

Life Cycle Assessment

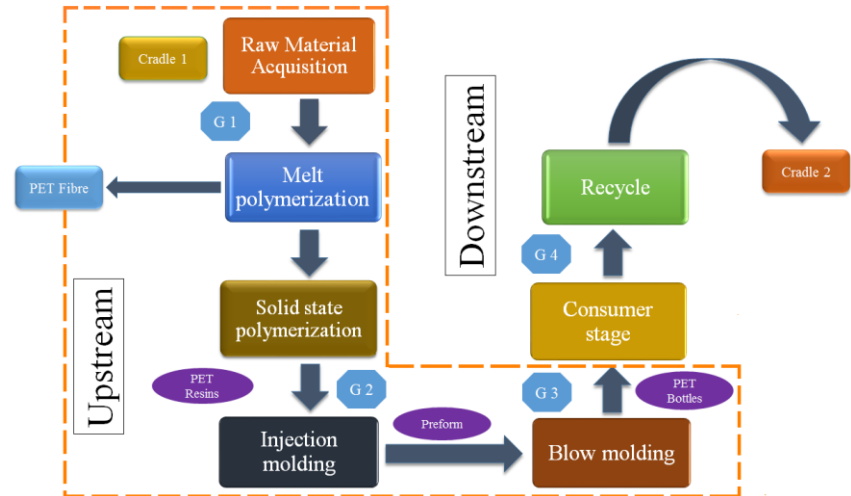
11th August, 2023

DDL753 Design of
sustainable habitats

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IIT Delhi



Topic 1: Life Cycle Assessment



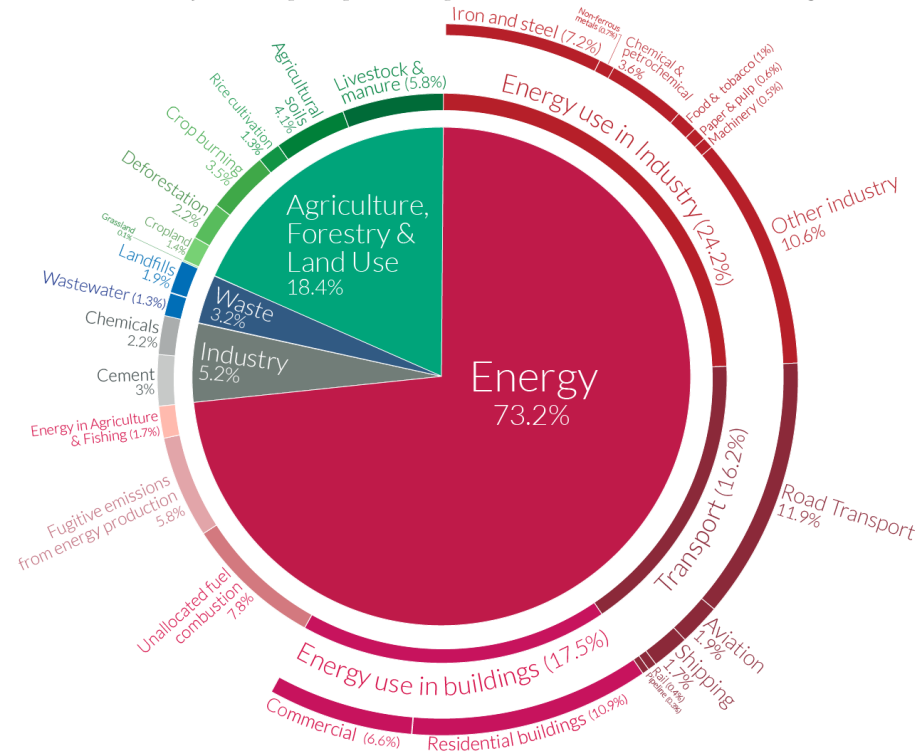
PET bottle LCA

LCA examples

Global greenhouse gas emissions by sector

This is shown for the year 2016 – global greenhouse gas emissions were 49.4 billion tonnes CO₂eq.

Our World
in Data



OurWorldinData.org – Research and data to make progress against the world's largest problems.

Source: Climate Watch, the World Resources Institute (2020).

Licensed under CC-BY by the author Hannah Ritchie (2020).

Industry (Life Cycle of a PET bottle)

