THESIS FOR THE DEGREE OF LICENTIATE OF ENGINEERING

Industrial Management of Environmental Data

Suggested procedures for internal allocation based on stakeholder needs

OLA SVENDING

Environmental Systems Analysis
CHALMERS UNIVERSITY OF TECHNOLOGY
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Chalmers University of Technology
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Chalmers University of Technology
SE-412 96 Göteborg
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Abstract

As society increases its focus on environmental issues, demand for environmental data from industry has also increased. The recent introduction of product related environmental information has placed new demands on industrial environmental data management. The Swedish pulp and paper industry needs to manage environmental data more efficiently and effectively with regards to stakeholders, environmental tools, and communication formats. For reasons of credibility and comparability, there is a need for an industry-wide consensus on how to harmonize calculation rules for product related environmental information. This thesis suggests methods the pulp and paper industry can use for handling internal allocation based on stakeholder needs.

The commitment and cooperation of Stora Enso has enabled case studies at production sites, and these have been the basis for this thesis. The nature of the thesis means that its findings should be easily adopted by the pulp and paper industry, and by other processing industries.

In the pulp and paper industry, the main internal uses of environmental data are for monitoring and controlling environmental performance. Externally, it is used in areas such as marketing and other communications. In supplying stakeholders with environmental information, many internal functions handle data. It is suggested here that thorough documentation of information content will minimize the risk of misinterpretation, and that a structure of areas of responsibility will reduce overlapping work. Documentation of information also facilitates the reuse of environmental data in new applications.

Possibilities for avoiding internal allocation by sub-division are presented together with suggested methods for managing some of the remaining multi-functional processes, including wood room, recovery boiler, mechanical pulping, combined heat and power plant and wastewater treatment. Different bases for allocation can be used to handle the multi-functional processes, for example economic value (or estimates thereof), exergy, or energy content. Criteria for selecting the suggested internal allocation methods intentionally focus on feasibility, acceptability and relevance, both for the pulp and paper industry and its stakeholders.

Flexibility in the environmental information system is needed to enable communication to new stakeholders, of new issues, and for new organizational structures. An organization needs to establish far-sighted monitoring of upcoming issues to enable the re-design of its information system.

Key words: internal allocation, multi-functionality, pulp and paper industry, forest products, life cycle assessment, stakeholders, environmental tools, environmental communication formats, environmental information flows.

List of appended papers

This thesis is based on the following appended papers.

I. Environmental Data Management: Stakeholders, tools and information flows in the Swedish pulp and paper industry.
Svending, O., Tillman, A-M and Bresky, J. Manuscript submitted in 2003.

II. Suggested methods for internal allocation in the Swedish pulp and paper industry.
Svending, O., Tillman, A-M and Bresky, J. Manuscript submitted in 2003.

Preface and acknowledgement

In 1999, Jan Bresky introduced me to Anne-Marie Tillman. Shortly thereafter, Jan introduced me to the idea of entering into a project that could lead to a Licentiate degree in engineering. I was offered the opportunity to continue working full time at Stora Enso, but conduct research in 50% of that time as an industrial Ph. D. student at Chalmers University of Technology. Two years earlier I had finished my Master of Science degree in Environmental Engineering at Luleå University of Technology, and going back to school was not my first priority. However, the outline for the project was tempting and after some thinking I agreed to do just so!

Conducting a large long-term project some 300 km away from home and my Stora Enso office has not been a walk in the park. For four years I have for instance spent more time just riding the train back and forth between Karlstad and Göteborg, than on vacation.[1] For very few periods was I able to achieve the agreed-upon 50% research time: I simply found other shorter-term projects to be more prioritized. Still, I believe working as an industrial Ph. D. student is a privilege that has given me an optimal combination of industrial and academic experience. Another experience I share with fellow industrial Ph. D. students the possibility of quickly transferring knowledge between the industrial and academic worlds.

I would like to thank Professor Anne-Marie Tillman for being an excellent co-author and supervisor. The many discussions with Anne-Marie throughout the project have been of tremendous help.

Those who know Jan Bresky know of his rich flow of ideas and visions. Thanks to one of these, I got the opportunity to run this project. I especially appreciate Jan for supporting me, and teaching me to look beyond the hurdles ahead.

Stora Enso is gratefully acknowledged for financing this project.

The staff at Environmental Systems Analysis, Chalmers University of Technology, have inspired me and treated me as a colleague, though I every now and then have appeared out of nowhere.

Finally (but definitely not least) I thank my wife Marie for not only putting up with all the time I have spent away from home during this project, but also giving birth to Hugo, our truly wonderful son!

[1] Please note that the typical Swedish vacation is five weeks!

Glossary

Allocation, partitioning the input or output flows of a unit process to the product system under study (ISO, 2002).

Benchmarking, the search for the best practices among competitors or non-competitors that lead to their superior performance (Robbins and Coulter, 2002).

Causal relationship, a relationship that relates to a cause, or a reason for an action or condition (Merriam-Webster, 2003).

Characterization factor, factor derived from a model which is applied to convert "LCI results" to the common unit of the "life cycle impact category indicator" (ISO, 2002).

Chemical pulp, pulp produced in a process where the fibers are released by heat and chemicals.

Chemi-thermo-mechanical pulp (CTMP), mechanical pulp enhanced by using steam and chemicals.

Controlling, management function that involves monitoring actual performance, comparing actual performance to the standard, and taking action if necessary (Robbins and Coulter, 2002).

Environmental aspect, element of an organization's activities, products or services that can interact with the environment. A significant environmental aspect is one that has or can have significant environmental impact (ISO, 2002).

Environmental communication format, format for communicating environmental data and/or information.

Environmental declaration, claim that indicates the "environmental aspects" of a product or service (ISO, 2002).

Environmental impact, any change to the environment, whether adverse or beneficial, wholly or partially resulting from an organization's activities, products, or services (ISO, 2002).

Environmental label, claim which indicates the "environmental aspects" of a product or service (ISO, 2002).

Environmental management system (EMS), part of the overall management system that includes organizational structure, planning activities, responsibilities, practices, procedures, processes and resources for developing, implementing, achieving, reviewing, and maintaining the environmental policy (ISO, 2002).

Environmental objective, overall environmental goal, arising from the environmental policy, that an organization sets itself to achieve, and which is quantified where practicable (ISO, 2002).

Environmental product declaration, see, "type III environmental declaration".

Environmental report, "environmental communication format" defined by and periodically sent to Swedish local authorities to confirm a production site's compliance with environmental laws and permits.

Environmental statement (EMAS report), "environmental communication format" used by EMAS-registered production sites to inform the public of its "environmental impacts", environmental performance, and continual improvements (EMAS, 2001).

Environmental targets, detailed performance requirement, quantified where practicable, applicable to the organization or parts thereof, that arises from the "environmental objectives" and that needs to be set and met in order to achieve those objectives (ISO, 2002).

Environmental tool, procedure that transforms environmental data into useful information according to a defined format.

Exergy, an energy measure that weights the energy according to its quality. Energy cannot be destroyed, but its quality (exergy) is degraded as the entropy increases.

Impact category, class representing environmental issues of concern to which LCI results may be assigned (ISO, 2002).

Integrated product policy (IPP), the European Commission's initiative to minimize the "environmental impacts" caused by a product, by looking at all phases of a product's life cycle. IPP attempts to stimulate each part of these individual phases to improve their environmental performance (IPP, 2003).

Life cycle assessment (LCA), compilation and evaluation of the inputs, outputs, and potential "environmental impacts" of a product system throughout its life cycle (ISO, 2002).

Life cycle impact assessment (LCIA), phase of "life cycle assessment" aimed at understanding and evaluating the magnitude and significance of the potential "environmental impacts" of a product system (ISO, 2002).

Life cycle impact category indicator, quantifiable representation of an "impact category" (ISO, 2002).

Life cycle interpretation, phase of "life cycle assessment" in which the findings of either the inventory analysis or the impact assessment, or both, are combined in accordance with the defined goal and scope in order to reach conclusions and formulate recommendations (ISO, 2002).

Life cycle inventory result (LCI result), outcome of a life cycle inventory analysis that includes flows crossing the system boundary and provides the starting point for "life cycle impact assessment" (ISO, 2002).

Lignin, polymeric compound that binds fibers together in wood. In "chemical pulp" processes, lignin is removed from the fiber and in "mechanical pulp" processes the lignin stays with the fiber.

Mechanical pulp, pulp produced in a process in which the fibers are released by mechanical work.

Multi-functional process, process which generates (or in the case of waste treatment – handles) two or more products/co-products.

Self-declared environmental claim, environmental claim made, without independent third-party certification, by manufacturers, importers, distributors, retailers or anyone else likely to benefit from such a claim (ISO, 2002).

Stakeholder, any constituency in the environment affected by an organization's decisions and policies and that/who can influence the organization (Robbins and Coulter, 2002).

Supercalendered (SC) paper, paper which properties are mechanically enhanced by treatment with steel rollers at the end of the production process.

Sustainable development, development meeting the needs of the present without compromising the ability of future generations to meet their own needs (WCED, 1987).

System expansion, expansion of the modeled production system to include additional functions related to co-products and thereby avoiding allocation (ISO, 1998).

Thermo-mechanical pulp (TMP), pulp produced by a mechanical pulping process enhanced by using steam.

Type III environmental declaration, quantified environmental data for a product with preset categories of parameters based on the ISO 14040 series of standards (ISO, 2002).

Value chain, the entire series of organizational work activities that add value at each step beginning with the processing of raw materials and ending with the finished product in the hands of end users (Robbins and Coulter, 2002).

Table of content

1 Introduction

Requests for environment-related information literally flood companies, and stakeholders seem to be constantly inventing new formats for environmental information. The recent focus on the environmental performance of specific products, driven by initiatives such as the EU's forthcoming Integrated Product Policy directive (IPP, 2003), rather than on location-specific emissions. This places new demands on an organization's knowledge of its own processes and products, and on cooperation throughout the product's value chain. To meet these demands, companies must not only continuously improve environmental performance, but also make their handling of environmental data more efficient and effective.

It is not enough for companies to handle environmental data efficiently and effectively: building credibility among their customers and other stakeholders is equally important. For a company and an industry sector, this means being able to handle environmental data transparently and stringently for a number of applications, such as life cycle assessment, and reporting to authorities. Stringent handling includes creating harmonized calculation rules for specific environmental communication formats. This study contributes to this effort by empirically mapping a production site's existing and needed systems. One identified need was for a procedure for handling multi-functional processes through allocation. A set of calculation rules for allocation were therefore suggested for harmonization both in Stora Enso in particular, and in the pulp and paper sector in general.

1.1 Goal

The overall goal of this project was to suggest methods for internal allocation in the pulp and paper industry. The suggested methods can later be a basis for a consensus process within, for example, the Swedish Forest Industries Federation[2]. In order to establish the suggested methods for internal allocation, a mapping of the existing stakeholders of the Swedish pulp and paper industry was first undertaken, along with their perceived need for environment-related information, and the environmental tools used to provide them with that information. The mapping also included the flows of environmental data in the organization to find potentials for more efficient and effective environmental data handling.

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[2] The Swedish Forest Industries Federation is the organization that represents the Swedish pulp and paper industry sector. For more information see www.forestindustries.se (visited Nov. 12, 2003).

1.2 Background

The project leading to this licentiate thesis developed partly in parallel with another project, named the SFIF/CPM project after its participants: SFIF, the Swedish Forest Industries Federation and CPM, the Centre for Environmental Assessment of Products and Material Systems[3] at Chalmers University of Technology. The SFIF/CPM project developed methods for improved management of environmental data. To facilitate this, the Swedish pulp and paper industry's stakeholders, and the tools and communication formats used to provide them with the requested information, were mapped (Svending, 2001).

As the SFIF/CPM project was winding up, it identified the need for harmonized calculation rules to generate product-specific environmental data. The conclusion was that the ISO standard describing allocation (ISO, 1998) was too open to be used as calculation rules. The later part of this licentiate project (Svending, 2002 and Svending et al., 2003b) provides input on how to deal with allocation in the specific processes of the pulp and paper industry.

1.3 Pulp, paper, and board production

For many people, paper is just paper. For others, the diversity of pulp, paper, and board production methods, their combinations and the subsequent products seem endless. The following section presents a brief introduction to some common pulp and paper production methods, based on information from the Finnish forest industries federation (FFIF, 2003).

First, what is paper and what is board? Paper is a single-layer fiber-based product weighing 25-300 g/m^2 (grams per square meter). Board is manufactured using a multi-layer technique, and it commonly weighs between 170 and 600 g/m^2. Generally paper is used for printing and board for packaging.

Paper is used for a number of applications. Wood-containing paper grades include newsprint, uncoated magazine paper (supercalendered, SC), and coated magazine paper (lightweight coated, LWC). These are called wood-containing papers since they are produced mainly from mechanical pulps. Wood-free printing papers, or fine papers, on the other hand contain mainly chemical pulps. These include uncoated and coated fine papers. Other paper grades include packaging papers, tissue, and label papers. Most of these paper grades can be produced from virgin fiber, recycled fiber, and combinations thereof.

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[3] For more information about CPM see www.cpm.chalmers.se (visited Nov. 12, 2003).

Board for packaging can be manufactured from combinations of chemical pulp, mechanical pulp, and recycled fibers. Board can be divided into several main categories according to their intended use: Raw materials for corrugated board, carton boards for boxes (such as liquid packaging boards), and graphic boards for cards, files, and folders.

1.3.1 Chemical and mechanical pulp production

In the chemical pulping process, wood fibers are separated from each other by dissolving the lignin (the substance holding them together) with chemicals and heat. The dissolved lignin and the chemicals are recovered in terms of both energy and material. Because of the manufacturing process, the pulp obtained is known as chemical pulp. In the Nordic countries, the most common chemical pulp is sulfate pulp, and the most common raw materials are pine and birch.

In mechanical pulping, wood fibers are separated from each other through mechanical work. Since mechanical pulps contain lignin, the wood yield for mechanical pulps are about twice as high compared to chemical pulps where the lignin is combusted to generate steam. Mechanical pulp is made in two ways: refining and grinding. In the refining method, the raw material is wood chips, which are ground into pulp between refiner discs. The efficiency of this process can be improved by using steam (thermo-mechanical pulp, TMP) and chemicals (chemi-thermo-mechanical pulp, CTMP). The raw material used in the grinding process consists of debarked logs. These are then pressed against a rotating grindstone (ground wood pulp).

De-inking is a process that utilizes recycled paper to produce pulp. In this process printing ink and other impurities are removed from the recycled paper by means of washing and screening.

Figure 1 presents a schematic process flowchart of the production of chemical, mechanical, and de-inked pulps.

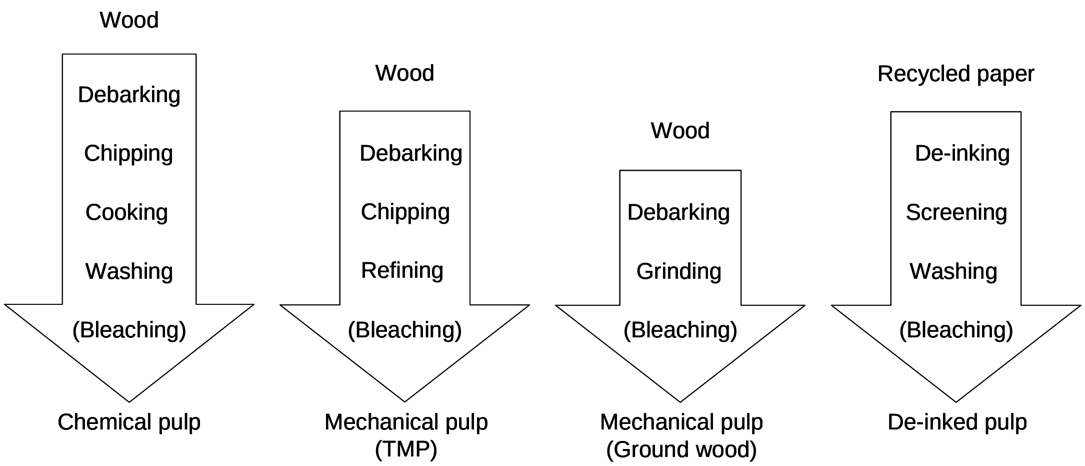


Figure 1 Schematic process flowcharts for the production of chemical pulp, thermo mechanical pulp, ground wood pulp, and de-inked pulp (after FFIF, 2003).

1.3.2 Paper and board production

Paper may consist of only chemical or mechanical pulp, but usually both are used together. De-inked pulp obtained from recycled paper can also be used in paper production. Various filling and coating agents, such as clay, carbonate, and talc are also needed in paper production.

Paper production begins when pulp and additives are mixed with water. This mixture is then spread on a moving plastic mesh belt that allows water to pass through (wet end). As water is gradually removed in successive pressing and drying steps, a paper web is formed. The quality and properties of the paper can be altered by glazing it with a calender or by using a coating machine that spreads coating pigments on the paper surface. Finally, the paper web is dried and wound into reels, which are then cut into smaller reels or sheets of suitable size for converting.

