# Impacts of life cycle assessment results on society – the case of packaging materials in Switzerland

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**Abstract**

In this contribution, we take a historical perspective on the interaction between society and LCA of packaging materials in Switzerland in the last 30 years. We assess the impacts this method had on society and vice-versa in order to sketch future orientations for a more effective LCA. LCA proved to be a useful tool to drive policy and legislation towards cost-efficient yet effective solutions for recycling. With respect to environmental awareness as a value, one should not forget that LCA operates strongly on the analytical level and is not able to deliver simple messages. However, such messages are known to be effective in changing values of society. Finally, methodological development of LCA is the reflection of a continuous adaptation to economic reality. In the future, input-output and hybrid LCA will be instrumental in this respect.

## 1 Introduction

Life cycle assessment (LCA) has a wide range of applications. From policy making to product optimization, from consumer information and awareness to method demonstration; its target audiences are of various types. This makes it certainly a unique method among the methods of environmental assessment. Indeed, while material flow analysis (MFA) is oriented towards policy making, that is, identifying hot spots with respect to flows of a certain element or material, environmental impact assessment (EIA) appeals to stakeholders of a project limited in space and time.

Astonishingly, little attention has been given so far to the impacts of LCA results on target audiences and those not targeted but possibly affected by the results. This seems crucial in order to improve the method towards better addressing

targeted audiences. A first step in this direction is to take a look back at a specific product for which many LCA studies have been conducted over a long period of time and analyze the results and their impacts.
In this contribution, we look at the case of packaging materials in Switzerland and its "LCA history" of now more than 30 years. Along this historical analysis, four questions guide are research:

1. How did the economic system, and the packaging industry in particular, react to LCA results?
2. What were the policy and legal implications of LCA results in the field of packaging materials?
3. Did LCA results affect values of society (environmental awareness as a value driving behavior)?
4. What kind of knowledge was improved through LCA results?

In the method part, we briefly describe how we structure the historical analysis and on which knowledge base we rely. We then analyze the impacts according to the four guiding questions. We conclude by reflecting on the impacts of LCA results and what it means for the future of LCA.

## 2 Method

Prior to looking at impacts of LCA results on society, it seems reasonable to provide a crisp definition of society in order to structure the historical analysis. Merton [1] distinguishes four systems of society, which correspond to our four guiding questions.
In the *economic system*, firms provide consumers with products and services. A key driver of today's western liberal economic system is the supply-demand relationship. For a firm to be competitive, it must satisfy different types of expectations on the consumer side.
In the *policy and legal system*, institutions of the state, within the framework of their jurisdiction, promulgate laws and ordinances and pursue policies for the sake of common good and wellbeing.
In the *social and cultural system*, one will find the values and norms of a society, which are key drivers of individual behavior. One value of interest in our analysis is environmental awareness, that is, how much we value the environment when making decisions as individuals. However, environmental awareness has also a knowledge component, that is, how well we know the environment and its dynamics [2].

In the *scientific and educational system*, knowledge of all types is accumulated and transmitted within a society.
The red thread of our historical analysis corresponds to a series of LCA studies on packaging materials/packages commissioned by the Swiss Environmental Protection Agency. The first LCA study was published in 1984. The second followed in 1991. The last update was divided into two publications, the first one consisting in life cycle inventories for packages, released in 1996, and the second one on the assessment of the life cycle inventories of 1996, released in 1998. We reviewed the literature (science and practice) relating the impacts of these studies on society and vice-versa. The literature review was supplemented by the interview of two members of the Swiss Environmental Protection Agency, who took an active role in the Swiss LCA studies on packaging materials/packages [3].

## 3 Historical analysis

### *3.1 How it all began*

In the 1970s, following the environmental and energy crises, so-called ecological balancing became increasingly popular within firms. Additionally to inventorying financial flows in conventional balance sheets, firms sought to account inputs and outputs of water, energy, waste, etc. Switzerland made no exception to this trend. Ruedi Müller-Wenk, a manager at Nestlé Frisco Findus, was conducting such work but became interested in taking a product approach, that is, looking at the environmental footprint of the product instead of that of the firm. In this way, the environmental problems could not be shifted from one firm to another. Such studies had already been conducted elsewhere. In fact, the first LCA study ever performed was commissioned by the Coca-Cola Company to compare glass and plastic bottles [4].
Next to this methodological breakthrough, two schools of thought in Switzerland were struggling with one another with respect to the disposal of packages. The first paradigm could be summarized by the expression “out of sight, out of mind”, meaning the incineration or landfilling of packaging waste. At that time, 77% of municipal solid waste was incinerated in grate incinerators without filter technology and 23% was dumped onto controlled landfills ([5], p.17). The other position advocated for recycling but was at the time not successful, probably because of the lack of scientific evidence that recycling is indeed better than incineration or landfilling.

