POLITECNICO MILANO 1863

SUSTAINABILITY & ENVIRONMENTAL FOOTPRINT

COURSE # 054412

EUROPEAN ENVIRONMENTAL AND LANDSCAPE POLITICS AND PROJECTS

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Definition

Sustainability is the long-term viability of a community, set of social institutions, or societal practice. In general, sustainability is understood as a form of inter-generational ethics in which the environmental and economic actions taken by present persons do not diminish the opportunities of future persons to enjoy similar levels of wealth, utility, or welfare.

Information available at:
https://www.britannica.com/science/sustainability
[accessed on 24/2/2021].

Viability is the ability to survive or live successfully.

Oxford Languages Online Dictionary.

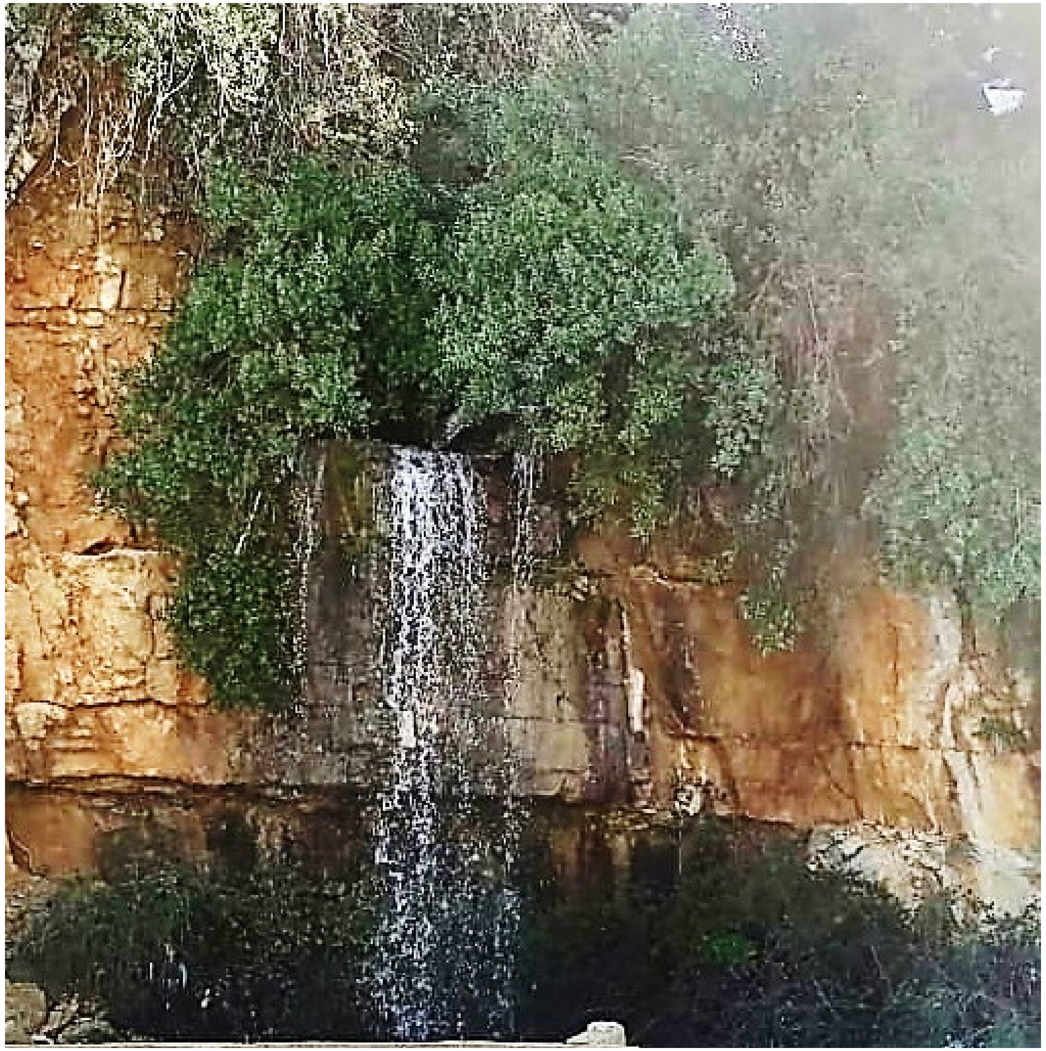

Figure 1 – Natural Resources

Terminology

Sustainable Development: The concept of sustainable development refers to a form of development policy which seeks to satisfy society's economic, social and environmental needs in terms of well-being in the short, medium and - above all - long term. It is founded on the assumption that development must meet today's needs without jeopardizing the welfare of future generations. In practical terms, this means creating the conditions for long-term economic development whilst ensuring due respect for the environment.

Information available at: https://ec.europa.eu/regional_policy/en/policy/what/glossary/s/sustainable-development [accessed on 27/2/2021].

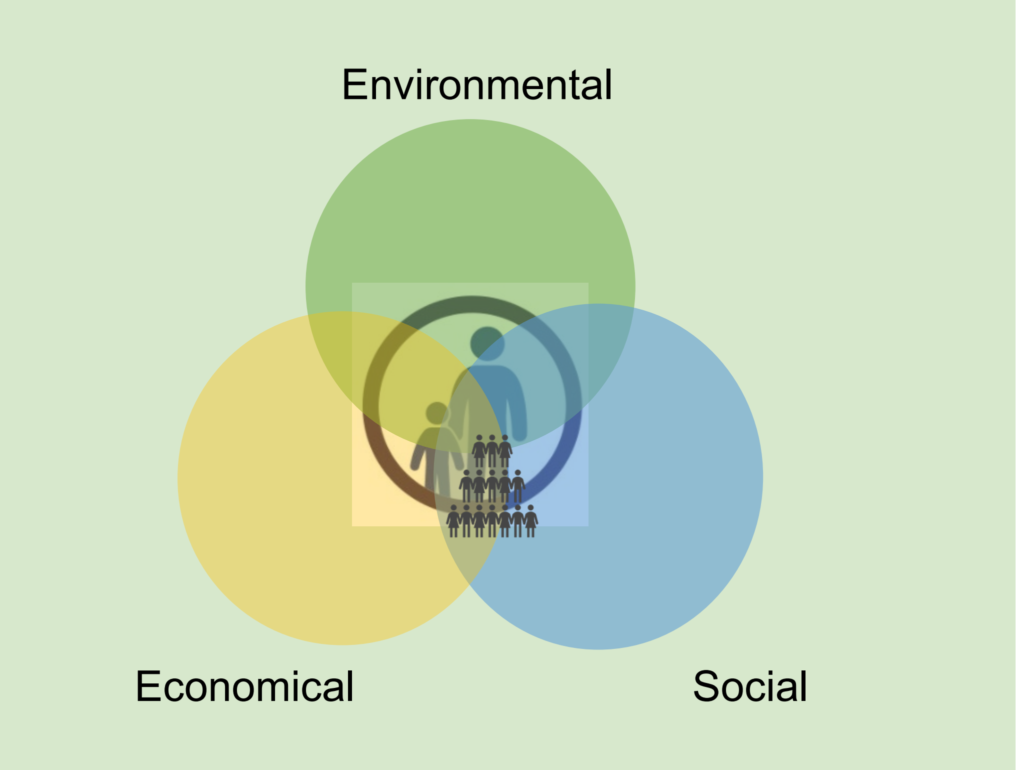

Figure 2 – Sustainable Development Policies

One Globe

"*We all share one planet and are one humanity; there is no escaping this reality*."

Wangari Maathai

Wangari Maathi (1940, 2011) is a Kenyan social, environmental, and political activist and the first African woman to win the Nobel Peace Prize in 2004.

Information available at
https://en.wikipedia.org/wiki/Wangari_Maathai
[accessed on 3/4/2021]

Figure 3 – Sustainable Earth Wealth

UN 17 Sustainable Development Goals

In 2015, all United Nations Member States adopted the 2030 Agenda for Sustainable Development i.e., a shared policy for peace and prosperity for people of this planet, in the present and in the future. All countries are committed to improve health and education, reduce inequality, and spur economic growth. This policy is to be applied in consideration of climate change and while preserving naturals reserves, oceans and forests.

Information available at : https://sdgs.un.org/goals [accessed on 27/2/2021].

United Nations | Department of Economic and Social Affairs
Sustainable Development

Figure 4 – The 17 SDGs

Environmental Impact / Footprint

Environmental impact is any change to the environment, whether adverse or beneficial, that wholly or partially results from an organization's activities, products or services.

Zampori, L. and Pant, R., *Product Environmental Footprint (PEF) method*, EUR 29682 EN, Publications Office of the European Union, Luxembourg, (2019) 14-15. ISBN 978-92-76-00653-4, doi: 10.2760/265244, JRC115959..

Environmental Footprint is the measurement of the performance an organizational activity(ies) to develop a given product or a service of its impact on the environment whether positive or negative.

The European Commission proposed the Product Environmental Footprint (PEF) and Organization Environmental Footprint (OEF) methods as a common way of measuring environmental performance.

Information available at: https://eplca.jrc.ec.europa.eu/EnvironmentalFootprint.html [accessed on 27/2/2021].

Figure 5 – Product Environmental Footprint

Product Environmental Footprint

Product Environmental Footprint Category Rules (PEFCRs) – Product category-specific, life-cycle-based rules that complement general methodological guidance for PEF studies by providing further specification at the level of a specific product category. PEFCRs help to shift the focus of the PEF study towards those aspects and parameters that matter the most, and hence contribute to increased relevance, reproducibility and consistency of the results by reducing costs versus a study based on the comprehensive requirements of the PEF guide.

Information available at:
https://ec.europa.eu/search/?QueryText=pef%20guide&swlang=en
[accessed on 7/3/2021].

