PAPER PRESENTED AT IAPRI WORLD CONFERENCE 2012

Eco-efficient Value Creation: An Alternative Perspective on Packaging and Sustainability

By Renee Wever^{1,2*} and Joost Vogtländer¹

¹Design for Sustainability group, Delft University of Technology, Landbergstraat 15, 2628 CE Delft, The Netherlands

²Department of Design and Manufacturing Technology, University of Limerick, Limerick, Ireland

The classical sustainability perspective on packaging is to reduce the environmental impact or eco-burden of the packaging, using life cycle assessment to evaluate different design alternatives. Simultaneously, the classical marketing perspective on packaging is to generate value through differentiation, for instance, by providing additional convenience. These two perspectives often conflict. In business reality, there is currently no established method to deal with these conflicts. Life cycle assessment is methodologically incapable of incorporating the difference in convenience. This article uses the eco-costs/value ratio (EVR), as a method for dealing with the environmental assessment of packaging design alternatives with such unequal 'soft' functionality.

The article reviews the current debate on packaging and sustainability, highlighting some of the shortcomings of the methods currently applied. Subsequently, the EVR model is introduced and applied to five examples. These examples consist of pairs of products, where the product, the amount, the brand and the retail outlet are identical and only the packaging design and the value differ. The examples illustrate how the EVR model fits better to design decision making in business reality than classical life cycle assessment. Copyright © 2012 John Wiley & Sons, Ltd.

Received 16 December 2011; Revised 25 April 2012; Accepted 26 April 2012

KEY WORDS: design; life cycle assessment; decision support; marketing; innovation

INTRODUCTION

Historically, growth of the economy came with increased environmental burdens. A major aim of sustainable development is to decouple these trends and achieve economic growth without increasing the eco-burden. In pursuit of such decoupling, designers and industry need models and tools that take both the eco-burden and the economic value creation into account simultaneously. This article applies the eco-costs/value ratio (EVR) model to packaging, with the aim to enable packaging professionals to assess how (potential) packaging solutions score in light of this notion of decoupling.

Sustainable packaging

Currently, there is no method to qualify a given packaging design as 'sustainable', at least not objectively. Sustainable development has been defined as 'development that meets the needs of the present without compromising the ability of future generations to meet their own needs'.¹ This is a definition on a system level, with the entire planet constituting the system. On the level of the total system,

*Correspondence to: Renee Wever, Design for Sustainability group, Delft University of Technology, Landbergstraat 15, 2628 CE Delft, The Netherlands.

E-mail: r.wever@tudelft.nl

a determination could potentially be made whether it is 'sustainable'. However, that would require a determination of both the total eco-burden on the eco-system Earth as well as a determination of the fulfilment of needs. A single packaging design or even a single physical package contributes both to the total eco-burden (related to the needs of the future generation) and to the fulfilment of the 'present needs'. Whether that combination of eco-burden and present need fulfilment is 'sustainable' is a subjective matter, which is furthermore highly dependent on the (also subjective) assessment of the combination of eco-burden and need fulfilment of the product contained within the packaging. At best, it is possible to assess whether one packaging design is more sustainable than another, either because it fulfils the same needs at a lower eco-burden or because it fulfils more needs at the same eco-burden.

Notwithstanding the impossibility of objectively determining whether a single packaging is 'sustainable' in an absolute sense, several attempts have been made to draft a definition of what sustainable packaging would be. The Australian Sustainable Packaging Alliance has defined Sustainable Packaging as consisting of the following four principles (<http://www.sustainablepack.org>, accessed 10 December 2011):

- Effective: fit for purpose (The packaging system achieves its functional requirements with minimal environmental and social impact.)
- Efficient: minimal use of materials and energy (The packaging system is designed to use materials and energy efficiently throughout the product life cycle.)
- Cyclic: renewable and recyclable materials (The packaging is designed to reduce reliance on non-renewable resources and to recover them for reuse or recycling.)
- Safe: non-polluting and non-toxic (The packaging materials and components used in the system, including materials, finishes, inks, pigments and other additives, do not pose any risks to humans or ecosystems. When in doubt, the precautionary principle applies.)

Although this definition may be helpful in reducing the eco-burden of packaging, it does not address the present need fulfilment side of the packaging. It only states 'fit for purpose', but it does not give a qualification or assessment of that purpose.

Another widely used definition of sustainable packaging is that by the Sustainable Packaging Coalition (<http://www.sustainablepackaging.org>, accessed 10 December 2011), who defines sustainable packaging as packaging that

- is beneficial, safe and healthy for individuals and communities throughout its life cycle;
- meets market criteria for both performance and cost;
- is sourced, manufactured, transported and recycled using renewable energy;
- optimizes the use of renewable or recycled source materials;
- is manufactured using clean production technologies and best practices;
- is made from materials healthy in all probable end of life scenarios;
- is physically designed to optimize materials and energy; and
- is effectively recovered and used in biological and/or industrial closed loop cycles.

This definition does pay lip service to the side of the present needs through the mentioning of 'beneficial' but still focuses on the reduction of eco-burden. The issue with only looking at the eco-burden is that the accompanying incentive is that the impact needs to be minimized at all costs, leading to what might be termed the brown-paper-bag dogma: the ill-informed position often observed among environmentalists, wherein the ideal packaging is no packaging at all, or at least nothing more than a proverbial brown paper bag. This guilt-based approach (i.e. blame the packaging) does not align well with business reality, which sees packaging as a differentiator through which value is created.

On a system level, a combined view on economic growth (basically representing value) and eco-burden has been articulated. Until now, the increase in eco-burden has been in step with economic growth. To reach a sustainable society, this trend has to be broken. In other words, the eco-burden needs to be decoupled from economic growth. To translate this notion to a product (or packaging) design level, a method that incorporates both the value side and the eco-burden side is needed. The method used in this article does exactly that.

The classical notion of sustainability does also contain both, and even a third one, as sustainability is often said to consist of three components (the 'triple P model', coined by John Elkington):

- people (in the Brundtland report: the people of the developing countries),
- planet (the eco-systems) and
- prosperity (profit where all stakeholders benefit: customers, employees, shareholders and society).

For packaging, the 'planet' side (e.g. the eco-burden) is covered extensively. In fact, the existing literature on sustainable packaging has focused mainly on reducing the eco-burden. The profit side is also covered extensively, although usually not explicitly as a component of sustainability. Addressing the 'people' component has proven difficult though. Several authors have made an attempt at addressing the people or social component of sustainable packaging (e.g. see Wever and Tempelman² and Nordin and Selke),³ but this remains an area of further potential. Within the concept of sustainability, the profit side of packaging relates to the needs fulfilment mentioned in the definition of sustainable development, namely, through the economic value provided: the perceived customer value ('fair price') of the product.

Reducing the eco-burden

As said, the perspective on packaging and sustainability has been mainly focused on the eco-burden, especially focusing on the production and end-of-life phase. The standard scientific approach of this subject is through life cycle assessment (LCA).^{4,5} For examples of case studies on reducing the eco-burden, see Singh *et al.*⁶ and Bovea *et al.*⁷

Although LCA quantifies the eco-burden in a more or less objective way, it does not lead to a qualitative assessment of whether a design is 'sustainable'. It only allows comparing design alternatives that are equal in functionality and quality. In case of two or more design alternatives with distinctly different functionalities, for instance, in case of a comparison between a re-usable and a one-way beverage packaging, the use of a well-chosen functional unit still enables a comparison. For instance, the delivery of X gallons of milk. However, although this brings the two design alternatives on a comparable basis from an eco-burden perspective, it does not incorporate the 'soft' differences, such as convenience and thereby value to the consumer.

