LCA of waste bags

on behalf of

European Waste Bag Producers

- Extended Summary -

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IFEU (BACKGROUND INFORMATION)

- The IFEU - Institute for Energy and Environmental Research was founded more than 30 years ago.
- Located in Heidelberg, Germany. About 50 employees.
- Its expertise covers areas like transport, energy supply and renewable energy sources, LCA, air pollution control, sustainable development, environmental impact assessment, and environmental management.
- About two thirds of the research projects and reports are com-missioned by clients in the public sector (local, national and interna-tional government agencies) and about one third by commercial clients and non-governmental organizations.
- Realized projects in Germany, Europe and overseas
- List of clients includes the World Bank, the European Commission, German Ministries on the Federal and State level, regional and local governments, national and international foundations, industry associations, companies and environmental organizations.

Study objectives

- Comparison of the environmental performance of waste bags for residual waste collection made from virgin polyethylene against those made – fully or in part – from post-consumer recycled material (PCR)

- Exploration of the environmental performance of waste bags from biodegradable materials currently sold by French and German retailers

- Provision of insights about the expected environmental effects of prospective potentials of biobags

Conclusions of LCA on Residual Waste Bags

- The environmental profiles of the examined waste bags are dominated by the raw material production. The conversion to bags and transport to point-of-sale are less significantly less relevant factors by comparison. Exceptions from this are:
  - the incineration step during end-of-life which contributes considerably to climate change indicator due to CO_2-emissions
  - the transportation step from Asia dominates the results for adicification and terrestrial eutrophication in the HDPE bags from China

  Consequently, the environmental impact of each bag type considered in the study, will be lower the thinner the product is, while performance requirements might set a limit to down-gauging of individual bag types

- Bags made from true PCR (*P*ost *C*onsumer *R*ecyclate) have generally the smallest environmental impact profiles and can be considered the most “eco-friendly” materials for waste bags; provided the bags can be made and also perform (i.e. are technically fit for purpose) at thicknesses similar to those made from virgin materials.

- The current bags made from bioplastics (in this study: biodegradable plastics) have less favourable environmental impact profiles than the other materials examined. It should be noted in this respect that BASF, a major supplier of raw materials for such products does not recommend its bioplastics for use in residual waste collection.

- Improvements, particulary of biobags, can be expected within the next years by installation of larger scale raw material manufacturing plants and improved product properties enabling significant down-gauging. Yet, none of the improvement scenarios examined indicated an overall environmental performance better than that of the current PE bags.

Target audience / Intended Application

Target Audience

- Bag producers and key customers
- Political decision makers in EU and Member States
- Study potentially also to be made available to consumers

Intended Application

- Product policy and strategy building at bag producers
- Basis for communication to authorities
- Information to the public

Project Organization (1/2)

- LCA Consultant
  - IFEU (Institut für Energie- und Umweltforschung Heidelberg GmbH)

- Project sponsors/initiators
  - CeDo Folien und Haushaltsprodukte GmbH
  - Cofresco Frischhalteprodukte GmbH & Co. KG
  - Fipp Handelsmarken GmbH & Co. KG
  - pely-plastic GmbH & Co. KG
  - Quickpack Haushalt + Hygiene GmbH

in cooperation with

  - IK (Industrievereinigung Kunststoffverpackungen e.V.)

Project Organization (2/2)

- Study is conform to LCA ISO Standards 14040/14044
- Critical Review by Panel of Interested Parties (according to §7.3.3 ISO 14040)
- Critical Reviewers
  - Hans-Jürgen Garvens (LCA consultant, UBA)
  - Maartje Sevenster (CE Delft)
  - Stéphane Lepochat (EVEA)
  - Bertrand Laratte (EVEA)

Allocation methods (1/3)

- The graphs on slide 10 show two exemplary product systems, referred to as product system A and product system B.
- In both systems showed, a virgin polymer is produced, converted into a product which is used and finally disposed of via MSWI.
- If the system boundaries are such that only one product system is examined it is necessary to decide as to how the possible environmental benefits and loads of the polymer material recovery and recycling shall be allocated (i.e. accounted) to the respective system.
- Important: The mass balance of all inputs and outputs of system A and system B after allocation must be the same as the inputs and outputs calculated for the sum of systems A and B before allocation is performed.

Allocation methods (2/3)

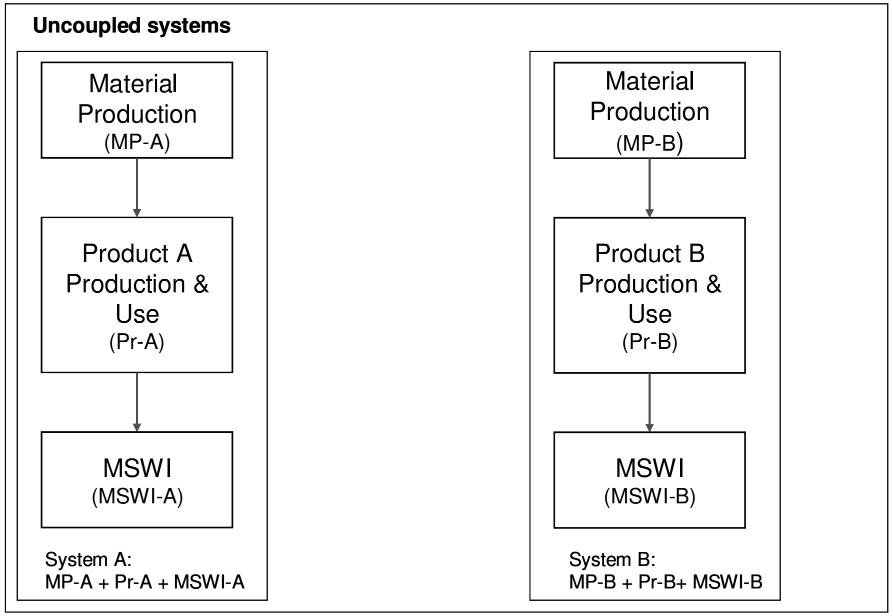
50% allocation method

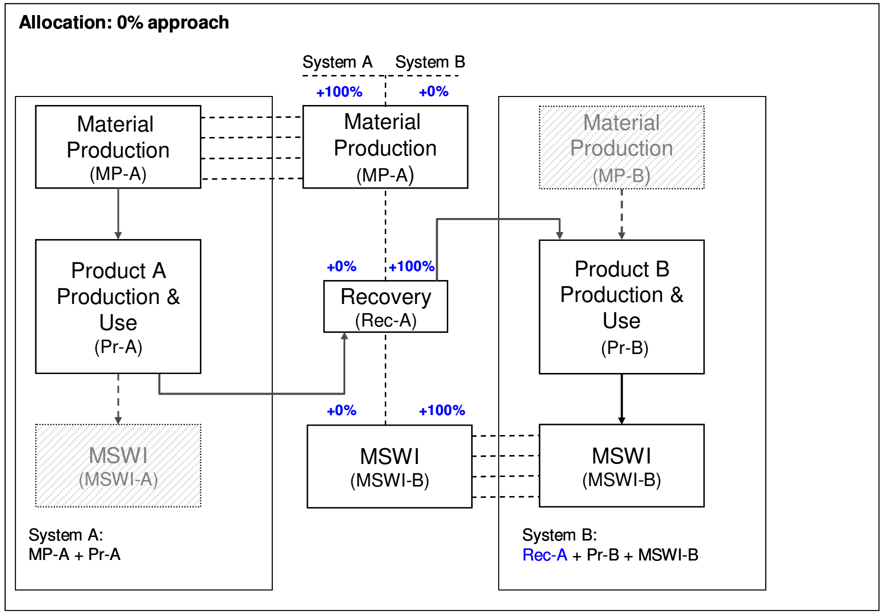
- in this method, benefits and loads of „PP-B“, „Rec“ and „MSWI-A“ are equally shared between system A and B. Thus, system A, from its viewpoint, receives a 50% credit.
- this method has been used for the base scenarios of the PCR bag, the PCR / LDPE bag and the PCR / LDPE / chalk bag

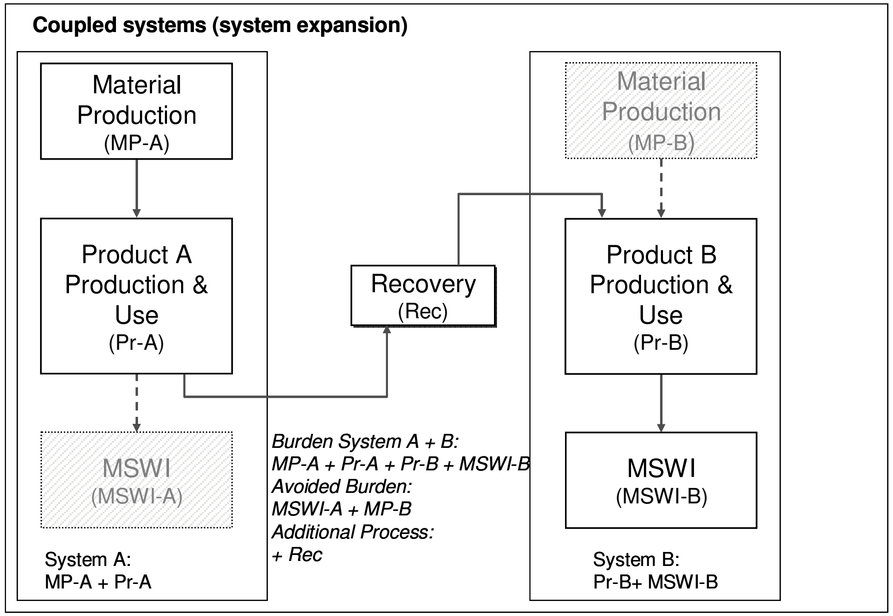
0% allocation method

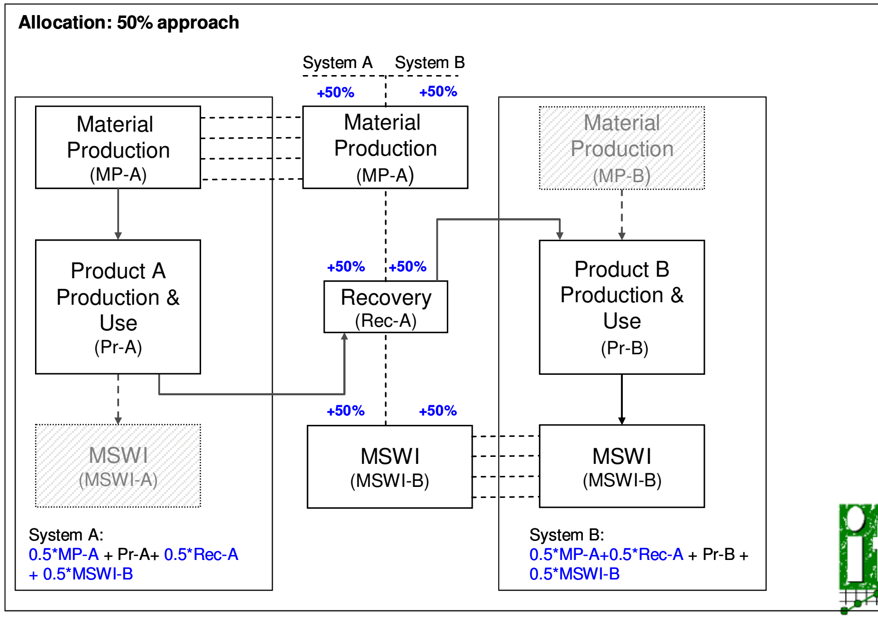
- the assessment of material flows ends with the recovery of post-consumer waste
- recyclates are not dealt with as co-products
- the benefits of „PP-B“ are completely assigned to system B
- the loads of „Rec“ and „MSWI-A“ are completely assigned to system B
- this method has been used for the sensitivity analysis of the PCR bag, the PCR / LDPE bag and the PCR / LDPE / chalk bag

Allocation methods (3/3)









Inventory and process datasets (1/2)

Material / process step	Source (Reference Period)
Polyethylene	
LDPE	Plastics Europe 2005 (1999)
LLDPE	Plastics Europe 2005 (1999)
HDPE	Plastics Europe 2005 (1999)
Polyesters	
PLA (Ingeo™)	NatureWorks (2009)
Ecoflex®*	BASF (2008)
Minerals	
$CaCO_3$	Ecoinvent V2.0 (2005)
CaO	Ecoinvent V2.0 (2005)
Starches	
potato starch	IFEU database, based on [Loose-Fill 2002] (2001/2005)
Bioplastics compounding	
Biopar®*	BIOP (composition and compounding) (2008)
Ecovio®*	composition data: BASF, compounding: IFEU (2005-2008)
Converting (pellets to bags)	
extrusion	CeDo (2007), data collected at CeDo production sites
finishing	CeDo (2007) , data collected at CeDo production sites

**** BASF recommends the usage of Ecoflex /Ecovio only for compost bags but not for refuse bags***

Inventory and process datasets (2/2)

Material / process step	Source (Reference Period)
Recovery	
PE film recycling	IFEU database, data collected at CeDo production site (2007)
End-Of-Life processes	
Landfilling	IFEU database, based on statistics and landfillmodels (2005)
Municipal waste incinceration	IFEU database, based on statistics and incinerator plant models (2005)
Background data	
Electricity generation, Poland	IFEU database, based on statistics and power plant models (2004)
Electricity generation, China	IFEU database, based on statistics and power plant models (2004)
Electricity generation, Italy	IFEU database, based on statistics and power plant models (2004)
Electricity generation, Netherlands	IFEU database, based on statistics and power plant models (2004)
Lorry transport	IFEU database, based on statistics and transport models (2005)

Specification of 20 L waste bags (German market)

20 L	PE bags			Biobag	Biobag variants [1]			
specifications	**HDPE bag**	**HDPE bag**	**LLDPE bag**	**Biopar 25 bag***	**Biopar 15 bag***	**Biopar 25 bag*** (Ecoflex NG)	**Biopar 15 bag*** (Ecoflex NG)	**Ecovio bag***
type	flush top	tie handle	flush top	flush top	flush top	flush top	flush top	flush top
source	Poland	China	Poland	Poland	Poland	Poland	Poland	Poland
volume	20 L	20 L	20 L	20 L	20 L	20 L	20 L	20 L
composition								
HDPE	93 %	100 %						
LDPE	7 %		11.5 %					
LLDPE			88.5 %					
Biopar*				100 %	100 %			
Biopar* (Ecoflex* NG)						100 %	100 %	
Ecovio*								100 %
weight per bag	6.45 g	6.92 g	9.99 g	17.69 g	10.61 g	17.69 g	10.61 g	11.50 g
thickness	12.5 µm	12.5 µm	20 µm	25 µm	15 µm	25 µm	15 µm	15 µm

[1] currently not sold on the German market

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Specification of 120 L waste bags (German market)

120 L bags: specifications	PCR bag	LLDPE bag
type	flush top	flush top
source	Poland	Poland
volume	120 L	120 L
composition		
LDPE	0.7 %	
LLDPE		100 %
PCR	98 %	
lime (CaO)	1.3 %	
weight per bag	57.60 g	56.98 g
thickness	40 µm	40 µm

Specification of 30 L waste bags (French market)

30 L bags	PE bags				Biobag
Group 3 specifications	**HDPE bag**	**LLDPE bag**	**PCR / LDPE bag**	**PCR / LDPE /chalk bag**	**Biopar* bag**
type	flush top	flush top	flush top	flush top	flush top
source	China	Poland	Poland	Poland	Poland
volume	30 L	30 L	30 L	30 L	30 L
composition					
HDPE	100 %				
LDPE		11.5 %	40 %	20 %	
LLDPE		88.5 %			
PCR			50 %	60 %	
RG			10 %		
chalk compound ($CaCO_3$)				20 %	
Biopar*					100 %
Ecovio*					
weight per bag	10.13 g	13.08 g	16.46 g	19.55 g	20.38 g
thickness	15 µm	20 µm	25 µm	25 µm	22 µm

***** BASF recommends the usage of Ecoflex /Ecovio only for compost bags but not for refuse bags***

Scenarios studied: residual waste collection

- 11 scenarios with focus on the German market (20 L and 120 L bags; End-of-life: incineration)

- 20 L base scenarios: PE bags and biobag
  (scenario overview: slide 17)
- 20 L variation scenarios: biobag variants
  (scenario overview: slide 19)
- 120 L base scenarios: LLDPE bag and PCR bag (post consumer recyclate bag, allocation factor 50%)
  (scenario overview: slide 20)
- 120 L sensitivity scenario: PCR, allocation factor 0%
  (scenario overview: slide 20)

- 7 scenarios with focus on the French market (30 L bags; End-of-life: incineration/landfill)

- Base scenarios: PE bags and PCR bags (allocation factor 50%); Biobag
  (scenario overview: slide 21)
- Allocation sensitivity scenarios: PCR bags (allocation factor 0%)
  (scenario overview: slide 21)

Scenarios: 20 L residual waste collection (German market)

- Base scenarios

Scenario shortname	Bag size & type	Weight	Film thickness	Converting site	End of Life
HDPE Poland, MSWI	20 L flush-top HDPE bag	6.45 g	12.5 µm	Poland	incineration
HDPE China, MSWI	20 L tie-handle HDPE bag	6.92 g	12.5 µm	China	incineration
LLDPE Poland, MSWI	20 L flush-top LLDPE bag	9.99 g	20 µm	Poland	incineration
Biopar* Poland, MSWI	20 L flush-top Biopar bag	17.69 g	25 µm	Poland	incineration

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Scenarios studied: residual waste collection

Four biobag variant scenarios are examined

- Biopar 15 Poland, MSWI:
  a Biopar bag with a potential future thickness of 15 µm
- Biopar 25 (Ecoflex NG*) Poland, MSWI:
  a Biopar bag with the consideration of Ecoflex NG* available in the second half of 2009
- Biopar 15 (Ecoflex NG*) Poland, MSWI:
  a Biopar bag combining the new two features of the preceding scenarios
- Ecovio* Poland, MSWI:
  a biobag made from Ecovio*, a bioplastic already available but not used for waste bags so far

