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Strategic sustainability: Creating business value with life cycle analysis

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Life cycle assessment;
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Abstract Markets are increasingly demanding more sustainable products and services, as well as more information about the environmental qualities of the products and services they use. To meet market expectations, modern management needs powerful tools that can create an understanding about the environmental traits of products and services and how these products and services can be made more sustainable. The environmental life cycle assessment (LCA) approach is one such powerful tool that can evaluate the environmental aspects and impacts of a product or service from cradle to grave. While LCA was originally designed to support decisions in the environmental engineering area, it is a tool that can also be used managerially to develop valuable and fact-based sustainability strategies within the company regarding its products and services. Recent examples from industry leaders report exciting evidence of the power of LCA. This article introduces the LCA method as a management decision tool, and illustrates its value creation potential through multiple industry examples.

1. Sustainability management: Fighting against blind spots

Scientific research regarding the role of humans on climate change, as well as many lessons learned from industrial pollution and its negative impacts upon the environment, have led to a greater general awareness of the need for sustainability. Customers are increasingly demanding that products be produced in environmentally friendly ways that limit negative impacts on the earth's resources (Thorn, Kraus, & Parker, 2011). Therefore, companies face a growing need to incorporate sustainability into their business models and marketing efforts. But that is easier said than done.

Although today's customers want more sustainable solutions and information about the environmental qualities of the products and services they buy, many companies struggle to fulfill these requests while concurrently adding value through

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mutually beneficial sustainability. This issue often stems from management's limited understanding and knowledge regarding general environmental traits of the company's products and services, as well as critical sustainability drivers throughout the entire product life cycle. In many companies, the traditional management perspective focuses mainly on customers, competitors, internal processes, and relationships with suppliers. Managers are trained to think along these categories and exchange processes between them. There is no doubt that this way of thinking is helpful and generally makes sense in the business environment. However, when it comes to sustainability considerations of products and processes, this classic management perspective becomes too narrow rather quickly, as it does not consider the relevant environmental impact parameters, which are often outside of the classic supplier-company-customer relationship.

If one considers the entire lifetime of products from cradle to grave, the critical environmental impact of products are caused not only by product conversion processes or product usage, but also by natural and physical traits of raw materials and other inputs, extraction methods (e.g., mining, refining), transportation, and storage processes, as well as final disposal (e.g., landfilling, incineration, recycling). Many early life cycle steps (e.g., raw material extraction) and later life cycle steps (e.g., disposal) are outside the traditional management focus and not considered relevant business topics. This is because companies are not directly involved in these market exchange processes. Moreover, the physical environmental traits of many input factors, such as raw materials, are often unknown because companies—prior to the rising sustainability trend—generally did not require this information. The result is that managers often suffer from blind spots about existing value creation opportunities in the markets through sustainability. In particular, this creates two typical management problems. First, companies are not aware of relevant strategic opportunities and challenges, which can be risky for the long-term development of the company. Second, in the absence of relevant required information, companies have an inherent risk of investing in ineffective sustainability improvement measures that are not honored by markets and that do not add value for mutual benefit.

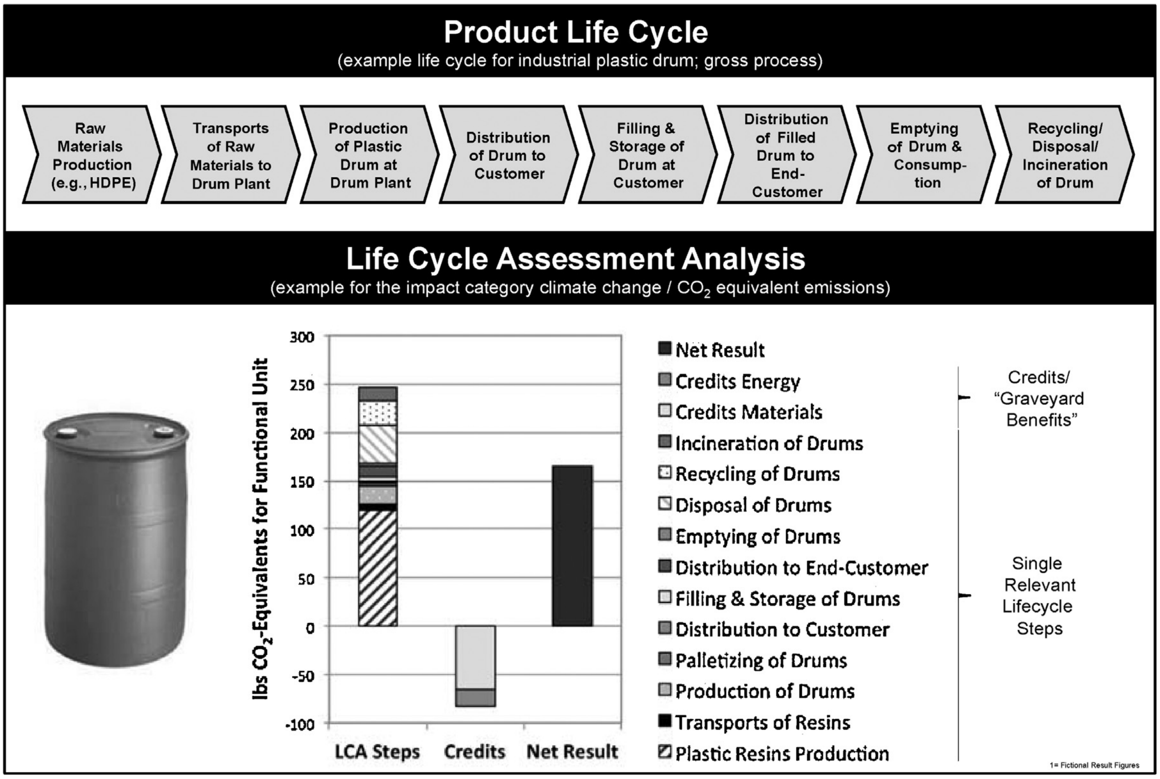
To overcome this blind spot issue in sustainability, as well as to better understand the general environmental traits of products and critical sustainability drivers over the entire product life cycle, management needs powerful tools that can close the information gap and move the company toward a more powerful strategy and product management approach. Such a fitting but often disregarded tool set on the management level is the environmental life cycle assessment (LCA) analysis approach. Herein, we demonstrate the power of using the LCA method as the management decision tool. To this end, we first introduce the method briefly in Section 2. We then illustrate in Section 3, through multiple industry examples, the value creation potential in five application areas including (1) strategy development, (2) R&D and product development, (3) supplier selection and production, (4) marketing and sales, and (5) information, training, and education. In Section 4, we discuss the potential challenges and pitfalls of implementing LCA analysis and prescribe some remedies. We discuss innovative uses of LCA in Section 5 and limitations of the method in Section 6. We conclude our analysis in Section 7.