Some of the limitations of LCA as a method have been discussed by Lewis *et al.*⁵ There are also alternative eco-burden indicators (often based on LCA) that have been tuned more to packaging optimization in business practice (e.g. see Wever,⁸ Svanes *et al.*⁹ and Wever *et al.*).¹⁰

Some authors have attempted to link sustainability to value instead of eco-burden. In their article on customer perception of refillable paper, Lofthouse *et al.*¹¹ essentially address the value side of design for sustainability. Also, the work on prevention littering by Wever *et al.*¹² and the work on re-use of packaging¹³ focus on the value of the packaging. However, these authors did not combine that value perspective with a quantified assessment of the eco-burden.

This article will propose an alternative perspective on packaging and sustainability, through a method that combines the eco-burden aspects with the value provided by the packaging: the so-called EVR.

An interesting method is presented by Svanes *et al.*,⁹ who propose a holistic approach incorporating both the eco-burden as well as the functionality, which they do in the form of five main categories: environmental sustainability, distribution costs, product protection, market acceptance and user-friendliness. By measuring the aspects of each of these five aspects, they provide a way for designers to optimize instead of minimize packaging [9, p.163]. The Svanes model seems strongly based on the insight that packaging fulfils functions across the entire supply chain, and not solely in at the point of purchase. The model explicitly distinguishes between the supply side (via distribution costs), the retail phase (via market acceptance) and the post-purchase phase (via user-friendliness). However, they leave the five components as separate spider diagrams, with some addressing costs (e.g. distribution) and others value (e.g. user-friendliness), thus not catching the essence of the design alternatives under review in a single score. The EVR is capable of doing this. It realizes that although there are functions to be fulfilled across the entire supply chain (and thereby require the business to spend money on doing so, thus constituting a cost), they only truly provide value if it results in the willingness to pay with the consumer. The willingness to pay incorporates the perceived benefits of

a product at the time of purchase. In a free market, the retail price reflects the perceived value of consumers. Hence, both methods have their pros and cons. The Svanes model will assist packaging designers to address all functionalities of a give packaging and will help visualizing decisions. The EVR model focuses more strongly on decoupling, capturing the balancing of environmental impact versus value creation.

THE EVR AS AN INDICATOR FOR SUSTAINABILITY

LCA and single indicators

As mentioned before, the widely accepted method to determine the eco-burden of a product is LCA as defined in the ISO 14044¹⁴ and described in recent LCA Guides.^{15,16} LCA is a process flow analysis of a product life (see Figure 1). The first step of the analysis, the Life Cycle Inventory (LCI), results in a list of all emissions to air, water and land and a list of required inputs (materials and energy). The second step in LCA is the Life Cycle Impact Assessment. In this second step, the emissions (often a long list of several hundreds of chemical substances) are combined in categories that cause the same effect, resulting in the so-called midpoints (e.g. greenhouse, acidification, eutrophication, photochemical oxidation, carcinogens, eco-toxicity, fine dust, etc.). In a final step in Life Cycle Impact Assessment, midpoints are often combined in a 'single indicator'.

There are three types of single indicators to express the eco-burden of a product in a quantitative way:

- Single issue, where the eco-burden is normally expressed in either kg CO₂ or use of energy.
- Damage based, where the damage of the emissions is expressed in three 'end points': damage to human health, damage to eco-systems and materials depletion.
- Prevention based, where the eco-burden is the sum of the prevention costs of all midpoint categories (adding up the prevention costs of climate change, acidification, eco-toxicity, etc.) and the future costs of avoiding materials depletion.

The best known single issue indicator is the carbon footprint: kg CO₂ (<http://www.carbonfootprint.com>, accessed 10 December 2011) or kg CO₂ equivalent (where other greenhouse gasses are taken into account as well). The advantage is that the calculation is relatively simple. However, the disadvantage is that toxic emissions are not taken into account. Another disadvantage is that they do not perform well in recycling calculations because the effect on materials depletion, the main reason for recycling, is not counted.

The best known damage-based indicators are the Ecoindicator 99 (<http://www.pre-sustainability.com/content/eco-indicator-99>, accessed 10 December 2011) and the ReCiPe (<http://www.lcia-recipe.net>, accessed 10 December 2011).

The advantage of a damage-based indicator is that it makes people aware of the environmental problems. However, the disadvantage is that the calculation method is complex and very inaccurate. To combine the three end points, a subjective weighting procedure (panel weighting) has to be applied, which is considered as a disadvantage^{17,18} and even formally 'forbidden' in public LCA studies.¹⁴

Figure 1. The basic calculation system of LCA.¹⁶

The best known prevention-based indicator is the eco-costs (<http://en.wikipedia.org/wiki/Eco-costs>, accessed 10 December 2011). It has been introduced in 2000.^{19,20} The advantage of prevention-based systems is that the calculations are less complex and less inaccurate (compared with the damage-based systems) and that the subjective weighting step at the end is avoided. Another advantage is that the result of the calculations is expressed in euros or in US dollars²¹ and that the result is focused on the decision processes in business and in design and engineering²² because the eco-costs are a proxy for the tradable emissions rights, which are required to reduce the emissions to the 'no effect level'. The calculation scheme is depicted in Figure 2.

An interesting issue of the classic LCA product benchmarking (comparison of two or more products) is that the products that have to be compared must have the same functionality ('functional unit') and the same quality (you cannot compare apples and oranges in a classical LCA). For the design of consumer products, this is a serious flaw in the classical LCA because product innovation is all about improving the functionality and/or quality (in the broad sense) of a product. In the case of consumer packaging, this issue is often about adding convenience and/or design (e.g. a packaging solution that is nice at the dinner table or has the convenience of the right dosing system). The functional unit is then more than just the 'delivery of x kg of product to the consumer'. We will show in this article how to resolve this issue by dividing the eco-costs by the value of the product: the model of the EVR.

Strategic consequences of eco-costs

The eco-costs of a product are relevant for business strategies because companies are facing the trend in society that people do not accept anymore that industry can pollute the world free of charge. The current 'external' environmental damage is expected to be 'internalized' in the costs structure of a product (by tax, tradable emission rights, obligatory best available technology or other governmental regulations). This process is slow but relentless. It might be a threat to companies, but it is also an opportunity for pro-active strategies. Having low eco-costs will contribute considerably to providing a product with a competitive edge in the future.

In business, however, other aspects ('dimensions') of a product cannot be forgotten: the quality–costs ratio or (even better) the value–costs ratio. The value is here defined as the 'customer perceived value' or 'fair price'. The fair price is defined as the price that a customer is prepared to pay. The customer perceived value can be defined as the use and fun that is expected by the buyer after the purchase. The customer perceived value and the market price are supposed to be the same in an open competitive market.

The two-dimensional character of the strategic issue is depicted in the product portfolio matrix of Figure 3, which shows that the 'greening' of a product portfolio (arrow 2) is required to become fit

Figure 2. Calculation structure of the eco-costs.¹⁶

Figure 3. Product portfolio matrix for the innovation strategy of a company.¹⁶

for the future because most of the current products are in the upper right quadrant. Doing nothing is no option: it will cause that products drift into the upper left quadrant (arrow 3) because of the aforementioned ‘internalization’ of costs of pollution. Such a product will be forced out of the market because the sales price of the product cannot be increased above the fair price in the eyes of the customers. The greening of a product portfolio by redesign has to be performed with great care because high value–costs ratios must be kept intact: there is no short time market for green products, which have either production costs that are too high or have a low (perceived) quality. In practice, there are plenty of opportunities to lower the eco-costs at even a higher value by a better choice of materials, by recycling and by saving energy.