Organization Environmental Footprint Sector Rules (OEFSRs)
http://ec.europa.eu/environment/eussd/pdf/Deliverable.pdf

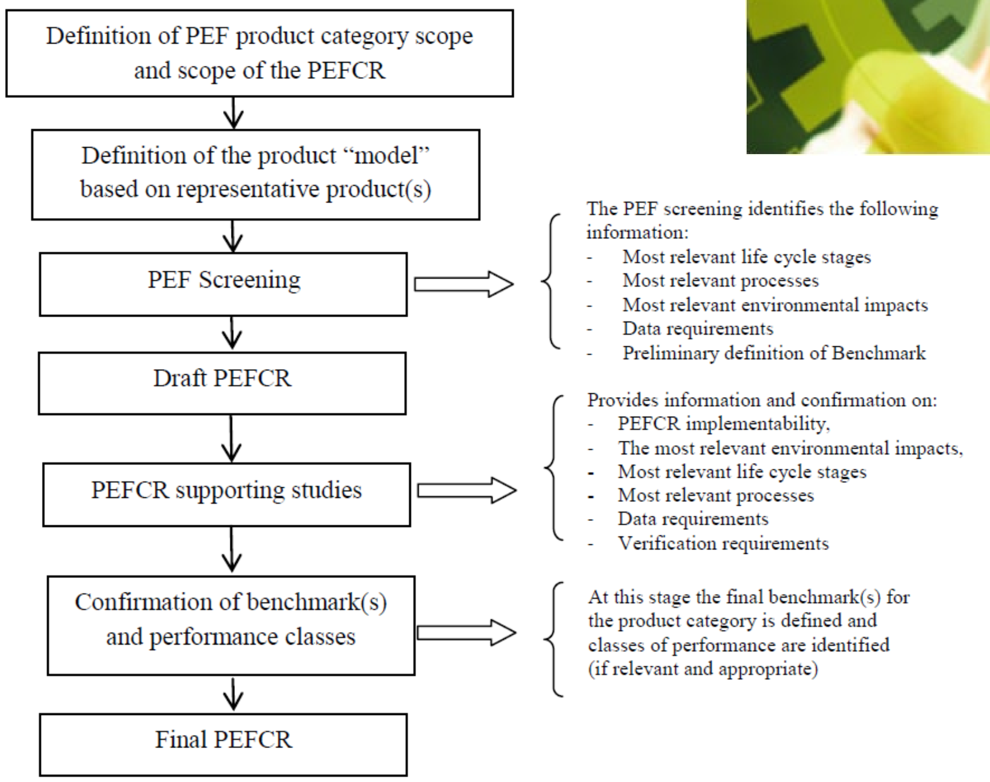

Figure 6 – Product Environmental Footprint Category Rules

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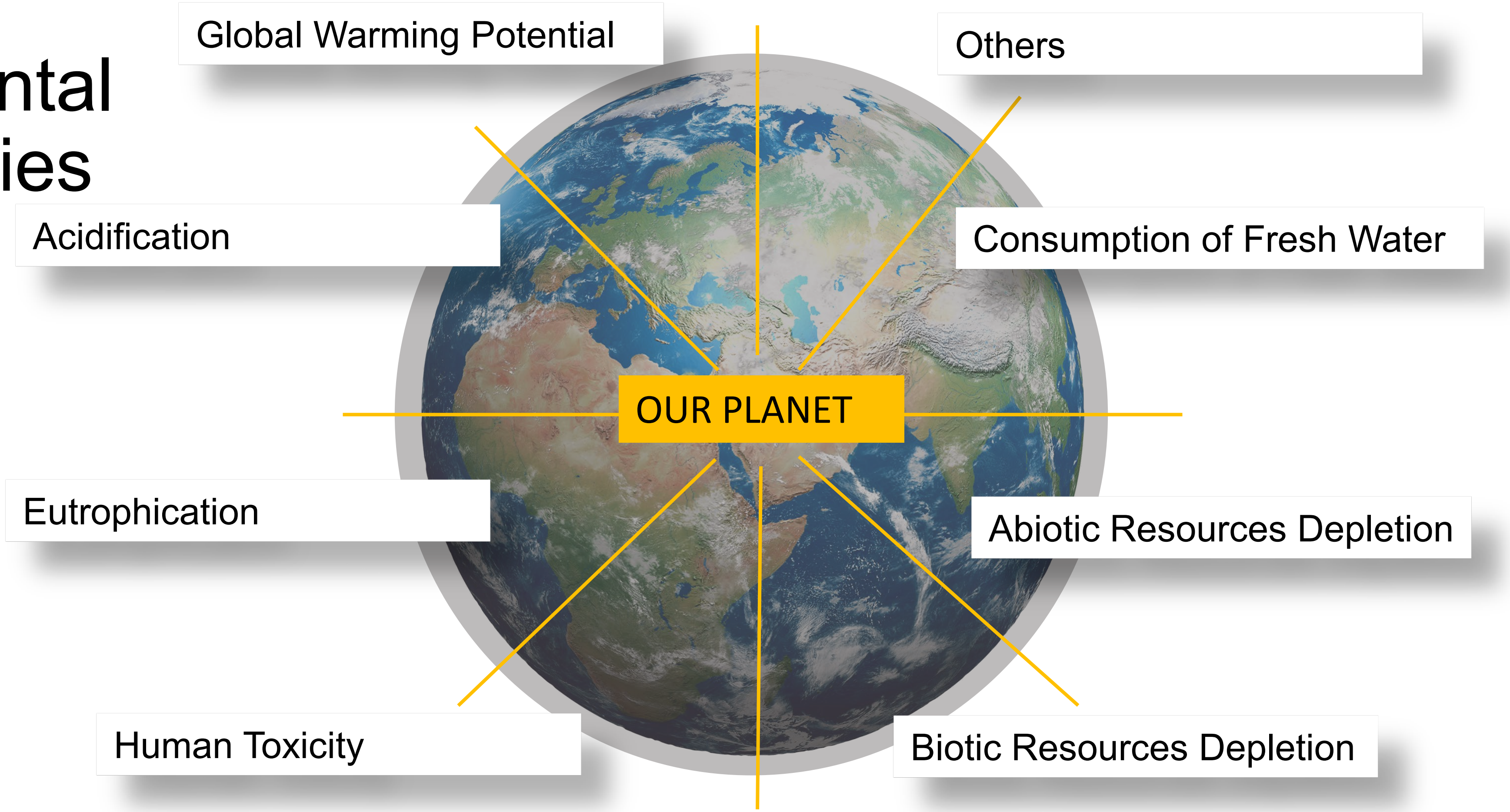
The Environmental Impact Categories

Acidification is a broad term that refers to the process by which aquatic ecosystems become more acidic. Acid rain and acid mine drainage are major sources of acidifying compounds, lowering the pH below the range where most living organisms function.



Information available at: https://www.epa.gov/national-aquatic-resource-surveys/indicators-acidification [accessed on 7/3/2021].

Figure 7 – Main Environmental Impact Categories

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The Environmental Impact Categories

Eutrophication is the change in biological productivity which all lakes and reservoirs undergo during their life history. It can be both beneficial and harmful depending on its degree and the way in which a lake or reservoir is used.

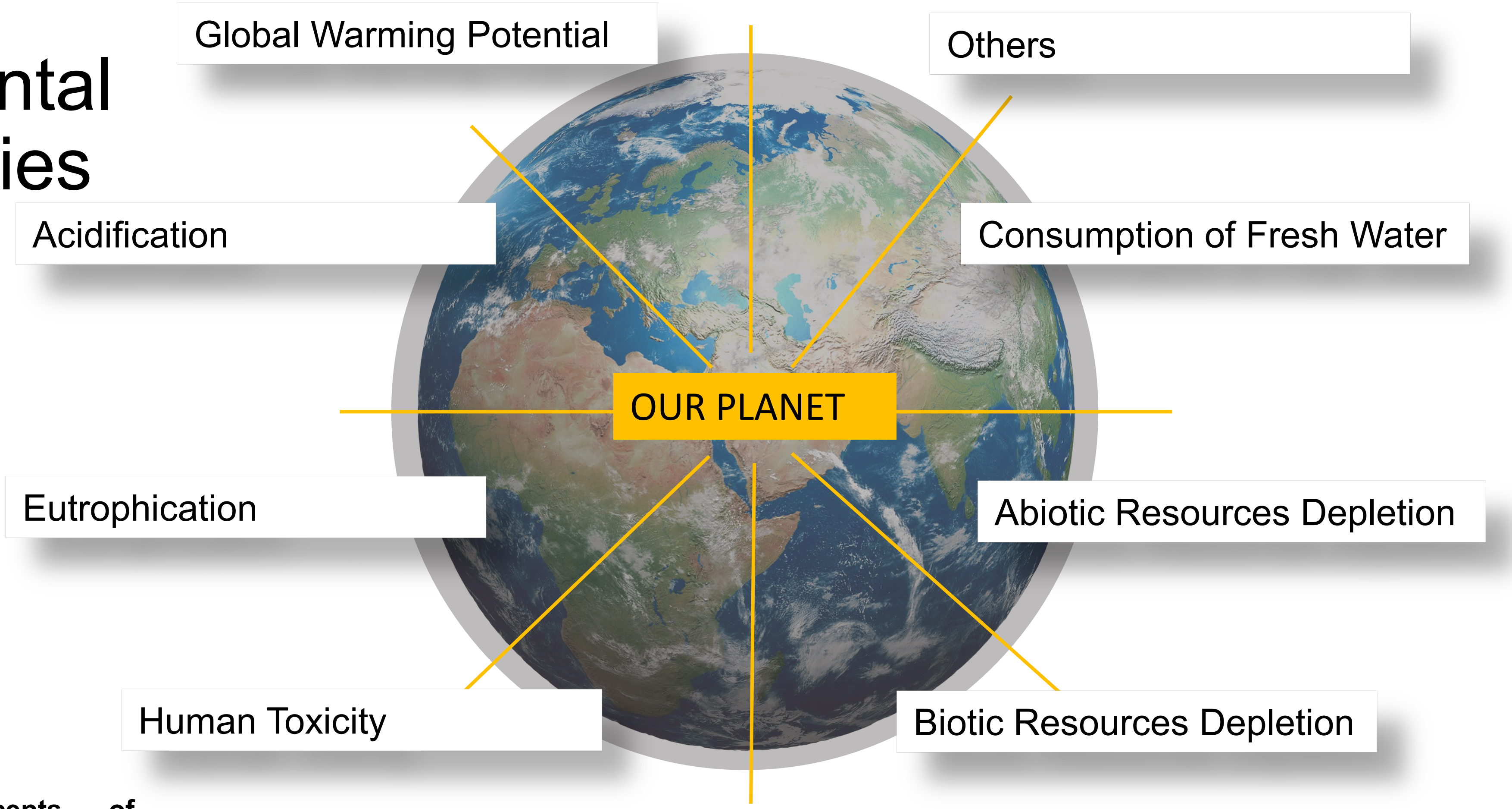

Figure 7 – Main Environmental Impact Categories

Sawyer, Clair N. **Basic Concepts of Eutrophication**. *Journal (Water Pollution Control Federation)*, vol. 38, no. 5, 1966, pp. 737–744. *JSTOR*, www.jstor.org/stable/25035549. [accessed on 7/3/2021]

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Life Cycle - Definitions

Life Cycle: consecutive and interlinked stages, from raw material acquisition or generation from natural resources to final disposal.