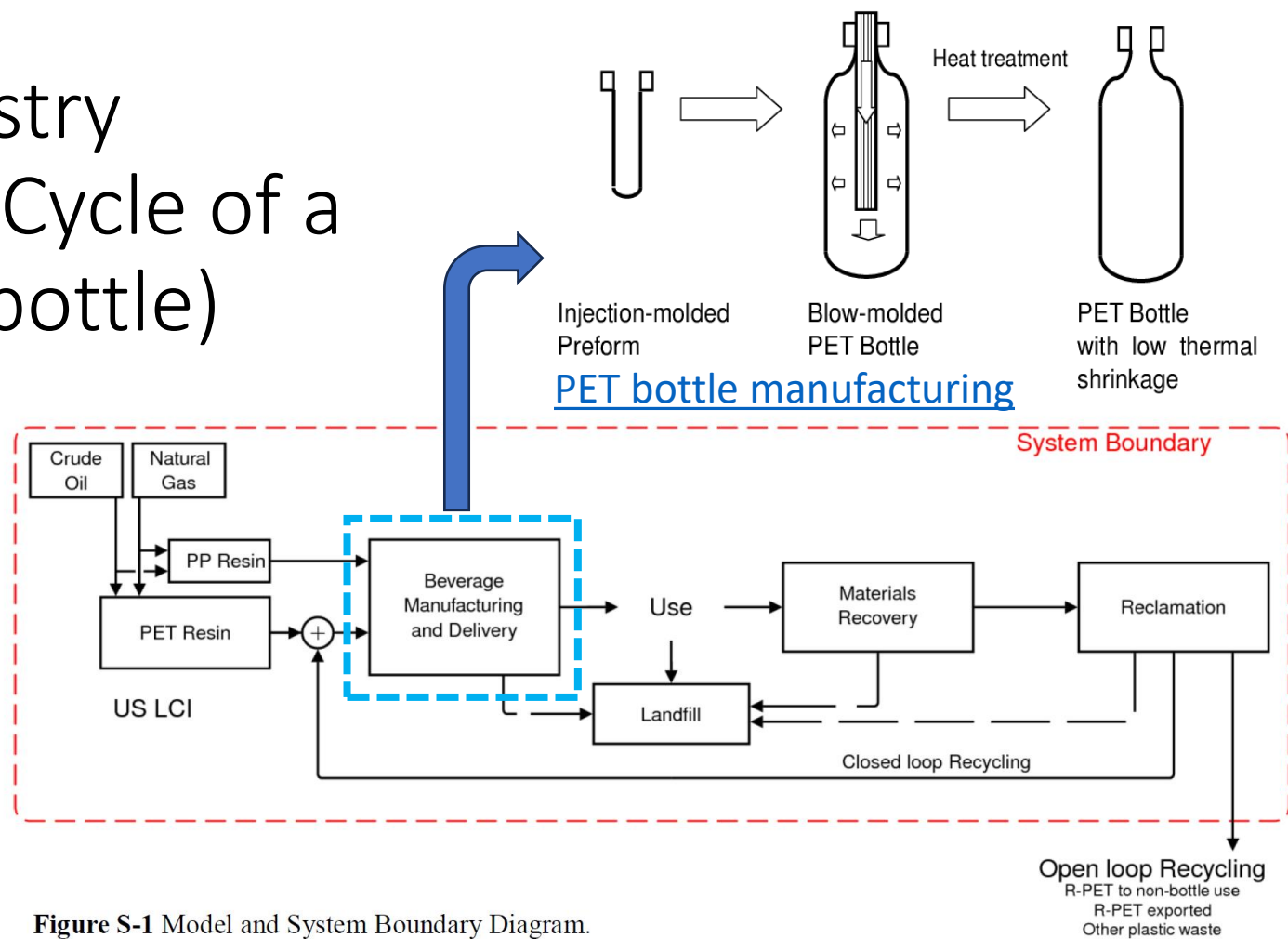


Figure S-1 Model and System Boundary Diagram.

Source: <https://www2.calrecycle.ca.gov/Publications/Download/1084?opt=dIn>

https://www.researchgate.net/figure/Schematic-illustration-of-PET-bottle-production-process_fig2_260602938

Scenario comparison

Table S-1 Description of the scenarios modeled in the study.

	2009 Baseline	California Scenario
Scenario Description:	2009 Collection statistics	15% Recycled Content / CA End-of-Life
Total weight of PET Resin [kg]: (Reference flow A)	1.00	1.00
Weight of secondary PET [kg]: (closed-loop recycling)	0.039	0.150
PET Recycled Content:	3.9%	15%
Weight of PP [kg]:	0.143	0.143
Contained Volume [L]: (Reference flow B)	27.9	27.9

Freight Services Required – Product
1 kg PET resin – 27.9 L Beverage Delivered

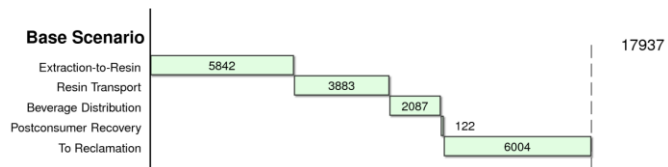
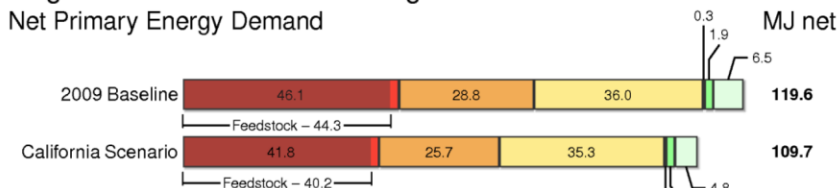


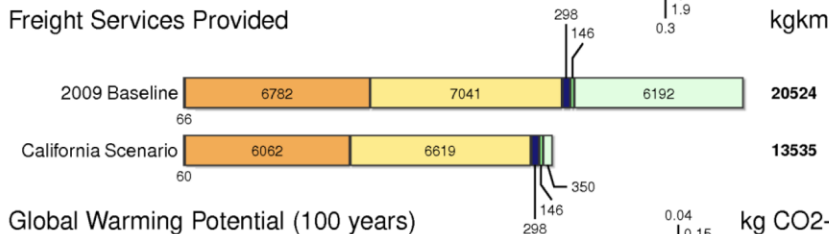
Figure S-5 Freight services used in transporting the product over its life cycle, by transportation step (freight services required upstream in the supply chain and for the fuel production cycle are excluded).

1 kg PET resin – 27.9 L Beverage Delivered

Net Primary Energy Demand



Freight Services Provided



Global Warming Potential (100 years)

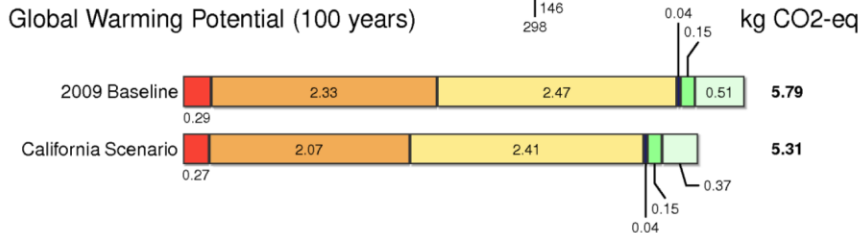


Figure S-4 Comparison of the Baseline and California alternative scenarios under three different indicators.

Life Cycle Model (GaBi)

PET Bottle Layout

GaBi 4 process plan: Mass [kg]