Board is made largely the same way as paper. The difference is that most boards are multi-layered, thus the wet end of a board machine has as many web formation units as the final product has fiber layers.

Figure 2 presents a schematic process flowchart of paper production.

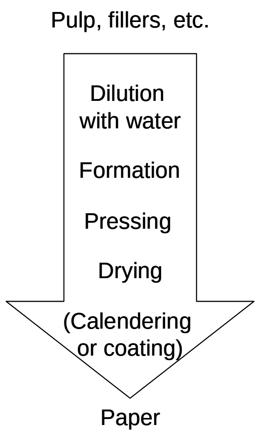


Figure 2 Schematic process flowchart for the production of paper (after FFIF, 2003).

1.4 LCA methodology

Life cycle assessment, LCA, is an internationally standardized method for assessing a product's environmental aspects throughout its life cycle. Typically this includes the relevant phases from raw-material extraction, via transportation, production, use, and recycling to final waste treatment – from cradle to grave. LCA methodology includes setting the goal and scope of the study, compiling a life cycle inventory of the inputs and outputs of a product system, evaluating the potential environmental impacts associated with the inputs and outputs, and interpreting the results of the inventory analysis and impact assessment phases in relation to the objectives of the study (ISO, 1997).

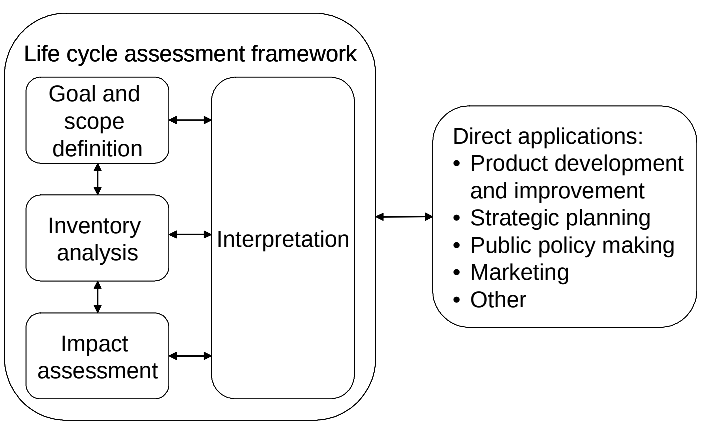


Figure 3 Phases of a LCA (ISO, 1997).

Some of the first approaches to LCA dated from the early 1970s under names such as Resource and Environmental Profile Analysis, Energy Analysis, and Product Ecobalance (Guinée et al., 2002). Since then LCA methodology has been, and still is being, developed by several international organizations, such as the International Organization for Standardization (ISO, 2003), the Society of Environmental Toxicology and Chemistry (SETAC, 2003), and the United Nations Environmental Programme (UNEP, 2003).

More information on LCA methodology can be found in the ISO 14040-series (ISO, 1997), in handbooks such as Guinée et al. (2002), and textbooks such as Baumann and Tillman (2004). Also, a number of web sites provide useful information on LCA, for example SETAC (SETAC, 2003), US EPA (EPA, 2003), and the EU Life project, DANTES (DANTES, 2003).

1.5 Multi-functionality

Multi-functionality, when a production process results in two or more products (goods and/or services), is a difficulty that needs to be dealt with when generating product-related environmental data. The problem is illustrated in Figure 4, where processes A and D are multi-functional. Many sub-processes at a pulp and paper production site are multi-functional, for example energy production unit generating both heat and power.

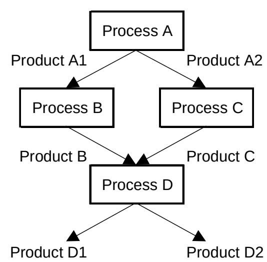


Figure 4 Schematic model of multi-functional processes (A and D).

Multi-functionality has been discussed frequently in the LCA-community (for example Ekvall, 1999 and Weidema, 2001), and a recommended procedure is given in the international standard on LCA (ISO, 1998). According to ISO, multi-functionalities should be avoided either by sub-division or by system expansion. As a later alternative, allocation based on causal relationships can be applied. Within the Swedish pulp and paper industry, sub-division is practiced to generate environmental data with an adequate level of detail and to avoid some multi-functionalities. For most of the intended applications, such as environmental declarations and benchmarking allocation is perceived to be more appropriate than system expansion.

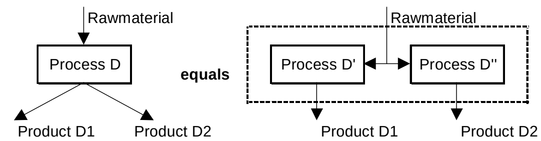


Figure 5 The multi-functionality of process D can sometimes be avoided by dividing process D into processes D’ and D’’ (based on Ekvall and Finnveden, 2001).

Figure 5 presents a method for increasing the level of detail in the model of the technical system, which is consistent with the first step of avoiding multi-functionalities in ISO (1998).

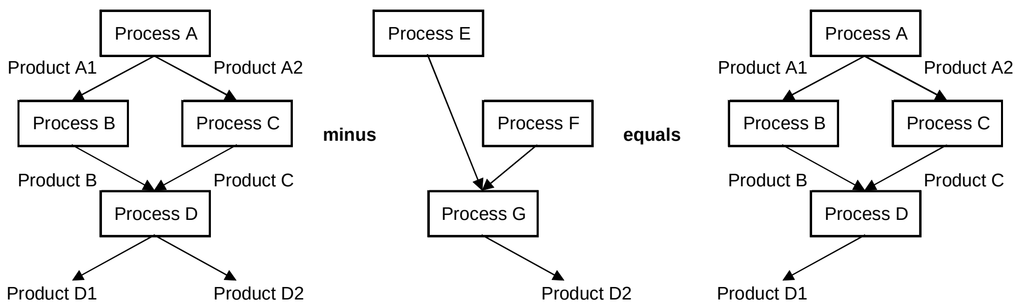


Figure 6 Schematic model of system expansion. Note that co-product D2 is excluded in the right-most part of the figure.

Figure 6 presents system expansion in a schematic way, where process D is a multi-functional process. System expansion implies that an alternative production system for co-product D2 can be subtracted from the original production system to achieve the environment-related flows for the studied product (D1) only.

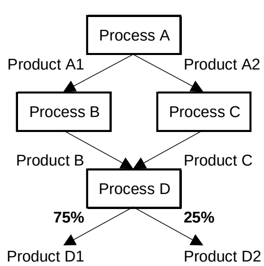


Figure 7 Schematic model of allocation through partitioning.

Figure 7 presents the basics of allocation through partitioning. Allocation implies that the environment-related flows of a multi-functional process are partitioned by each of the multiple products based on the products’ economic values, estimations thereof, or other relationships (i.e. physical ones). These relationships can then yield a percentage (as in Figure 7) that can be used for the basis for allocation.

The choice between system expansion and allocation is only one of many methodological choices LCA practitioners face. Tillman (2000) claims these choices should be based on the perspective to which the study should adapt: prospective or retrospective. System expansion can, for example, be used in studies reflecting the effects of a change in consumption patterns. Allocation, on the other hand, can be used to derive data on the potential environmental effects accounted for by a specific product. The two perspectives and some of the methodological choices related to them appear in Table 1.

Table 1 Characteristics of prospective and retrospective LCAs (after Tillman, 2000).

	Prospective LCA	Retrospective LCA
System boundaries	Includes only the affected parts of the system.	Complete picture of the studied product, and possibility of adding other products to a studied system.
Managing multi-functionalities	Reflecting effects of a change, e.g., through system expansion.	Allocation reflecting the causes of a product system.
Choice of data	Marginal data reflecting the relevant changes in the product system.	Average data.
System sub-division	A foreground system is where a change is implemented. Background systems are other systems affected by such change.	Not applicable.

Table 1 presents some characteristics of prospective and retrospective LCA. One of the choices a LCA practitioner needs to make is how to manage multi-functionalities. These choices have to some extent divided the LCA community into three camps. Some authors claim that the prospective view can be applied in most types of life cycle assessments (for example Weidema et al., 1999 and Weidema, 2001), while others claim that the prospective view can be replaced by a retrospective view in most assessments (for example Guinée et al., 2002). Still other authors (for example Tillman, 2000) claim that the scope of the study should determine which perspective and consequently which approach to managing multi-functionalities should be applied. Examples of applications of prospective LCA include assessing the potential environmental impacts of changing consumption patterns and predicting future scenarios. Examples of common application of retrospective

LCA include learning, the identification of possibilities for improvement, and environmental product declarations.

2 Literature review

In the area of information management the terms data and information are sometimes mixed without much thought. Richards and Kabjian (2001) make a distinction between data, information, and knowledge that is useful to bear in mind when reading the following literature review:

- Data is obtained by observing and documenting facts.
- Information is obtained by analyzing and processing data.
- Knowledge requires cognition, experience and understanding.

The following section first looks at the term stakeholder. Then a number of support processes carried out by these stakeholders that require environmental information are presented. These processes are here denoted top-down as they reflect internal and external stakeholders' needs for information. Finally, bottom-up processes are presented, which reflect the organization's environmental aspects and its possibility of generating environmental information from data which is generated by measurements at production plants.

2.1 Identifying stakeholders

In management literature, stakeholders are typically defined as "any constituencies in the organization's external environment that are affected by the organization's decisions and actions" (Robbins and Coulter, 2002). Using this definition a number of stakeholders can be identified, for example:

- Employees
- Customers
- Social and political action groups
- Competitors
- Trade and industry associations
- Governments
- Media
- Suppliers
- Communities
- Shareholders
- Unions

A good relationship with the stakeholders is important for an organization's success. However, some authors claim that traditional definitions of stakeholder result in a focus on human stakeholders at the expense of non-human stakeholders and on future generations. Because they have no voice, the environment and future generations are often ignored in decision making, both at the macro economic level and in firms. Individuals or groups representing the interests of the environment or future generations can, however, be represented in decision-making structures (Jacobs, 1997). Nature both constrains and facilitates business and all human existence, hence the natural environment affects the firm. In some definitions this is sufficient to grant it stakeholder status (Starik, 1995 and Phillips and Reichart, 2000). Jacobs (1997) claims that seeing the environment as a stakeholder is in the interest of future generations, and thereby means for sustainable development.

This thesis and Paper I in particular deal with a specific kind of stakeholders the ones requesting or supplying environmental data. Neither the environment nor future generations have been included as an environmental data stakeholder, although other stakeholders can represent them.

2.2 Support processes using environmental data

Support processes using environmental data are sometimes difficult to distinguish from one another, and may also be partly integrated. One example is the communication of environmental performance facilitated by environmental performance indicators, EPI. When intended for internal stakeholders, the EPIs should reflect the organizations environmental objectives and targets and is thus closely related to the internal environmental controlling process. Common for these top-down processes is a focus on the stakeholder's need for information, rather than on the organization's ability to supply that information. As these support processes develop over time, the organization needs to establish new procedures to manage them.

2.2.1 Controlling

Environmental management requires data for several applications. Internally, many of these relate to the controlling phase of environmental management. The controlling process is a repeating loop of measuring actual performance, comparing it against a defined standard, and taking managerial action. Some communication formats used by the organization to facilitate controlling include environmental aspects and environmental objectives and targets. The main reason for this loop is the desire to achieve the organization's goals and objectives (Robbins and Coulter, 2002). Other reasons to measure an organization's environmental performance include comparing indicators over time to create trends, empowering the environmental policy by monitoring environmental objectives, and allowing benchmarking between companies (Rickhardsson, 1998 and Bartolomeo, 1995).

An increasing number of organizations are implementing environmental management systems. For these organizations the controlling process is integrated into the management system. Environmental management systems are commonly based on and third-party verified according to the ISO standard (ISO, 1996) and the voluntary European environmental management and auditing scheme (EMAS, 2001). Also, environmental performance indicators (EPIs) can be integrated into the management system to allow internal evaluation of an organization’s past and present environmental performance (ISO, 1999a). The choice of EPI depends on its intended use, the organization's environmental policy, and data accessibility.

Balanced scorecard, BSC (Kaplan and Norton, 1992), is an approach for collecting the most essential management controlling parameters in one format. The BSC is often used in a total quality management context to control a variety of issues influencing an organization's goals and objectives. The balanced scorecard typically includes customer, financial, internal business, and innovation and learning perspectives. The scope of one or more of these perspectives can be extended with environmental, or sustainability, controlling parameters. Extended balanced scorecard approaches that include sustainability aspects have been suggested by for example Gminder and Bieker (2002) and Hockerts and O'Rourke (2002).

2.2.2 Communication and reporting

Environmental communication can be aimed at both internal and external stakeholders. One form of communication is environmental reporting to external stakeholders, such as authorities and the public. At the investigated production sites, this reporting is mainly conducted through the mandatory environmental report to authorities and the EMAS statement. Both these communicate the organization's environmental performance.

Environmental performance indicators, EPIs, can also be used for communication. In these cases, the EPIs should be kept simple if intended for stakeholders unfamiliar with the technical properties of the organization (Carlson, 2002). EPIs and similar non-financial indicators tend to be specific for certain industry sectors, or even for certain companies (Evans, 1996).

In addition to the communication of an organization's environmental performance, there is also communication of environmental performance related to specific products. Life cycle assessment is one important tool that generates information on product performance. Formats for this type of communication include environmental labels (ISO, 1999b) and environmental declarations (ISO, 2000). Separate reports from life cycle studies have also been used to communicate with external stakeholders; see, for example, the LCA of newspapers and magazines (Anon., 1998).

A two-way dialogue on issues such as environmental performance is important for an organization in establishing stakeholder respect (Wheeler and Elkington, 2001). However, the case study of this thesis identified few examples of lively dialogue.

2.2.3 Product and process development

The case studies identified several environmental tools used in product and process development; these tools include benchmarking, environmental risk assessment, and life cycle assessment. The literature suggests that these tools can be complemented by the product realization process and design for environment (DfE). Graedel (2001) describes the product realization process, or the gate model, and some of its drawbacks, for example that environmental issues are often omitted due to lack of proper tools. This problem occurs particularly often in the early stages of the process, when concepts are transformed into designs and materials are specified. At these stages coarse prioritization models are needed to avoid faulty designs and related choices. As successive gates are passed, assessments need to be based on more detailed and comprehensive environmental information.

Design for Environment systematically integrates environmental considerations into product and process design. In DfE environmental considerations such as minimizing resource use while maximizing user benefits are integrated with product development (Tischner and Charter, 2001). These approaches generally focus on the assembling industry rather on processing industries, like the pulp and paper industry. DfE and other environmentally aware design approaches, such as, design for recycling (DfR) are frequently described in the literature by authors such as Graedel and Allenby (1997), Fiksel (1996) and Mackenzie (1997). No explicit DfE or DfR approaches were identified in the case study.

2.3 Descriptions of integrated information environmental systems

Integrated environmental information systems focus on an organization's ability to fulfill its stakeholders' requests for information, or to be more precise its ability to collect relevant data and transform it to useful information. Due to this perspective integrated environmental information systems are here called bottom-up approaches. They are also called integrated, since they are designed to manage the demands of several stakeholders' simultaneously. These integrated systems are below divided into two categories: environmental accounting and environmental information systems. Rikhardsson (1998) distinguishes between environmental accounting and environmental information systems, claiming that the former describes the process of handling information, while the latter enables the process by providing suitable hardware, software, etc.

2.3.1 Environmental accounting

Environmental accounting and environmental information systems are sometimes presented together in the literature. Horngren and Foster (1987) describe environmental management accounting as the process of identifying, measuring, accumulating, analyzing, preparing, interpreting, and communicating environmental information to help managers fulfill an organization's environmental objectives. Environmental accounting can supply both internal and external stakeholders with information. External environmental accounting is based on internal accounting, but the amount and degree of detail differs. Environmental accounting is also a tool management can use to achieve goals such as eco-efficiency and sustainability (though environmental accounting does not cover social issues). Eco-efficiency requires information on both the financial impacts of environmental factors and the environmental impacts of the organization. According to Schaltegger and Burritt (2000), there is a tendency for traditional financial accounting and environmental accounting to close in one another, as stakeholders realize that decisions cannot be based on either financial or environmental factors only. Other authors who have examined environmental accounting include Schroeder and Winter (1997), Bartolomeo (1997), and Bennett and James (1997).

2.3.2 Environmental information systems

Carlson and Pålsson (2001) describe a concept, called PHASETS, for creating models of technical systems for handling environmental data. PHASETS comprises six phases, starting with defining an entity for a selected parameter and ending with communicating information between different contexts. The order of implementing the six phases can be reversed to better reflect the previously described top-down approaches. The generality of PHASETS seems to make it usable for establishing an environmental information system for most organizations and applications. This generality, however, means that the concept needs to be adapted to each organization or industry sector implementing it. Pålsson et al. (2002) discusses how PHASETS can be implemented in the forest industry sector.