British Standards (BS) EN ISO 14040:2006 + A1:2020, (2020), ***Environmental Management – Life Cycle Assessment – Principles and Framework***. BSI Standards Publication. London. Pp 1-8. ISBN 978 0 539 01348 1.

ISO is an independent, non-governmental international organization with a membership of 165 [national standards bodies](). Through its members, it brings together experts to share knowledge and develop voluntary, consensus-based, market relevant International Standards that support innovation and provide solutions to global challenges.

Information available at : https://www.iso.org/about-us.html [accessed on 5/3/2021].

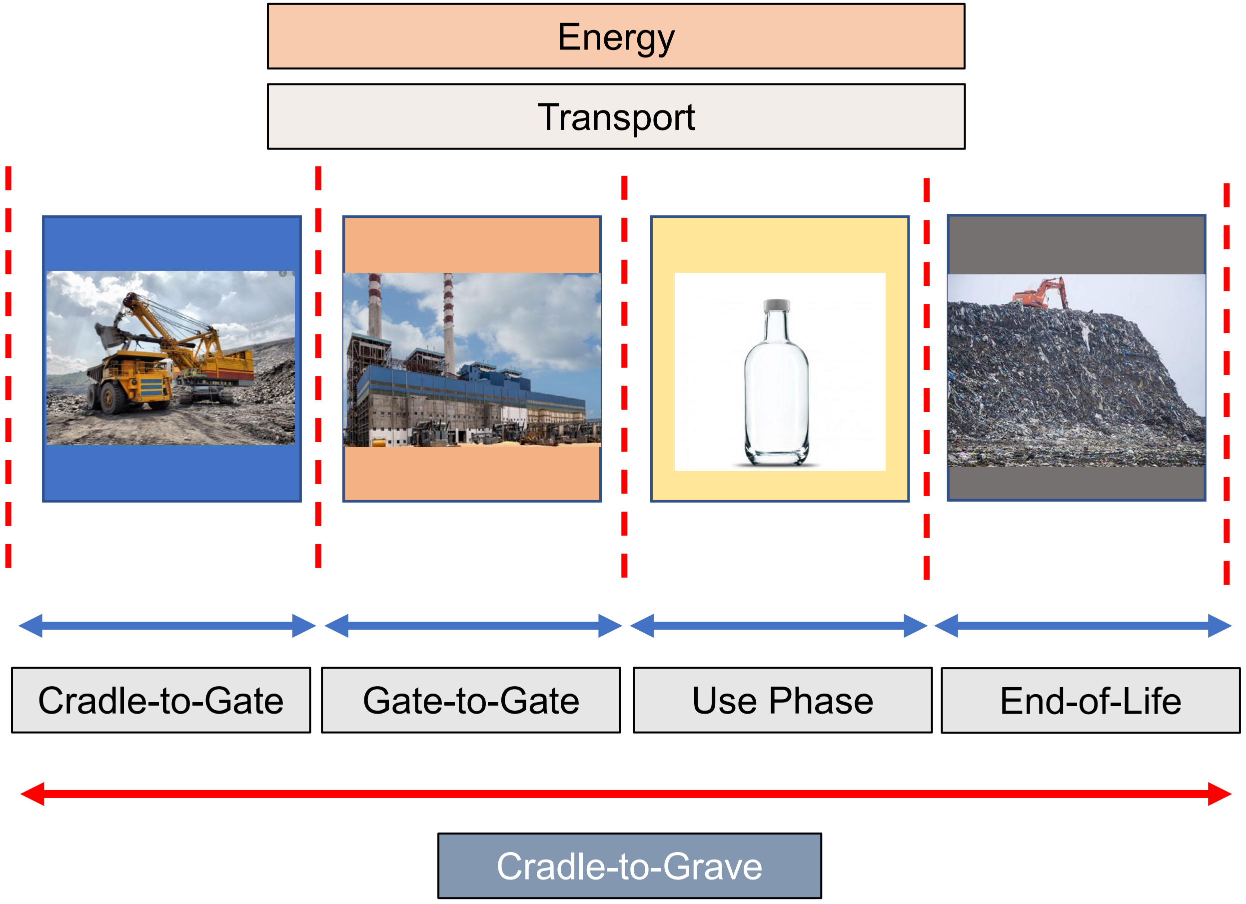

Figure 8 – Cradle-to-Grave Life Cycle of a Glass Bottle

Life Cycle Assessment

Life Cycle Assessment - LCA: compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle.

Goal & Scope Definitions:

- **Goal** refers to the intended application, the reason for the study in addition to the intended audience and communication.
- **Scope** refers to the product system to be studied, the functions, the functional unit, the system boundaries, the impact categories, data quality, etc.

British Standards (BS) EN ISO 14040:2006 + A1:2020, (2020), ***Environmental Management – Life Cycle Assessment – Principles and Framework***. BSI Standards Publication. London. Pp 1-8. ISBN 978 0 539 01348 1.

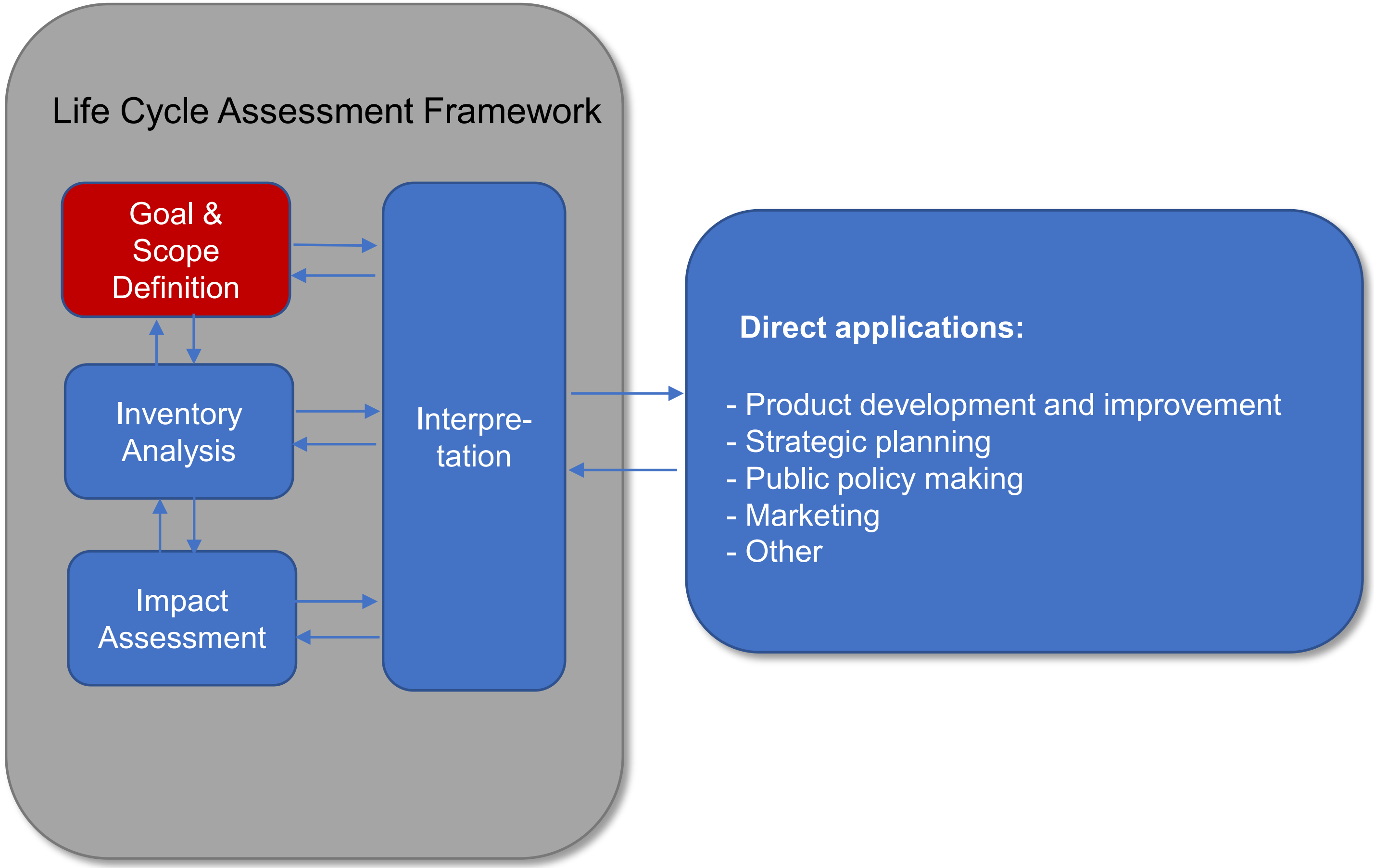

Figure 9 – Phases of an LCA Framework – Goal & Scope

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Life Cycle Assessment

Life Cycle Inventory Analysis - LCI: phase of life cycle assessment involving the compilation and quantification of inputs and outputs for a product throughout its life cycle.