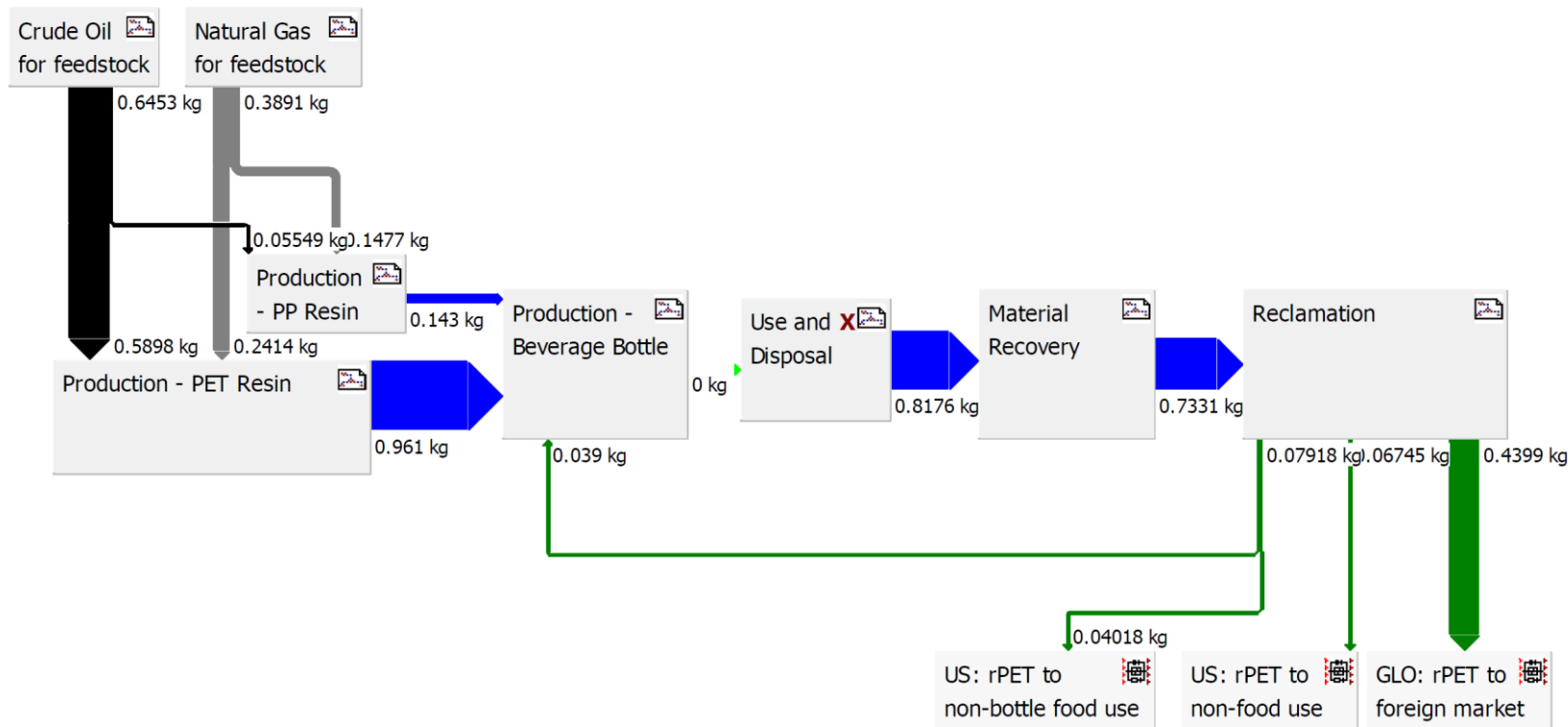
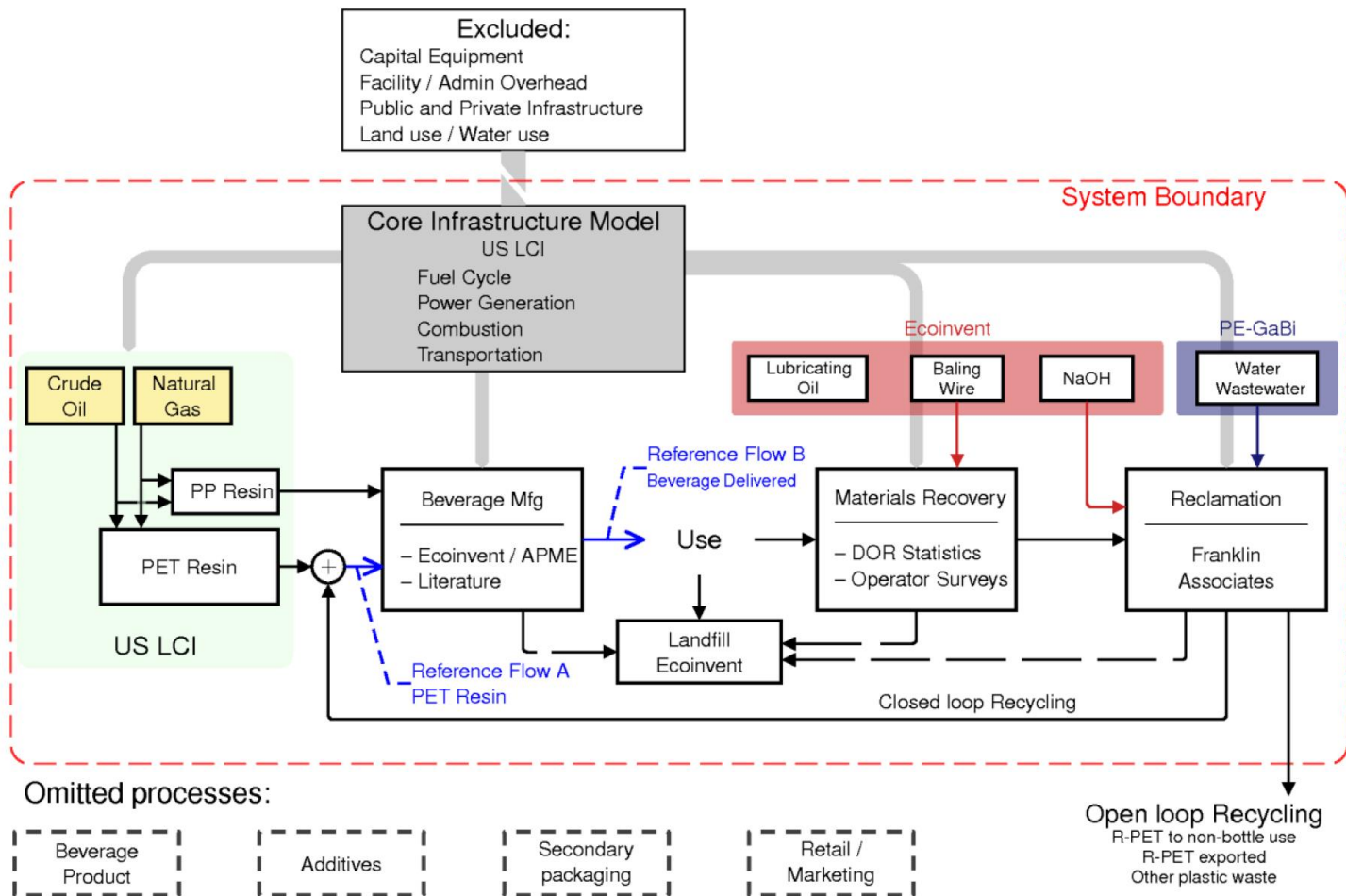


