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Life Cycle Assessment of shopping bag out of bioplastics – and its comparison with other shopping bags

Your research and test laboratory

A study covering the topic „Life Cycle Assessment of Shopping Bags“ on behalf of Papier-Mettler, Morbach (Germany)

Version v1.0

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FINAL REPORT

Table of Content

1 Introduction

Since 2008, Roland Hischier from the Technology & Society Lab (TSL) at Empa in St. Gallen (Switzerland) has established several life cycle assessment (LCA) studies on behalf of the company Papier-Mettler, Morbach (Germany), covering a whole bunch of different types of shopping bags.

Beginning of 2011, Papier-Mettler contacted the author with the request for a further calculation, the calculation of a shopping bag out of the bioplastics 'I'm green', and its comparison with the various already calculated types of shopping bag. The bioplastics 'I'm green' is a polyethylene, produced out of sugar cane.

This document here summarizes the results for this most recent type of shopping bags, the "I'm green' bioplastics and of its comparison with all, so far on behalf of Papier-Mettler examined shopping bag types.

The results of all previous shopping bag studies have been updated from the database ecoinvent v2.01 to the most recent version of this globally leading database for LCA studies, the version v2.2. For the impact assessment, the two so far used methods (CML and Eco-Indicator'99) have been replaced by their common successor, the method 'ReCiPe'.

2 Goal and Scope

The objective of this study is to examine by the aid of the framework of LCA the life cycle of the new shopping bag model, and to integrate its results in the existing comparison of various types of shopping bags.

2.1 Functional Unit and Study object

As a functional unit for this comparison, similar as in the already existing studies (Hischier 2008 and 2009) the unit of „1 shopping bag“ has been chosen. The following table summarizes the data used for this new shopping bag, as well as the data from the various calculations in the two above mentioned studies.

Tab. 2.1 Examined Shopping Bag Options

(i) NEW shopping bag – made out of ‚I’m green‘ bioplastics

shopping bag type	weight [g]	size HxBxT [cm]	volume [L]	thick-ness [μm]	data source
‚I’m green‘ shopping bag (polyethylene, from renewable materials)	30.3	46 x 52 x 10 (pleat)	26	55	Same size like a conventional polyethylene shopping bag

(ii) shopping bags from the former studies (Hischier 2008 and 2009)

shopping bag type	weight [g]	size HxBxT [cm]	volume [L]	thick-ness [μm]	data source
Primary plastics (LDPE, new granulate)	30.3	46 x 52 x 10 (pleat)	26	55	Detzel et al. (2007)
ECOLOOP (LDPE, Recycling plastic)	30.3	46 x 52 x 10 (pleat)	26	55	Detzel et al. (2007)
Biologically degradable shopping bag	44.8	46 x 52 x 10 (pleat)	26	55	Data from producer
paper	42	32 x 44 x 17	24	90	Data from producer & Hischier (2008)
cotton	62	42 x 38	n.a.[1)]	190	Data from producer

[1)] n.a. : not applicable

2.2 System boundaries

The system boundaries have been taken over without any changes from the very first study (Hischier 2008); i.e. the study covers production and supply of raw materials, production of the actual shopping bag (i.e. printing and making-up), as well as the final disposal in a municipal solid waste incineration plant (MSWI); including the credits due to the waste heat and electricity production – resp. the final disposal in a composting plant, with respective credits for the replaced fertilizer amounts.

2.3 Used method in Life Cycle Impact Assessment

Since the first study (Hischier 2008), the basic background database has changed (with the change from ecoinvent v2.01 to v2.2). In the same time, in the area of life cycle impact assessment, the existing methods have been further developed and actualized.

The method “ReCiPe” (Goedkoop et al. 2009) has been developed in the Netherlands, and the method is considered the successor of the two former Dutch methods – i.e. Eco-Indicator’99 and CML’01. Hence, for this study here we also changed from the former CML’01 and Eco-Indicator’99 result presentation to a presentation of results, based on the midpoint and endpoint approaches of the ReCiPe framework.

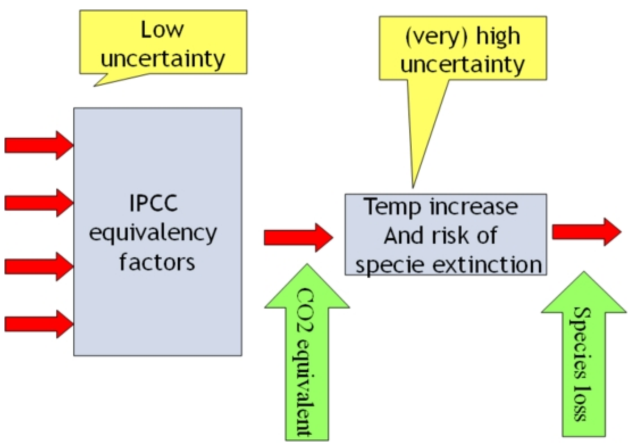
ReCiPe method - a brief summary

The primary objective of the ReCiPe method is to transform the long list of Life Cycle Inventory results, into a limited number of indicator scores. These indicator scores express the relative severity on an environmental impact category. In ReCiPe we determine indicators at two levels:

1. Eighteen midpoint indicators
2. Three endpoint indicators

ReCiPe uses an environmental mechanism as the basis for the modelling. An environmental mechanism can be seen as a series of effects that together can create a certain level of damage to for instance, human health or ecosystems. For instance, for climate change we know that a number of substances, increases the radiative forcing, this means heat is prevented from being radiated from the earth to space. As a result, more energy is trapped on earth, and temperature increases. As a result of this we can expect changes in habitats for living organisms, and as a result of this species may go extinct.