2. From cradle to grave: Life cycle assessment

LCA is a technique that measures the environmental aspects and impacts of a product over its entire lifetime, from cradle to grave (i.e., from raw material extraction through materials processing, manufacturing, distribution, use, repair and maintenance, and disposal or recycling). While simple and rudimentary LCA methods were first considered in the 1960s in the area of environmental and chemical engineering to identify key environmental issues of products or processes, the main development phase of modern LCA approaches began in the 1990s (Curran, 1996) and are now chiefly regulated by ISO 14040 and 14044 (International Standardization Organization, 2006a, 2006b). A life cycle assessment weighs a product or process by asking two main questions: (1) How big are the total environmental impact and the corresponding emissions of a product system over its entire lifetime? (2) Looking at the different life cycle steps, which life cycle steps are critical and have the highest impact on the environment?

To answer these questions, the LCA method calculates specific measures for a product or process along several environmental impact categories. For example, global warming is considered one of today's most pressing environmental problems (Natural Resources Defense Council, n.d.). To measure a product's or process's impact on global warming, the impact category 'CO_2 equivalent emissions' is used. If only CO_2 is considered, the LCA result is often called the 'carbon footprint.' In addition to global warming, there are several other environmental impact categories such as acidification or eutrophication of the environment; depletion of the

Figure 1. Product life cycle and life cycle assessment



ozone shield; release of fine dust particles triggering human toxicity; and reduction of non-renewable energy sources, fresh water, and forest. Many actions that are effective in reducing the global warming impact of a product can trigger other environmental problems. To get a holistic view of a product's environmental impact, LCA considers several impact categories simultaneously.[1]

Within the LCA process, the environmental impact of a product in an impact category like global warming is derived by evaluating every single life cycle step in this category. The sum of the impacts of all life cycle steps represents the gross environmental impact estimate for the product. An analysis only based on the sum of the impacts from these life cycle steps would not be a fair evaluation of a product's environmental performance because many products contribute positively to the environment at the end of their life cycle, for example by leaving recyclable materials behind that can be used in subsequent products to replace virgin raw material needs. Some products can likewise be incinerated upon disposal, thereby generating heat or electricity and thus decreasing demand for other energy resources. For such beneficial contributions, the products receive credits that reduce their gross environmental score. By deducting the credits from its gross environmental impact, a net score is derived, which represents the product's total environmental performance including its harmful and beneficial aspects in the impact category. Figure 1 illustrates an example of LCA featuring an industrial plastic drum that is used for shipping liquids, such as chemicals or foods, within industry.

By screening a product life cycle, LCA produces an accurate and clear picture of the product's total environmental performance. It also identifies the critical life cycle steps with high environmental impacts and enables companies to conduct various simulation analyses to answer questions including, but not limited to: how the environmental impact would change if other materials were used, parts of products or processes were removed, transportation methods or suppliers were changed, or the recyclability or reusability of a product were increased by a percentage. Such information is invaluable when improving products and processes to optimize their environmental performance.

Next, we provide an example to demonstrate the details of LCA steps. We refer interested readers to Guinée (2002), Baumann and Tillmann (2004), and Klöppfer and Grahl (2009) for further details regarding methodology.

[1] For an overview see Institute for Environment and Sustainability of the European Commission (2010) and Klöppfer and Grahl (2009).

2.1. How to run LCA

LCA can be conducted by a company with its own resources or with external support. Due to the growing role and popularity of LCA in today's business environment, several software tools are available (European Commission Institute for Environment & Sustainability, 2014); independent organizations also offer LCA service support to companies. Although it is good news that no internal expert know-how on the technical side of LCA is required to run a project efficiently and successfully when engaging an external supporter, it would be useful to understand the four basic steps in a life cycle assessment project (Williams, 2009). To briefly illustrate these steps, we next present an example of a new product development case:

> A manufacturer of industrial packaging has invented a new manufacturing process for 55-gallon plastic drums. The new manufacturing process consumes less energy and results in a product design that is of equal quality but saves 15% of raw materials compared to conventional drum designs as offered by competitors. Management wants to evaluate the environmental benefit of the new drum to be able to base its market introduction on a sustainability platform.

2.1.1. Step #1: Goal and scope definition

The company needs to define an appropriate goal of the study in the first step to make sure that the LCA supports the intended application focus. In our case, the goal of the LCA would be to find answers to these two questions: What is the overall environmental performance of the new product? If the new product is compared against conventional designs, what is the environmental benefit?

Next, a functional unit that allows a meaningful comparison of the new drum and competitive products should be defined. The main function of a drum is to ship liquids. Some competitors may offer 55-gallon drums, but some may also offer 50-gallon drum designs, too. Therefore, a direct comparison of the drums themselves does not make sense, as the designs vary by 5 gallons. Comparison becomes meaningful only if the function of the product is the same, so the functional unit could be defined as 'transport of 1,000 gallons.' This allows us to compare the performance of drum systems accurately. In addition to defining the functional unit, decision criteria need to be chosen for the analysis, such as deciding which environmental impact indicators should be included (e.g., global warming impacts, water usage, acidification, or eutrophication).

