is to generate ideas for future decisions regarding the product investigated.

6 Methods Reflecting Effect-Oriented Causality

To account for all effects of a decision, system boundaries must be expanded to include all processes affected by the decision, also taking indirect effects of economic and social forces into account. This is the socio-economic, whole-system approach described by TILLMAN *et al.* (1994). The approach is likely to result in very large systems. TILLMAN *et al.* (1994) state that strict application of this approach is probably only rarely feasible.

A technological whole-system (TWS) includes all processes affected by the investigated decision, assuming that the demand for the functions fulfilled by the systems is not affected by the decision (TILLMAN *et al.* 1994). A TWS is a simplification of the socio-economic whole-system. The effects of inflows and outflows of cascade material on the demand for other products are neglected. The TWS is a good approximation of the socio-economic whole-system if these effects are small.

Strict application of the TWS approach may also result in large and complex systems. The following examples refer to **Figure 1**:

- When material from P1 is recycled into P2, more material may be needed in P2 to fulfil the same function, *i.e.* the weight of P2 may be increased. This affects the environmental impacts of transporting P2 and of waste management. This should be accounted for in a TWS analysis of P1.
- When material from P1 is recycled into P2, the material quality in P2 may be reduced. This may reduce the probability that P2 will be recycled after use. This should also be accounted for in a TWS analysis of P1.
- When material from P1 is recycled into P2, other material is replaced. This may be virgin or recycled material of the same type or a completely different material. A TWS analysis of P1 should include all savings in terms of avoided virgin material production.
- The replaced material may also be recycled material from other products. This means the recycling rate of other products may be reduced, *i.e.* final waste management of these products is increased. These effects should also be accounted for in a TWS analysis of P1.
- When material from P1 is recycled into P2, there may be final waste management savings of P1. The waste management savings should be accounted for in a TWS analysis of P2.
- If material from P1 was not recycled into P2, it might have been recycled into other products. If so, the weight and recyclability of these products may be affected. Virgin material or other recycled material would be replaced. These effects should also be accounted for in a TWS analysis of P2.

The systems can be reduced by deciding to ignore small effects.

7 Intuitively Reasonable or Fair Methods

It is difficult to state what procedure is most reasonable or fair, since these are subjective evaluations. What procedures are considered to be reasonable or fair is likely to depend on the perspective of the individual. This section presents eight different perspectives and allocation procedures that can be considered fair from each perspective, but it is probably not exhaustive.

1. Man-made materials are valuable resources. Virgin material production is necessary to obtain this resource. The recycling process is needed because the quality of material after use is too low to be used again without upgrading.

From this perspective, the following allocation based on reductions in material quality may seem fair:

$$L1 = \frac{Q1\text{-}Q2}{Q1} \bullet V1 + R1 \quad (1)$$

$$L2 = \frac{Q2\text{-}Q3}{Q1} \bullet V1 + R2 \quad (2)$$

$$L3 = \frac{Q3}{Q1} \bullet V1 + W3 \quad (3)$$

Where L1 are the impacts allocated to P1, L2 are the impacts allocated to P2 and L3 are the impacts allocated to P3. Q1 is the quality of the material in P1, Q2 is the material quality of P2 and Q3 is the material quality of P3. The environmental impacts of production and use of the products are not included in these equations since they are not part of the allocation problem (see above).

This method has been suggested by KARLSSON (1994). It has been recommended by the Swedish Product Ecology Project and used in the EPS system (Environmental Priority Strategies in Product Design; RYDING *et al.* 1995).

2. Man-made materials are valuable resources. Virgin material production and final waste management are both necessary to obtain this resource. The recycling process is needed because the quality of material after use is too low to be used again without upgrading.

From this perspective, the following allocation based on reductions in material quality may seem fair:

$$L1 = \frac{Q1\text{-}Q2}{Q1} \bullet (V1+W3) + R1 \quad (4)$$

$$L2 = \frac{Q2\text{-}Q3}{Q1} \bullet (V1+W3) + R2 \quad (5)$$

$$L3 = \frac{Q3}{Q1} \bullet (V1+W3) \quad (6)$$

This method is presented, used and recommended by the Danish EDIP project (Environmental Development of Industrial Products; WENZEL *et al.* 1996).

