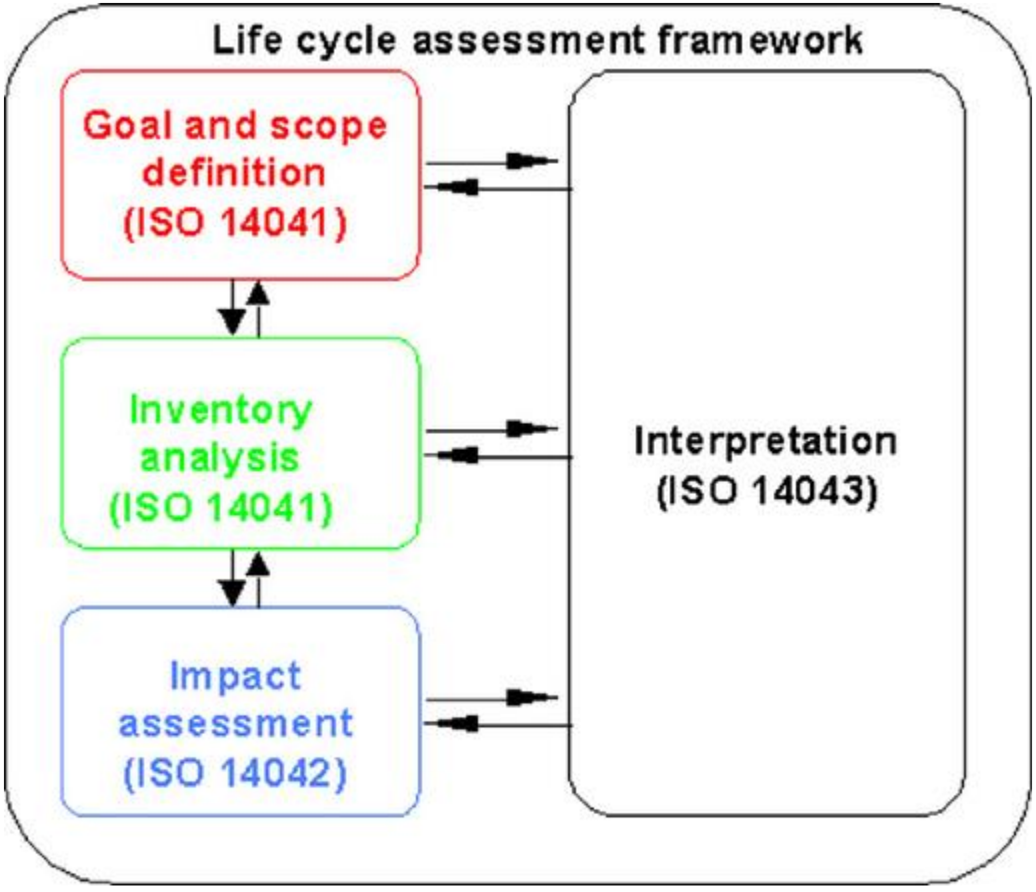

Life Cycle Assessment

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Life Cycle Assessment

LCA is an objective process to evaluate the environmental burdens associated with a PRODUCT, PROCESS, or ACTIVITY by:

1. Identifying and Qualifying Energy and Material Uses and Releases on the Environment (*Inventory analysis*),
2. Assessing the Impact of Those Energy and Material Uses and Releases on the Environment (*Impact Analysis*),
3. Evaluating and Implementing Opportunities to Effect Environmental Improvements (*Improvement Analysis*).