When a product design is in the lower left quadrant, something has to be performed to increase its value, either by adding convenience and/or services or by adding image by design and/or marketing (arrow 1).

Decoupling and the EVR model

The main issue of sustainability is the required decoupling (delinking) of economic growth and environmental degradation. From the report of Brundtland [1, page xii of the conclusions], ‘What we need now is a new era of economic growth—growth that is forceful and at the *same time* socially and environmentally sustainable’, and from the mission statement of the World Business Council of Sustainable Development (1995), ‘The delivery of competitively priced goods and services that satisfy human needs and bring ‘quality of life’, while progressively reducing ecological impacts and resource intensity, throughout the lifecycle, to a level at least in line with the earth’s estimated carrying capacity’. Note that this definition combines the customer value of a product (‘the delivery...quality of life’) with its eco-burden (‘reducing impacts...earth’s estimated carrying capacity’). Note also that the EVR model is about the prosperity and the planet of the triple P model (not about the people of this model).

The EVR is developed to analyze the required decoupling on a product level: it is a single indicator for sustainability. The basic idea is to link the ‘value chain’ of Porter²⁵ to the ecological product chain (see Figure 4). A product has three dimensions in this model: the costs, the eco-costs and the (customer perceived) value (see Figure 5). The costs (cradle to gate) in Figure 5 are derived from the materials,

Figure 4. The basic idea of the EVR: combining the value chain with the ecological chain.²³

Figure 5. The value, the costs and the eco-costs of a product and/or service, cradle to gate.²³

the energy, the depreciation of equipment and infrastructure and the labour (and tax). The difference of the value (price) and the costs is the profit. The eco-costs are calculated by LCA (cradle to gate), applying the same components as used in the cost calculation.

The EVR model links the production side of the environmental problem (i.e. make products with lower eco-costs) to the consumer side (i.e. give green products a higher value so that consumers will buy it). It must be mentioned here that many surveys of customer behaviour show that most people agree that the environment is important; however, they are not prepared to pay more for the fact that a product is green. Therefore, the required added value must be created in other aspects: product quality, service and/or image (branding, where the environment plays a secondary role, next to health, nature, design and other 'feel good' aspects).

The strategic issue of decoupling can be explained by Figure 6, which shows the EVR (= eco-costs / price) on the y-axis as a function of the cumulative expenditures of all products and services of all citizens in the (at that time) 25 European Union (EU) countries on the x-axis. The data are calculated from the Environmental Impact of Products study of the EU.²⁴ The area under the curve is proportional to the total eco-costs of the 25 EU countries.

There are two strategies to reduce the area under the curve (and thereby reduce unsustainability):

- Force the industry to reduce the eco-costs of their products (this will shift the curve down).
- Try to influence the buying behaviour (preference) of the consumers by making products with low eco-costs more attractive; the result will be less expenditures at the right side of the curve and more expenditures at the left side of the curve (this will shift the middle part of the curve to the right). Note that people tend to spend what they earn (the savings ratio is <5% in most countries).

Figure 6. The EVR and the total expenditures of all consumers in the EU25, recalculated from the Joint Research Centre European Commission.²⁴

In environmental economics, this is called the *rebound effect*: when people save money in one area, they will spend that money in another area. (The term rebound effect was introduced in environmental economics as a second-order effect of savings: the consumer will tend to spend (part of) the saved money at the same type of products; e.g. when the fuel efficiency of cars is enhanced, people tend to drive more; when light bulbs are made more efficient, people tend to apply light bulbs in their gardens).^{23,24}

The question is how designers can contribute to both strategies and what it means for the product portfolio of companies (Figure 3). The solution is eco-efficient value creation. (Note: Detailed background information on the EVR is provided by Vogtländer *et al.*²³. General information can be found at http://en.wikipedia.org/wiki/Eco-costs_value_ratio and www.ecocostsvalue.com.)

Eco-efficient value creation

The road towards sustainability requires a double objective in design and engineering: lower eco-costs and at the same time a higher value (a higher market price; see Figure 7). We call this ‘eco-efficient value creation’ (in fact, eco-efficient is here eco-effective because it aims at an optimum value rather than minimum costs). The EVR model has a lot in common with the C2C philosophy,²⁶ which also emphasizes eco-effective solutions (less use of materials, more recycling). However, the EVR model combines this philosophy with LCA and business science).^{16,26}

The reason we need value creation for sustainable products is threefold:

- The higher price in the market may be required to cover the potential extra production costs of green products (note that a higher price is only accepted by the customer when the perceived value is higher).
- The higher price prevents the ‘rebound effect’ (or can even be seen as a reverse rebound effect). One can spend one’s income only once. If a person is convinced (even if only through marketing-created brand image) to spend more money on a given product, that money is not spend on other products or services. Thus, through the simple fact of increased value of a given product, the eco-burden associated with spending a person’s entire income is reduced.
- Lowering the EVR is the key to sustainability at the macro-economic level (Figure 6).

Examples of eco-efficient value creation are in the European and Japanese automotive industry:

- BMW and Volkswagen developed engines with an ever better fuel efficiency: they combine lower CO₂ emissions with higher acceleration characteristics. Note that they emphasize in their advertisements the fact that they offer top technology (= value) rather than low emissions.
- The Hybrid Lexus in the USA combines power with excellent fuel efficiency as well. From an advertisement in the USA: ‘...While it may have a V6 engine under the hood, the extra boost from the electric-drive motor gives the vehicle the acceleration power of a V8...’

It is not always possible to increase value without increasing eco-costs. However, when the EVR is lower, it is positive for sustainability. Adding value at low additional eco-costs is good for sustainability as such, from the macro-economic point of view. On the other hand, lowering eco-costs at the cost

Figure 7. The double objective: lower eco-costs and higher value.

of quality (value) is generally not good for sustainability: it is damaging the reputation of green products (many people do not trust the quality of green apparel fibre, dislike recycled writing paper, etc.).

Figure 8 depicts the possibilities of a new design in terms of its eco-costs and its value compared with the reference (the old product which is replaced by the new design). There are four quadrants:

- Quadrant 2 is the quadrant of eco-efficient value creation: it is the preferred quadrant for innovation.
- Quadrant 1 is the classical eco-design, where the eco-costs have been reduced at the cost of quality (or price). In sector 1a, there is a reduction of the EVR; however, the value is decreased as well, so the product is not liked (and may be hard to sell). In sector 1b, the EVR even increases, so even with lower eco-costs, the product is not good for sustainability at all.
- Quadrant 3 has a sector 3a, which has a lower EVR and so is good for sustainability. A design in sector 3b has a higher EVR and so should be abandoned.
- Quadrant 4 must be avoided because it is unsustainable: if the EVR is higher, the eco-costs is higher and the value is lower; hence, such a product does not make sense from a sustainability perspective.

Innovations in packaging for food often are in quadrant 3; new packaging will aim to differentiate the product and thus provide additional value. This value is (often) achieved through additional material or higher impact materials. The relevant question on proposed innovations is whether they fall in scenario 3a (which is positive) or scenario 3b (which is negative). In the next section, we will provide data on an analysis of the examples of packaging in the food industry.

