

DDL313 Creativity and Sustainability in Nature

DDL753 Design of Sustainable Habitats



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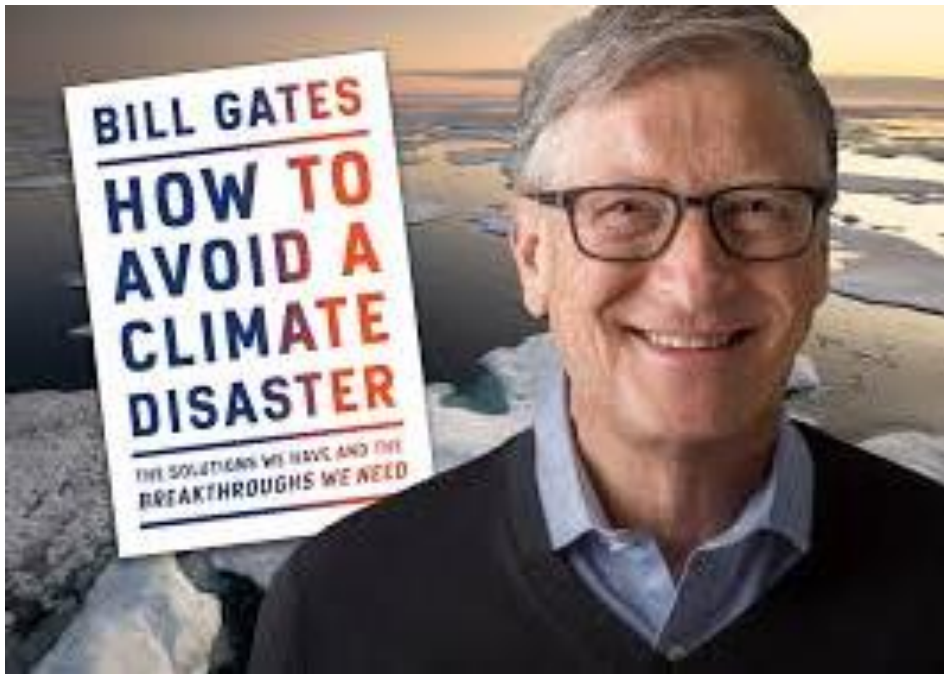


Life Cycle Assessment
22nd August, 2024

Can we improve the TSG carbon footprint estimate?

- **Measuring energy consumption in buildings**
- **Understanding travel related emissions**
- **Estimating food related emissions**
- Estimating product related emissions
- How about internet?
- Anything else?





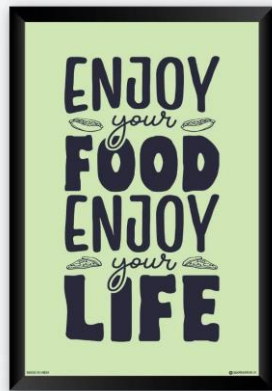
Introduction: 51 Billion to Zero

- 1 Why Zero?
- 2 This Will Be Hard
- 3 Five Questions to Ask in Every Climate Conversation
- 4 How We Plug In
- 5 How We Make Things
- 6 How We Grow Things
- 7 How We Get Around
- 8 How We Keep Cool and Stay Warm
- 9 Adapting to a Warmer World
- 10 Why Government Policies Matter
- 11 A Plan for Getting to Zero
- 12 What Each of Us Can Do

How to get from 51 billion tCO₂e to 0?

Emissions
about how we
grow things

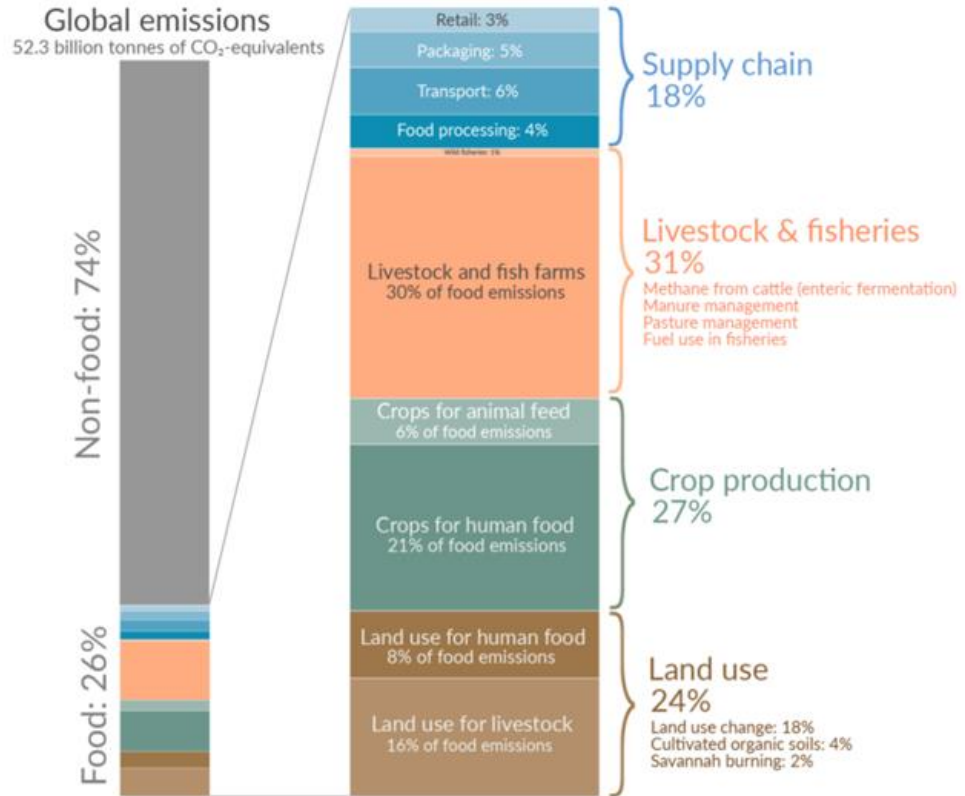




Should we
live to eat or
eat to live?



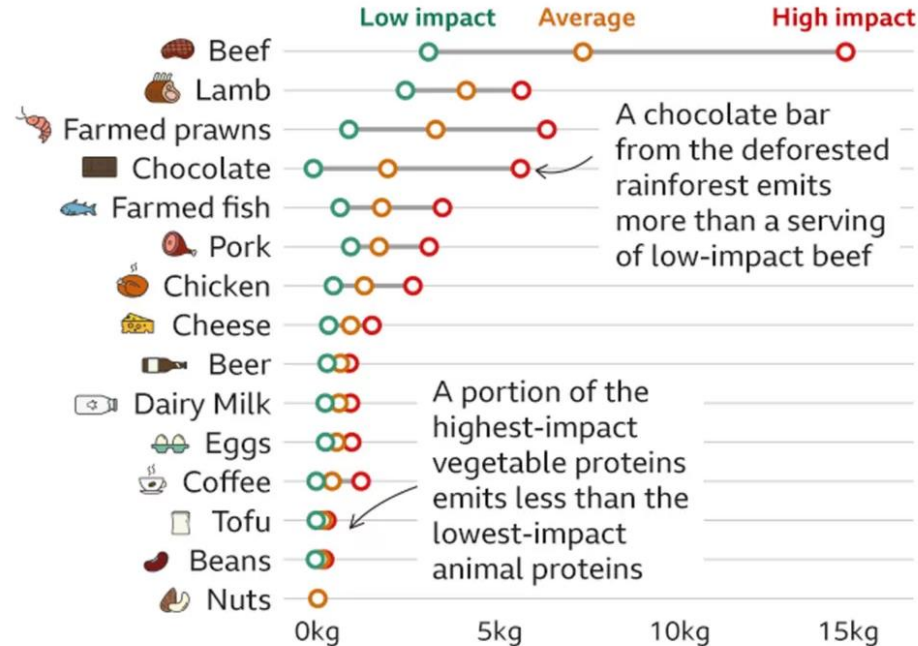
Global GHG emissions from food production



Poore, J., & Nemecek, T. (2018). Reducing food's environmental impacts through producers and consumers. *Science*, 360(6392), 987-992.

Carbon footprint of different types of food

Kilograms of greenhouse gas emissions per serving

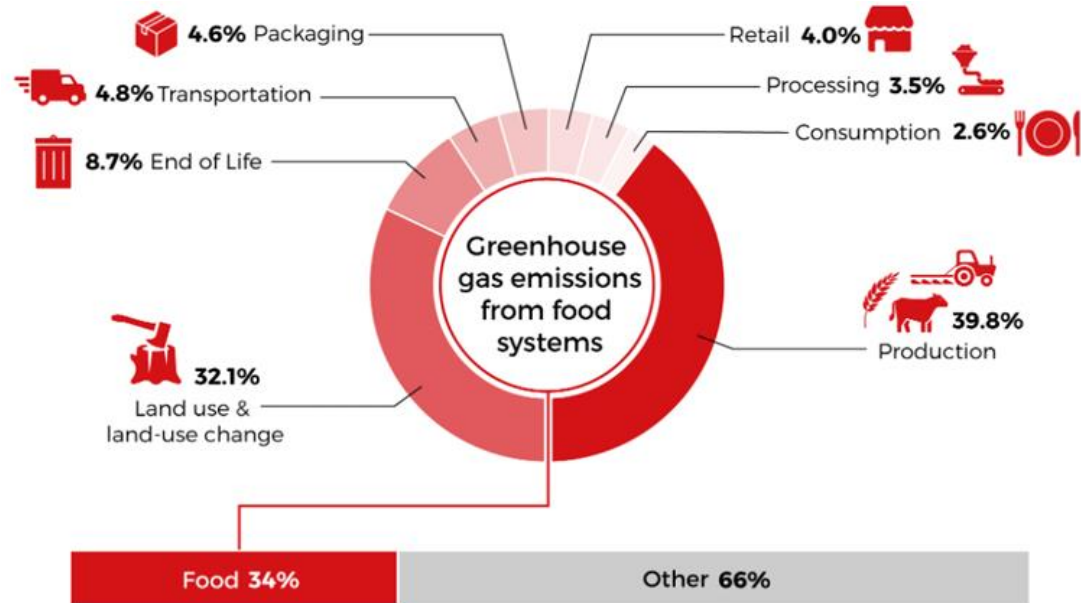


Note: The figures for each food are based on calculations using data from 119 countries. Serving sizes are from the British Dietetic Association (BDA) and Bupa.