Finally, the relevant system boundaries of the LCA study should be considered. For example, some processes used in plastic drum manufacturing may vary between the U.S. and Asian markets because of the differences in recycling quota at end-of-life. Thus, it is important to decide if the focus of the analysis should be a North American market, an Asian market, or both.

2.1.2. Step #2: Inventory analysis

Based on the goal and scope definition, a process tree or flow chart should be created to classify the events in a product's life cycle. In our example, it would be the processes for producing plastic resins at a supplier → transport of the resins to the drum making plant → production of the drums out of the resins by a blow molding process → palletizing of the drums to prepare them for shipping → distribution of the drums to a customer → filling of the drums with a liquid → distribution of the filled drums to end customers who need the liquids → emptying of the drums → disposal and recycling or incineration of drum parts. For each of the life cycle steps, all mass and energy inputs and outputs should be determined by collecting relevant process data, such as how much energy and water is needed for the blow molding process of the drums at the plant, and how much plastic resin is needed in the process to create one drum.

2.1.3. Step #3: Impact assessment

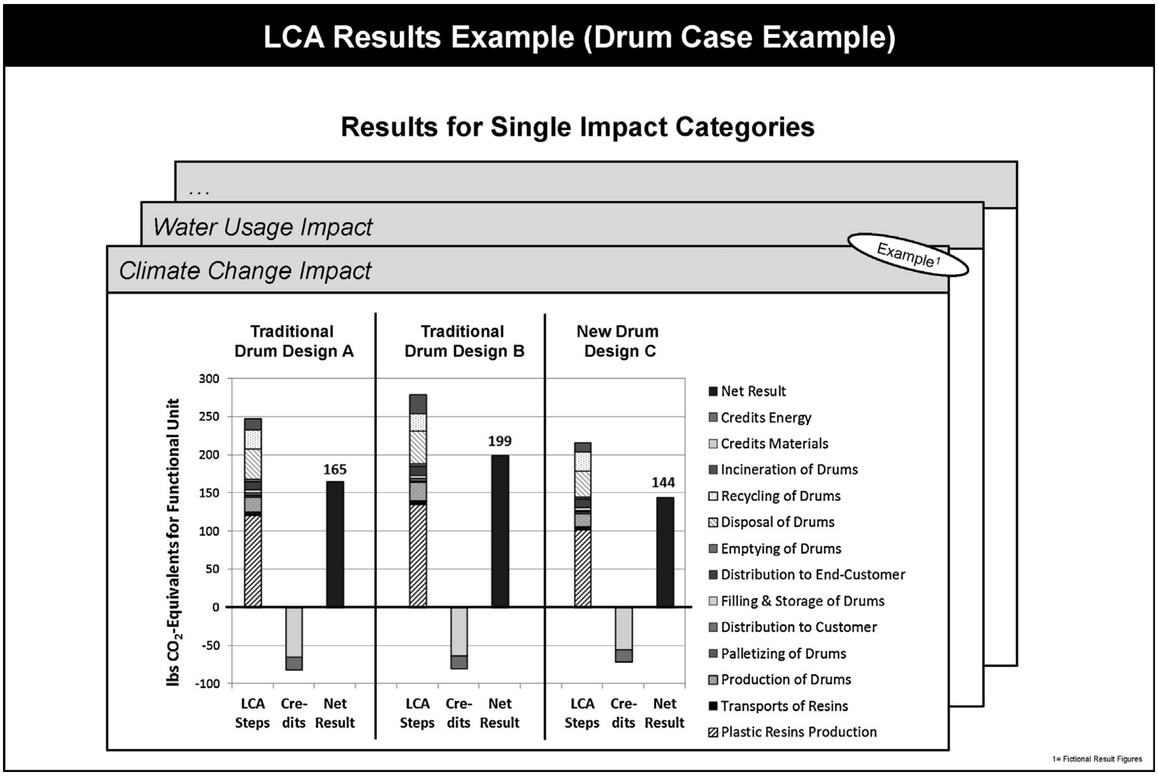
For each of the life cycle steps, the emissions and consumptions should be translated into environmental effects. For example, if global warming is the focus and the life cycle step of producing drums by blow molding consumes 100 kWh of electrical energy, the emissions for producing this electrical energy are assigned to the production step using the emissions data for equivalents of CO_2 produced by energy plants.

2.1.4. Step #4: Improvement assessment

In this last step, analysis results should be plotted on output graphs that allow an interpretation and a review along the impact categories. An illustration of an analysis of the results comparing the new drum design with two other traditional designs is provided in Figure 2.

From Figure 2, we observe that the new drum design has a 28% lower impact score on climate change compared to traditional drum design B, and a 13% lower impact score than that of traditional drum design A. In addition, the new drum design has a positive overall environmental profile compared to both traditional drum designs in all other impact categories. Next, we discuss how a company

Figure 2. LCA results example (drum case)



can use such information as a powerful value-adding tool.

3. LCA as a management tool: Value creation areas

Life cycle assessment creates huge learning value within companies (Frankl, 2001). It is a very powerful support tool for decision making that can be of great worth in various areas along the product development and implementation chain (Baumann, 1998; Bültmann & Rubik, 1999), including improving products and processes by optimizing their environmental performance or marketing the environmental benefits of products compared to competitive solutions (Frankl & Rubik, 2000; Jensen, Hoffman, Møller, & Schmidt, 1998). Next, we identify five specific application areas as summarized in Figure 3 and provide examples from industry to illustrate how the LCA can be used to create value.

