Application of A Comparative Multidimensional Life Cycle Analysis in Solid Waste Management Policy: The Case of Soft Drink Containers

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ABSTRACT

The paper describes the application of a multidimensional Life Cycle Analysis (LCA) for packaging soft drinks in Israel. The suggested approach combines the conventional product LCA, vertical summation of all environmental burdens along the chain of production, use and disposal activities, and horizontal comparison of different products and disposal options, such as recycling, incineration or landfilling.

The paper attempts to show that the most effective, as well as transparent means, of comparing packaging alternatives, is to place them on a commensurate basis, the most appropriate one being a monetary basis. Taking into account limitations and drawbacks of monetary valuation of non-market assets (namely, environmental assets), the study derived estimates of environmental benefits and damages associated with each alternative.

The production of soft drinks containers in Israel, used here as an example for the above mentioned considerations, is based mainly on imported materials, since natural resources such as oil or bauxite do not exist in Israel. Locally, only direct production and pollution abatement costs are incorporated in the final bill, while global environmental burdens are excluded. Countries extracting and producing raw material to the packaging industry, in effect, grant an environmental subsidy to the final users, in this case- the Israeli user. The paper suggests that only by globalization of externalities and fully internalizing environmental costs into the price of the final product (the packaging material or the packaged product), an equitable full environmental accounting can be designed. This mechanism can be even accompanied by global trading in the relevant environmental credits. Decisions will, consequently, follow a sustainable path, in both importing and exporting countries.

Key words

Life cycle analysis, solid waste, environmental policy, soft drink bottles.

INTRODUCTION

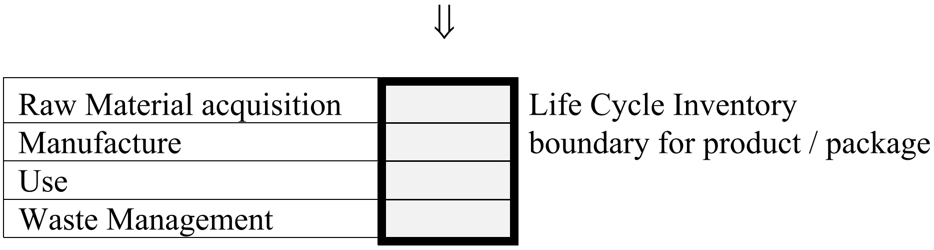
In recent years many countries have adopted product-related policies and targeted packages as one of the key issues in waste management. The Ministry of the Environment in Israel is considering a packaging law that will tax non-recyclable and non-recycled packages and will subsidize recycled ones.

The concern about the environmental impacts of packages has been dealt using several approaches in environmental management, such as Risk Assessment, Environmental Impact Assessment, Environmental Auditing, Substance Flow Analysis, Energy Analysis, Material Flow Analysis and Life Cycle Analysis (LCA) (Finnveden, 1998). LCA is a tool used to evaluate the environmental impacts associated with a product over its entire life-cycle, from the manufacturing processes to the final waste disposal stages (Schaltegger, 1996; Curran, 1996 etc.).

Individual LCAs are modified to fit the specific objectives of individual analyses. Generally, a producer should use LCA to compare alternatives involving environmental externalities at any stage of production, use and disposal of intermediate and final goods. The classic product LCA (Fig 1a) is based on a vertical summation of all environmental inputs associated with a product, "from cradle to grave" (Hunt et. al., 1992 etc.).

Fig. 1a

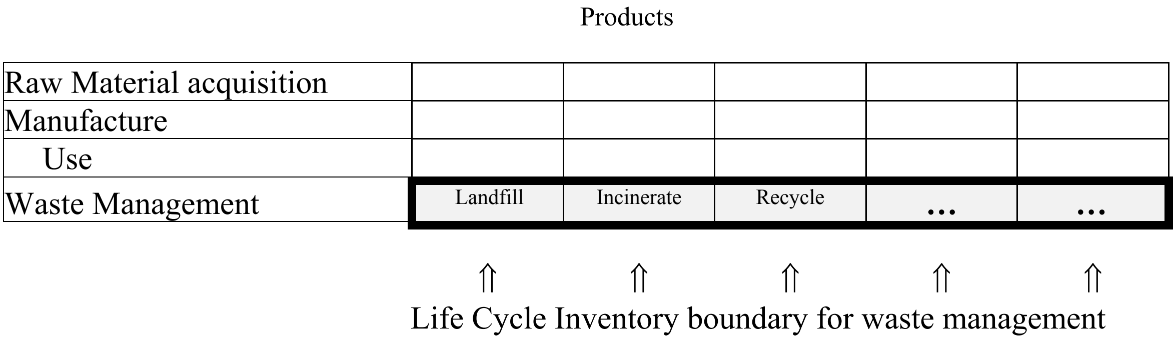
Vertical Life Cycle Inventory (adopted from White et al., 1995)