Source: Poore & Nemecek (2018), Science

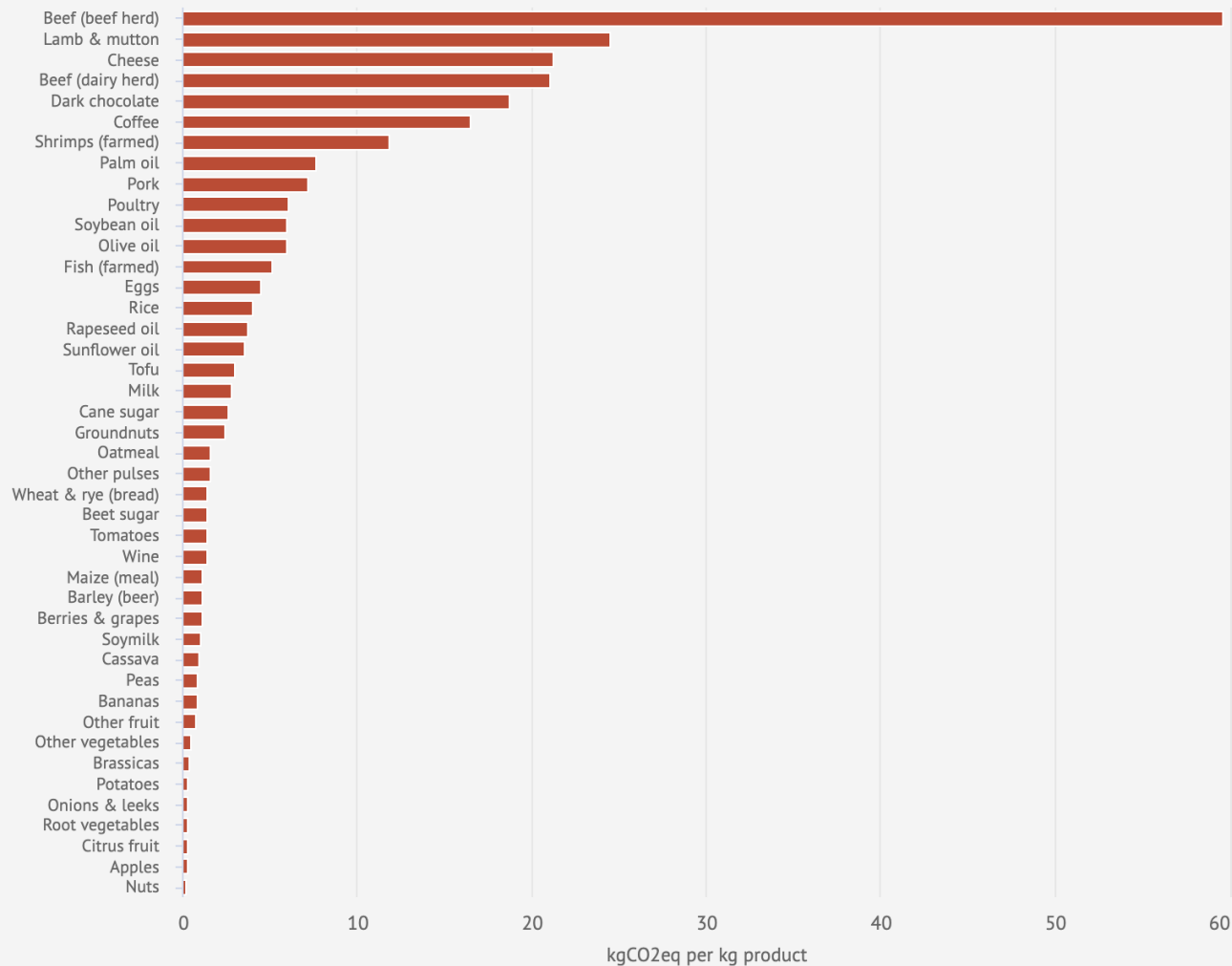
GHG emissions from the food system

- The global food system accounts for one-third of human-caused greenhouse gas emissions
- Climate Change Conference (COP26) dedicated zero days to food, unlike other big polluters like the energy and the transport sectors



Prof Atul Jain and team. (2021). Global greenhouse gas emissions from animal-based foods are twice those of plant-based foods. *Nature Food*, 2(9), 724–732.

Animal-based foods tend to have a larger carbon footprint



➤ Animals (such as cattle and sheep) produce greenhouse gases through a process called ‘enteric fermentation’ – when microbes in their digestive systems break down food, they produce methane as by product.

Atul Jain and team (2021). Global greenhouse gas emissions from animal-based foods are twice those of plant-based foods. *Nature Food*, 2(9), 724–732.

Food - Environment and Health

Ultra-processed food linked to 32 harmful effects to health, review finds

World's largest review finds direct associations with higher risks of cancer, heart disease and early death



☛ Ultra-processed foods undergo multiple industrial processes and often contain colours, emulsifiers, flavours and other additives. Photograph: MBI/Alamy



Ultra-processed foods are not only bad for our bodies, their production damages our environments

Published: September 24, 2023 1:10pm BST

Our grocery stores are increasingly filled with ultra-processed foods, which have little to no nutritional value and a huge environmental impact. (Nathalia Rosa)

<https://theconversation.com/ultra-processed-foods-are-not-only-bad-for-our-bodies-their-production-damages-our-en>
<https://www.theguardian.com/society/2024/feb/28/ultra-processed-food-32-harmful-effects-health-review>

Requirements

Land



Water



Energy



Chemicals



Machineries



Burning



Studied 21 crops

Cereals



Vegetables



Fruits



Oil seeds



Cash crops



Others



Life Cycle Analysis of Crops

Measured impact indices

Ecosystem quality (11 indices)

- agricultural land occupation (ALOP)
- climate change (GWP500)
- freshwater ecotoxicity (FETPinf)
- freshwater eutrophication (FEP)
- marine ecotoxicity (METPinf)
- marine eutrophication (MEP)
- natural land transform. (NLTP)
- terrestrial acidification (TAP500)
- terrestrial ecotoxicity (TETPinf)
- urban land occupation (ULOP)
- water depletion (WDP)

Human health (5 indices)

- human toxicity (HTPinf)
- ionising radiation (IRP_HE)
- ozone depletion (ODPinf)
- particulate matter form. (PMFP)
- photochemical oxidant form.(POFP)

Resources (2 indices)

- fossil depletion (FDP)
- metal depletion (MDP)

Table 1. Crops in this study.

Sl. no	Category	Selected crops
1	Cereals	Rice, wheat, barley, maize, and millets
2	Fruits	Apple, mango, banana, and grapes
3	Oilseeds	Castor, rapeseeds, oilseed, and sunflower seeds
4	Vegetables	Potato, tomato, carrots, and beans
5	Cash crops	Coffee and cocoa
6	Others (commercial and food)	Coconut and sugarcane



Current Research in Environmental
Sustainability
Volume 3, 2021, 100074



Life cycle sustainability assessment of crops in India

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Rice lifecycle from farm to fork

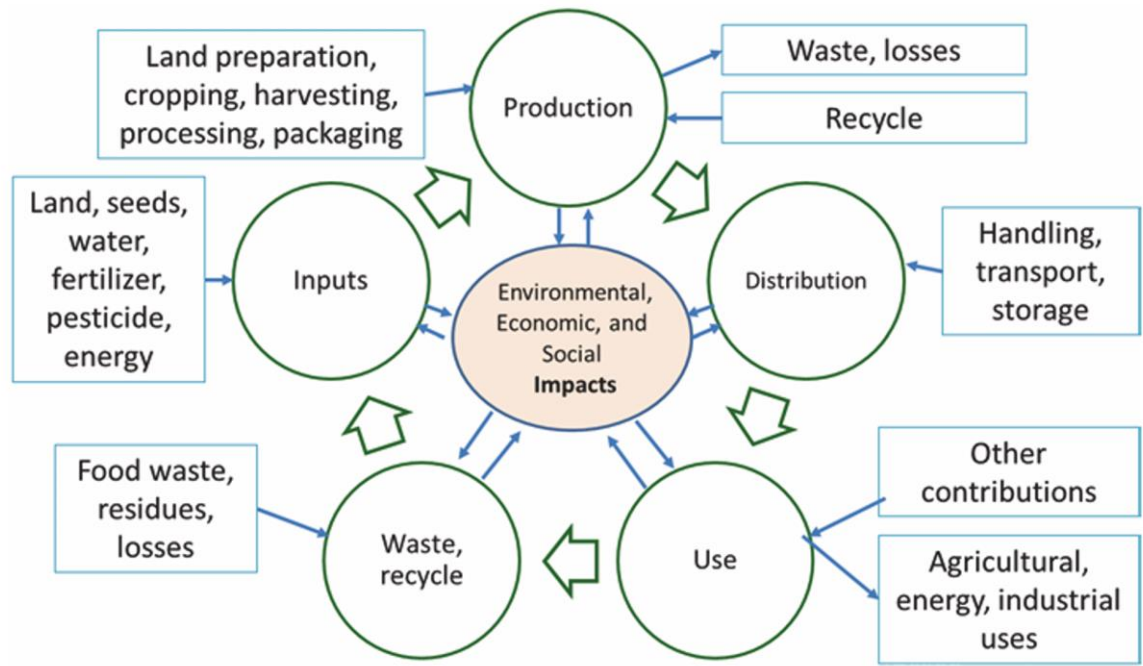


Fig. 10.1 Rice production life cycle

Martin Gummert · Nguyen Van Hung
Pauline Chivenge · Boru Douthwaite
Editors

Sustainable
Rice Straw
Management

[Remarkable Rice: how does rice grow](#)
[How It's Made: Rice](#)
[Agriculture : Rice Cultivation in India](#)
[Life cycle assessment \(LCA\) of rice](#)