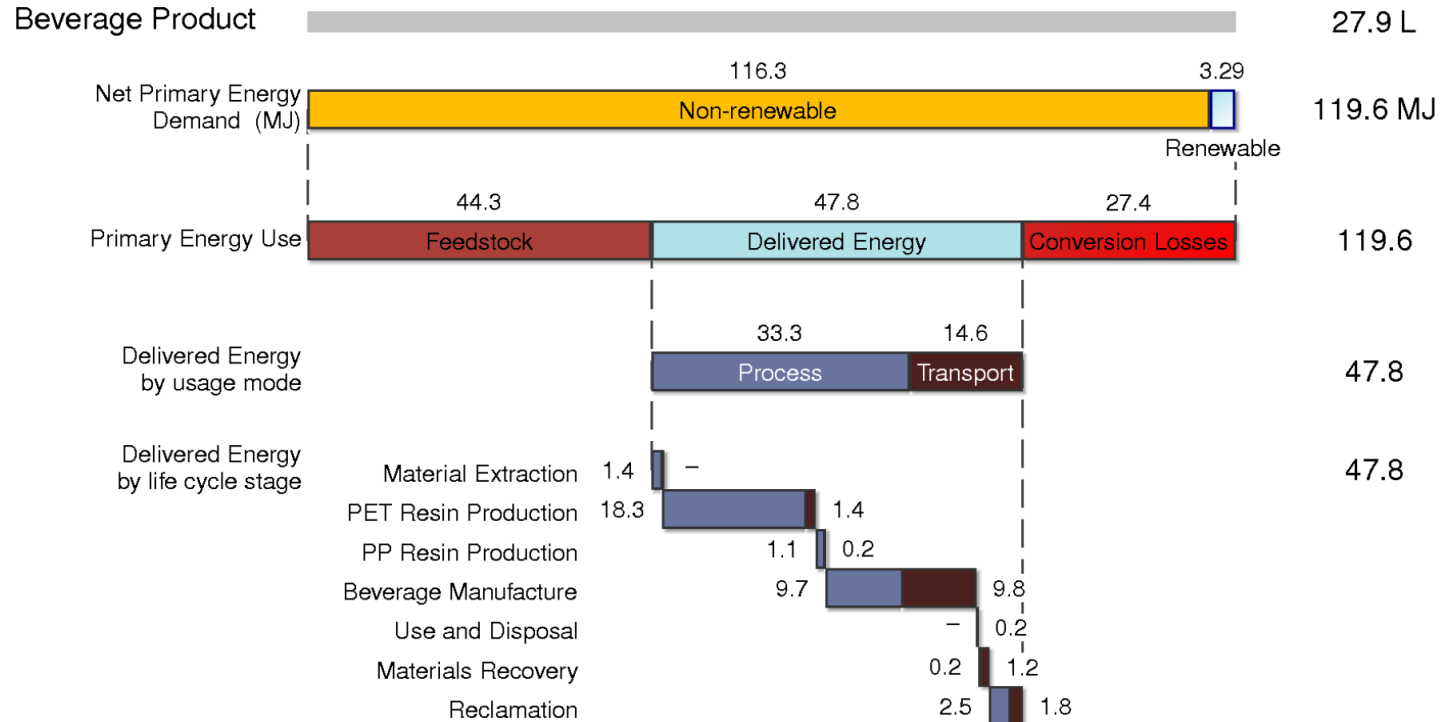
Figure 1.1 GaBi Life cycle model showing mass flows under the 2009 baseline scenario, for bottles made from 1 kg of PET resin.

System Diagram with data and model boundaries



Detail of energy usage in the product system

1 kg PET Resin





[society composter](#)

Examples from the Built Env't.

गाव स्वयंपूर्ण होण्या अगोदर आपला आश्रम
स्वयंपूर्ण करूयात !

Lets First Try to Make 'Vigyan Ashram' campus Self Sufficient

Energy	Agriculture	Water	Waste Management	Education
ऊर्जा	शेती	पाणी	कचरा व्यवस्थापन	शिक्षण



Vigyan
Ashram

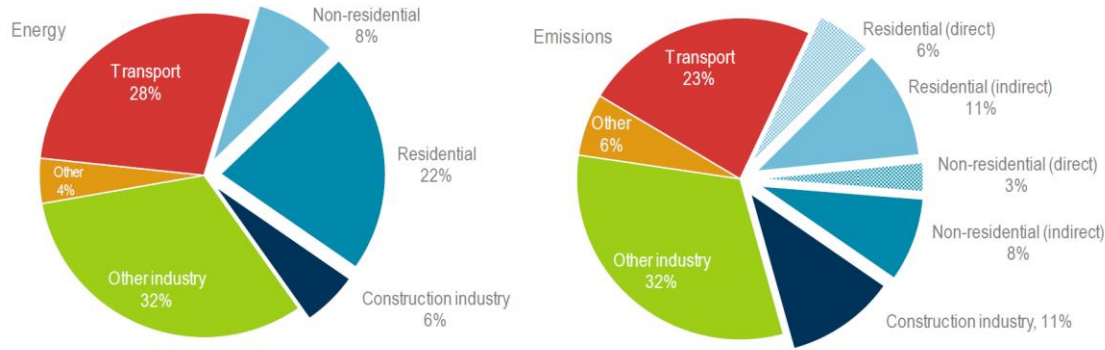
www.vigyanashram.com

Vigyan Ashram: self sufficient village

India has also allocated Rs 35,000 crore in the Union Budget for 2023-24 for priority capital investment towards energy transition and achieving the net-zero emission goal.

<https://theprint.in/india/campuses-of-all-educational-institutions-should-be-carbon-neutral-by-2030-prakash-javadekar/1551107/>

Figure 1 • Global share of buildings and construction final energy and emissions, 2017



Note: *Construction industry* is an estimate of the portion of the overall industry sector that applies to the manufacture of materials for buildings construction, such as steel, cement and glass.

Sources: Derived from IEA (2018a), *World Energy Statistics and Balances 2018*, www.iea.org/statistics and IEA *Energy Technology Perspectives* buildings model, www.iea.org/buildings.