The Swedish iron and steel industry provides an example of an environmental information system that improves handling of site- and product-related environmental data (Axelsson et al., 2002). Other internal advantages of the suggested environmental information system, described by Axelsson, include quality assurance and traceability, simplified aggregation, and enhanced reusability of basic information in new applications. The suggested system points towards environmental communication formats and applications that require both site- and product-related environmental data, but a detailed description of how the system manages these formats is lacking. Neither does the report describe how existing procedures for handling environmental data were either integrated into the suggested system or taken out of operation.

2.4 Summary, literature review

There are two main approaches to building a structure for the handling of environmental data by an organization. Top-down approaches focus on the support processes for which the internal or external stakeholders require information. Many of the presented support processes are related to one another, however, the differences between them in terms of scope and data requirements can be difficult to articulate. Bottom-up approaches, on the other hand, focus on an organization's ability to generate relevant information describing its environmental aspects.

In reality organizations must handle both approaches and there is therefore a risk for mismatch, as illustrated in Figure 8. As different functions within an organization are assigned to reply to the top-down support processes, there is a risk of parallel procedures for handling similar information being created. Parallel systems are in this case negative, since they are likely to be resource ineffective and unsynchronized regarding information content. However, without a thorough mapping of the organization's stakeholders and their requests for environmental information (Paper I provides one relevant example), there is a clear risk of overlooking some information needs.

None of the reviewed examinations of integrated environmental information systems deal with the organization's existing procedures for handling environmental data. Many organizations have working procedures in which they have invested considerable resources. The procedures for handling environmental information identified in the case study do deliver results, though, they can in terms of avoiding parallel systems and dependence on individuals be made more effective and efficient. For those reasons they cannot be easily abandoned. Nearly all industrial organizations have already established some sort of systematic methods for handling environmental information that could be expanded into an integrated system.

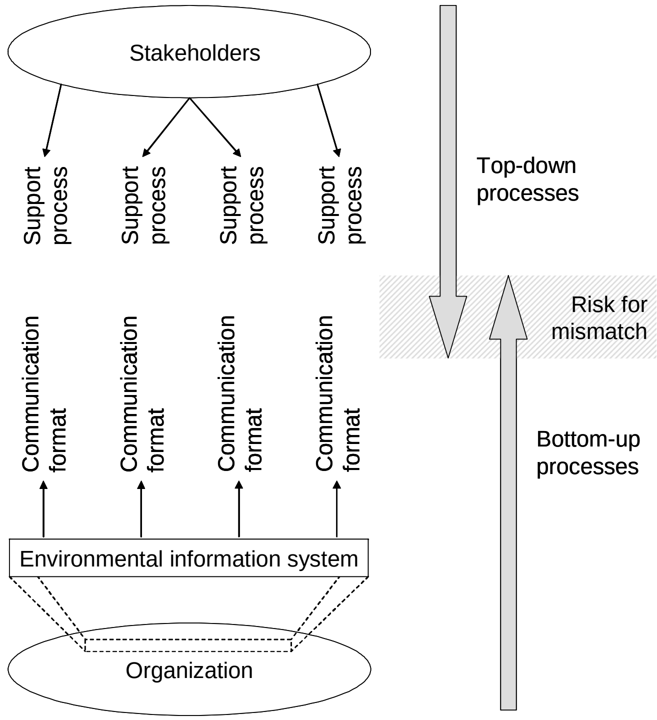


Figure 8 Risk of mismatch between bottom-up and top-down processes.

3 Methodology

This thesis is based on case studies carried out at Stora Enso production sites. This choice was made to facilitate results that would likely be applicable in the context of the production units. However, Paper I also map the environmental data management procedures at Stora Enso's product areas and corporate level.

The research methodology for mapping stakeholders, tools, and information flows (Paper I) includes identification of:

- The pulp and paper industry's environmental data stakeholders, including descriptions of the perceived applications of the communicated data from the production site's perspective. Studying environment-related support processes help identifying internal stakeholders, while a general stakeholder model was used to identify external stakeholders. The stakeholders' perceived needs for environmental data were identified by studying the organization's procedures for handling communication formats.
- The environmental tools and the corresponding communication formats which were used to modify and present data according to the perceived applications. These were identified by studying the responsibilities of the functions in the organization and the tools and communication formats they use.
- Pathways of environment-related data through the internal organization (production site, product area, and corporate levels) and the environmental tools used to meet the stakeholders' requests for information.
- The existing environmental data management system was then analyzed based on the demands made by the internal and external stakeholders.

Paper I uses the Stora Enso Skoghall mill as a case study.

The following research methodology was used to suggest methods for internal allocation (Paper II):

- Six steps were developed to identify internal multi-functional processes and choose applicable allocation methods. The steps include describing products and co-products, drafting a model of the technical system, identifying the sub-processes' functions and relevant in- and outflows, describing properties of flows from multi-functional processes relevant to base allocation on, and investigating the possibility of avoiding allocation through further sub-division.

- These six steps were used in three case studies (the Hylte, Skoghall, and Skutskär mills).
- Methods for internal allocation were suggested for the multi-functional processes identified in the case studies.
- The suggested internal allocation methods were discussed with a reference group.

4 Results

For a more comprehensive presentation of these results presented in Sections 4.1-3, please refer to appended Paper I (Svending et al., 2003a) or to the report on which that Paper is based (Svending, 2001). For the results presented in Section 4.4 see Paper II (Svending et al., 2003b) or the report on which that Paper is based (Svending, 2002).

4.1 Stakeholders and the requested data

4.1.1 Internal stakeholders

The internal environmental data stakeholders of the Skoghall mill include functions both at the production site, and at the product area and corporate levels. These stakeholders and their demands for environmental data were identified by studying the environment-related support processes conducted at the production site. The support processes are:

- Process monitoring; to ensure that routine production processes run effectively and efficiently by avoiding abnormal wastewater flows, spills of chemicals, etc.
- Environmental controlling; to ensure compliance with environmental laws and permits, the environmental policy is deployed, and the environmental performance is improved as committed to in ISO 14001 (ISO, 1996).
- Purchasing of raw materials; to provide eco-efficient raw materials and other supply materials for production processes
- Product and process development; to reduce environmental impacts of the organization's production processes and products.
- Market communication; to market the environmental performance of products and the production site to customers.
- Other external communications; to inform external stakeholders (other than customers) of the environmental performance of the production site and products.

The links between support processes, internal stakeholders, and utilized environmental communication formats appear in Table 2, where each environment-related support process is presented along with a description of its function, the internal stakeholder performing the support process, and what environmental communication formats are used to facilitate the support process. The production site's internal stakeholders have set high demands regarding the level of detail, accuracy, and availability of the data, while the possibility of accessing the data and aggregating it to suit organizational and other patterns is of particular interest at the product area and corporate levels.

Table 2 The production site's environmentally related support processes, internal stakeholders, and the communication formats used.

Support process	Internal stakeholder	Communication formats utilized
Process monitoring	Operators and other personnel	▪ Environmental process control data ▪ Environmental aspects ▪ Environmental objectives and targets
Environmental controlling	Management (at various levels)	▪ Environmental process control data ▪ Environmental aspects ▪ Environmental objectives and targets ▪ Economical accounting reports ▪ Environmental report
Purchasing of raw materials	Purchasing function	▪ Environmental aspects ▪ Environmental objectives and targets Input from suppliers: ▪ Environmental labels ▪ Environmental product declarations ▪ Product safety information
Process and product development	Research and development (R&D) function	▪ Reports from benchmarking with similar processes or sub-processes ▪ Reports from environmental risk assessment ▪ Results from life cycle assessments ▪ Product safety information
Market communication	Marketing function	▪ Replies on customers' questionnaires ▪ Environmental labels ▪ Environmental product declarations (always in combination with EMAS statements)
Other external communication	Communication function	▪ EMAS statement ▪ Environmental labels ▪ Environmental product declarations (always in combination with EMAS statements)

The environmental support processes at the production site level are primarily designed to provide environmental data for monitoring and controlling the environmental performance of processes and products. Each support process is generally performed by a specific function using various communication formats which, in turn, are prepared by other functions. Many of these communication formats are then re-used for different support processes.

4.1.2 External stakeholders

Identification of external stakeholders was facilitated by the general stakeholder model presented in Figure 9 and by studying the communication procedures at the Skoghall mill. One common purpose of the external stakeholders' requests for environmental data is to enable monitoring. Authorities, investors, shareholders, customers, neighbors, media, and environmental non-governmental organizations (ENGOs) all wish to monitor the environmental performance of for example a product or a production site to ensure that the environmental performance is improving or that environmental laws and permits are upheld.

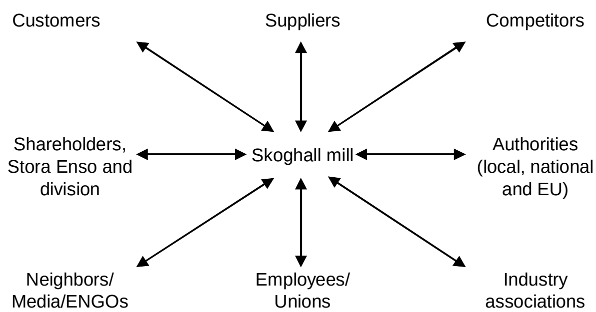


Figure 9 Illustration of the Skoghall mill's groups of stakeholders. Most of these can also be identified as environmental data stakeholders. Based on Robbins and Coulter, 2002.

Following is a list of the Skoghall mill's environmental data stakeholders and the main scope of the data they request:

- Environmental authorities request data from production sites to monitor that the environmental permits stated for operation of the production site are being upheld, to monitor whether national environmental objectives are being achieved (Ministry of the Environment, 2001), and to evaluate the influence of various industrial sectors on these objectives, or on specific issues (Koch, 1999).
- As owner of the Skoghall mill, Stora Enso and the Packaging product area wish to control and improve their environmental performance while possibly avoiding costly, unproductive environmental investments. Aggregation of data for communication with external stakeholders is also a priority.
- The customers of the Skoghall mill are struggling to improve their environmental performance. One way of doing this is to influence suppliers by inquiring about the environmental performance of their production sites and products.

- One important task for industry organizations is lobbying on behalf of member companies, for which purpose facts such as environmental information are needed.
- An open communication with the neighbors, media and environmental non-governmental organizations (ENGOs) is important to avoid situations characterized by lack of confidence and irritation. ENGOs commonly strive to improve the environment in general, or to solve a specific local environmental problem. However, few if any regular contacts with ENGOs were identified at the Skoghall mill.
- Suppliers include organizations that deliver goods in the form of energy carriers, raw materials, auxiliary materials, machinery, and equipment to a production site. As with customers, close relationships have also been established with some suppliers. Unlike the other stakeholders, suppliers are not provided with environmental information on a regular basis. Instead, some suppliers are asked to provide with environmental information on the products they deliver. Requested data typically comprise life cycle assessments information pertaining to specific products. When a supplier is involved in a project, the contact is typically established with the environmental department at the production site.

Competitors, employees, and unions are other groups of stakeholders, but ones to whom no environmental data is supplied. However, employees and unions are regarded as internal stakeholders when they perform their professional activities and as neighbors in their capacities as private persons. It is through these roles that they receive environmental information.

4.2 Environmental communication formats and tools

In Table 3 each environmental communication format is presented together with a description of its function and the tools used to generate it. The environmental communication formats are usually generated with a specific environmental tool. Sometimes combinations of tools can be used to generate a single communication format. Some formats, such as the EMAS statement, are used to communicate with several stakeholders. Some stakeholders, such as authorities and some customers provide predefined formats for the environmental data they request. Other customers, however, rely on externally defined formats, such as environmental labels and declarations. These communication formats are designed to correspond to the stakeholders' perceived need for information, and must be further evaluated together with key stakeholders to facilitate the communication for which they are intended.

Table 3 Environmental communication formats and the corresponding tools used to generate them. Note: The communication formats are numbered and reappear in Figure 10 as examples of information flows within the organization and to its stakeholders.

Communication format	Function of communication format	Tool
1. Environmental process control data	Provides indicators for monitoring and controlling processes	On-line process monitoring systems, e.g. WinMops[4], and periodical reports generated manually and/or automatically
2. Environmental aspects	Lists identified environmental aspects and prioritizes them by significance	Procedure for identifying and evaluating direct and indirect environmental aspects
3. Environmental objectives and targets	Facilitates continual improvement of the organization's environmental performance	Procedure for establishing environmental objectives and targets based on environmental, financial, and technical considerations
4. Economical accounting reports	Provides data on raw materials, auxiliaries, energy carriers, and intermediate products	Accounting systems including invoicing for purchased materials
5. Environmental report	Responds to the environmental permit issued by the local authority	Procedure for generating environmental report
6. Product safety information	Provides safety information on purchased and delivered products	Procedure for managing product safety, via, e.g. ChemSource[5] and Safety Data Sheets (SDS)
7. Results of life cycle assessments (LCA)	Mainly used to identify improvement potentials and communicate them internally	LCA models according to ISO 14040 family (ISO, 1997) with scope varying from cradle-to-grave to gate-to-gate (only pulp and paper production), depending on the intended application
8. Reports on environmental risk assessment	Mainly used to prevent accidents with chemical products and other hazardous materials	Risk assessment models for identification and valuation of probability and consequence of environmental risks

[4] WinMops is a Tieto Enator registered trademark for an on-line process monitoring system. For more information see www.mopssystems.com (visited Oct. 1, 2003).

[5] For more information on ChemSource see www.stfi.se (visited Oct. 1, 2003).

9. EMAS statement	Presents the organization's environmental performance and significant environmental aspects	Procedure for generating environmental statements according to EMAS (2001)
10. Customer questionnaires	Inquiries about, e.g. contribution to climate change, specific parameters or substances for products, sub-processes, or production site	Depending on scope of questionnaire: ▪ "Full" or gate-to-gate LCA models for specific or a selection of parameters ▪ Environmental report ▪ Environmental statement
11. Benchmarking reports	Conducted to compare products, production sites, sub-processes, etc.	Depending on scope of benchmark: ▪ "Full" or gate-to-gate LCA models for specific or a selection of parameters ▪ Environmental report ▪ Environmental statement
12. Stora Enso Environmental Reporting System (SEERS)	Collecting and reporting key indicators from production sites that facilitate aggregation to correspond to product area and geographic structures, etc.	Procedures for manual or automatic input of key indicators

4.3 Flows of environmental data

The flows of environmental data between internal functions and to external stakeholders were identified by studying internal routines for handling environmental communication formats. The resulting flows are presented in Figure 10, where the dotted lines indicate the production site, product area, and corporate level. Functions within these organizational levels that are involved in the flows of environmental data are indicated as boxes with straight edges. External stakeholders receiving environmental communication formats are indicated as boxes with rounded corners. The numbers in Figure 10 refer to the flows of environmental data in the form of the environmental communication formats presented in Table 3. The symbol market "db" indicates any database in which manually or automatically measured data is stored and later extracted to suit the environmental communication formats presented.

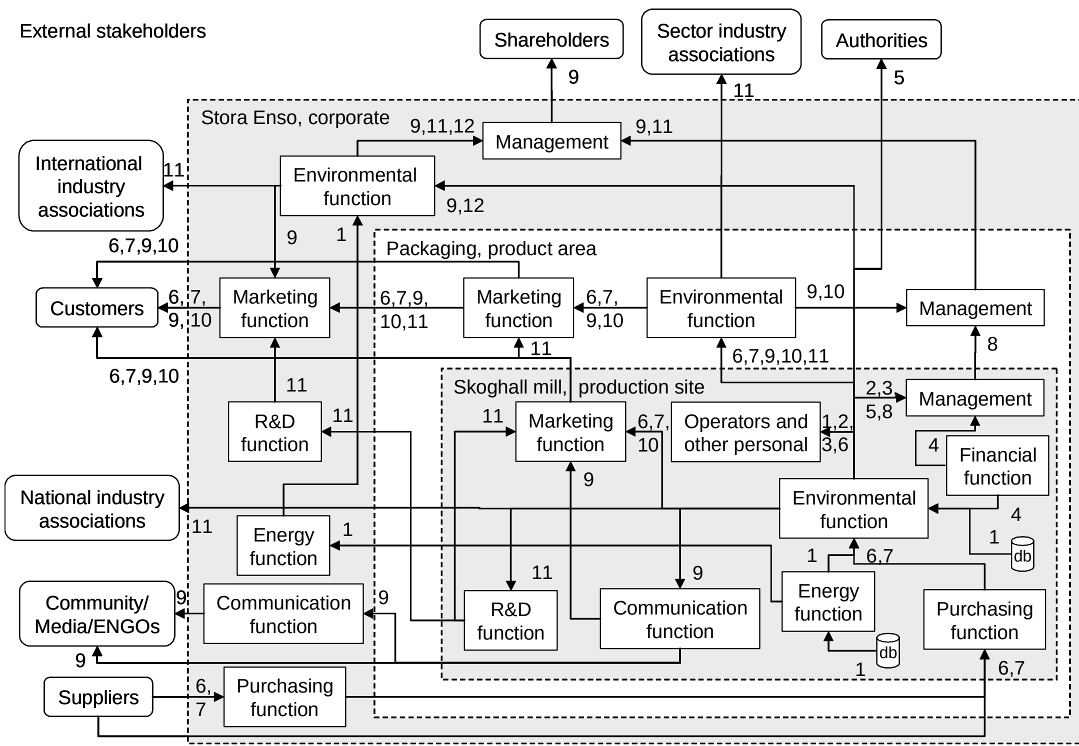


Figure 10 Flows of environmental communication formats between internal functions (boxes with straight edges within dotted areas) and to external stakeholders (boxes with rounded corners outside dotted areas). The numbers refer to the environmental communication formats presented in Table 3.