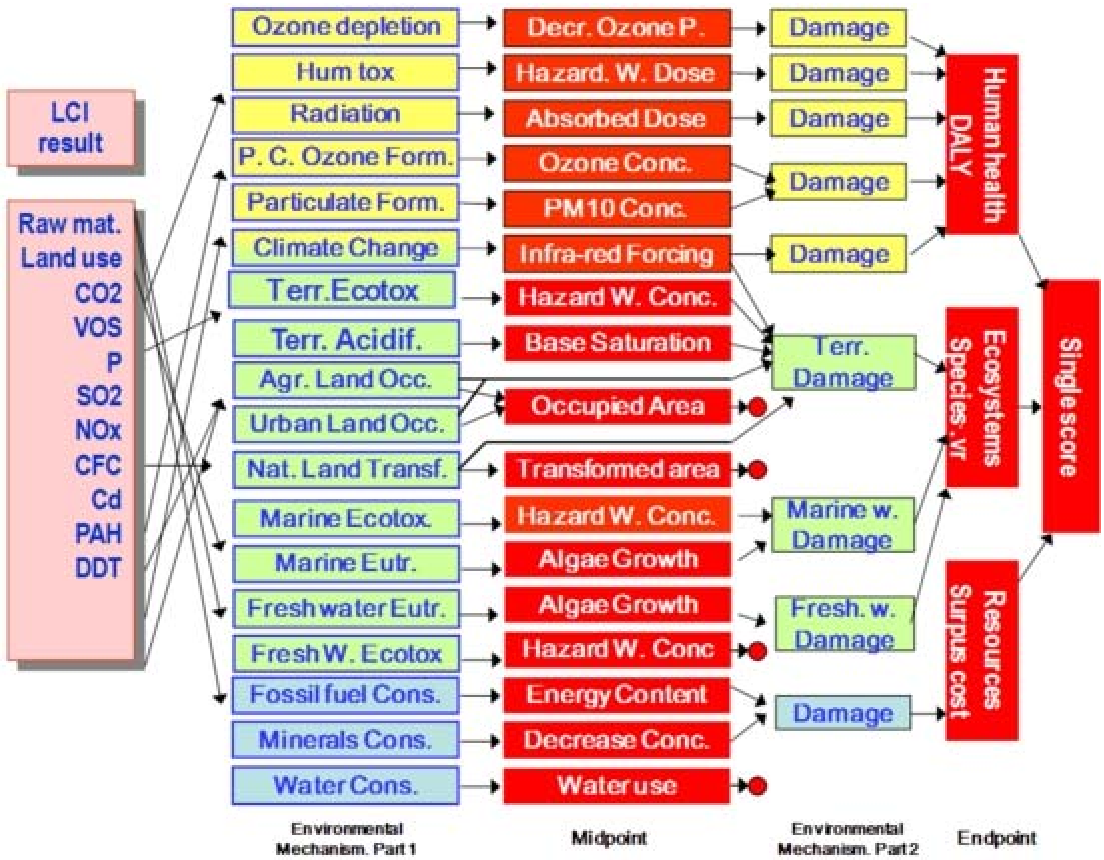
From this example it is clear that the longer one makes this environmental mechanism the higher the uncertainties get. The radiative forcing is a physical parameter that can be relatively easily measured in a laboratory. The resulting temperature increase is less easy to determine, as there are many parallel positive and negative feedbacks. Our understanding of the expected change in habitat is also not complete, etc. The following figure shows an example of a harmonised midpoint-endpoint model for climate change, linking to human health and ecosystem damage.



So the obvious benefit of taking only the first step is the relatively low uncertainty. In ReCiPe we indeed calculate eighteen of such midpoint indicators, but also calculate three much more uncertain endpoint indicators. The motivation to calculate the endpoint indicators, is that the large number of midpoint indicators are very difficult to interpret, partially as there are too many, partially because they have a very abstract meaning. How to compare radiative forcing with base saturation numbers that express acidification? The indicators at the endpoint level are intended to facilitate easier interpretation, as there are only three, and they have a more understandable meaning. The idea is that each user can choose at which level it wants to have the result:

- Eighteen robust midpoints, that are relatively robust, but not easy to interpret
- Three easy to understand, but more uncertain endpoints:
    - Damage to Human health
    - Damage to ecosystems
    - Damage to resource availability

The user can thus choose between uncertainty in the indicators, and uncertainty on the correct interpretation of indicators. The figure below provides the overall structure of the method



3 Inventory Analysis

Tab. 3.1 shows the most important information about the modelling of the shopping bag out of the 'I'm green' bioplastics – the newly calculated type of shopping bags.

Tab. 3.1 Information concerning the life cycle modelling of the newly examined shopping bag, made out of the ‚I'm green' bioplastics ([1] if nothing else is mentioned, the data are taken from the database ecoinvent v2.2; [2] amount according to Papier-Mettler; [3] amount according to Papier-Mettler, production efforts based on confidential information from the producer of the ‚I'm green' bioplastics[1])

process step	details of step	amount	used inventory dataset [1]
plastic bag out of 'I'm green' bioplastics			
raw materials	Delivery (from/to harbour)	600 km	33% transport, lorry >16t, fleet average 67% transport, freight, rail
	Delivery (sea transport)	10'000	km transport, transoceanic freight ship
	PE-Granulat	[3]	polyethylene, LDPE, I'm green, granulate, at plant
production of bag	extrusion	[2]	electricity mix, medium voltage, at grid (DE)
	Masterbatch	[2]	60% titanium dioxide, at plant / polyethylene, LDPE, I'm green, granulate, at plant
	printing	[2]	electricity mix, medium voltage, at grid (DE)
	making-up	[2]	electricity mix, medium voltage, at grid (DE)
	losses in production	[2]	- (to material recycling)
disposal of bag	incineration in MSWI	30.3 g	disposal, polyethylene, I'm green, 0.4% w ater, to MSWI

All requested data (raw materials, energy carriers, disposal processes, etc.) for the various process steps have been taken from the most suitable data source available – and this has been in all cases the currently most comprehensive and internationally most complete life cycle inventory database, the database ecoinvent (version v2.2). The database ecoinvent has been established, under the direction of Empa, from several institutes within the ETH domain in the years 2000 to 2004 – and in the the period 2004 to 2007 further expanded (among others with data about renewable fibres like e.g. cotton) to the current version v2.2. Further information about the various shopping bags is based on personal information from companies as well as on literature surveys.