In the broader national discussion on waste, the Federal Commission for Waste Management, composed of influential members of academia, industry and politics, was responsible for elaborating strategic guidelines of waste management in Switzerland.

### *3.2 Life cycle assessment of packaging materials of 1984*

In this context, the Swiss Environmental Protection Agency commissioned Empa (the Swiss research institute for materials science and technology) to compare on an environmental basis different packaging materials in collaboration with the Federal Commission for Waste Management. Ruedi Müller-Wenk, member of this commission, was highly involved in the studies resulting in the first LCA of packaging materials in Switzerland, published in 1984 [5].
The main challenge in this study was to provide indicators on the environmental performance of packaging materials. Clearly, package weight could not be one of those as for instance glass bottles could be used in mutli-trip systems. The impact categories selected were raw materials, energy consumption, consumption of landfill volume, air emissions and water emissions. For the two last categories, a method was developed, the so-called method of critical volumes, which normalizes the emissions of a technological process according to legal threshold values. Inventory data for the production and elimination of the different packaging materials was gathered and assessed with the impact categories. In a demonstration example, the environmental impacts of 1'000 milk packages made of different packaging materials were assessed. The results are shown in Fig.1, on which the weight of the different packages can also be read (The weight of the glass bottles is divided by the number of trips).

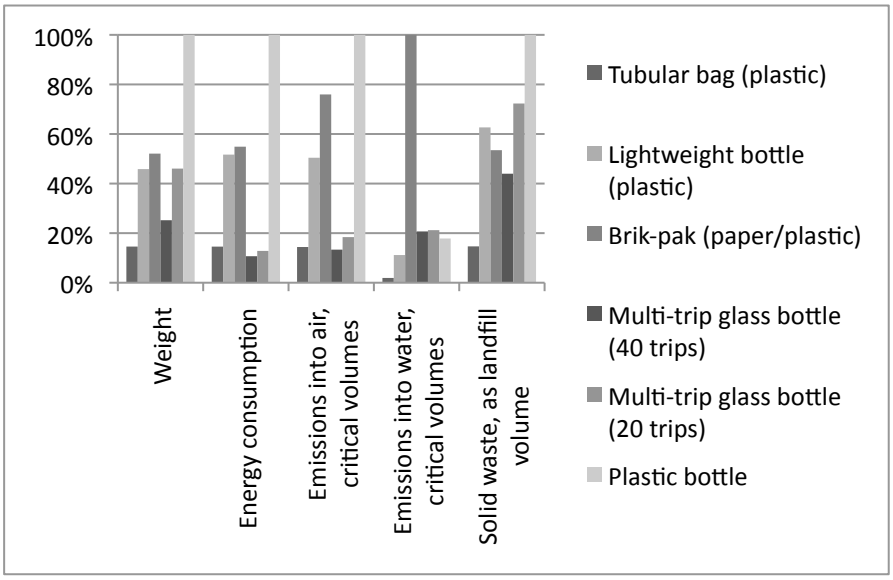


**Fig.1: Weight and environmental impacts of 1'000 milk packages in the LCA of 1984**

The study authors did not choose milk by chance. It was a product sold or used to be sold in the different packages investigated, with a 90% share for the Brik-pak at the beginning of the 1980s [6]. As a result, the winning package of the LCA, the plastic tubular bag, became best-selling package for milk. Today, however, it has almost disappeared from retailer shelves due to its low convenience. Following broad media coverage of the study results, the Brik-pak industry contested the results by pointing out to foreign studies which showed different results [6]. Indeed, those studies included the manufacturing and distribution of the packages and not just the manufacturing and disposal of packaging materials. More care was given to the definition of system boundaries in following studies. But despite such a shortcoming, the industry relied increasingly on the LCA of 1984 to develop environmentally friendlier packages in order to improve its image. A rudimentary software was even developed for this purpose which contributed to boost the use of the inventories.