The organizational structure needs to serve many purposes, of which managing environmental issues is only one. The structure is therefore not necessarily the best one for dealing with environment-related issues.

However, the procedures for managing environmental data within the case study are well adjusted to its structure and no clear needs for re-organization were identified. The environmental information system needs to be flexible to accommodate new organizational structures and to enable communication either to new stakeholders or of new issues, for example the EU integrated product policy directive and the EU emission trading scheme.

Many functions at the production site have mirror functions both in the product area and at the corporate level, dealing with similar tasks but at different levels of aggregation. In these cases, well-defined areas of responsibility are important. One obstacle observed is the use of different terms and language between the environmental functions and, for example, energy or financial functions within the organization. Routines for documenting the information content could bridge such obstacles as could closer cooperation. Overlapping work or gaps in the generation of environmental data can be avoided by clarifying the environmental functions' areas of responsibility. It is recommended that the:

- The production site environmental function should focus on site-specific information and data which can be aggregated to represent the national pulp and paper industry. This function should also facilitate for functions at product area and corporate level in their aggregation by providing transparent environmental information.
- The product area environmental function should focus on product-related information and data which can be aggregated to represent product sectors within the pulp and paper industry.
- The corporate environmental function should focus on information representing the entire company and data that can be aggregated to represent the international pulp and paper industry.

4.4 Suggested methods for internal allocation

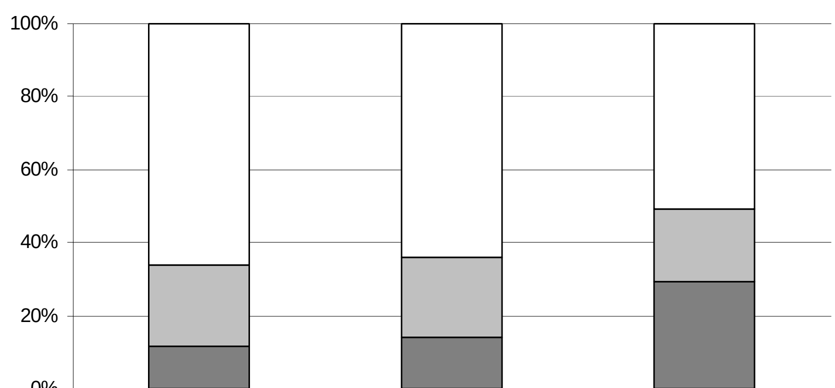
This section presents the identified multi-functional processes at three typical pulp and paper production sites. After a brief introduction to the functions of each process, suggestions on methods for handling allocation are given. In addition to the two more comprehensive examples of suggested internal allocation methods given below, Table 4 summarizes the other identified multi-functional processes and presents the suggested allocation methods for these. For a more complete treatment of the results presented in this section, please refer to appended Paper II (Svending et al., 2003b) or to the report on which Paper II is based (Svending, 2002).

4.4.1 Combined heat and power plant

In the combined heat and power (CHP) plant, incoming steam is reduced over one or more turbines to generate electrical power and steam. Incoming steam is delivered from, for example, recovery boilers. The suggested methods for internal allocation are:

- Allocation based on exergy content is suggested for internal allocation in cases where power generation is almost equally important (in economic or energy terms) as heat generation. Exergy reflects the quality of energy, resulting in a higher availability of 1 MJ electricity than, for example, 1 MJ steam.
- The turbine efficiency method can be applied when for example the paper products contain only one pulp type. The turbine efficiency method is based on the energy content method but includes consideration of the turbine's efficiency in electricity generation. However, when both mechanical and chemical pulps are produced these products affect the internal energy production in different manners and allocation based on energy content alone is insufficient. Instead, an allocation base is needed which reflects the difference in the properties of steam and electricity (the exergy content method).
- The energy content method can be used for simplified calculations where the expected environmental impacts of energy production are small. For other applications its use is not recommended.

Should environmental data on the co-product (hot water for municipal heating) be needed, it could be derived by applying allocation based on exergy content. However, the exergy of hot water is often very low, thus resulting in close to 0% allocation to the co-product.



	Energy content	Turbine efficiency	Exergy content
LP steam	66%	64%	51%
HP steam	22%	22%	20%
Int. prod. el.	11%	14%	29%
Hot water	0,1%	0,1%	0,04%

Figure 11 Examples of allocation factors resulting from the three internal allocation methods for low-pressure steam, high-pressure steam, internally produced electricity, and hot water for municipal heating. Underlying data and calculations are presented in Paper II, appendix A.

Figure 11 presents the allocation factors for products from a typical CHP plant operating in the pulp and paper industry. Of the three allocation methods, the results obtained by the exergy content method deviate from those obtained by the other two methods. The exergy content method, being based on more comprehensive thermodynamic data, results in a more than doubled allocation factor for internally produced electricity than do the other two methods, and the allocation factor for the low-pressure steam is consequently less. However, the allocation factor for high-pressure steam is more or less constant for the three internal allocation methods. The relatively small deviation between the two first methods (the energy content and turbine efficiency methods) can be explained by the fact that the turbine efficiency method is based on the energy content method, with the addition of the turbine efficiency increasing the allocation factor for the internally produced electricity.

For environmental calculations where the internally produced electricity is the focus of study, the exergy content method is recommended. This is of particular importance at production sites producing both mechanical and chemical pulps, due to the difference in electricity consumption and steam generation between the two pulps. The exergy content method gives a thermodynamically acceptable allocation base between steam and electricity, acknowledging the higher usefulness of electricity. However, the practitioner needs to put in some more work looking in tables of the thermodynamic properties of steam and doing some calculations. The required data for these calculations is already available.

4.4.2 Wastewater treatment plant

The wastewater treatment (WWT) plant purifies various wastewater streams. Each stream may enter the sub-process at various positions. The suggested methods for internal allocation are:

- The multi-input allocation is suggested to be based on the WWT plant’s incoming flows' content of Chemical Oxygen Demand (COD). COD reduction is a primary reason for the WWT plant’s existence. Absorbable Organic Chlorine compounds (AOX) and chlorate are assumed to originate from pulp bleaching operations involving the use of chlorine dioxide. AOX is therefore treated separately, allocated only to the bleaching operations. The origin of the nutrients (mainly phosphorus and nitrogen) is commonly not completely identified. They can therefore not be allocated to a specific wastewater flow, but are allocated equally to the main products. No allocation is performed for the co-products (various types of sludge) of the WWT plant.

- If required by a sludge customer, the same allocation method as above can be used, with the addition of economic allocation between the main products and the sludge.

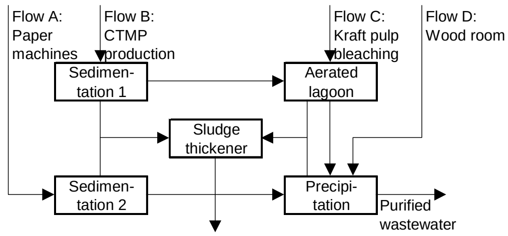


Figure 12 Flowchart of a multi-functional WWT plant.

4.4.3 Summary of other identified multi-functional processes

Table 4 presents the additional multi-functional processes along with their products and co-products and the suggested allocation methods. Full presentation of each of these multi-functional processes is available in Paper II.

Table 4 Summary of additional multi-functional processes and suggested allocation methods.

Multi-functional process	Products and co-products	Suggested allocation method	Suggested alternative allocation method
Wood room	Wood chips and bark	Allocation based on the products' economic value.	100% allocation to wood chips due to low economic value of bark.
Recovery boiler	Recovered boiling chemicals (white liquor), steam, co-products (tall oil and turpentine)	The recovery boiler is functionally split into a steam-producing part and a chemical recycling part. Air emissions, ashes, other solid waste, and the use of supplementary fuels associated with the combustion of black liquor are allocated to the steam. Other flows, such as fuel to the lime kiln, are allocated to the white liquor. It is suggested that no allocation is conducted for the co-products due to their low economic value.	If required by a co-product customer, for example, a similar functional split as above, with the addition of economic allocation between the products (white liquor and steam) and the co-products (tall oil and turpentine).
Mechanical pulping	Mechanical pulp and steam	The economic value of pulp and steam (or estimations thereof) can be used as a basis for allocation.	Due to the relatively low economic value of steam, it is sometimes justifiable to allocate to the mechanical pulp only.
Pulp bleaching, including preparation of bleaching chemicals	Bleached pulp and co-products (typically sulfur dioxide, sodium sulfate, and sodium bisulfate)	The economic value of the bleached pulp and co-products (or estimations thereof) can be used as a basis for allocation. Sometimes this may result in 100% allocation to the bleached pulp.	When specific environmental data on the co-products is required internal allocation can be based on the economic value of the bleaching agent and the co-products.

5 Discussion and conclusion

From the case study it is concluded that monitoring and controlling the environmental performance of processes and products are the main internal uses of environmental data. External uses include marketing and other communications, which in turn facilitate external stakeholders' monitoring. In designing an environmental data system, each stakeholder's demands for environmental data need to be considered, and the demands for the most detailed data must be the ones that set the scope of the system. The most detailed demands are often made by internal stakeholders, such as research and development functions.

Handling environment-related data is part of the daily routine of most internal functions. These may be various functions at production sites or mirror functions at higher levels within the organization. When data is transferred between these functions there is a risk of overlapping responsibilities and misinterpretation of the information content. Misinterpretation can be avoided through comprehensive and precise documentation of information content and the clarification of areas of responsibility. Closer cooperation between different internal functions and with external stakeholders can also prevent potential misunderstandings.

Flexibility is needed in the environmental information system to enable communication to new stakeholders and of new issues, and for new organizational structures. Examples of new stakeholders and forthcoming issues include the EU Integrated Product Policy Directive and the EU Emission Trading Scheme. One example of a new demand that has been dealt with is the product perspective on environmental data, which has placed new demands on environmental information systems pertaining to, for example, how to allocate between products. As many communication formats are derived from the same basic data, the possibility of reusing basic data for new applications is essential. One obstacle to this is that in many cases only a few people in the environmental functions have detailed knowledge of how the communication formats have been derived. Improved documentation of the information content of both basic data and the communication formats would decrease the risk of creating information systems that depend on individuals, and would improve understanding between internal functions, such as the energy, financial and environmental functions.

Product-specific environmental data in the pulp and paper sector has generally been generated to enable communication of environmental performance to both internal and external stakeholders (for example in the form of information for benchmarking and market communications such as the Paper

Profile[6]). For this purpose, the Swedish pulp and paper industry claims that a retrospective view gives fair credit to the production infrastructure that has been established for a production site, for example, the energy production established to supply a specific paper mill. For other purposes, for example, evaluating the consequences of changed production capacities, the prospective view can be more suitable. These two views and their implications for allocation or system expansion have been frequently discussed in the LCA community. It is recommended that the implications of retrospective and prospective views be acknowledged in the pulp and paper industry and implemented in the relevant applications of environmental information. Information used for communication of environmental performance should continue to have a retrospective perspective, but information used to evaluate changes in, for example, production methods should use a prospective perspective.

Internal and external stakeholders' requests for environmental data in various formats have increased in recent years, both as a result of the increased focus on environmental issues in society in general and of the consequent need for improved monitoring and controlling procedures in business. The recent focus on product-related environmental information has highlighted the need to harmonize calculation procedures within a company or even an industry sector. One such calculation procedure is allocation. Paper II identifies internal multi-functional processes and suggests how to manage these. The suggested allocation methods have intentionally been kept simple to make them acceptable to practitioners while still, in a relevant way, reflecting relationships between products. Acceptability to industry has also been an important criterion when suggesting methods for internal allocation.

The process of mapping an organization's stakeholders, their information needs, and the ways information is generated has been informative. From industry's point of view, improvement potentials in the existing data-handling procedures have been spotted. The mapping of stakeholders, their information demands, and the tools and communication formats used to meet these demands can comprise a basis for identifying the potential for improved handling of environmental data in organizations other than that examined in the case study. This mapping can also serve as the basis for specifying the performance of new information systems. From an academic point of view much knowledge has been gained about the function of today's industrial environmental information systems and the requests for information that these systems must manage. This knowledge can be used by researchers in

[6] More information on the environmental declaration Paper Profile is available on www.paperprofile.com (visited Nov. 12, 2003).

understanding top-down support processes and designing bottom-up information systems.

6 Outlook

Based on the experiences from this thesis, the outlook for further research and development can discerned into two perspectives of interest. According to an industrial perspective, the framework this thesis presents could be developed into a specification for development needs of existing environmental information systems. In cases where an entirely new environmental information system is needed, this thesis could provide a basis for determining whether a proposed new system can meet the demands placed on it. Furthermore, the methods for internal allocation suggested in Paper II need to be agreed on by the pulp and paper industry, or at least by those parts of industry that currently use the Paper Profile or other common communication formats for presenting environmental information on products.

From an academic perspective, this thesis is an example of descriptive and empirical research. Industry generally needs such applied research more than it needs research resulting in yet another tool for assessing some environmental property. The understanding gained from this type of research can be used by researchers in understanding top-down support processes and designing bottom-up information systems.

The dynamics of stakeholders and their information needs drive industry to develop tools and procedures used for responding to these needs. As time passes, new environmental issues need to be managed, and the systems presented in the case study will soon be obsolete. The methodology for identifying stakeholders, their information needs, and the tools used to provide them with that information can however continue to be reused. Continued harmonization in terms of, for example, levels of aggregation and screening relevant information needs is needed between industry, academia, and society in general.

The literature review includes another industrial sector's similar mapping of environmental stakeholders in order to enhance handling of environmental information. More industrial sectors need to follow these examples, as demands for environmental information are likely to increase as competing industrial sectors are able to provide corresponding information more effectively. Harmonized methods for handling environmental information, as presented in this thesis, could therefore become a competitive advantage.

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Paper I

Environmental Data Management

Stakeholders, tools and information flows in the Swedish pulp and paper industry

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Ola Svending is employed at Stora Enso to work on a Ph D project at Environmental Systems Analysis, Chalmers University of Technology in Göteborg, Sweden. His field of work includes LCA, environmental declarations, calculations for emission trading and environmental data management methods.

Stora Enso Environment, Box 9090, S-650 09 Karlstad, Sweden. Tel: +46 54 775 3107, fax: +46 54 775 3333, e-mail: Ola.Svending@storaenso.com.

Anne-Marie Tillman is professor of environmental systems technology at Chalmers University of Technology in Göteborg, Sweden, and director of the research group in Environmental Systems Analysis. On the basis of longstanding research experience in life cycle assessment she is now addressing a broader range of environmental systems analysis methods.

Chalmers University of Technology, Environmental Systems Analysis, S-412 96 Göteborg, Sweden. Tel: +46 31 772 2122, fax: +46 31 772 2172, e-mail: Anne-Marie.Tillman@esa.chalmers.se.

Jan Bresky is Senior Advisor Environment at Stora Enso. Mr. Bresky is responsible for LCA development within the company, and environmental calculations for all similar environmental communication.

Stora Enso Environment, Södra Mariegatan 18, S-791 80 Falun, Sweden. Tel: +46 23 78 8202, fax: +46 23 8282, e-mail: Jan.Bresky@storaenso.com

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Abstract

As the focus on environmental issues in society increases, the requests for environmental data from industry also increase. The Swedish pulp and paper industry needs to manage environmental data more efficiently and effectively with regard to stakeholders, tools and communication formats. This study maps the environmental information system in a large integrated pulp and board mill, in order to improve its efficiency and effectiveness.

Monitoring and controlling of environmental performance are the main uses of environmental data within the organization. External uses include marketing and other communication.

Many functions handle the environmental data. It is suggested here that thorough documentation of information content will minimize the risk of misinterpretation, and that a structure for areas of responsibilities will reduce overlapping work. Documentation of information also facilitates reuse of environmental data for new applications.

Flexibility in the environmental information system is needed to enable communication to new stakeholders, of new issues and for new organization structures. The organization needs to establish far-sighted monitoring of upcoming issues to enable re-design of its information system.