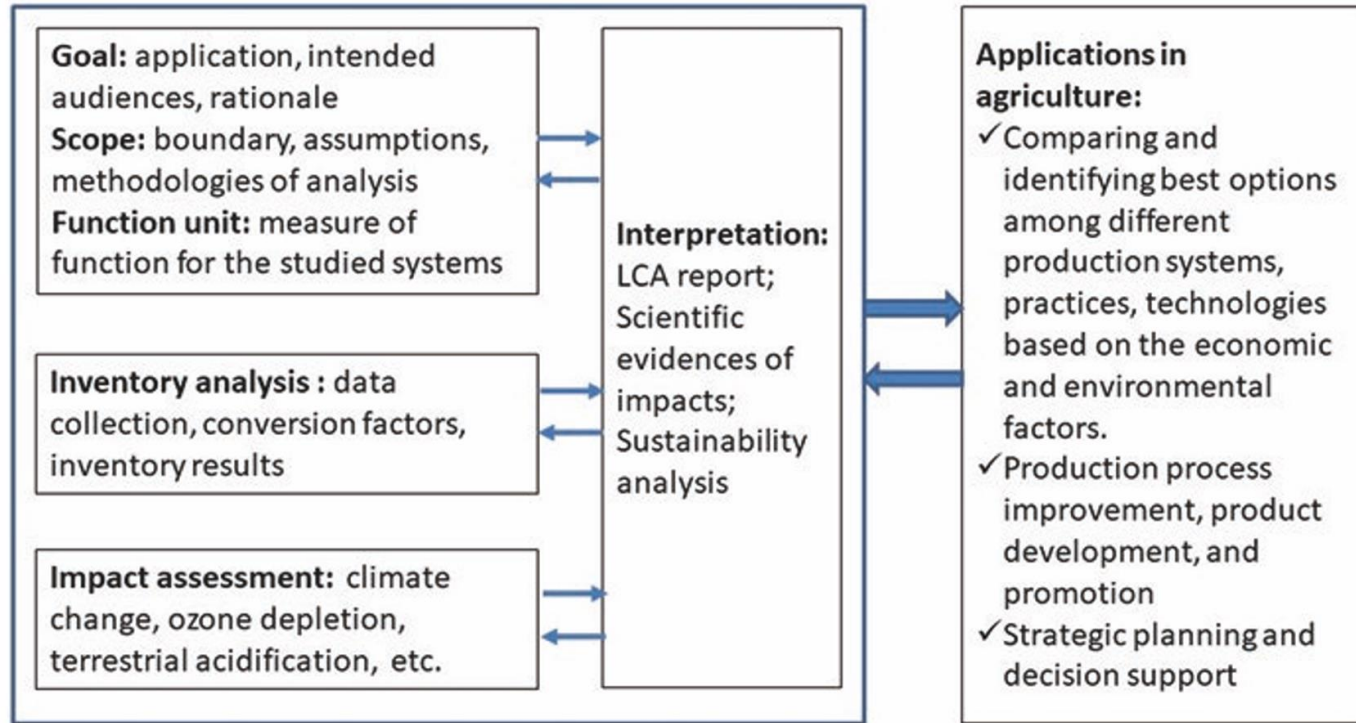


Fig. 10.2 LCA framework and applications

Quick guide to Life Cycle Assessment (LCA)

WHAT'S THE ENVIRONMENTAL IMPACT OF MY PRODUCT / COMPANY / SERVICE?



Why ask?

Management

Make sustainable decisions

Product Development

Develop sustainable products

Sales & Marketing

Prove sustainable claims

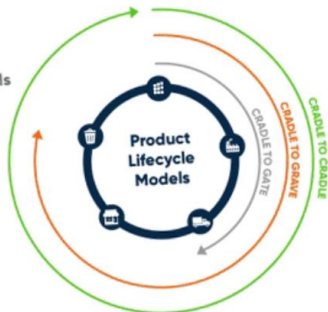
Supply Chain

Find better suppliers

What is the „Life Cycle“?

Stages:

- Raw Materials
- Processing
- Transport
- Retail / Use
- Waste



LCA is a framework standardized by ISO 14044 to measure this impact!
It's conducted in 4 stages:

1

Goal & Scope

WHAT DO WE WANT TO MEASURE?



Define the product / company / service you want to measure



What system do we measure in?
Which parts of the life cycle?
Which impact category (CO₂, water,...)?



What do we exclude?

You can't just compare one LCA to another. It's important to compare the goal & scope of each analysis! For better comparison, there are Product Category Rules (PCR) that define how to analyze a certain product or industry.



2

Life Cycle Inventory

COLLECT AND STRUCTURE OUR DATA

What data do we need? In this stage, we collect all the inputs and processes that we want to measure. For example...

The raw materials and bill of materials
The energy we use and buy
Supplier data
... everything that goes into and flows out of the system we want to measure!

The easiest way to structure your data is in a flow- or tree-chart - from input, over processes, to outputs, and waste.



3

Impact Assessment

TRANSLATE OUR DATA TO IMPACTS



We look at Life Cycle Databases (for example Ecoinvent) and scientific papers to define what the impact of our Life Cycle Inventory is.



We sum up the impacts in category totals - for example, Global Warming Potential (CO₂).

We translate everything to our total. Example: Our category is CO₂. 1 kg of nitrogen equals 25 kg of CO₂ according to norm EN15804.



4

Interpretation

WHAT DOES ALL OF THIS MEAN?

How high are our emissions?

How do our products compare? Can we improve them?

Can we improve our processes?

What are the biggest levers for us?



Based on the interpretation, it is common to go back to the analysis and re-assess certain aspects of it.

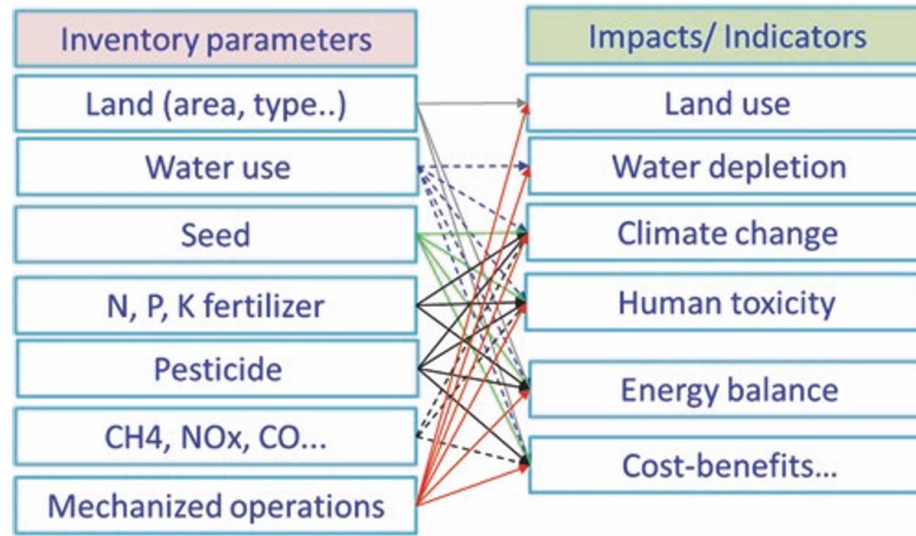


Fig. 10.4 Example of LCIA classification based on LCI results

Table 10.1 Characterization, normalization, and weighting, for example, of rice-straw burning

LCI results			
Factors	Emissions (kg t ⁻¹ of straw)	Climate change: GWP-100a (kg CO ₂ -eq)	Human toxicity potential (kg 1,4 DB-eq)
CH ₄	4.5	X 30.5 = 137.3	–
N ₂ O	0.07	X 265 = 18.6	–
PM _{2.5}	10	–	X 0.82 = 8.2
PM ₁₀	6	–	X 0.82 = 4.9
Characterized results		155.8 kg CO ₂ -eq	13.1 kg 1,4 DB-eq

Life cycle assessment in conventional rice farming system: Estimation of greenhouse gas emissions using cradle-to-gate approach

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2.1. Goal and scope

The goal of the study is to establish the hotspots in the cradle-to-gate greenhouse gas emissions (CO₂ equivalent) of un-milled rice grains from any seed varieties by the conventional farming method. The process carried out by LCA helps to identify which of the parameters are likely to be significant to the GHG emission in rice cultivation. The scopes of the product system are described in the following definition of functional unit and system boundary.

2.2. Functional unit

The functional unit is important since it ensures that all data are normalised in any specific LCA procedure (Weidema et al., 2004). It has to be clearly defined as it provides relevant parameters which can affect the conclusions of any specific study (Matheys et al., 2007). The functional unit used in this study is 1 tonne of un-milled rice grain uploaded to the lorry for transportation to the mill.

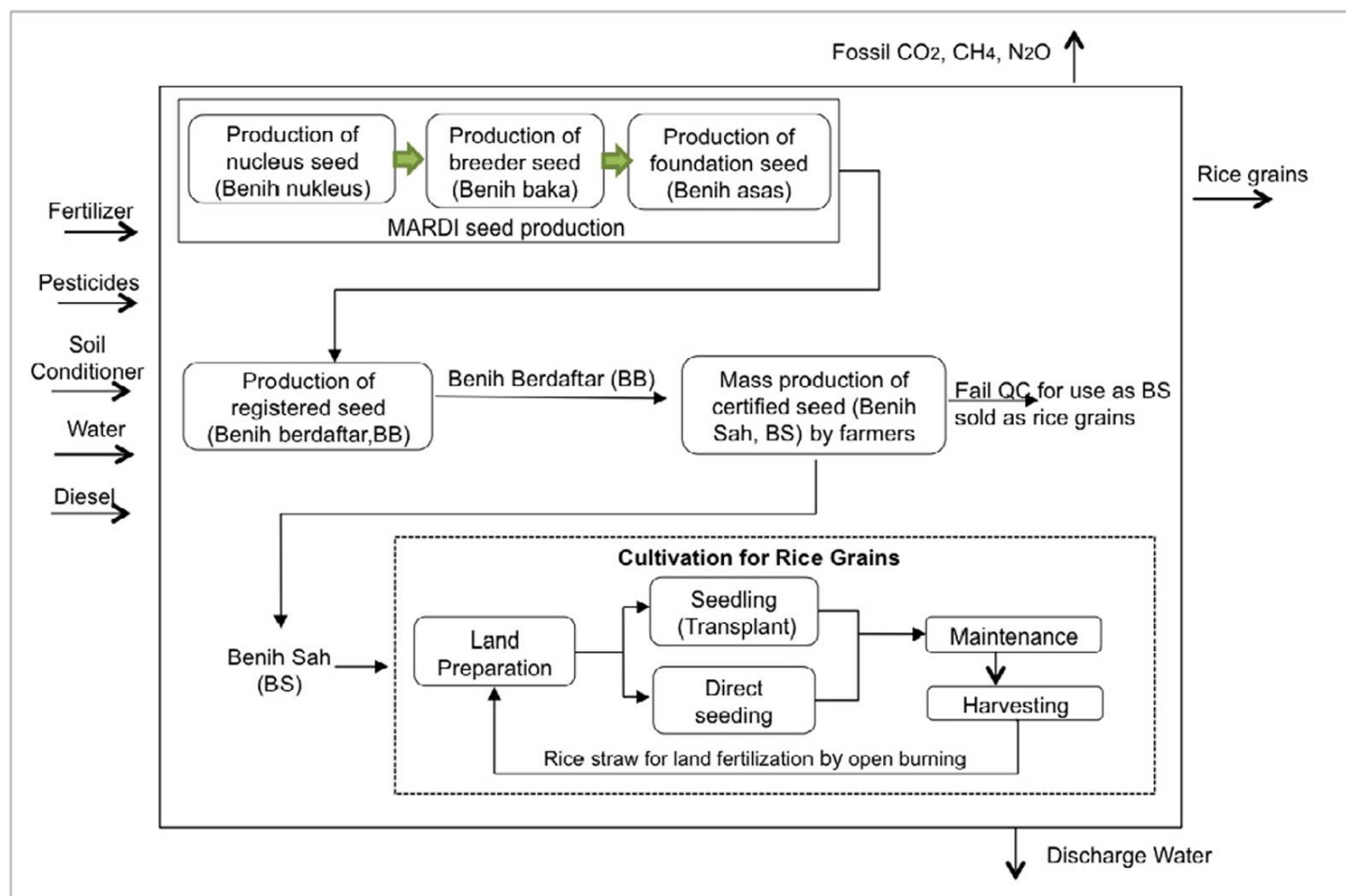


Fig. 1. System boundary for conventional rice farming in Malaysia.