This exploration with existing cases of scenarios 3a versus 3b (and to a certain extent scenario 1a) is also the scientific contribution of this article to the existing literature on the EVR,^{19–23} which has so far focused on arguing in favour of scenario 2, as the best direction for innovation.

PACKAGING IN THE FOOD INDUSTRY

Methods

To clarify what the EVR model can contribute to assessing the sustainability profile of packaging, and especially what it can mean for packaging with higher functionality than minimum requirements, we have sought examples for several case studies.

Although one of the strengths of the EVR model is that it is capable of comparing designs of unequal functionality, for example, portion packs with family packs, we have placed some restrictions on the selection of packages because of the context and the clarity of this article. To say something specifically about both the eco-cost and the value of the packaging on its own, hence separate of the contained product or other variables, we wanted the packaging to be the only variable that could explain the difference in value. This meant that we had to find example packages where the same

Figure 8. The six directions of product innovation.

product, from the same brand, in the same amount, was sold in the same retail outlet at the same time. Hence, the only two variables for each pair of packages would be the packaging design and the retail price.

For this article, we worked with existing examples available in the market. When applying the EVR model in a packaging design process, different design concepts would be compared with each other, or with an existing packaging solution.

Five pairs fitting the selection criteria were purchased. Each pair was purchased only once (although never at a discount), which means the price difference reported here is based on a single store at a single time and the weights of the packages are also based on measurements of a single sample. This means that the results, as reported in this article, have some uncertainty as to the accuracy for the specific cases reported here. This is not a problem because these uncertainties are assessed to be smaller than those in the eco-burden data in generic LCA databases. Furthermore, the purpose of this article is not to study these specific examples but to explore the potential of the EVR model for these types of packaging design choices.

The first pair of packages is for ketchup (see Figure 9). Here, we have an iconic glass bottle and a squeezable plastic bottle. The bottles both contain 300 ml and were both bought at a supermarket in Delft, the Netherlands. The glass bottle (a 197.1 g glass with a 3.19 g steel cap) retailed at €1.22. This bottle represents the classic image of this brand, but at the same time the bottle is hard to fully empty, and it is heavy and breakable. The alternative packaging is a combination of a PET (Polyethylene terephthalate) bottle (22.69 g) with an injection-moulded PP (Polypropylene) cap (3.88 g). The plastic bottle cost €1.35 (retail price).

The second pair of packages is for bottled water (see Figure 9). The difference here is that one has a regular cap, whereas the other has a so-called sports cap, providing additional ease of use to the user.

Figure 9. The five pairs of food packaging under study.

The bottles both contain 500 ml and were both bought at a supermarket in Delft, the Netherlands. The basic bottle (15.33 g PET) had a 2.03 g cap (injection-moulded PP), whereas the sports cap weighed 4.1 g (also injection-moulded PP). The basic bottle retailed at €0.36, whereas the bottle with a sports cap cost €0.61.

The third pair of packages is for mustard (see Figure 9). These jars contain 215 g and were both bought in a hypermarket near Lille, France. The jar on the right is the basic one. It is a glass jar weighing 145.1 g. It has a steel lid weighing 5.93 g. The retail price of the basic jar was €1.47. The jar on the left is a luxury 'table' jar, with a blue-coloured foot (202.9 g of glass). It has a plastic lid (4.72 g injection-moulded PE (polyethylene)), which means that there is no thread on the glass, making it more presentable on a table. The paper label on both jars is assumed to be insignificant and therefore disregarded. The retail price of the luxury jar was €1.77.

The fourth pair of packages is for Italian herbs (see Figure 9). These herbs were both bought at a supermarket in Delft, the Netherlands. Both packages contain 12 g of herbs. On the left is a glass jar (85.9 g) with a plastic lid (6.49 g injection-moulded PP). The retail price of the jar was €1.39. The alternative package is a reclosable flexible plastic pouch (3.11 g LDPE (low-density polyethylene)), which could either be used as a refill or a primary pack. The retail price of the pouch was €1.25.

The fifth and final pair of packages is for chocolate drink (see Figure 9). Here we compare a so-called Tetra Brick (1 l) with a multipack of four cans (4x 250 ml). Like with the other pairs, the total amount of chocolate drink is identical for both options. The products were both bought at a supermarket in Delft, the Netherlands. The Tetra Brik is made of a carton with a PE liner (29.94 g) and some plastic and aluminium foil for the closure (3.56 g PP and 0.069 g aluminium). It retails at €1.17. The alternative is four cans (each 11.69 g of aluminium) in a paper and foil multipack (3.99 g of carton and 1.82 g of LDPE). The multipack cost €3.10.

Each of these pairs can be seen as two design options, where one is more basic whereas the other provides users with more convenience and therefore more value. Classical sustainability assessments (e.g. LCA) would continuously point to the basic designs as the better solution, for example, the aforementioned brown paper bag dogma. The EVR model, on the other hand, will give a more balanced picture by assessing which of the categories mentioned in Figure 8 they follow.

In the analysis, the basic version will be treated as the reference (i.e. the existing design) and the more luxurious or more convenient version will be treated as the proposed innovation.

Calculations

The analyses (LCA) of the five pairs of product packaging have been performed in terms of two single indicators: kg CO₂ equivalent (greenhouse gasses) and in terms of eco-costs (damage based). The LCIs, which are used in the analyses, are from the Idemat 2010 database of the Delft University of Technology. The Idemat database has primarily been built on LCIs of the Ecoinvent V2.2 database of the Swiss Centre for Life Cycle Inventories, with extensions based on data of several other databases, like Cambridge Engineering Selector and the Danish food database. Lookup tables can be found on www.ecocostsvalue.com tab data, calculated using Simapro software version 7.3.2.

The analyses have been made for two cases: the packaging is not recycled at all or is 'upcycled' in a so-called *closed loop system*^{15,16} in which the material is re-used for the same purpose. (Note that the flexible plastic herb pouch and the Tetra Brik can only be 'downcycled' in 'open loop' systems). For all packages, there are also other end-of-life scenarios, such as open-loop recycling or incineration with energy recovery. The EVR model is capable of dealing with those scenarios, but they would needlessly add much complexity to the analysis and are therefore deemed beyond the scope of this article.

Best practice recycling rates have been taken. Because recycling rates differ for each country, the reader might interpolate for his or her own country.

The data on basic materials are the cradle to gate of the materials warehouse (for glass, including the production of bottle, and for plastics, including the moulding or extrusion process). The tables are kept as short as possible: items and processes that have a minor contribution to the total eco-burden are left out (the cut-off criterion is 5%, i.e. the total influence of what is left out is expected to be less than 5%).

Transport distances are based on the average situation in the western part of Europe. The distances are given in the tables, so the reader might adapt it to the situation in a typical country or region.

Note that it has been assumed in these examples that the alternative packaging designs have no influence on the amount of content that would be wasted. Food often has a much higher environmental burden than its packaging. Especially in the case of two very distinct solutions (e.g. with the chocolate drink), the amount of wasted product might differ. In such cases, the EVR method would be capable of incorporating those differences as long as data are available or realistic estimates can be made. However, for the purposes of this article, it is sensible to assume that the design alternatives do not differ on food waste.

Tomato ketchup. The LCA summary of the tomato ketchup is given in Table 1. The results are depicted in Figure 10.

Figure 10 shows that the redesign of the glass bottle is an example of eco-efficient value creation, (for systems with no recycling; Figure 8):

- The eco-costs of the PET bottle system are lower than the glass bottle system, mainly because of the low weight of the PET bottle.
- The value of the PET bottle is higher, partly because the PET bottle is squeezable, which is convenient in cases of high viscosity products.