The final disposal of most of the here described shopping bags in a municipal solid waste incinerator results in a recovery of a part of the energy that actually is stocked in the material. This recovered energy is in form of electricity and (vapour) heat. For the amount of energy produced in the incineration process, credits based on the following datasets are established and given:

- electricity: German electricity production (using the dataset „electricity mix (DE)" from ecoinvent v2.2)
- heat: light fuel heating installation (using the dataset „heat, light fuel oil, at boiler 100 kW, non-modulating" from ecoinvent v2.2)

[1] The data from the producer of the poylethylene ‚I'm green' have been expanded by land use data, based on the sugar cane dataset from ecoinvent data v2.2.

The biological degradable shopping bag is sent to a composting plant, where it is transformed into a material that can replace fertilizers. In the framework of this study here, the credits given for this are based on information of the "Schweizer Kompostberatung" concerning the nutrients amount that can be found in compost (i.e. 12 kg nitrogen, 8 kg phosphate, 13 k of potassium oxide, 8 kg of magnesium oxide and 56 kg calcium oxide per tonne of dried substance). For the calculation of the actual credits, again, data from the database ecoinvent are used.

The modelling (raw materials, production and disposal) of all other shopping bags has been done in a similar way – and by using similar data sources as for the 'I'm green' shopping bag. In Tab. 3.2 und Tab. 3.3 the most important elements of these further shopping bags are listed.

Tab. 3.2 Information concerning the life cycle modelling of the further, plastics-based, shopping bag, ([1] if nothing else is mentioned, the data are taken from the database ecoinvent v2.2; [2] amount according to Papier-Mettler; [3] calculated, out of other substances …)

process step	details of step	amount	used inventory dataset [1]
plastic bag out of primary			
raw materials	Delivery	300 km	33% transport, lorry >16t, fleet average 67% transport, freight, rail
	primary plastic, PE	[3]	polyethylene, LDPE, granulate, at plant
production of bag	extrusion	[2]	electricity mix, medium voltage, at grid (DE)
	Masterbatch	[2]	60% titanium dioxide, at plant / 40% polyethylene, LDPE, granulate, at plant
	printing	[2]	electricity mix, medium voltage, at grid (DE)
	making-up	[2]	electricity mix, medium voltage, at grid (DE)
	losses in production	[2]	- (to material Recycling)
disposal of bag	incineration in MSWI	30.3 g	disposal, polyethylene, 0.4% w ater, to municipal incineration
ECOLOOP plastic bag, out of recycled plastic			
raw materials	transport to re-granulation	250 km	transport, lorry >16t, fleet average
	energy re-granulation	[2]	electricity mix, medium voltage, at grid (DE)
	losses re-granulation	[2]	disposal, municipal solid w aste, to municipal incineration
production of bag	extrusion	[2]	electricity mix, medium voltage, at grid (DE)
	Masterbatch	[2]	60% titanium dioxide, at plant / 40% polyethylene, LDPE, granulate, at plant
	printing	[2]	electricity mix, medium voltage, at grid (DE)
	making-up	[2]	electricity mix, medium voltage, at grid (DE)
	losses in production	[2]	- (to material Recycling)
disposal of bag	incineration in MSWI	30.3 g	disposal, polyethylene, 0.4% w ater, to municipal incineration
biological degradable bag out of 30% renewables in minimum			
raw materials	Delivery (all raw materials)	300 km	33% transport, lorry >16t, fleet average 67% transport, freight, rail
	starch	[2]	50% maize starch, at plant (DE) 50% potatoes starch, at plant (DE)
	ecoflex	[2]	data from Chaffee & Yaros 2008 from a blend of 65% ecoflex, 10% PLA and 25% calcium carbonate. Here, the amounts of PLA and calcium carbonate have been substracted by using the follow ing ecoinvent datasets: - polylactide, granulate, NatureWorks Nebraska, at plant (US) - limestone, milled, loose, at plant (RER)
production of bag	extrusion	[2]	electricity mix, medium voltage, at grid (DE)
	Masterbatch	[2]	60% titanium dioxide, at plant / 40% above 50:50-Mix of ecoflex and starch
	printing	[2]	electricity mix, medium voltage, at grid (DE)
	making-up	[2]	electricity mix, medium voltage, at grid (DE)
	losses in production	[2]	- (to material Recycling)
disposal of bag	composting	44.8 g	compost, at plant (CH)

Tab. 3.3 Information concerning the life cycle modelling of the paper and cotton shopping bags, ([1] if nothing else is mentioned, data are taken from database ecoinvent v2.2; [3] calculated, out of other substances; [4] information from Papier-Mettler concerning the plastics bags are taken as a proxy here …)

process step	details of step	amount	used inventory dataset [1]
paper shopping bag			
raw materials	Delivery	300 km	33% transport, lorry >16t, fleet average 67% transport, freight, rail
	packaging paper	[3]	kraft paper, bleached, at plant
production of bag	printing	[4]	electricity mix, medium voltage, at grid (DE)
	making-up	[4]	electricity mix, medium voltage, at grid (DE)
	losses in production	[4]	- (to material Recycling)
disposal of bag	incineration in MSWI	42 g	disposal, packaging paper, 13.7% w ater, to municipal incineration
cotton shopping bag			
raw materials	Delivery (from/to harbour)	600 km	33% transport, lorry >16t, fleet average 67% transport, freight, rail
	Delivery (sea transport)	10'000	km transport, transoceanic freight ship
	cotton yarn production	[3]	yarn, cotton, at plant
production of bag	w eaving	[3]	w eeving, cotton
	printing	[4]	electricity mix, medium voltage, at grid (DE)
	making-up	[4]	electricity mix, medium voltage, at grid (DE)
	losses in production	[4]	disposal, textiles, soiled, 25% w ater, to municipal incineration
disposal of bag	incineration in MSWI	62 g	disposal, textiles, soiled, 25% w ater, to municipal incineration

4 Results

4.1 Assessment on the level of „Midpoints“

For the comparison of the various, in this study examined, shopping bags a single use with a subsequent disposal in a municipal solid waste incineration (resp. in a compost plant in case of the biologically degradable shopping bag model) is assumed here. Using the Midpoint approach from the ReCiPe method results in the following picture (the expression “I’m green” represents a shopping bag made out of 100% sugar-cane-based polyethylene).