3.1. Strategy development

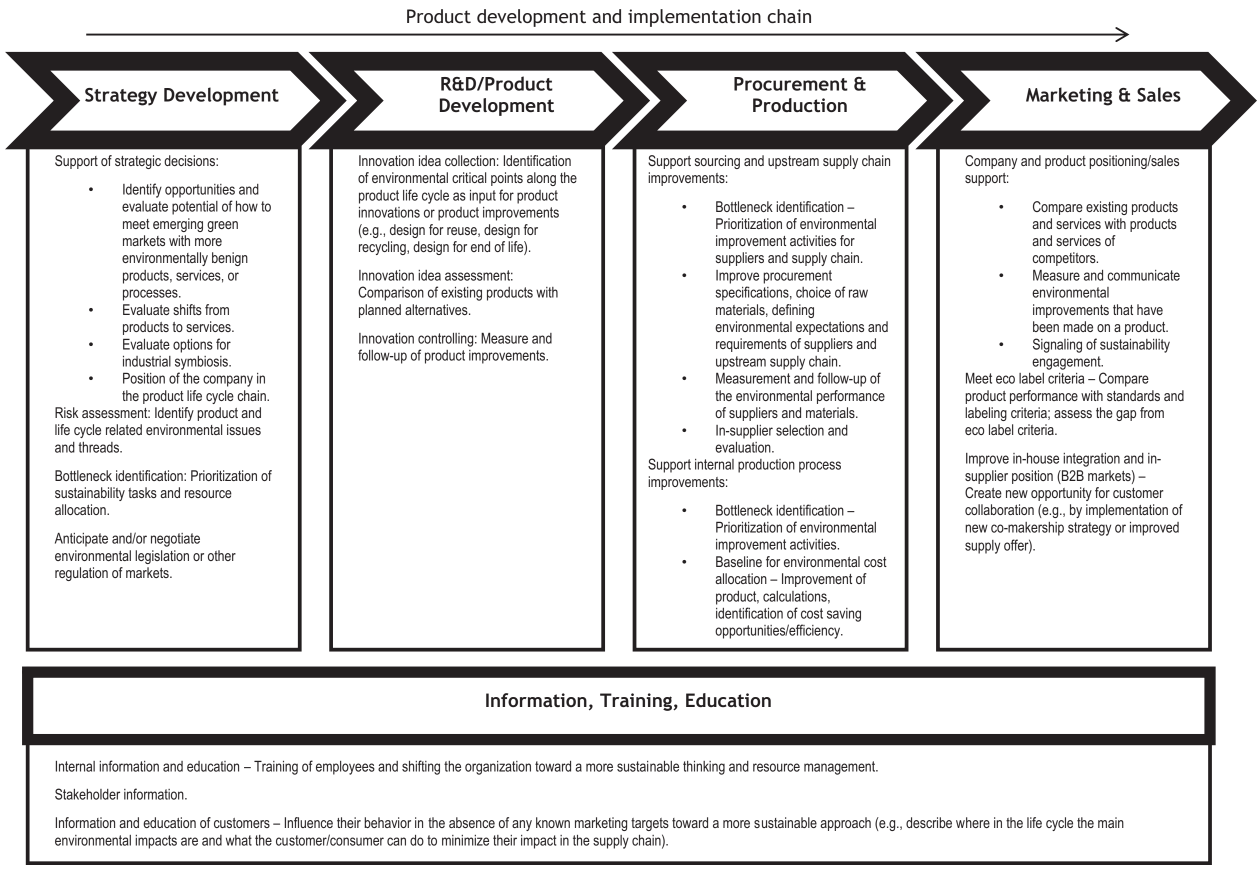
One way that LCA can add value to the company is through strategy development. LCA allows a systematic identification of critical sustainability issues related to a product's entire life cycle, and also reveals opportunities and risks within the company's product line. This information enables companies to develop better and more fact-based strategies to meet future market challenges in the context of sustainability. Greif Inc. starting a new business and Procter & Gamble offering a new product line exemplify the value creation power of LCA in strategy development.

3.1.1. Greif

Greif Inc., the world leader in industrial packaging products and service, realized some of its key customers were increasingly demanding environmentally friendlier product solutions. Many of these customers have their own corporate sustainability programs and began asking for environmental information (e.g., greenhouse gas emissions data) on Greif products, including its industrial shipping containers. It became apparent that customer priorities were shifting from buying shipping containers to seeking shipping solutions that could also help fulfill environmental goals. Greif Inc. conducted a life cycle assessment on its products to identify areas for improvement.

Previously, customers had suggested that ensuring shipping containers were full would be key to improving their environmental profiles because this would reduce emissions from transportation. Greif

Figure 3. Application and value creation areas of LCAs in management



itself had assumed that 'thin-gauging'—making shipping containers lighter and thereby reducing the use of materials—would be the best option to reduce containers' environmental impact. The LCA data, however, showed that while transportation emissions are a factor in the environmental profile of shipping containers, engineering the containers to lengthen their useful life via re-usage is the most effective option, even if that means constructing slightly heavier containers. Based on this, Greif determined that its core business should strategically shift toward the reconditioning of containers and offer re-usability services for these containers.

With this goal in mind, Greif made a series of acquisitions to broaden its expertise. For example, Container Life Cycle Management was a joint venture in North America between Greif and two environmentally responsible industry leaders: DRUMCO, a reconditioning, recycling, and remanufacturing company, and IndyDrum, a reconditioning company. Then, Greif acquired Pack2Pack, a European steel and plastic drum reconditioning company. Together they created EarthMindedTM Life Cycle Services, a service company that re-collects used containers and reconditions them for re-usage. Now, EarthMindedTM Life Cycle Services is the largest packaging reconditioner in the world, covering the U.S., Canada, and Europe.

The LCA studies helped Greif identify environmental risks in its value chain and develop a successful strategy via integrating additional sustainability services into its business model. Today, a significant share of Greif's revenue comes from reconditioned drum sales.