Life Cycle of Stuff

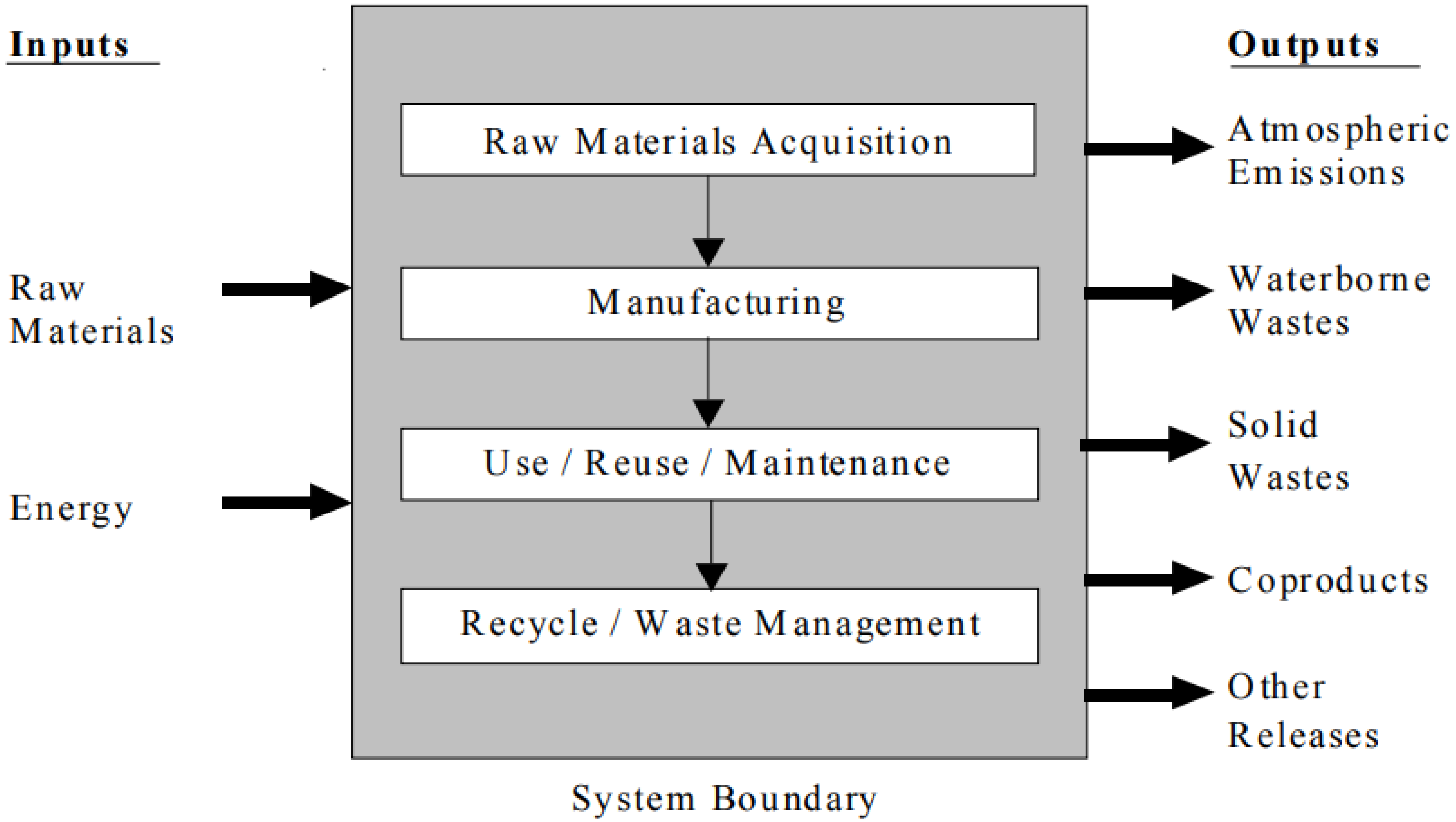
The assessment includes the entire life-cycle of the product, process or activity encompassing extraction and processing of raw materials, manufacturing, transportation and distribution, use/reuse, recycling and final disposal.

Curran, M. AND B. Lignon. EPA'S RESEARCH IN LCA METHODOLOGY. U.S. Environmental Protection Agency, Washington, D.C., EPA/600/A-93/154 (NTIS PB93212439), 1993.

Stages	**Green Tips**
Materials Extraction	Buy products made with recycled content
Manufacturing	Reduce
Distribution	Choose Sustainable and local products
Usage	Power down
End-of-Life Management	Donate your used electronics and media Recycle Start your own compost pile Be waste conscious

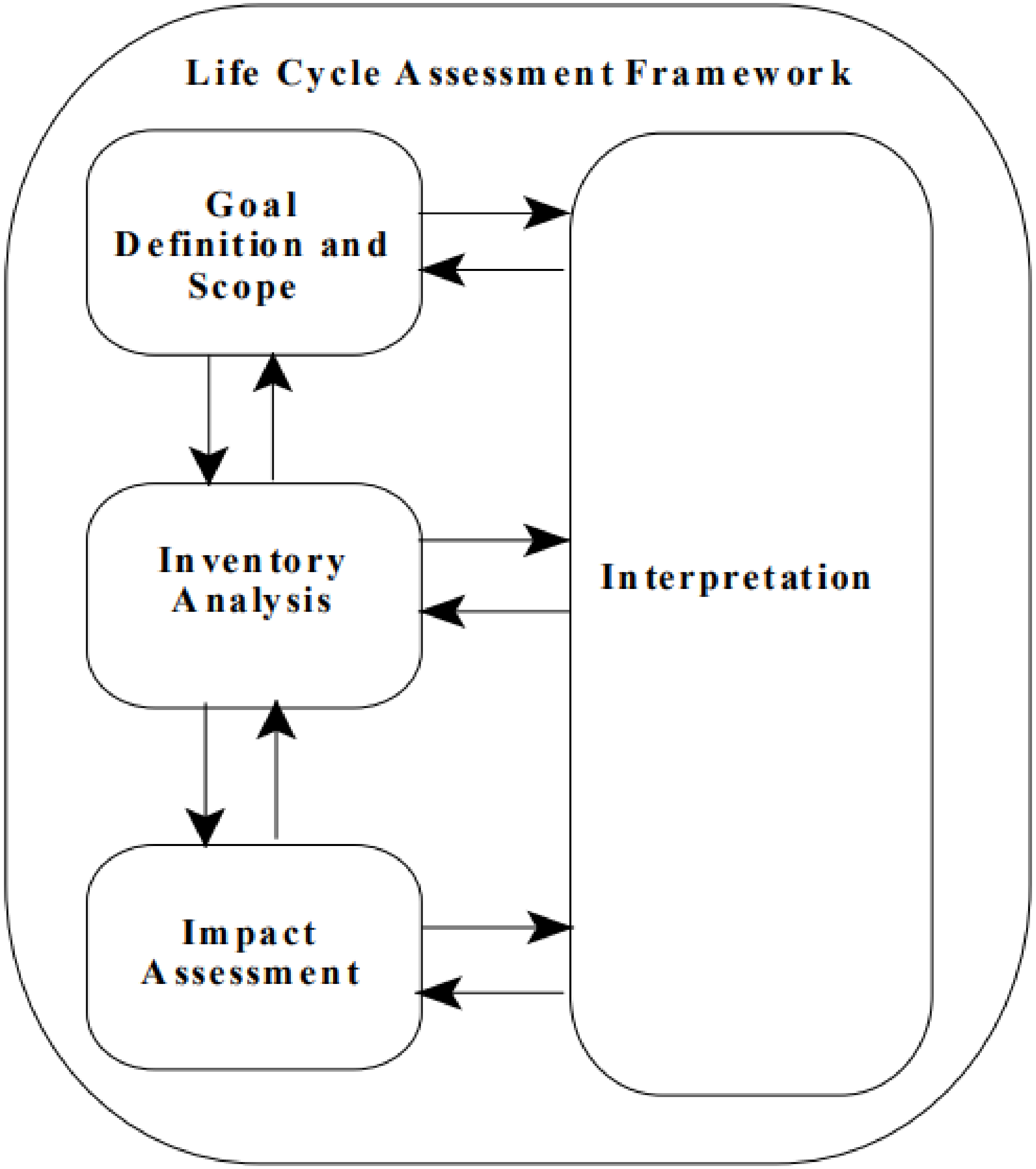
http://epa.gov/climatechange/climate-change-waste/life-cycle-diagram.html