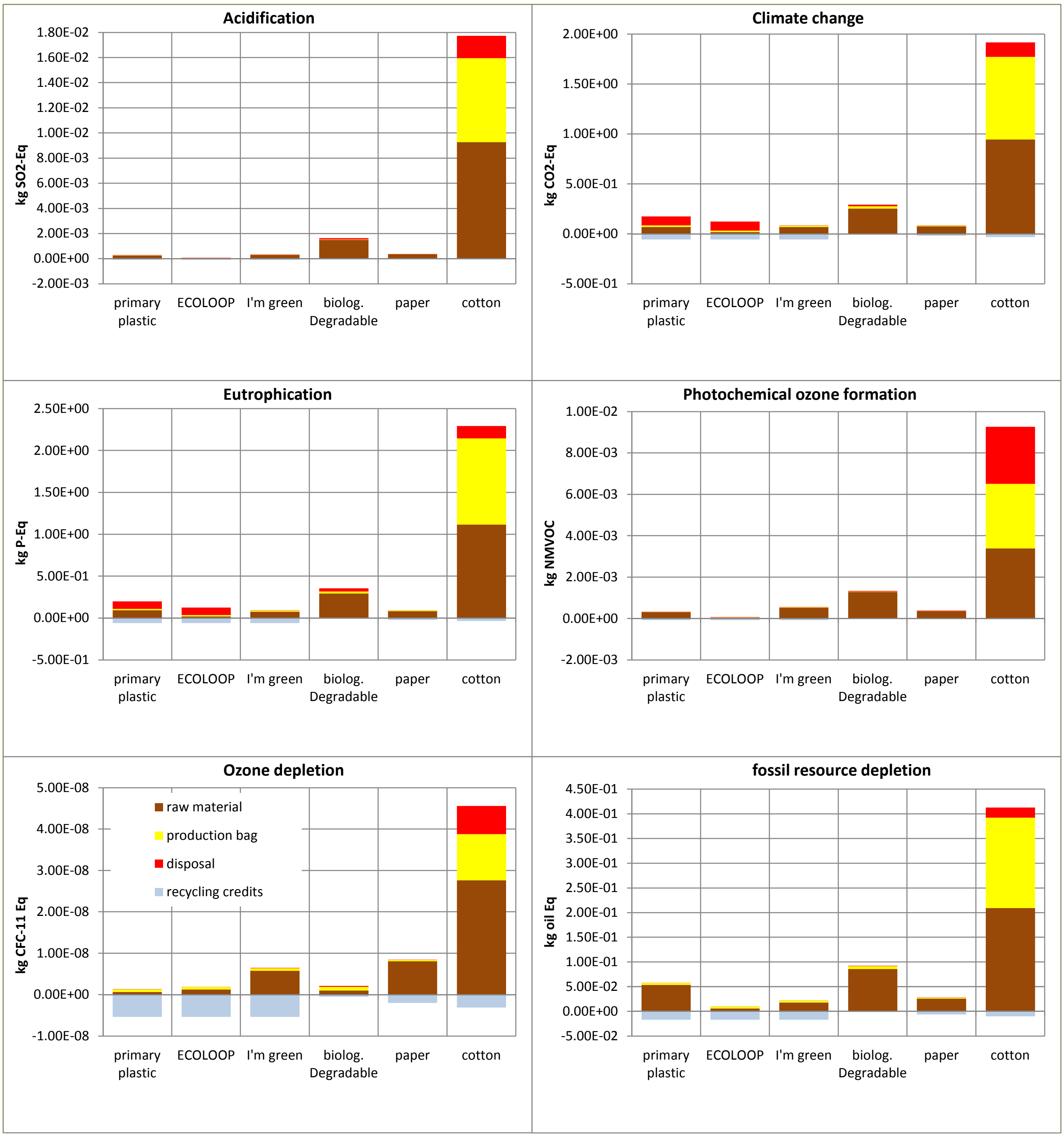


Fig. 4.1 global and regional environmental aspects according to the Midpoint approach of the ReCiPe method for a single use of the various shopping bags.