Table 1

Emission factors used in the life cycle inventory of un-milled rice grain. Foreground data for direct emission.

No. Source of Direct Emissions	Emission Factors (kg/kg)*			Remarks
	CO ₂	CH ₄	N ₂ O	
1. Adjusted daily CH ₄ emission (kg CH ₄ ha ⁻¹ day ⁻¹)	—	1.30* (1+(Y*0.29)) ^{0.59}	—	Based on IPCC default baseline emission factor of 1.30 kg CH ₄ ha ⁻¹ day ⁻¹ ; SF _w , scaling factor for continuous flooded practice of 1.0; SF _p , scaling factor for pre-season of non-flooded activity of 1; and SF _o , the adjusted scaling factor for applied organic input of (1+(Y*0.29)) ^{0.59} where Y is tonne of straw ha ⁻¹
2. Direct N ₂ O from addition of synthetic fertilizer and crop residues in flooded rice fields	—	—	0.005	Based on IPCC default value of 0.003 kg N ₂ O-N/kg N from synthetic fertilizer and rice straw
3. Indirect N ₂ O from atmospheric desposition of N volatilized from managed soils	—	—	0.0016	Based on IPCC default value of 0.01 kg N ₂ O-N/kg N volatilized (10% of applied N is volatilized) as default
4. Indirect N ₂ O from N leaching/runoff from soil of paddy plot	—	—	0.0035	Based on IPCC default value of 30% (0.3 fraction) of N applied to soil and 0.75% (0.0075) of leached N is volatilized
5. Urea fertilisation	0.73	—	—	Based on IPCC default value of 0.2 tonne C/tonne urea as default
6. Liming (limestone application)	0.44	—	—	Based on IPCC default value of 0.12 tonne C/tonne limestone as default
7. Rice straw burning	1.515	0.0027	0.00007	Based on IPCC default value (Burning of dry matter - agriculture residues). CO ₂ emitted is considered biogenic carbon and not included in the ghg profile
8. Combustion of diesel and gasoline for farm equipment	3.188	0.00045	0.00008	Extracted from IPCC EFDB for combustion of diesel for 'Uncontrolled Emission: Farm Equipment. Density of diesel is taken as 0.85 kg/litre. Gasoline is assumed similar characteristic as diesel

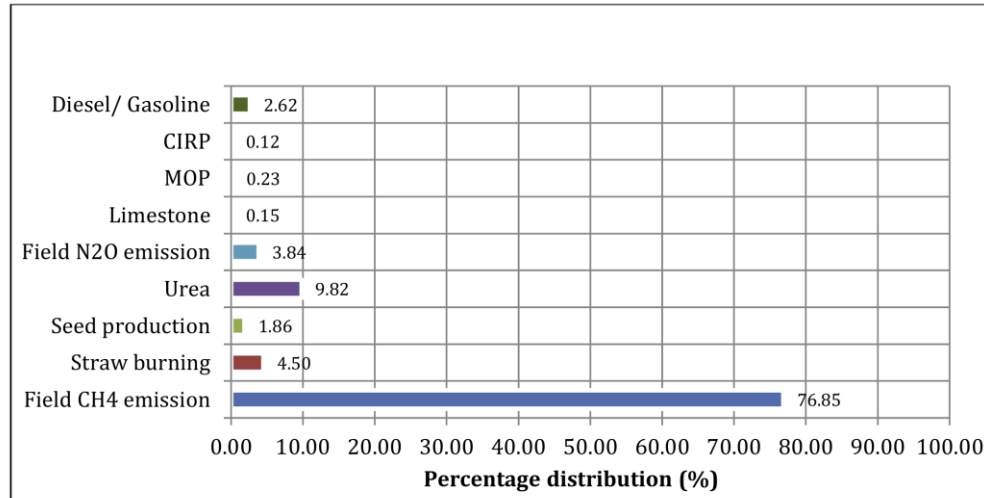
Table 2
Data inventory for functional unit inputs of 1 tonne of un-milled grains.

Parameter	Input Item	Quantity	Unit
Landuse	Paddy plot	0.172	ha
	Rice straw (soil incorporation) (4.1 tonnes/ha)	0.707	tonne
	Rice straw (open burning)	0.707	tonne
Material	Benih sah/Benih berdaftar	17.241	kg
Fuel	Diesel to mobilize tractors during land preparation (3x per season)	5.172	liter
	Diesel to mobilize 1 combined harvester	2.931	liter
	Gasoline for blower and sprayer	3.793	liter
Fertilizer & Soil Conditioner	Urea (46% N)	14.310	kg
	Urea - N (17.5%)PK Sebatian	13.121	kg
	CIRP- N (17.5%) P(15.5%) K Sebatian	16.707	kg
	MOP- N (17.5%) P(15.15%) K (10%) Sebatian	5.741	kg
	Urea - N (17%) PK Tambahan	10.638	kg
	CIRP - N (17%) P(3%) K Tambahan	2.707	kg
	MOP - N (17%) P(3%) K (25%) Tambahan	12.000	kg
	Organic (5% N)	14.310	kg
	Total Urea	38.069	kg
	Tota CIRP	19.414	kg
	Total MOP	17.741	kg
	Total N	18.232	kg
	Limestone	4.655	kg
	Pretilachor	0.293	liter
Pesticide	Buprofezin and Cartap Hydrochloride	0.724	liter
	Azoxystrobin	0.293	liter
	Fipronil	71.897	g

Table 3

GHG profile of the un-milled rice grain.

Parameter	Source	Un-milled Rice Grains via Direct Seeding (kg CO ₂ eq/1000 kg un-milled rice grain)
Landuse	Paddy straw open burning	62.46
	Anaerobic fermentation (include paddy straw soil incorporation)	1067.53
Material	Seed (certified seed)	25.88
Fuel	Diesel and gasoline production	3.84
	Diesel and gasoline combustion	32.59
Fertilizer	Urea production	108.44
	Urea application	27.92
	Limestone production	0.03
	Limestone application	2.05
	Muriate of potash production	3.22
	Rock phosphate production	1.72
	Fertilizer (N) application	53.36
GHG Profile/Carbon Footprint		1389.05

**Fig. 2.** Percentage distribution of GHG for rice cultivation (un-milled grains).

Are there ways to reduce field CH₄ emission during rice production?

Generative AI tool use: chatGPT for Rice

PROMPT: Please share a life cycle assessment of greenhouse gas emissions of rice from farm to fork in India.

Total GHG Emissions from Farm to Fork

Summarizing emissions across all stages, the total GHG emissions for rice from farm to fork in India can be estimated as follows:

1. **Agricultural Production:** 1,400 to 4,100 kg CO₂e/ha
2. **Post-Harvest Processing:** 110 to 280 kg CO₂e/ha
3. **Transportation and Distribution:** 30 to 80 kg CO₂e per ton
4. **Consumption (Cooking):** 150 to 300 kg CO₂e per ton
5. **Waste Management:** 10 to 30 kg CO₂e per ton

Talk to a farmer, farm expert about the methods used in your farm. Watch videos, read articles to understand the entire lifecycle for this food item.
Create your own supply chain geographically to know the distances for where your farm, processing unit, warehouse, retailer, etc. are.
Validate/replace values from other sources such as food databases, research papers if these values are reasonable?
Present your findings visually.

Total Estimated GHG Emissions: 1,700 to 4,790 kg CO₂e per hectare from farm to fork (Considering the average yield of 3-4 tons per hectare, this translates to approximately **425 to 1,197 kg CO₂e per ton of rice**).

Generative AI tool use: chatGPT for Rice

PROMPT: Please share a cradle to grave life cycle assessment of greenhouse gas emissions of rice in India.

Total GHG Emissions from Cradle to Grave

Summarizing emissions across all stages, the total GHG emissions for rice from cradle to grave in India can be estimated as follows:

1. Cradle (Input Production): 130-380 kg CO₂e/ha
2. Agricultural Production: 1,400-4,100 kg CO₂e/ha
3. Post-Harvest Processing: 110-280 kg CO₂e/ha
4. Transportation and Distribution: 30-80 kg CO₂e per ton
5. Consumption (Cooking): 150-300 kg CO₂e per ton
6. Grave (Waste Management): 10-30 kg CO₂e per ton

Total Estimated GHG Emissions: 1,830 to 5,170 kg CO₂e per hectare from cradle to grave (Considering the average yield of 3-4 tons per hectare, this translates to approximately **458 to 1,292 kg CO₂e per ton of rice**).

Generative AI tool use: chatGPT for Eggs

PROMPT: Please share a cradle to grave life cycle assessment of greenhouse gas emissions of eggs in India.

Total GHG Emissions from Cradle to Grave

Summarizing emissions across all stages, the total GHG emissions for egg production from cradle to grave in India can be estimated as follows:

1. **Cradle (Input Production):** 1,600-2,700 kg CO₂e per ton of eggs
2. **Agricultural Production:** 3,700-7,500 kg CO₂e per ton of eggs
3. **Post-Harvest Processing:** 70-150 kg CO₂e per ton of eggs
4. **Transportation and Distribution:** 70-200 kg CO₂e per ton of eggs
5. **Consumption (Cooking):** 50-100 kg CO₂e per ton of eggs
6. **Grave (Waste Management):** 10-20 kg CO₂e per ton of eggs

Total Estimated GHG Emissions: 5,500 to 10,670 kg CO₂e per ton of eggs from cradle to grave.

Activity

- Let's identify the most common foods that we eat.
- Only identify items which you eat at least 5 times in a year or more.
- We will assign a person each to do the life cycle assessment for each of the food items

Food item LCA

- Poore, J., & Nemecek, T. (2018). Reducing food's environmental impacts through producers and consumers. *Science*, 360(6392), 987-992.

Get the data from <https://ourworldindata.org/food-choice-vs-eating-local>

- Create an account on <https://apps.carboncloud.com/climatehub/>

Check out many different food items and their environmental impacts here

- Talk to farmers about the cradle to gate or beyond cycles
- Use generative AI tools
- Perform the LCA for the food item assigned to you for the Indian context.