***** BASF recommends the usage of Ecoflex /Ecovio only for compost bags but not for refuse bags***

Scenarios: 20 L residual waste collection (German market)

- Biobag variant scenarios

Scenario Category	Scenario shortname	Bag size & type	Weight	Film thickness	Converting site	End of Life
Biopar* variation: reduced film thickness	**Biopar 15 Poland, MSWI**	20 L flush-top Biopar bag	10.61 g	15 µm	Poland	incineration
Biopar variation: Ecoflex* production ("New Generation")	**Biopar 25 (Ecoflex NG*) Poland, MSWI**	20 L flush-top Biopar bag	17.69 g	25 µm	Poland	incineration
Biopar combined variation: - Film thickness; and - Ecoflex* production ("New Generation")	**Biopar 15 (Ecoflex NG*) Poland, MSWI**	20 L flush-top Biopar bag	10.61 g	15 µm	Poland	incineration
Material: Ecovio* (currently not on the market as waste bag)	**Ecovio* Poland, MSWI**	20 L flush-top Ecovio* bag	11.50 g	15 µm	Poland	incineration

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Scenarios: 120 L residual waste collection (German market)

Scenario Category	Scenario shortname	Bag size & type	Allo-cation	Weight	Film thickness	Converting site	End of Life
Base	**PCR Poland MSWI 50% Alloc**	120 L flush-top PCR bag	50%	57.60 g	40 µm	Poland	incineration
Sensitivity: allocation factor	**PCR Poland MSWI 0% Alloc**	120 L flush-top PCR bag	0%	57.60 g	40 µm	Poland	incineration
Base	**LLDPE Poland MSWI**	120 L flush-top LLDPE bag	-	56. 98 g	40 µm	Poland	incineration

Scenarios: 30 L residual waste collection (French market)

Scenario Category	Scenario shortname	Bag size & type	Allo-cation	Weight	Film thickness	Converting site	End of Life
Base	**HDPE China MSWI/landfill**	30 L flush-top HDPE bag	-	10.13 g	15 µm	China	incineration / landfill
Base	**LLDPE Poland MSWI/landfill**	30 L flush-top LLDPE bag	-	13.08 g	20 µm	Poland	incineration / landfill
Base	**PCR / LDPE Poland MSWI/landfill**	30 L flush-top PCR / LDPE bag	50%	16.46 g	25 µm	Poland	incineration / landfill
Sensitivity: allocation factor	**PCR / LDPE Poland MSWI/landfill**	30 L flush-top PCR / LDPE bag	0%	16.46 g	25 µm	Poland	incineration / landfill
Base	**PCR / LDPE / chalk Poland MSWI/landfill**	30 L flush-top PCR /LDPE / chalk bag	50%	19.55 g	25 µm	Poland	incineration / landfill
Sensitivity: allocation factor	**PCR / LDPE / chalk Poland MSWI/landfill**	30 L flush-top PCR /LDPE / chalk bag	0%	19.55 g	25 µm	Poland	incineration / landfill
Base	**Biopar* Poland MSWI/landfill**	30 L flush-top Biopar* bag	-	20.38 g	22 µm	Poland	incineration / landfill

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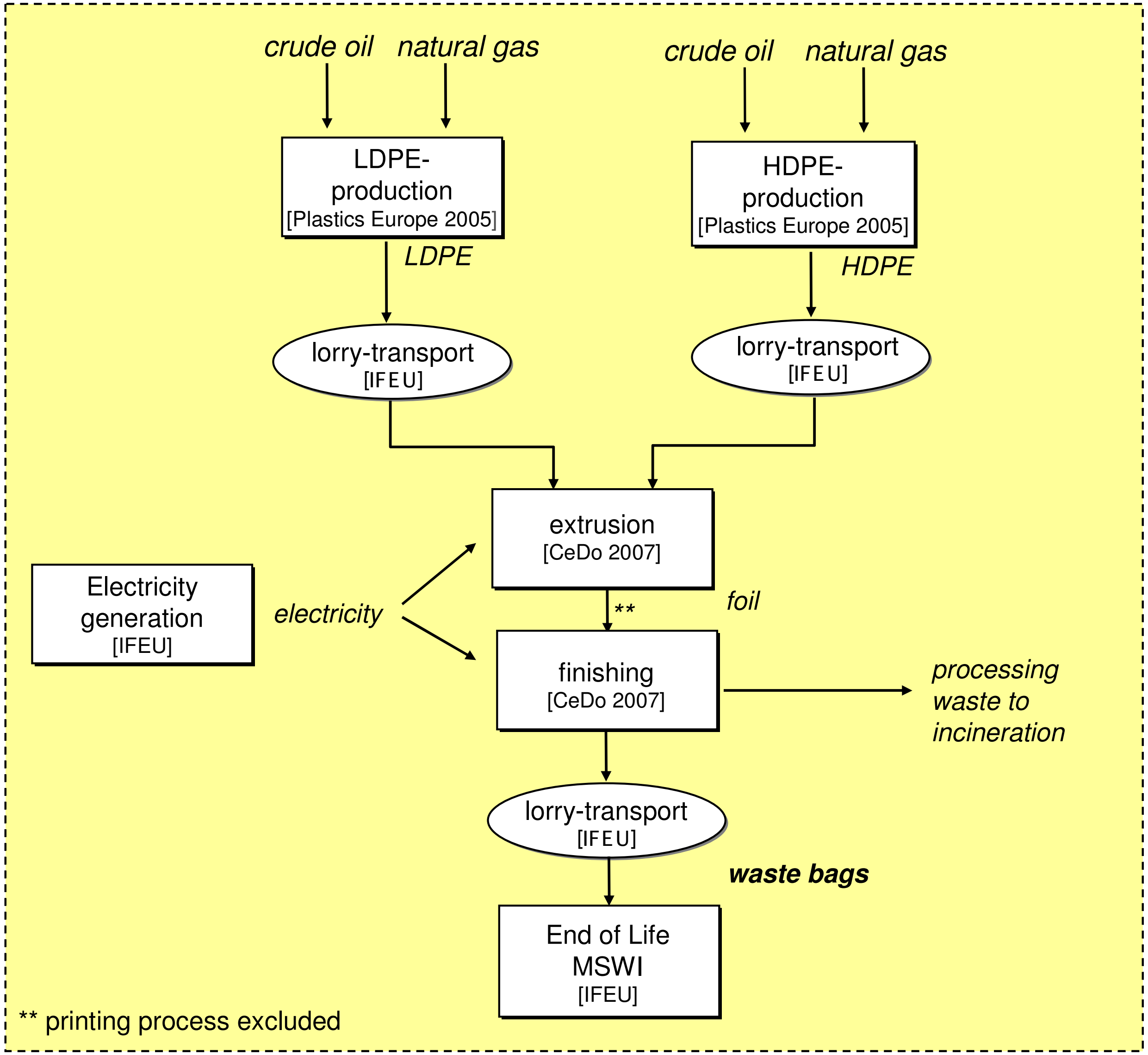
Implementation

- For the implementation of the system models the computer tool Umberto® (version 5.5) was used. Umberto® is a standard software for mass flow modelling and LCA.

- All system models and the related module processes were implemented into mass-flow scenarios. Calculation of input/output balances was scaled to the defined functional flow. Input/output balances are composed of elementary and non-elementary flows. Elementary flows are materials or energy entering the system being studied, which have been drawn from the environment without previous human transformation or materials and energy respectively leaving the system, which are discarded into the environment without subsequent human transformation. The materials listed in the input/output balances are compiled into environmental profiles.

The following graphs show the main material flows within a system as a simplified flow chart.

System boundaries (1/2)



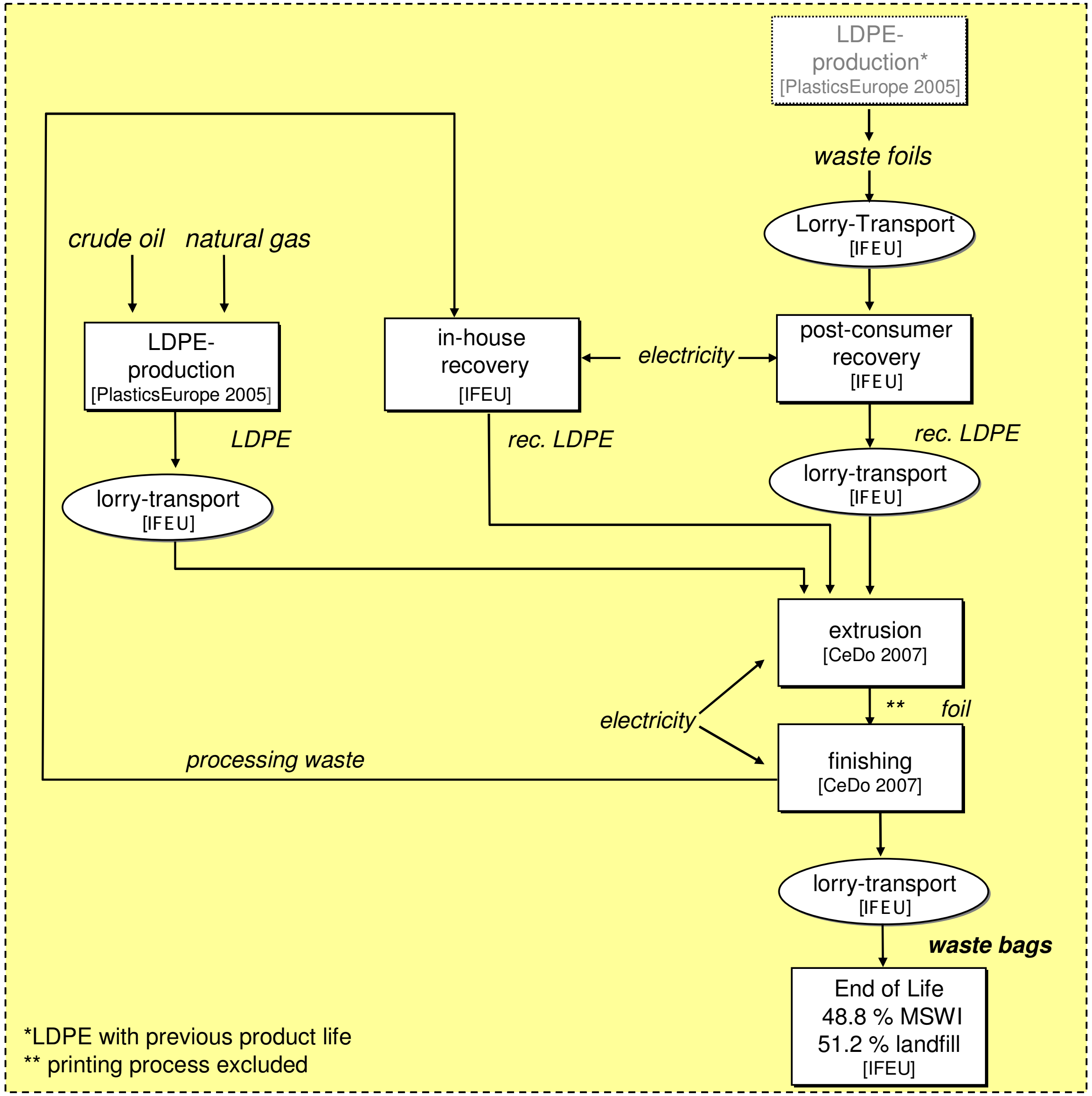
Waste Bags from virgin petrochemical plastics (example: **HDPE bag; 20 L flush-top**):
Flow chart and data sources.

<u>Data Sources:</u>
[CeDo] Data provided by CeDo 2007 this refers to information on energy consumption, supply transport distances and transport means

[Plastics Europe 2005]: Ecoprofiles of Low-Density Polyethylene and High-Density Polyethylene, last calculated March 2005; www.plasticseurope.com

[IFEU]: Datasets and emission factors taken from IFEU's internal database

System boundaries (2/2)



Waste Bags from plastics waste (example: **PCR / LDPE / RG bag; 30 L flush-top**)
Flow chart and data sources.

<u>Data Sources:</u>
[CeDo] Data provided by CeDo 2007 this refers to information on energy consumption, supply transport distances and transport means

[Plastics Europe 2005]: Ecoprofile of Low-Density Polyethylene, last calculated March 2005; www.plasticseurope.com

[IFEU]: Datasets and emission factors taken from IFEU's internal database

Environmental indicators overview

Resource-related categories		Indicator
Fossil resource consumption	⇨	Crude Oil Equivalents

Emission-related categories		Indicator
Climate Change	⇨	CO2-Equivalents
Acidification	⇨	SO2-Equivalents
Eutrophication, terrestrial	⇨	PO4-Equivalents
Eutrophication, aquatic	⇨	PO4-Equivalents
Summer Smog	⇨	C2H4-Equivalents (POCP)
Human Toxicity*	⇨	PM10-Equivalents
Human Toxicity*	⇨	Carcinogenic Risk

Inventory level categories		Indicator
Non-renewable primary energy	⇨	GJ
Total primary energy	⇨	GJ
Land use: Farm land	⇨	m2/year

**Indicator results for Human Toxicity are only presented in an appendix of the full report*

Environmental impact assessment (1/4)

A set of environmental impact categories has been used to asses the environmental performance of the examined packaging systems. These indicators stand for environmental issues generally perceived to be relevant. They are also widely used in LCA practice across Europe. They are listed and shortly addressed below.

Categories related to resources

- **Fossil Resource Consumption** (restricted to the consumption of energy resources)
  This category refers to the depletion of fossil energy resources. The resources are aggregated using individual scarcity factors.

Environmental impact assessment (2/4)

Categories related to emissions

- **Climate Change** (“Global Warming”)
  Climate Change is the impact of emissions from human activities on the radiative forcing of the atmosphere. Greenhouse gas emissions enhance the radiative forcing, resulting in an increase of the earth’s temperature. The characterisation factor applied here is the Global Warming potential for a 100 year time horizon.

- **Photo-Oxidant Formation** (“Summer Smog”)
  Photo-oxidant Formation is the photochemical creation of reactive substances (mainly ozone) which affect human health and ecosystems. This ground-level ozone is formed in the atmosphere by nitrogen oxides and volatile organic compounds in the presence of sunlight. Another name for this problem is “summer smog”. The characterisation factor applied here is Photochemical Ozone Creation Potential (POCP)

- **Acidification**
  Acidification affects aquatic and terrestrial eco-systems by changing the acid-basic-equilibrium through the input of acid building substances. The acidification potential is applied here as characterisation factor.

Environmental impact assessment (3/4)

Eutrophication

Eutrophication includes all impacts due to excessive levels of macro-nutrients in ecosystems. Compounds containing nitrogen and phosphorus are among the most eutrophicating elements. Here, eutrophication is differentiated by its target media:

- ***Terrestrial Eutrophication*** (i.e. nutrification of soils by atmospheric emissions)

- ***Aquatic Eutrophication*** (i.e. nutrification of water bodies by effluent releases)

The eutrophication potential of emissions to air and to water is applied here as characterisation factor.

Environmental impact assessment (4/4)

Inventory information

- **Non-renewable primary energy**
  This indicator is calculated by adding the energy content of all used fossil fuels and nuclear energy. It is a measure for the overall energy efficiency of a system, confined to non-renewable energy. In addition, it does consider resources without the scarcity aspect which is included in the impact category Fossil Resources.

- **Total primary energy**
  This indicator is calculated by adding the energy content of all used fossil fuels, nuclear and renewable energy (including biomass). This indicator is a measure for the overall energy efficiency of a system, regardless of the type of energy resource which is used. In addition, it does consider resources without the scarcity aspect which is included in the impact category Fossil Resources.

- **Land use: Farm land**
  Regarding the assessment of land use several methodological approaches have emerged in recent years. The method developed by IFEU is based on an ordinal scale of seven area classes of proximity-to-nature
  For the purpose of this study a simplified approach was used, considering only the use of ***Farm land*** (area classes 5&6).

Life cycle steps (1/2)

LCA results are presented in this section in graphical format as bar charts (one for each impact category or additional indicator at the inventory level) which are broken down to individual life cycle steps, so-called sectors, which are:

- the production of HDPE, LDPE, LLDPE and Biopar (“**Polymer raw materials**”)
- the environmental burden of waste foils (“**Env. Burden of waste foils**”)
- the production of additives and mineral components like CaCO3 (“**Additives and mineral components**”)
- the transport of raw materials (“**Transport of raw materials**”)
- the transport of waste foils to recycling (“**Transport of waste foils to recycling**”)
- the recycling of PC waste foils to PCR (“**Recycling of PC waste foils to PCR**”)
- the production of waste bags and in-house recycling of waste foils (“**Converting (incl. in-house recycling)**”)
- the retail of the waste bags from the production site to the point-of-sale (“**Transport to point-of-sale**”)
- the waste collection and treatment (“**Waste collection + treatment**)

Life cycle steps (2/2)

Secondary products (e.g. recovered energy) are obtained through waste treament processes of used waste bags. It is assumed that those secondary materials are used by a subsequent system. In order to consider this effect in the LCA, the environmental impacts of the waste bag system under investigation are reduced by means of credits based on the environmental loads of the substituted energy.