3.1.2. Procter & Gamble

Procter & Gamble (P&G) commissioned LCA studies on laundry detergents and washing processes to identify the best ways to reduce the environmental impacts of its products and thus serve the growing number of consumers who demand more sustainable products. The LCA results highlighted the usage phase and revealed that 60%—80% of total life cycle energy consumption stems from in-machine use of a detergent, prompted mainly by the electricity needed to heat wash water during the main cycle. As a strategic response, P&G decided to develop new products that would allow washing at lower temperatures. The result was a new cold-wash laundry detergent product line designed to clean as well at 15°C as at 40°C: Actif Á Froid in France, Ariel Kalt-Aktiv in Germany, and Tide Coldwater in the U.S. and Canada. These new products were perceived as evidence of Procter & Gamble's (n.d., 2014) commitment to the development of sustainable cleaning methods.

3.2. R&D and product development

Another way that LCA adds value to a company and its customers is via product innovation and development. There are several ways in which the firm may benefit from LCA for research and development (R&D) purposes: First, the LCA identifies critical product parameters and components for sustainability improvements within existing product designs. Additionally, LCA studies allow simulations of alternative product designs, such as how the environmental performance would change if a different material or process were applied. Finally, LCA view opens a new perspective for the company and thus can raise new ideas regarding how to improve products (Bhander, Hauschild, & McAloone, 2003; Klöppfer, 2003). Nestlé and AEG are exemplars of the value creation power of LCA in R&D and product development.

3.2.1. Nestlé

Nestlé compared the environmental impacts of different coffee capsule designs (e.g., aluminum, plastics, bio-plastics) for its Nespresso machine in a life cycle assessment study. Nestlé also used LCA to evaluate various end-of-life routes for coffee grounds and packaging systems (disposal vs. recycling). The findings were interesting: among all scenarios, aluminum capsules sent for recycling after use turned out to be the best alternative from an environmental perspective. Based on this result, Nestlé decided that increasing the recycling quota of its aluminum capsules rather than using alternative capsule materials should be the company's priority. Nestlé has been increasing its re-collection share by installing additional collection points and systems around the globe. The company's target is to reach an overall re-collection capacity of 75% of its capsules by the end of 2013 (Nestlé Nespresso S.A., 2011; Quantis, 2011).

3.2.2. AEG

Similar to Nestlé, AEG—a German producer of household devices, acquired by Electrolux in 2005—successfully used LCA methodology to optimize the product design of its washing machines. Washing machines require weights that are installed in the appliances to prevent them from vibrating and moving; very often, simple concrete blocks are used, which usually constitute one-fourth of a machine's total weight. AEG wanted to review if replacing the concrete blocks with alternative materials (e.g., steel, aluminum) would reduce the overall environmental impact of the machines. Various weight alternatives were compared through a life cycle assessment study. Surprisingly, the results showed that weights made from concrete blocks are an environmentally superior alternative, as long as the end-of-life appliances are not shredded but rather dismantled and recycled. As a result, AEG decided to incorporate design changes that would facilitate dismantling and recycling in its next generation of products (Bültmann & Rubik, 1999).

3.3. Supplier selection and production

Companies can also benefit from LCA when making decisions about supplier selection and production. This is because LCA allows a systematic review of sourcing and production processes of products and their contribution to sustainability issues. Based on this review, management can identify critical bottlenecks and optimize supply and production processes by prioritizing environmental improvement activities (Rebitzer, 2002). Patagonia and Staples exhibit the value creation power of LCA in the supply chain and production.

3.3.1. Patagonia

Well known for its interest in making apparel with the least amount of environmental impact, U.S.-based clothing company Patagonia runs a program called the Common Threads Initiative, which recycles used garments. Under this initiative, Patagonia collects old clothes from customers and recycles them into filament yarns to be used in polyesters. For final recycling, the collected garments are sent to a fabric manufacturer in Japan where Patagonia's clothes are also manufactured. Although this recycling program has obvious environmental benefits such as reducing the direct use of petroleum and natural gas for making polyester, there were concerns about the environmental impact of sending the U.S.-based used garments all the way to Japan for recycling. In order to clarify the issue, Patagonia evaluated and compared the energy use and greenhouse gas emissions that result from various scenarios. Fortunately for Patagonia, recycling of garments turned out to be more environmentally friendly than using virgin polyester, even if the U.S.-based used garments are shipped from the U.S. to Japan. But interestingly, Patagonia's LCA study also revealed that the transportation required to move old garments from customers' closets to domestic collection centers has the greatest potential environmental impact—not the international shipping from the U.S. to Japan (Patagonia, n.d.a).

Patagonia used this opportunity to optimize its recycling program by offering customers the option of returning garments through mail. Customers are also encouraged not to use the drop-off option, especially if they are driving to a store location just to turn in used garments (Patagonia, n.d.b).

3.3.2. Staples

Staples is yet another company that uses LCA results to optimize its supply chain. Paper is a large component of Staples' total footprint; therefore, Staples decided to review its paper procurement and supplier selection policy through a life cycle assessment study. Currently, the company achieves an average of more than 30% post-consumer recycled content for all its paper sales (Staples, 2006). It has also worked with a local farming community to create paper with less environmental effect. When the farming community harvests its crops, a large amount of plant materials are left over and typically burned, releasing particulates and CO_2 in the process. Staples saw this as an opportunity and worked with the farmers to develop a technology that creates slurry out of the plant mass to be used in paper production (Grayson et al., 2008).

3.4. Marketing and sales

Marketing and sales may receive value-add benefits from LCA. This can occur in various ways: First, results enable companies to make comparisons between competing products or solutions under sustainability aspects and can be used for sustainability-based product positioning and a market communication approach. At the same time, LCA results help customers better integrate sustainability aspects into purchasing decisions. Second, as LCAs consider the entire life cycle of products and processes—including customer handling and disposal—LCA results often allow companies to open the door for customers to jointly develop business projects that create mutually beneficial products, services, and solutions toward heightened sustainability, thus supporting in-house integration and relationship building with customers. How Excel Dryer Inc. and Orange used LCA results exemplifies the value creation power of LCA in marketing and sales.