1 Introduction

Requests for environmentally related data literary flood companies, and stakeholders seem to constantly be inventing new formats for environmental data. The recent focus on specific products' environmental performance (e.g. through the forthcoming EU Integrated Product Policy directive, IPP) rather than on location specific emissions has set new demands on knowledge of an organization's own processes and products, and on good cooperation throughout the product's value chain. To meet these demands, companies need to continuously improve their environmental performance, but also make their handling of environmental data more efficient and effective. This study maps the Swedish pulp and paper industry's stakeholders, their perceived need for environmentally related data, the tools used to provide the data and the flows of environmental data within the organization generating replies to the stakeholders. In this mapping focus has been on the production site perspective.

1.1 Goal

The goal of this study is to identify the internal and external stakeholders of environmental data, the tools used to provide the environmental communication formats and the flows of environmental data within the organization. From this identification, potentials are sought to improve the effectiveness and efficiency of environmental data handling.

In the design of an environmental information system, a number of aspects need to be considered. In this study a typical Swedish pulp and paper industry production site is in the focus, with an example of how these aspects are handled. First, a specification is given regarding demands on how the environmental data needs to be managed, depending on requests from internal and external stakeholders. Then a mapping of the existing environmental data management routines is conducted. Finally, inconsistencies and improvement potentials are identified by mapping the demands set on the existing procedures. The production site's stakeholders and their specific demands for environmental data are presented. The environmental tools used in the organization to generate the demanded environmental data are also identified along with the communication formats used to present data to the stakeholder. The flows of environmental data through the organization are identified to emphasize the need for transparent and stringent environmental data. The environmental data management system typically connects different environmental data systems, as well as connecting them with other information systems, e.g. financial accounting systems. The results are also utilized in a consecutive study aiming at facilitating management of data for specific products generated from multi-functional processes within the pulp and paper industry (Svending et al, 2003). The results can be used by other industries facing increasing demands from their stakeholders to present various formats of environmental data to better organize their environmental information systems.

1.2 Context of the study

This study was conducted in parallel with a project within the Swedish forest industry, aiming at improving handling of environmental data by implementing a method called PHASETS (Carlson and Pålsson, 2001) to design calculation models for generation of environmental data and to document them in a formalized database structure entitled SPINE (Carlson et al, 1995). This parallel project is henceforth referred to as the SFIF/CPM project, as the participating parties were Swedish pulp and paper producers organized in the Swedish Forest Industries Federation, SFIF (Note 1) and CPM (Note 2), the Competence Centre for Environmental Assessment of Product and Material Systems hosted by Chalmers University of Technology. The corresponding author of this paper participated in the SFIF/CPM project as Stora Enso's representative and was assigned to identify the pulp and paper industry's stakeholders of environmentally related data and what type of data they request. Thus, that task was part of the goal for this paper. The SFIF/CPM project has now been completed and the resulting methodology is available for implementation. Parts of that methodology are based on the results presented in this paper.

Other studies in this field include, for example, a study conducted in the Swedish steel industry (Axelsson et al, 2002). That study identifies the Swedish steel industry's environmental data stakeholders and methods for managing their environmental data for communication. The study also suggests a common structure for managing environmental data in the steel sector. The structure includes procedures for generating various communication formats by facilitating re-use of unit processes identified. The generated data is both production site specific and product specific. An industry sector or company that is lagging behind in implementing effective and efficient environmental data management systems could experience increased pressure from external stakeholders to deliver credible environmental communication formats, since competing material systems or competitors within an industry sector successfully supply such data. Taprantzi (2001) presents an approach for managing requests for and deliveries of environmental data involving both internal and external stakeholders. The international standard ISO/TS 14048 (ISO, 2002) is also available in the field of environmental data management, presenting a format for documenting environmentally related data to ensure data quality.

1.3 Limitations

In this paper only institutionalized procedures for environmental data management are studied. Handling of environmental data for projects, etc., is beyond the scope of this study. Neither do we investigate how the external stakeholders process the received environmental data. This study was conducted for the pulp and paper industry, but general conclusions can be transferred to other industry sectors.

2 Research methodology

Since this study focuses on an industry's needs to handle environmental data, a case study from the industry was chosen. At Stora Enso most environmental data management is conducted at the production sites, but some synthesizing and aggregation efforts are also undertaken at product area and corporate levels. The amount of environmental data management in combination with the flow of environmental data from production sites to corporate level via product area level led us to choose a production site as our case study. This choice is in line with the SFIF/CPM project, which also focuses on production sites. The Stora Enso Skoghall mill was therefore chosen for our case study.

The research methodology in this study includes identification of:

- The pulp and paper industry's environmental data stakeholders, including descriptions of the perceived applications of the communicated data from the production site's perspective. Internal stakeholders were identified by studying the environmentally related support processes, which also gives valuable input about which communication formats are utilized. External stakeholders were identified using a general stakeholder model. All stakeholders' perceived needs of environmental data were identified by studying the organization's procedures for handling communication formats.
- The environmental tools and the corresponding communication formats were used to modify and present data according to the perceived applications. These were identified by studying the responsibilities of functions in the organization and which tools and communication formats they utilize.
- Pathways of environmentally related data through the internal organization (production site, product area and corporate levels) and the environmental tools to meet the stakeholders' requests for information.

- The existing environmental data management system was then analyzed based on the demands set by the internal and external stakeholders.

Inconsistencies and other improvement possibilities in the identified pathways of environmental data with regard to the environmental tools and communication formats and the environmental stakeholders were then suggested. The information listed above represents some of the information necessary to be identified for the creation of a production site's information management system. The actual creation of an information management system is, however, beyond the scope of this study.

2.1 Case study

Stora Enso is an integrated paper, packaging and forest products company producing publication and fine paper, packaging board and wood products, areas in which the group is a global market leader. The Skoghall mill is one of Stora Enso's production sites. The Skoghall mill is organized in two business areas, (Tetra Pak Boards and Liquid Packaging Boards) both part of the Consumer Boards division. Consumer Boards is part of Packaging, one of four product areas of Stora Enso. The Packaging product area has very few internal functions, as these are organized at the production sites within that product area. In other product areas (e.g. Paper) some of those functions can be found at divisional or product area levels. The organizational structure including the Skoghall mill's superior organization is presented in Figure 1. The organizational structure of Stora Enso is focused on products, and also to a lesser extent on geographical areas e.g. the North America and Asia divisions within the Paper product area. Other production sites are organized in two or more divisions or product areas depending on the mill's product portfolio. Environmental data may need to be aggregated not only according to the organizational structure, but also according to geographical areas. One example of a geographical aggregation structure is presented in Figure 2.

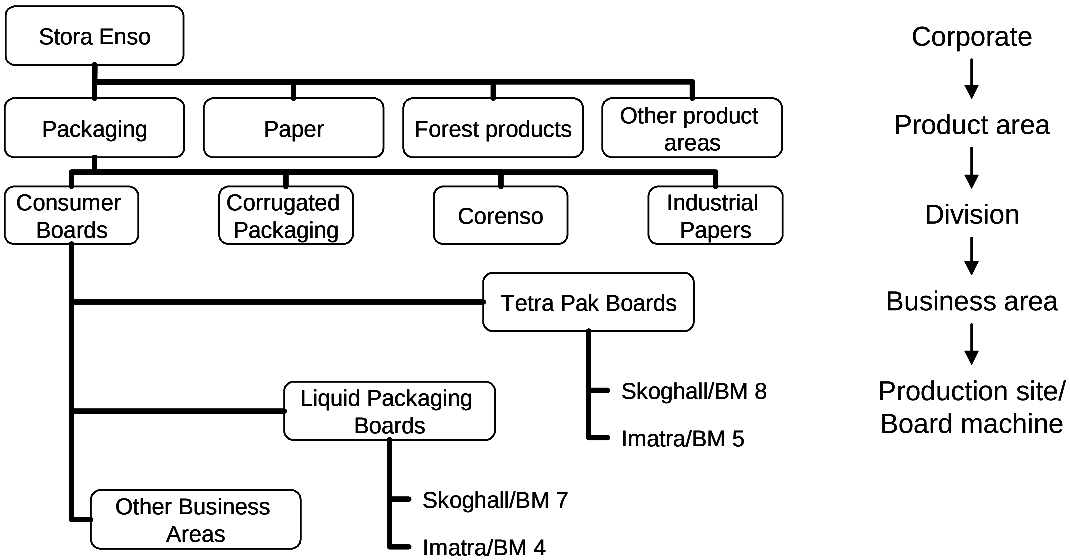

Figure 1 Organizational relation between corporate, product area, division, business area and production site within Stora Enso.

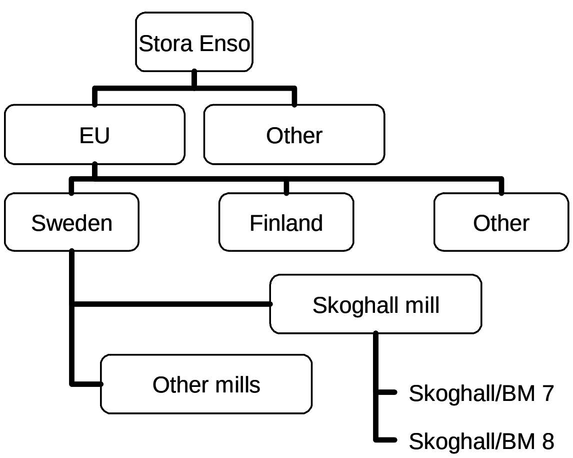

Figure 2 Example of geographical aggregation structure involving the Skoghall mill.

The study was carried out in 2002 using the Stora Enso Skoghall mill as a case study. The Skoghall mill is located in Sweden 10 km south of Karlstad on Lake Vänern. The product portfolio includes mainly board used for packaging of liquid and frozen food products. Figure 3 presents packaging materials made from the Skoghall mill's board. Reasons for choosing the Skoghall mill were:

- The Skoghall mill has a large number of stakeholders today, each requesting environmental data in specific formats. Some of these stakeholders can be regarded as frontrunners in setting demands for product specific environmental data utilizing a life cycle perspective, for example. The variation in demanded and supplied environmental data provides a wide base for this study.

- The Skoghall mill is a large modern integrated production site, with mechanical pulp production, chemical pulp production, energy production, board production, etc. For this reason an extensive model of the technical system is used for generation of e.g. product specific environmental data.
- The corresponding author's familiarity with the Skoghall mill after 2.5 years of employment there, implementing their ISO 14001 (ISO, 1996) and EMAS (EMAS, 2001) system and assisting in generating environmental data to customers and other stakeholders. This enhances the insight into the organization, its stakeholders and the environmental data supplied to them.

Figure 3 Packaging materials made from board from the Skoghall mill.

2.2 Definitions

The following definitions are used in this study.

Environmental data stakeholder
A general definition of a stakeholder is "any constituency in the organization's external environment that is affected by the organization's decisions and actions" (Robbins and Coulter, 2002). An environmental data stakeholder is here defined as an organization or group of individuals to which the studied organization supplies environmental data. Note that also internal functions in an organization are considered stakeholders in this respect and that a stakeholder must not actively define the format of the communicated environmental data.

Environmental tool
A systematic procedure to refine basic environmental data in a way that suits an environmental data stakeholder. The results from one or more

environmental tools can be presented in an environmental communication format.

Environmental communication format
A format for presenting results from one or more environmental tools designed to fit one or more environmental data stakeholders' perceived need of information. An environmental communication format can be a report, a symbol (label), a graph, etc. or combinations thereof, and can be aimed at both internal and external stakeholders.

Process related data
Data representing environmental properties of a specific process or an aggregation of selected processes. In many applications of process related data the processes included match the organization's legal boundaries. Process related data can be used, for example, to report data from a specific part of a production site, the whole production site, a division, the group, or the entire industrial sector.

Product related data
Data representing environmental properties of a product (goods or service) throughout its life cycle or parts thereof, regardless of organizational or legal boundaries.

Main and support processes
The main process of an organization generates the products (goods or services) identified in the organization's business mission, or business plan. Support processes are activities aiming at making the main process more effective and efficient. A number of environmentally related support processes can be identified aiming at making the main process more eco-efficient. The relationship between main and support processes is illustrated in Figure 4.

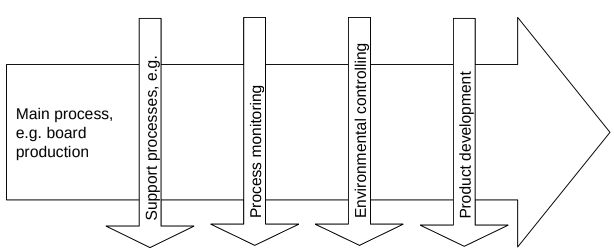

Figure 4 Illustration of main process (e.g. production of board) and environmentally related support processes (e.g. process monitoring, environmental controlling and product development).

3 Results and discussions

In the results section, the internal and external environmental data stakeholders are presented together with the supplied environmental communication formats. Each utilized communication format together with its corresponding environmental tool and the functions operating the tools is presented. Finally, the flows of environmental data through the organization and the tools and communication formats are described and mapped onto the stakeholders' requests.

3.1 Stakeholders and the requested data

The environmental data stakeholders of the Skoghall mill include both internal ones (functions within the production site, and also at division and corporate levels) and external ones (customers, investors, suppliers, branch organizations, authorities, communities and ENGOs). Below, each stakeholder is presented and their perceived need for environmental data is described. The results are used to find similarities between the various stakeholders' demands and thereby simplify handling of environmental data. Also, the most detailed demands set the level of detail in the model or routine used for assembling the environmental data.

3.1.1 Internal stakeholders

The internal stakeholders and their demands for environmental data were identified by studying the environmentally related support processes conducted at the production site. The support process and its aim are presented below. The links between support process, internal stakeholders, and utilized environmental communication formats are presented in Table 1. In the table, each environmentally related support process is presented along with a description of its function, the internal stakeholder performing the support process, and what environmental communication formats are used to facilitate the support process. The production site's internal stakeholders set high demands regarding level of detail, accuracy, and availability of the data, while the possibility of accessing data and aggregating it to fit organizational and other patterns is of particular interest at divisional and corporate levels. The most detailed demands on the data must set the scope of the bottom level models used to derive the data. The possibility to understand the information content of data through sufficient documentation facilitates re-use of basic environmental data for new applications.

The support process and their aims are:

- Process monitoring
  To run daily production processes effectively and efficiently by avoiding abnormal wastewater flows, spills of chemicals, etc.

- Environmental controlling
  To ensure that environmental laws and permits are complied with, the environmental strategy is deployed and the environmental performance improved as committed to in ISO 14001 (ISO, 1996).
- Purchasing of raw materials
  To provide eco-efficient raw materials and other supply materials for production processes
- Product and process development
  To reduce environmental impacts of the organization's production processes and products.
- Market communication
  To market the environmental performance of products and production site to customers.
- Other external communication
  To inform external stakeholders (other than customers) of the environmental performance of the production site and products.

Table 1 The production site's environmentally related support processes, internal stakeholders and the communication formats utilized.

Support process	Internal stakeholder	Communication formats utilized
Process monitoring	Operators and other personnel	▪ Environmental process control data ▪ Environmental aspects ▪ Environmental objectives and targets
Environmental controlling	Management (at various levels)	▪ Environmental process control data ▪ Environmental aspects ▪ Environmental objectives and targets ▪ Economical accounting reports ▪ Environmental report
Purchasing of raw materials	Purchasing function	▪ Environmental aspects ▪ Environmental objectives and targets Input from suppliers: ▪ Environmental labels ▪ Environmental product declarations ▪ Product safety information

Process and product development	Research and development (R&D) function	▪ Reports from benchmarking with similar processes or sub-processes ▪ Reports from environmental risk assessment ▪ Results from life cycle assessments ▪ Product safety information
Market communication	Marketing function	▪ Replies on customers' questionnaires ▪ Environmental labels ▪ Environmental product declarations (always in combination with EMAS statement)
Other external communication	Communication function	▪ EMAS statement ▪ Environmental labels ▪ Environmental product declarations (always in combination with EMAS statement)

The environmental support processes at production site level are primarily designed to provide environmental data for monitoring and controlling of the environmental performance of processes and products. Each support process is generally performed by a specific function utilizing various communication formats which, in turn, are prepared by other functions. Many of these communication formats are re-used for different support processes.

3.1.2 External stakeholders

The identification of external stakeholders is facilitated by the general stakeholder model presented in Figure 5 and by studying the communication procedures at the production site. One purpose of the external stakeholders' requests for environmental data is to enable monitoring. Authorities, investors and shareholders, customers and neighbors, media and environmental non-governmental organizations (ENGOs) wish to monitor the environmental performance of e.g. a product, or a production site to ensure that the environmental performance improves or that environmental laws and permits are withheld.