It is not a surprise that the systems with closed loop recycling score better. It is interesting to mention here that the situation is different in each country. For Instance, the glass system scores better in the Netherlands because the Netherlands has a very good closed loop recycling system for glass, combined with no closed loop recycling system for PET.

Water bottles. The LCA summary of the water bottles is given in Table 2. The results presented in Figure 11 show that the redesign of the cap is not an example of eco-efficient value creation because the added value of a sports cap requires added materials and therefore added eco-costs. Hence, the sports cap is a clear example of scenario 3a in Figure 8.

As expected, closed loop recycling of the PET bottle system brings the innovation in the quadrant of the eco-efficient value creation (Figure 8).

Mustard. The LCA summary of the mustard packaging is given in Table 3. It must be mentioned here that the LCI of mustard is not known. A 'surrogate LCI' (the LCI of a similar product) has been applied here: the LCI of clover seed (from the Danish food database). The eco-costs of the other ingredients (mainly water, some oil and some vinegar) have been neglected in the calculation. The results are depicted in Figure 12.

Figure 12 shows that the redesign of jar in a deluxe jar is not an example of eco-efficient value creation. The added value of the deluxe jar requires added glass and therefore added eco-costs (just like the previous example of the water bottles). It is what it is expected in packaging innovations. Compared with the previous example of the water bottles, however, the improvement of the EVR is limited: the EVR of the deluxe design has a relative improvement of less than a factor of 2, which is less than what we need for a sustainable society in the future.

Note that a rough calculation on the average relative improvement of the EVR shows that we need a factor of 7.25. This calculation has been based on the required reduction of CO₂ in the far future: a factor of 2.5 to obtain the current excess of CO₂ emissions under control, a factor of 2 to give everybody on the earth the same wealth as Europe has at this moment and a factor of 1.45 for the increase of population. For the detailed calculation, see www.ecocostsvalue.com, tab general.

Herbs. The LCA summary of the herbs packaging is given in Table 4. Because the LCI for this herbs blend is not known, the clover seed LCI has been taken here as a proxy for the ingredients as well. Because it is an Italian herb sold in the Netherlands, a transport distance of 2000 km (transport in the total chain) has been assumed. The results are depicted in Figure 13.

Figure 13 shows that the innovation of the herbs packaging is unsustainable because the EVR of the new design is higher than the EVR of the reference product. It is striking that consumers apparently do not allocate a much higher value to the little jar (otherwise, the retailer would had asked more money for it). The product can exist because the added costs are lower than the added price: from the

Table 1. Summary of the calculations on packed tomato ketchup.

Weight		Materials type, primary production and processing	Eco-costs (€/kg)	CO ₂ equivalent (kg CO ₂ /kg)	Eco-costs (€/bottle)	CO ₂ equivalent (kg CO ₂ /bottle)
300 ml tomato ketchup in glass + closure, 0% recycled						
197.1 g	Glass	Idemat2010 Glass bottles	0.207	0.888	0.04090	0.17504
3.19 g	Steel	Idemat2010 Steel (market mix average)	0.494	1.609	0.00157	0.00513
		Idemat2010 Rolling steel	0.029	0.051	0.00009	0.00016
		Total			0.04256	0.18034
300 ml tomato ketchup in PET + closure, 0% recycled						
22.69 g	PET	Idemat2010 PET bottle grade	1.070	2.893	0.02428	0.06563
		Idemat2010 Blow moulding bottles	0.213	1.088	0.00482	0.02468
3.88 g	PP	Idemat2010 PP	1.028	1.973	0.00399	0.00766
		Idemat2010 Injection moulding	0.257	1.333	0.00100	0.00517
		Total			0.03409	0.10314
300 ml tomato ketchup in glass + closure, 90% recycled glass						
19.71 g	Glass	Idemat2010 Glass bottles	0.207	0.888	0.00409	0.01750
177.39 g	Glass	Idemat2010 Glass from recycled bottles	0.071	0.373	0.01265	0.06618
3.19 g	Steel	Idemat2010 Steel (market mix average)	0.494	1.609	0.00157	0.00513
		Idemat2010 Rolling steel	0.029	0.051	0.00009	0.00016
		Total			0.01841	0.08898
300 ml tomato ketchup in PET + closure, 50% recycled						
11.345 g	PET	Idemat2010 PET bottle grade	1.070	2.893	0.01214	0.03282
11.345 g	PET	Idemat2010 PET, recycled (estimate)	0.212	1.081	0.00241	0.01226
		Idemat2010 Blow moulding bottles	0.213	1.088	0.00482	0.02468
1.94 g	PP	Idemat2010 PP	1.028	1.973	0.00199	0.00383
1.94 g	PP	Idemat2010 PP, recycled	0.240	1.240	0.00047	0.00241
		Idemat2010 Injection moulding	0.257	1.333	0.00100	0.00517
		Total			0.02283	0.08116
Contents and transport						
300 ml tomato ketchup glass, contents and transport						
300 g	Tomato	Idemat2010 Tomato, standard	0.493	3.30	0.14783	0.99017
500 g	500 km	Idemat2010 Truck + trailer 24 tons net (ton-km)	0.036 €/ton-km	0.095 CO ₂ /ton-km	0.00901	0.02387
		Total			0.15684	1.01403
300 ml tomato ketchup PET, contents and transport						
300 g	Tomato	Idemat2010 Tomato, standard	0.493	3.30	0.14783	0.99017
327 ton-km	500 km	Idemat2010 Truck + trailer 24 tons net (ton-km)	0.036 €/ton-km	0.095 CO ₂ /ton-km	0.00589	0.01561
		Total			0.15372	1.00578
Summary table						
Tomato ketchup			Eco-costs (€)	Price (€)	Relative value	Relative eco-costs
300 ml tomato ketchup in glass + closure, 0% recycled			0.199	1.22	1	1
300 ml tomato ketchup in PET + closure, 0% recycled			0.188	1.35	1.11	0.94
300 ml tomato ketchup in glass + closure, 90% recycled glass			0.175	1.22	1	0.88
300 ml tomato ketchup in PET + closure, 50% recycled			0.177	1.35	1.11	0.89

Figure 10. The value and the eco-costs of a 300 ml tomato ketchup in a glass or PET bottle.

Table 2. Summary of the calculations on the water bottles.