3. Virgin material production, final waste management and recycling are all necessary to facilitate the combined functions of the material.

From this perspective, the following allocation based on material quality may seem fair:

$$L1 = \frac{Q1}{Q1+Q2+Q3} \bullet (V1+R1+R2+W3) \quad (7)$$

$$L2 = \frac{Q2}{Q1+Q2+Q3} \bullet (V1+R1+R2+W3) \quad (8)$$

$$L3 = \frac{Q3}{Q1+Q2+Q3} \bullet (V1+R1+R2+W3) \quad (9)$$

Alternatively, it may be fair to use the usefulness or the economic value of the products as a basis for the allocation. It may also be fair to base the allocation on quality reduction instead of material quality.

4. Since all material will end up as waste, final waste management is an inevitable consequence of material extraction from the biosphere or geosphere.

From this perspective, the following extraction-load allocation may seem fair:

$$L1 = V1 + W3 \quad (10)$$

$$L2 = R1 \quad (11)$$

$$L3 = R2 \quad (12)$$

This method is discussed by ÖSTERMARK and RYDBERG (1995). It promotes use of recycled material as long as the environmental impacts of recycling are less than the combined impacts of virgin material production and final waste management. However, this method gives no incentive to the development and production of recyclable products.

5. To avoid reductions in the amount of material available in the technosphere, material lost from the technosphere must be replaced through virgin material production.

From this perspective, the following disposal-load allocation may seem fair:

$$L1 = R1 \quad (13)$$

$$L2 = R2 \quad (14)$$

$$L3 = V1 + W3 \quad (15)$$

This method is also discussed by ÖSTERMARK and RYDBERG (1995). It is similar to the method suggested by FLEISCHER (FLEISCHER 1994, KLÖPFFER 1996).

The disposal-load method promotes development and production of recyclable products when the environmental impacts of recycling are less than the combined impacts of virgin material production and final waste management. It gives no incentive to use recycled material, however.

6. Supply and demand for recycled material are both necessary to enable recycling.

From this perspective, the following 50/50 method may seem fair:

$$L1 = \frac{V1\text{-}W3}{2} + \frac{R2}{2} \quad (16)$$

$$L2 = \frac{R1\text{-}R2}{2} \quad (17)$$

$$L3 = \frac{V1\text{-}W3}{2} + \frac{R2}{2} \quad (18)$$

This method is presented in an earlier paper (EKVALL 1994). It is recommended for "key issue identification" in the Nordic Guidelines for LCA (LINDFORS *et al.* 1995). It promotes the use of recycled material as well as the production of recyclable products when the environmental impacts of recycling are less than the combined impacts of virgin material production and final waste management.

7. Each product should be assigned *all* the environmental impacts caused by the product.

From this perspective, it may seem fair to use a good approximation of the socio-economic whole-system method (see above).

8. Each product should only be assigned the environmental impacts *directly* caused by that product.

From this perspective, the cut-off method may seem fair, for instance:

$$L1 = V1 \tag{19}$$

$$L2 = R1 \tag{20}$$

$$L3 = R2 + W3 \tag{21}$$

In this simple example all impacts of recycling processes are allocated downstream in the cascade. As a refinement, part of the recycling processes may be allocated upstream. The allocation of a recycling process may be based, for example, on the gross sales value of the waste management service and the recycled raw material (Huppes 1994).

8 Easily Applicable Methods

Of the methods discussed in this paper, the simple cut-off method (equations 19-21) is the easiest to apply. No data from outside the life cycle of the investigated product are necessary. For the elaborated cut-off method, economic data on the recycling processes are necessary when allocation of these processes is based on the economic value of the waste management service and the material produced.

Most other methods are likely to demand data on virgin material production, even if the investigated product is produced from 100% recycled material. They are also likely to demand data on final waste management, even if the investigated product is recycled to 100%.