Horizontal LCA (Fig. 1b) is widely used by waste managers, local authorities or the central government, to compare waste management alternatives such as recycling, incineration or landfill (White et al., 1995; Thoreneloe et al., 1998 etc.)

Fig. 1b

Horizontal Life Cycle Inventory (adopted from White et al., 1995)



	Products				
Raw Material acquisition					
Manufacture					
Use					
Waste Management	Landfill	Incinerate	Recycle	…	…

The possibility to take into account the availability of alternative options at different stages of product life cycle is rather limited in the approaches described above. A comprehensive approach requires, however, consideration of alternative inputs, production and disposal processes or outputs in a multi-dimensional, expanded space. We suggest a matrix of a vertical LCA, examining different raw materials and production processes, as well as a horizontal comparison of different waste treatment options (Fig. 1c), in order to choose the alternative in which costs and environmental burdens are minimized. In other words, decisions would need to relate to the preferred type of the packaging material overall, as well as the selection of waste management for each packaging material.

Usually, the results of a LCA are evaluated according to pre-determined sets of priorities, including such items as mitigation of greenhouse gases, ozone depletion, water pollution or the effects on the marine environment (i.e., UNEP, 1996). The ISO 14040ff standards address specifically the normalization, grouping and weighting of the LCA inventory analysis (SETAC, 1998) but, yet, different individuals, organizations, and societies may have different values, therefore, different parties will reach different weighting results based on the same indicator results. Similarly, as will be shown, different decisions, based on LCA, will be made by different countries, depending on their participation along the production line of a given product.

The concern about environmental burdens, as well as the misperception of the weight of these burdens has led to mistakes, some of them very costly (e.g., the first years of the packaging ordinance in Germany, see Bilitewski & Copeland, 1997). Therefore, there is a need to put these figures into perspective and to analyze their relative importance. Due to the fact that direct costs are given in monetary terms, it reasonable to assign monetary values to the environmental damages as well, and the optimal solution will be chosen according to cost-benefit analysis or economic efficiency (Tietenberg, 1992; Turner et al., 1994). It is important to note, however, that there is neither a perfect way to assign monetary values to environmental issues nor an agreed ultimate method to price “nature” and resources scarcity.

This paper presents a methodology to be used by decision-makers using LCA and monetizing methods to assess environmental impacts, prior to implementing laws and regulations governing, in this case- the production and disposal of soft drink bottles (SDB). It should be emphasized clearly that the economic data and environmental values provided here are only a rough estimate. Data quality should be carefully assessed before any comprehensive policy could be drawn from this analysis

BASIC DATA, ASSUMPTIONS AND CALCULATIONS

1. The theoretical pattern.

In order to describe the range of alternatives we assessed a matrix of vertical LCA, examining different production processes, as well as a horizontal comparison of different containers collection systems and different waste treatment options (Fig. 1c). We analyzed the production and disposal of three soft drinks container options [P.E.T (polyethylene terephtalate), aluminum or glass]. The use phase of the bottles was not included in this analysis since our main target was to compare alternatives. It is anticipated that the differences between products during the short use phase are minor.

Fig 1c

Multidimensional Life Cycle Inventory.

	j= P.E.T			j= Aluminum			j= glass		
	i=1	i=2	i=..n	i=1	i=2	i=..n	i=1	i=2	i=..n
Raw Material acquisition									
Manufacture									
Use									
Waste Management	Land fill	Incinerate	Recycle	Land fill	Incinerate	Recycle	Land fill	Incinerate	Recycle

We define the following:

I. $PC_{ij} = (RM_{ij} + EC_{ij} + PRC_{ij})$

PC_{ij} is direct production cost ($/ton) in alternative method i for product (or material) j. RM_{ij} is raw material cost, EC_{ij} is energy cost and PRC_{ij} represents all other production costs for each production alternative i ; j represents P.E.T, aluminum or glass.