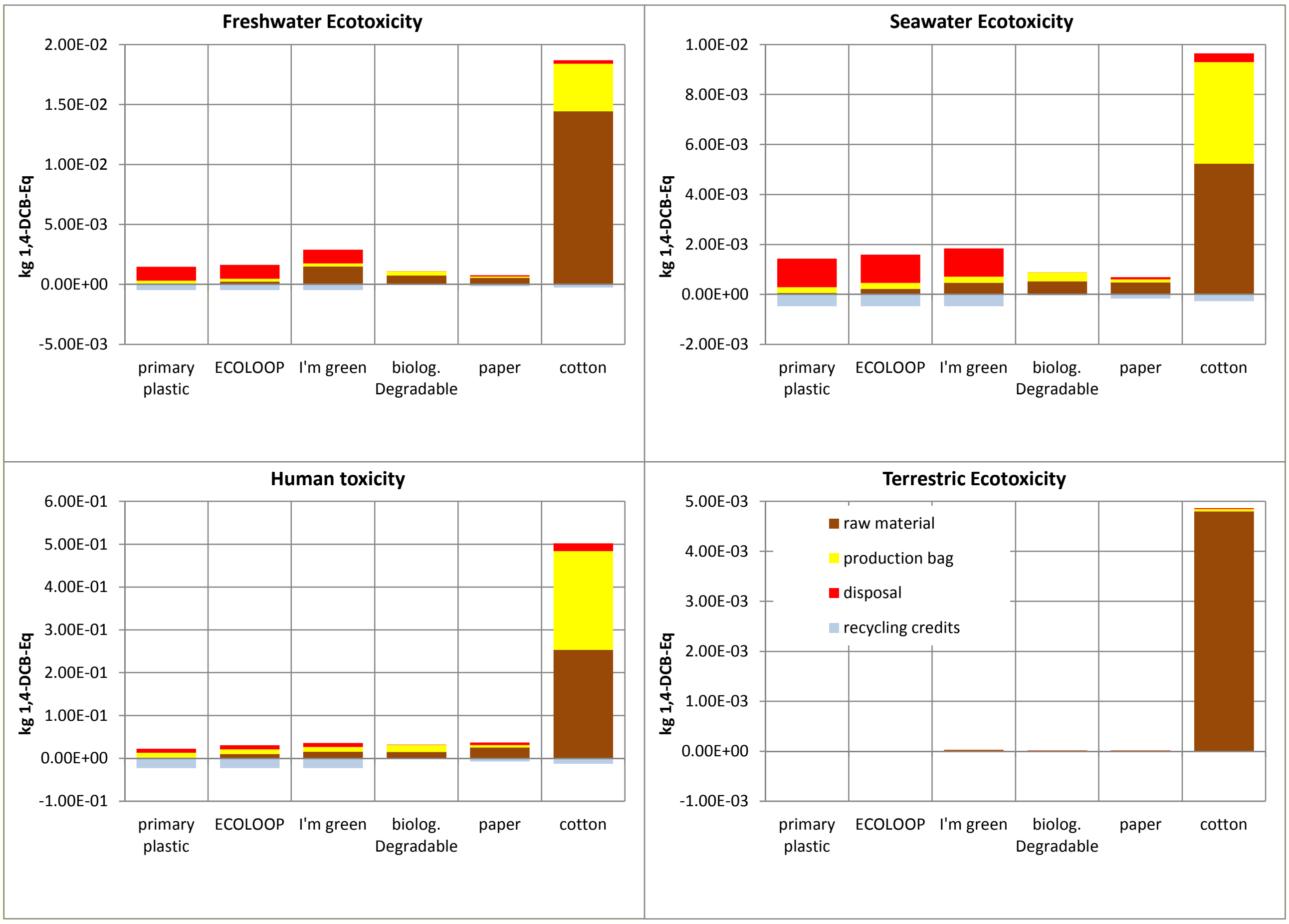


Fig. 4.2 **(Cont.) global and regional environmental aspects according to the Midpoint approach of the ReCiPe method for a single use of the various shopping bags.**

As clearly shown in Fig. 4.1 and Fig. 4.2, the cotton bag has by far the highest scores in all examined environmental aspects due to the high environmental impacts in the cotton production (and partly in the production of the bag itself!). However, these results of the cotton bag are that high that the two above figures show hardly any differences between the five other shopping bag models.

Hence, for a second comparison only the remaining five models have been taken into account – i.e. the four shopping bags out of plastics (primary plastics, recycling plastics, bioplastics ‘I’m green’ and the biologically degradable material) as well as the paper bag. And similar to the figures above, a single use - with a subsequent disposal in a municipal solid waste incineration (resp. in a compost plant in case of the biologically degradable shopping bag model) is assumed. Using the Midpoint approach from the ReCiPe method results in the following picture:

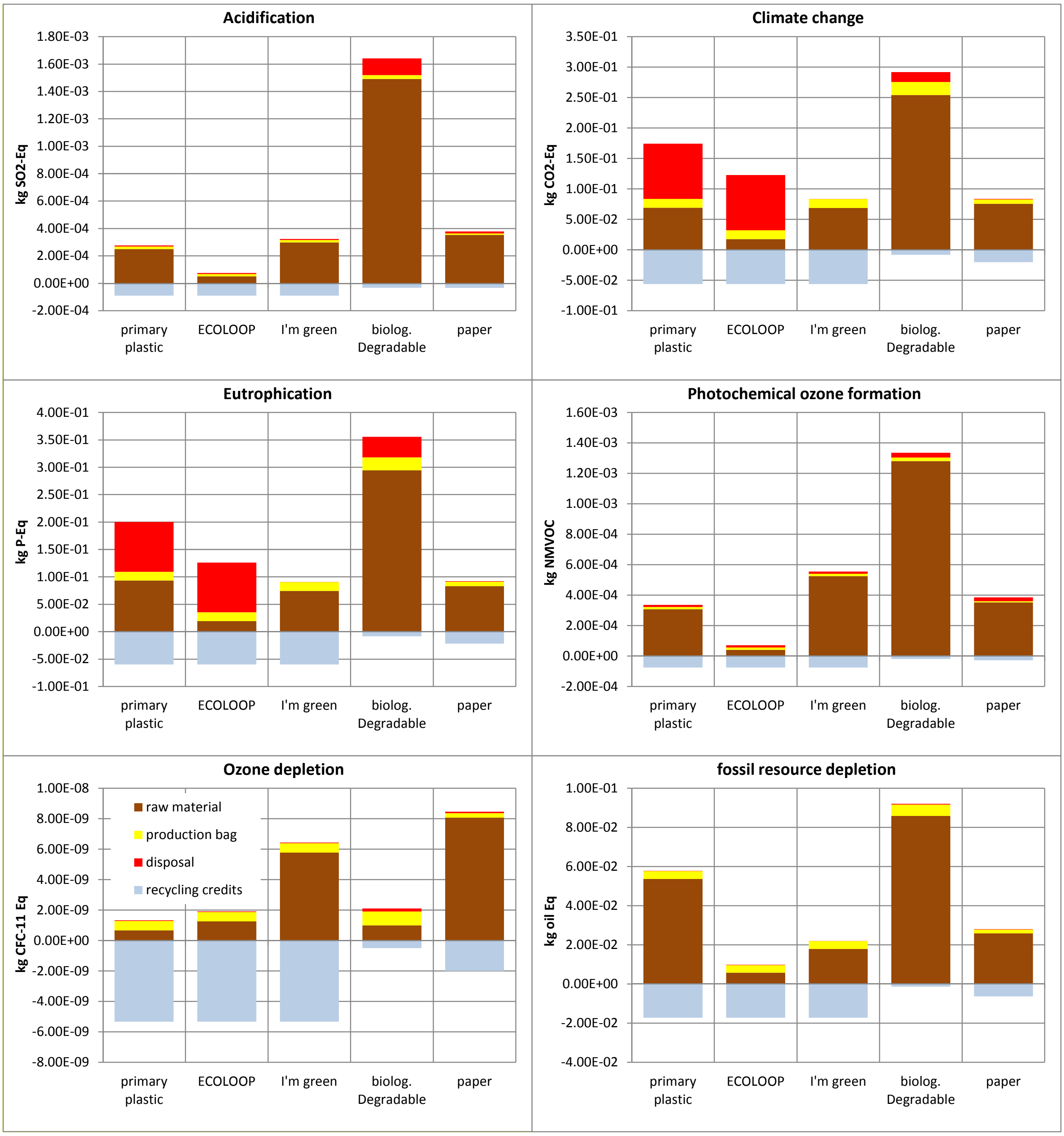


Fig. 4.3 global and regional environmental aspects according to the Midpoint approach of the ReCiPe method for a single use of the various shopping bags (without the cotton bag).

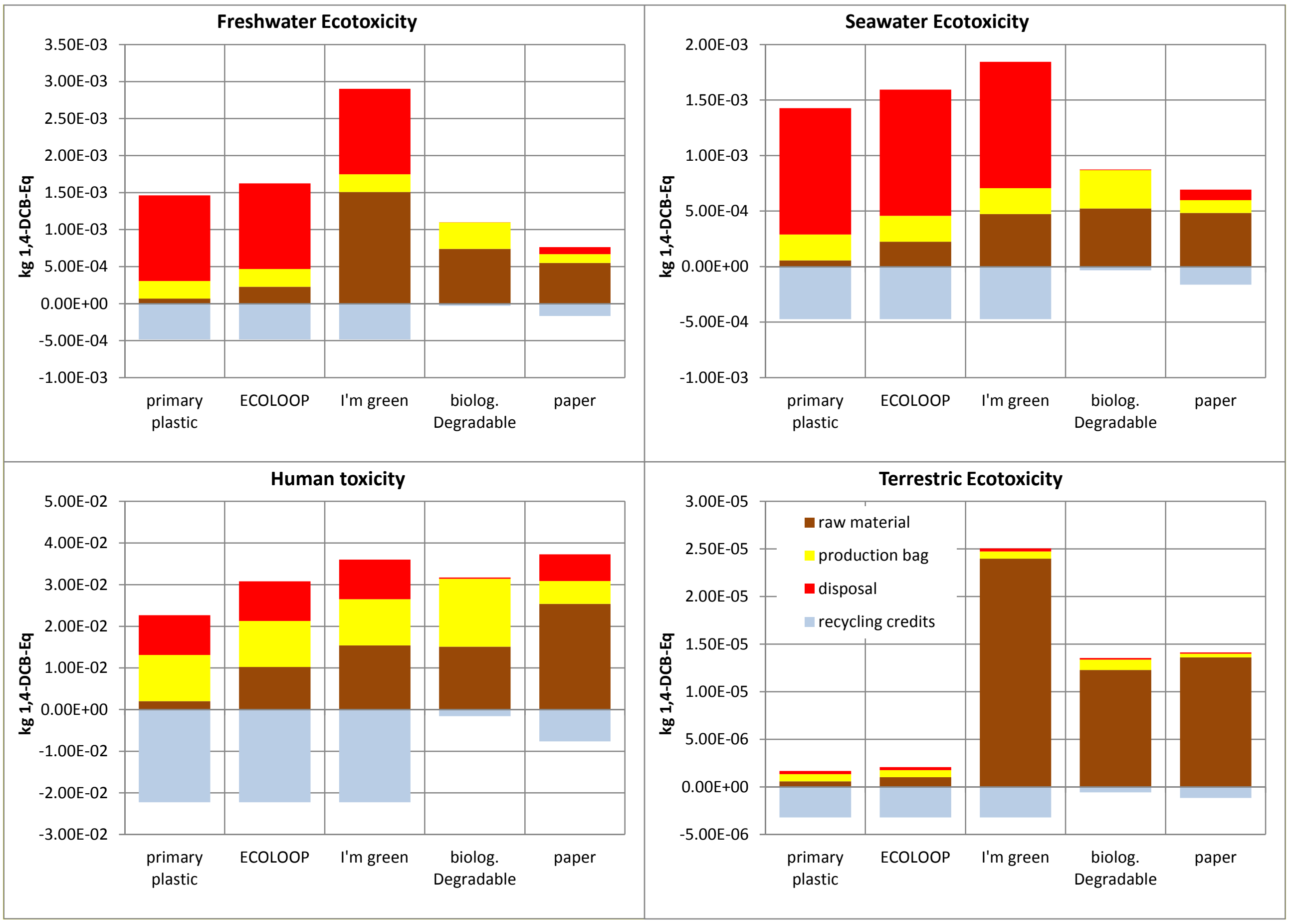


Fig. 4.4 **(Cont). global and regional environmental aspects according to the Midpoint approach of the ReCiPe method for a single use of the various shopping bags (without the cotton bag).**

As shown in Fig. 4.3 und Fig. 4.4, the newly added shopping bag out of the bioplastics ‘I’m green’ has the lowest impact in the area of climate change and eutrophication. In most other aspects, the model ECOLOOP has the lowest scores.

4.2 Assessment on the level of „Endpoints“

Also in this case, a single use of all different shopping bags has been assumed, with a subsequent disposal in the municipal waste incineration plant. When using this “endpoint” approach of the ReCiPe-Method[2] a somehow different pictures – see the following two diagrams – results for the examined shopping bags. The order of the results is then: 1) ECOLOOP – 2) I’m green – 3) primary plastics.

2 the Endpoint approach of ReCiPe represents the further development & update of the „Eco-Indicator‘99“ framework.