3.4.1. Excel Dryer Inc.

Excel Dryer Inc., a manufacturer of air hand dryers, used LCA results to support the market introduction of its latest hot air hand dryer system, called XLERATOR. XLERATOR was designed to be a leader in energy efficiency among electric hand dryers. With the aim of independently confirming the system's efficiency benefits and being able to spread that message as part of the product's marketing campaign, Excel commissioned a comparative LCA and evaluated the environmental performance of its XLERATOR, conventional air dryers, and paper towels. The LCA results showed XLERATOR performs significantly better environmentally (Quantis, 2009) and this information was used as a pillar of the system's market communication concept (Excel, 2014).

3.4.2. Orange

LCA studies can help develop sophisticated communication approaches that extend beyond a standard public relations approach. For example, global IT and communications services provider Orange uses LCA methodology to support the sales of its telepresence solutions. Orange developed a life cycle assessment-based online tool that enables companies to evaluate the greenhouse gas emissions that could be saved through deployment of a telepresence solution in place of holding physical meetings. Companies can visit Orange's website (www.orange. mu) and work with the tool by changing parameters and designing the settings to suit individual situations, conducting what-if analyses. The LCA data is not only used to inform customers about the environmental benefits of a telepresence solution in general, but also to support direct sales of the service.

3.5. Information, training, and education

LCA can add value not only to the company, but also to its employees by providing the means for exchanging information, training, and education. LCA results allow fact-based information, training, and discussion with employees, suppliers, stakeholders, and customers about the company and its products, which is a necessary pre-step when shifting an organization and market processes toward more sustainable thinking, acting, and resource management. The value creation power of LCA in information, training, and education is apparent from the way the European Aluminum Foil Association (EAFA) and Nestlé Waters North America utilized the results of their LCA projects.

3.5.1. EAFA

Due to growing awareness and interest of the food industry in using environmentally friendly packaging materials, the European Aluminum Foil Association (EAFA) commissioned several LCA studies to evaluate the relative impact of aluminum packaging on the overall environmental impact of ready-packed food products sold by retailers. Several exemplary food products packed in aluminum components—such as coffee in flexible containers, goulash soup in stand-up pouches, ready-to-serve lasagna, chocolate bars, and roasts in aluminum foil—were considered (European Aluminum Foil Association, n.d.). The results showed that for most of the products, the relative environmental impact of the aluminum was rather small compared to other impact factors, including the raw materials used for food product, their cooking, and logistics. The results were published to inform general discussion about aluminum packaging and also to contribute to the discussion toward more sustainable food production and consumption in general (European Aluminum Foil Association, n.d.).

3.5.2. Nestlé Waters North America

In an era in which bottled water usage is high and the resulting environmental impacts are criticized wholeheartedly (Didier, n.d.), Nestlé Waters North America—the regional market leader—commissioned a life cycle assessment study. The firm's goals included better understanding the environmental impacts of bottled water and available alternatives, and exploring ways of further reducing its own environmental footprint. The LCA compared performance of various beverages, including tap water. Though bottled water showed positive environmental performance compared to many other bottled beverages, the results also indicated that using tap water could be seen as a more environmentally friendly alternative than using bottled water. While not necessarily favorable to the firm, Nestlé still published the LCA results to contribute to the general discussion in public about bottled beverages and their environmental impacts by providing fact-based information for an objective discussion (Nestlé Waters North America, n.d.).

4. Path to successful LCA projects: Avoiding potential challenges

To run a life cycle assessment project successfully, it is important that the technical LCA modeling is done accurately and the data used is of good quality. It is also important that the project is defined and set up to ensure that the intended management application focus would be reached in the most efficient way. Therefore, management must be aware of several important criteria that should be considered when setting up a project.

4.1. Avoiding unnecessary complexity

The effort required to run a life cycle assessment is linked to the complexity of the life cycle of the product under consideration. If the main goal is to review the impact of an improved product design for internal reasons, running a full LCA may be unnecessary. In this case, it would be better to focus on the improved component and the life cycle steps affected by this improvement. Therefore, modeling complexity should be aligned to the intended application focus.

4.2. Using internal vs. external resources

It is possible to run LCA projects with internal or external resources. If a life cycle assessment is designed with the aim of comparing products and sharing the information with markets, then credibility and independency are important factors for recognition of the final message. This is especially true if products of competitors are also included in the analysis. When a high level of credibility is mandatory, transfer of the project to an external institute should be considered. In addition, this should be combined with establishing an external review panel to accompany the project and ensure an independent result.

4.3. Speaking to the target audience

Several impact categories—such as global warming, depletion of the ozone shield, and reduction of nonrenewable energy resources—can be considered under a life cycle assessment. The more impact categories that are considered, the more precise the sustainability profile becomes for the product; on the other hand, including too many impact categories increases information complexity and thus it becomes more difficult to communicate the results. To produce a useful LCA, selection of impact categories should be based on the needs of the target group. If the results of the LCA are intended to be used in customer communication and the majority of the target customers are only familiar with carbon emissions, then global warming could be chosen as the main LCA impact category and other impact categories may be neglected.

4.4. Ensuring efficiency

Conducting a life cycle assessment requires availability of data about the main input and output factors of the life cycle steps (e.g., material flows and their impacts) as well as the collection of some process data about the company's own processes. If the necessary data is not easily available, the cost of conducting a life cycle assessment can become relatively high. Furthermore, if the quality of the data is bad, the quality of the LCA results is limited

(Frankl & Rubik, 2000; Reap, Roman, Duncan, & Bras, 2008). Before starting a life cycle assessment, companies should consider what data pieces will be needed, what data is readily available, and what effort and time it will take to collect missing data. Management may then compare data availability, time requirement, and availability of financial resources against projected benefits of the LCA.

4.5. Providing top management support

Finally, successful LCA project implementations normally require involvement of the top management team. They also require thinking outside the classic management perspective of the company. If management fails to show dedication, LCA projects have an inherent risk of failure in the implementation phase (Frankl & Rubik, 2000).