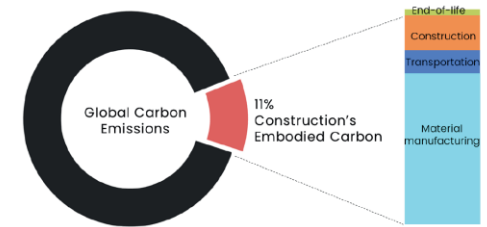


Fig. 2. Contribution of embodied carbon

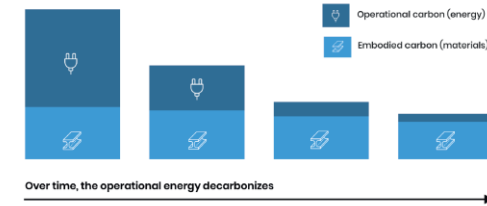
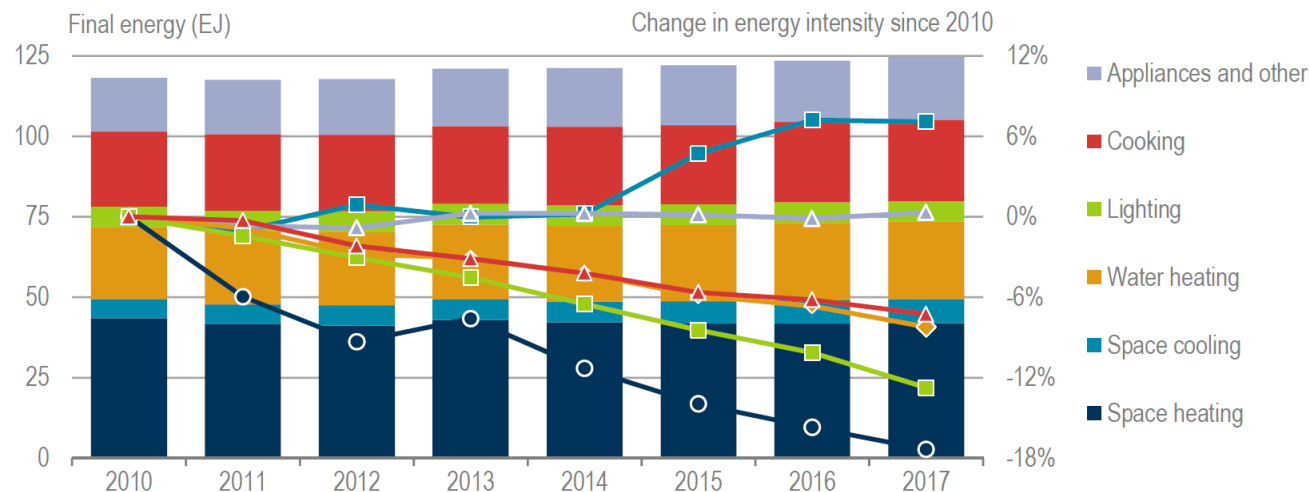


Fig. 3. Operational carbon emissions will decrease over time

Source:
<https://www.oneclicklca.com/building-life-cycle-assessment-ebook/>

Buildings

Figure 3 • Global buildings final energy use and change in intensity by end use, 2010-17

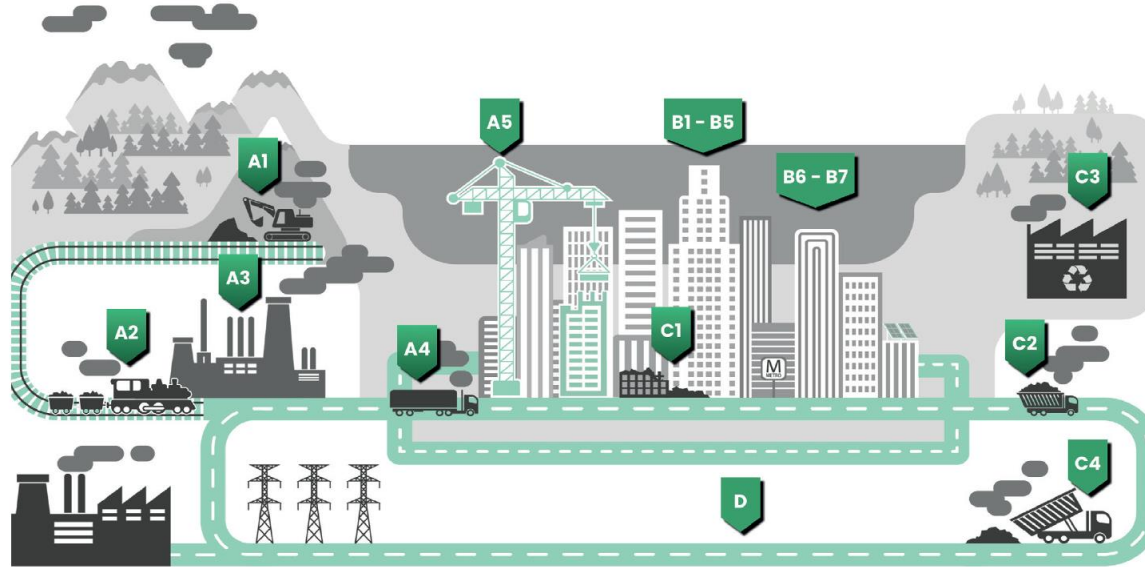


Notes: *Energy intensity* is final energy per unit floor area. *Appliances and other* includes household appliances (e.g. refrigerators, washers and televisions), smaller plug loads (e.g. laptops, phones and electronics) and other services equipment.

Sources: Derived from IEA (2018a), *World Energy Statistics and Balances 2018*, www.iea.org/statistics and IEA *Energy Technology Perspectives* buildings model, www.iea.org/buildings.

Key message • Space cooling and appliances and other plug loads are the fastest-growing building end uses; however, only space cooling has grown in energy intensity per unit floor area.