Perhaps the most interesting impact of this first LCA is that on the policy and legal system. In the middle of the 1980s, aluminum cans and polyethylene terephthalate (PET) started conquering the Swiss soda (later also beer) and mineral water markets. However, littering and the Refonda scandal[1] made these

[1] Refonda, now closed, was a secondary aluminum smelter located near Zurich. It had commissioned a Portuguese company to dispose of its salt cake waste stream. In Portugal,

packaging materials increasingly unpopular, especially among environmental NGOs. The latter pressured the government to act. In 1988, a draft ordinance was made public which would have banned the use of certain packaging materials, aluminum among others, and restricted others. During the consultation of the draft ordinance, the concerned industry adopted two strategies: demonstrate by means of LCA that aluminum, provided it is recycled, causes low environmental impacts [7] and regroup industry actors to finance and implement collection and recycling schemes. Thanks to such initiatives, no ban or restriction was prescribed in the final version of the ordinance. The industry was held responsible for recycling a minimum quantity of packaging materials (later: shares).

### *3.3 Life cycle assessment of packaging materials of 1991*

Following the success of the first LCA, the Swiss Environmental Protection Agency decided to proceed to an update of the inventories. Indeed, as already mentioned above, new packages had appeared in the meantime and production technology had evolved. The study [8], published in 1991 and reflecting the industrial state-of-the-art of 1990, also showed major improvements in LCA methodology brought about either by the first study or by other contributions of the emerging LCA community. A sensitivity analysis was conducted for the life cycle of aluminum with respect to the origin of electricity, as the production phase is electricity-intensive. Additionally, different recycling rates were applied to packaging materials (see Fig.2). The environmental flows were aggregated to the same impact categories as in the first study.

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this company was dumping the waste near the sea, which eventually flooded the landfill and became polluted.

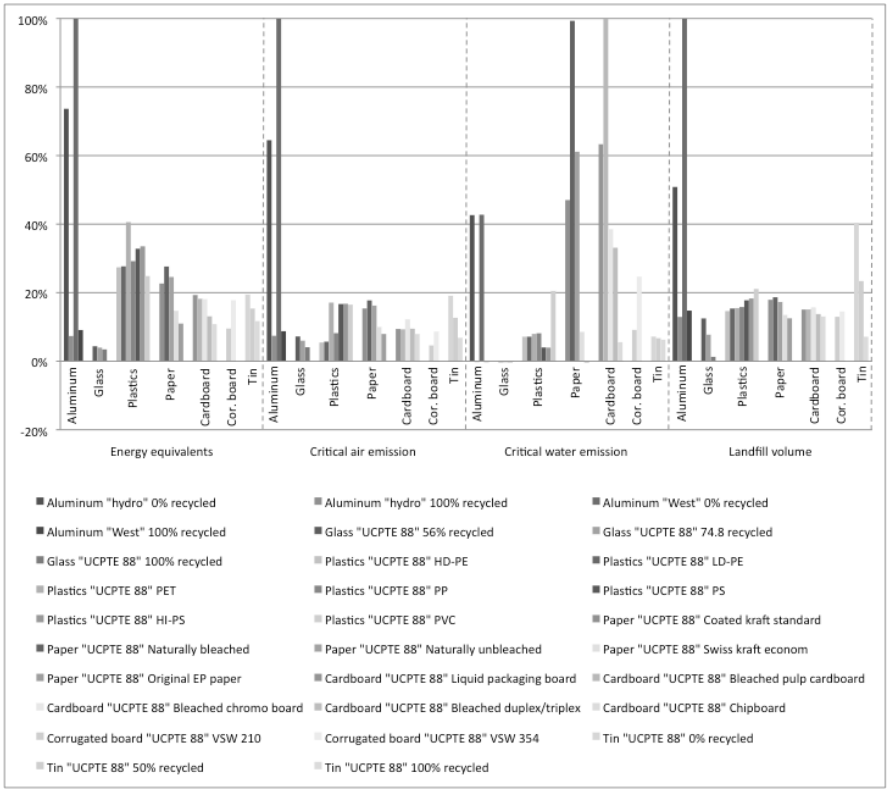


**Fig.2: Environmental impacts of packaging materials in the LCA of 1991 (Cor. board corresponds to corrugated board)**

Instead of providing a concrete example of LCA of packages as in the first study, some figures were given for the manufacturing of packages, such as the energy consumption of the processing of plastics to packages. Users of the study could thus build their own specific product system.

It can be said that the sensitivity analysis with respect to the origin of electricity, performed in this study, put forward the effects of *uncertainties in the inventory data*. While reflecting better the economic system, thereby building up knowledge, the analytical dimension of LCA was deepened.