5. LCA extensions for management support

As we have discussed, life cycle assessment may serve management as a powerful tool toward improving business performance. Beyond that, it is possible to combine results from a life cycle assessment with other decision-making criteria such as cost or performance information. Eco-improvement analysis and eco-efficiency portfolio analysis, especially, are two recent management tools that can support business successfully. Another innovative way of using LCA entails providing an interactive consultancy tool. Next, we discuss the details of these tools.

5.1. Eco-improvement analysis

When companies work on improving the sustainability performance of their products and processes, available resources are usually limited and therefore efficiency is important. Management needs to prioritize potential improvement actions and focus on those areas in which the relationship between the impact of improvement and the necessary resources for improvement is positive.

The eco-improvement analysis is an approach that is used to identify, evaluate, and prioritize potential improvement actions. Within eco-improvement analysis, each single life cycle step—reflecting either single product components or actions within the life cycle—is plotted in a two dimensional matrix. On the x-axis, the overall environmental impact of the single life cycle step is presented, which is derived from the LCA results. The ability and effort to improve each single life cycle step is shown on the y-axis. A scoring model is used to measure ability and effort to improve. For scoring, potential improvement measures per life cycle step are taken and their impact rated. This step can be supported by what-if analysis from the LCA. In addition, effort to improve in the life cycle step is rated, too. Finally, those life cycle steps that show a high environmental impact and allow a relatively large improvement at low efforts are identified. This allows a systematic and efficient management toward more sustainability.

5.2. Eco-efficiency portfolio analysis

Regarding both purchasing and sourcing decisions, customers and companies need to make a choice between different suppliers and their alternative products. To integrate sustainability impacts into the decision-making process, the eco-efficiency portfolio analysis—which supports a rating of products within purchasing decisions—can be applied.

Under an eco-efficiency portfolio analysis, products are compared and rated along two or three decision-making criteria. The first rating criterion is relative environmental performance of the products, based on the results from LCA. The second rating criterion is relative price or cost performance of the different products. Further, relative quality performance of the products in fulfilling the intended application need can be included as a third rating criterion. For this quality rating of the products, a scoring model is normally applied based on pertinent quality dimensions. Based on these relative performance ratings, the alternative products are placed in a multi-dimensional decision support matrix that allows the relative overall performance of the different products to be identified. The eco-efficiency portfolio analysis can be used for supporting purchasing decisions as well as sales processes.

5.3. Interactive consultancy tool

Besides supporting important decisions such as purchasing, LCA can also be used as an interactive consultancy tool to create value on the customer side. A good example is Greif Inc.'s Green Tool.

5.3.1. Greif

Again considering industrial packaging company Greif Inc.: LCA results enabled Greif not only to review its strategy and respond to customer requests for general information about the environmental properties of its products, but also give customers advice on what they could do to improve sustainability in their packaging application. Even though most customers did not expect more than some high-level information regarding the environmental properties of industrial containers, Greif took a more comprehensive approach and decided to be transparent and provide as much information as possible. To do so, Greif developed a specific LCA calculator called the Green Tool, which enables packaging users to evaluate the environmental impact of industrial packaging usage in their given individual situation. The Green Tool allows users to create what-if scenarios and determine the environmental impact of industrial packaging under different parameters; for example, assuming various trip-rates via reconditioning, using different container specifications, sourcing containers from different plants within varying distances, or increasing the recycling quota of the used packaging by a factor of 20%. In addition, an eco-efficiency analysis model was implemented to consider packaging decisions by taking cost and environmental aspects into account at the same time.

Those customers interested in the environmental properties of their containers were invited by Greif to consider not only their given environmental performance in packaging, but also the effects of changes in their behavior; for example, if they decided to switch from one container type to a different type, or if they increased the re-usage quota of their containers.

Interest in the tool was high and came not only from customers' purchasing departments (which are traditionally the main contacts for the sales force at Greif) but also from their marketing, sales, and sustainability departments (which can be classified as core decision makers when it comes to packaging purchasing decisions). The initiated sessions enabled Greif to establish relationships with these contacts and then learn about their unmet needs and specific issues. Valuable information was gained from discussing the different LCA findings; this offered Greif new business opportunities to initiate joint business process developments between Greif and its customers for mutual benefit (Figure 4).

6. LCA is not without its limitations

As discussed so far, the LCA method can be a very helpful learning and decision support tool for managers and can contribute positively to successful development of the company. Still, some potential limitations of LCA as a decision support tool exist (Finnveden, 2000). In order to make any LCA project effective and successful, management should be aware of the following issues regarding the design and conduct of a life cycle assessment, which can limit the tool's power.

6.1. Complexity of results and conclusions

The LCA method considers several environmental impact categories—including but not limited to climate change, ozone creation potential, and water use—at the same time. Interpretation of the different indicators to draw an overall conclusion can become difficult if the indicators have contradicting impact results. For example, an action that is effective in reducing the global warming impact of a product can also be bad for the environment if it triggers other environmental problems. A manager must then decide which priorities he/she wants to set to improve the product; this often is a subjective choice.

A life cycle assessment based on several indicators can also cause difficulties in communicating the results. This is especially true if the target audience is not trained to work with multi-dimensional indicator sets. To overcome this issue, however, a few methods are able to break down the complex results to a single overall cumulative environmental result. Using a single environmental result can support easier communication and interpretation.