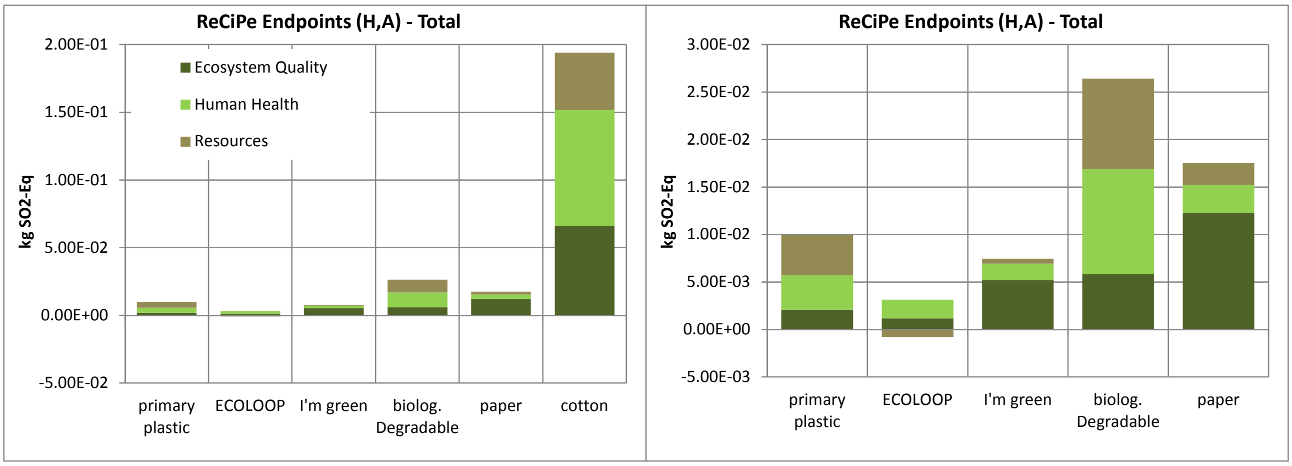


Fig. 4.5 **Endpoint ReCiPe results split into the three damage categories of this approach. The figure on the left contains also the cotton bag – for the figure on the right, similar as above, only the remaining shopping bags are compared to the bioplastics 'I'm green'.**

If we look (both for the total, as well as the three distinct categories of damage) again without the cotton bag, and at the level of the endpoint approach, the breakdown of the various phases of life, reveals the following picture:

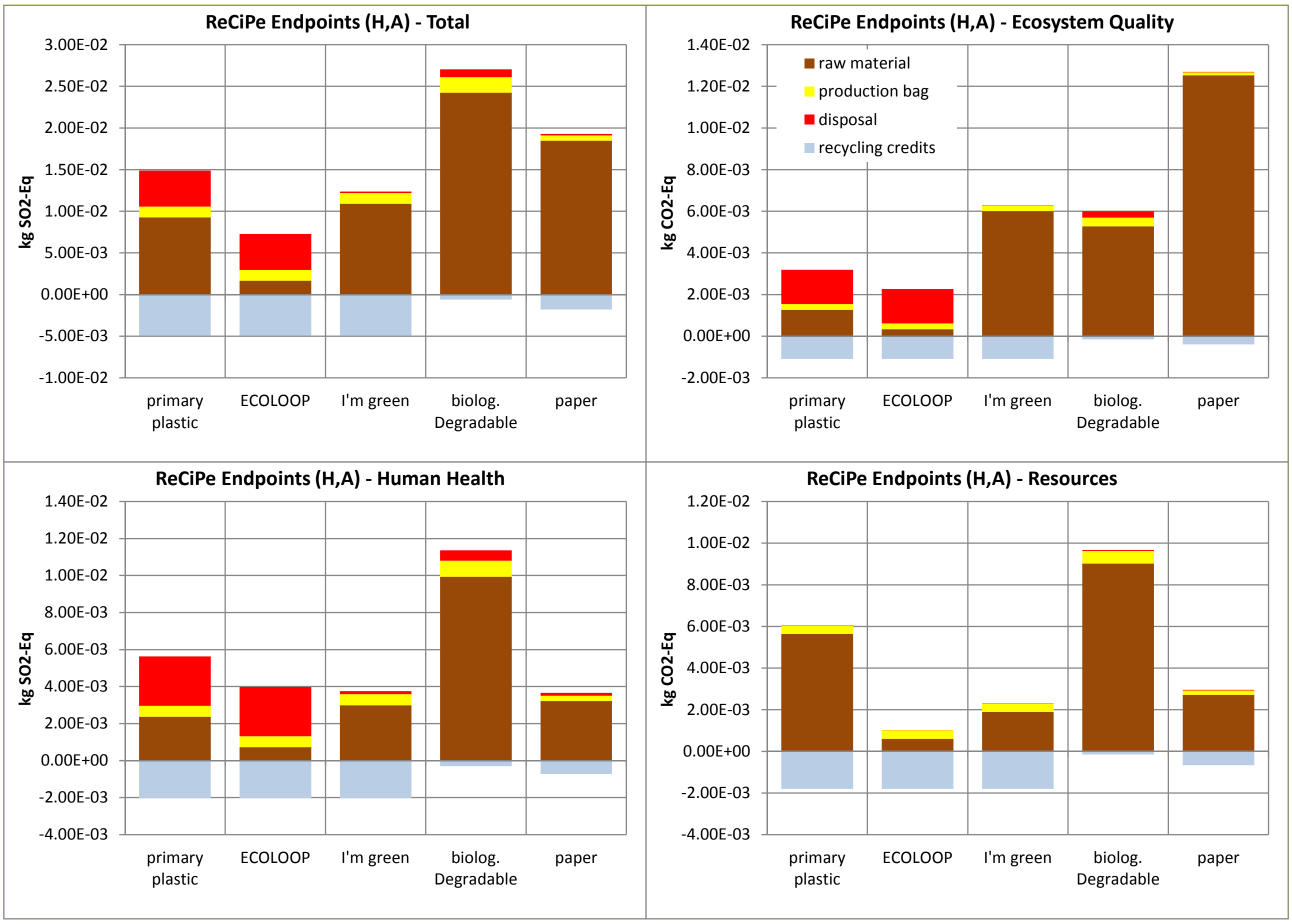


Fig. 4.6 **Endpoint ReCiPe result of the life cycle stages, analogous to the midpoint of the charts for a single use shopping bag models (without the cotton bag).**

4.3 Multiple use of shopping bags

It is very difficult to say that a shopping bag made of this material is more often used by customers than the shopping bags made of other materials. Hence, in order to examine the influence of a multiple use of shopping bags, the following form of presentation was chosen here: the environmental impact of the various shopping bags was compared with the impact of the bag ECOLOOP and the number of times these other bags have to be used was calculated in order to get an environmental impact (per use) similar to the ECOLOOP model.