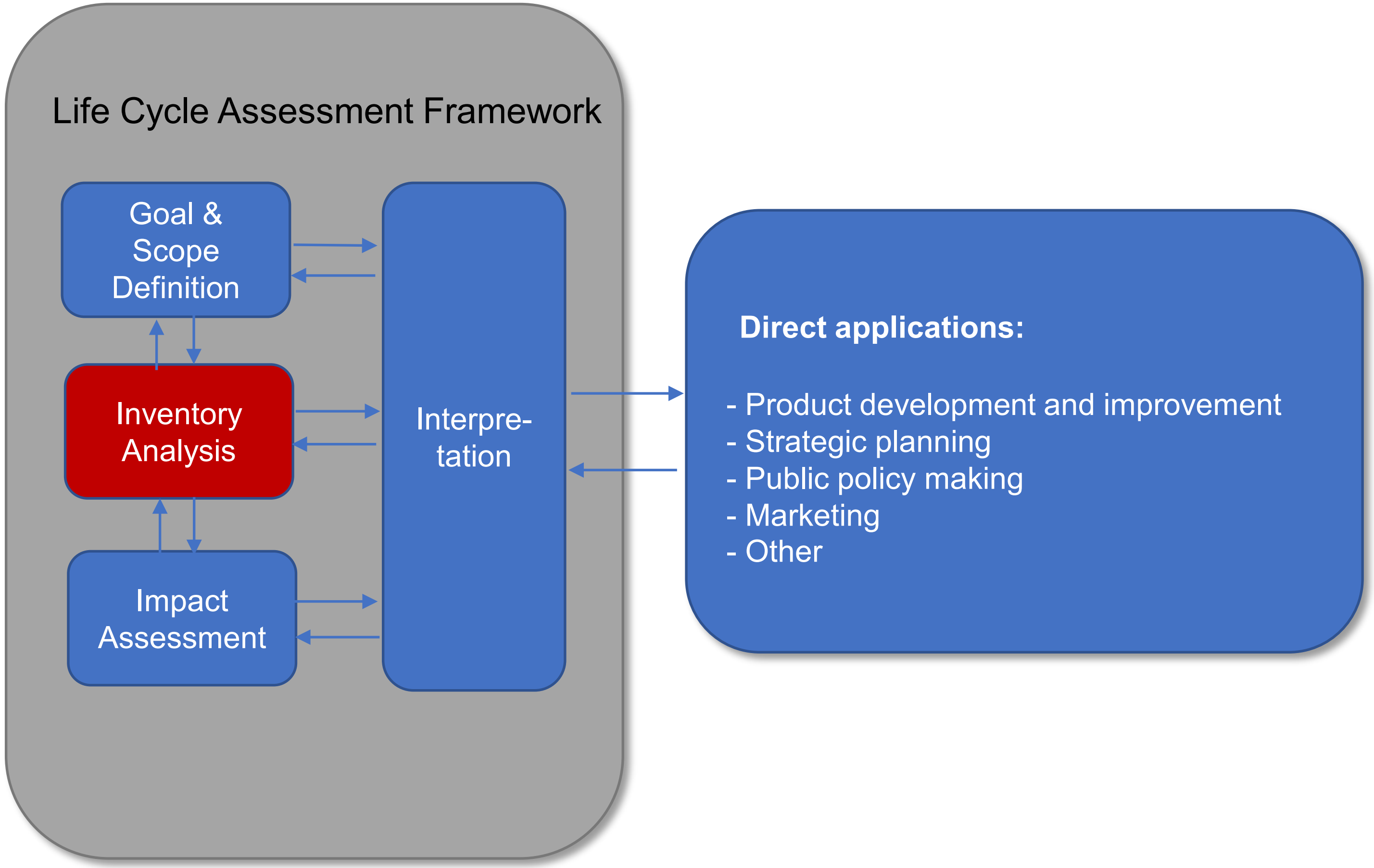

Figure 10 – Phases of an LCA Framework – Inventory Analysis

British Standards (BS) EN ISO 14040:2006 + A1:2020, (2020), ***Environmental Management – Life Cycle Assessment – Principles and Framework***. BSI Standards Publication. London. Pp 1-8. ISBN 978 0 539 01348 1.

Life Cycle Assessment

Life Cycle Impact Assessment - LCIA: phase of life cycle assessment aimed at understanding and evaluating the magnitude and significance of the potential environmental impacts for a product system throughout the life cycle of the product.

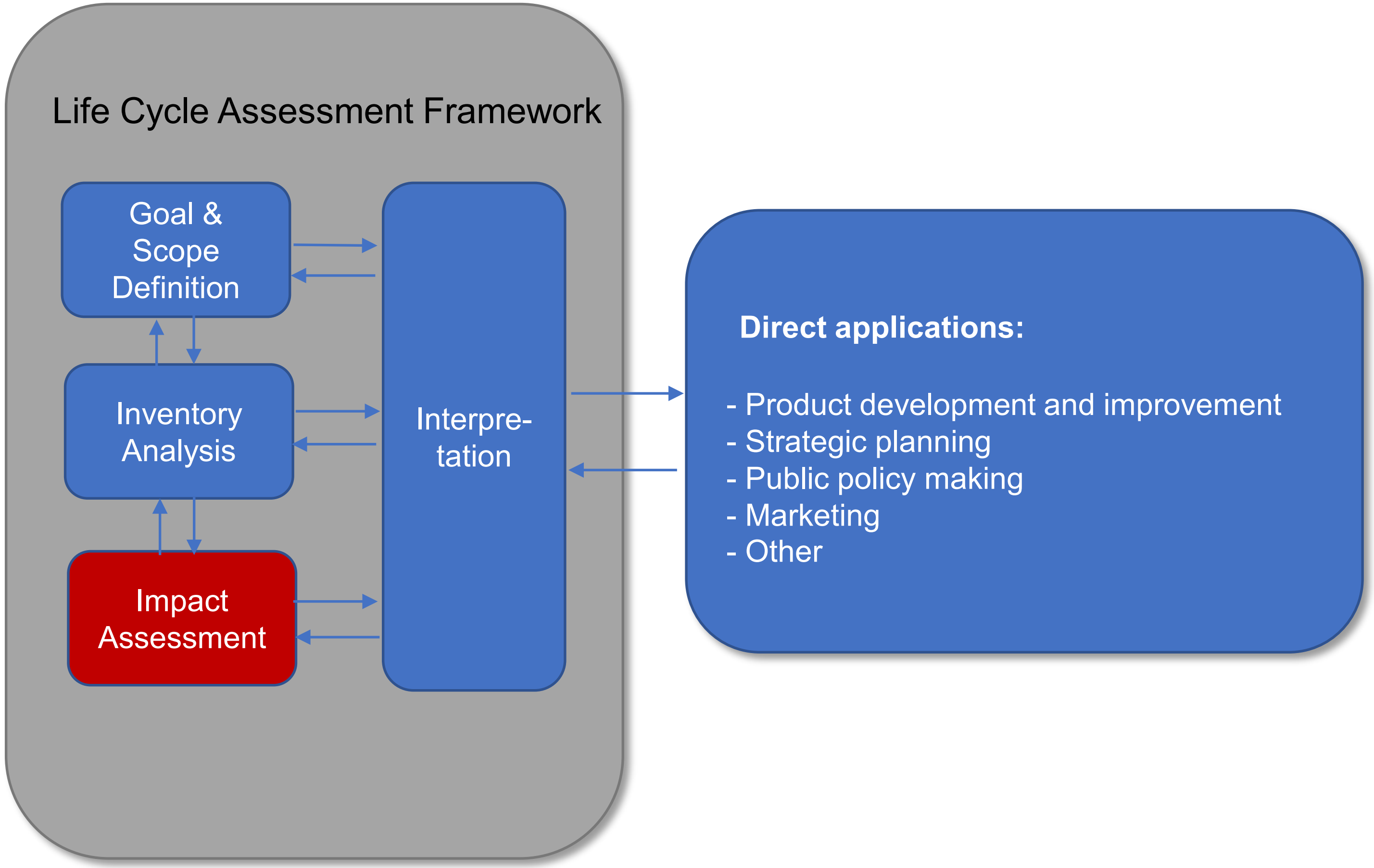

Figure 11 – Phases of an LCA Framework – Impact Assessment

British Standards (BS) EN ISO 14040:2006 + A1:2020, (2020), ***Environmental Management – Life Cycle Assessment – Principles and Framework***. BSI Standards Publication. London. Pp 1-8. ISBN 978 0 539 01348 1.

Life Cycle Assessment

Life Cycle Interpretation: phase of life cycle assessment in which the findings of either the inventory analysis or the impact assessment, or both, are evaluated in relation to the defined goal and scope in order to reach conclusions and recommendations.

British Standards (BS) EN ISO 14040:2006 + A1:2020, (2020), ***Environmental Management – Life Cycle Assessment – Principles and Framework***. BSI Standards Publication. London. Pp 1-8. ISBN 978 0 539 01348 1.