Lifecycle stages of a building



A1 – A3 Product stage

- A1** Raw material extraction
- A2** Transport to manufacturing site
- A3** Manufacturing

A4 – A5 Construction stage

- A4** Transport to construction site
- A5** Installation / Assembly

B1 – B7 Use stage

- B1** Use
- B2** Maintenance
- B3** Repair
- B4** Replacement
- B5** Refurbishment
- B6** Operational energy use
- B7** Operational water use

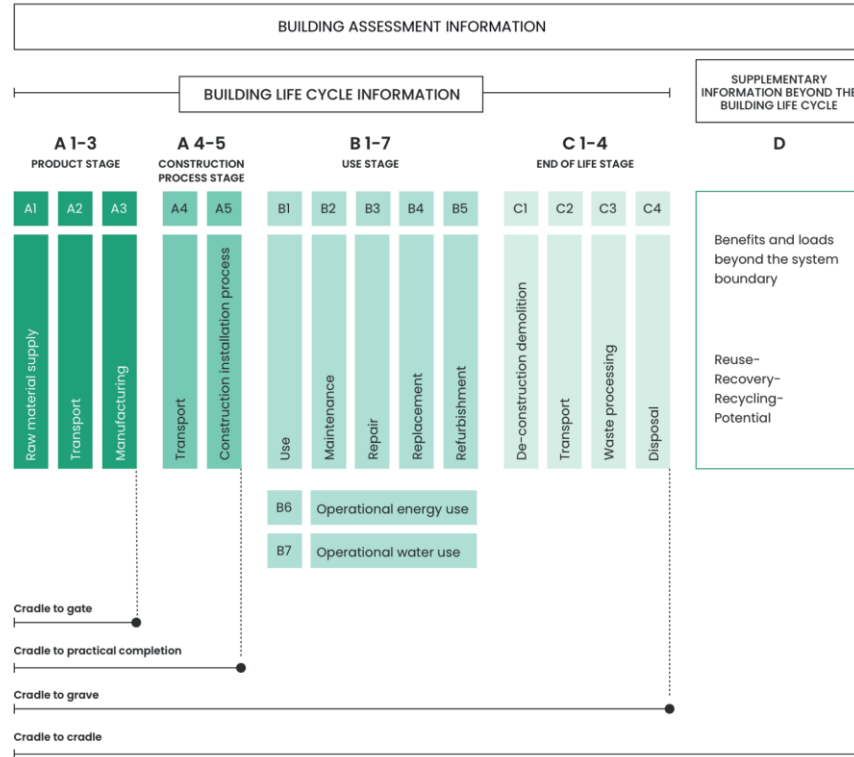
C1 – C4 End of life stage

- C1** Deconstruction & demolition
- C2** Transport
- C3** Waste processing
- C4** Disposal

D – Benefits and loads beyond system boundary

Reuse, recovery and/or recycling potentials, expressed as net impacts and benefits

System boundary



Life Cycle Inventory

Table 5. Details of inventory analysis in One Click LCA

Inventory	Source of inventory (varies by module used)	Required for
 A1 - raw material extraction/supply A2 - transport to the manufacturing site A3 - manufacturing	Bill of materials (BOM) are manually inputted, imported from BIM models or cost schedules or created with Carbon Designer, possibly completed with One Click LCA default structures.	Level(s), LEED, BREEAM, RICS, GLA.
 A4 - transportation scenarios A5 - construction installation process	One Click LCA provides appropriate default values for transport distances, which can be used when a specific source is not known.	Level(s), LEED-only A4, BREEAM, RICS, GLA.
 B1 - installed products B2 - maintenance B3 - replacement B4 - repair B5 - refurbishment	B1-B3 are based on user input of quantities. B4 and B5 are based on default material service life settings and the asset calculation period.	Level(s) - except B2, LEED (only B3, B4-B5), BREEAM, RICS, GLA, (only B4, B6)
 B6 - details of annual electricity, fuel, and energy consumption includes district heating and cooling	Based on user input of consumption quantities. In One Click LCA database, the impacts of electricity and district heat are based on the energy production fuel mixes provided for each country by IEA, or local and regulatory sources.	Level(s), BREEAM, RICS, GLA.
 B7 - estimated annual water consumption during the operational stage of the building	Based on user input of consumption quantities.	Level(s), BREEAM, RICS, GLA
 C1-C4 - details of processes that occur during and after the building or asset is demolished	Based on options such as Material-locked and End of life (EOL) scenarios. EOL processes are based on regulatory scenarios. For non regulatory tools, One Click LCA provides its own end of life default processing methods for various materials.	Level(s), BREEAM, RICS, GLA.
 D - includes reuse and recovery of materials and energy, based on their recycling potential D2 - is the exported energy	Based on the material and on the end-of-life process that is chosen.	Level(s), BREEAM, RICS, GLA.

Impact assessment

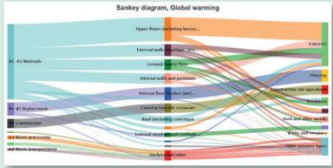
	INVENTORY	X	IMPACT	=	TOTAL
Process	Quantities of materials and processes in building	X	Environmental impacts for each material and process	=	Total environmental impact of building
Example	100 kg steel 	X	1.5 kg per kg steel 	=	150 kg CO ₂ e 