To apply methods based on reduction in material quality (*e.g.* equations 1-3 and 4-6), the products that receive recycled material from the investigated product must be known. These methods also demand data on material quality (Q) in the investigated product and in the receiving products. Material quality can be difficult to define and measure because it is a complex concept. Different quality aspects are important for different products. The cascade material, for example, can be recycled from a product where elasticity is the most important material aspect to a product where strength or corrosion resistance is more important. Various attempts have been made to define material quality (*e.g.* Karlsson 1995, Wenzel 1996). No definition has been agreed upon internationally. In many cases, the price of the material may be an adequate quality measure.

The method illustrated in equations 7-9 demands data on the number of products in the cascade and on the material quality in all these products.

As stated above, a strict application of the whole-system approaches demands data for a large number of processes outside the investigated product life cycle.

To get accurate data, the specific processes (V1, R1, R2, W3, etc.) must be known. If accurate information cannot be obtained, general data or estimates can be used or assumptions can be made. This, however, is likely to increase the uncertainty of the results.

9 Discussion, Conclusions and Future Outlook

9.1 Discussion of system levels

Since recycling processes are multi-function processes, allocation at the level of the recycling process can be performed with methods designed for multi-function processes. If such a method is used to allocate the impacts of the recycling processes, the allocation procedure does not include virgin material production and final waste management. The procedure is similar to the elaborated cut-off method. The cut-off method in general has certain advantages: it is well established in practise and relatively easy to apply. However, it does not reflect the effects of cascade material flows on virgin material production and final waste management.

The socio-economic or technological whole system approaches can be applied on the level of the recycling process. This means that system boundaries are expanded to include waste management, virgin material production, etc. which are affected by the recycling process. This is equivalent to applying socio-economic or technological whole-system approaches on the cascade level.

The level of the product life cycle has the same drawbacks as the recycling process level: allocation of the impacts of the investigated product life cycle does not reflect the effects of cascade material flows to and from the life cycle. Furthermore, allocation on this system level is not well established in practice. Application of socio-economic or technological whole-system approaches is equivalent to application on the cascade level.

The cascade level is the only level where virgin production and final waste management are always included in the system. This means it may be possible to find or develop allocation methods on the cascade level that reflect the effects of cascade material flows. For this reason, we believe that the cascade level is the most *adequate* system level for dealing with open-loop recycling.

We also believe that the cascade level is the most *relevant* system level to deal with open-loop recycling. This opinion is based on the recognition that cascade materials are multifunctional materials which fulfil more than one function before final waste management.

9.2 Criteria for good allocation procedures

There are clearly different criteria for good allocation procedures. If the goal of the LCA is to support decisions that affect inflows or outflows of cascade material, it is important that the procedure be *based on effect-oriented causalities*. This is also an advantage when the goal of the LCA is to generate and evaluate ideas for future decisions.

It is generally important that the allocation procedure is *acceptable* to the decision makers using the LCA results. It is also an advantage if the procedure is *easy to apply*.

Each criterion is fulfilled by different allocation procedures. We have not been able to identify any procedure which fulfils all the criteria. In fact, the applicability criterion seems to be in conflict with the criterion that effect-oriented causalities should be accurately reflected. The socio-economic whole-system method provides the most accurate reflection of the consequences of the inflows and outflows of cascade material, but it is probably only rarely feasible. The simple cut-off method is the easiest to apply but it does not reflect the full consequences of the outflows and inflows. The conflicting criteria are probably part of the explanation as to why it is difficult for the international LCA community to agree on what allocation procedure is the best.

The consequences of cascade material flows may be important for a decision when the decision has major effects on the cascade material flows. If the decision has little effect on these flows, their consequences are correspondingly less important. This means that the accurate reflection of effect-oriented causalities is more important in some LCA applications than in others. This is also true for the applicability criterion. As stated earlier, the applicability of the allocation procedure is especially important in certain LCA applications, *e.g.* when the aim of the LCA is to generate ideas for future decisions. The importance of applicability also depends on the total resources available for the LCA, which vary from case to case.

The conclusion is that different criteria are important for different LCA applications. We have also found that it is difficult to identify a single allocation procedure that is both easy to apply and also gives an accurate reflection of effect-oriented causalities. This indicates that there is indeed a connection between the goal of the study and the method that should be used. Different allocation procedures will probably be appropriate for different LCA applications.