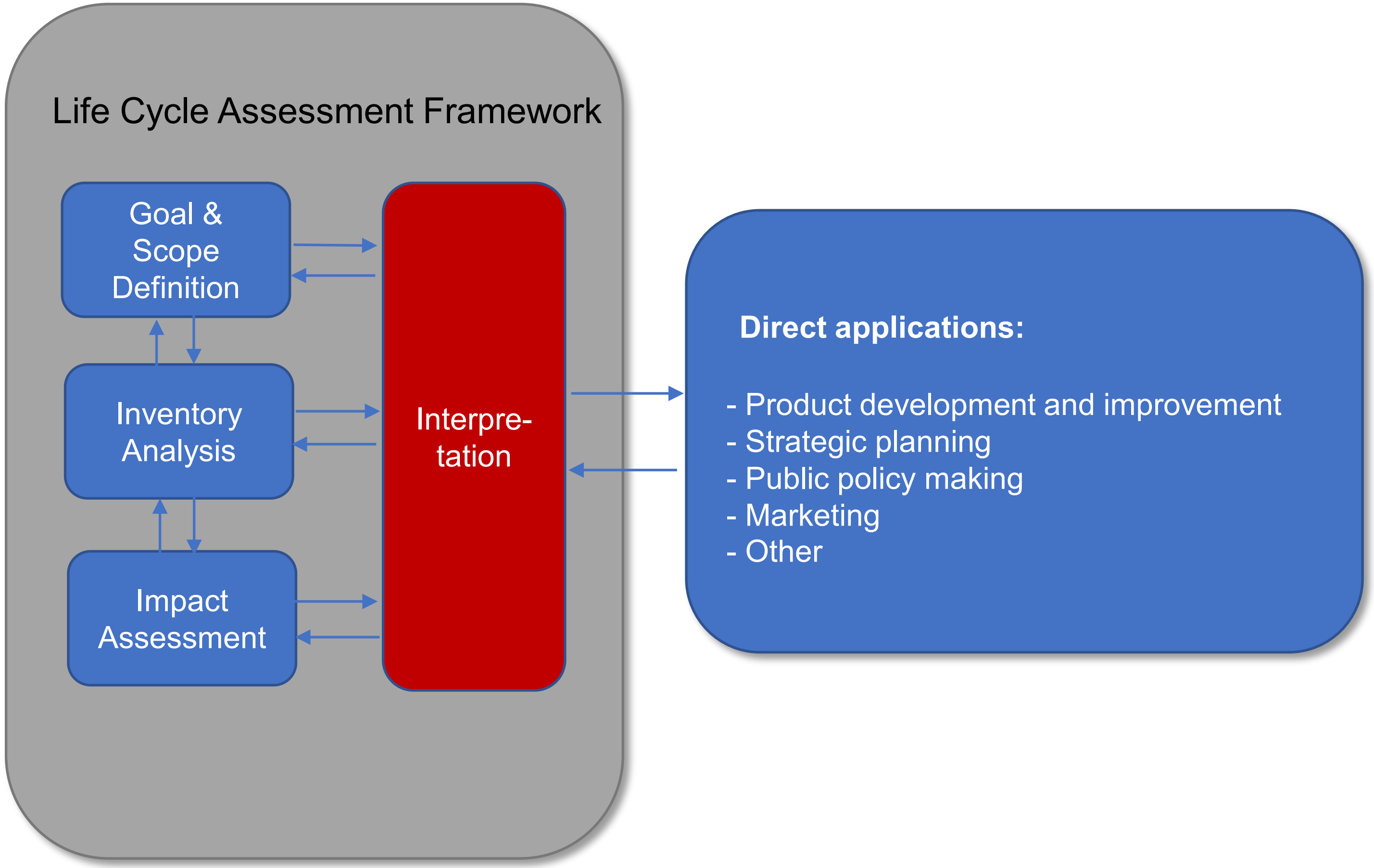

Figure 12 – Phases of an LCA Framework - Interpretation

Life Cycle Assessment

Direct Applications are: 1. improve a given product/service in comparison to a benchmark or alternative; 2. & 3. set basis for related strategic planning or public policy making; 4. market the product/service (such as EPD or environmental Product Declaration); 5. Others.

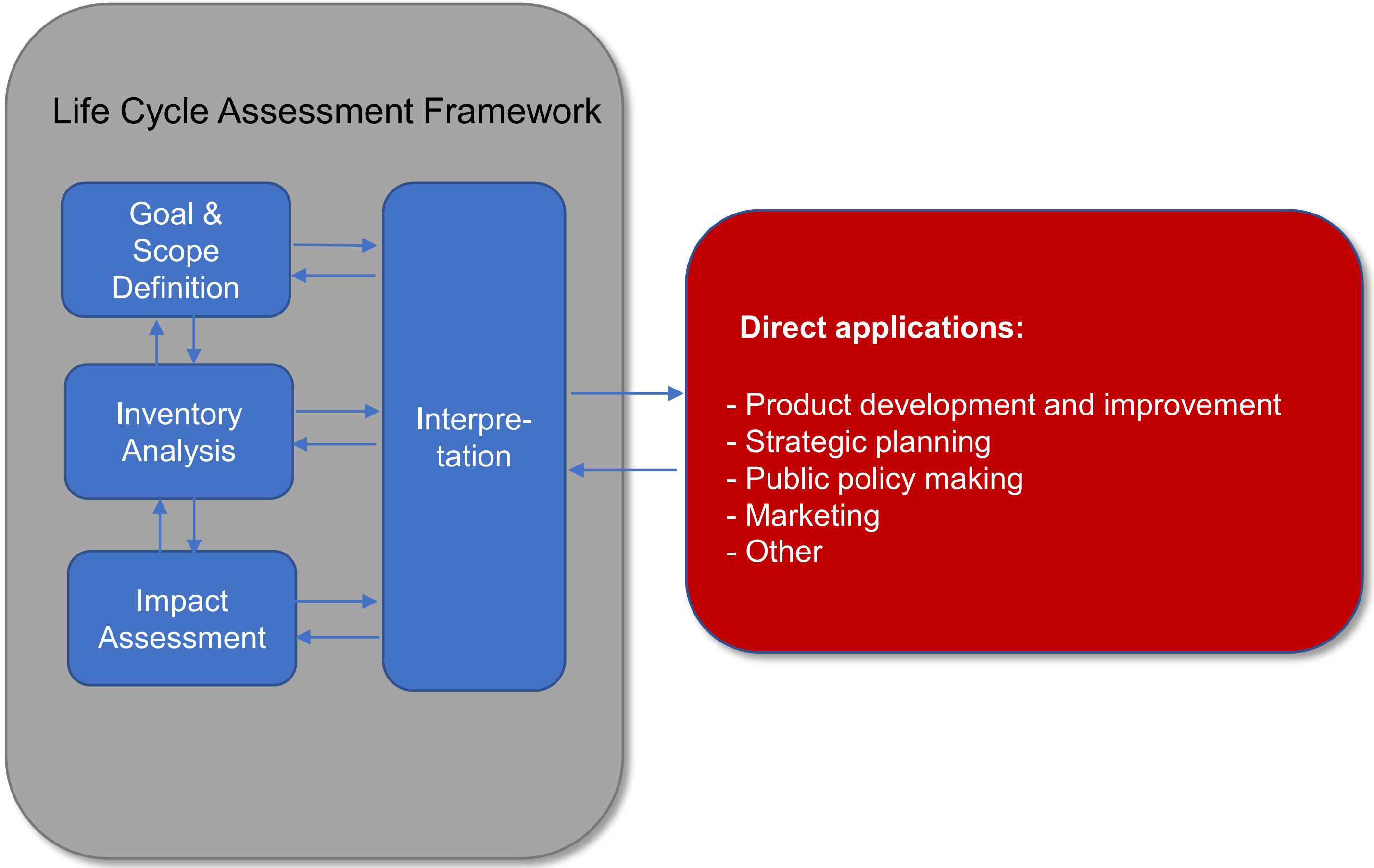

Figure 13 – Phases of an LCA Framework – Direct Applications

British Standards (BS) EN ISO 14040:2006 + A1:2020, (2020), ***Environmental Management – Life Cycle Assessment – Principles and Framework***. BSI Standards Publication. London. Pp 1-8. ISBN 978 0 539 01348 1.

Life Cycle Impact Assessment

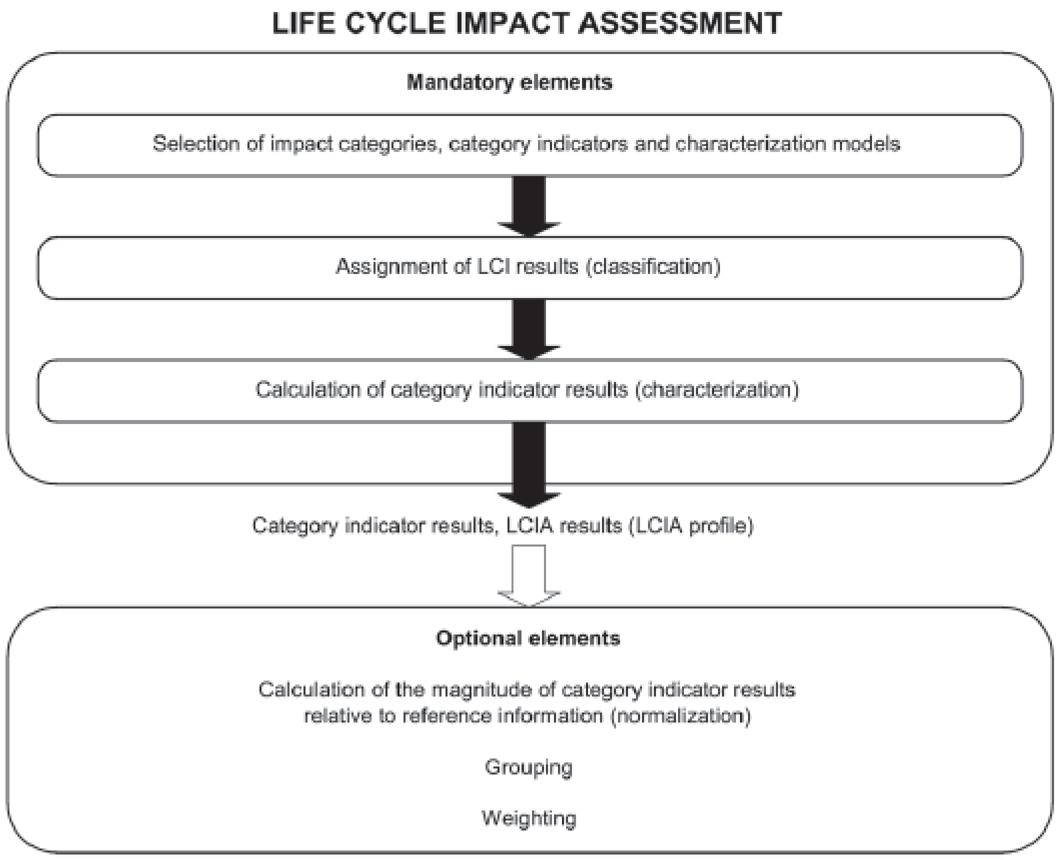

Figure 14 – Elements of the LCIA Phase

British Standards (BS) EN ISO 14040:2006 + A1:2020, (2020), ***Environmental Management – Life Cycle Assessment – Principles and Framework***. BSI Standards Publication. London. Pp 1-8. ISBN 978 0 539 01348 1.