Fig. 11. Example of impact assessment calculations

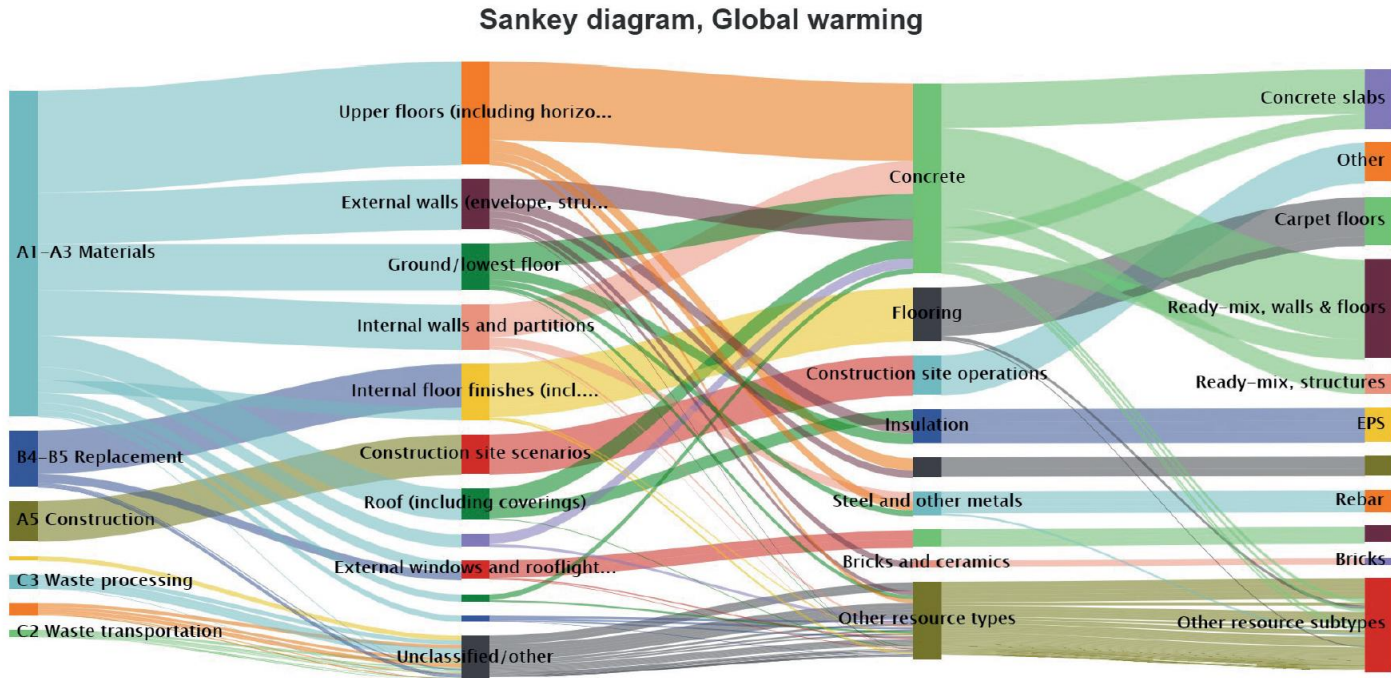
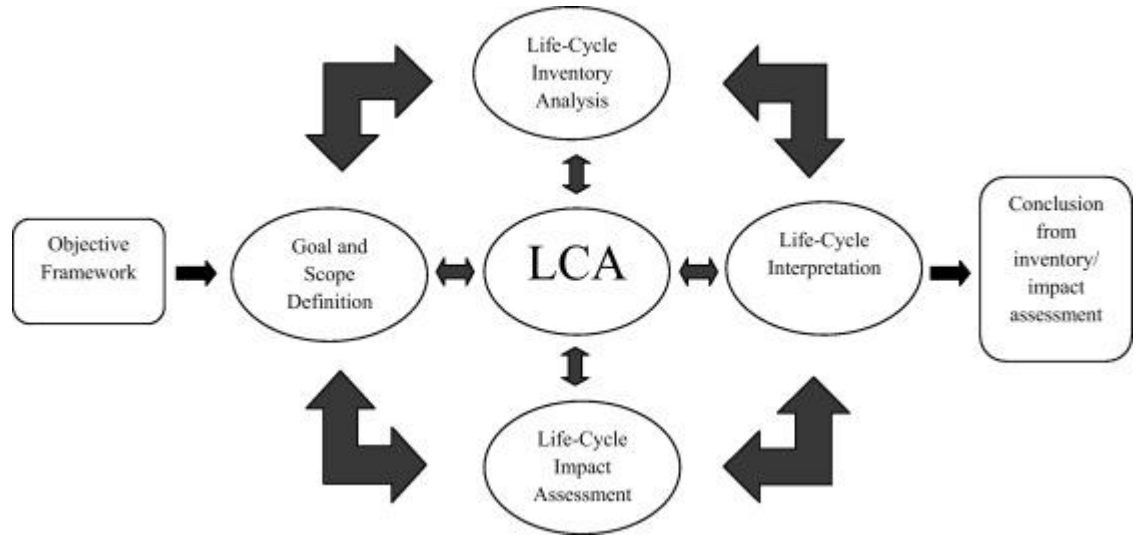


Fig.15. Embodied carbon breakdown by key building elements (Treemap and Sankey diagram)

Stages of life cycle assessment

Embodied carbon benchmark

Cradle to grave (A1-A4, B4-B5, C1-C4)	kg CO ₂ e/m ²
(180-259) A	303
(259-337) B	
(337-416) C	
(416-494) D	
(494-573) E	
(573-651) F	
(651-730) G	



Source: <https://www.oneclicklca.com/library/case-studies/>

Source: Aashish Sharma, Abhishek Saxena, Muneesh Sethi, Venu Shree, Varun, Life cycle assessment of buildings: A review, Renewable and Sustainable Energy Reviews, Volume 15, Issue 1, 2011, Pages 871-875, ISSN 1364-0321, <https://doi.org/10.1016/j.rser.2010.09.008>.

Transport

Basis 1 for calculation: from fuel consumption per flight

One way to calculate CO₂ emissions is from fuel consumption per flight.

A **Boeing 737-400** jet is typically used for short international flights.

For a distance of 926 km, the amount of fuel used is estimated to be 3.61 tonnes [1], including taxiing, take-off, cruising and landing.

Using a seating capacity of 164 [Wikipedia, viewed 28.2.08] and an average seat occupancy (or 'load factor') of 65% [2], this gives a fuel use of 36.6 g per passenger per km.

CO₂ emissions from aviation fuel are 3.15 grams per gram of fuel [1], which gives CO₂ emissions from a Boeing 737-400 of 115 g per passenger per km.

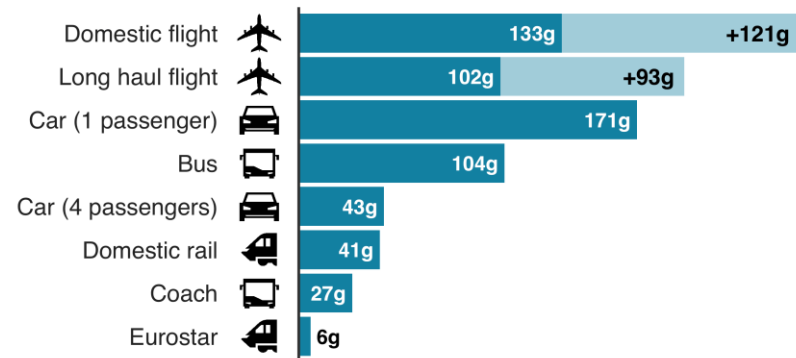
At a cruising speed of 780 km per hour [Wikipedia, 28.2.08], this is equivalent to 90 kg CO₂ per passenger per hour.