The impact of this study is related in the foreword of the subsequent update of 1996/1998 ([9], vol. 1, p. V). Thanks to the LCA of 1991, experience was gathered and technical improvements were made. Such progress can be seen as the materialization of new knowledge (scientific and educational system). The study also had an impact beyond Switzerland and made a substantial contribution to the standardization process of LCA lead by the Society for Environmental Toxicolgy and Chemistry (SETAC) (scientific and educational system as well).

### *3.4 Life cycle inventories (1996) and assessment of life cycle inventories of packages (1998)*

The reasons for updating in 1996 and 1998 the LCA of 1991 were again further market changes and technological evolution [9], [10]. The standardization process initiated by the international LCA community (counting many Swiss practitioners) at the dawn of the 1990s is clearly reflected in the methodology applied in the study: 1) Goal and scope definition, 2) Life cycle inventory, 3) Life cycle impact assessment, 4) Interpretation (e.g. [11]). Moreover, the study authors bumped into a problem linked with the economic and legal reality of recycling. Although theoretically possible, not all waste is recycled to the original product. For instance, due to legislation on foodstuff, both outer layers of PET bottles can only be used for downcycling to, among others, clothes. Two approaches were applied in the study: In the cut-off approach, none of the environmental burdens of the original product is allocated to the downcycling product. With a closed-loop allocation, a share of the environmental impacts arising from the production of raw materials is allocated to the downcycling product, whereas the impacts from recycling are allocated to the original product.

For the sake of demonstration, the life cycle impacts of various packages (1'000 units) were assessed with three impact assessment methods: 1) Eco-indicator 95 [12], 2) Ecological Scarcity 97 [13], 3) CML [14] (see Fig. 3). Differences across methods for the same package were important. For instance, the jam glass jar performed worse when assessed with Eco-indicator 95 than with Ecological Scarcity 97. This is due to the strong weight attributed by the latter to the emission of lead into air (74% of total score). Ecological Scarcity 97 attributes to this emission only 14% of its total score. Moreover, the results of the single-use PET bottle proved to be very sensitive to the choice of allocation method.

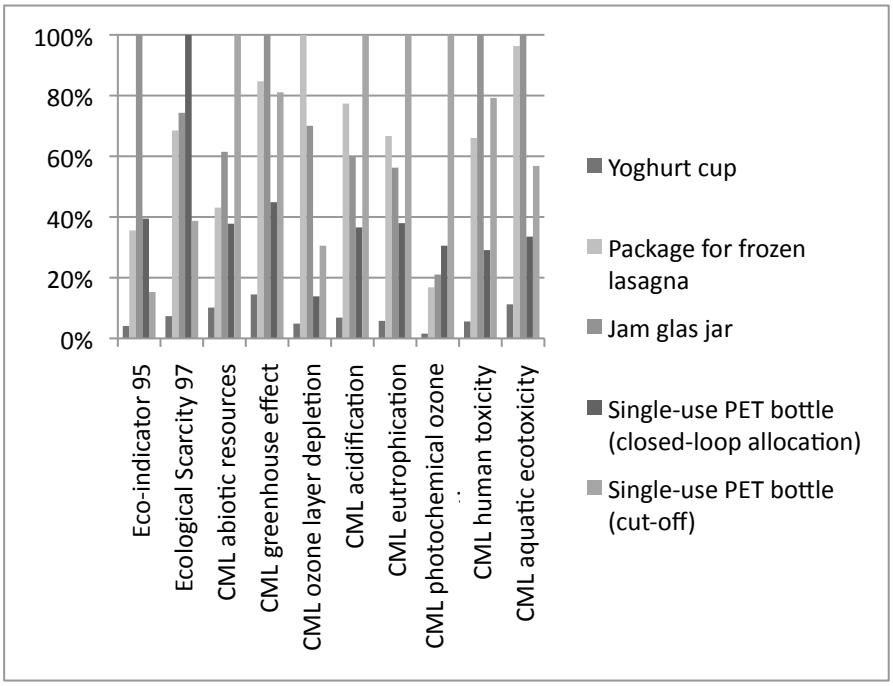


**Fig.3: Environmental impacts of various packages (1'000 units) assessed with Eco-indicator 95, Ecological Scarcity 97 and CML in the LCA of 1996/1998**

Hence, this study revealed the importance of *methodological uncertainties*, which are certainly a greater challenge than data uncertainties with respect to the communication of results to target audiences.