Weight			Materials type, primary production and processing	Eco-costs (€/kg)	CO ₂ equivalent (kg CO ₂ /kg)	Eco-costs (€/bottle)	CO ₂ equivalent (kg CO ₂ /bottle)
50 cl water bottle, standard, 0% recycled							
15.33 g	PET	Idemat2010 PET bottle grade		1.070	2.893	0.01641	0.04434
		Idemat2010 Blow moulding bottles		0.213	1.088	0.00326	0.01667
2.03 g	PP	Idemat2010 PP		1.028	1.973	0.00209	0.00401
		Idemat2010 Injection moulding		0.257	1.333	0.00052	0.00271
		Total				0.02227	0.06773
50 cl water bottle, sports cap, 0% recycled							
15.33 g	PET	Idemat2010 PET bottle grade		1.070	2.893	0.01641	0.04434
		Idemat2010 Blow moulding bottles		0.213	1.088	0.00326	0.01667
4.1 g	PP	Idemat2010 PP		1.028	1.973	0.00421	0.00809
		Idemat2010 Injection moulding		0.257	1.333	0.00105	0.00547
		Total				0.02493	0.07457
50 cl water bottle, standard, 50% recycled							
7.67 g	PET	Idemat2010 PET bottle grade		1.070	2.893	0.00820	0.02217
7.67 g	PET	Idemat2010 PET, recycled		0.212	1.081	0.00163	0.00828
		Idemat2010 Blow moulding bottles		0.213	1.088	0.00326	0.01667
1.02 g	PP	Idemat2010 PP		1.028	1.973	0.00104	0.00200
1.02 g	PP	Idemat2010 PP, recycled (estimate)		0.240	1.240	0.00024	0.00126
		Idemat2010 Injection moulding		0.257	1.333	0.00026	0.00135
		Total				0.01463	0.05174
50 cl water bottle, sports cap, 50% recycled							
7.67 g	PET	Idemat2010 PET bottle grade		1.070	2.893	0.00820	0.02217
7.67 g	PET	Idemat2010 PET, recycled		0.212	1.081	0.00163	0.00828
		Idemat2010 Blow moulding bottles		0.213	1.088	0.00326	0.01667
2.05 g	PP	Idemat2010 PP		1.028	1.973	0.00211	0.00404
2.05 g	PP	Idemat2010 PP, recycled		0.240	1.240	0.00049	0.00254
		Idemat2010 Injection moulding		0.257	1.333	0.00053	0.00273
		Total				0.01621	0.05645
50 cl water bottle, standard, contents and transport							
50 g	Water	Negligible		0	0	0.00000	0.00000
67 g	500 km	Idemat2010 Truck + trailer 24 tons net (ton·km)	0.036 €/ton·km		0.095 CO ₂ /ton·km	0.00121	0.00320
		Total				0.00121	0.00320
50 cl water bottle, sports cap, contents and transport							
50 g	Water	Negligible		0	0	0.00000	0.00000
69 g	500 km	Idemat2010 Truck + trailer 24 tons net (ton·km)	0.036 €/ton·km		0.095 CO ₂ /ton·km	0.00124	0.00329
		Total				0.00124	0.00329
Summary table							
Water				Eco-costs (€)	Price (€)	Relative value	Relative eco-costs
50 cl water bottle, standard, 0% recycled				0.023	0.36	1	1
50 cl water bottle, sports cap, 0% recycled				0.026	0.61	1.69	1.11
50 cl water bottle, standard, 50% recycled				0.016	0.36	1	0.67
50 cl water bottle, sports cap, 50% recycled				0.017	0.61	1.69	0.74

Figure 11. The value and the eco-costs of 50 cc water, standard or with sports cap.

Table 3. Summary of the calculations on packed Italian herbs.

Weight			Materials type, primary production and processing	Eco-costs (€/kg)	CO ₂ equivalent (kg CO ₂ /kg)	Eco-costs (€/container)	CO ₂ equivalent (kg CO ₂ /container)
12 g herbs in plastic bag, 0% recycled							
3.11 g	PE (?)	Idemat2010 PE (HDPE)		1.026	1.929	0.00319	0.00600
		Idemat2010 Extrusion		0.115	0.422	0.00036	0.00131
		Total				0.00355	0.00731
12 g herbs in glass + closure, 0% recycled							
85.9 g	Glass	Idemat2010 Glass bottles		0.207	0.888	0.01782	0.07629
6.49 g	PP	Idemat2010 PP		1.028	1.973	0.00667	0.01280
		Idemat2010 Injection moulding		0.257	1.333	0.00167	0.00865
		Total				0.02616	0.09774
12 g herbs in glass + closure, 90% recycled							
8.59 g	Glass	Idemat2010 Glass bottles		0.207	0.888	0.00178	0.00763
77.31 g	Glass	Idemat2010 Glass from recycled bottles		0.071	0.373	0.00551	0.02884
6.49 g	PP	Idemat2010 PP		1.028	1.973	0.00667	0.01280
		Idemat2010 Injection moulding		0.257	1.333	0.00167	0.00865
		Total				0.01563	0.05793
12 g herbs in plastic bag, contents and transport							
12 g	Herbs	Idemat2010 Clover seed, from farm		1.7126	6.85	0.02055	0.08223
15 g	2000 km	Idemat2010 Truck + trailer 24 tons net (ton-km)	0.036 €/ton-km	0.095 CO ₂ /ton-km		0.00108	0.00286
		Total				0.02163	0.08510
12 g herbs in glass + closure, contents and transport							
12 g	Herbs	Idemat2010 Clover seed, from farm		1.7126	6.85	0.02055	0.08223
104.4 g	2000 km	Idemat2010 Truck + trailer 24 tons net (ton-km)	0.036 €/ton-km	0.095 CO ₂ /ton-km		0.00752	0.01993
		Total				0.02807	0.10216
Summary table							
Herbs			Eco-costs (€)	Price (€)	Relative value	Relative eco-costs	
12 g herbs in plastic bag, 0% recycled			0.0252	1.25	1	1	
12 g herbs in glass + closure, 0% recycled			0.0542	1.39	1.11	2.15	
12 g herbs in glass + closure, 90% recycled			0.0437	1.39	1.11	1.74

Figure 12. The value and the eco-costs of 215 g mustard jar, standard and 'deluxe'.

commercial perspective, it is still an attractive proposition; however, from the perspective of sustainability, the product should be abandoned (Figures 3 and 8).

Chocolate milk. The LCA summary of the chocolate milk packaging is given in Table 5. The results are depicted in Figure 14.

Perhaps surprisingly, the aluminium cans score rather well in terms of EVR, especially when they are recycled in closed loop. There are two reasons:

- The customer is prepared to pay a high price for the cans.
- Milk has a rather high eco-burden.

Table 4. Summary of the calculation on packed mustard.

Weight			Materials type, primary production and processing	Eco-costs (€/kg)	CO ₂ equivalent (kg CO ₂ /kg)	Eco-costs (€/container)	CO ₂ equivalent (kg CO ₂ /container)
215 g mustard in glass + closure, 0% recycled glass							
145.1 g	Glass	Idemat2010 Glass bottles	0.207	0.888	0.03011	0.12886	
5.93 g	Steel	Idemat2010 Steel (market mix average)	0.494	1.609	0.00293	0.00954	
		Idemat2010 Rolling steel	0.029	0.051	0.00017	0.00030	
		Total			0.03321	0.13871	
215 g mustard in glass + closure 'deluxe', 0% recycled glass							
202.9 g	Glass	Idemat2010 Glass bottles	0.207	0.888	0.04210	0.18019	
4.72 g	PE	Idemat2010 PE (LDPE)	1.058	2.098	0.00499	0.00990	
		Idemat2010 Injection moulding	0.257	1.333	0.00121	0.00629	
0.91 g	Liner	Idemat2010 Al trade mix (65% prim 35% sec)	2.748	8.434	0.00250	0.00767	
		Total			0.05081	0.20406	
215 g mustard in glass + closure, 90% recycled glass							
14.51 g	Glass	Idemat2010 Glass bottles	0.207	0.888	0.00301	0.01289	
130.59 g	Glass	Idemat2010 Glass from recycled bottles	0.071	0.373	0.00931	0.04872	
5.93 g	Steel	Idemat2010 Steel (market mix average)	0.494	1.609	0.00293	0.00954	
		Idemat2010 Rolling steel	0.029	0.051	0.00017	0.00030	
		Total			0.01543	0.07145	
215 g mustard in glass + closure 'deluxe', 90% recycled glass							
20.29 g	Glass	Idemat2010 Glass bottles	0.207	0.888	0.00421	0.01802	
182.61 g	Glass	Idemat2010 Glass from recycled bottles	0.071	0.373	0.01302	0.06813	
4.72 g	PE	Idemat2010 PE (LDPE)	1.058	2.098	0.00499	0.00990	
		Idemat2010 Injection moulding	0.257	1.333	0.00121	0.00629	
0.91 g	Liner	Idemat2010 Al trade mix (65% prim 35% sec)	2.748	8.434	0.00250	0.00767	
		Total			0.02594	0.11002	
215 g mustard in glass + closure, contents and transport							
72 g	Mustard seeds	Idemat2010 Clover seed, from farm	1.7126	6.85	0.12331	0.49339	
143 g	Vinegar	Negligible	0	0			
366 g	500 km	Idemat2010 Truck + trailer 24 tons net (ton-km)	0.036 €/ton-km	0.095 CO ₂ /ton-km	0.00659	0.01747	
		Total			0.12990	0.51086	
215 g mustard in glass + closure 'deluxe', contents and transport							
72 g	Mustard seeds	Idemat2010 Clover seed, from farm	1.7126	6.85	0.12331	0.49339	
143 g	Vinegar	Negligible	0	0			
423 g	500 km	Idemat2010 Truck + trailer 24 tons net (ton-km)	0.036 €/ton-km	0.095 CO ₂ /ton-km	0.00762	0.02019	
		Total			0.13093	0.51358	
Summary table							
Mustard			Eco-costs (€)	Price (€)	Relative value	Relative eco-costs	
215 g mustard in glass + closure, 0% recycled glass			0.163	1.47	1	1	
215 g mustard in glass + closure 'deluxe', 0% recycled glass			0.182	1.77	1.20	1.11	
215 g mustard in glass + closure, 90% recycled glass			0.145	1.47	1	0.89	
215 g mustard in glass + closure 'deluxe', 90% recycled glass			0.157	1.77	1.20	0.96