You can relate 90 kg CO₂ eq per person per hour to 50 billion tons CO₂ eq per year for planet!
What would be the CO₂ emissions if you use a car/public transport/bike ride?

Emissions from different modes of transport

Emissions per passenger per km travelled

■ CO2 emissions ■ Secondary effects from high altitude, non-CO2 emissions



Note: Car refers to average diesel car

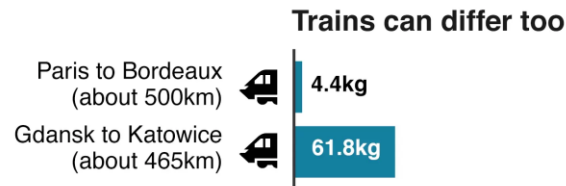
Source: BEIS/Defra Greenhouse Gas Conversion Factors 2019

BBC

Emissions from different journeys

Emissions per passenger for journey

■ CO2 emissions ■ Secondary effects from high altitude, non-CO2 emissions



Source: EcoPassenger

BBC

Goal and Scope



Goal

- Compare the three models :

Two-Stroke engine

Four-Stroke engine

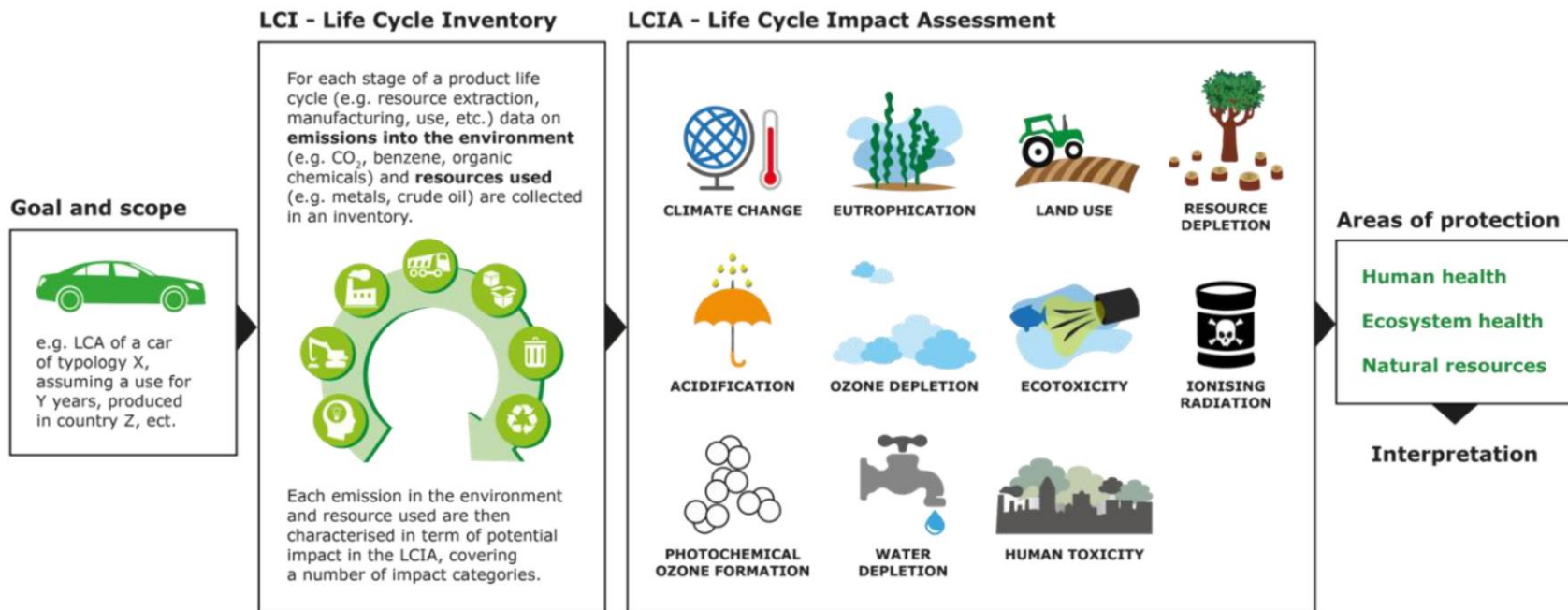
Electric

- Considering Scooters (50 cc) used in Berlin
- From cradle-to-grave
- Motor Scooters: Data preferentially from EURO2, direct injection, and catalyst

Source: https://www.openlca.org/wp-content/uploads/2021/10/Report_Scooters_in_Berlin.pdf

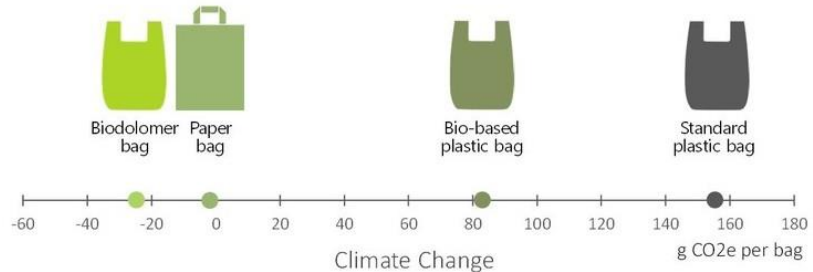
OpenLCA: [Case Study: Scooters LCA Using Ecoinvent 3.6](#)

Life Cycle Assessment



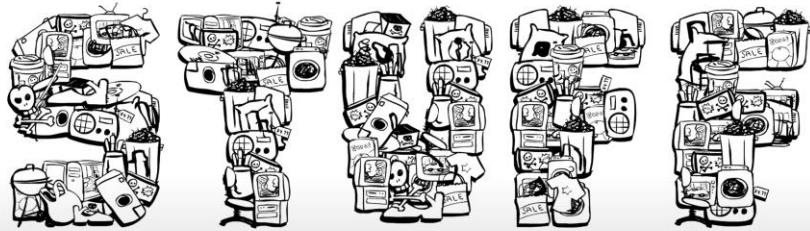
Impact of our choices on our and our planet's health

- Bike ride vs. public transport vs. a car
- AC vs. natural ventilation
- Local foods vs. Foods with ingredients from far off places
- Online order vs. Eating at a restaurant
- Biofuel vs. Petrol



Source: <https://biodolomerforlife.se/lca-comparing-biodolomer-fossil-pe-bio-pe-september-1-2019/>

THE STORY OF



WITH ANNIE LEONARD