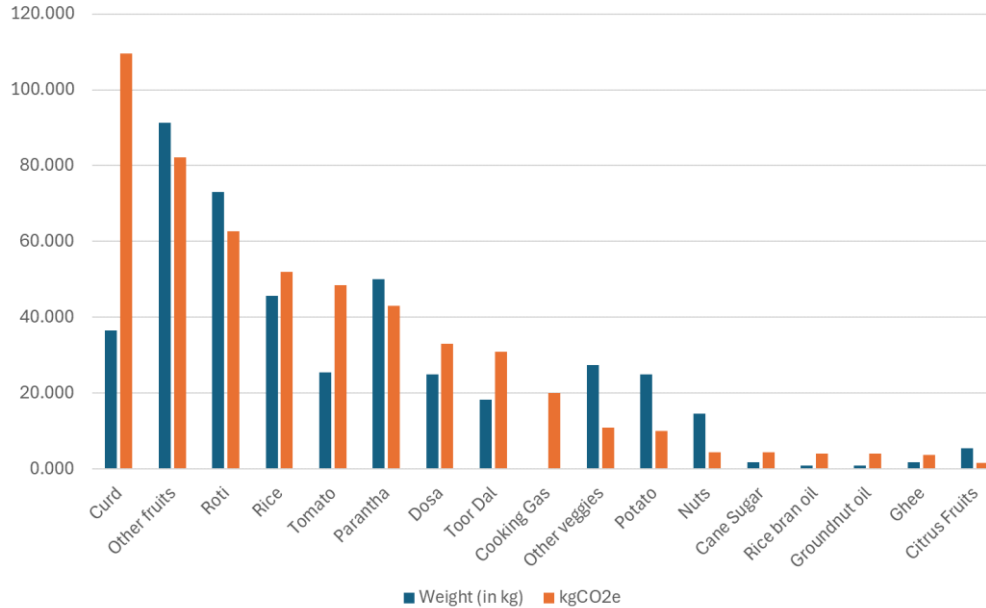
Carbon footprint from annual food consumption (525 kgCO₂e per year = 25% of TSG calculator)

- Breakfast – Dosa + Sambhar (3 days a week), Aloo Parantha + Curd (4 days a week)
- Lunch – 5 Roti + Green Veggies + Lemon
- Dinner – Dal + Rice (4 days a week), Pulao (3 days a week)
- Use of cooking oil, ghee, cooking gas.
- Eat nuts, fruits in between.
- Sugar for seasoning.
- Things to be considered: Salt, Sweets, Pickle, Eating in restaurants, etc.

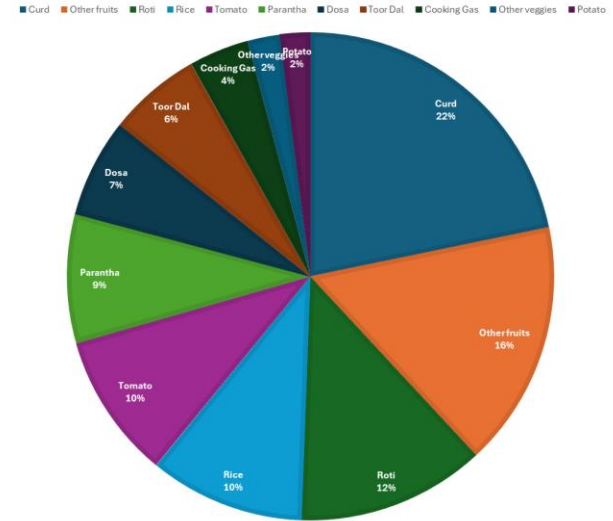


Insights from the food emissions

My annual food related carbon footprint



KGCO2E FOR ANNUAL FOOD CONSUMPTION



Highest CO2 emissions are from curd, fruits, roti/parantha and rice for myself.

Assignment 3

Part A: Food item LCA

Please compute the environmental impact of the food item of your choice (assigned to you in the class) using the Life Cycle Assessment methodology. Please identify the goal and scope of your analysis, the life cycle model and the system boundary, state your assumptions, the functional unit and the life cycle inventory data used along with the sources. You should estimate the carbon footprint for the lifecycle of this food item. But you should also comment on one more life cycle impact assessment indicator from amongst water depletion, human health, human toxicity, air/water/plastic pollution, etc. for this item. For example, how much water is used from the cradle to grave of this product or what are the health concerns with the consumption of this food item, etc.

Please create your own supply chain geographically to know the distances for where your farm, processing unit, warehouse, retailer, etc. are. Please talk to a farmer/farm expert/food processing expert about the methods used in your supply chain and share their insights with us. You can watch videos, read articles to understand the entire lifecycle for this food item. You can use generative AI tools for this assignment. Please validate values from other sources such as food databases, research papers to make sure that the life cycle inventory values for inputs/processes values are reasonable. Share the most important insights about your findings textually and visually.

Please also find the consumption of this food item at the country level and how can the environmental impact be brought down for this food item (for example, you can also think of substitution of this food item with another food item).

Part B: Carbon footprint of annual food consumption

Please estimate the carbon footprint (in kgCO₂e) of your food consumption on a yearly basis. Please use this [spreadsheet as a template](#) for your computation. Please share the calculations for each food item. Please also express your annual carbon footprint from your food consumption in the form of histograms, pie charts, etc to know which food items lead to higher GHG emissions. Please share your insights from this analysis.

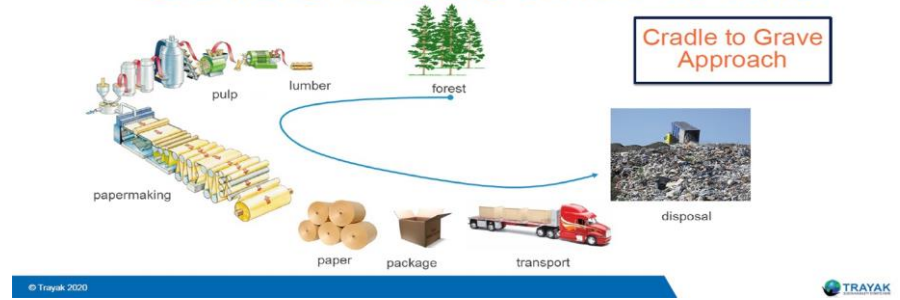


Emissions for how we make things



Life Cycle Assessment (LCA)

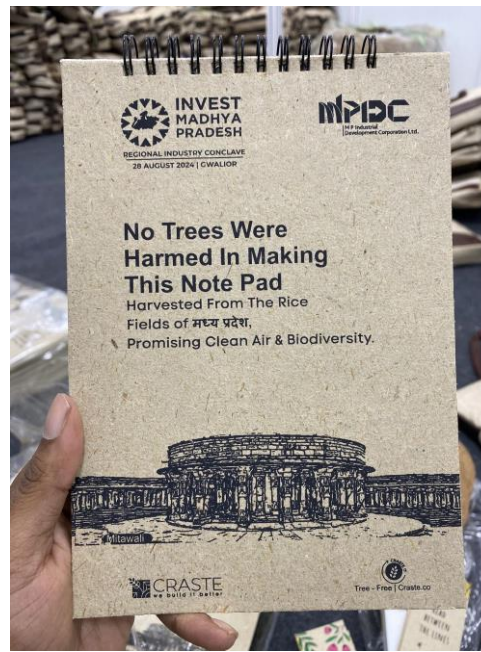
Calculate environmental impacts of a package from:
Material Sourcing - Manufacturing - Distribution - Use - Disposal



How is Paper made?

Are paper cups made of paper only? [Link2](#)

Product Life Cycle Assessment



Rice crop residue based products

Dharaksha Ecosolutions' rice waste based foam

Edible Cutlery



the
better
india

**Kerala Man Quits CEO Job to Make
Edible Cutlery Using Wheat Bran & Rice,
Gets Orders From Across The World**

Stone Paper

**Raw material
collected**



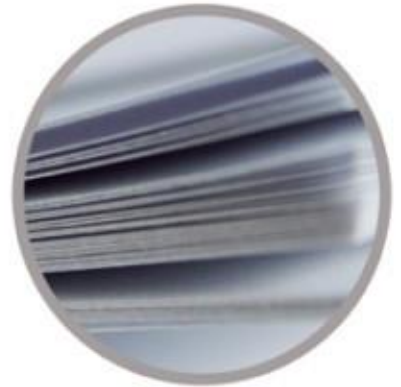
**Grounded
into fine powder**



**Mixed with
HDPE**



**Stone paper
produced**



Biodegradable fabrics

#circulartextile #thetimeisnow #biodegradable
#sustainablefashion #slowfashion #circulareconomy
#circularfashion #regenerativefashion
#regeneration