Life Cycle Stages



Life Cycle Assessment: Principles and Practice, EPA/600/R-06/060, 2006

Phases of an LCA



Phases of an LCA

- Goal definition and scoping: the phase of the LCA process that defines the purpose and method of including life cycle environmental impacts into the decision-making process.
- Inventory Analysis: The identification and quantification of energy, resource usage, and environmental emissions for a particular product, process, or activity.
- Impact Assessment: The assessment of the environmental consequences of energy and natural resource consumption and waste releases associated with an actual or proposed action.

Commonly Used Life Cycle Impact Categories

Impact Category	Scale	Examples of LCI Data (i.e. classification)	Common Possible Characterization Factor	Description of Characterization Factor
Global Warming	Global	Carbon Dioxide (CO_2) Nitrogen Dioxide (NO_2) Methane (CH_4) Chlorofluorocarbons (CFCs) Hydrochlorofluorocarbons (HCFCs) Methyl Bromide (CH_3Br)	Global Warming Potential	Converts LCI data to carbon dioxide (CO_2) equivalents Note: global warming potentials can be 50, 100, or 500 year potentials.
Stratospheric Ozone Depletion	Global	Chlorofluorocarbons (CFCs) Hydrochlorofluorocarbons (HCFCs) Halons Methyl Bromide (CH_3Br)	Ozone Depleting Potential	Converts LCI data to trichlorofluoromethane (CFC-11) equivalents.
Acidification	Regional Local	Sulfur Oxides (SOx) Nitrogen Oxides (NOx) Hydrochloric Acid (HCL) Hydroflouric Acid (HF) Ammonia (NH_4)	Acidification Potential	Converts LCI data to hydrogen (H+) ion equivalents.

Commonly Used Life Cycle Impact Categories

Impact Category	Scale	Examples of LCI Data (i.e. classification)	Common Possible Characterization Factor	Description of Characterization Factor
Eutrophication	Local	Phosphate (PO_4) Nitrogen Oxide (NO) Nitrogen Dioxide (NO_2) Nitrates Ammonia (NH_4)	Eutrophication Potential	Converts LCI data to phosphate (PO_4) equivalents.
Photochemical Smog	Local	Non-methane hydrocarbon (NMHC)	Photochemical Oxident Creation Potential	Converts LCI data to ethane (C_2H_6) equivalents.
Terrestrial Toxicity	Local	Toxic chemicals with a reported lethal concentration to rodents	LC_{50}	Converts LC_{50} data to equivalents; uses multi-media modeling, exposure pathways.
Aquatic Toxicity	Local	Toxic chemicals with a reported lethal concentration to fish	LC_{50}	Converts LC_{50} data to equivalents; uses multi-media modeling, exposure pathways.

Commonly Used Life Cycle Impact Categories

Impact Category	Scale	Examples of LCI Data (i.e. classification)	Common Possible Characterization Factor	Description of Characterization Factor
Human Health	Global Regional Local	Total releases to air, water, and soil.	LC_{50}	Converts LC_{50} data to equivalents; uses multi-media modeling, exposure pathways.
Resource Depletion	Global Regional Local	Quantity of minerals used Quantity of fossil fuels used	Resource Depletion Potential	Converts LCI data to a ratio of quantity of resource used versus quantity of resource left in reserve.
Land Use	Global Regional Local	Quantity disposed of in a landfill or other land modifications	Land Availability	Converts mass of solid waste into volume using an estimated density.
Water Use	Regional Local	Water used or consumed	Water Shortage Potential	Converts LCI data to a ratio of quantity of water used versus quantity of resource left in reserve.

Impact Categories and Associated Endpoints

The following is a list of several impact categories and endpoints that identify the impacts.

Global Impacts

Global Warming - polar melt, soil moisture loss, longer seasons, forest loss/change, and change in wind and ocean patterns.

Ozone Depletion - increased ultraviolet radiation.

Resource Depletion -decreased resources for future generations.

Regional Impacts

Photochemical Smog - "smog," decreased visibility, eye irritation, respiratory tract and lung irritation, and vegetation damage.

Acidification - building corrosion, water body acidification, vegetation effects, and soil effects.

Local Impacts

Human Health - increased morbidity and mortality.

Terrestrial Toxicity - decreased production and biodiversity and decreased wildlife for hunting or viewing.

Aquatic Toxicity - decreased aquatic plant and insect production and biodiversity and decreased commercial or recreational fishing.

Eutrophication – nutrients (phosphorous and nitrogen) enter water bodies, such as lakes, estuaries and slow-moving streams, causing excessive plant growth and oxygen depletion.