The credits are shown in form of separate bars in the LCA result graphs. They have been broken down into:

- Credit for the replacement of peat or fertilizer (**"credits for composting"**)
- Credit for energy recovery from landfill or incineration plants (replacing e.g. grid electricity) (**"credits energy")**

Each impact category graph shows 3 bars for each one of the packaging systems under investigation, namely the following (as seen from left to right):

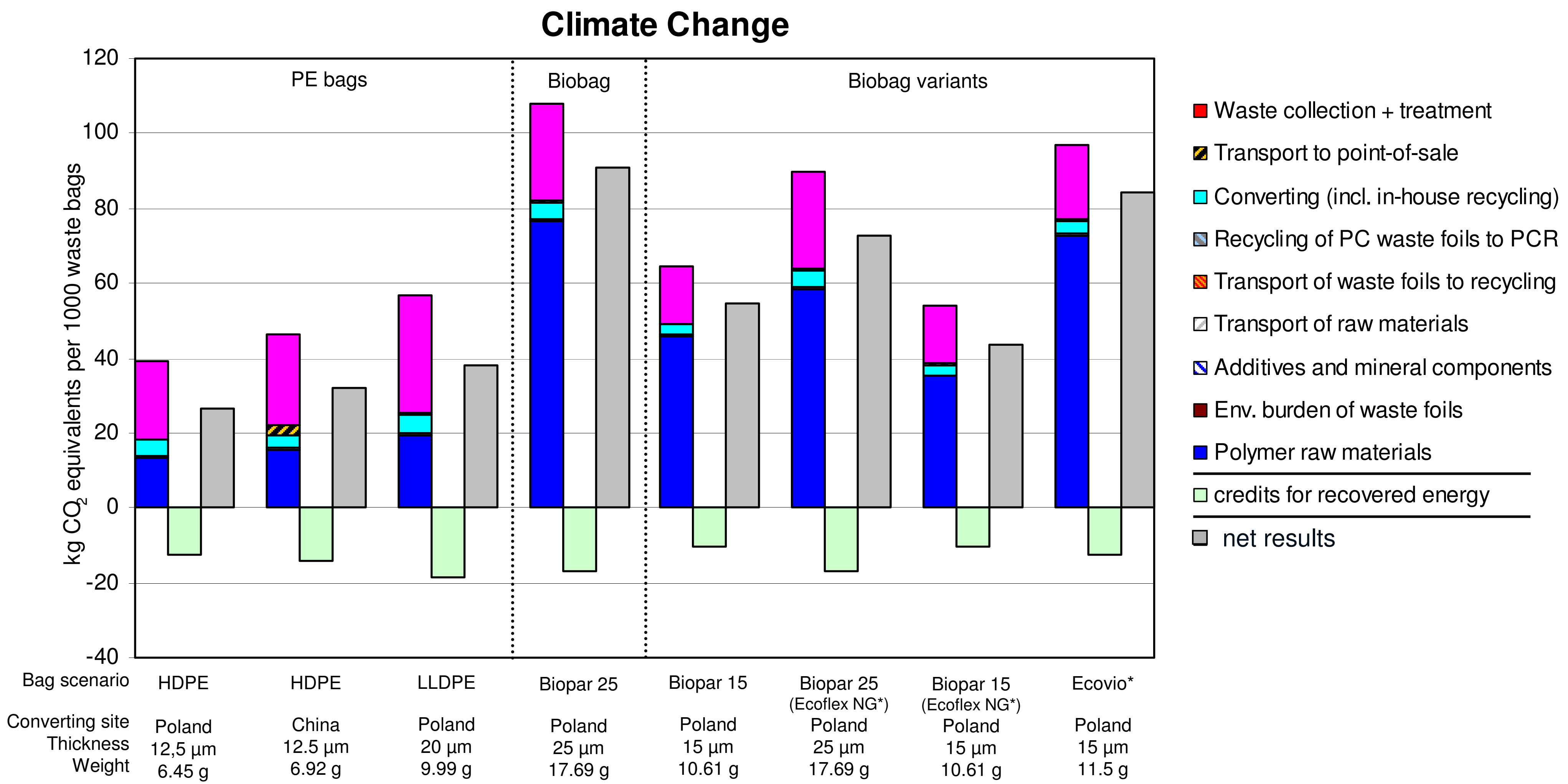
- sectoral results of the waste bag system itself (stacked bar) **"system results"**
- credits given for secondary products leaving the system (negative stacked bar) **"credits"**
- net results (grey bar) as a result of the subtraction of credits from overall environmental loads **"net results"**

Presentation of results:

20 L residual waste collection

(German market)

Results: 20 L residual waste (German market)



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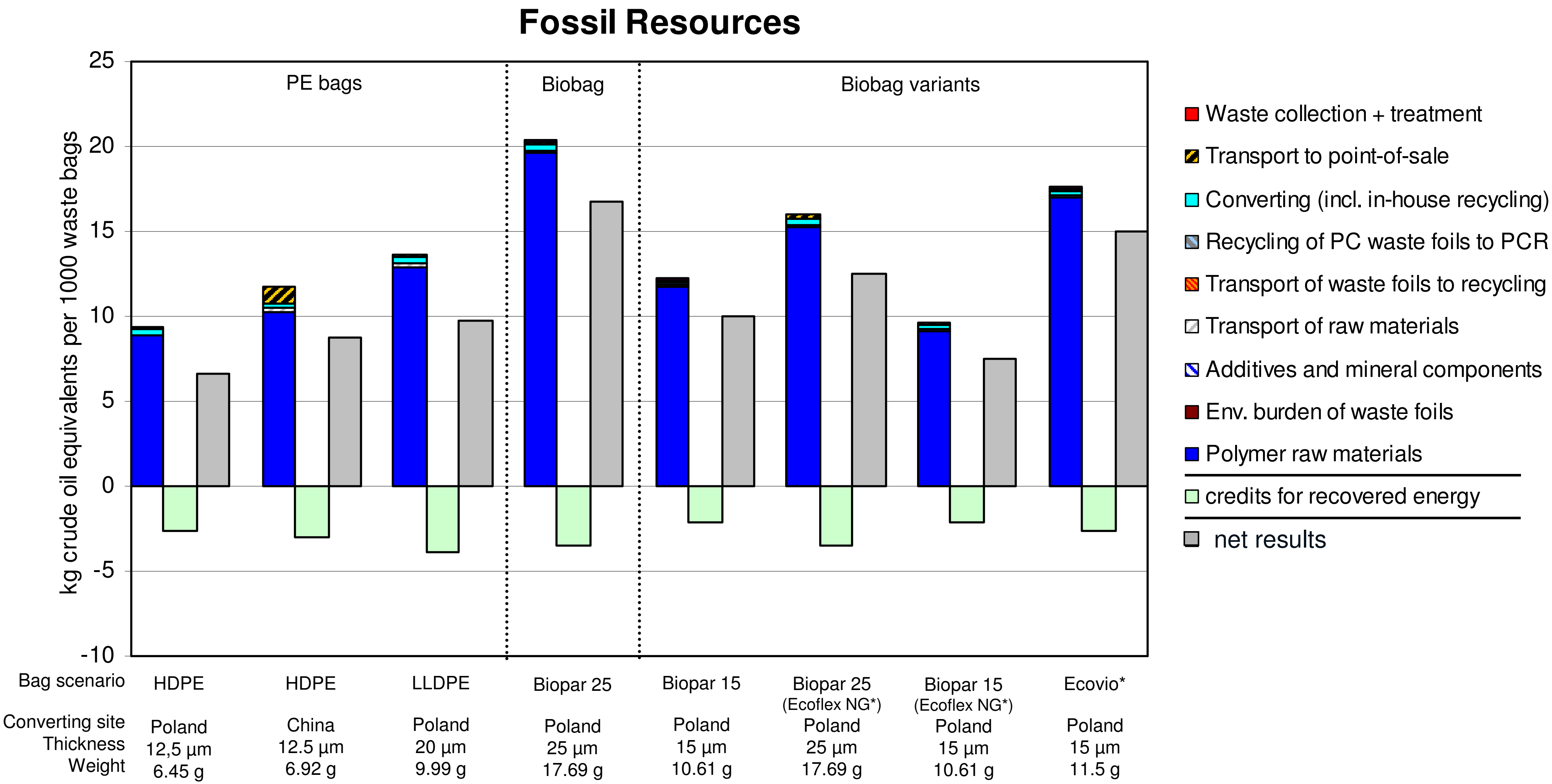

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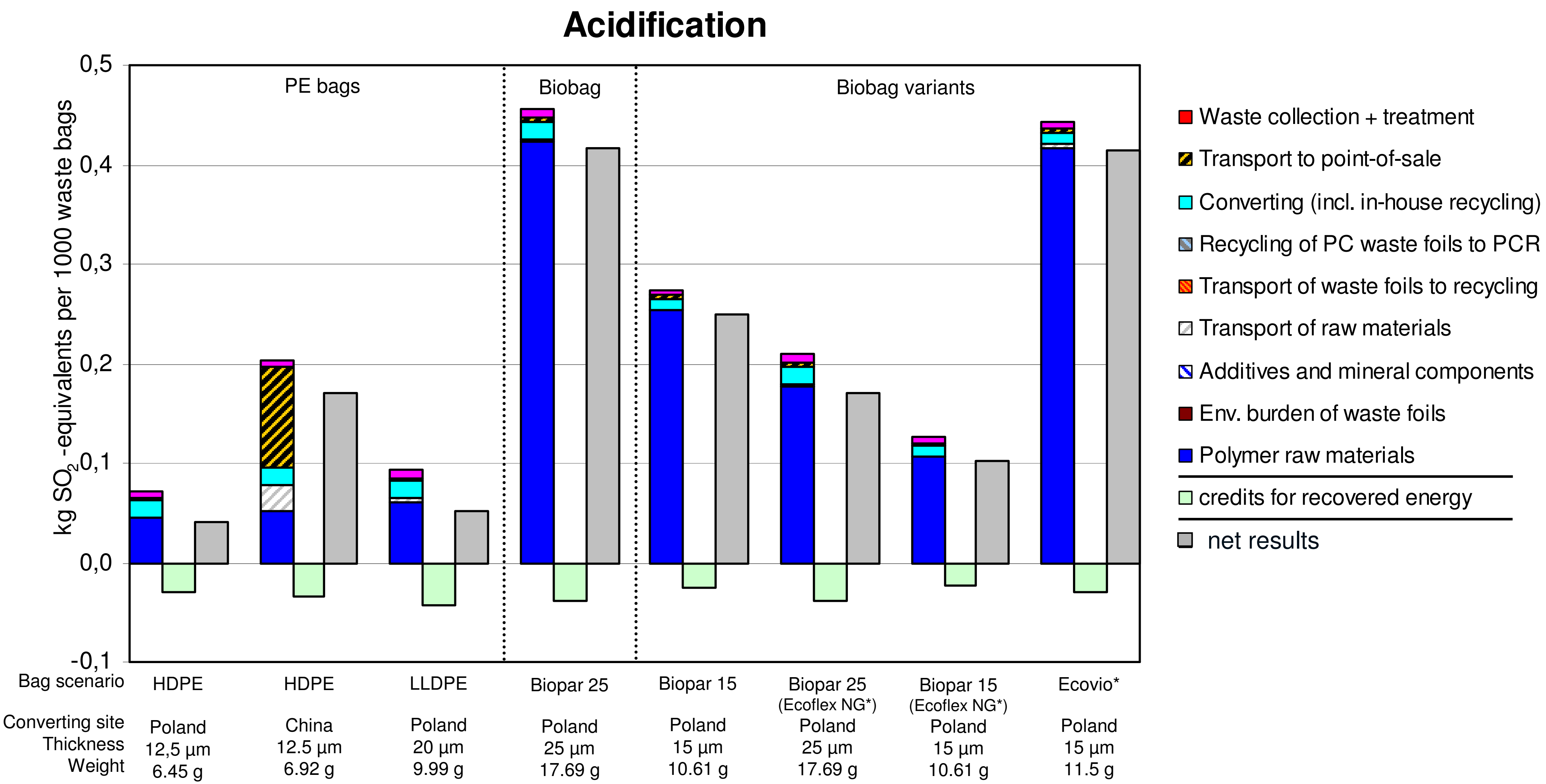

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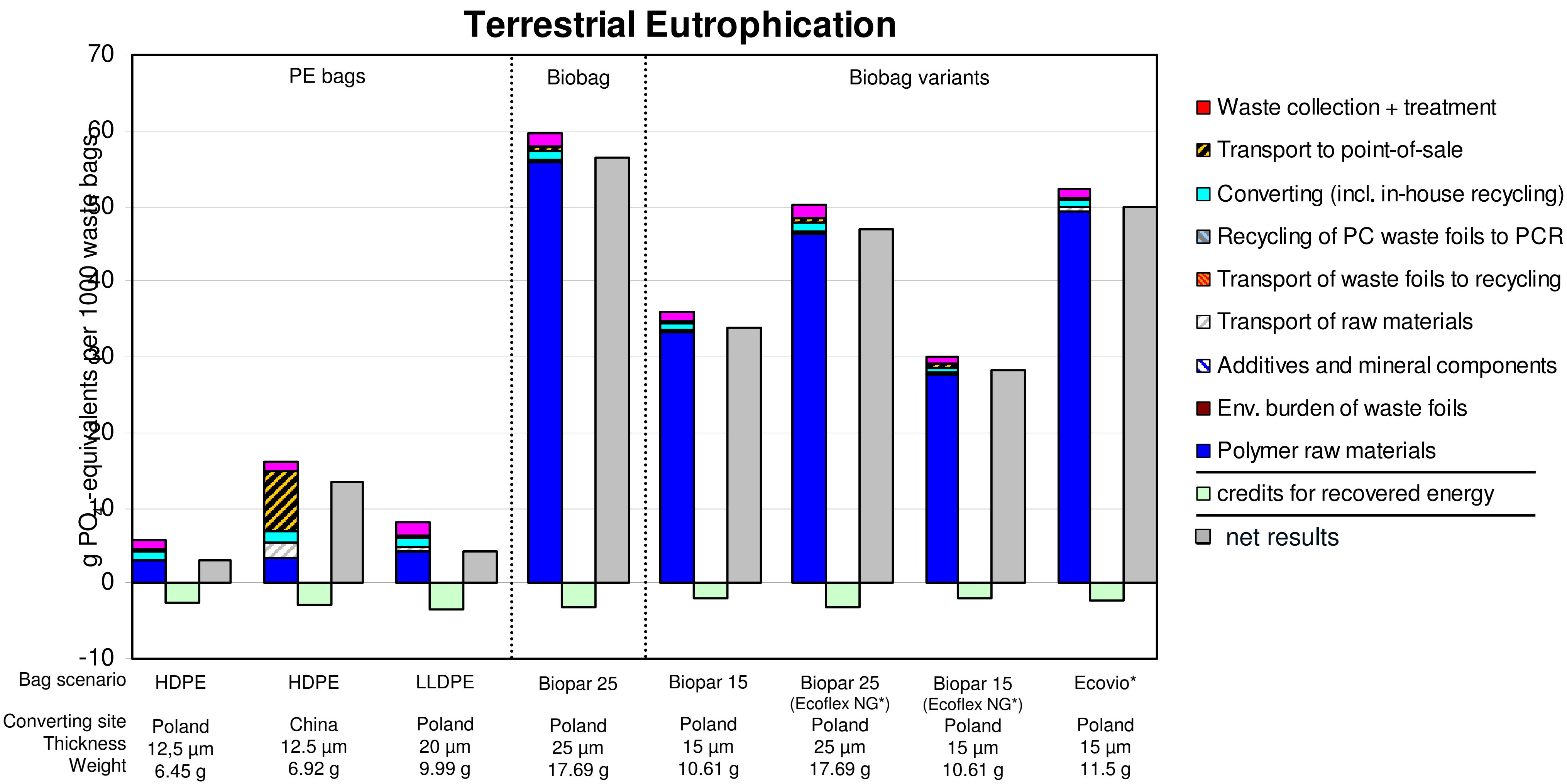

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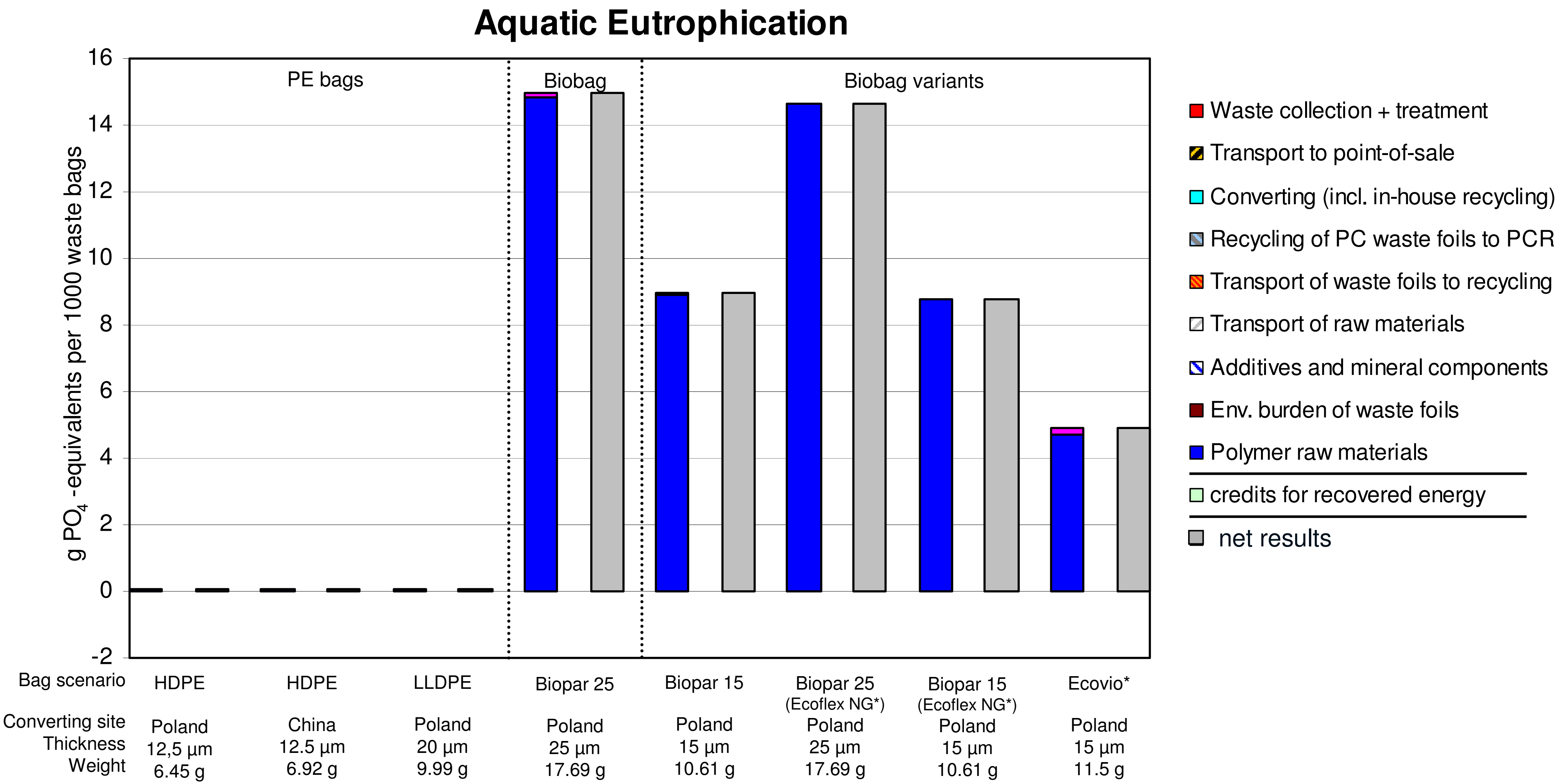