Figure 13. The value and the eco-costs of 12 g herbs in a plastic bag or a glass jar.

Table 5. Summary of the calculations on packed chocolate milk.

Weight		Materials type, primary production and processing	Eco-costs (€/kg)	CO ₂ equivalent (kg CO ₂ /kg)	Eco-costs (€/container)	CO ₂ equivalent (kg CO ₂ /container)
1000 ml chocolate milk in carton, 0% recycled						
29.94 g	Carton	Idemat2010 Board	0.178	0.985	0.00534	0.02950
3.56 g	PP	Idemat2010 PP	1.028	1.973	0.00366	0.00702
		Idemat2010 Injection moulding	0.257	1.333	0.00092	0.00475
		Total			0.00992	0.04127
4 × 250 ml four-pack chocolate milk in Al containers, 35% recycled						
30.394 g	Aluminium	Idemat2010 Aluminium (primary)	4.028	12.232	0.12242	0.37179
16.366 g	Aluminium	Idemat2010 Aluminium (secondary)	0.373	1.379	0.00610	0.02256
		Idemat2010 Forging aluminium	0.042	0.238	0.00198	0.01111
3.99 g	Carton	Idemat2010 Board	0.178	0.985	0.00071	0.00393
1.82 g	PE	Idemat2010 PE (LDPE)	1.058	2.098	0.00192	0.00382
		Idemat2010 Extrusion	0.115	0.422	0.00021	0.00077
		Total			0.13334	0.41398
4 × 250 ml four-pack chocolate milk in Al containers, 85% recycled						
7.014 g	Aluminium	Idemat2010 Aluminium (primary)	4.028	12.232	0.02825	0.08580
39.746 g	Aluminium	Idemat2010 Aluminium (secondary)	0.373	1.379	0.01482	0.05480
		Idemat2010 Forging aluminium	0.042	0.238	0.00198	0.01111
3.99 g	Carton	Idemat2010 Board	0.178	0.985	0.00071	0.00393
1.82 g	PE	Idemat2010 PE (LDPE)	1.058	2.098	0.00192	0.00382
		Idemat2010 Extrusion	0.115	0.422	0.00021	0.00077
		Total			0.04789	0.16022
1000 ml chocolate milk in carton, contents and transport						
1000 g	Milk	Idemat2010 low-fat milk from dairy, no quotas	0.2644	0.60	0.26445	0.60000
1070 g	500 km	Idemat2010 Truck + trailer 24 tons net (ton-km)	0.036 €/ton-km	0.095 CO ₂ /ton-km	0.01928	0.05107
		Total			0.28372	0.65107
4 × 250 ml four-pack chocolate milk in Al containers, contents and transport						
1000 g	Milk	Idemat2010 Mini milk, from dairy, no quotas	0.272	1.168	0.27205	1.16817
<50 g	Ingredients	Negligible				
1033 g	500 km	Idemat2010 Truck + trailer 24 tons net (ton-km)	0.036 €/ton-km	0.095 CO ₂ /ton-km	0.01861	0.04931
		Total			0.29066	1.21748
Summary table						
Chocolate milk			Eco-costs (€)	Price (€)	Relative value	Relative eco-costs
1000 ml chocolate milk in carton, 0% recycled			0.294	1.17	1	1
4 × 250 ml four-pack chocolate milk in Al containers, 35% recycled			0.424	3.1	2.65	1.44
4 × 250 ml four-pack chocolate milk in Al containers, 85% recycled			0.339	3.1	2.65	1.15

Figure 14. The value and the eco-costs of 1 l water, in carton or in four cans.

Summary of calculations

The calculations have been summarized in Figures 15 and 16.

From Figure 15, it can be concluded that

Figure 15. The relative eco-costs and the relative value of packaging for tomato ketchup and mustard.

Figure 16. The relative eco-costs and the relative value of packaging for water, chocolate milk and herbs.

- in comparison with a basic glass package (the reference for both the mustard and the ketchup), most innovations are in the quadrant of eco-efficient value creation;
- for ketchup, the switch to PET can be regarded as a sustainable innovation; and
- in the studied context on Western-Europe, recycling is a sustainable solution (closed loop upcycling).

From Figure 16 it can be concluded that

- innovation in packaging can sometimes be economically viable but not sustainable (herbs in bottles);
- closed loop recycled aluminium cans score well from an EVR perspective because of the substantial increase in value; and
- the extra convenience of a sports cap on a water bottle is so substantial, that the relative increase in value is considerably bigger than the relative increase in eco-burden. Hence, from an EVR perspective, it is a positive innovation.

DISCUSSION AND CONCLUSIONS

The classical approach to packaging and sustainability is to reduce the eco-burden of the packaging, with the help of LCA calculations. The risk is that the reduction of eco-burden comes with a decrease in value, either through a lower physical functionality or through a lower intangible functionality. Classical LCA is incapable of incorporating different value in a benchmark study. In the example of the water bottles, it would for instance be incapable of accounting for the additional convenience of the sports cap. Ignoring the additional convenience of the sports cap, that is, only looking at the shared

physical functionality of containing 500 ml of water, would result in an outcome of the LCA that the basic package has a lower eco-burden and is therefore more sustainable, and as a consequence the preferable design choice.

At the same time, the leading thought in the FMCG business is to use packaging design to create value through differentiation. The market performance of many products is because they do have different functionalities, especially also intangible functionalities.

Hence, there is a friction between design for sustainability professionals and marketing professionals.

The EVR model applied in this article provides a way to simultaneously consider these two business drivers. It provides a way to assess which differentiation efforts make sense from a sustainability perspective because their relative increase in value is larger than the relative increase in eco-burden (or is even combined with a reduction in eco-burden) and which differentiation efforts do not make sense because the relative increase in eco-burden is too big to justify the relative increase in value.