Land Use - loss of terrestrial habitat for wildlife and decreased landfill space.

Water Use - loss of available water from groundwater and surface water sources.

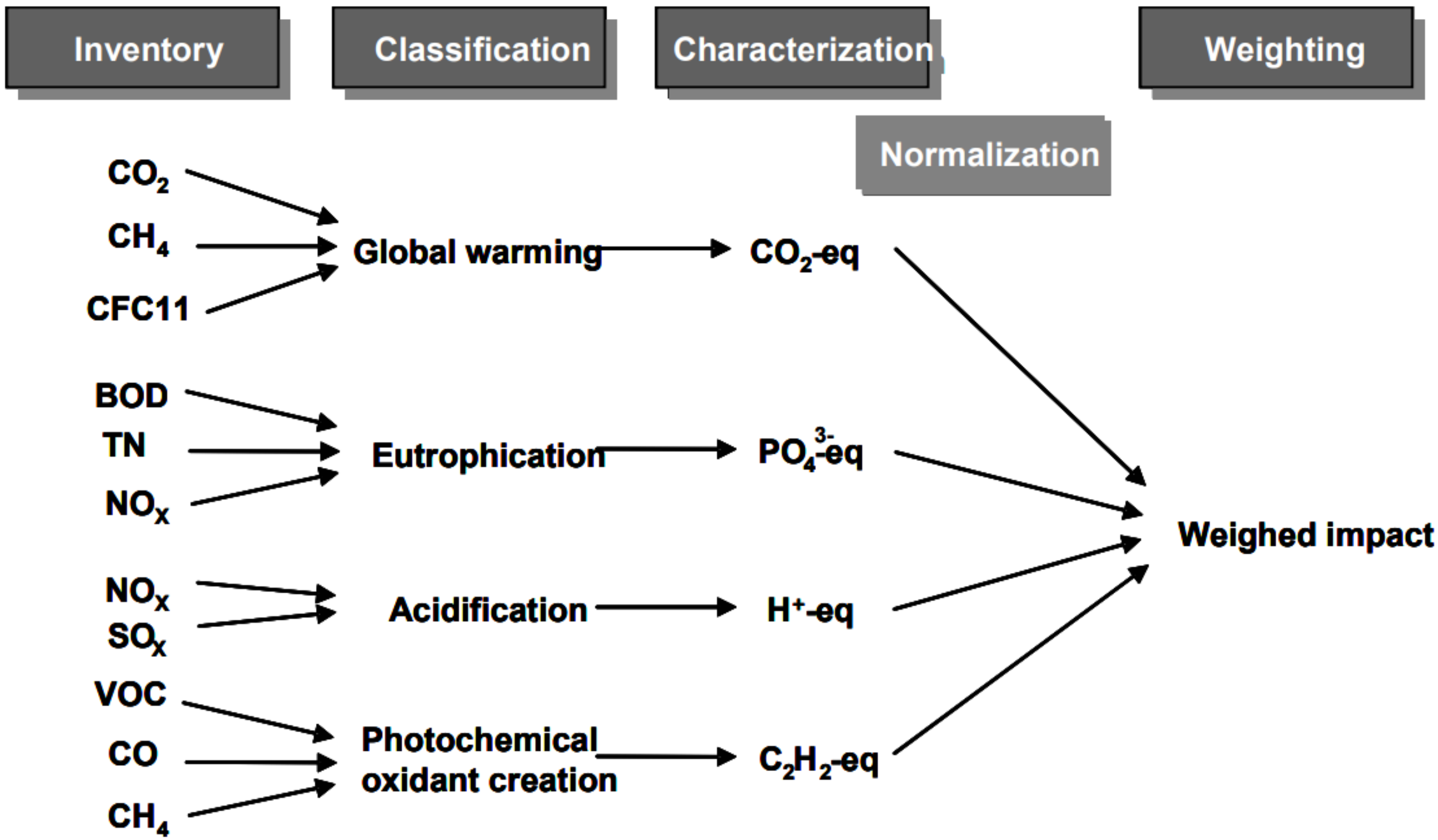
Impact Assessment

Impact Indicators = Inventory Data × Characterization Factor

Example:

- Chloroform GWP Factor Value = 9 Quantity = 5kg
- Methane GWP Factor Value = 21 Quantity = 2kg
-
- Chloroform GWP Impact = 5kg x 9 = 45
- Methane GWP Impact = 2kg x 21 = 42