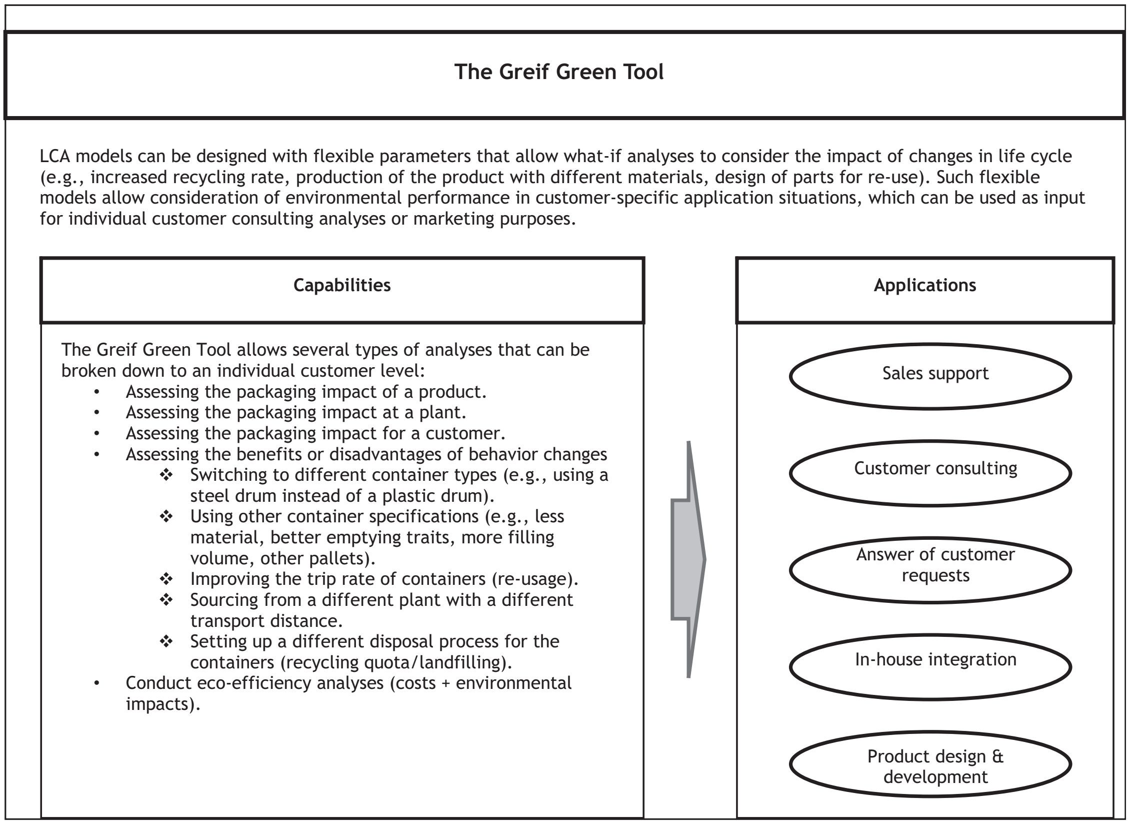
6.2. Resource-time intensity

A holistic LCA can become very data intensive and time consuming, depending on the given product or process complexity. The more comprehensive a life cycle assessment, the more time consuming and expensive it will be. High costs are, in part, prompted by data collection and necessary expert knowledge in the stages of impact and improvement analyses.

6.3. Lack of data

The accuracy of a life cycle assessment study depends on the quality and availability of relevant data. A detailed LCA requires inventory data of all the elementary processes included within the parameters of the system. This data is sometimes not available to those who perform the modeling, as they do not have direct access to all life cycle steps such as processes at supplier or customer plants and product usage parameters. When this is the case, assumptions must be made. And when data is missing and the LCA needs to be based on assumptions, several sensitivity analyses should be conducted to review the vulnerability of results from making these assumptions. Such sensitivity analyses normally have a direct impact on the complexity and costs of LCA projects (Guinée, 2002).

Figure 4. The Greif Green Tool



6.4. Subjectivity

The LCA method has some inherent methodological difficulties, too. When setting up the life cycle assessment, boundaries, data sources, and impact assessment choices have to be determined, which may be influenced by assumptions and subjectivity. Also, credit and debit scores can differ depending on the chosen allocation method (Frankl & Rubik, 2000; Reap et al., 2008). Therefore, results of different LCAs on a single subject may vary according to the objectives, modeling, quality of data, and impact assessment methods used. That is why transparency is key in LCA.

6.5. Not everything is measured

While specific impact assessment indicators have been developed for several environmental burdens, such indicators do not exist for all concerns; likewise, many extant indicators have no common acceptance. For example, noise—a commonly noted environmental burden—can be measured by decibel (dB) releases, but there is no accepted model regarding how to evaluate a specific dB release with respect to its harmfulness.

In addition, LCA considers environmental aspects of products and processes, but includes neither price and cost considerations nor social impacts. Therefore, it cannot be used to determine which product or process is best from a holistic welfare perspective. Furthermore, following LCA recommendations from product comparisons may have unintended implications on other areas of the market as they may lead to unwanted rebound effects such as increased overall consumption; for example, heightened fuel efficiency may lead to an increase in car usage rather than a reduction in environmental impact. In a recent discussion about fuels, many suggested using ethanol rather than gasoline because corn is a renewable energy source and LCA showed ethanol to have a lower environmental impact. However, the cost of ethanol is higher than the cost of gasoline if used on a large scale, and some argue that such corn usage would spike prices and potentially prompt food shortages (Pentland, 2012). Therefore, as part of a welfare evaluation, LCA should be just one component of a more comprehensive cost performance assessment.

7. Concluding remarks

Today's typical management thinking in most companies focuses on the exchange processes with suppliers, customers, and competitors. However, especially in the area of sustainability, the critical environmental impact of products or processes often is not caused by the producer or the customer directly, but rather is linked to the natural and physical traits of the raw materials used and the behavior of all actors and their integrated behavior in the whole product life cycle. Accordingly, identifying and creating new business opportunities in sustainability requires a holistic business perspective from cradle to grave of a product or service, considering also processes outside of the classic supplier-company-customer relationship. The life cycle assessment method helps managers view the market in this holistic perspective more systematically.

The LCA method itself produces environmental impact figures for the entire life cycle of a product or service, which not only enable management to identify critical life cycle steps of their products and services, but also enable management to make what-if analyses to evaluate improvement measures. The results can help managers improve business performance in the areas of strategy development, R&D and product management, sourcing and production, marketing and sales, and also information and training. As shown in the cases, the business impact on adding value can be enormous in all of these areas.

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