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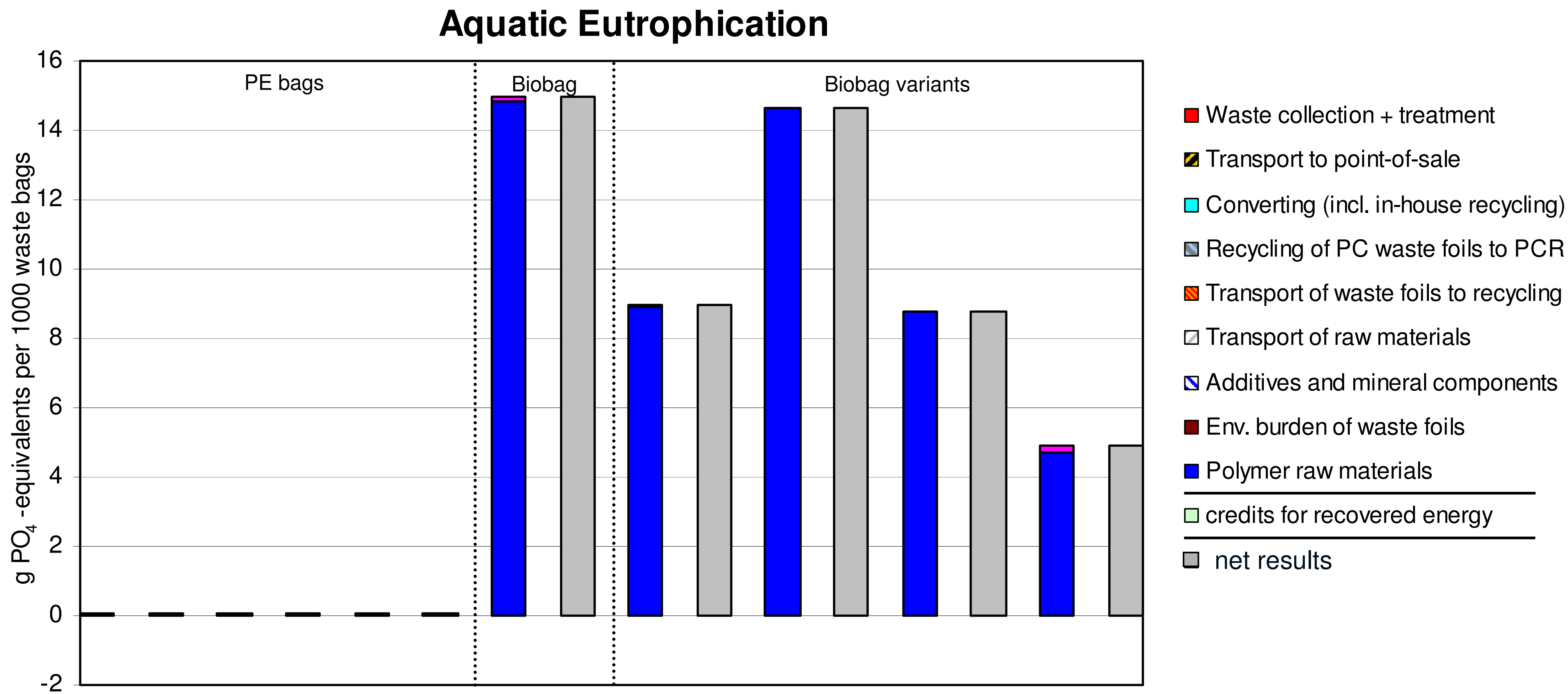

Bag scenario	HDPE	HDPE	LLDPE	Biopar 25	Biopar 15	Biopar 25 (Ecoflex NG*)	Biopar 15 (Ecoflex NG*)	Ecovio*
Converting site	Poland	China	Poland	Poland	Poland	Poland	Poland	Poland
Thickness	12,5 µm	12.5 µm	20 µm	25 µm	15 µm	25 µm	15 µm	15 µm
Weight	6.45 g	6.92 g	9.99 g	17.69 g	10.61 g	17.69 g	10.61 g	11.5 g

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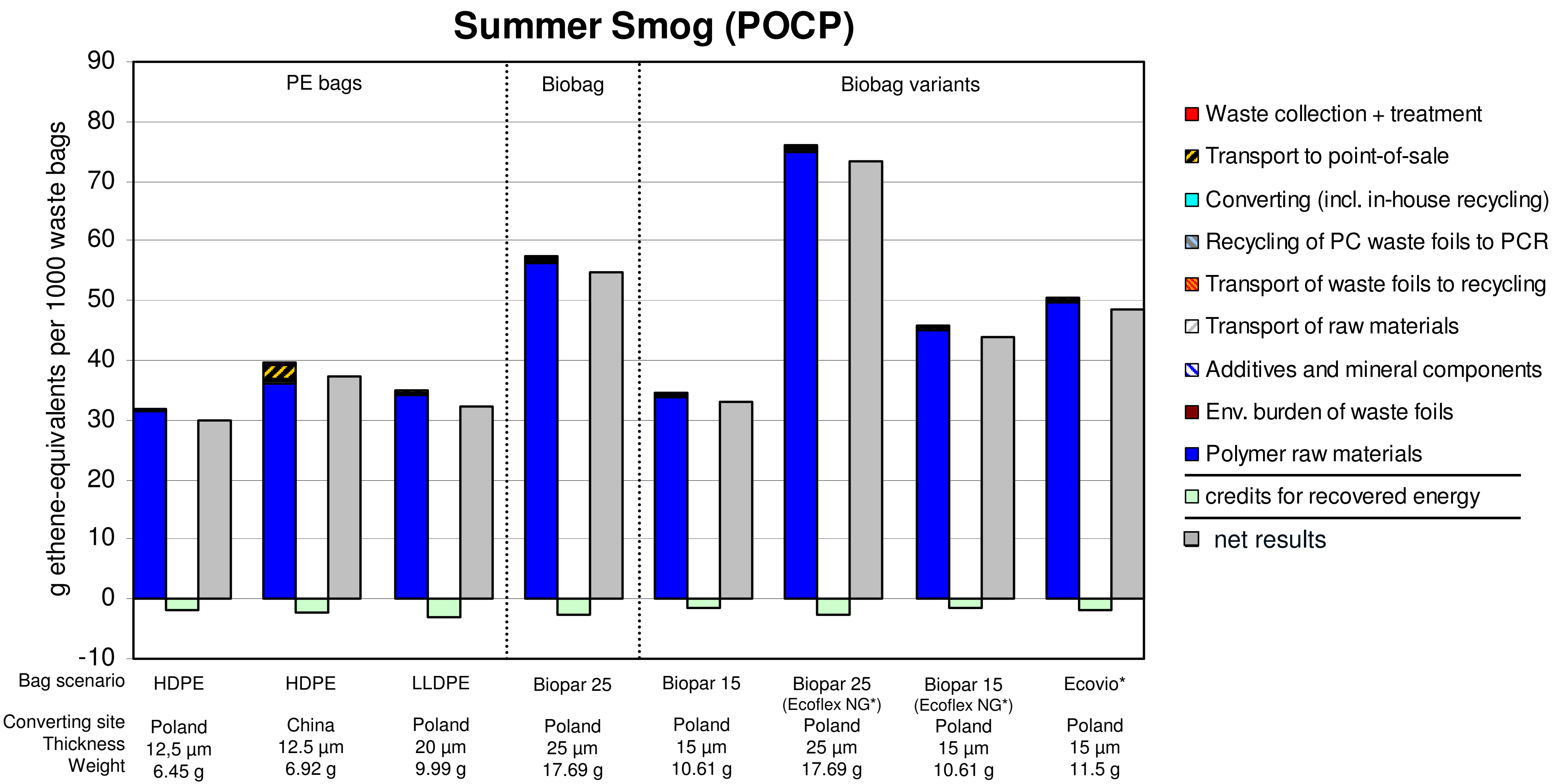

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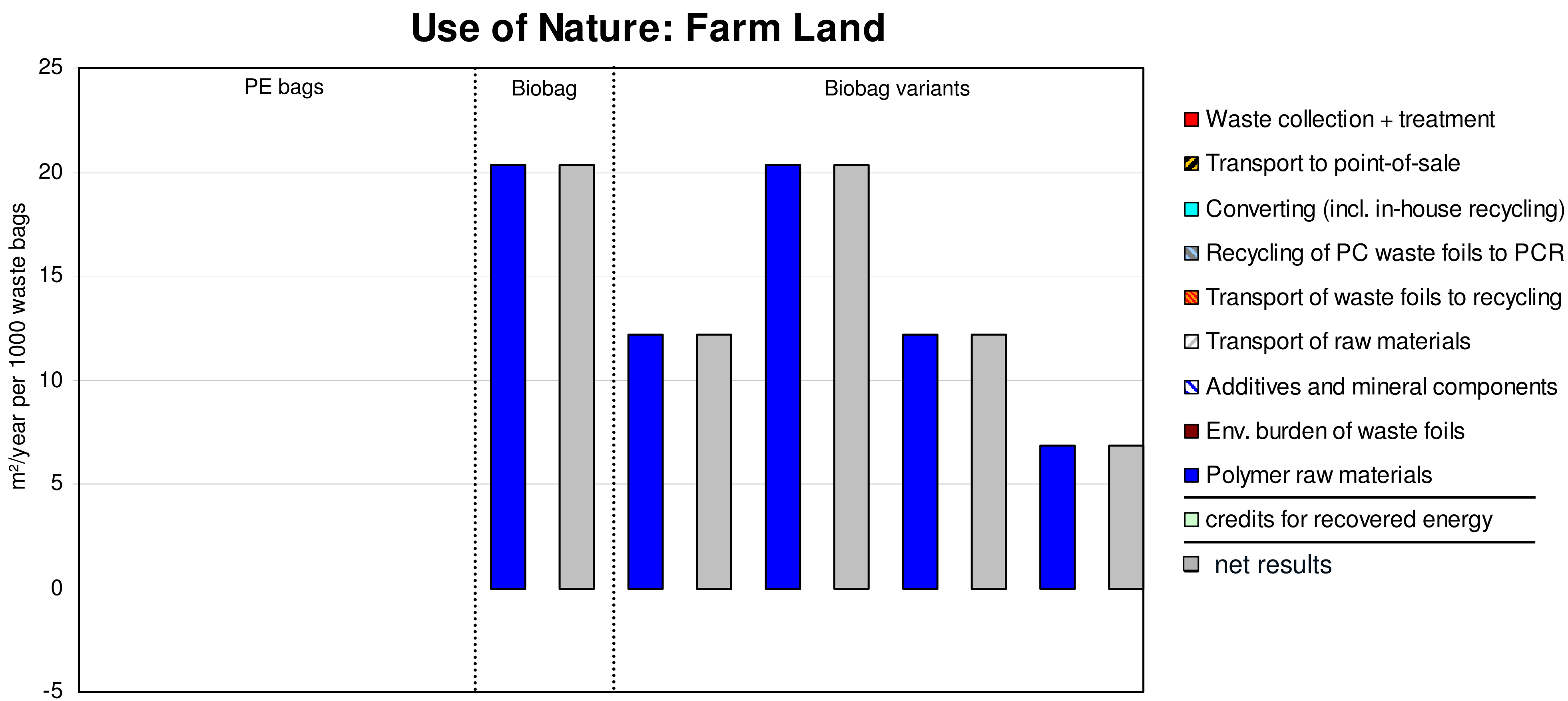
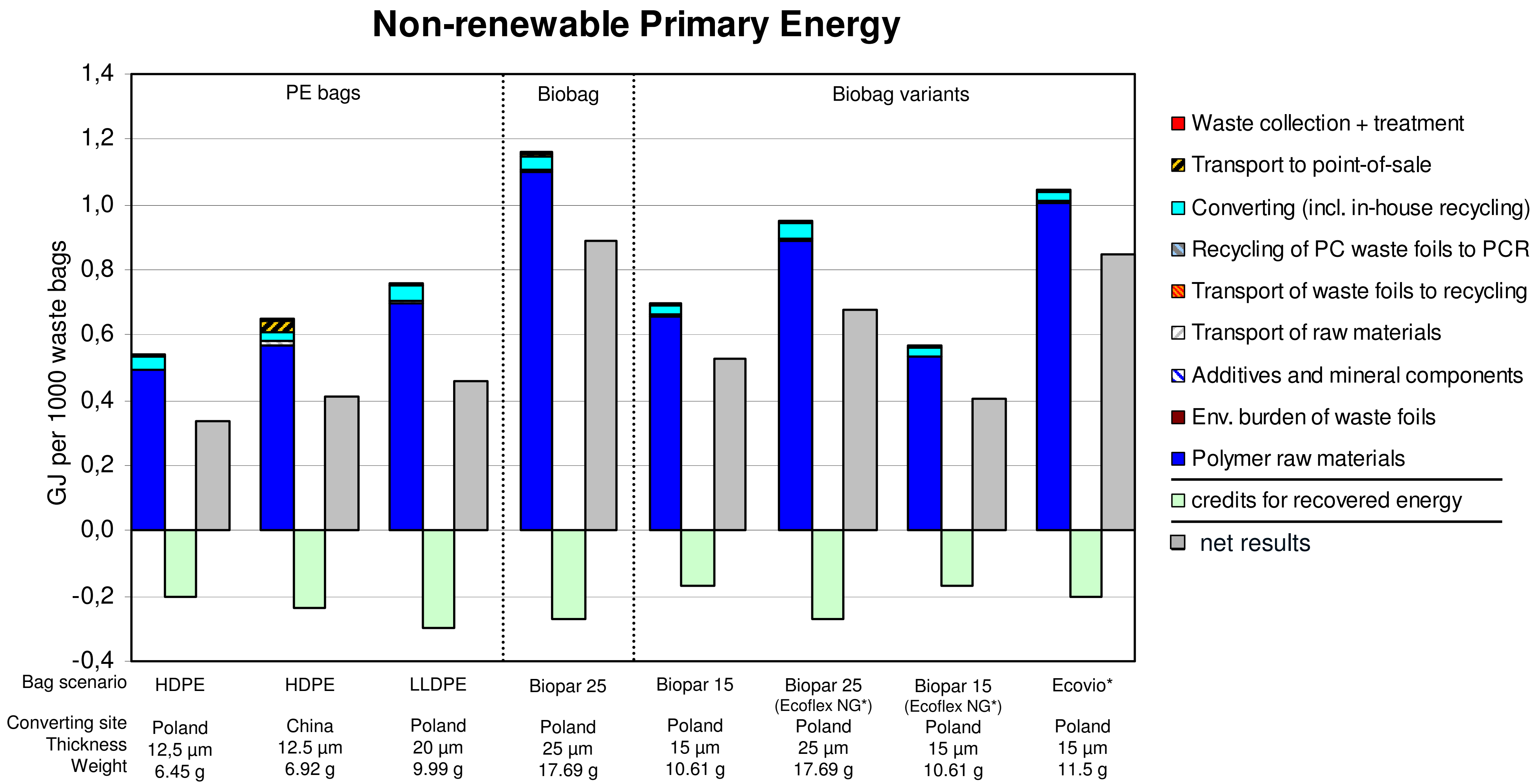
Results: 20 L residual waste (German market)



Bag scenario	HDPE	HDPE	LLDPE	Biopar 25	Biopar 15	Biopar 25 (Ecoflex NG*)	Biopar 15 (Ecoflex NG*)	Ecovio*
Converting site	Poland	China	Poland	Poland	Poland	Poland	Poland	Poland
Thickness	12,5 µm	12.5 µm	20 µm	25 µm	15 µm	25 µm	15 µm	15 µm
Weight	6.45 g	6.92 g	9.99 g	17.69 g	10.61 g	17.69 g	10.61 g	11.5 g