The results for the various impact categories of the Midpoint approach within the ReCiPe framework are the following:

	Climate change	Eutro-phication	Freshwater ecotoxicity	Seawater ecotoxicity	Human toxicity
primary plastic	1.8	2.1	0.9	0.9	0.0
ECOLOOP	**1.0**	**1.0**	**1.0**	**1.0**	**1.0**
I'm green	0.4	0.5	2.1	1.2	1.6
biolog. Degradable	4.3	5.2	0.9	0.8	3.5
paper	1.0	1.1	0.5	0.5	3.5
cotton	28.3	34.1	16.2	8.4	57.3

Remark: For the factors acidification, summer smog, ozone depletion, fossil resource depletion and terrestrial ecotoxicity the calculation can't be performed, since credits (from electricity and heat) are higher than the load from the production of the shopping bag ECOLOOP ... and so no matter how high the multiple use, a different shopping bag will never reach the area of this bag made from recycled material.

If one makes a similar observation with the Endpoint approach, the result is the following:

	Total	Ecosystem Quality	Human Health	Resources
primary plastic	4.2	1.8	1.8	n.a.
ECOLOOP	**1.0**	**1.0**	**1.0**	**1.0**
I'm green	3.2	4.4	0.9	n.a.
biolog. Degradable	11.2	5.0	5.6	n.a.
paper	7.4	10.5	1.5	n.a.
cotton	82.4	56.2	43.7	n.a.

Remark: For the damage category "Resources" the calculation can't be performed, since credits (from electricity and heat) are higher than the load from the production of the carrying case ECOLOOP [Therefore, the entry "n.a."].

As in the earlier graphs, we also clearly demonstrate here that the shopping bag from 'I'm green' bioplastics, taking into account the overall assessment, occurs between the values of the other two polyethylene bags (primary plastic, ECOLOOP).

4.4 Material thickness as environmental indicator

Due to the difficulties described above concerning the frequency of use of the various types of shopping bags, a further comparison was done based on the thickness of the materials used. That resulted in the following: the environmental impact of the five shopping bags “primary plastic”, “I’m green” (bioplastics), “biologically degradable”, “paper”, and “cotton” was compared with the impact of the ECOLOOP bag, and a calculation was done to determine the (theoretical) thickness of the respective material in order to get an environmental impact (per use) similar to the ECOLOOP model.

The results for the various impact categories of the Midpoint approach within the ReCiPe framework are the following:

	thick-ness	Climate change	Eutro-phication	Freshwater ecotoxicity	Seawater ecotoxicity	Human toxicity
primary plastic	55	31.0	26.0	64.0	64.7	1185.8
ECOLOOP	**55**	**55**	**55**	**55**	**55**	**55**
I'm green	55	133.0	117.6	25.9	45.0	34.1
biolog. Degradable	55	12.9	10.5	58.5	73.3	15.6
paper	90	94.6	84.6	171.6	190.2	25.9
cotton	190	6.7	5.6	11.7	22.7	3.3

Remark: For the factors acidification, summer smog, ozone depletion, fossil resource depletion and terrestrial ecotoxicity the calculation can’t be performed, since credits (from electricity and heat) are higher than the load from the production of the shopping bag ECOLOOP ... and so no matter how small the material thickness, a different shopping bag will never reach the area of this bag made from recycled material.

The, from the bioplastics ‘I'm green' produced shopping bag shows especially for the different factors of ecotoxicity layer thicknesses, which are well below the original thickness. It is now up to the technical experts to assess whether the listed thicknesses for shopping bags are still realistic or not. For the other impact categories, the calculated layer thickness is even higher than the default 55 μm.

If one makes a similar observation with the Endpoint approach, the result is the following – result, that in analogy to the above results with the Midpoint approach, need to be judged by technical experts concerning their feasibility:

	thick-ness	Total	Ecosystem Quality	Human Health	Resources
primary plastic	55	13.0	30.8	29.9	n.a.
ECOLOOP	**55**	**55**	**55**	**55**	**55**
I'm green	55	17.4	12.4	62.3	n.a.
biolog. Degradable	55	4.9	11.1	9.8	n.a.
paper	90	12.1	8.6	60.2	n.a.
cotton	190	2.3	3.4	4.4	n.a.

Remark: For the damage category "Resources" the calculation can’t be performed, since credits (from electricity and heat) are higher than the load from the production of the carrying case ECOLOOP [Therefore, the entry "n.a."].

5 Summary & Conclusions

From all of these findings the following conclusions can be drawn:

- The shopping bag ECOLOOP has in almost all examined areas the lowest environmental impact of the here examined shopping bag types.
- A shopping bag from ‘I’m green’ bioplastics has an overall ecological load that is between the results for the shopping bags out of primary plastic and the ECOLOOP bag; its result is however clearly lower (i.e. better) than the one from the biological degradable and the paper shopping bags.
- This fact is also visible in the table below; table that shows how many times a shopping bag has to be used in order to have a similar environmental impact (per use) like the model ECOLOOP.

	Total	Ecosystem Quality	Human Health	Resources
primary plastic	4.2	1.8	1.8	n.a.
ECOLOOP	**1.0**	**1.0**	**1.0**	**1.0**
I'm green	3.2	4.4	0.9	n.a.
biolog. Degradable	11.2	5.0	5.6	n.a.
paper	7.4	10.5	1.5	n.a.
cotton	82.4	56.2	43.7	n.a.

All in all and based on the detailed results shown in this report here, we can conclude that the shopping bag ECOLOOP – under the here used boundary conditions – is the ecological winner, followed by the ‘I’m green’ shopping bag.

6 References

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