Examples

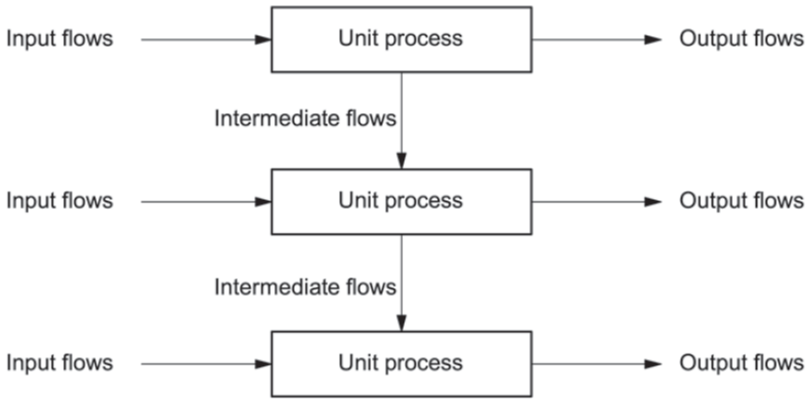

Figure 15 – Example of a set of unit processes within a product system

British Standards (BS) EN ISO 14040:2006 + A1:2020, (2020), ***Environmental Management – Life Cycle Assessment – Principles and Framework***. BSI Standards Publication. London. Pp 1-8. ISBN 978 0 539 01348 1.

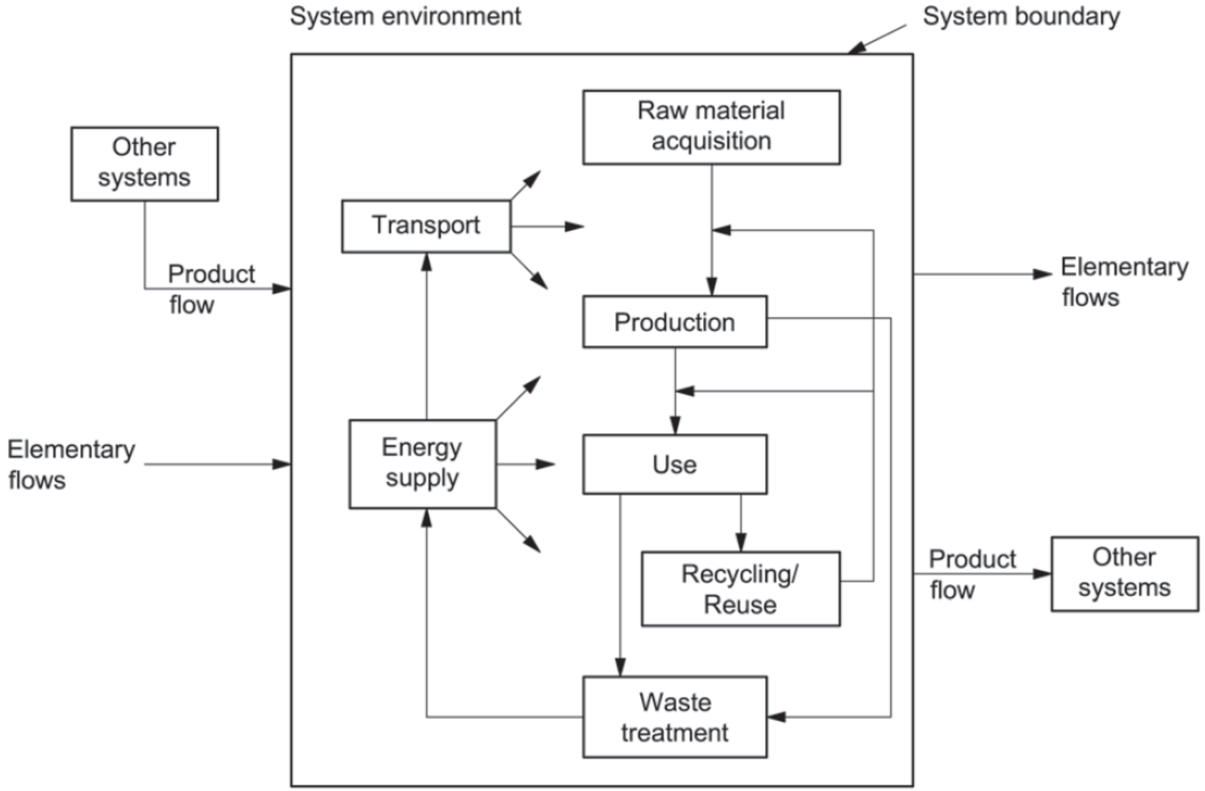

Figure 16 – Example of a product system for LCA

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Life cycle assessment of supermarket carrier bags: a review of the bags available in 2006

Case Study: Life Cycle Assessment Framework

Table 1 – Seven Carrier Bags Types in UK Supermarkets in 2006

Bag type	Picture example	Weight* [g]	Volume capacity* [litres]
Conventional HDPE bag		7.5 – 12.6	17.9 – 21.8
HDPE with prodegradant additive		5.9 – 8.2	16 – 19.6
Heavy duty LDPE bag ('bag for life')		27.5 – 42.5	19.1 – 23.9
Non-woven PP bag		107.6 - 124.1	17.7 – 21.8
Paper bag		55.2	20.1
Biopolymer bag		15.8	18.3
Cotton bag		78.7 – 229.1	17 – 33.4

The following types of carrier bags were studied:

- a conventional, lightweight carrier made from high-density polyethylene (HDPE);
- a lightweight HDPE carrier with a pro-degradant additive designed to breakdown the plastic into smaller pieces;
- A "bag for life" made from low-density polyethylene (LDPE)
- A heavier more durable bag, often with stiffening inserts made from non woven polypropylene(PP)
- A paper carrier;
- A biodegradable carrier made from starch-polyester (biopolymer) blend; and
- A cotton bag.

U.K. Environment Agency (2011) - ***Evidence. Life cycle assessment of supermarket carrier bags: a review of the bags available in 2006***. Report: SC030148. U.K. ISBN: 978-1-84911-226-0

Life cycle assessment of supermarket carrier bags: a review of the bags available in 2006

Case Study

Goal & Scope

Goal is to assess the potential life cycle environmental impacts of the various bags:

- Compile life cycle inventory data
- Use the data to compare environmental impacts
- Compare results and identify significant differences among products.

U.K. Environment Agency (2011) - ***Evidence. Life cycle assessment of supermarket carrier bags: a review of the bags available in 2006***. Report: SC030148. U.K. ISBN: 978-1-84911-226-0

Scope is as follows:

1. To define a **functional unit** based on comparable results: "**Carrying one month's shopping (483 items) from the supermarket to the home in the UK in 2006/07".**

2. To determine the **reference flow**: the number of carrier bags required to fulfil the functional unit. This depends on the bag characteristics (volume, weight, strength, etc.).

3. To define the **system boundaries**: cradle-to-grave. These are all inputs and outputs from the system. However, they are determined to be either elementary flows, or materials or energy. Thus, the study quantifies all energy and materials used from extraction of resources to the emissions from each life cycle stage including waste management.

Life cycle assessment of supermarket carrier bags: a review of the bags available in 2006

Case Study

Reference Flows

Table 2 – The Reference Flow for Each Bag Type

Bag type	Volume per bag (litres)	Weight per bag (g)	Items per bag	Refflow – No. bags
Conventional high-density polyethylene (HDPE) bag	19.1	8.12	5.88	82.14
High-density polyethylene (HDPE) bag with a prodegradant additive	19.1	8.27	5.88	82.14
Starch-polyester blend bag	19.1	16.49	5.88	82.14
Paper bag	20.1	55.20	7.43	64.98
Low-density polyethylene (LDPE) bag	21.52	34.94	7.96	60.68
Non-woven polypropylene (PP) bag	19.75	115.83	7.30	66.13
Cotton bag	28.65	183.11	10.59	45.59

U.K. Environment Agency (2011) - ***Evidence. Life cycle assessment of supermarket carrier bags: a review of the bags available in 2006***. Report: SC030148. U.K. ISBN: 978-1-84911-226-0

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Life cycle assessment of supermarket carrier bags: a review of the bags available in 2006