Building a bottle house



Single-Use Plastic Water bottles

Prof Chetan Singh Solanki's
thoughts

Turning plastic waste into useful chemicals



Energy Swaraj Foundation
Energy by Locals for Locals

#PaapKaPaani

**When you think, Plastic Bottles will get recycled
but the fact is that more than 85% of them never
gets recycled.**



Follow the 5R strategy at home



11 SUSTAINABLE CITIES AND COMMUNITIES



8 DECENT WORK AND ECONOMIC GROWTH



12 RESPONSIBLE CONSUMPTION AND PRODUCTION



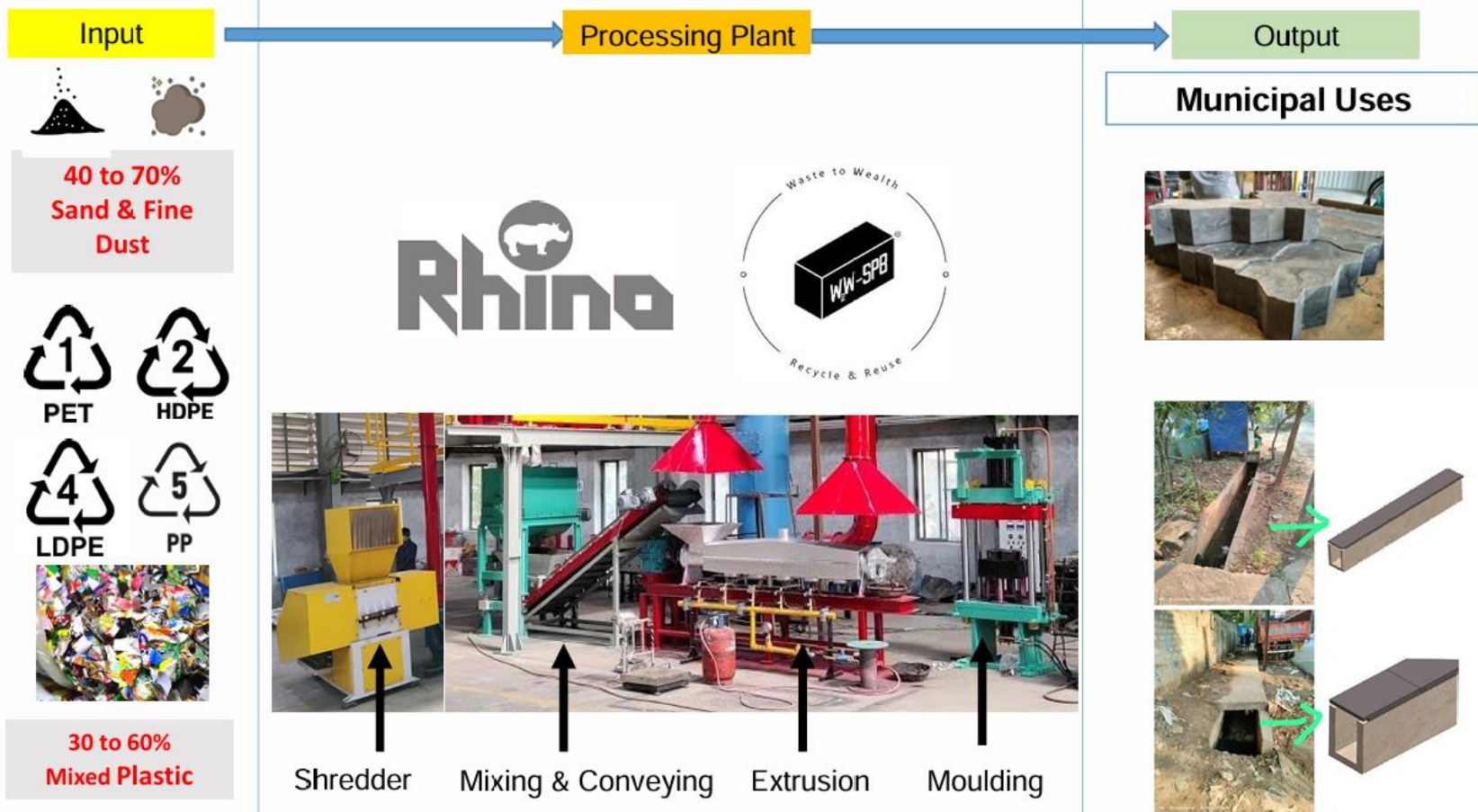
13 CLIMATE ACTION



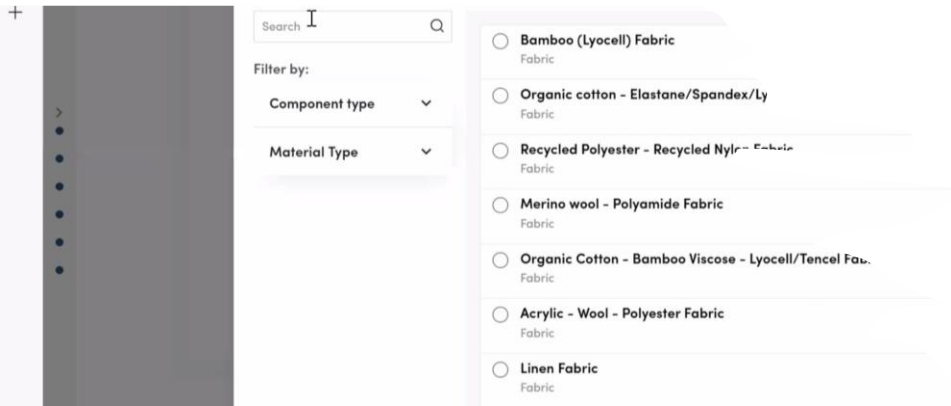
17 PARTNERSHIPS FOR THE GOALS



Silica Plastic Block – Adding Value to Low Value Plastic



Should we take up this project?



LCA at the Fashion School, RCA

Rashmi's work in MA Design Products



Environmental Impact

60%

We are currently using about 60% more of the earth's resources than it can regenerate every year; meaning that we are using about 1.6 earths yearly.

Source: World Wide Fund for Nature

8%

The vital LCA analyst role is expected to grow by 8% by 2028 and produce over 7,000 job opportunities across the U.S.

The high demand for more sustainable brands could make this projection even larger.

Source: Zippia

2 Billion tons

Today, the world produces over 2 billion tons of solid waste yearly, and that amount is expected to grow to 3.4 billion tons by 2050. About one-third of that waste is not managed properly.

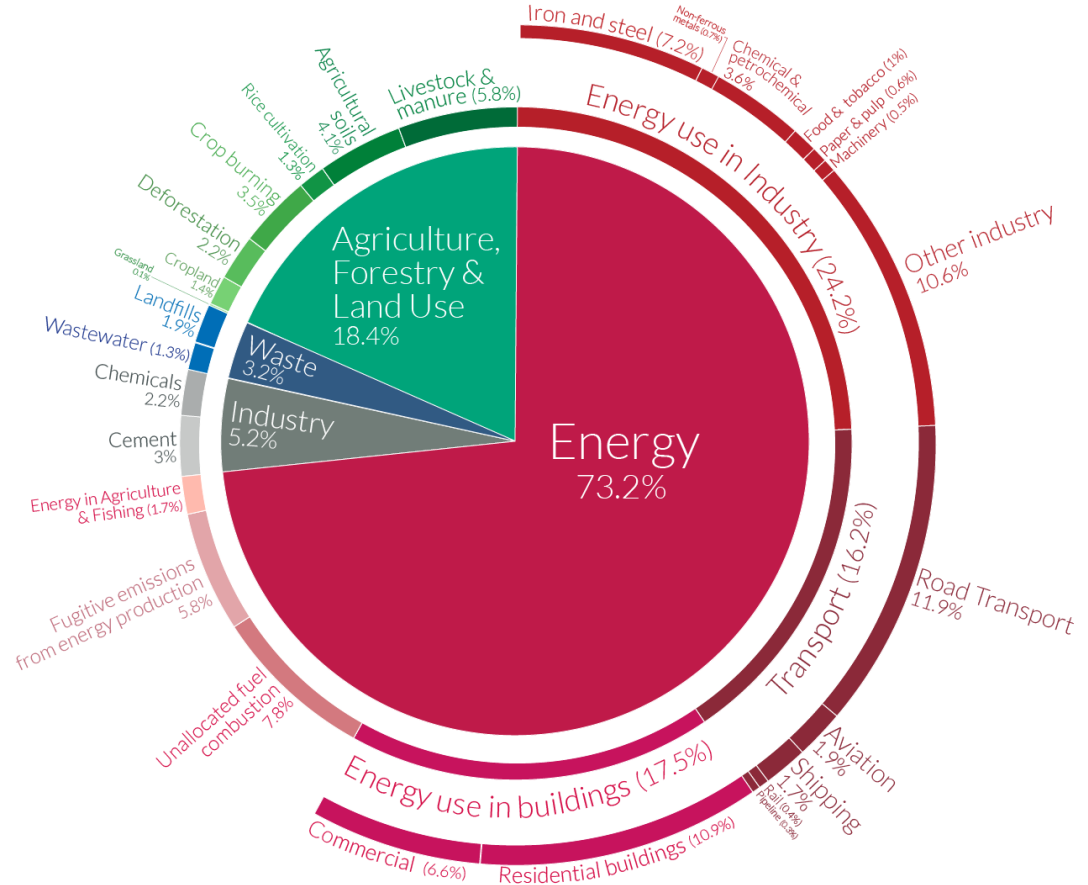
Source: The World Bank

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

Which
materials have
the highest
carbon
footprint?

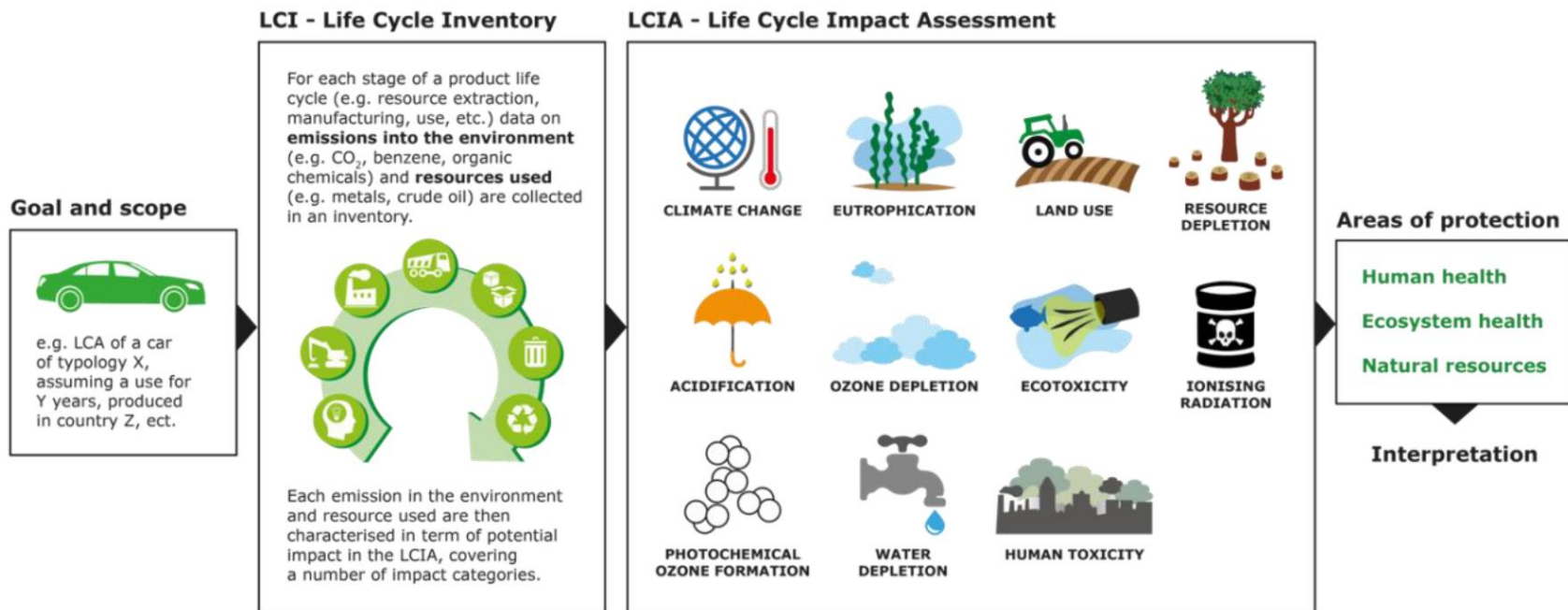


OurWorldinData.org – Research and data to make progress against the world's largest problems.