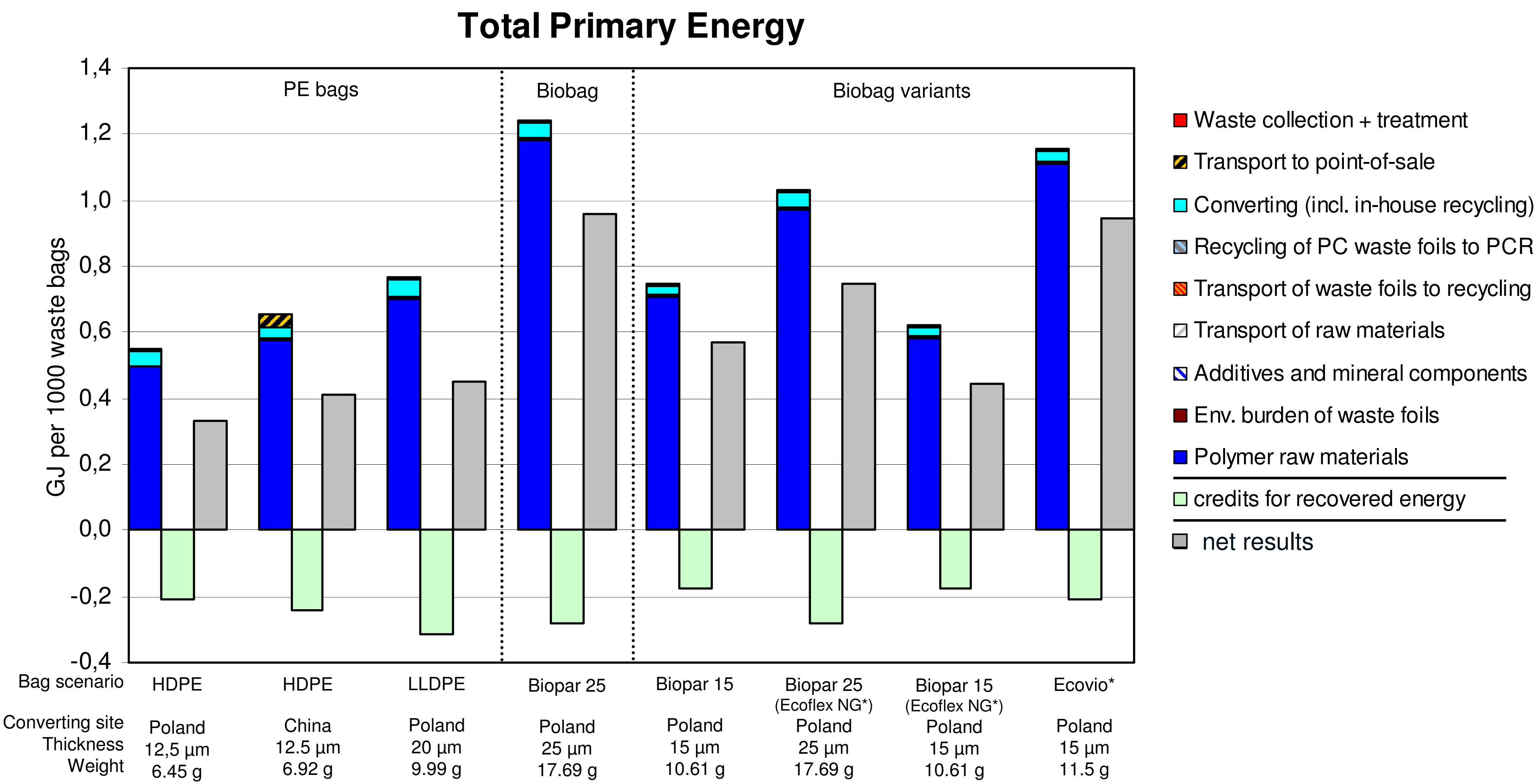
**** BASF recommends the usage of Ecoflex /Ecovio only for compost bags but not for refuse bags***

Results: 20 L residual waste (German market)



**** BASF recommends the usage of Ecoflex /Ecovio only for compost bags but not for refuse bags***

Results: 20 L residual waste (German market)



**** BASF recommends the usage of Ecoflex /Ecovio only for compost bags but not for refuse bags***

Findings: 20 L residual waste collection (1/2)

Environmental performance of traditional waste bags from PE

- The largest contributions to the environmental burden of the PE bag systems come from the production of the virgin PE polymers
- The HDPE bag (produced in Poland) shows the smallest environmental indicator results
- On the other hand, if produced in China they have the largest indicator results of all PE bags for Acidification and *Terrestrial Eutrophication* due to the overseas transport
- Overall, PE bags have a more favourable environmental impact profile than the Biopar 25 bag which is used on the German market

*Environmental performance of biobags (Biopar*25 bag)*

- The largest contributions to the environmental burden of the Biopar 25* bag system comes from the production of the bioplastics raw material.
  - The results of the environmental impact categories *Climate Change* and *Fossil Resource Consumption* can be largely related to the share of fossil based raw materials in the bioplastic
  - The results of the environmental impact categories *Acidification* and *Terrestrial Eutrophication* can be related to both emissions released along the upstream production of the fossil raw materials as well as the emissions related to growing of the starch crop
- The disadvantagous result of Biopar 25 bag as compared to PE bags can be explained by the rather thick film (and thus material mass) used for Biopar 25* production in combination with the considerable fossil raw material content of the raw material.

**** BASF recommends the usage of Ecoflex /Ecovio only for compost bags but not for refuse bags***

Findings: 20 L residual waste collection (2/2)

Improvement Potentials of Biobags

- Without any change in the film thickness of Biopar 25* the future availability of *Ecoflex* new generation* has the potential to reduce the environmental indicator result of Biopar by about 20% for the indicator *Climate Change*

- Reduction of film thickness from 25µ to 15µ would reduce *Climate Change* results of the Biopar bag by about 40%.

- Combination of reduction of film thickness and use of Ecoflex* new generation would potentially achieve a reduction of about 50% of the results of the Biopar bag for the indicator *Climate Change*.

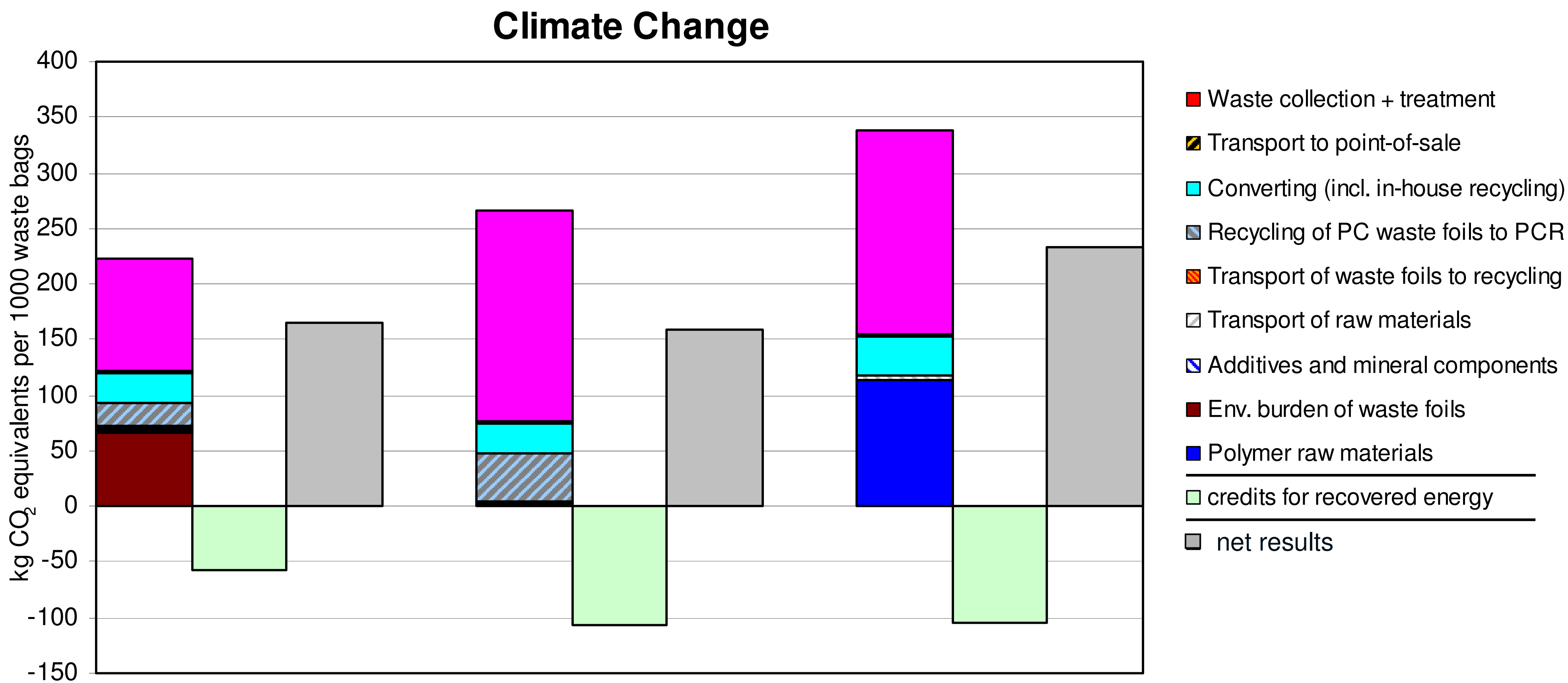
BASF recommends the usage of Ecoflex /Ecovio only for compost bags but not for refuse bags

Presentation of results:

120 L residual waste collection

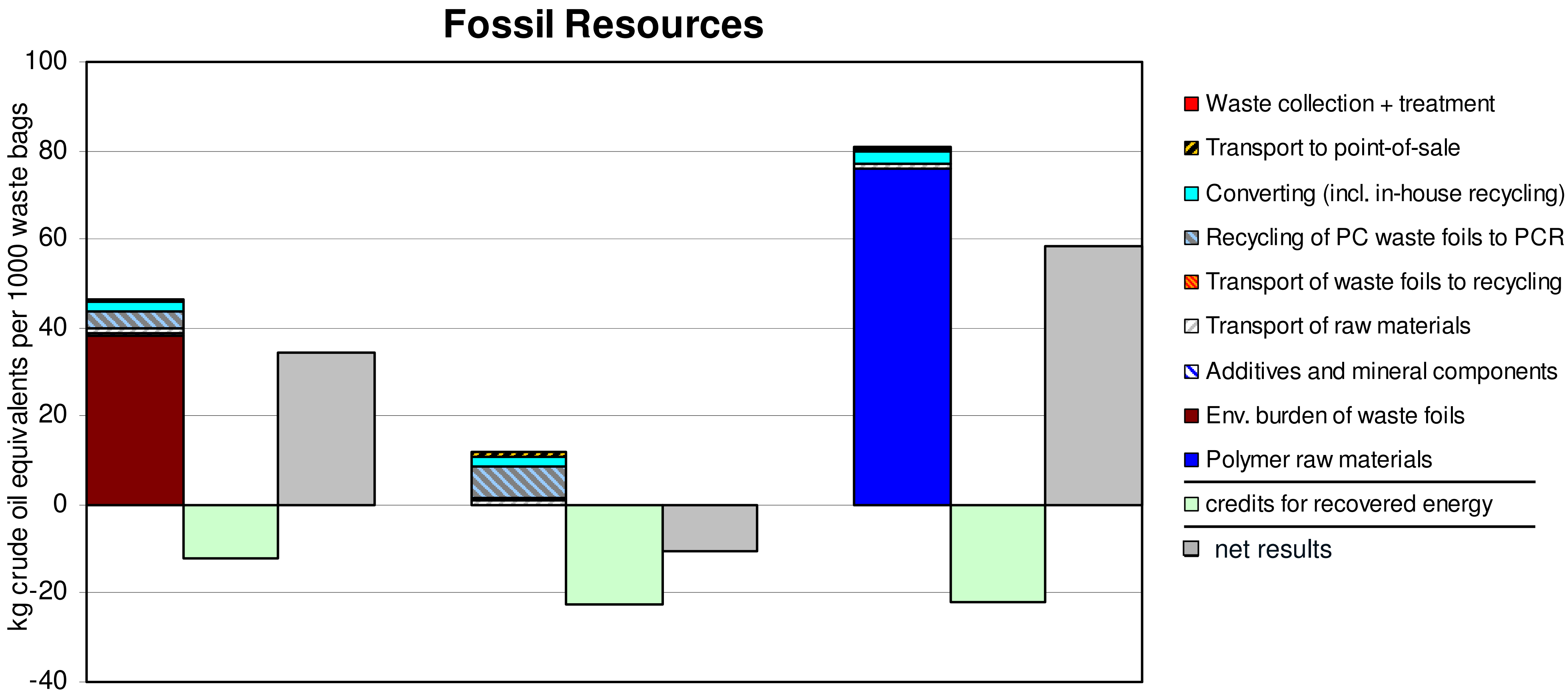
(German market)

Results: 120 L residual waste (German market)



Bag scenario	PCR	PCR	LLDPE
Converting site	Poland	Poland	Poland
Thickness	40 µm	40 µm	40 µm
Weight	57.60 g	57.60 g	56.98 g
Allocation factor	50%	0%	n/a

Results: 120 L residual waste (German market)



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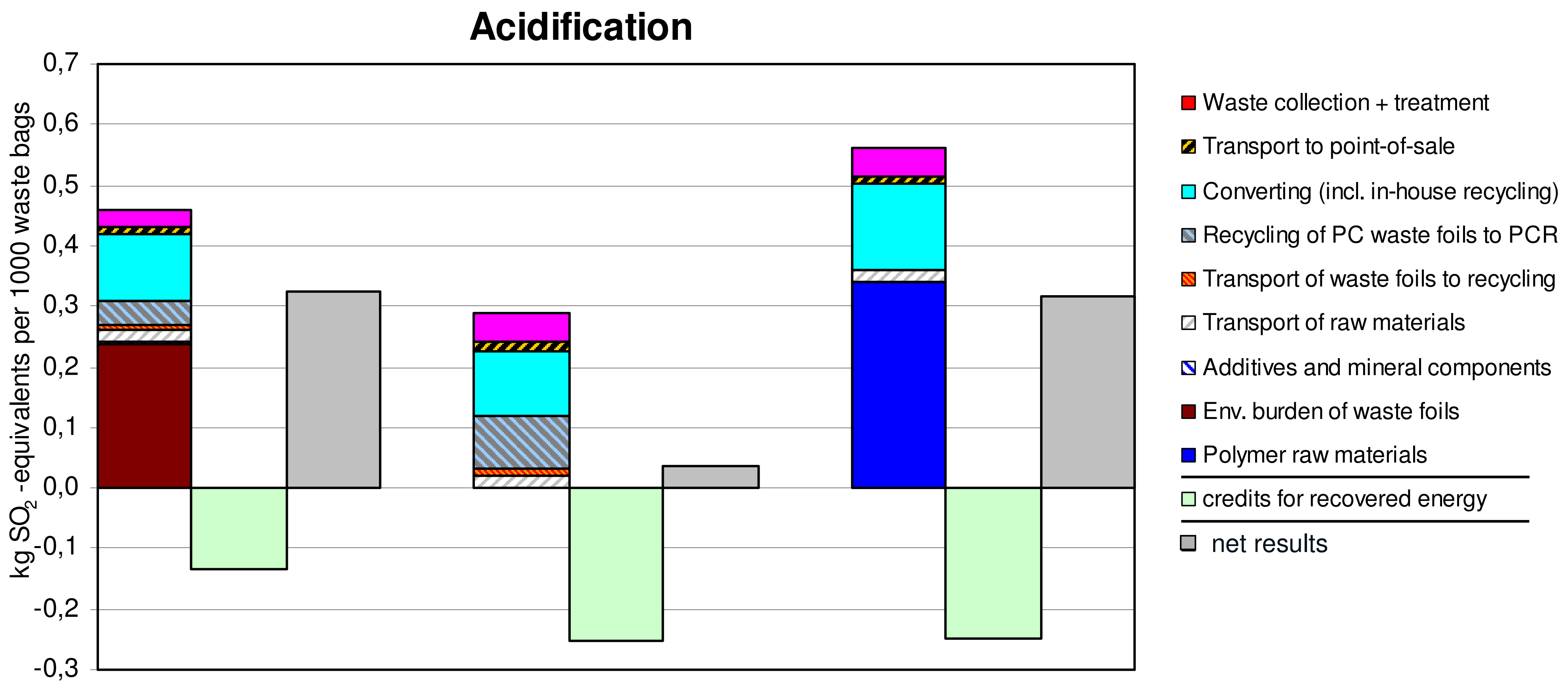
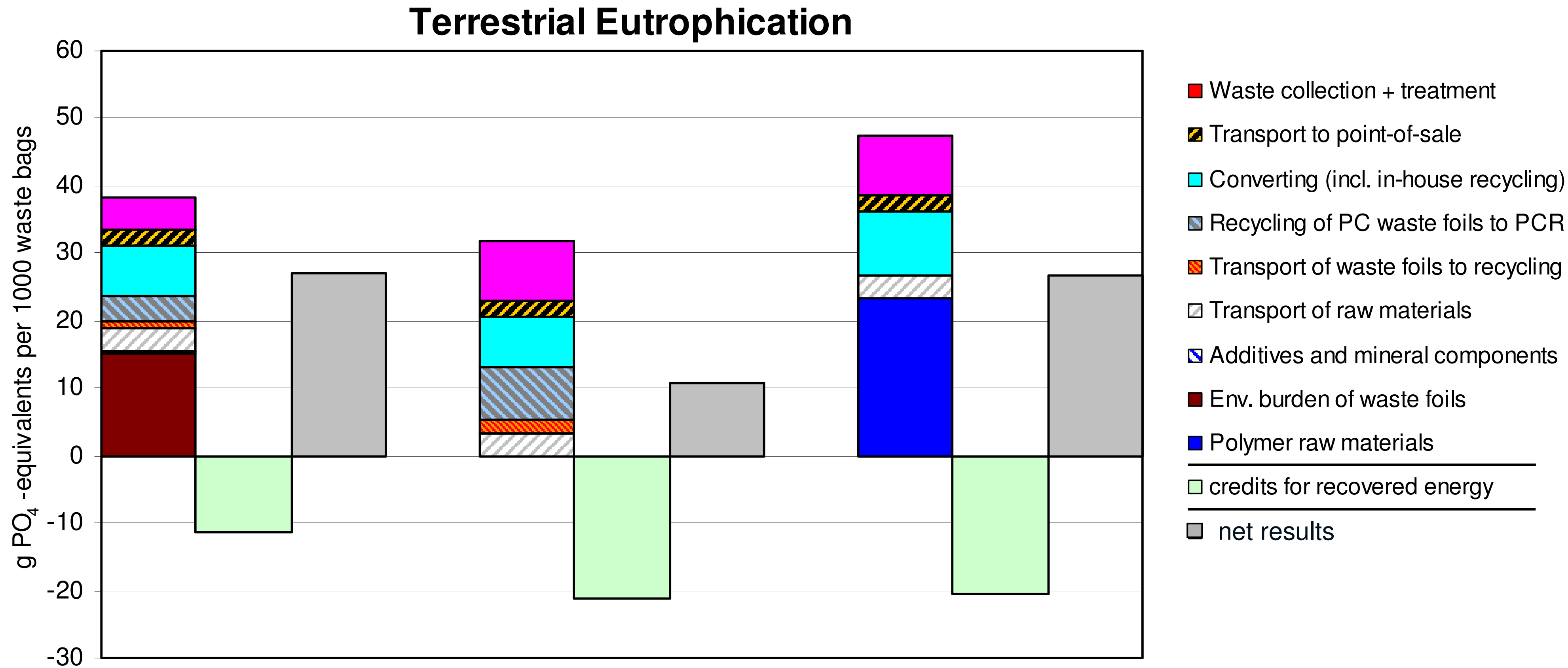
Converting site	Poland	Poland	Poland
Thickness	40 µm	40 µm	40 µm
Weight	57.60 g	57.60 g	56.98 g
Allocation factor	50%	0%	n/a