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General Units Processes

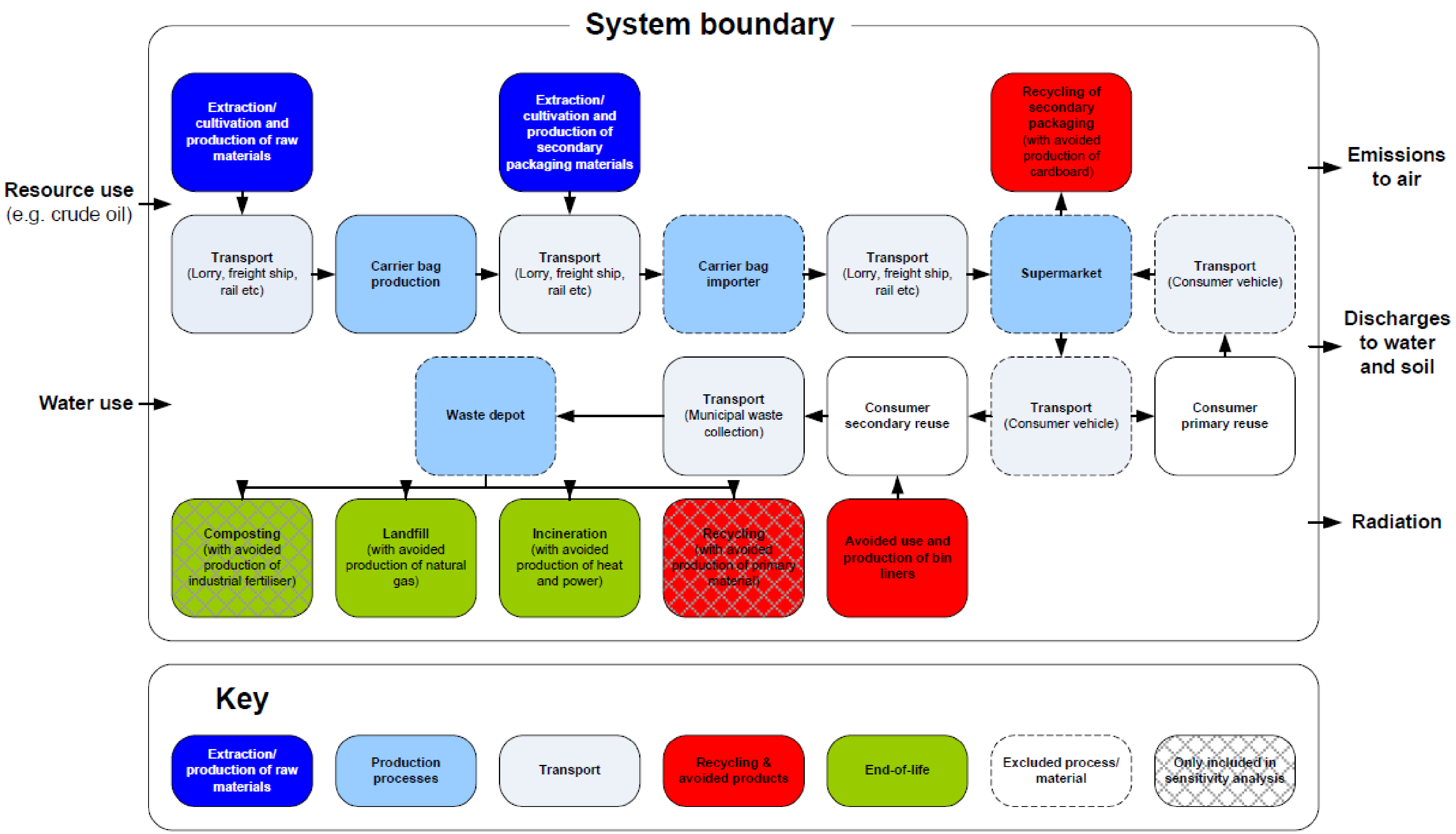

Figure 17 – General Processes for each of the Seven Carrier Bags

U.K. Environment Agency (2011) - ***Evidence. Life cycle assessment of supermarket carrier bags: a review of the bags available in 2006***. Report: SC030148. U.K. ISBN: 978-1-84911-226-0

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Life cycle assessment of supermarket carrier bags: a review of the bags available in 2006

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Energy / Waste

Table 3 – Energy Consumption for film and cotton bags (per 1000 bags)

Bag type	Electricity	Heat (from natural gas)	Heat (from heavy fuel oil)	Waste
Conventional high-density polyethylene (HDPE) bag	6.151 kWh (22.144 MJ) (0.758 kWh/kg)			418.4 g
High-density polyethylene (HDPE) bag with a prodegradant additive	6.392 kWh (23.011 MJ) (0.773 kWh/kg)			426.1 g
Starch-polyester blend bag	17.24 kWh (62.064 MJ) (1.045 kWh/kg)			94.8 g
Low-density polyethylene (LDPE) bag	32.58 kWh (117.288 MJ) (0.932 kWh/kg)	13.953 kWh (50.23 MJ) (0.399 kWh/kg)		171.2 g*
Non-woven polypropylene (PP) bag			87.75 kWh (315.9 MJ) (0.758 kWh/kg)	5,850 g
Cotton bag	11 kWh (39.6 MJ) (0.06 kWh/kg) *			1,800 g*

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Life cycle assessment of supermarket carrier bags: a review of the bags available in 2006

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Transport

Table 4 – Transport Modes and Distances

Bag type	From	To	Transport modes	Distance
Conventional high-density polyethylene (HDPE) bag	Polymer resin producer in Far East	Bag producer in Far East	Lorry Sea freight	100 km 500 km
	Titanium oxide and chalk producer in Far East	Bag producer in Far East	Lorry Sea freight	200 km 500 km
	Bag producer in Far East	Bag importer in UK	Lorry Sea freight Rail	100 km 15,000 km 280 km
	Bag importer	Supermarket	Lorry	200 km
High-density polyethylene (HDPE) bag with a prodegradant additive	Polymer resin producer in Far East	Bag producer in Far East	Lorry Sea freight	65 km 500 km
	Titanium oxide and chalk producer in Far East	Bag producer in Far East	Lorry Sea freight	200 km 500 km
	Bag producer in Far East	Bag importer in UK	Lorry Sea freight Rail	100 km 15,000 km 280 km
	Bag importer	Supermarket	Lorry	200 km
Starch-polyester blend bag	Polymer resin producer in Italy	Bag producer in Norway	Lorry	3,500 km
	Titanium oxide producer in Europe	Bag producer in Norway	Lorry	200 km
	Bag producer in Norway	Bag importer in UK	Lorry Sea freight Rail	100 km 1,200 km 200 km
	Bag importer	Supermarket	Lorry	200 km

Bag type	From	To	Transport modes	Distance
Paper bag	Bag producer in Europe	Bag importer in UK	Lorry	1,000 km
	Bag importer	Supermarket	Lorry	200 km
Low-density polyethylene (LDPE) bag	Polymer resin producer in Europe	Bag producer in Turkey	Lorry	300 km
	Bag producer in Turkey	Bag importer in UK	Sea freight Rail	5,000 km 280 km
	Polymer resin producer in Far East	Bag producer in Far East	Lorry Sea freight	100 km 500 km
	Titanium oxide producer in Far East	Bag producer in Far East	Lorry Sea freight	200 km 500 km
	Bag producer in Far East	Bag importer in UK	Lorry Sea freight Rail	100 km 15,000 km 280 km
	Bag importer	Supermarket	Lorry	200 km
Non-woven polypropylene (PP) bag	Polymer resin producer in Far East	Bag producer in Far East	Lorry	100 km
	Bag producer in Far East	Bag importer in UK	Lorry Sea freight Rail	100 km 15,000 km 280 km
	Bag importer	Supermarket	Lorry	200 km
Cotton bag	Textile producer in China	Bag producer in China	Lorry	100 km
	Bag producer in China	Bag importer in UK	Lorry Sea freight Lorry	100 km 15,000 km 280 km
	Bag importer	Supermarket	Lorry	200 km

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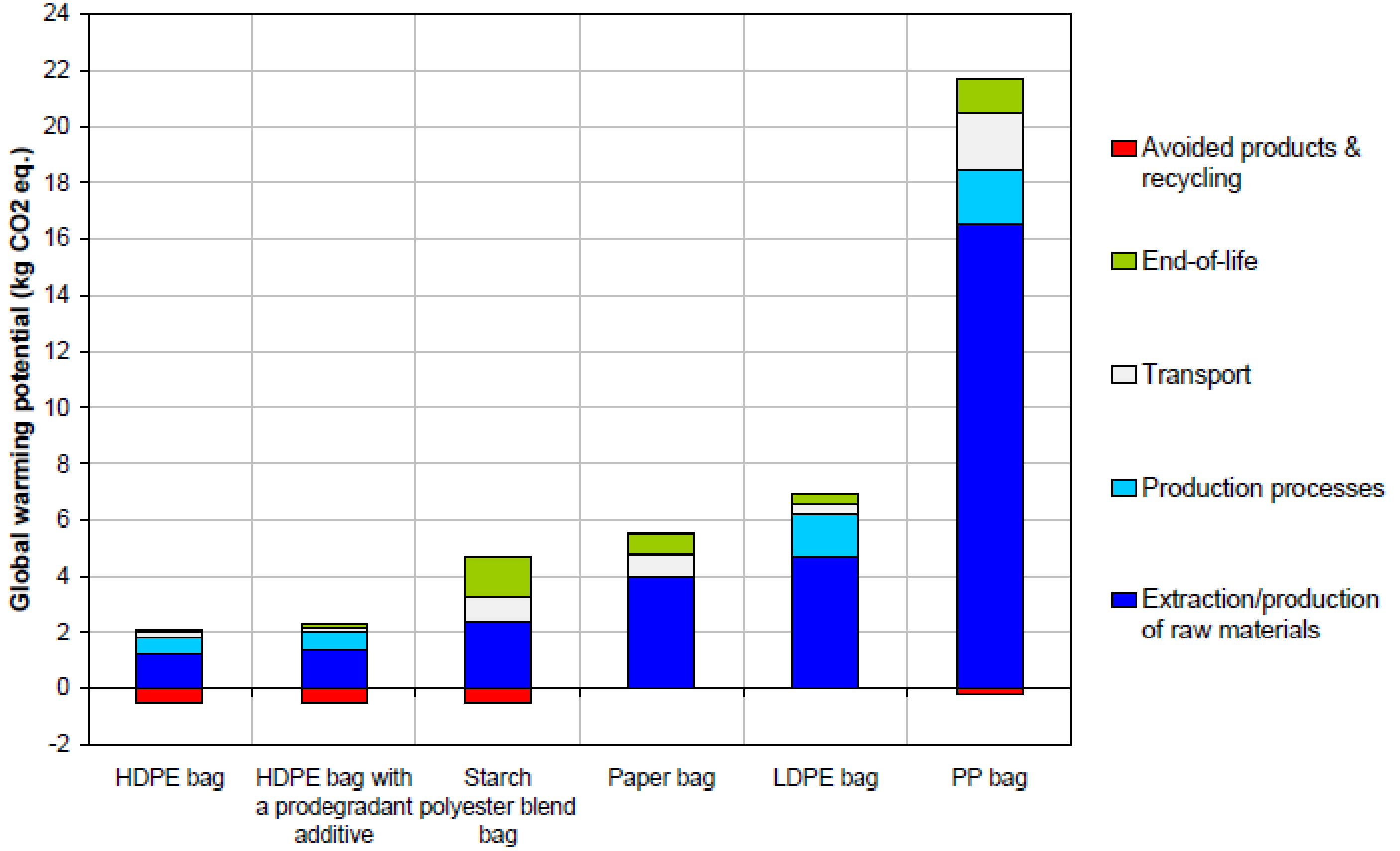