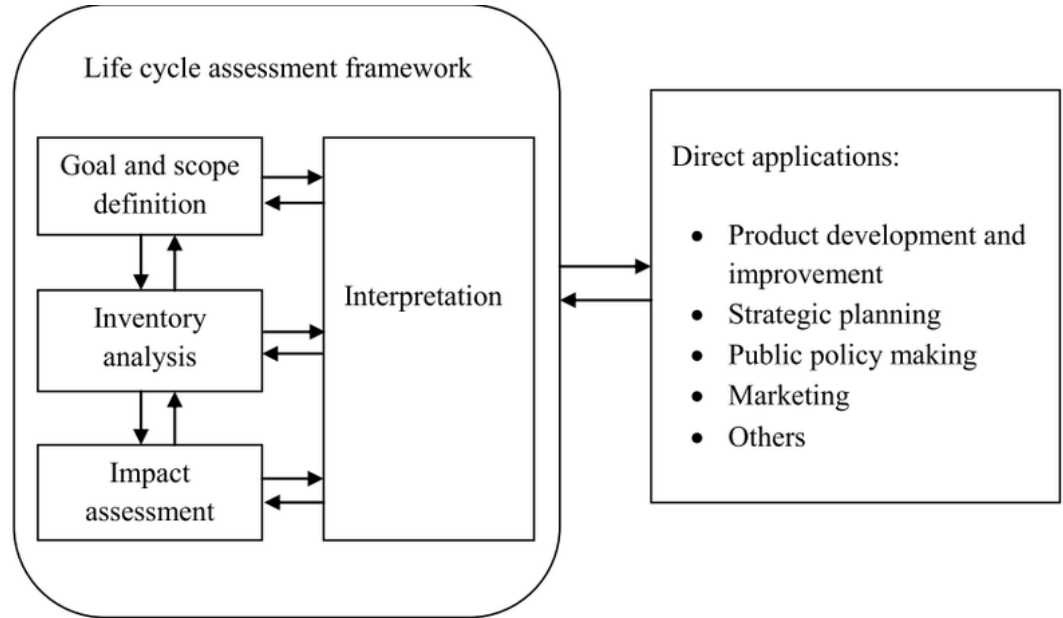
Source: Climate Watch, the World Resources Institute (2020).

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Life Cycle Assessment

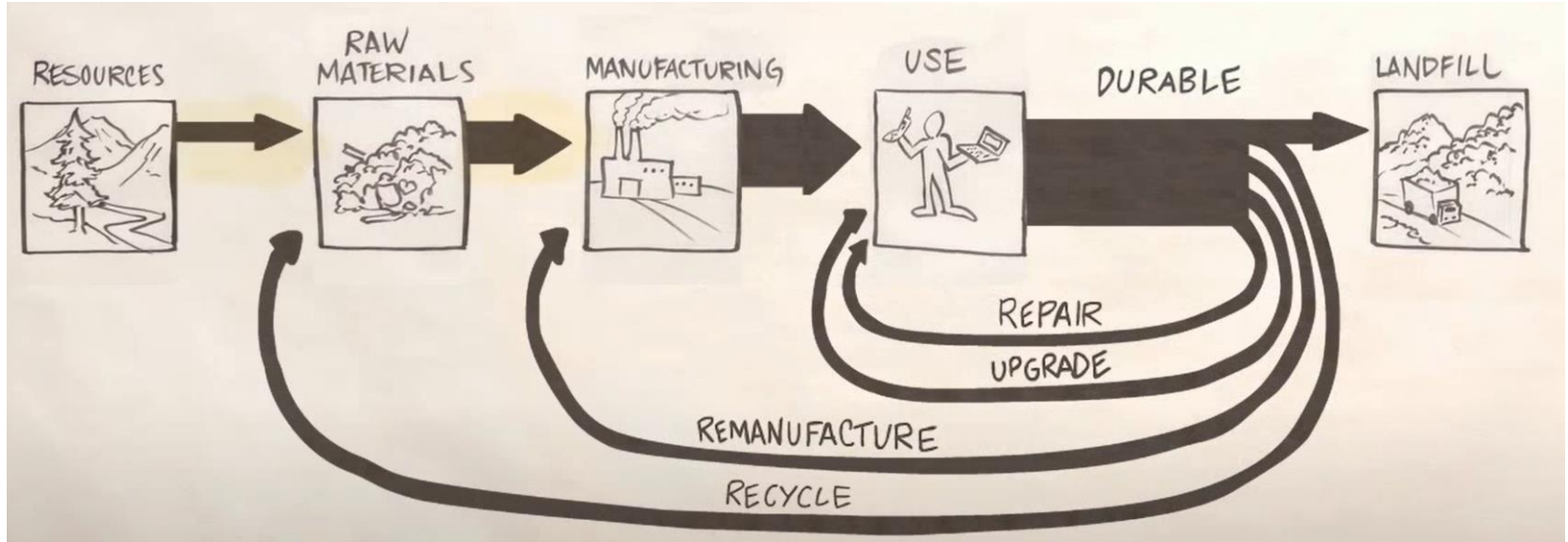


ISO 14040:2006

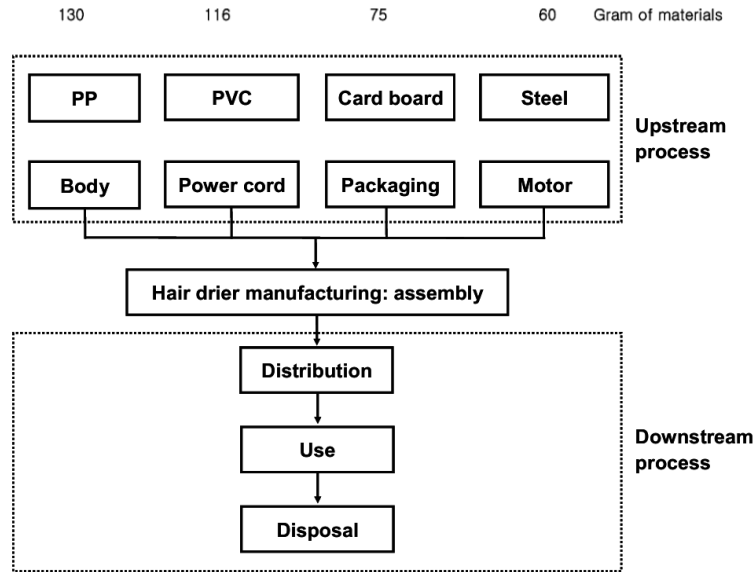


Life Cycle Assessment: Best Practices of International Organization for Standardization (ISO) 14040 Series, 2004

Design for Lifetime



LCA of a hair dryer



[How does a hair dryer work?](#)

Example of Life cycle inventory analysis: hair drier case

1) Life cycle data

Manufacturing data (including component manufacturing)

Manufacturing is mostly dominated by injection molding of body / power cord / packaging / motor. Note: The weight of each component is shown in material composition Table E2.1 in chapter 2. Up to 80% cumulative weight is considered in this study (20% decision rules for mass contribution).	Two products are assembled at the site, model A and model B. Total electricity consumed in manufacturing is 5,040 kWh per year. Note: This will be allocated to Model (A) based on economic value.
---	--



Distribution data

The distribution distance is approximately 3,000 km within Eastern China by 20 ton trucks.	
--	--



Use data

Use scenario - drying hair in 5 minutes (requires 83.33 Wh) - once a day - 6 days a week - 50 weeks a year - the total uses add up to 1,200 over the 4 year lifetime of the product	Electricity consumed 0.083 kWh/time. Note: Electricity consumption is data based on a scenario, which should be checked in the sensitivity analysis described in Chapter 5, Life Cycle Interpretation.
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Disposal data

Disposal via municipal waste (waste incineration only)	There are two scenarios (A and B) for disposal. - Scenario A (Old fashioned way): Incineration 50%, the rest is landfill. - Scenario B (by WEEE directive): The ratio of recycling, incineration, and landfill is 50%, 20%, and 30%, respectively.
--	--

Database

	Substance	Category	Unit	Total
PP (1 kg)	Crude oil	Raw	g	1.20E+03
	CO ₂	Air	g	1.80E+03
	NO _x (as NO ₂)	Air	g	1.00E+01
	SO _x (as SO ₂)	Air	g	1.10E+01
	VOC	Air	g	9.60E+00
Cardboard (1 kg)	Crude oil	Raw	g	1.14E+02
	CO ₂	Air	g	4.67E+02
	NO _x	Air	g	3.96E+00
Steel (1 kg)	Crude oil	Raw	g	3.60E+01
	Coal	Raw	g	3.84E+02
	Iron ore	Raw	g	9.79E+02
	CO ₂	Air	g	1.52E+03
PVC (1 kg)	Crude oil	Raw	g	3.70E+02
	Coal	Raw	g	1.30E+02
	CO ₂	Air	g	1.94E+03
	VOC	Air	g	1.43E+01
Electricity (1 kWh)	Coal	Raw	g	4.95E+01
	CO ₂	Air	g	2.90E+02
	Methane	Air	g	5.32E-01
	SO ₂	Air	g	1.18E+00
Transportation (20t Truck, 1ton-km, 50% loaded)	Crude oil	Raw	g	2.81E+01
	CO	Air	g	5.08E-01
	CO ₂	Air	g	9.25E+01
Incineration (50%) (1 kg waste)	Coal	Raw	g	1.89E-01
	Crude oil	Raw	g	2.76E+00
	CO ₂	Air	g	7.09E+02
	NO _x (as NO ₂)	Air	g	1.57E-01
Landfill (50%) (1 kg waste)	Coal	Raw	g	4.33E-02
	Crude oil	Raw	g	1.90E+00
	CO ₂	Air	g	3.07E+01
	Methane	Air	g	3.07E+00
	SO _x (as SO ₂)	Air	g	1.51E-01
Incineration (20%) (1 kg waste)	Coal	Raw	g	1.61E-01
	Crude oil	Raw	g	7.02E-01
	CO ₂	Air	g	3.56E+00
	NO _x (as NO ₂)	Air	g	1.27E-01
Landfill (30%) (1 kg waste)	Crude oil	Raw	g	9.54E-01
	CO ₂	Air	g	1.87E+01
	Methane	Air	g	1.97E+00
	SO _x (as SO ₂)	Air	g	3.24E-02
Recycling (50%) (1 kg waste)	Coal	Raw	g	7.88E+00
	Crude oil	Raw	g	-7.49E+01
	Iron ore	Raw	g	-1.06E+02
	CO ₂	Air	g	-2.00E+02

a) Body manufacturing

Data collected per unit body	Electricity	0.27 kWh
	PP	130 g
	Calculation of environmental load (EL): DB electricity/kWh×0.27 kWh/unit body DB PP/kg×0.13 kg/unit body	

b) Power cord manufacturing

Data collected per unit power cord (PVC)	Electricity	0.5 kWh (Data allocated by physical mass)
	PVC	116 g
	Calculation of environmental load (EL): DB electricity/kWh× 0.5 kWh/unit power cord (PVC) DB PVC/kg× 0.116 kg/unit power cord (PVC)	

c) Packaging manufacturing

Data collected per unit packaging	Electricity	0.1 kWh
	Paper carton (Cardboard)	75 g
	Calculation of environmental load (EL): DB electricity/kWh× 0.1 kWh/unit packaging DB Cardboard/kg× 0.075 kg/unit packaging	

d) Motor manufacturing

Data collected per unit motor (steel)	Electricity	0.6 kWh (Data allocated by physical mass)
	PVC	60 g
	Calculation of environmental load (EL): DB electricity/kWh×0.6 kWh/unit motor DB Steel/kg× 0.06 kg/unit motor	

d) Total EL from the upstream processes

Sum of EL from body (1), power cord (2), packaging (3), and motor manufacturing (4)

c) Calculation of electricity consumed for Model (A)

Electricity consumed	Allocation factor	Electricity consumed (Allocated)	Electricity consumed (Allocated)/reference flow
5,040 kWh	0.414	2,089 kWh for Product A	0.33 kWh

5,040 kWh x (0.414)/(6,420unit) = 0.33 kWh/one unit of Model(A)

Calculation of environmental load (EL): DB electricity/kWh× 0.33 kWh/unit hair drier

7) Data from distribution process

Data collected from distribution process	Distance	3,000 km
	Location	within Eastern China
	Transportation means	20 tons
Calculation of environmental load (EL): DB 20 ton truck(ton-km) × distance traveled (3,000 km) × hair drier weight (0.475 kg/(1,000 kg/ton))		

In calculating the EL of distribution, a single hair drier is considered.