From Midpoint to Endpoint



Life Cycle Assessment
Best Practices of ISO 14040 Series

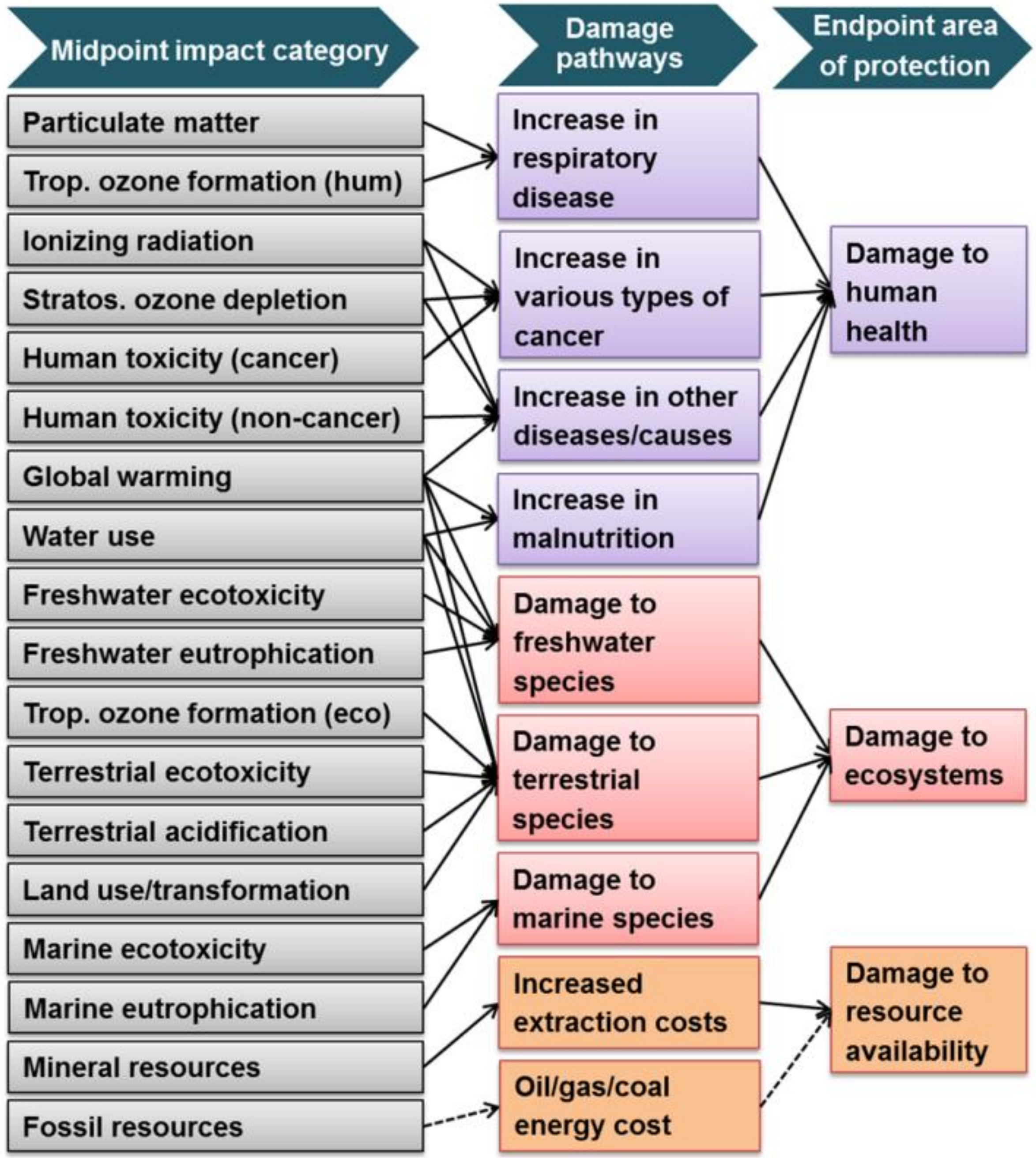


Figure 1.1. Overview of the impact categories that are covered in the ReCiPe2016 methodology and their relation to the areas of protection.

ReCiPe2016v1.1

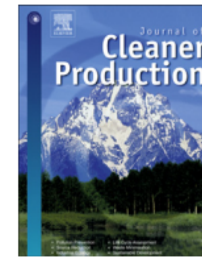
Example LCA Studies

Journal of Cleaner Production 179 (2018) 160–168

Contents lists available at ScienceDirect

Journal of Cleaner Production

journal homepage: www.elsevier.com/locate/jclepro



ELSEVIER

Environmental assesment of intensive egg production: A Spanish case study

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Check for updates

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R. Abín et al. / Journal of Cleaner Production 179 (2018) 160–168