The Swiss LCA community, wishing to boost and facilitate the use of the packaging material database as well as others (i.e. energy and construction materials), then launched the ecoinvent 2000 project, an internet-based electronic database [15]. Today, ecoinvent is one of the most used inventory databases for LCA, with some 4'000 processes modeled. The Swiss packaging LCA studies thus had a huge impact on the scientific and educational system.

### *3.5 Life cycle assessment as decision-base for disposal options of packages*

Besides comparisons between packages made of different materials, life cycle inventories became increasingly used for the management of waste options. When the government started in 2001 levying an anticipated disposal fee on glass packages for beverages to compensate communities for the collection and

transport of used packages, the question arose as to which disposal option was more environmentally friendly. Two options dominated the glass package disposal practice at the time : 1) recycling in the sole glass factory in the country or in glass factories abroad and 2) downcycling to sand substitute used in the construction sector. It was thought that downcycling was the less environmentally friendly option so that a lower compensation rate for communities was applied to it. The idea was to encourage downcycling communities to switch to recycling. However, it became clear that both options showed considerably different logistics schemes. While high transport distances characterized recycling (maximum distance of 250 km), downcycling was done in nearby quarries (average distance of 20 km).
In 2006, an LCA commissioned by the Swiss Environmental Protection Agency was performed to compare both options [16]. The main result was that recycling was the environmentally friendliest option up to a transport distance of 1'700 km. Differences between Ecological Scarcity 97 and Eco-indicator 99 were not significant and even when the impacts of traffic noise were added to the total score of Ecological Scarcity 97, the tipping distance did not become significantly smaller. The impact of the study was to legitimize the different compensation rates, which in turn contributed to transform the disposal practice of glass packages in Switzerland. In 2009, only 540 tons of a total of 316'000 tons were downcycled to sand substitute [17] in comparison to the 29'000 tons of a total of 284'000 tons in 2002 [18]. Most of these 29'000 tons are now downcycled to insulation material. The insulation material shows a higher environmental performance, evidenced by LCA, and is thus compensated with a higher rate than sand substitute.

## 4 Conclusions and outlook

In the Swiss history of packaging materials, LCA proved to be at best an indirect tool to raise environmental awareness as a value, that is, have an impact on the *social and cultural system*. This is the case of legislation stressing recycling instead of banning specific materials based on LCA results. In turn, recycling has acquired the status of value. Interestingly, after focusing on packaging materials until 1998, the Swiss Environmental Protection Agency turned to the packaged material itself. For this purpose, it developed educational material for the youth relying on LCA studies of food products (e.g. tomatoes) [19]. It would be interesting to measure the long-term impact of such an environmental awareness campaign directly challenging consumer habits.
To be fair, it was the *economic system* that was targeted in the first place by the Swiss LCA studies on packaging materials. The impact was important and long-

lasting, which is confirmed by the fact that in the 1990s Swiss environmental NGOs ceased pressuring industry on packaging materials, as they acknowledged that it had taken its responsibility and that they should focus on other issues. A main challenge for LCA is to model sufficiently the economic system. As we have seen in this historical analyse, methodological issues were raised by the economic reality (origin of electricity, recycling/downcycling options). What does this mean for the future of LCA? Adopting eco-efficiency is an obvious step towards taking better into account the value system of economic agents. However, depending on the goal and scope of an LCA, more attention could be paid to the structure of the economic system. Here, questions of interest are: What is the economic contribution of an activity, what is its environmental cost in a specific country? How relevant are imports and exports of goods, services and waste? Input-output and hybrid LCAs can tackle such questions.

LCA can have a strong impact on the *policy and legal system* as we see for the recycling of glass packages. However, today environmental legislation is still characterized by an end-of-pipe, emission threshold value approach. The adaptation of the ordinance on beverage packages from maximum residual quantities of waste not recycled to maximum percentages was certainly a step towards more life cycle thinking in legislation. Indeed, keeping a very low quantity of waste not recycled could cost the industry a lot in terms of collection and transport efforts, while not adding much environmental benefits.

From the previous paragraphs, we understand how the LCA methodology, as part of the *scientific and educational system*, was and is shaped by the other systems of society. For instance, the valuation stage of life cycle impact assessment methods relies either on different value systems (Eco-indicator) or on environmental policy goals (Ecological Scarcity). A challenge for LCA is the inclusion of new impact categories reflecting new knowledge, especially when updates must be performed. This should be communicated appropriately to target audiences but should in any case not be subject of negotiation.

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