II. $WMC_{ij} = (CC_{ij} + TC_{ij} + HC_{ij} + TF_{ij} - RF_{ij})$

WMC_{ij} is waste management cost in alternative method i for product j. CC_{ij} is waste collection cost, TC_{ij} is transportation costs, HC_{ij} is handling cost (e.g., at a transfer station), TF_{ij} is tipping fee in a final disposal facility (landfill or incinerator) and RF_{ij} represents the returns from selling secondary materials.

III. $EXC_{ij} = (PR_{ij} + TR_{ij} + WR_{ij})$

EXC_{ij} is cost of environmental externalities, not covered in previous budgets, associated with each alternative method i for product j. These costs are a function of production environmental effects (PR_{ij}) , transportation- related environmental pollution (TR_{ij}) and environmental costs of waste management (WR_{ij}). In this work, our assumption is that landfilling and incineration costs have already incorporated the externalities due to strict regulations and enforcement, therefore, $WR_{ij} = 0$[1].

The objective function of the decision-making authority should be:

$$\min_{ij} \{PC_{ij} + WMC_{ij} + EXC_{ij}\}$$

PC_{ij} and WMC_{ij} are costs born by the industry or the municipality, while EXC_{ij} represents the environmental costs sustained mostly by the community at risk.

In order to demonstrate this approach, we analyzed a case study of soft drinks, bottled in a 330 ml. P.E.T, aluminum or glass containers. One of the factors influencing the consumer's demand for soft drinks is the cost of the product that includes also the cost of the package. This cost is (ideally) the composite of the above three components (I+II+III) per given volume of the container.

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[1] Both incineration and landfilling are considered to practice state of the art technologies to minimize environmental effects. It is assumed that the tipping fee includes all expenses needed to minimize pollution and to ensure correction of potential damages. This is technologically (and politically), a problematic assumption that should be carefully considered. It may be expected that the authorities tend to underestimate the potential risks e.g., the collapse of an environmental barrier preventing pollution from a landfill or an incinerator could lead to huge damages.

2. Data sources and assumptions.

Most of the raw materials for the packaging industry in Israel are imported. Only the last stages of the manufacturing processes are carried out locally. Ninety percent of the waste is being landfilled presently, and there are only two material recovery facilities whose main product is compost. There are no recycling plants for aluminum and P.E.T, yet, there is one glass manufacturing plant that can also recycle glass. Several hypothetical scenarios have also been included. One of these is a waste-to energy plant, which does not exist presently in Israel. This option was evaluated as well, since the construction of at least one plant is being seriously considered.

Characteristics of the production of SDB (P.E.T, glass and aluminum) in Israel are presented in Table 1.

TABLE 1

The data for this study were obtained from various sources. Our model is based on economic evaluations of each stage, processes and environmental burdens from available European studies, mainly in the United Kingdom (UK), conducted by CSERGE (Powell & Brisson, 1994; Frakhauser, 1994; Craighill & Powell, 1966 etc.) and in the USA (Tellus Inst., 1992). We have applied data from the literature unchanged when we analyzed raw material acquisition and processes performed outside Israel. We had to use our best estimates and make new assessments regarding the environmental impacts of processes performed in Israel. For example, actual impacts of acidification would be negligible in arid and semi-arid regions (as is the case in Israel), due to high alkalinity of soils, surface and ground water, compared with wet regions (Avnimelech et al., forthcoming).

The basis in this case study was 330 ml SDB. Two different calculations were carried out: the first in terms of a ton of each packaging material and the second in terms of 1000 liters of soft drinks (3030 containers per 1000 l drinks).

RESULTS AND DISCUSSION

1. Alternative LCAs for P.E.T. bottles.

Five relevant LCAs of P.E.T. bottles were analyzed[2]:

1.1 Incineration of P.E.T. bottles[3]

1.2 Collection and recycling of bottles in Israel to SDB[4]

1.3 Collection and sorting used bottles for shipment to the Netherlands for recycling[5].

1.4 As c, yet the recycled P.E.T. will be used for products other than SDB.

1.5 Disposal of used bottles in sanitary landfills.

Other alternatives such as reusable bottles, P.E.T recycling in Israel to other uses etc. were not analyzed.