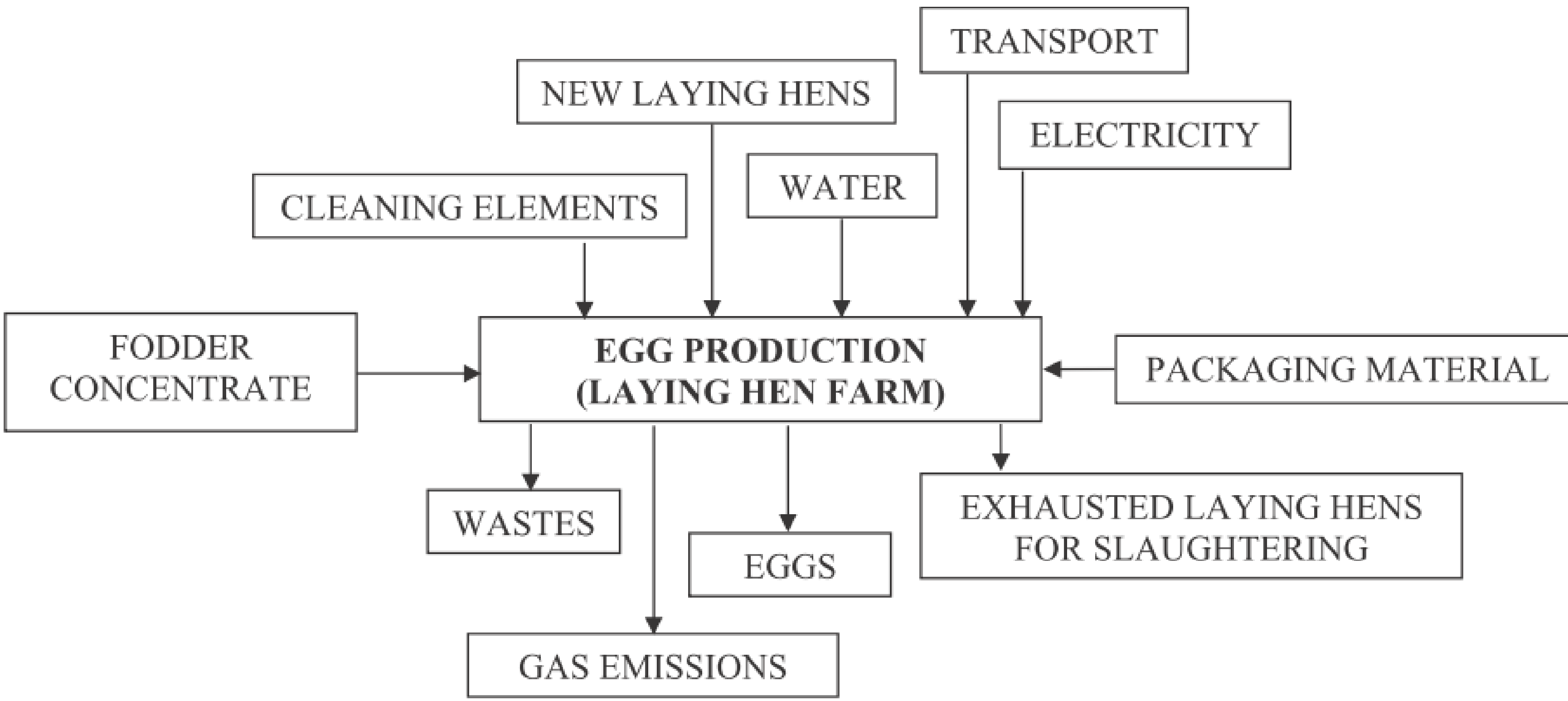

Fig. 1. System boundaries.

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Table 2
Inventory data of the farm, expressed per functional unit (FU = 13,344,000 eggs).

Inputs	
1. New laying hens (units)	55000
2. Water (m^3)	3471
3. Electricity (kWh)	49369
4. Cleaning products (bleach) (t)	0.017
5. Fodder (t)	
a. Maize (50%)	1200
b. Soybean (31%)	744
c. Palm oil (11%)	264
d. Sodium bicarbonate (8%)	192
6. Packaging material (t)	
a. Recycled cardboard	56.70
b. Solid cardboard	30.57
7. Transport	
a. By truck (tkm)	543486.42
b. Diesel (t)	3.0
Outputs	
1. Eggs (units)	13344000
2. Exhausted laying hens for slaughtering (t)	111.3
3. Wastes	
a. Wastewater (to treat) (m3)	347.1
b. Cardboard (to recycle) (t)	69.6
c. Manure (to be used as fertilizer) (t)	1980
d. Municipal wastes (to landfill) (t)	10.4
e. Dead hens (hazardous waste for incineration) (t)	4.77
4. Emissions to air (t)	
a. CH_4	4.8
b. N_2O-N	0.42
c. NH_3-N	1.88

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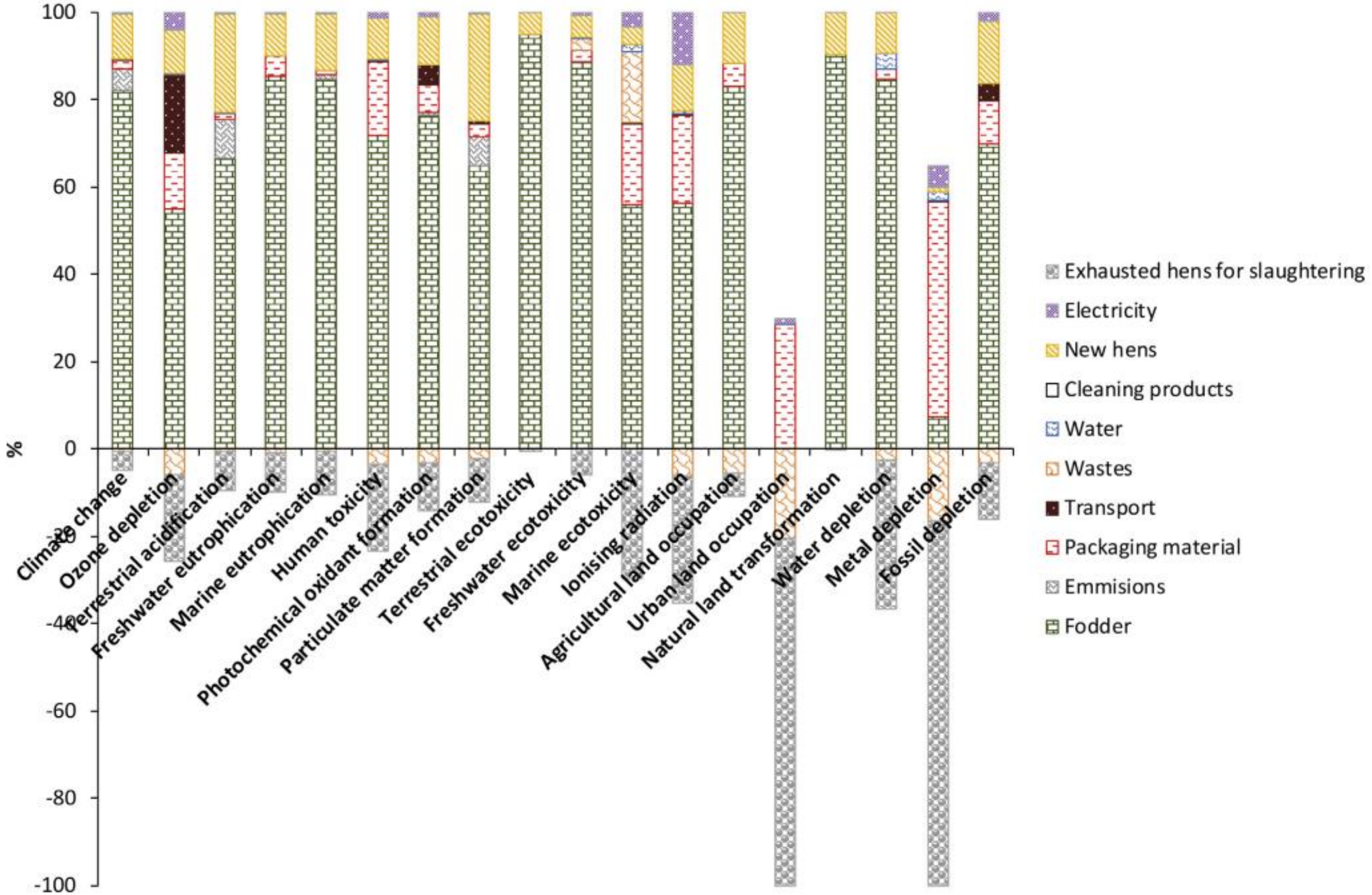