Results: 120 L residual waste (German market)



Bag scenario	PCR	PCR	LLDPE
Converting site	Poland	Poland	Poland
Thickness	40 µm	40 µm	40 µm
Weight	57.60 g	57.60 g	56.98 g
Allocation factor	50%	0%	n/a

Results: 120 L residual waste (German market)



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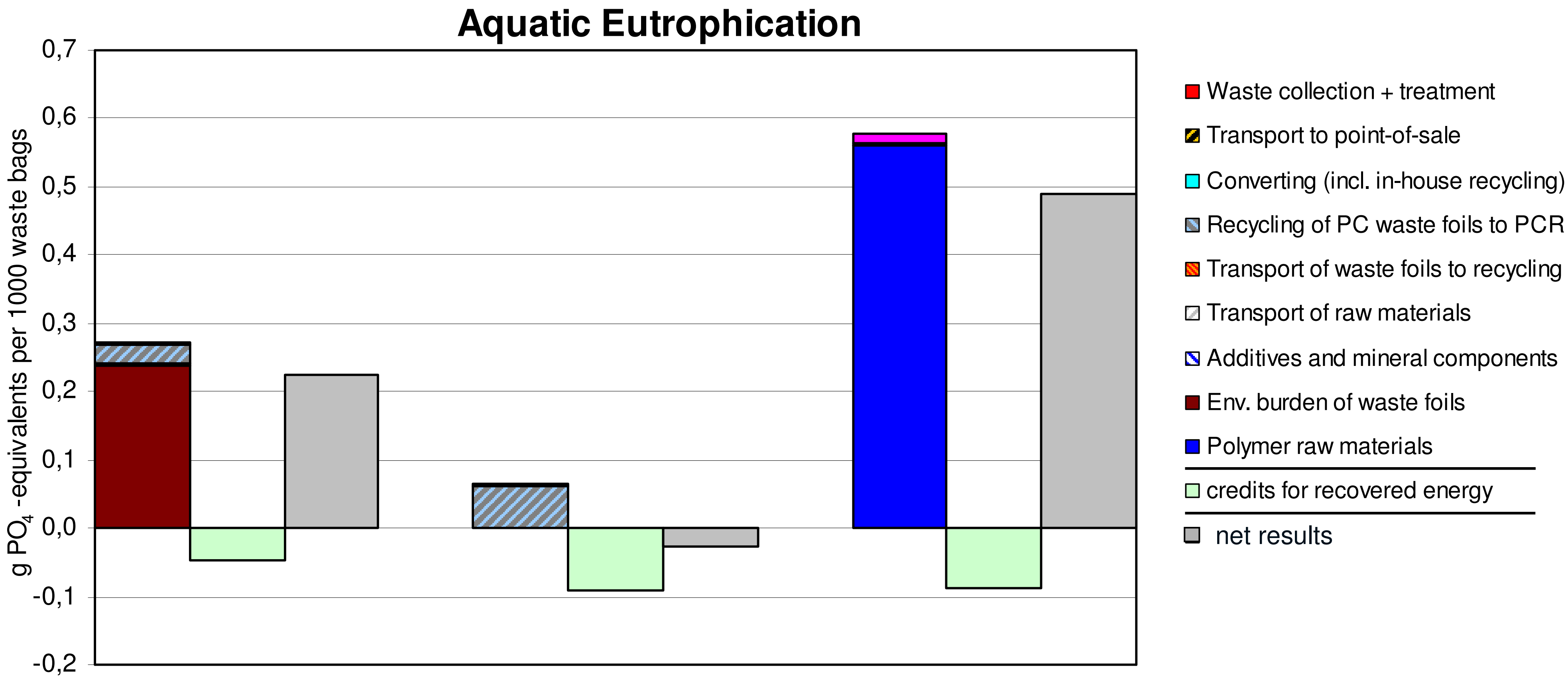

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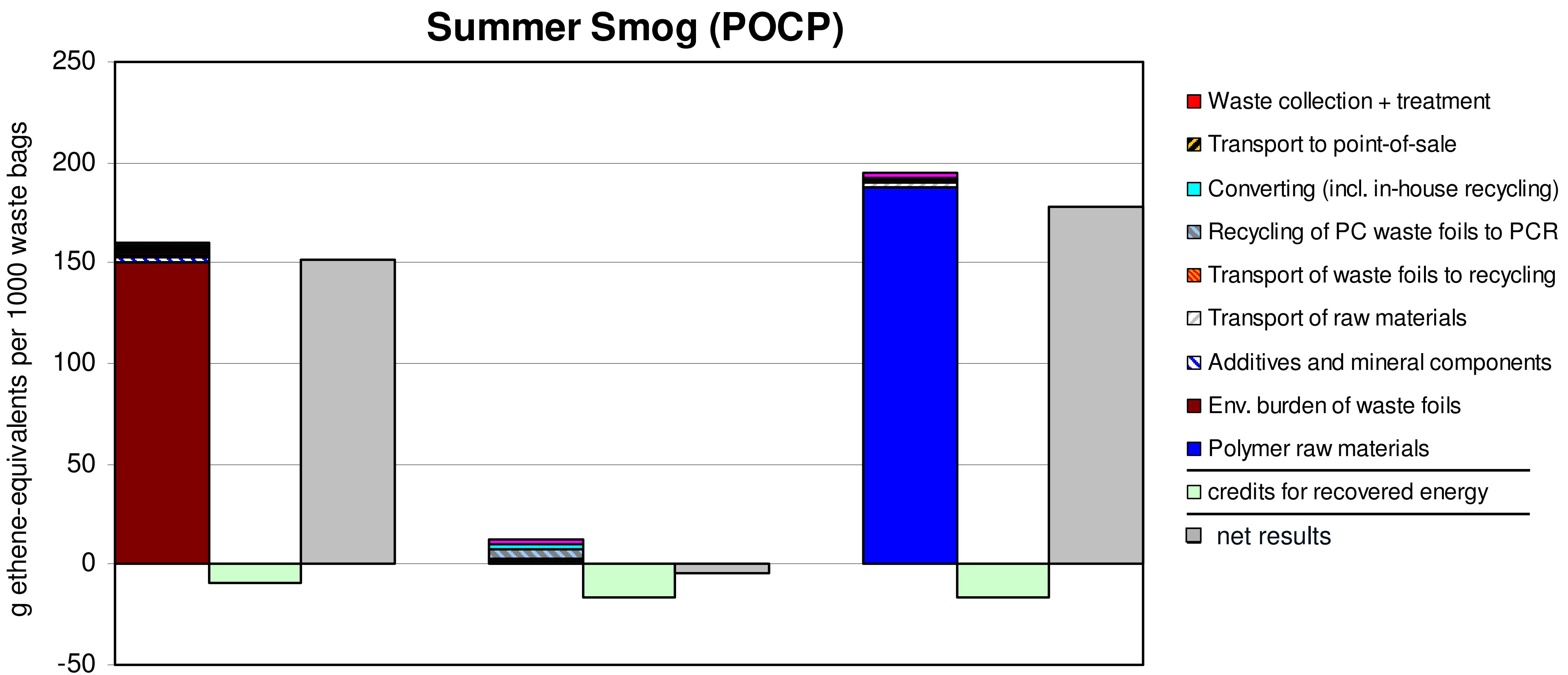

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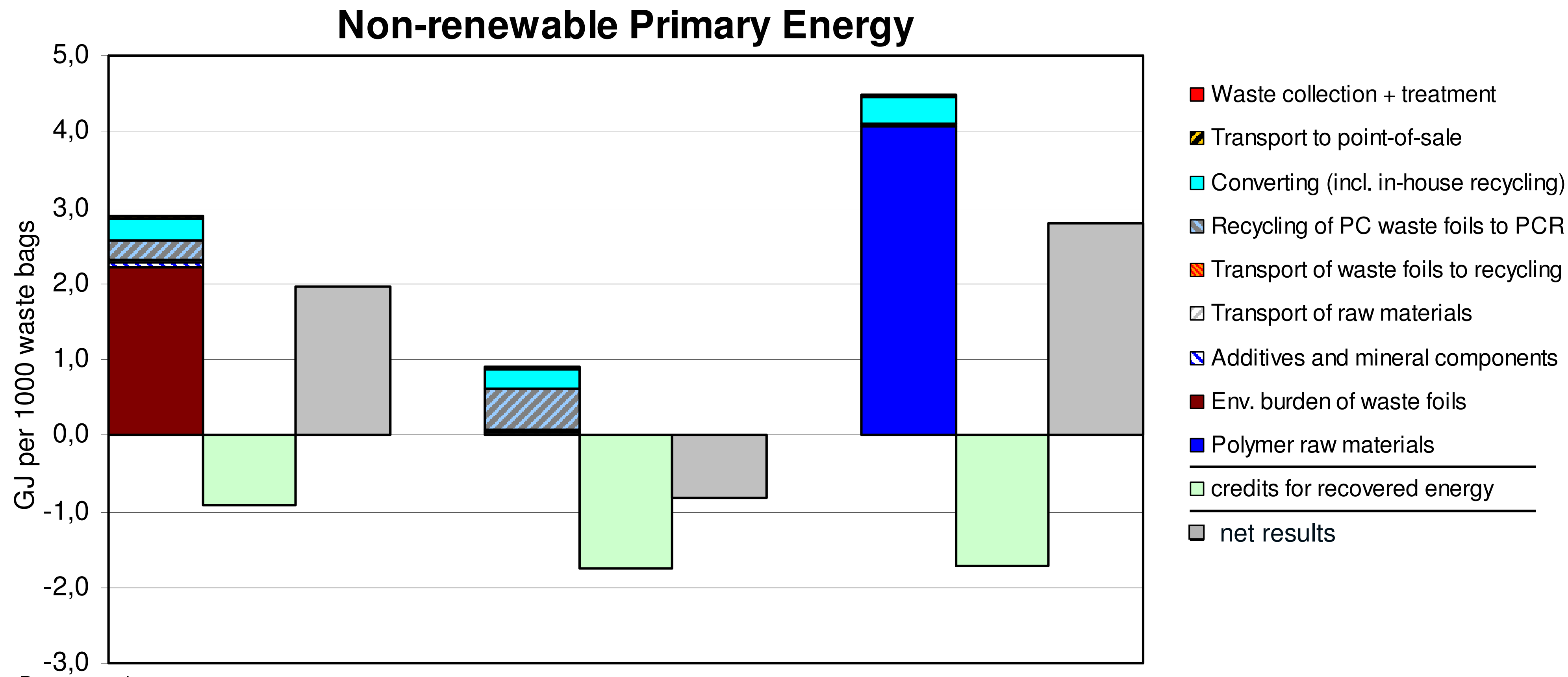
Results: 120 L residual waste (German market)



Bag scenario	PCR	PCR	LLDPE
Converting site	Poland	Poland	Poland
Thickness	40 µm	40 µm	40 µm
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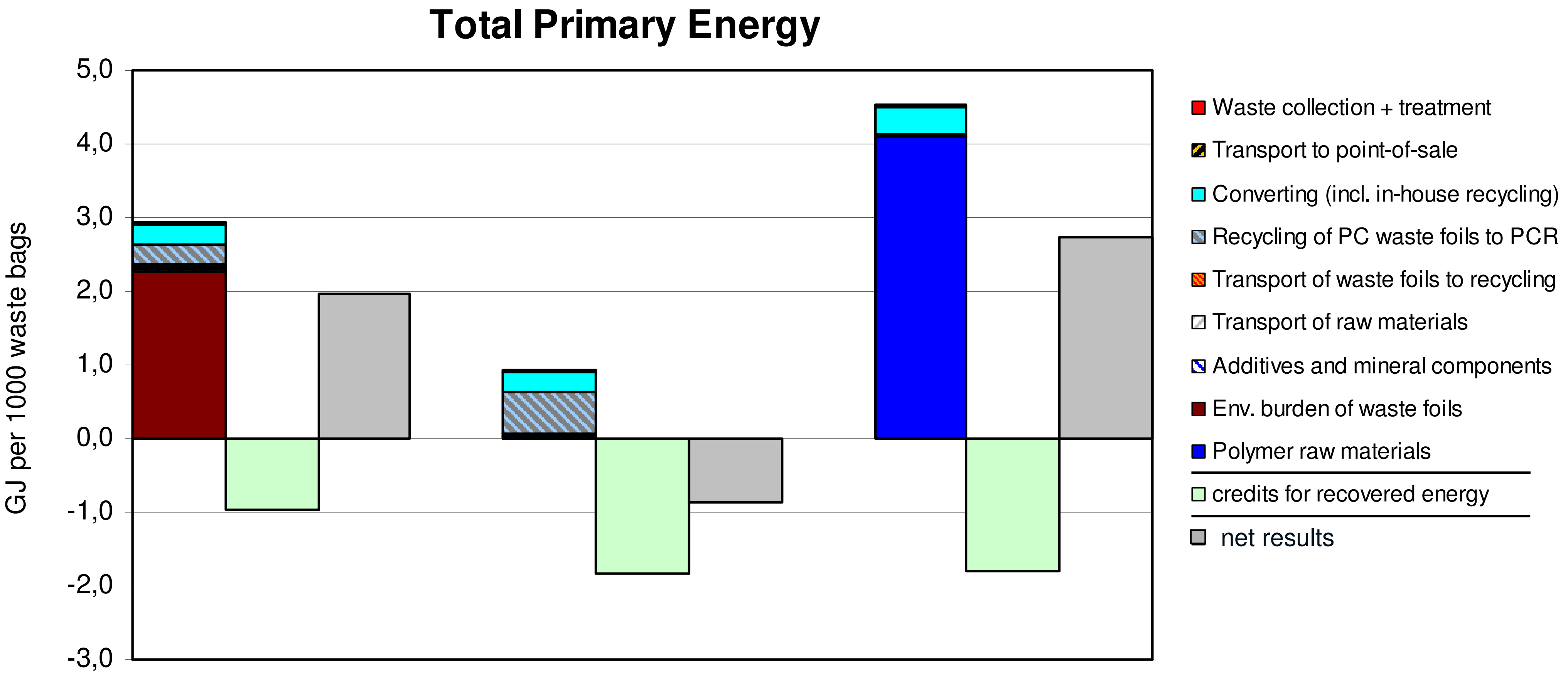
Results: 120 L residual waste (German market)



Bag scenario	PCR	PCR	LLDPE
Converting site	Poland	Poland	Poland
Thickness	40 µm	40 µm	40 µm
Weight	57.60 g	57.60 g	56.98 g
Allocation factor	50%	0%	n/a

Findings: 120 L residual waste collection

Virgin PE bags vs. PCR bags (50% allocation)

- In general, waste bags made from PCR material show lower environmental impact results for all indicators examined in this study in comparison to the virgin LLDPE bag.
- The main difference between the virgin LLDPE system and the PCR system is caused by the environmental burden of the raw material production and in case of the waste bags made from PCR the recycling of PC films to PCR.
- Great differences between the LLDPE and the PCR (50% allocation) system can be seen for the indicators *Fossil Resources, Aquatic Eutrophication, Summer Smog, Non-renewable Primary Energy* and *Total Primary Energy*.
- Smaller differences between both systems can be seen for *Climate Change* and *Acidification* which mainly depends on the life cycle steps converting, recycling and waste treatment.