The results of the analyses of the five scenarios are presented in Table 2.

TABLE 2

Manufacturing costs are given in section I of Table 2. These direct production costs of P.E.T. bottles are covered by the manufacturer of the SDB ($PC_{i,\, j=P.E.T}$, in function I). The market price of recycled material (120 $/ton) is significantly lower compared with 1100 $/ton for virgin material. This difference could be explained by the different quality, and therefore, possible uses, of the recycled material.

Waste management costs are given in section II. Theses costs ($WMC_{i,\, j=P.E.T}$) are covered by the local authority, the private collector when a recycling scheme is being incorporated, or the producer in the case where responsibility for the waste is transferred by law to the producer (e.g. German packaging law).

The collection costs within the city of P.E.T. bottles for either landfilling or incineration is assumed to be a part of the general collection and its cost is equivalent to the cost of

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[2] Data was obtained from the Israeli industry, municipal authorities, the Transportation Institute (Israel, 1994), market prices from the Internet (www.recycle.net), surveys on environmental externalities conducted by EMC (Israel, 1996), and estimations from the Tellus Institute and CSERGE studies.

[3] A hypothetical scenario; presently there is no waste-to-energy plant in Israel

[4] A hypothetical scenario; there is no P.E.T. recycling plant in Israel. It was also assumed that the recycled material would be used in the production of new SDB, although a 100 percent recycling back to SDB is not feasible.

[5] As in 1.2., it was assumed that the recycled material would be used in the production of new SDB.

municipal solid waste (MSW) collection, i.e. 50 \$/ton. The separate collection of P.E.T. bottles, a prerequisite for recycling, is significantly more expensive and is considered to be 150 \$/ton, due to the low weight and high volume of these bottles. The waste collector is, however assumed to be refunded for the value of the recycled material (120\$/ton). Thus, the net collection fee is 30 \$/ton, less than that of the regular MSW collection. The final collection costs might be even lower, depending on the revenues the collector can obtain in return for the recyclables. Establishing a market, or some other mechanism to provide economic inducement for collecting these products, may provide incentives for greater collection efforts.

<u>The external costs</u> ($EXC_{i,\ j=P.E.T}$) are given in section III. They include pollution damages arising from the production process, transportation externalities inside and outside of the country and waste management costs, unless already internalized.

It should be noted that there are differences in the literature dealing with external costs associated with plastic manufacturing and recycling- The Tellus Institute (1992) estimated production externalities of P.E.T to be as high as 854\$/ton; Combined results of Hunt (1995) and cost estimation of Fankhauser (1994) yield external costs of P.E.T production to be in the range of 17\$ per ton, though, only the implications for global warming were considered; Craighill and Powell (1996) assumed 34\$/ton external costs for sorting and shipping plastics waste from the UK to Netherlands (NL) , *without* the recycling process itself. In our analysis we assumed equal external costs for both production and recycling and estimated them, rather arbitrarily, to be about 10 percent of the Tellus Institute's estimation, since most of the pollutants were emitted during crude oil extraction, refining and monomer production, carried outside Israel. Inclusion of the high external costs will dramatically favor the recycling option, though, realistically, recycling of P.E.T back to SDB is not a widely used option.

Trade in waste and related pollutants is another important issue to be discussed. If sorted and bailed post consumer P.E.T is shipped to the NL, the costs of transportation (direct and environmental) will increase significantly (following Craighill and Powell, 1996). We assumed 10\$/ton for the transportation-related externalities, since mainly marine transportation is practiced.

P.E.T bottles consumed in Israel are being recycled in NL, therefore, the community in NL bears all environmental costs associated with recycling processes. Environmental costs associated with recycling P.E.T bottles in Israel (option 1.2.) would have comprise 14 percent of the total costs. If recycling processes take place outside

Israel, both production and energy-related pollutants, as well as most of the transportation-related pollutants are emitted outside the geographical borders of Israel. The Israeli consumer does not see these external costs. This situation brings to light an interesting case. Van Beukering and Duraiappah (1996) discussed the case of "exporting pollution". It was shown that there is a sustainable (economic and environmental) advantage for India to import waste paper for its paper industry. The trade in waste paper is also advantageous to the developed country that exports it. In a global, sustainable, economic framework, India should be credited for paper recycling since it reduces both harvesting of trees (forests sequester carbon dioxide, a greenhouse gas) and disposal of paper (disposal can generate emissions of greenhouse gases from landfills, among other damages).