Fig. 2. Characterization results obtained using ReCiPe Midpoint.

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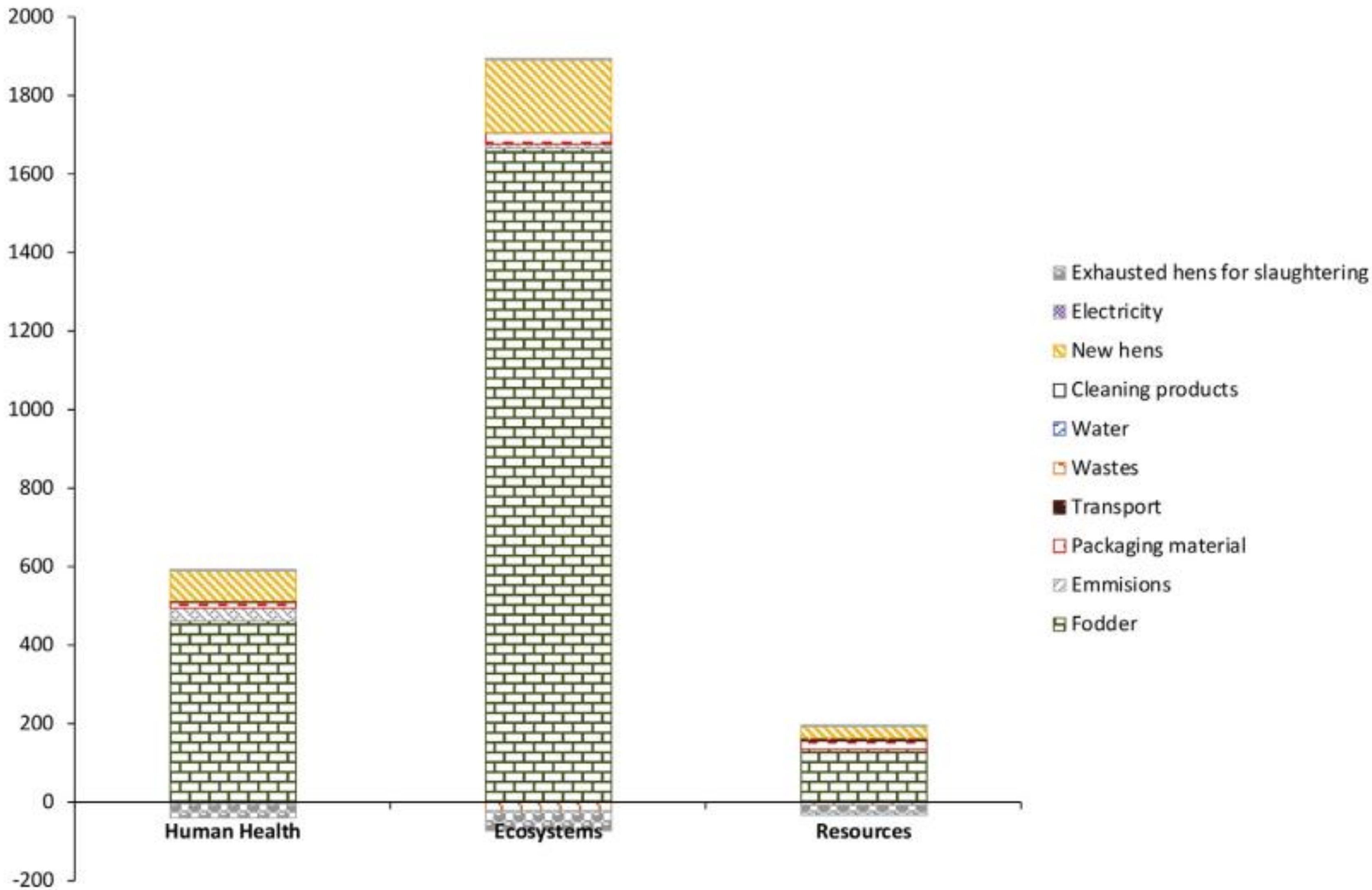

Fig. 3. Normalization results obtained using ReCiPe Endpoint.