PCR bags with 50% allocation vs. PCR bags with 0% allocation

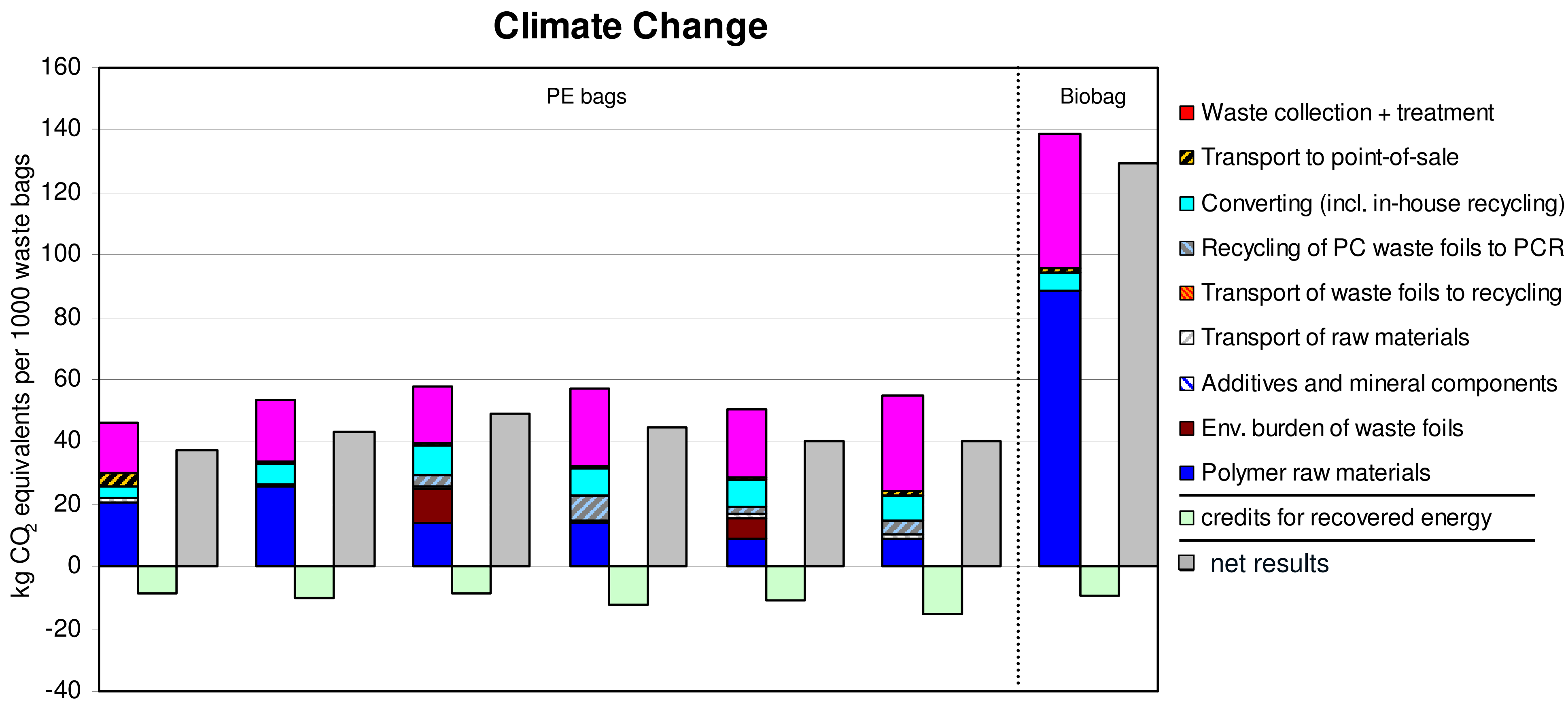
- Allocation 50% means that 50% of the environmental burden of the primary LDPE production, 50% of the burdens of “waste collection and treatment” and 50% of “recycling of PC waste foils to PCR” is allocated to the PCR bag system. On the other hand, energy credits from incineration are cut in half.
- If an allocation factor 0% is calculated, the recycled LDPE brings no environmental burden to the PCR bag system and 100% of the energy credits from incineration is conceded. But the system has to carry the full burdens of “waste collection and treatment” and “recycling of PC waste foils to PCR”.
- For some indicators, impact results of PCR bags (0% allocation) decrease significantly. On the other hand, *Climate Change* results are very close to those of PCR bags (50% allocation). For all other impacts PCR bags (0% allocation) score lower than PCR bags (50% allocation).

Presentation of results:

30 L residual waste collection

(French market)

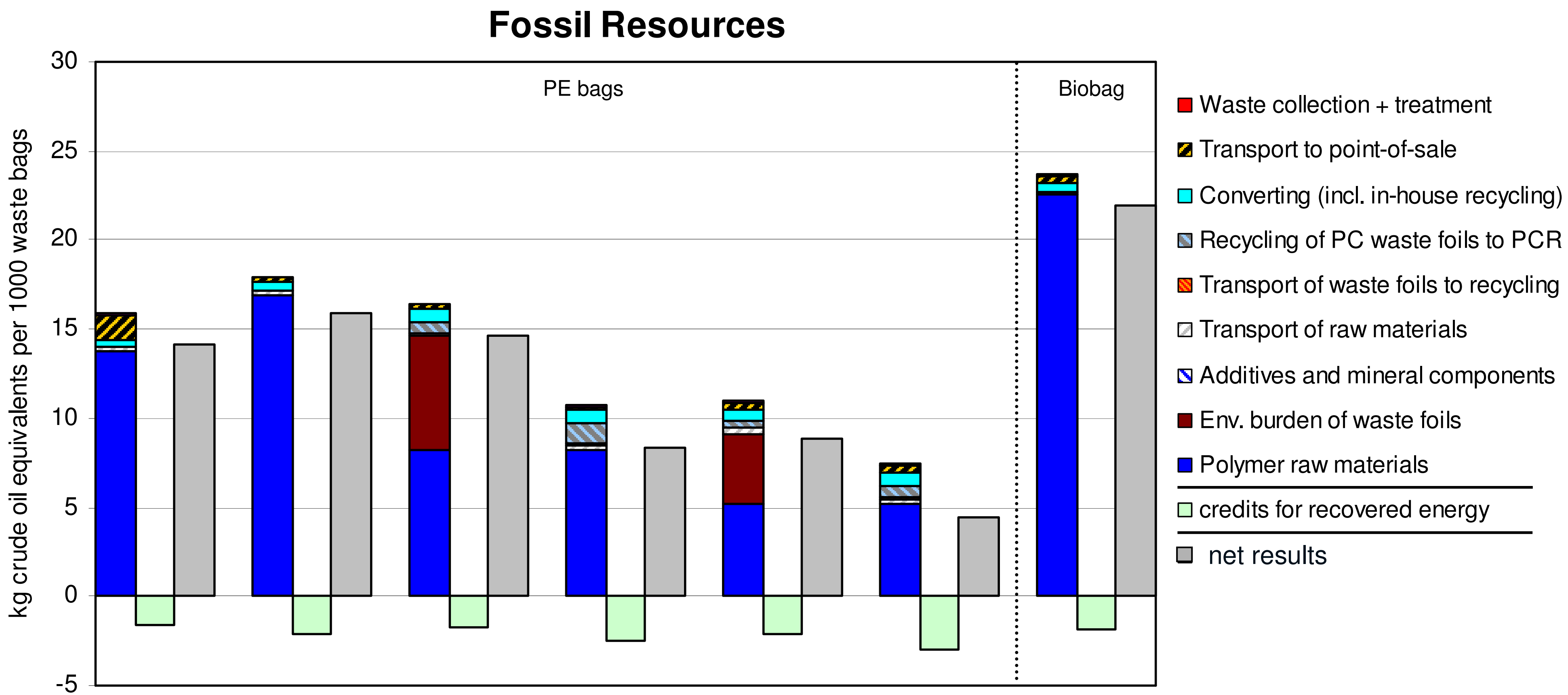
Results: 30 L residual waste (French market)



Bag scenario	HDPE	LLDPE	PCR/ LDPE	PCR/ LDPE	PCR/LDPE/ Chalk	PCR/LDPE/ Chalk	Biopar*
Converting site	China	Poland	Poland	Poland	Poland	Poland	Poland
Thickness	15 µm	20 µm	25 µm	25 µm	25 µm	25 µm	22 µm
Weight	10.13 g	13.08 g	16.46 g	16.46g	19.55 g	19.55 g	20.38 g
Allocation factor	-	-	50%	0%	50%	0%	-

**** BASF recommends the usage of Ecoflex /Ecovio only for compost bags but not for refuse bags***

Results: 30 L residual waste (French market)



Bag scenario	HDPE	LLDPE	PCR/ LDPE	PCR/ LDPE	PCR/LDPE/ Chalk	PCR/LDPE/ Chalk	Biopar*
Converting site	China	Poland	Poland	Poland	Poland	Poland	Poland
Thickness	15 µm	20 µm	25 µm	25 µm	25 µm	25 µm	22 µm
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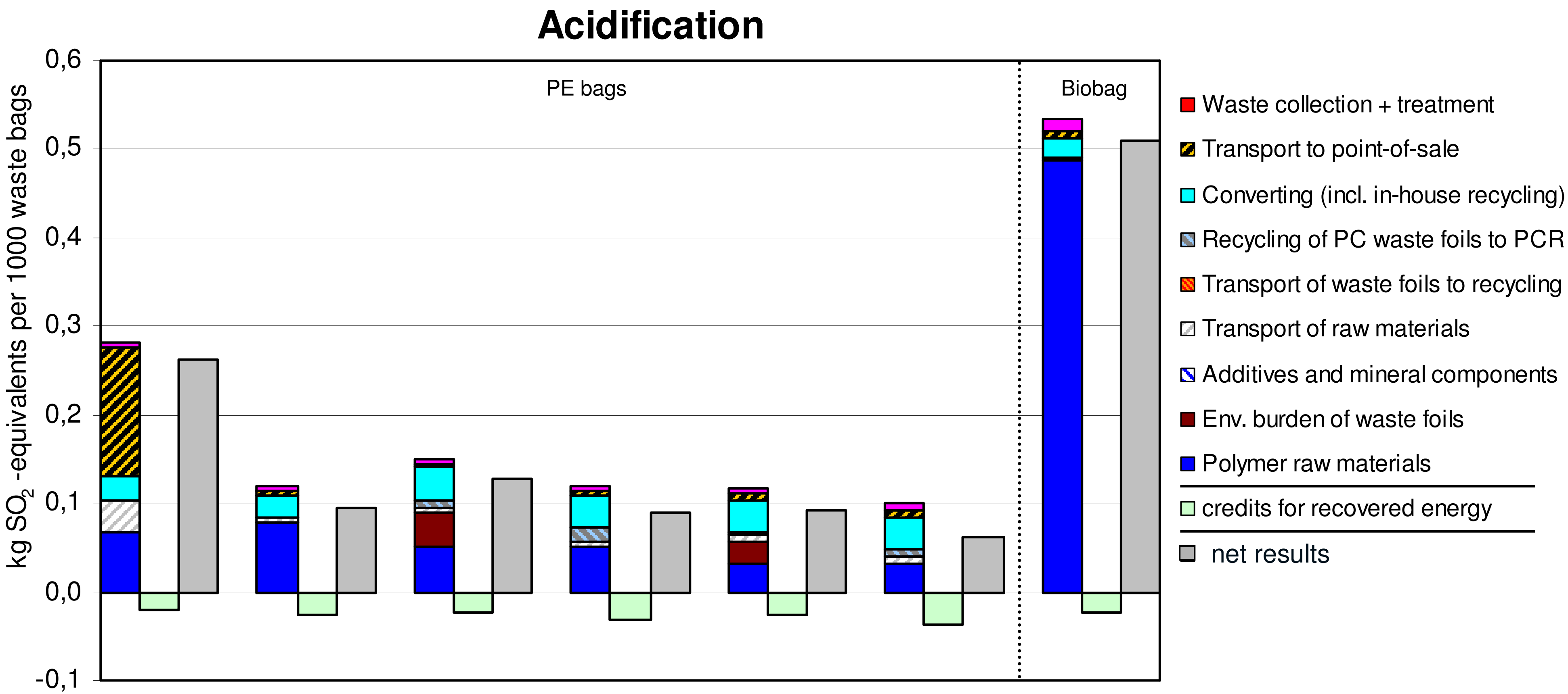

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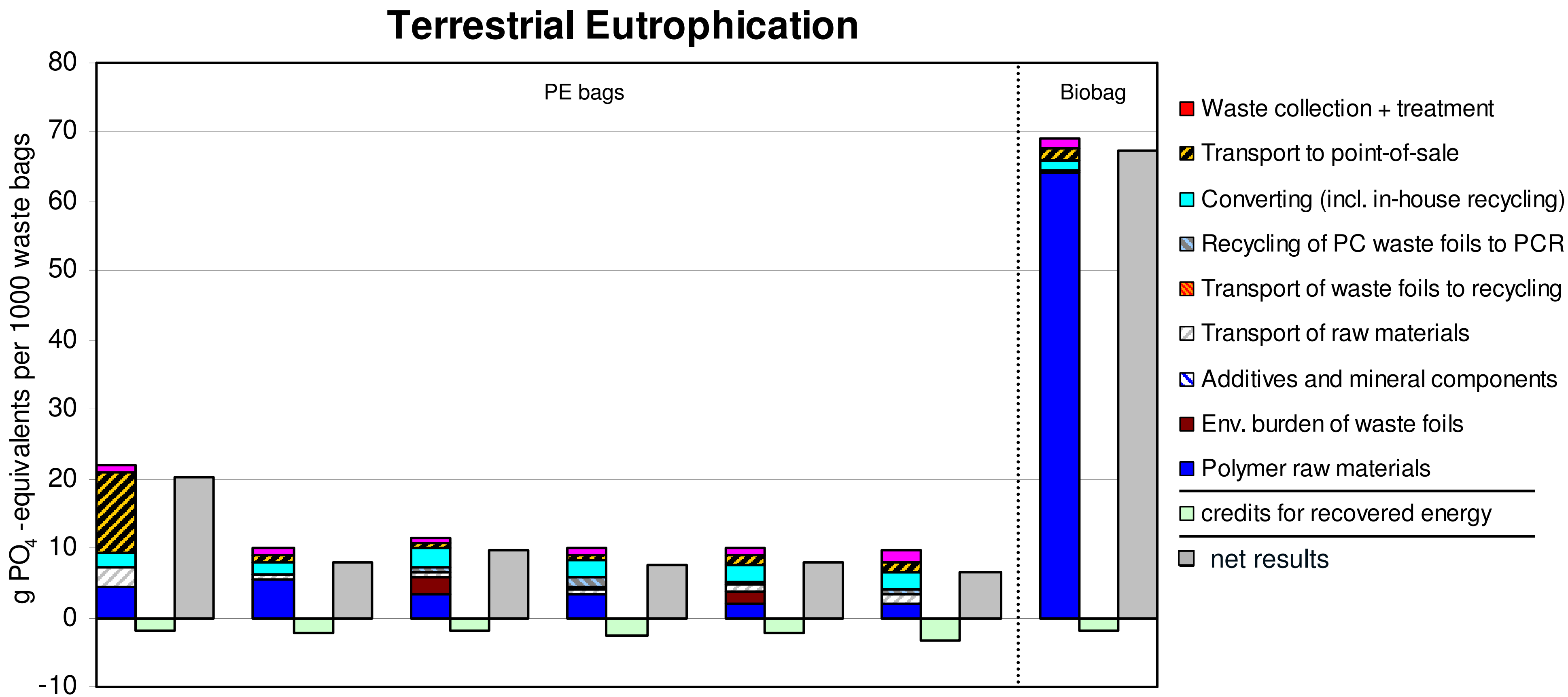

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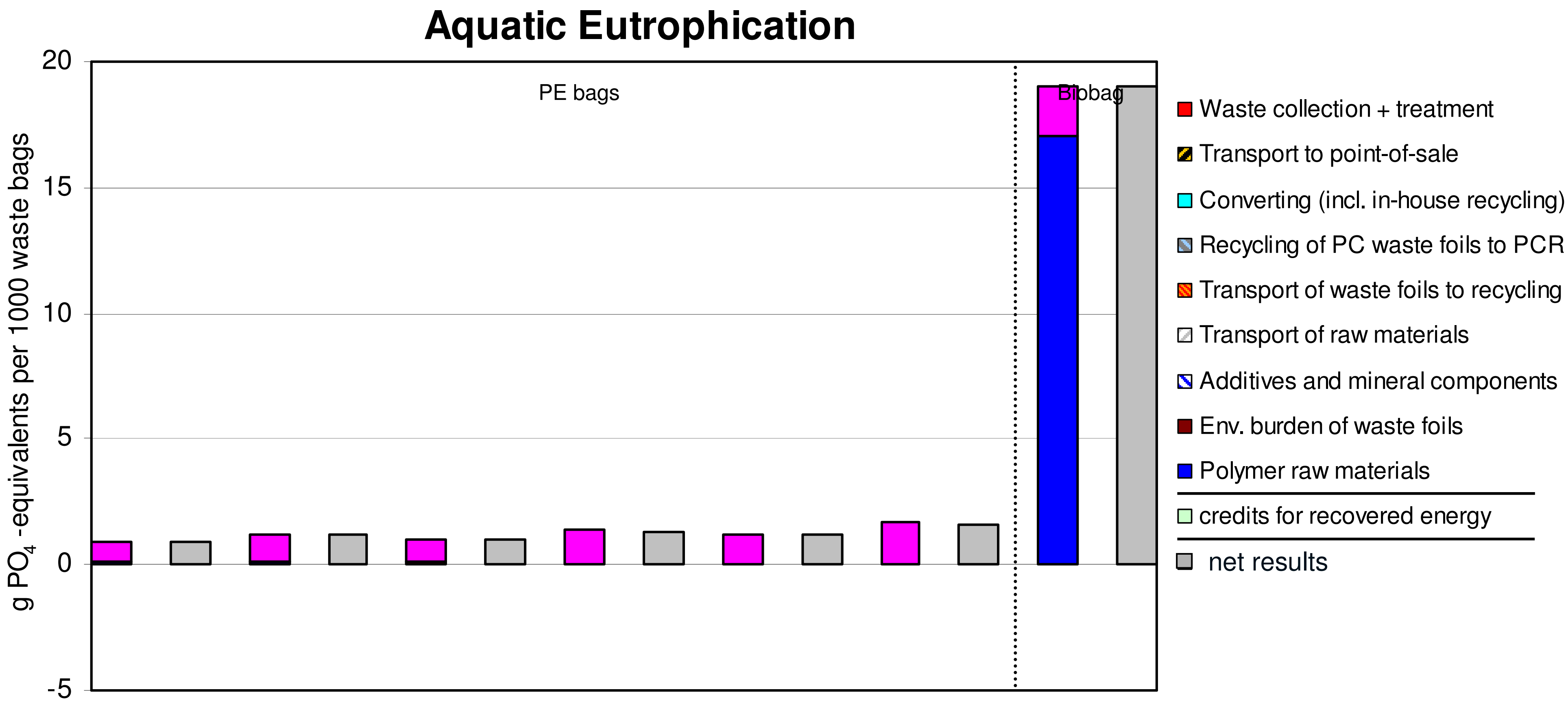