The total costs, including production, disposal and external costs of producing P.E.T. bottles, are about 1700 $/ton for bottles produced from virgin raw materials and less than 700 $/ton for bottles produced from recycled material. Since the production of P.E.T. bottles from 100 percent recycled fibers is not a realistic option[6], it could be stated that the soft drink consumer pays the equivalent of 1000 $/ton P.E.T to protect himself from the low probability risk of drinking a contaminated beverage.

The estimated environmental costs of P.E.T production or recycling are 93$/ton, compared with total costs of 660-1752$/ton. Our analysis reveals that direct costs comprise most of the entire costs. This is mainly, due to high prices of raw materials and production costs. Since the only stage of production, which takes place in Israel, is forming the bottles (or cans), the local environmental costs involved with production and disposal at a landfill or incineration plant after one use, comprise about 5 percent of the total costs. The near environment or inhabitants of Israel do not bear the burden of environmental costs associated with the production process.

Comparing the estimated environmental costs of P.E.T recycling (93$/ton) with the price of the recycled material (120$/ton), it seems that the environmental costs are not internalized. This conclusion contradicts the global sustainability framework. Results of the LCA budget will be different from the local, national, or global point of view. In other words, one can see that presently, the producing country is subsidizing the product by not charging the full environmental costs in the price of the product. The Israeli consumer does not bear the external costs and only the people in NL endure them.

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[6] There is a limit as to the number of recycling cycles and the amount of recycled fibers in the final product, without loss of mechanical properties. In addition, production of SDB from recycled P.E.T. is prohibited in most countries due to the risk of recycled bottles used for handling of hazardous chemicals.

Another conclusion that could be drawn out of the analysis is that if recycling P.E.T. plants were available in Israel, recycling would have been the cost effective alternative since the total costs (direct and environmental) are minimized. About 40,000 tons of P.E.T are imported to Israel each year. The Israeli consumer has one of the highest average annual consumption in the world (7.5 kg per capita), therefore, the annual net benefit from recycling would have been 40 million US$[7]. Furthermore, since our analysis was limited for one cycle only, recycling is further credited since it reduces the need to produce new bottles from virgin raw materials.

2. Alternative LCAs for aluminum cans.

Three different scenarios were considered:

2.1 Local production of aluminum from ores, used beverage cans (UBC) are disposed of at sanitary landfills without recycling[8].

2.2 Import of aluminum sheets and local recycling of aluminum cans.

2.3 Import of aluminum sheets with disposal of used cans in sanitary landfills.

The results of the analyses of the different scenarios are presented in Table 3.

TABLE 3

The first option (2.1) is shown for the sake of demonstrating the distribution of environmental externalities in world trade. The production of aluminum has very high environmental costs due to high energy consumption and emission of pollutants (Tellus Inst., 1992). The magnitude of these environmental burdens imposed by the production of virgin aluminum is as high as $1,930 per ton. It is obvious that these costs are not included in the price of the product which is $1,300$/ton. Therefore, countries such as Israel that do not produce aluminum do not bear these externalities. Thus, countries that produce aluminum sheets from raw bauxite give an environmental subsidy to the importers of aluminum. Equivalently, importing aluminum sheets implies a hidden transfer of pollutants such as particulate matter and greenhouse gas emissions arising from the high-energy consumption in the primary production stages of aluminum cans.

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[7] This result is deceptive, since 100 percent recycling of P.E.T is not yet permitted for SDB. Therefore, recycling of P.E.T does not reduce the need (and costs) of producing new P.E.T for SDB.

[8] Since Israel does not have bauxite ores, this scenario is hypothetical.

The melting of UBC requires less than 10 percent of the energy used in the primary stages of aluminum production (Habersatter, 1991). This fact, along with the high price of bauxite, are the main driving forces for aluminum recycling. Nevertheless, even the high price of aluminum still does not reflect all environmental burdens associated with aluminum production. Therefore, both the producer and consumer, regardless of their location, are “free riders” with regard to environmental costs related to energy consumption and pollution emitted along the aluminum production process.