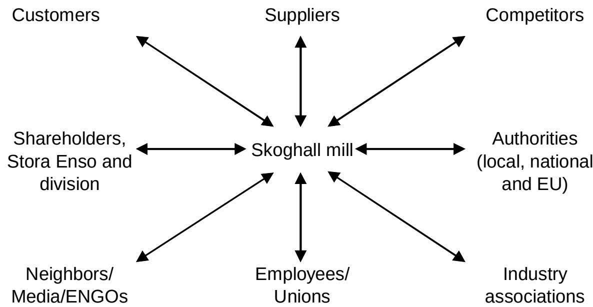

Figure 5 Illustration of the Skoghall mill's groups of stakeholders. Most of these can also be identified as environmental data stakeholders. Based on Robbins and Coulter, 2002.

Environmental authorities

Environmental authorities are active on local, national and European levels.

- Local authorities (county or municipality administrative boards) request data from production sites to monitor that the environmental permits stated for operation of the production site are withheld.
- National authorities (e.g. Swedish environmental protection agency) monitor the status of the national environmental objectives (Ministry of the Environment, 2001) and evaluate the influence of different sectors of industry on these objectives.
- European authorities may conduct studies on specific issues. CORINAIR (Koch, 1999) was one such study, mapping air emissions from the member states of the European Union to predict their development.

The local authority receives the environmental report, assembled by the production site's environmental function. The structure of the environmental report may change periodically to include data collection for national or European authorities.

Stora Enso and division

As owner of the Skoghall mill, Stora Enso and the Packaging division wish to control and improve the environmental performance of the organization and possibly avoid costly, non-productive environmental investments. The following communication formats are delivered from the Skoghall mill to Stora Enso and the Packaging division:

- Stora Enso Environmental Reporting System (SEERS) input format for assembling of e.g. group environmental report and benchmarking studies.
- EMAS statement for distribution to the group's or the division's stakeholders.

Competitors
Few if any examples of direct communication of environmental data to competitors were found. Therefore competitors are not regarded as environmental data stakeholders. Benchmarking with competitors is facilitated through indirect communication via either industry associations or based on publicly available data.

Customers
Customers of the Skoghall mill are other businesses, mainly packaging converters. In line with the intentions of ISO 14001 (ISO, 1996) and EMAS (EMAS, 2001) most customers struggle to improve their environmental performance. One way of doing this is to influence suppliers by making inquiries about the environmental performance of the suppliers' production sites and products. In some cases where close relationships with customers have been established, joint product development projects take place. Other communication formats supplied include environmental statement (EMAS, 2001).

Industry organizations
Industry organizations include, for example, the Swedish Forest Industries Federation (SFIF), The Alliance for Beverage Cartons and the Environment (ACE) and the Confederation of European Paper Industries (CEPI). One important task for industry organizations is lobbying on behalf of member companies, for which facts in the form, for instance, of environmental data are needed. Data are generally collected for benchmarking or assembling of data representative of typical pulp and paper products or production sites. No standard formats for supplying environmental data to industry organizations have been identified.

Employees and unions
This group of stakeholders may be regarded as internal stakeholders when they perform their professional activities and as neighbors in their capacities as private persons. Employees and unions are not further considered here.

Neighborhood, media and ENGOs
Open communication between a production site and the neighbors is important to avoid situations with lack of confidence and irritation. Environmental non-governmental organizations (ENGOs) include international, national and local organizations that commonly strive to improve the environment in general, or to solve a specific local environmental problem. Few if any regular contacts with ENGOs were identified at the Skoghall mill, which makes ENGOs different from other

environmental data stakeholders. Either the same data as is published in environmental statements (EMAS, 2001) is supplied to ENGOs, else environmental reports to authorities or other official data can be used. Due to the sporadic contact with the ENGOs, no clear routines for handling these contacts have been identified.

Suppliers

Suppliers include organizations that deliver goods in the form of energy carriers, raw materials, auxiliary materials and machinery equipment to a production site. As with customers, close relationships have also been established with some suppliers. Unlike the other stakeholders, the suppliers are not provided environmental data on a regular basis. Instead, some suppliers are requested to provide with environmental data on the products they deliver. Requested data typically comprise life cycle assessments based data on specific products. When a supplier is involved in a project, the contact is typically established with the environmental department at the production site.

External environmental data stakeholders can be well identified by a general stakeholder model (presented by e.g. Robbins and Coulter, 2002). Each stakeholders' demands for environmental data need to be considered when designing an environmental data system, and when models of technical systems need to be established for e.g. product specific data, the most detailed demands on the data must be the demands that set the scope of that model.

3.2 Tools and communication formats

In Table 2 each communication format is presented with a description of its function and the environmental tools used to generate the communication format. The internal function at the production site preparing each communication format is also presented.

Table 2 Environmental communication formats, the corresponding tools and the internal functions using the tools. Note: The communication formats are numbered and reappear in Figure 5 as examples of information flows within the organization and to its stakeholders.

Communication format	Function of communication format	Tool	Internal function operating tool
1. Environmental process control data	Provides indicators for monitoring and controlling processes	On-line process monitoring systems, e.g. WinMops® (Note 3) and periodical reports generated manually and/or automatically	▪ Environmental function ▪ Energy function
2. Environmental aspects	Lists identified environmental aspects and prioritizes them by significance	Procedure for identifying and evaluating direct and indirect environmental aspects	▪ Environmental function ▪ Energy function ▪ Each affected department ▪ Purchasing (if required)
3. Environmental objectives and targets	Facilitates continual improvement of the organization's environmental performance	Procedure for establishing environmental objectives and targets based on the environmental aspects, financial and technical considerations	▪ Management ▪ Environmental function ▪ Energy function ▪ Each affected department ▪ Purchasing (if required)
4. Economical accounting reports	Provides data on raw materials, auxiliaries, energy carriers and intermediate products	Accounting systems including invoicing for purchased materials	▪ Economy function
5. Environmental report	Responds to the environmental permit issued by the local authority	Procedure for generating environmental report	▪ Environmental function ▪ Energy function
6. Product safety information	Provides safety information on purchased and delivered products	Procedure for managing product safety, via e.g. ChemSource® (Note 4) and Safety Data Sheets, SDS	▪ Environmental function

7. Results from life cycle assessments (LCA)	Mainly used to identify improvement potentials and communicate them internally	LCA models according to the ISO 14040 family (ISO, 1997) with scope varying from cradle-to-grave to gate-to-gate (only pulp and paper production), depending on the intended application	▪ Environmental function ▪ Energy function ▪ Purchasing (if required)
8. Reports from environmental risk assessment	Mainly used to prevent accidents with chemical products and other hazardous materials	Risk assessment models for identification and valuation of probability and consequence of environmental risks	▪ Environmental function
9. EMAS statement	Presents the organization's environmental performance and significant environmental aspects	Procedure for generating environmental statement according to EMAS, 2001	▪ Environmental function ▪ Purchasing (if required)
10. Customers' questionnaires	Inquiries about e.g. contribution to climate change, specific parameters or substances for products, sub-processes or production site	Depending on scope of questionnaire: ▪ "Full" or gate-to-gate LCA models for specific or a selection of parameters ▪ Environmental report ▪ Environmental statement	▪ Environmental function ▪ Energy function (if required) ▪ Purchasing (if required) ▪ Other functions depending on scope of study
11. Benchmarking reports	Conducted to compare products, production sites, sub-processes, etc.	Depending on scope of benchmark: ▪ "Full" or gate-to-gate LCA models for specific or a selection of parameters ▪ Environmental report ▪ Environmental statement	▪ Environmental function ▪ Energy functions ▪ Purchasing ▪ Other functions depending on scope of study
12. Stora Enso Environmental Reporting System (SEERS)	Collecting and reporting of key indicators from production sites that facilitate aggregation to correspond to divisional and geographical structures, etc.	Procedures for manual or automatic input of key indicators	▪ Environmental function

Table 3 presents other possible communication formats currently not used at the Skoghall mill.

Table 3 Other possible environmental communication formats not used at the Skoghall mill.

Possible communication format	Function of communication format	Tool
Environmental labels	Statement that a certain product surpasses the criteria for a labeling system	Criteria document for each label, e.g. the Nordic Swan, the EU Flower and other systems in line with ISO 14024 (ISO, 1999)
Environmental product declarations	Presents selected parameters for a certain product	Calculation guideline for each system, e.g. Paper Profile (Paper Profile, 2001), the EPD-system (EPD, 1999) and other systems in line with ISO 14025 (ISO, 2000)

The environmental communication formats are usually generated with a specific environmental tool. Sometimes combinations of tools can be used to generate one communication format. Some formats (e.g. the EMAS statement) are used for communication with several stakeholders. Some stakeholders (e.g. authorities and some customers) provide defined formats for the environmental data they request. Other customers, however, rely on externally defined formats, such as environmental labels and declarations. These communication formats are designed to correspond to the stakeholders' perceived need for information, and have to be further evaluated together with key stakeholders to facilitate the communication for which they are intended.

3.3 Flows of environmental data

The flows of environmental data between internal functions and to external stakeholders were identified by studying internal routines for handling environmental communication formats. The resulting flows are presented in Figure 6, where the dotted lines indicate the production site, product area and corporate levels as presented in Figure 1. Functions within these organizational levels that are involved in the flows of environmental data are marked as boxes with straight edges. External stakeholders receiving environmental communication formats are marked as boxes with rounded corners. The numbers in the figure refer to the flows of environmental data in the form of the environmental communication formats presented in Table 2. The symbol market "db" indicates any database in which manually or automatically measured data is stored and later extracted to fit the environmental communication formats presented. Note that the flows of environmental data in Figure 6 only include those with a direction from the organization to the external stakeholders. Incoming requests for data are intentionally omitted, as they are beyond the scope of this study.

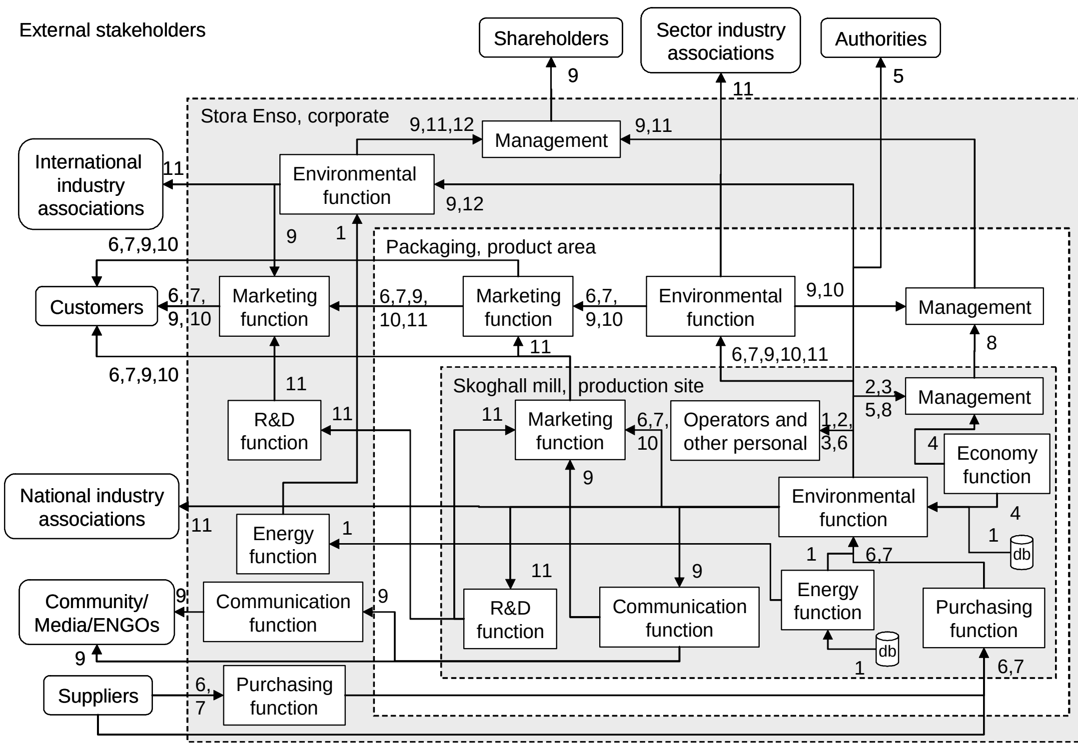

Figure 6 Flows of environmental communication formats between internal functions (boxes with straight edges within dotted areas) and to external stakeholders (boxes with rounded corners outside dotted areas). The numbers refer to the environmental communication formats presented in Table 2.

The organizational structure needs to serve many purposes, of which managing environmental issues is only one. The structure is therefore not necessarily the best one for dealing with environmentally related issues. However, the procedures for managing environmental data within the studied organization are well adjusted to its structure and no clear needs for re-organization were identified. The functions within the organization structure have also survived several minor organizational changes with continued ability to provide stakeholders with environmental data. The environmental information system needs to be flexible not only to fit new organizational structures, but also to enable communication either to new stakeholders or of new issues. Examples of new stakeholders and new issues are the EU Integrated Product Policy (IPP) directive and the EU emission trading scheme. The organization needs to establish far-sighted monitoring of upcoming issues to enable redesign its information system and respond to these issues.

Many functions at the production site have mirror functions both at product area and corporate levels, dealing with similar tasks but at different levels of aggregation. In these cases, well defined areas of responsibility are important. The environmental functions play a central role in providing both internal and external stakeholders with environmental data. However, the environmental functions rely on other functions both for their supply of data and knowledge and also to deliver environmental communication formats to various stakeholders. One obstacle observed is the use of different terms and linguistics between the environmental functions and, for example, energy or financial functions within the organization. Routines for documenting the information content could bridge such obstacles as could closer cooperation. Some of these functions derive communication formats from basic data and others refine one or more communication formats to other communication formats. Overlapping work or gaps in the generation of environmental data can be avoided by emphasizing the environmental functions' areas of responsibility. It is recommended that the:

- Production site environmental function focuses on site specific data and data which can be aggregated to represent the national pulp and paper industry.
- Product area environmental function focuses on product related data and data which can be aggregated to represent product sectors within the pulp and paper industry.
- Corporate environmental function focuses on data representing the entire company and data which can be aggregated to represent the international pulp and paper industry.

4 Conclusions

Internal and external stakeholders' requests for environmental data in various formats have increased in recent years, both as a result of the increased focus on environmental issues in society in general and of the consequent need for improved monitoring and controlling procedures in business. The environmental information system in the case study meets these requests well, but its function can still be improved in some senses.

It is concluded that monitoring and controlling of the environmental performance of processes and products are the main internal uses of environmental data. External uses include marketing and other communication, which in turn facilitates external stakeholders' monitoring. In the design of an environmental data system each stakeholders' demands for environmental data need to be considered and when models of technical systems need to be established for e.g. product specific data, the most detailed demands on the data must be the ones that establish the scope of that model. The most detailed demands are often set by internal stakeholders, e.g. research and development functions.

Many internal functions are involved in the handling of environmental data. These may be different functions at a production site or mirror functions at various levels within the organization. When data is transferred between these functions there is a risk of overlapping responsibilities and misinterpretation of the information content. Misinterpretations can be avoided through comprehensive and precise documentation of information content and a clarification of areas of responsibility, for example as suggested below. The environmental function at a production site should be responsible for data for that site, while the environmental function at corporate level should be accountable for data for the entire group. Both types of data can either be presented separately or aggregated to represent the national or international pulp and paper industry. The environmental function at product area level should be responsible for product related data. Energy data reporting is one example where a description of the information content is essential. If the receiver of such a report cannot determine whether, for instance, upper or lower heat values have been used, there can easily be misinterpretations. Closer cooperation between different internal functions, and also with external stakeholders can also bridge any potential misunderstandings.

Flexibility is needed in the environmental information system to enable communication to new stakeholders, of new issues and for new organizational structures. Examples of new stakeholders and new issues include the EU Integrated Product Policy (IPP) directive and the EU emission trading scheme. The organization needs to establish far-sighted monitoring of topical issues, and to enable re-design of its information system in response to these issues. One example is the product perspective of environmental data, which has set new demands on the environmental information system about, for example, how to allocate between products (Svending et al, 2003). As many communication formats are derived from the same basic data, the possibility to reuse the basic data for new applications is essential. One obstacle to this is that in many cases only a few people in the environmental functions have detailed knowledge of how the communication formats have been derived. Improved documentation of information content of both basic data and the communication formats would decrease the risk of creating information systems depending on individuals, and would improve understanding between internal functions e.g. energy, financial and environmental functions.

Relevant documentation of information content in combination with knowledge of available environmental tools and communication formats would also facilitate the choice of relevant communication formats for various applications. The EMAS statement is an example of a communication format used for communication with several stakeholders. This can be perceived as efficient, but is only effective if the stakeholder is aware of the scope and limitations set by the environmental tool used to generate the communication format with which they are provided. The potential risk of delivering environmental data that does not correspond to the stakeholder's needs is significant when data is delivered to external stakeholders.

5 Acknowledgements

Without the open-minded assistance of the personnel at the Skoghall mill, and at other levels in the Stora Enso group this study would not have been possible. Stora Enso also financed this work.