Example LCA Studies

Air Quality, Atmosphere & Health (2018) 11:549–558
https://doi.org/10.1007/s11869-018-0559-3

Life cycle assessment and greenhouse gas emission evaluation from Aksaray solid waste disposal facility

Afşın Yusuf Çetinkaya[1] · Levent Bilgili[2] · S. Levent Kuzu[3]

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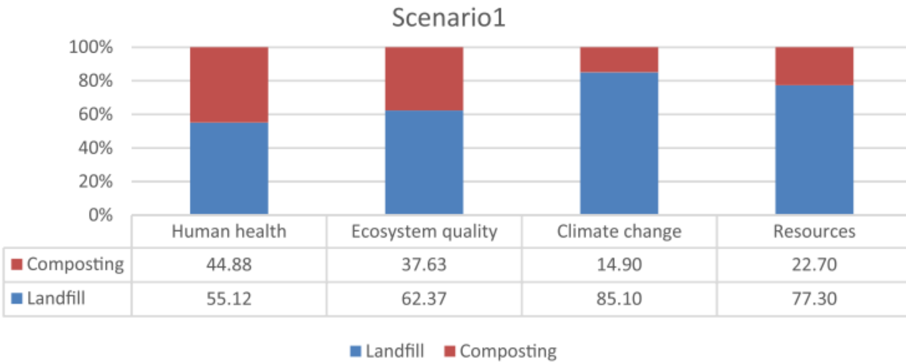

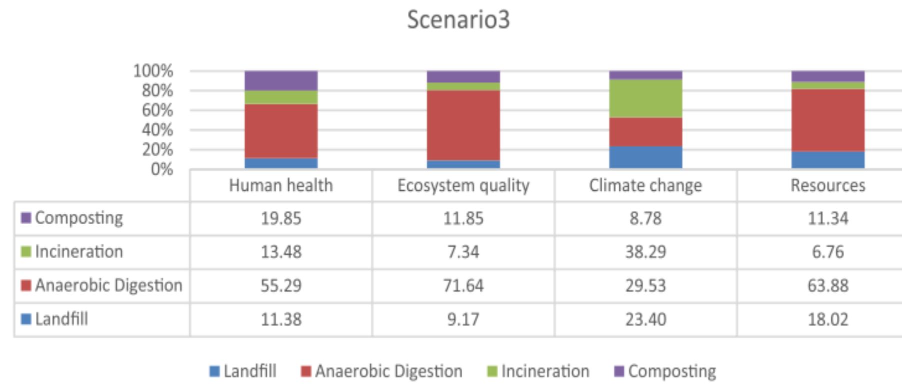

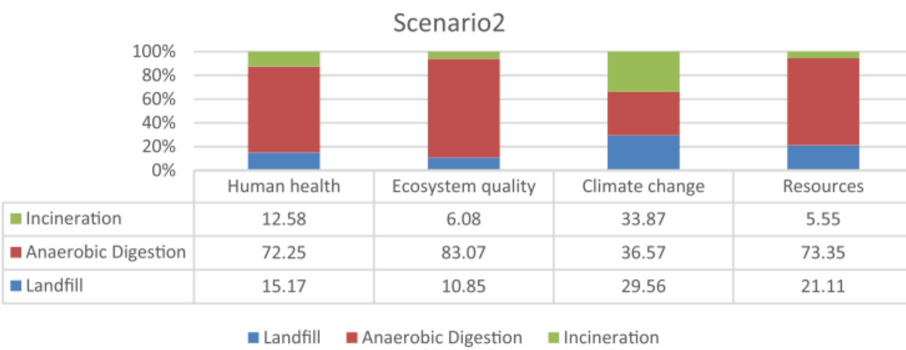

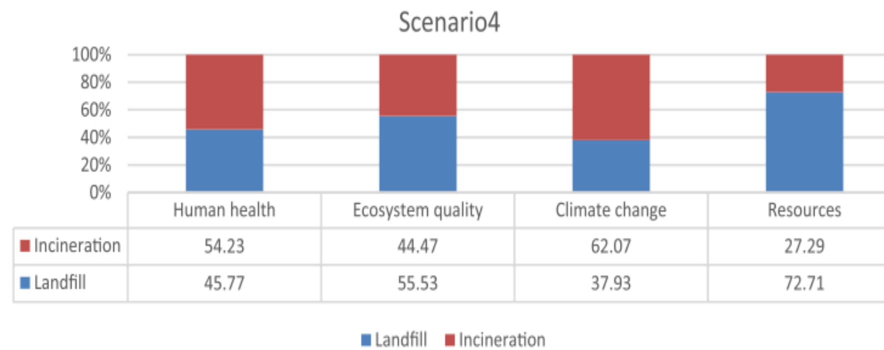

Table 1 Damage assessment values of current situation and scenarios

Damage categories/scenarios	Current situation	Scenario1	Scenario2	Scenario3	Scenario4
Human health (DALY)	0.0000366	0.0000499	0.000121	0.000113	0.000082
Ecosystem quality (PDF × m^2 × year)	8300	9980	38,265	31,693	13,349
Climate change (kg $CO_{2(eq)}$)	134,223	118,300	226,998	200,779	399,008
Resources (MJ primary)	374,925	363,759	888,116	728,328	342,322

Example LCA Studies

Energy 47 (2012) 174–198

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Energy

journal homepage: www.elsevier.com/locate/energy

Comparison of Life Cycle energy consumption and GHG emissions of natural gas, biodiesel and diesel buses of the Madrid transportation system

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https://doi.org/10.1016/j.energy.2012.09.052