Looking at the examples described in this article, the introduction of a squeezable plastic ketchup bottle next to, or instead of, a glass bottle makes perfect sense because it increased value and reduced the eco-burden (see scenario 2 in Figure 8). The sports cap water bottle, the deluxe mustard jar and the aluminium cans for chocolate drink make sense because their relative EVR score is sensible (relatively more additional value than more eco-burden, see scenario 3a in Figure 8). Finally, the herbs jar is an example where the glass jar provides insufficient additional value to justify to additional eco-burden (scenario 3b in Figure 8).

Note here that we have chosen to take the product with the lower value of the pair as the reference. For some, this is certainly in line with the chronological order of the two design alternatives (i.e. there first was a glass ketchup bottle, and then the PET version became an alternative) for others this may be reverse.

One can also take the other package of the pair as a reference. For the ketchup, this would place a glass alternative to a PET bottle in the wrong direction, namely, scenario 4 in Figure 8. Taking the sports cap bottle, the deluxe mustard jar and the aluminium cans as the reference design would place their alternatives (basic water bottle, basic mustard jar and Tetra Brik) in scenario 1b (e.g. considerably less value and slightly less eco-burden), which is not an improvement. In case of the herbs, taking the glass jar as the reference point would place the plastic pouch in scenario 1a in Figure 8, which could be considered an improvement, as it reduces the eco-burden considerably, at only a minimal loss of value, resulting in an improved EVR score.

The cases in this article were intended as examples to illustrate the potential of an EVR approach to packaging design. The examples are not intended to give definitive answers in relation to the studied products. In an actual industry application of the EVR method, several things will probably be different. First, the compared alternatives need not both be products that are actually on the market; designers could take an existing solution as a reference and subsequently score their design concepts. Also, comparisons between different brands would be possible. Second, data collection would be different. The marketing department would be capable of providing more robust information on the (spread of) retail prices for certain packaging solutions.

As such, the EVR model provides an alternative perspective to packaging design and sustainability that is better suited to business reality than classical LCA. We feel that, without dismissing other approaches, including such a perspective will enrich the on-going debate on packaging and sustainability.

REFERENCES

1. Brundtland GH. *Our Common Future*. United Nations World Commission on Environment and Development. Oxford University Press: Oxford, 1987.
2. Wever R, Tempelman E. The Social Component of Sustainable Packaging. in: *Proceedings of the 24th IAPRI symposium on packaging*. Greenville, SC. May 17–20, 2009.
3. Nordin N, Selke S. Social Aspect of Sustainable Packaging. *Packaging Technology and Science* 2010; **23**(6): 317–326. DOI: 10.1002/pts.899
4. Sonneveld K. The Role of life cycle assessment as a Decision Support Tool for Packaging. *Packaging Technology and Science* 2000; **13**(2): 55–61. DOI: 10.1002/1099-1522(200003/04)13:2 < 55::AID-PTS490 > 3.0.CO;2-G

5. Lewis H, Verghese K, Fitzpatrick L. Evaluating the Sustainability impact of Packaging: the Plastic Carry Bag Dilemma. *Packaging Technology and Science* 2010; **23**(3): 145–160. DOI: 10.1002/pts.886
6. Singh J, Krasowski A, Singh SP. Life cycle inventory of HDPE bottle-based liquid milk packaging systems. *Packaging Technology and Science* 2011; **24**(1): 49–60. DOI: 10.1002/pts.909
7. Bovea MD, Serrano J, Bruscas GM, Gallardo A. Application of life cycle assessment to improve the environmental performance of a ceramic tile packaging system. *Packaging Technology and Science* 2006; **19**(2): 83–95. DOI: 10.1002/pts.711
8. Wever R. Design for Volume Optimization as a Strategy for Sustainable Packaging. *Packaging Technology and Science* 2011; **24**(4): 211–222. DOI: 10.1002/pts.927.
9. Svanes E, Vold M, Møller H, *et al.* Sustainable packaging design: a holistic methodology for packaging design. *Packaging Technology and Science* 2010; **23**(3): 161–175. DOI: 10.1002/pts.887
10. Wever R, Boks C, Marinelli Th, Stevels, A. Increasing the benefits of product-level benchmarking for strategic eco-efficient decision-making. *Benchmarking: an International Journal* 2007; **14**(6): 711–727. DOI: 10.1108/14635770710834509
11. Lofthouse VA, Bhamra TA, Trimmingham RL. Investigating Customer Perceptions of Refillable packaging and Assessing Business Drivers and Barriers to Their Use. *Packaging Technology and Science* 2009; **22**(6): 335–348. DOI: 10.1002/pts.857
12. Wever R, Van Onselen L, Silvester S, Boks C. Influence of Packaging Design on Littering and Waste Behavior. *Packaging Technology and Science* 2010; **23**(5): 239–252. DOI: 10.1002/pts.892
13. Langley J, Turner N, Yoxall A. Attributes of packaging and influences on waste. *Packaging Technology and Science* 2011; **24**(3): 161–175. DOI: 10.1002/pts.924
14. ISO 14044, International Standard, Environmental management – life cycle assessment – Requirements and guidelines, 2006.
15. Joint Research Centre European Commission. *ILCD handbook, General guide Life Cycle Assessment – Detailed guidance*, 2010.
16. Vogtländer JG. *A practical guide to LCA for students, designers and business managers, cradle-to-grave and cradle-to-cradle*. VSSD: Delft, the Netherlands, 2010.
17. Bengtsson M, Steen B. Weighting in LCA, approaches and applications. *Environmental Progress* 2000; **19**(2): 101–109. DOI: 10.1002/ep.670190208
18. Finnveden G. On the Limitations of Life Cycle Assessment and Environmental Systems Analysis Tools in General. *International Journal of Life Cycle Assessment* 2000; **5**(4): 229–238. DOI: 10.1007/BF02979365
19. Vogtländer JG, Bijma A. The “virtual pollution costs ‘99”, a single LCA-based indicator for emissions. *International Journal of Life Cycle Assessment* 2000; **5**(2): 113–124. DOI: 10.1007/BF02979733
20. Vogtländer JG, Brezet HC, Hendriks ChF. The Virtual Eco-costs ‘99, a single LCA-based indicator for sustainability and the Eco-costs / Value Ratio (EVR) model for economic allocation *International Journal of Life Cycle Assessment* 2001; **6**(3): 157–166. DOI: 10.1007/BF02978734
21. Vogtländer JG, Bijma A, Brezet H. Communicating the eco-efficiency of products and services by means of the Eco-costs / Value Model. *Journal of Cleaner Production* 2002; **10**(1): 57–67. DOI: 10.1016/S0959–6526(01)00013–0
22. Vogtländer JG, Hendriks ChF, Brezet HC. The EVR model as a tool to optimise a product design and to resolve strategic dilemmas. *Journal of Sustainable Product Design* 2001; **1**(2): 103–116. DOI: 10.1023/A:1014478027160
23. Vogtländer JG, Baetens B, Bijma A, *et al.* *LCA-based assessment of sustainability: the Eco-costs/Value Ratio (EVR)*. VSSD: Delft, the Netherlands, 2010.
24. Joint Research Centre European Commission, *EIPRO. Environmental Impact of Products*, 2006.
25. Porter ME. *Competitive Advantage*. Free Press: New York, 1985.
26. McDonough W, Braungart M. *Cradle2Cradle / Remaking the way we make things*. North Point Press: New York, 2002.