UBC could be either discarded or recycled in Israel. Recycling aluminum is not free of environmental costs. The recycling of aluminum cans emits acidic effluents with high heavy metals contents (Israeli Ministry of Environment, personal communications). The external costs of aluminum recycling were estimated to be 313$/ton by Tellus Inst. (1992), while Craighill & Powell (1996) estimated external costs of collection and sorting UBC to be ca. 177$ (*without* the process of recycling itself). Its disposal in a properly designed landfill bears very little environmental hazard since solid aluminum is a relatively inert and safe material, especially in the non acidic soils of Israel. Nevertheless, if aluminum is landfilled, new bauxite should be extracted in order to produce new SDB.

The difference in price of virgin and recycled aluminum in the world market is not particularly large. Therefore, the producer of SDB can use either virgin materials or recycled ones both imported to the country. For the Israeli economy, as well as from a global perspective, recycling aluminum cans in Israel is economically and environmentally the better option. However, this option implies higher environmental burdens in Israel. Currently, there is no aluminum recycling plant in Israel, and none is planned for the near future. There is a clear economic interest in collecting aluminum cans, due to the high refund from material selling. An interesting observation should be noted. If the Ministry is not involved in the collection and recycling operation (as usually is the case), it is not affected by WMC_{ij} (given in section II of Table 3), but is very sensitive to the effects reflected in section III, i.e. the environmental cost. In the case of Israel, the least cost alternative is to recycle aluminum, but, from the local environmental point of view, landfilling entails less environmental impacts compared with recycling, therefore, the environmental costs are minimized if aluminum cans are disposed of and not recycled. On the other hand, from a global perspective, recycling of aluminum is of high priority. Israel is not comparing a full global LCA but facing only the comparison between landfilling vs. acidic wastewater rich with heavy metals from the recycling plant. However, the decision to landfill implicates an additional burden on the environment of countries that produce aluminum from virgin ores. Ideally, the importing country (Israel, in this case) should be credited for recycling aluminum since it reduces the environmental burdens of producing primary aluminum. An alternative to this would be a complete internalization of all the external costs in the price of the product.

3. Alternative LCAs for glass bottles.

Two alternatives were studied:

3.1 Locally produced glass using local raw materials with disposal of used bottles in sanitary landfills.

3.2 Locally produced glass using recycled materials.

Other alternatives such as reusable bottles, glass recycling in Israel to other uses etc. were not analyzed.

The analyses of the different scenarios are presented in Table 4.

TABLE 4

The comparison of the two LCA scenarios for glass SDB is much simpler. Both alternatives are feasible in Israel. The total costs of producing primary glass or recycling it are \$512 and \$438 per ton, respectively. There is an advantage to recycling due to the fact that energy input for recycling is lower than needed for raw materials (and, therefore, also the environmental costs associated with it). The collection and transport for recycling is somewhat higher than the disposal alternative, but the total WMC are lower due to refund from selling the glass, so the local authority should be interested in glass recycling. Glass beverage bottles are the only product that can be produced either from raw or recycled materials in Israel. There are also no limitations, as to the percent of recycled material in the final product or to the number of recycling cycles. When raw materials are extracted and the full process of glass production takes place in Israel, the environmental impacts are in the range of 50-90 \$ per ton (13-17% of the total cost).

4. Comparison among SDB packaging materials

Production, use and disposal costs of SDB from virgin P.E.T are twice as high, and from virgin aluminum four times higher, compared with glass. However, there is a significant change in the weight of these materials needed to pack soft drinks. Thus, on a basis of package material needed for 1000 liter of drink, the picture is totally different from the one described above. As seen in Table 5, since P.E.T SDB are light, the direct and environmental costs associated with their production and disposal, on a soft drink volume basis, are significantly lower than other alternatives. Even when a P.E.T bottle is disposed of or incinerated after one use, the total costs are only 30-40% of the total costs of an aluminum or glass bottles.

TABLE 5

Environmental costs related to P.E.T and aluminum SDB production in Israel are negligible due to the fact that only the final stage of production is taking place in Israel and all the major production processes and energy consumption take place elsewhere. In the case of glass, there is a slight difference between producing a bottle from raw materials or from recycled bottles, since both, full production stages, take place in Israel.