Figure 18 – The Life Cycle Impacts of Each Carrier Bag on the GWP

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Life cycle assessment of supermarket carrier bags: a review of the bags available in 2006

Impact category	Unit	Total
Global warming potential	kg CO2 eq	1.578
Abiotic depletion	g Sb eq	16.227
Acidification	g SO2 eq	11.399
Eutrophication	g PO4--- eq	0.775
Human toxicity	kg 1,4-DB eq	0.211
Fresh water aquatic ecotox.	g 1,4-DB eq	66.880
Marine aquatic ecotoxicity	kg 1,4-DB eq	126.475
Terrestrial ecotoxicity	g 1,4-DB eq	1.690
Photochemical oxidation	g C2H4	0.531

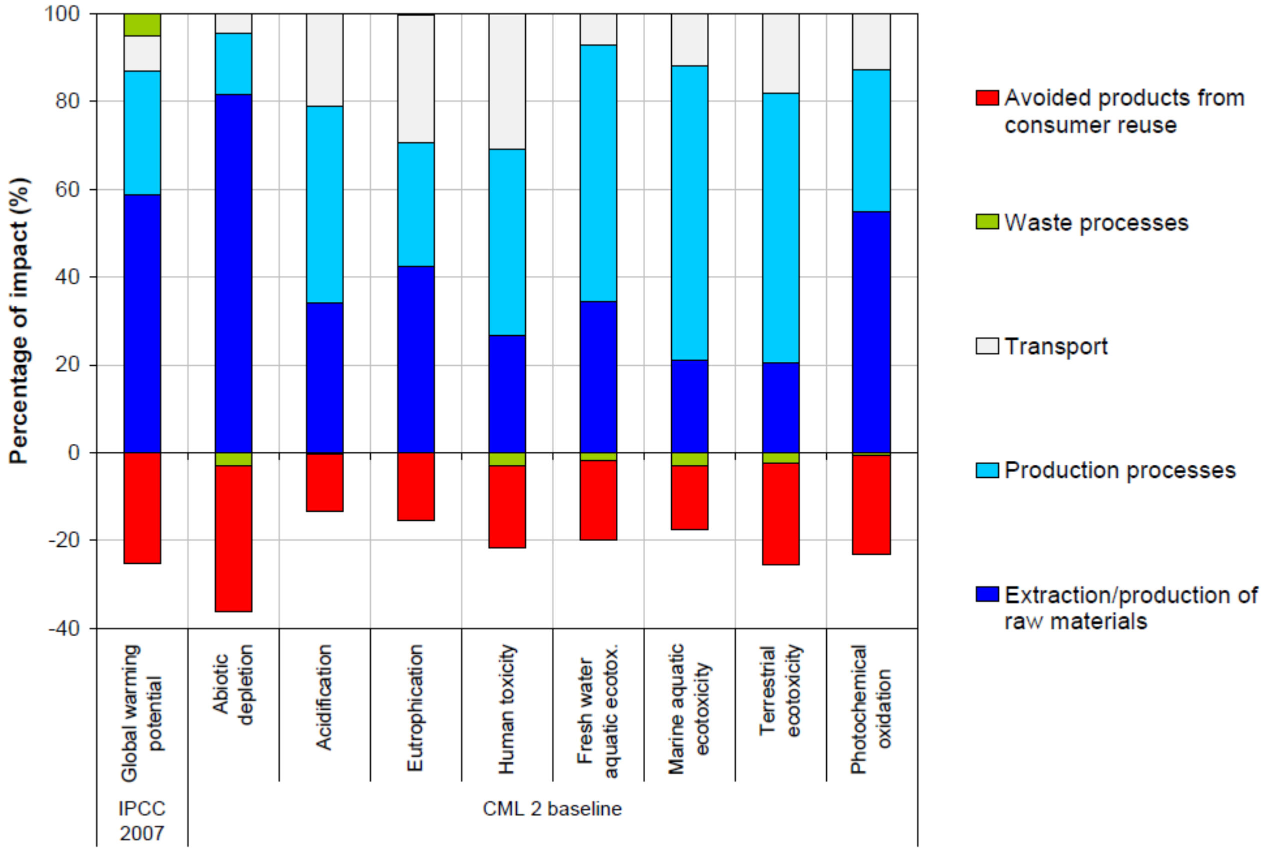

Figure 19 – The Environmental Impact of the HDPE bag

U.K. Environment Agency (2011) - ***Evidence. Life cycle assessment of supermarket carrier bags: a review of the bags available in 2006***. Report: SC030148. U.K. ISBN: 978-1-84911-226-0

Case Study

Life cycle assessment of supermarket carrier bags: a review of the bags available in 2006

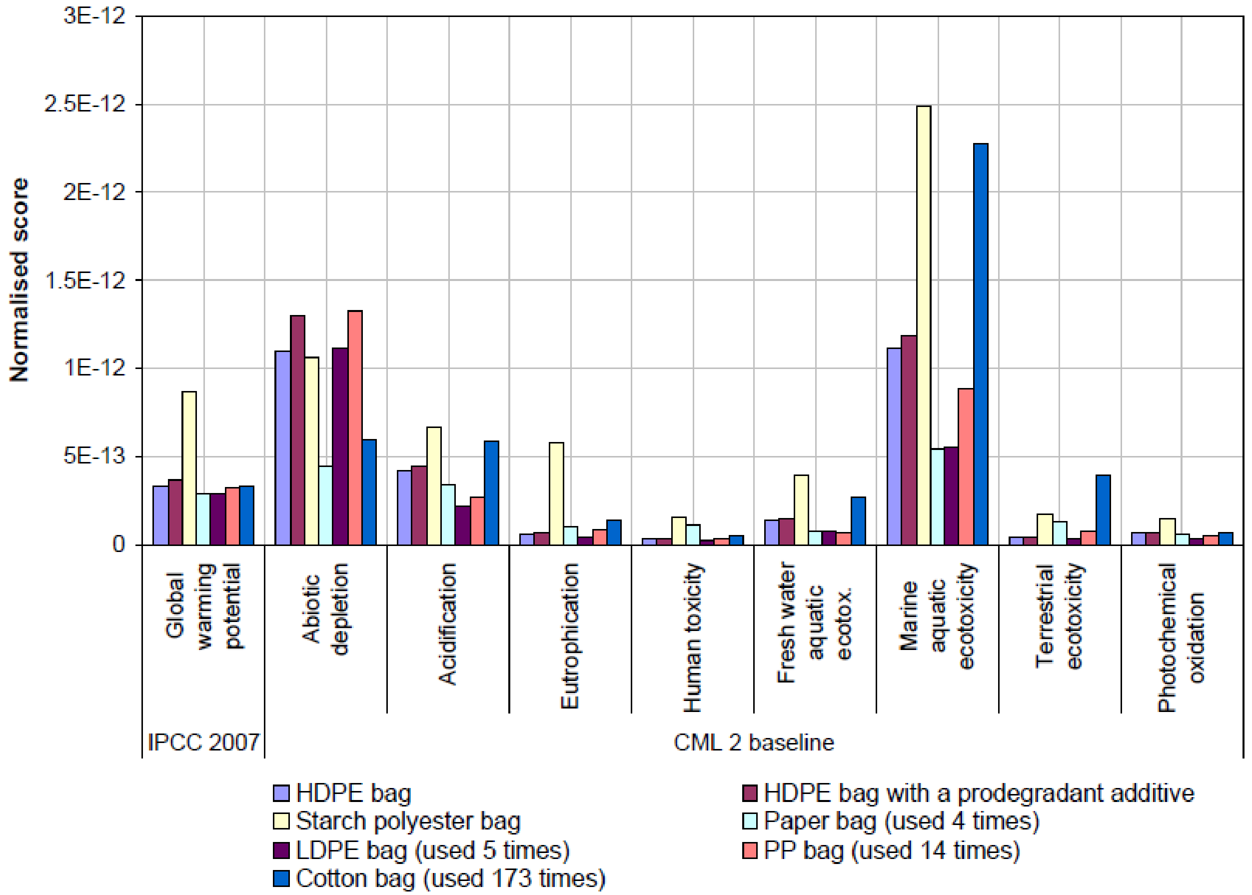

Figure 20 – The Normalized Results of the Impact Assessment

U.K. Environment Agency (2011) - ***Evidence. Life cycle assessment of supermarket carrier bags: a review of the bags available in 2006***. Report: SC030148. U.K. ISBN: 978-1-84911-226-0

Life cycle assessment of supermarket carrier bags: a review of the bags available in 2006

Case Study

Conclusion:

According to the study above, the starch-polyester carrier bags had the highest impact on every category apart from abiotic resource depletion.

Impact on GWP is explained due to the :

- Greater weight in comparison with conventional HDPE and HDPE pro-degradant bags.
- The large transport distance by road
- The impact from its landfill.

In conclusion, the starch-polyester bag us worse than the conventional plastic bags due to the high impacts of raw material production, transport and landfill mainly on global warming potential, eutrophication, toxicity and ecotoxicity.

Note: Starch polyester is a biodegradable polymer composite.

U.K. Environment Agency (2011) - *Evidence. Life cycle assessment of supermarket carrier bags: a review of the bags available in 2006*. Report: SC030148. U.K. ISBN: 978-1-84911-226-0

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