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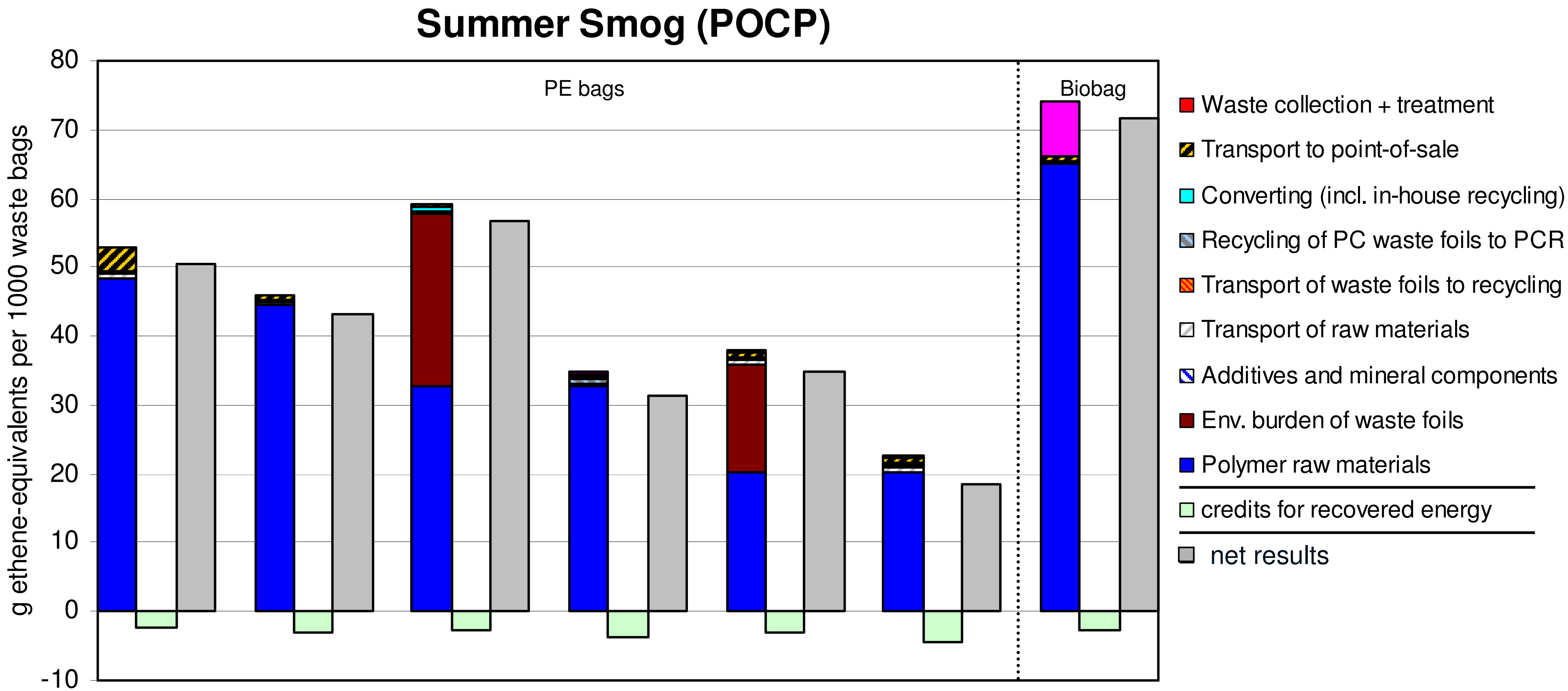

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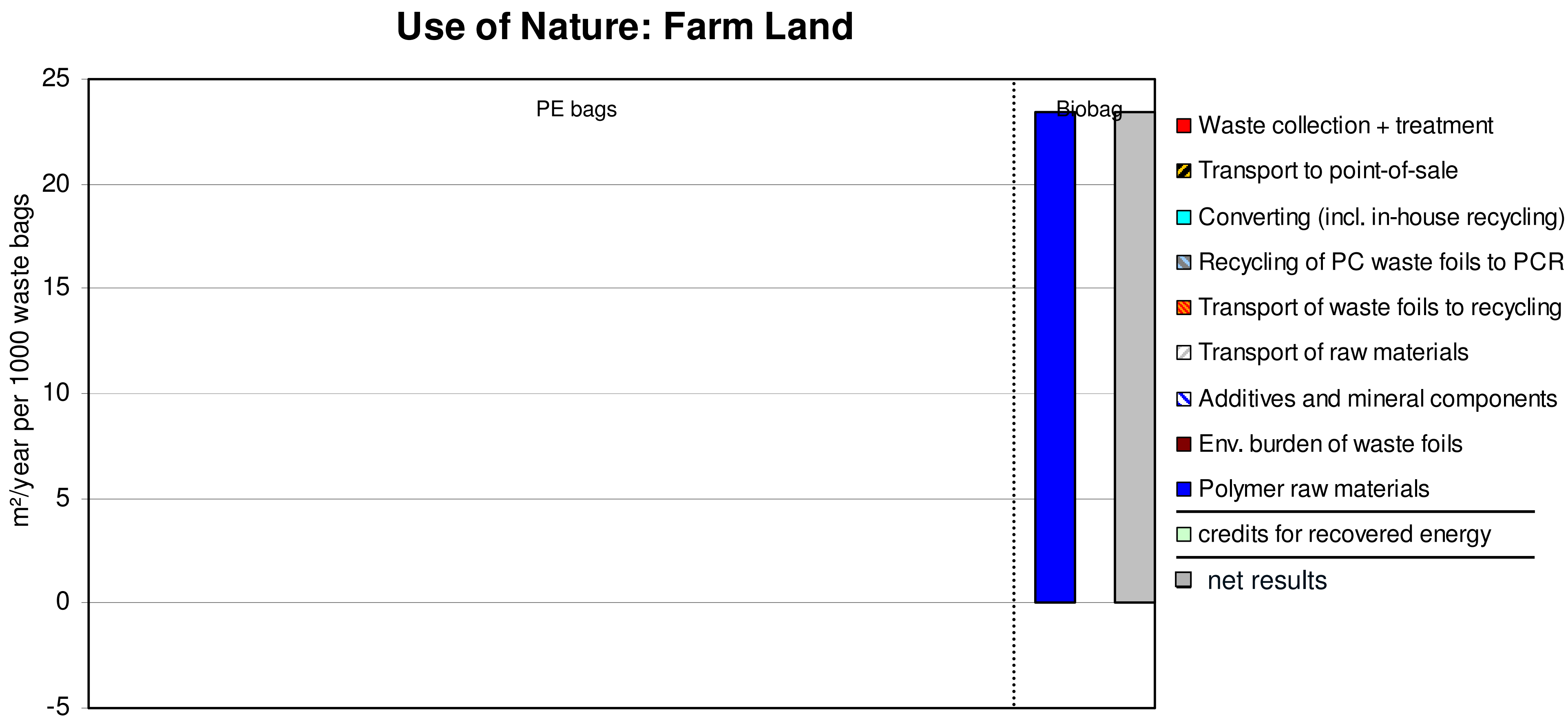

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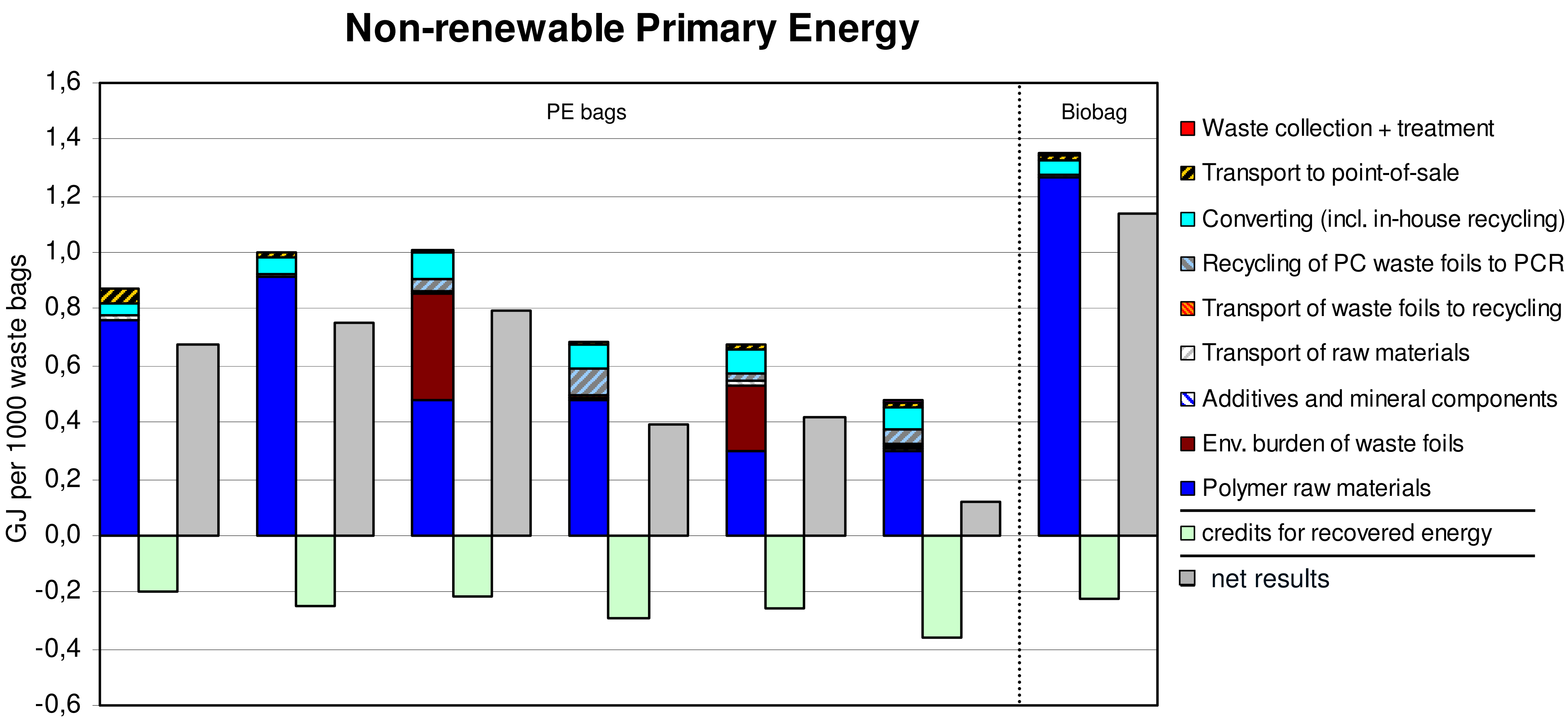

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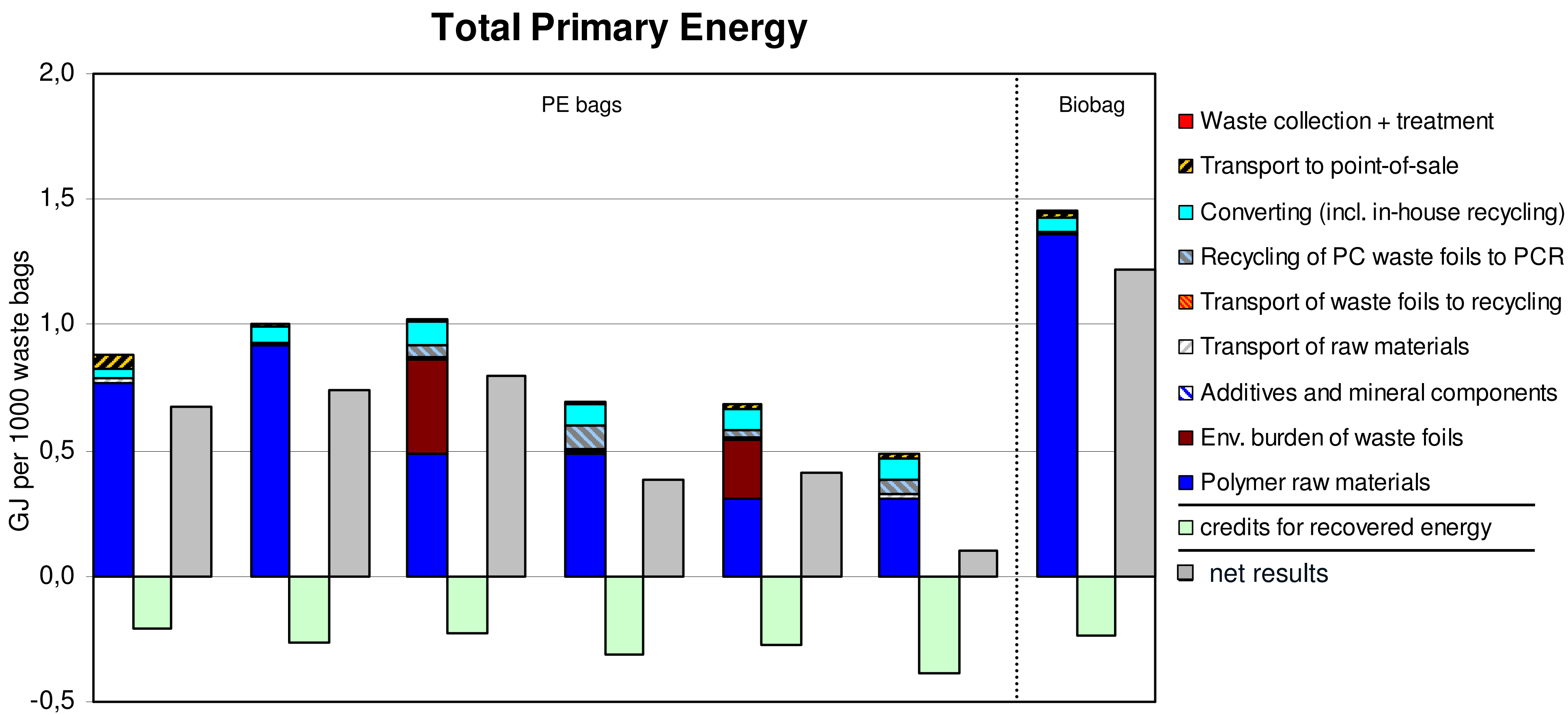

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Converting site	China	Poland	Poland	Poland	Poland	Poland	Poland
Thickness	15 µm	20 µm	25 µm	25 µm	25 µm	25 µm	22 µm
Weight	10.13 g	13.08 g	16.46 g	16.46g	19.55 g	19.55 g	20.38 g
Allocation factor	-	-	50%	0%	50%	0%	-

**** BASF recommends the usage of Ecoflex /Ecovio only for compost bags but not for refuse bags***

Findings: 30 L residual waste collection

PE bags vs. Biopar* bag

- Compared to the Biopar bag, PE bags without recycled content show lower environmental impact results for all indicators.
- PE bags with recycled content show definitely lower environmental impact results for all indicators, except PCR/LDPE bag which shows no clear advantages

PE bags 100% virgin material vs. PE bags with recycled content

- The PCR/LDPE/Chalk bag with a 50% allocation factor shows lower results than the PCR/LDPE bag with a 50% allocation factor in all available impact categories because of its higher PCR and lower virgin PE share.
- PCR/LDPE/Chalk bags (50% allocation) compared with PE bags from 100% virgin material have lower environmental impact results in all available impact categories.
- If a 0% allocation factor is used, both PCR bags show lower environmental impact results than the LLDPE bag made from 100% virgin material for the indicators: *Fossil Resources*, *Acidification*, *Terrestrial Eutrophication*, *Summer Smog*, *Non-renewable Primary Energy*, *Total Primary Energy*
- Both PE bags (0% allocation) with recycled content compared to the HDPE bag show definitely lower results for the indicators *Fossil Resources, Acidification, Terrestrial Eutrophication, Summer Smog, Non-renewable Primary Energy* and *Total Primary Energy.*

**** BASF recommends the usage of Ecoflex /Ecovio only for compost bags but not for refuse bags***

Synopsis

- Virgin polyethylene waste bags have the largest market share and can be considered a commodity product existing for many years already
- Waste bags from alternative raw materials are available on the market:
  - Bags from PCR material (in this study: from agriculture films)
  - Bags from PCR material combined with chalk
  - Bags from biodegradable material
- Those alternative materials have only recently been developed and are still on their learning curve
- Data from different European producers of biodegradable raw materials have been collected in the course of the study. Among those, BIOP and BASF agreed that their inventory data could be used in the scenarios examined in this study
  - BIOPAR (containing ECOFLEX, starch and additives) is already in use for waste bags sold on the German and French market
  - ECOVIO currently is rather used for shopping bags. Scenarios with ECOVIO data have been included in this study in order to provide a broader view on biodegradable materials as such*

* *BASF recommends the usage of Ecoflex /Ecovio only for compost bags but not for refuse bags*

Synopsis

- This current LCA study shows that the use of PCR in waste bags has the potential to improve the environmental performance of waste bags
  - Provided that PCR content does not increase the weight of the bags considerably waste bags with PCR content are a recommendable option for bag producers and retailers

- The scenarios of currently existing biobags show larger environmental pollution indicator results than those of polyolefine bags. This applies for all environmental pollution indicators examined and is true for both, the German and the French market framework

- The existing potentials for environmental improvements of biodegradable bags are large. However, only a combination of options (i.e. material, design and technical improvements) would bring the environmental impact profiles of biobags in the range of those of the polyethyene bags

- A close cooperation within the supply chain will be necessary to put the improvement potentials analysed in this study into practice