CONCLUDING REMARKS

The paper argues for the use of a multidimensional LCA as well as for the inclusion of both local and global externalities. The different options for the production, recycling and disposal of SDB were analyzed using an integrated LCA. The basic feature of this methodology is that all stages in the life cycle of a number of alternative products and waste management options are taken into account. This approach fully uncovers the different costs that each actor along the production, use and disposal stages, is responsible for. Presently, each actor throughout the life cycle of a package views only his part of the picture, possibly leading to ineffective decisions and policies.

Regulators and solid waste managers have targeted packaging and packaging waste, due to the constant increase of this component in the waste stream. Free trade in packaging (raw materials, products and waste), mainly encouraged by the General Agreement on Tariffs and Trade (GATT), has created a situation where products are being produced in one place and consumed elsewhere. Implementation of a "Producer Pays Principal" approach regarding the entire life cycle of a package becomes, therefore, much more difficult (i.e., Ekins, 1994). In order to overcome this problem, environmental costs could and should be included in international trade agreements. Thus for example, a country that produces and exports aluminum from bauxite ores should be credited in the equivalent greenhouse emission of the production and delivery, and the country that imports it should be charged by these emissions. It is possible that such agreements will partially alleviate existing conflicts, since such trade in emission rights can enable each country to choose the option where it employs relative advantages. Alternatively, all environmental costs should be internalized in the price of the product.

The European Community addressed the issue of trading waste (EC internet site, 1996) and banned export of waste for disposal to other countries and recommended avoiding shipment of waste to be recovered in countries where lower environmental standards entail lower treatment costs. The advantage of the suggested LCA methodology is that the description of the problem is comprehensive and transparent, the costs of each decision made are known.

Due to the global aspects of production, use and disposal of goods, there should be a market mechanism to internalize environmental costs. The use of the suggested approach will promote optimal economic and environmental decisions. The multidimensional LCA methodology elaborated in this paper illustrates how to account for the full costs of alternative packaging materials and their disposal options, while taking into consideration the entire life cycle. To insure a fair and globally sustainable comparison, the costs of environmental burdens (or benefits) should be internalized in the price of the product. This mechanism will ensure that there will be no advantage for importing countries over the exporting ones that bear most of the environmental burdens occurring mainly in the first stages (i.e., raw material acquisition).

It should be emphasized, however, that data used here serve only as an example. There is a further need to obtain more precise data, including a thorough data quality assessment prior to the development of a specific policy. The evaluations presented in this paper serve as a demonstration of the importance of such an investigation as a support for policy makers. In order to overcome conflicts, due to partial picture viewed by different actors, the central authority should be in a position to take into consideration the overall picture and urge the more sustainable alternatives.

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Table 1

Characteristics of production of soft drinks bottles (SDB) in Israel

Material	**Production**	**Present recycling situation in Israel**
P.E.T.	P.E.T. is imported in pellets form; or Polyethylene is imported and the last stage of polymerization completed in Israel	P.E.T. is sorted at a material recovery facility. Since there is no current recycling of P.E.T. in Israel, it is baled and sent to be recycled in the Netherlands. Imported recycled P.E.T. is used as raw material for trays, plate's etc., **not** for SDB. The construction of a local recycling plant is planned.
Aluminum	Imported sheets[9]	No recycling of aluminum
Glass	Sand and limestone are extracted in Israel. Soda ash and other ingredients are imported. Empty glass bottles are imported, as well.	One glass bottles producer in Israel (that also has recycling capabilities). Only clear glass is recycled.

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[9] Due to high prices of aluminum sheets and lack of recycling infrastructure, beverage cans are presently made from steel. Nevertheless, this case study was related to aluminum in order to emphasize some very dominant points in aluminum beverage-can production and recycling.

Table 2

Alternative LCAs for P.E.T bottles (1 ton of raw material basis)