When the aim of the LCA is to support a decision that affects an inflow or outflow of recycled material to or from the life cycle of the investigated product – or when the aim is to generate and evaluate ideas for future decisions that might affect such a flow – the criteria presented in this paper can assist in identifying an appropriate allocation procedure for dealing with this flow. In principle, the most appropriate procedure can be defined as the one acceptable procedure which results in the most accurate reflection of the environmental consequences of the decision(s) while being feasible within the framework of the study. In practise, we believe that considered judgement and professional experience will be needed to weigh the importance of accuracy and feasibility against one another. As stated earlier, acceptability can be based on scientific foundations, *e.g.* on our criteria. It can also be based on acceptance in or recommendations from expert fora.

The relation between the study goal and the allocation procedure is not recognised in the ISO draft, where the same ranking order of allocation procedures is recommended for all LCA applications (ISO 1996). This means that the recommendations do not fulfil the early SETAC criterion that the procedure should be consistent with the study goal (SETAC 1993).

9.3 The need for further development

To make LCA a more efficient tool for decision support, feasible allocation procedures should be developed that reflect the consequences of inflows and outflows of cascade material. Such procedures may be simplified TWS approaches and/or allocation methods which approximate the whole-system approaches.

Since different criteria are important for different applications, it would be useful to develop a library of allocation procedures for use in different LCA applications. These procedures should put different emphasis on applicability and accuracy. They might range from the simple cut-off method to fairly complex whole-system approaches.

To ensure that the new allocation procedures are acceptable to the decision makers using the LCA results, they should be based on physical and/or social sciences; they should be tested and demonstrated in many case studies; they should be discussed in international fora for LCA harmonisation and standardisation. It is also an advantage if they are intuitively fair or reasonable and/or easy to communicate.

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New Reports

Guidelines for Pulp and Paper LCA

A joint Nordic project has been conducted with a view to developing and documenting a methodology for the collection, processing and reporting of data, in such a way that Life Cycle Assessment (LCA) of forest industry products can be performed and combined in the same way. The work considers all steps from forestry to paper production, including transportations and recycling. It builds upon the methodological development and harmonization presented in the Nordic Guidelines on LCA. It also utilizes the more recent developments within the SETAC-Europe working group on Inventory Enhancement.

The project has been carried out by STFI and KCL (the Swedish and Finnish pulp and paper research institutes) and by Chalmers Industriteknik. The report from the project includes four parts which deal with the items considered to be most important in setting up a Life Cycle Inventory Analysis. These are:

- parameters and units
- data quality
- system boundaries
- allocation.

Within the section on parameters and units, a list has been compiled of the relevant variables relating to resources (materials and energy), emissions to air and water, and waste. The section establishes which units are appropriate for use with the proposed parameters. Also included are definitions of functional units and requirements for additional data.

The section on data quality deals with the demands that can be imposed on the data used in an inventory. These demands may relate to data acquisition, references, age of data, representativeness, and geographical and technical correlations. A method has been developed for the quantitative expression of data quality in relation to the different demands.

The section on system boundaries focuses on production of electricity and fuel and chemicals. The significance of chemical production is illustrated by an example. The section on allocation includes several examples with the purpose to demonstrate different allocation methods. A ranking order for the best methods of dealing with allocation is proposed.

The title of the report is "Guidelines on Life Cycle Inventory Analysis of Pulp and Paper" (report No. NORDPAP/DP2/30). It can be ordered without charge from Nordisk Industrifond, Nedre Vollgatan 8, N-0158 Oslo, Norway (tel. +47-22 41 64 80; fax. +47-22 41 22 25), from CIT, Chalmers Teknikpark, S-412 88 Gothenburg, Sweden (fax. +46-31-82 74 21; e-mail tomas.ekvall@cit.chalmers.se), from STFI, Box 5604, S-114 86 Stockholm, Sweden (tel. +46-8-67 67 000; fax. +46-8-411 55 18), or from KCL, P.O. Box 70, FIN-02151 Espoo, Finland (tel. +358-9-437 11; fax. +358-9-46 43 05).

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