6 Glossary

- Mechanical pulp – Production of ground wood pulp, thermo mechanical pulp (TMP) and chemi-thermo mechanical pulp (CTMP), in which the lignin is not separated from the fiber, but included as a raw material in the production of paper.
- Chemical pulp – Production of sulfate and sulfite pulp. In these processes, a boiling procedure separates the fibers from the polymeric compound (lignin) that holds fibers together in the wood.
- EMAS – The EU Commission’s voluntary Environmental Management and Auditing Scheme.
- Environmental aspect – element of an organization’s activities, products or services that can interact with the environment. A significant environmental aspect is an environmental aspect that has or can have a significant impact on the environment.
- Environmental objective – overall environmental goal, arising from the organization’s environmental policy.
- Environmental policy – statement by the organization of its intentions and principles in relation to its overall environmental performance.
- Environmental target – measurable, broken-down environmental objective that is applicable to the organization or parts thereof.

7 Footnotes

1. For more information on the SFIF, see: www.forestindustries.se (visited Oct 1st 2003).
2. For more information on CPM, see www.cpm.chalmers.se (visited Oct 1st 2003).
3. WinMops® is a Tieto Enator registered trademark for an on-line process monitoring system. For more information see www.mopssystems.com (visited Oct 1st 2003).
4. For more information on ChemSource® see www.stfi.se (visited Oct 1st 2003).

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Paper II

Suggested methods for internal allocation in the Swedish pulp and paper industry

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Ola Svending [1, 2], Anne-Marie Tillman [2], Jan Bresky [3]
[1] Stora Enso Environment, Box 9090, SE-650 09 Karlstad, Sweden
[2] Chalmers University of Technology, Environmental Systems Analysis, SE-412 96 Göteborg, Sweden
[3] Stora Enso Environment, Södra Mariegatan 18, SE-791 80 Falun, Sweden
Corresponding author: Ola Svending (e-mail: ola.svending@storaenso.com)

Keywords: Internal allocation, multi-functionality, pulp and paper industry, forest products, life cycle assessment.

Abstract

Background, Aim and Scope

Today's environmental data focus more and more on products rather than on production sites. For reasons of credibility and comparability, the Swedish pulp and paper industry needs to reach an industry wide consensus on how to perform these calculations uniformly. This article presents suggestions on how to manage internal multi-functionalities – one of the issues enabling uniformity. The study has been conducted in cooperation with representatives from the Swedish pulp and paper industry and Chalmers University of Technology, Sweden.

Methods

Based on case studies, methods to handle multi-functional processes within the Swedish pulp and paper industry have been suggested. These methods are in line with the retrospective view adopted by the industry for generation of product related life cycle data used for environmental declarations, benchmarking etc.

Results

Possibilities to avoid internal allocation by sub-division are presented together with suggested methods for managing some of the critical multi-functional processes, i.e. wood room, recovery boiler, mechanical pulping, combined heat and power plant and wastewater treatment. Different bases for allocation can be used in the multi-functional processes, e.g. economic value

(or estimations thereof), exergy and energy content. Some multi-functional processes can be functionally split to avoid allocation.

Conclusion

Criteria for selection of the suggested internal allocation methods have intentionally been focused on feasibility, acceptability and relevance, both for the pulp and paper industry and industry's stakeholders. Other important criterion has been not to reveal information on e.g. production costs or detailed composition of the products, which is perceived sensible by the pulp and paper industry.

Recommendation and Perspective

These results are suggestions on how the pulp and paper industry could manage internal multi-functionalities. For these methods to be generally implemented, they should firsts be accepted in a consensus process within the pulp and paper industries. A relevant pulp and paper industry associations, e.g. the Swedish Forest Industries Federation (SFIF) or the Swedish Forest Industry Environmental Research Foundation (SSVL), could initiate such process. Similar uniformity is also needed for external allocation (open loop recycling etc.), cut-off rules, system boundaries etc.

1 Introduction

1.1 Main approaches for managing multi-functionalities

Within the Swedish pulp and paper industry, environmental data have traditionally been presented for separate production sites. Such data are available in e.g. the European Environmental Management and Auditing Scheme statements (EMAS, 2001) and environmental reports to authorities. More recently, customers and authorities have started to request environmental data also for products. Such data can be presented in environmental product declarations, e.g. the Paper Profile (Paper Profile, 2001). However, when preparing a model for calculation of product related environmental data new problems occur. One of these is partitioning of environmental aspects between the different products derived from a production site. This problem is referred to as multi-functionality and occurs when a process generates more than one function as illustrated in Figure 1. Many sub-processes within a pulp and paper production site are multi-functional, e.g. energy production where both heat and power are generated.

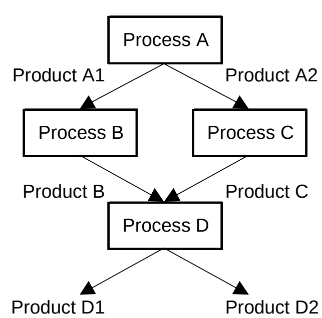


Figure 1 Schematic model of multi-functional processes (A and D).

Multi-functionality has been discussed frequently in the Life Cycle Assessment (LCA) community (e.g. Ekvall, 1999 and Weidema, 2001) and a recommended procedure is given in the international standard on LCA (ISO, 1998). According to ISO, multi-functionalities should be avoided either by sub-division or by system expansion. As a later alternative allocation based on causal relationships can be applied. Within the Swedish pulp and paper industry, sub-division is practiced to generate environmental data with the adequate level of detail and to avoid some multi-functionalities. For the intended applications (e.g. environmental declarations and benchmarking) allocation is perceived to be more appropriate than system expansion.

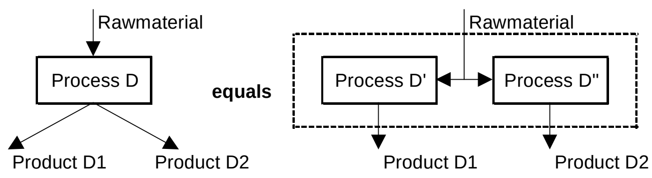


Figure 2 The multi-functionality of process D can sometimes be avoided by dividing process D into processes D' and D'' (modified from Ekvall and Finnveden, 2001).

Figure 2 presents the method to increase the level of detail in the model of the technical system, which is consistent with the first step of avoiding multi-functionalities in ISO, 1998.

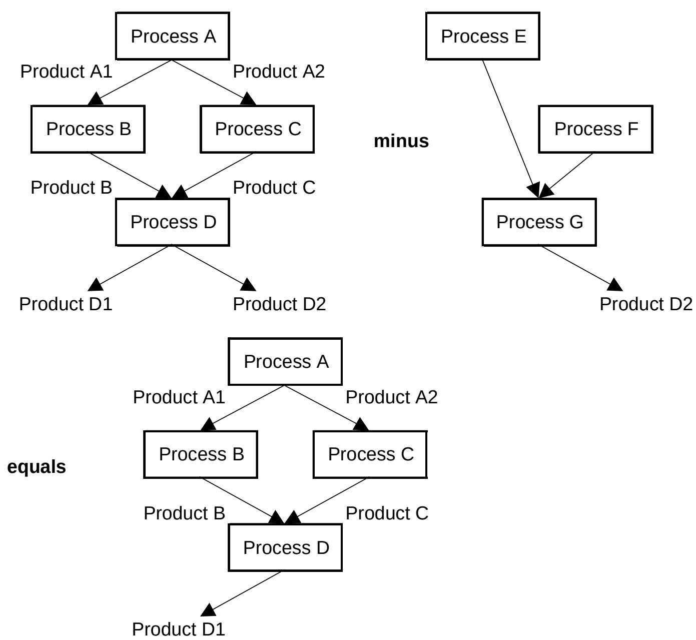


Figure 3 Schematic model of system expansion. Note that co-product D2 is excluded in the right-most figure.

Figure 3 presents system expansion in a schematic way, where process D is a multi-functional process. System expansion implies that an alternative production of co-product D2 can be subtracted from the original production system to achieve the environmentally related flows for the studied product (D1) only.

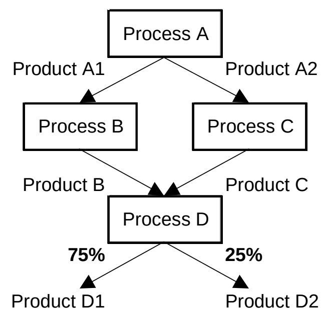


Figure 4 Schematic model of allocation through partitioning.

Figure 4 presents the basics for allocation through partitioning. Allocation implies that environmental aspects of a multi-functional process are partitioned upon the multiple products based on the products' economic values, estimations thereof, or other relationships (i.e. physical ones). These relationships can then form a percentage (as in Figure 4) as basis for the allocation.

The choice between system expansion and allocation is only one of many methodological choices LCA practitioners are faced with. According to Tillman, 2000 these choices should be based on which perspective the study should adapt to; prospective or retrospective. System expansion can e.g. be used in studies reflecting effects of a change in consumption patterns. Allocation, on the other hand, can be used to derive data on what potential environmental effects a specific product accounts for. The two perspectives and some of the methodological choices related to them are presented in Table 1.

Table 1 Characteristics of prospective and retrospective LCA (modified from Tillman, 2000).

	Prospective LCA	Retrospective LCA
System boundaries	Includes only the affected parts of the system.	Complete picture of the studied product, and possibility to add other products to a studied system.
Managing multi-functionalities	Reflecting effects of a change, e.g. through system expansion.	Allocation reflecting the causes of a product system.
Choice of data	Marginal data reflecting the relevant changes in the product system.	Average data.
System subdivision	A foreground system is where a change is implemented. Background systems are other systems affected by such change.	Not applicable.

Table 1 presents some characteristics of prospective and retrospective LCA. One of the choices a LCA practitioner needs to deal with is how to manage multi-functionalities. These choices have to some extent divided the LCA community in three camps: Those claiming that the prospective view can be applied in most types of life cycle assessments (e.g. Weidema et al, 1999 and Weidema, 2001) and those claiming that the prospective view can be replaced by a retrospective view in most assessments (e.g. Guinée et al, 2002). Other scientists (e.g. Tillman, 2000) claim that the scope of the study should decide which perspective and consequently which approach to manage multi-functionalities should be applied. Examples of applications of prospective LCA are; assessing potential environmental impacts of changing consumption patterns or predicting future scenarios. Examples of common application of retrospective LCA are; learning and identification of improvement possibilities or environmental product declarations.

Specifically for the forest industry allocations have been studied in the Cost Action E9 project: Life cycle assessment of forestry and forest products. In that project the possibilities to follow the ISO procedure for allocation (ISO, 1998) for wood-based products and bio-energy are explored (Jungmeier et al, 2002a). The paper describes allocation for recycling and multi-functionalities, the latter on a more aggregated level than the procedures presented in this paper. However no recommendations are made concerning whether to adopt a retrospective or prospective perspective.

1.2 Purpose

Managing internal multi-functionalities in a uniform manner is one of the issues that need to be dealt with for industry to gain credibility for its product related environmental data. The uniformity is needed to establish common grounds for environmental calculations, which in turn are the basis for environmental product declarations, emission trading and benchmarking etc. The purpose of this paper is to provide the Swedish pulp and paper industry with suggestions on how internal allocations can be avoided and/or solved. These suggestions can then be basis for a consensus process on how internal multi-functionalities can be managed uniformly. External allocation such as e.g. open loop recycling is not discussed in this paper.

1.3 Context of study

As the demands for product specific environmental data have increased and the Swedish pulp and paper industry has realized the complexity of such data, methods for improved management of environmental data has been developed. Such methods have been developed in a joint project between the Swedish Forest Industries Federation (SFIF) and Center for Environmental Assessment of Products and Material Systems (CPM) at Chalmers University of Technology (Chalmers). In parallel to that, a project incorporating Stora Enso and Chalmers has been conducted to suggest applicable methods for managing internal multi-functionalities. This article is a result of this later cooperation, for which SFIF and CPM have been involved as a reference group, testing and exchanging ideas. This article has been extracted from a previously published report (Svending, 2002).

1.4 Definitions

In this article the following definitions are used.

- Internal allocation: Partitioning of environmentally related flows onto two or more products generated from a sub-process within a production site. Hence, allocation associated with e.g. recycling of paper is not dealt with here.
- Economic allocation: Internal allocation method based on the economic value (internally estimated or market price) of the products concerned.
- Energy content method: Internal allocation method applicable for energy production (e.g. production of steams of various characters and/or electricity) based on the energy content of the energy carrier.
- Turbine efficiency method: Internal allocation method applicable for energy production based on the energy content of the carrier and the efficiency of the turbine, which affects the production of electricity.

- Exergy content method: Internal allocation method applicable for energy production based on the exergy content of the carrier.

2 Research methodology

The following research methodology was used to suggest methods for internal allocation:

- The six steps presented in Section 2.1 were developed.
- These steps were used in three case studies (presented in Section 2.2).
- Methods for internal allocation were suggested for the multi-functional processes identified in the case studies.
- The suggested internal allocation methods were discussed with the SFIF and CPM reference group.

2.1 Identifying internal multi-functional processes and choosing applicable allocation methods

Six steps were developed to identify internal multi-functional processes and choose applicable allocation methods. The steps can be split into two main parts:

<u>Identification of internal multi-functional processes</u>

- Step 1: All products and co-products from a production site are described.
- Step 2: A model of the technical system is drafted to identify the production site's internal sub-processes. The model of the technical system needs to be sufficiently detailed to correspond to the desired level of detail in the environmental data and avoid unacceptable approximations of data but still be feasible to manage. A simplified calculation model (including perhaps only one sub-process) can be used in some cases where no relevant co-products are produced and the main products are similar. In these cases the internal allocation can be managed using simple physical relationships between the main products, e.g. grammage.
- Step 3: Each sub-process's function and relevant in- and outflows are identified. Multi-functional processes are hereby identified.

<u>Choosing applicable internal allocation methods</u>

- Step 4: For each identified multi-functional process, properties of the relevant flows possible to base an allocation upon are described. These properties can include physically measurable properties, causal dependencies, economic values etc.
- Step 5: The possibility of avoiding allocation through a further sub-division of the sub-process is investigated. A further sub-division can

only be justified if the “new” in- and outflows can be quantified, either by measurements or by assumptions. Finding the necessary level of detail without creating a too complex model is an iterative process. Keeping the model as simple as possible within the scope of the intended information is desired.

- Step 6: Finally one or more methods for allocation are suggested. Each is justified for different applications depending on the scope of the assessment.

The Swedish pulp and paper industry has set up the following criteria for allocation methods. The methods should:

- Be repeatable from one year to the other without the data on which the allocation is based changes inconsistently.
- Be based on a stringent procedure that is in line with the ISO 14041 standard (ISO, 1998).
- Not make data public that can be sensitive for the supplier/customer relationship, e.g. production cost or sheet composition.
- Be based on a retrospective view. Please refer to Section 4 for discussion about the arguments.

2.2 Case studies for testing internal allocation methods

Three Stora Enso productions sites were selected as case studies to represent different types of processes and products. The case studies also represent different needs of detail in the generated environmental data. In the case studies, the following pulp production processes were represented:

- Chemical pulping
  Production of sulfate and sulfite pulp. In these processes, a boiling process separates the fibers from the polymeric compound (lignin) holding fibers together in the wood. The lignin is then combusted to generate energy for the pulp and paper production.
- Mechanical pulping
  Production of ground wood pulp, thermo mechanical pulp (TMP) and chemi-thermo mechanical pulp (CTMP), in which the lignin is not separated from the fiber, but included as a raw material in the production of paper. Since the lignin is included in the pulp, it cannot be combusted to generate energy. Externally purchased energy is therefore needed to run the processes. However, the electricity required for the grinding/refining operations can to some extent be recovered as steam.
- Recovered paper processing
  Production of pulp from recovered paper where ink, fillers etc. are separated from the fibers. Only small or no amounts of recovered

energy can be delivered from the pulp production from recovered paper.

Table 2 Description of the case studies included in the study.

Production site	Main products	Main processes	Environmental data needed
Hylte	Newsprint	▪ TMP ▪ Groundwood pulp ▪ Recovered paper pulp ▪ 4 paper machines	▪ Production site specific data ▪ Product specific data ▪ No data required for sub-processes within the production site
Skoghall	Board, mainly used for packaging of liquid and solid food products	▪ Sulfate kraft pulp ▪ Elementary chlorine free bleaching ▪ CTMP ▪ 2 board machines	▪ Production site specific data ▪ Product specific data ▪ Data required for sub-processes within the production site
Skutskär	Bleached long and short fiber kraft pulp and bleached fluff pulp	▪ Sulfate kraft pulp ▪ Elementary chlorine free bleaching	▪ Production site specific data ▪ Product group specific data ▪ Data required for sub-processes within the production site

Table 2 presents the case studies in which the methodology for identifying internal multi-functional processes and addressing relevant methods has been applied. Processes common for all case studies include; wastewater treatment and internal energy production (steam and electricity). Other non-production related processes like administration, product development and marketing have normally been omitted from the environmental studies performed within the pulp and paper industry. This limitation is valid also in this study.