$/ ton raw material	**P.E.T Incinerated**	**P.E.T 100% Recycled to SDB in ISRAEL**	**P.E.T 100% Recycled to SDB in the NL**	**P.E.T Recycled, not to SDB in the NL**	**P.E.T Landfilled**
DIRECT COSTS					
I. PRODUCER COSTS					
raw material	1100	120	120	1100	1100
Production costs (energy included)	400	400	400	400	400
Total production costs	**1500**	**520**	**520**	**1500**	**1500**
II. WASTE MANAGEMENT					
Collection costs	50	150	150	150	50
Transportation	9.75	15	100	100	9.75
transfer station					7
Landfill					20
Incineration	100				
refund from material selling		-120	-120	-120	
Net costs- waste management	**160**	**45**	**130**	**130**	**87**
III. ENVIRONMENTAL COSTS *In Israel*					
production- total pollution	92	92	(92 in NL)	(92 in NL)	92
Transportation	0.5	0.5	10	10	0.5
Total environmental costs In Israel	**93**	**93**	**10**	**10**	**93**
TOTAL COSTS ($/ TON)	**1752**	**658**	**660**	**1640**	**1679**
Total production costs (%)	*85.60*	*79.09*	*78.79*	*91.46*	*89.33*
Waste management (%)	*9.12*	*6.84*	*19.70*	*7.93*	*5.17*
Total environmental costs (%)	*5.28*	*14.07*	*1.52*	*0.61*	*5.51*

Table 3

Alternative LCAs for aluminum cans (1 ton of raw material basis)

$/ ton raw material	**ALUM. Ore in Israel**	**ALUM. Recycled**	**ALUM. Landfilled**
DIRECT COSTS			
I. PRODUCER COSTS			
Raw material	1296	1000	1296
Production costs (energy included)	1403	1331	1403
Total production costs	**2699**	**2331**	**2699**
II. WASTE MANAGEMENT			
Collection costs	50	100	50
Transportation	9.75	15	9.75
Transfer station	7		7
Landfill	20		20
Incineration			
Refund from material selling		-1000	
Net costs- waste management	**87**	**-885**	**87**
III. ENVIRONMENTAL COSTS In Israel			
Production- total pollution	1930	313	10
Transportation	0.4	0.5	0.4
Total environmental costs In Israel	**1930**	**314**	**10**
TOTAL COSTS ($/ TON)	**4716**	**1760**	**2796**
Total production costs (%)	*57.23*	*	*96.53*
Waste management (%)	*1.84*	*	*3.10*
Total environmental costs (%)	*40.93*	*	*0.37*

* Not relevant (there is a benefit in the waste management section due to high refund from material selling).

Table 4

Alternative LCAs for glass bottles (1 ton of raw material basis)

	GLASS	**GLASS**
$/ ton raw material	**Recycled**	**Landfilled**
DIRECT COSTS		
I. PRODUCER COSTS		
Raw material	40	65
Production costs (energy included)	260	275
Total production costs	**300**	**340**
II. WASTE MANAGEMENT		
Collection costs	100	50
Transportation	22.5	9.75
Transfer station		7
Landfill		20
Incineration		
Refund from material selling	-40	
Net costs- waste management	**83**	**87**
III. ENVIRONMENTAL COSTS *In Israel*		
Production- total pollution	55	85
Transportation	0.6	0.4
Total environmental costs In Israel	**56**	**85**
TOTAL COSTS ($/ TON)	**438**	**512**
Total production costs (%)	*68.48*	*66.39*
Waste management (%)	*18.83*	*16.94*
Total environmental costs (%)	*12.69*	*16.67*

Table 5

Alternative LCAs for SDB (1000 lit. drink basis)

	P.E.T **Incinerated**	**P.E.T** **100% Recycled to SDB in ISRAEL**	**P.E.T** **100% Recycled to SDB in the NL**	**P.E.T** **Recycled not to SDB in the NL**	**P.E.T** **Landfilled**	**ALUM.** **Ore in ISRAEL**	**ALUM.** **Recycled**	**ALUM.** **Landfilled**	**GLASS** **Recycled**	**GLASS** **Landfilled**
SDB weight for 1000 l. drink	0.085	0.085	0.085	0.085	0.085	0.112	0.112	0.112	0.515	0.515
Total costs ($ / 1000 l. drinks)	**149**	**56**	**56**	**139**	**143**	**528**	**197**	**313**	**226**	**264**
Direct cost ($/ 1000 l. drinks)	141	48	55	139	135	312	162	312	197	220
Environmental costs ($/1000 l. drinks)	8	8	1	1	8	216	35	1	29	44
Direct costs (%)	*94.72*	*85.93*	*98.48*	*99.39*	*94.49*	*59.07*	*82.18*	*99.63*	*87.31*	*83.33*
Environmental costs (%)	*5.28*	*14.07*	*1.52*	*0.61*	*5.51*	*40.93*	*17.82*	*0.37*	*12.69*	*16.67*