3 Results

3.1 Possibility to avoid allocation by further sub-division

The models used in three case studies have been sub-divided to generate a specific level of detail required by the most demanding stakeholder, which in most cases were internal. Attention had to be paid not to sub-divide to far, since the work intensity of creating a to detailed calculation model multiplies rapidly. In addition, uncertainty tends to increase with increased level of detail, since data on some internal flows may be unreliable.

3.2 Identified multi-functional processes and suggested methods for internal allocation

In the following some of the most critical multi-functional processes are presented and methods for internal allocation are suggested.

Wood room

In the wood room, wood logs are debarked and chipped to wood chips, which are delivered to the pulp production. The removed bark is delivered to a boiler for combustion and energy production. In some cases, e.g. when only one type of pulp is produced, the wood room can be aggregated with the pulp production. This results in simplified data collection, but a lower level of resolution in the model. The suggested method for internal allocation is:

- Both aggregated and non-aggregated models need to deal with allocation of internally produced bark from the wood room. It is here suggested to use the economic value of bark and woodchips (or estimations thereof) as basis for allocation. Due to the relatively low economic value of bark it can sometimes be justified to allocate to woodchips only.

Recovery boiler

The recovery boiler includes both energy production and chemical recycling. The boiling liquor used in the sulfate pulp process (black liquor) is evaporated and then incinerated in the recovery boiler. Steam is generated as the black liquor is reduced to green liquor, which thereafter is recovered (to white liquor) in a causticizing operation. Two co-products (tall oil and turpentine) are also generated. The suggested method for internal allocation are:

- The chemical recycling unit is functionally split into a steam producing part and a chemical recycling part. Emissions to air, ashes and other solid waste and the use of supplementary fuels associated with the combustion of black liquor are allocated to the high-pressure steam. Other flows (e.g. fuel to the lime kiln) are allocated to the white liquor via the green liquor. It is suggested that no allocation is conducted to the co-products due to their little economic value. The functional split into production of steam and recycling of white liquor is a feasible approach since few internal flows within the recovery boiler are measured.
- If e.g. required by a co-product customer, a similar functional split as above with the addition of economic allocation between the internal products (white liquor and high-pressure steam) and the co-products generated in the chemical recycling (tall oil and turpentine).

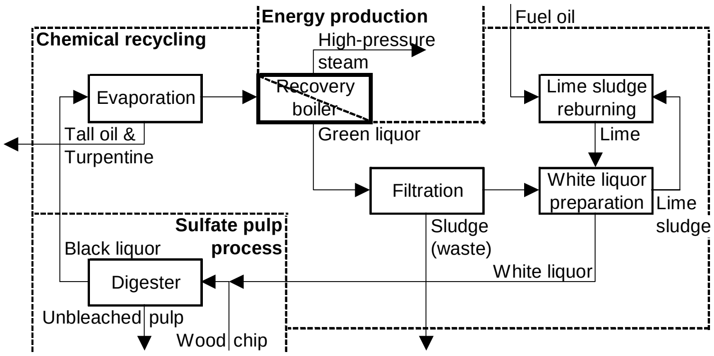


Figure 5 Flowchart of the multi-functional recovery boiler and its surrounding processes. The functional split into production of steam and white liquor is a feasible approach since few internal flows within the recovery boiler are measured.

Mechanical pulping

In the mechanical pulping, pulp is produced by disengaging wood fibers in grinders or refiners, from where excess steam can be generated. The suggested method for internal allocation is:

- The economic value of pulp and steam (or estimations thereof) can be used as basis for allocation. Due to the relatively low economic value of steam it can sometimes be justified to allocate to the mechanical pulp only.

Pulp bleaching, including preparation of bleaching chemicals

Pulp bleaching is not a multi-functional process, but as the preparation of chemicals can be aggregated to this sub-process, multi-functionality occurs. The aggregation presented in Figure 6 can sometimes be performed when mainly bleaching agents are prepared in the preparation of chemicals. The suggested methods for internal allocation are:

- When no specific environmental data on the co-products is required, the aggregated model in Figure 6 can be used basing the internal allocation on estimations of the economic value. Sometimes this may result in 100% allocation to the bleached pulp.
- When specific environmental data on the co-products is required, a non-aggregated model must be used. Internal allocation can then be based on the economic value of the bleaching agent and the co-products (e.g. sulfur dioxide, sodium sulfate and sodium bisulfate).

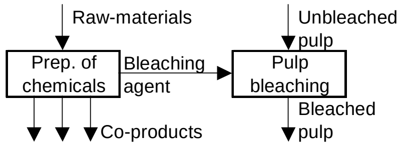


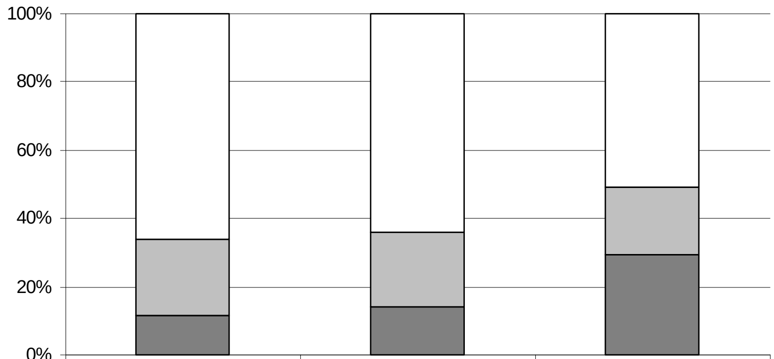
Figure 6 Flowchart of the multi-functional preparation of chemicals, here aggregated with the pulp bleaching.

Combined heat and power plant

In the combined heat and power (CHP) plant high-pressure steam is reduced over one or more turbines to generate electrical power. Incoming steam is delivered from e.g. recovery boilers. The suggested methods for internal allocation are:

- Allocation based on exergy content is suggested for internal allocation in cases where power generation is of similar importance (economy- or energy-wise) as the heat generation. Exergy reflexes the quality of energy, resulting in a higher availability of 1 MJ electricity than compared with e.g. 1 MJ steam.
- The turbine efficiency method can be applied when e.g. the paper products contain only one pulp type. The turbine efficiency method is based on the energy content method but includes consideration of the turbine's efficiency in electricity generation. However, when both mechanical and chemical pulps are produced these products affect the internal energy production in different manners and allocation based on energy content only is not enough. Instead an allocation base is needed which reflects the difference in properties of steam and electricity (i.e. the exergy content method).
- The energy content method can be used for simplified calculations where the expected environmental impacts from energy production are small. For other applications it is recommended not to be used.

Should environmental data on the co-product (hot water for municipal heating) be needed could it be derived by applying allocation based on exergy content. However, the exergy of hot water is often very low, thus resulting in 0% allocation to the co-product.



	Energy content	Turbine efficiency	Exergy content
LP steam	66%	64%	51%
HP steam	22%	22%	20%
Int. prod. el.	11%	14%	29%
Hot water	0,1%	0,1%	0,04%

Figure 7 Examples of allocation factors resulting from the three internal allocation methods for; low-pressure steam, high-pressure steam, internally produced electricity and hot water for municipal heating. Underlying data and calculations are presented in appendix A.

Figure 7 presents the allocation factors for products from a typical CHP-plant within the pulp and paper industry. From the three allocation methods, the exergy content method shows a deviating result compared to the other two methods. The exergy content method, being based on more comprehensive thermodynamic data, results in a more than doubled allocation factor for the internally produced electricity than do the other two methods, and the allocation factor for the low-pressure steam is subsequently less. However, the allocation factor for high-pressure steam seems to be (more or less) constant for the three internal allocation methods. The relatively small deviation between the two first methods (energy content and turbine efficiency methods) can be explained by the fact that the turbine efficiency method is based on the energy content method with the addition of the efficiency of the turbine increasing the allocation factor for the internally produced electricity.

For environmental calculations where the internally produced electricity is in focus of the study, the exergy content method is recommended. This is of particular importance at production sites producing both mechanical and chemical pulps, due to the difference in electricity consumption and steam generation between the two pulps. The method gives a thermodynamically accepted allocation base between steam and electricity, acknowledging the higher usefulness of electricity. However, the practitioner needs to put in some more work consisting in looking in tables for thermodynamic properties of steam and doing some calculations. The required data for these calculations is generally already in place.

Wastewater treatment plant

In the wastewater treatment (WWT) plant different flows of wastewater streams are purified. Each flow may enter the sub-process at various positions. The suggested methods for internal allocation are:

- The multi-input allocation is suggested to be based on the WWT plant's incoming flows' content of Chemical Oxygen Demand (COD). COD reduction is a primary reason for the WWT plant's existence. Absorbable Organic Chlorine compounds (AOX) and chlorate are assumed to origin from pulp bleaching operations involving the use of chlorine dioxide. AOX is therefore treated separately, allocated only to the bleaching operations. The origin of the nutrients (mainly phosphorus and nitrogen) is commonly not completely identified. They can therefore not be allocated to a specific wastewater flow, but are allocated equally to the main products. No allocation is performed to the co-products (different types of sludge) from the WWT-plant.
- If required by a sludge customer, the same allocation method as above can be used with the addition of economical allocation between the main products and the sludge.

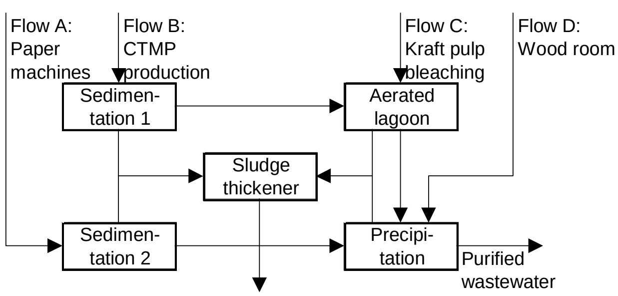


Figure 8 Flowchart of a multi-functional WWT-plant.

4 Conclusions and discussions

This study identifies internal multi-functional processes and provides suggestions of how to manage these. Allocation of the multi-functional process can either be avoided by sub-dividing a unit process into two or more non-multi functional unit processes. However, it must be feasible to acquire relevant data for these new sub-processes. The suggested allocation methods have intentionally been kept simple to make them acceptable by practitioners and still in a relevant way reflect the relationships between the products. For most presented multi-functional processes, two or more methods for internal allocation are suggested. Depending on market demands or on internal desires either of these can be used, given that the recommendations in Section 3.2 are followed. The suggestion of no allocation to co-products is an estimation of an economic allocation since the economic value of the co-products is generally small compared to the economic value of the main products.

The results presented have been derived from three case studies and may not be directly applicable in all other pulp and paper production sites. However the case studies represent a broad range of pulp and paper production technologies.

Acceptability by the industry has been an important criterion when suggesting methods for internal allocation. The scope for generating product specific environmental data in the sector has generally been to enable communication of environmental performance to both internal and external stakeholders (e.g. in the form of information for benchmarking and market communication such as the Paper Profile). Due to this scope the Swedish pulp and paper industry claims that a retrospective view gives fair credit to the production infrastructure that has been established for a production site, e.g. energy production established to supply a specific paper mill. The ability to add data along a production chain is another important feature for the identified key applications. Marginal data on e.g. energy production is therefore perceived not to be applicable for these types of industrial activities. Neither are system expansions. An additional argument against system enlargement is that for many co-products from a pulp mill (e.g. tall oil) there are no alternative production processes. Thus, the Swedish pulp and paper industry prefers retrospective LCA and allocation rather than prospective LCA and system expansion.

The suggested methods to deal with internal multi-functionalities (sub-division and allocation through partitioning) comply with a general recommendation in the ISO standard that methodological choices should be made in relation with the goal and scope definition. However they are partly in conflict with the ISO priority order for allocation (ISO, 1998). The suggestions made are based on a belief that relevance of environmental information in relation to its intended use is more important than strict compliance to a set of rules.

Allocation between heat and electricity in a CHP boiler has also been evaluated in other studies (e.g. Nilsson and Strömberg, 2000 and Jungmeier et al, 2002b). Nilsson and Strömberg, 2000 evaluated allocation based on energy content, exergy content, economic factors and system expansion. Their study was made in order to underpin allocation rules for CHP in environmental product declarations. The client of their study chose to use a system expansion approach which credits the CHP system with the advantages of having combined heat and power generation compared to separate heat and power production (PSR, 1998). Such an approach is more prospective than retrospective and does not give an allocation that sums up to 100% of the multifunctional sub-process's environmental impact. It could be argued that the heat and power industry's choice of allocation method is less suitable for an environmental product declaration which should be based on a retrospective perspective. It is less suitable for the pulp and paper industry in the applications discussed in this paper, in which a retrospective perspective is adopted. In the Cost Action E9 project (Jungmeier et al, 2002b) allocation based on energy content is suggested to be used in combined heat and power generation. However the energy content method is not recommended for the applications intended in this paper.

5 Recommendations and Outlook

In this paper suggestions on how the Swedish pulp and paper industry could manage internal multi-functionalities are given. The recommendations concern applications where a retrospective perspective on environmental data is relevant. They are not intended to be used in change-oriented applications, e.g. in studies of effects of change in industry structure and similar. For the suggested methods to be generally implemented, they first need to be accepted in the Swedish pulp and paper industries. A consensus process could be initiated by one of the industry associations, e.g. the Swedish Forest Industries Federation (SFIF) or the Swedish Forest Industry Environmental Research Foundation (SSVL).

6 Acknowledgements

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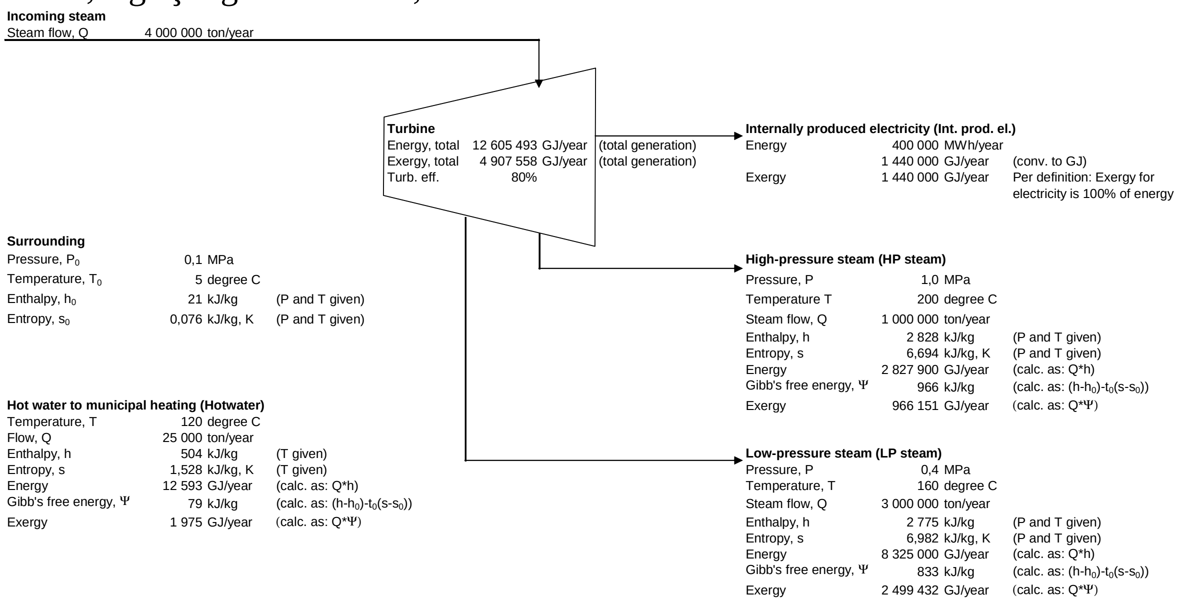
Appendix A

Underlying data and calculations for Figure 7. Data on steam flows, temperature, pressure, turbine efficiency and electricity generation are typical for a pulp and paper industry's CHP plant. Enthalpy and entropy are taken from thermodynamic tables, e.g. Çengel and Boles, 2001.



Calculation of allocation factors for CHP generation:

Energy content method: $F_N = Energy_N / (Energy_{Int.\ prod.\ el.} + Energy_{HP\ steam} + Energy_{LP\ steam} + Energy_{Hotwater})$

Turbine efficiency method: $F_N = Energy_N / [(Energy_{Int.\ prod.\ el.} / \text{Turb. eff.}) + Energy_{HP\ steam} + Energy_{LP\ steam} + Energy_{Hotwater}]$

Exergy content method: $F_N = Exergy_N / (Exergy_{Int.\ prod.\ el.} + Exergy_{HP\ steam} + Exergy_{LP\ steam} + Exergy_{Hotwater})$

, where N represents any of the energy carriers (internally produced electricity, high-pressure steam, low-pressure steam and hot water to municipal heating).