8) Data from use stage

- Electricity used for drying hair was the only source of input.
- No consideration was given to water.

Use scenario

- Drying hair in 5 minutes (requires 83.33 Wh)
- Once a day
- 6 days a week
- 50 weeks a year

The total uses add up to 1,200 times over the 4 year lifetime of the product.

Data collected from use stage	Electricity consumed	0.0833 kWh/each use
	Calculation of environmental load (EL): DB electricity/kWh× 0.0833 kWh/each use× 1,200 uses	

9) Data from disposal stage

Scenario A - Assume that 50% of the hair drier by mass is combustible parts, while the remaining 50% is non combustible. The combustible parts are incinerated and the rest is landfilled.

Scenario B - Assume that 20% of the hair drier will go into incineration, 30% to landfill and the remaining 50% into recycling. (This is to reflect the requirements set in the WEEE directive)

In this example, the two disposal scenarios will be compared to determine the impact of different scenarios on the environmental load of disposal of the hair drier.

- Assume that the environmental load associated with the collection of waste hair drier is negligible.

Scenario A	Scenario B
Landfill – 50%	Landfill – 20%
Incineration – 50%	Incineration – 30%
	Recycling – 50%
Calculation of environmental load (EL): DB incineration (50%)/kg × 0.475 kg/unit hair drier DB landfill (50%)/kg × 0.475 kg/unit hair drier	Calculation of environmental load (EL): DB incineration (20%)/kg × 0.475 kg/unit hair drier DB landfill (30%)/kg × 0.475 kg/unit hair drier DB recycling (50%)/kg × 0.475 kg/unit hair drier

10) LCI of hair drier

Sum of EL from the upstream, manufacturing, distribution, use and disposal stages:

a) EL from the upstream processes

Parameter	Body (housing)		Power cord manufacturing		Packaging manufacturing		Motor manufacturing		Total (EL /0.80)
	PP	Electricity	PVC	Electricity	Card-board	Electricity	Steel	Electricity	
Crude oil	1.56E+02		4.29E+01		8.57E+00		2.16E+00		2.62E+02
Coal		1.34E+01	1.51E+01	2.48E+01		4.95E+00	2.30E+01	2.97E+01	1.39E+02
Iron ore							5.87E+01		7.34E+01
CO ₂	2.34E+02	7.83E+01	2.25E+02	1.45E+02	3.50E+01	2.90E+01	9.12E+01	1.74E+02	1.26E+03
Methane		1.44E-01		2.66E-01		5.32E-02		3.19E-01	9.78E-01
CO									
VOC	1.25E+00		1.66E+00						3.63E+00
NO _x (Air)	1.30E+00				2.97E-01				2.00E+00
SO _x (Air)	1.43E+00	3.19E-01		5.90E-01		1.18E-01		7.08E-01	3.96E+00

Note: 0.80 is the mass fraction included in the product system as defined by the decision rule for mass contribution, 80%.

b) EL from the manufacturing, distribution, and use stage

Parameter	Manufacturing	Distribution	Use	Total
	Electricity	Transportation	Electricity	
Crude oil		4.00E+01		4.00E+01
Coal	1.61E+01		4.95E+03	4.96E+03
Iron ore				
CO ₂	9.43E+01	1.32E+02	2.90E+04	2.92E+04
Methane	1.73E-01		5.32E+01	5.34E+01
CO		7.24E-01		7.24E-01
VOC				
NO _x (Air)				
SO _x (Air)	3.84E-01		1.18E+02	1.18E+02

c) EL from the disposal stage

Parameter	Scenario A			Scenario B			
	Incineration (50%)	Landfill (50%)	Total	Incineration (20%)	Landfill (30%)	Recycling (50%)	Total
Crude oil	1.31E+00	9.02E-01	2.21E+00	3.33E-01	4.53E-01	-3.56E+01	-3.48E+01
Coal	8.98E-02	2.05E-02	1.10E-01	7.65E-02		3.74E+00	3.82E+00
Iron ore						-5.03E+01	-5.03E+01
CO ₂	3.37E+02	1.46E+01	3.52E+02	1.69E+00	8.89E+00	-9.52E+01	-8.46E+01
Methane		1.46E+00	1.46E+00		9.36E-01		9.36E-01
CO							
VOC							
NO _x (Air)	7.48E-02		7.48E-02	6.03E-02			6.03E-02
SO _x (Air)		7.18E-02	7.18E-02		1.54E-02		1.54E-02

f) Sum of EL

Parameter	Upstream	Manufacturing	Distribution	Use	Disposal		Sum of EL (g/hair drier)	
					Scenario A	Scenario B	Scenario A	Scenario B
Crude oil	2.62E+02		4.00E+01		2.21E+00	-3.48E+01	3.04E+02	2.67E+02
Coal	1.39E+02	1.61E+01		4.95E+03	1.10E-01	3.82E+00	5.10E+03	5.11E+03
Iron ore	7.34E+01					-5.03E+01	7.34E+01	2.32E+01
CO ₂	1.26E+03	9.43E+01	1.32E+02	2.90E+04	3.52E+02	-8.46E+01	3.08E+04	3.04E+04
Methane	9.78E-01	1.73E-01		5.32E+01	1.46E+00	9.36E-01	5.58E+01	5.53E+01
CO			7.24E-01				7.24E-01	7.24E-01
VOC	3.63E+00						3.63E+00	3.63E+00
NO _x (Air)	2.00E+00				7.48E-02	6.03E-02	2.07E+00	2.06E+00
SO _x (Air)	3.96E+00	3.84E-01		1.18E+02	7.18E-02	1.54E-02	1.22E+02	1.22E+02

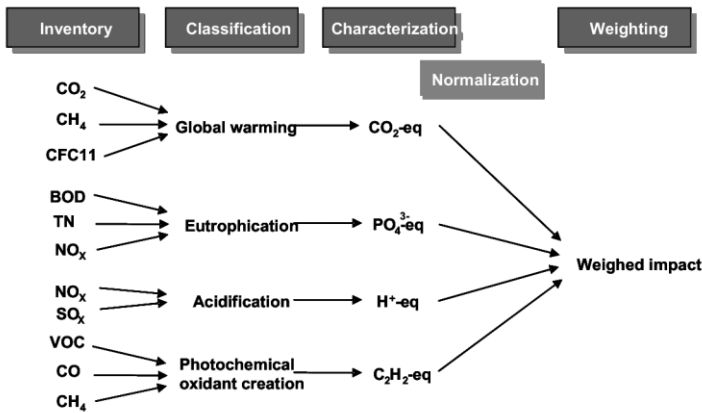


Figure 4.1 Elements and relationship among the elements of LCIA

Example of life cycle impact assessment: hair drier case

1) Classification

Inventory parameter	Global Warming (GW)	Ozone Depletion (OD)	Acidification (AD)	Eutrophication (EU)	Photochemical Ozone Creation (POC)	Abiotic Resource Depletion (ARD)
Crude oil						●
Coal						●
Iron ore						●
CO ₂	●					
Methane	●				●	
CO					●	
VOC					●	
NO _x (Air)			●	●	●	
SO _x (Air)			●			

Note: Since the hair drier does not exert impact on OD, the environmental impact on OD will not be dealt with here.

2) Characterization

a) Characterization (equivalency) factor

Parameter	Characterization factor				
	GWP (g CO ₂ eq/g)	AP (g SO ₂ eq/g)	EP (g PO ₄ ³⁻ eq/g)	POCP (g ethene eq/g)	ADP (1/yr) Reserve-to-Use method
	eqv _{i,j}	eqv _{i,j}	eqv _{i,j}	eqv _{i,j}	eqv _{i,j}
Crude oil					2.48E-02 (BP 2001)
Coal					3.44E-03 (BP 2001)
Iron ore					7.21E-03 (USGS 2001)
CO ₂	1.00E+00 (IPCC 2001)				
Methane	2.30E+01 (IPCC 2001)			6.00E-03 (Heijungs et al., 1992)	
CO				2.70E-02 (Derwent et al., 1996)	
VOC				4.16E-01 (Heijungs et al., 1992)	
NO _x (Air)		7.00E-01 (Hauschild et al., 1999)	1.30E-01 (Heijungs et al., 1992)	2.80E-02 (Derwent et al., 1996)	
SO _x (Air)		1.00E+00 (Hauschild et al., 1999)			

b) Characterization

Parameter	Load _{ij}	Characterized Impact (CI _i)				
		GW (g CO ₂ eq / hair drier)	AD (g SO ₂ eq / hair drier)	EU (g PO ₄ ³⁻ eq / hair drier)	POC (g ethene eq / hair drier)	ARD (g/hair drier -yr)
Crude oil	3.04E+02					7.55E+00
Coal	5.10E+03					1.76E+01
Iron ore	7.34E+01					5.29E-01
CO ₂	3.08E+04	3.08E+04				
Methane	5.58E+01	1.28E+03			3.35E-01	
CO	7.24E-01				1.95E-02	
VOC	3.63E+00				1.51E+00	
NO _x (Air)	2.07E+00		1.45E+00	2.69E-01	5.80E-02	
SO _x (Air)	1.22E+02		1.22E+02			
Total		3.21E+04	1.24E+02	2.69E-01	1.92E+00	2.56E+01

c) Characterized Impact (CI_i)

Impact category		Life cycle stage						Total	
		Upstream	Manu- facturing	Distri- bution	Use	Disposal			
						Scenario A	Scenario B	Scenario A	Scenario B
GW	g CO ₂ eq/ hair drier	1.29E+03	9.83E+01	1.32E+02	3.02E+04	3.85E+02	-6.31E+01	3.21E+04	3.17E+04
AD	g SO ₂ eq/ hair drier.	5.35E+00	3.84E-01		1.18E+02	1.24E-01	5.76E-02	1.24E+02	1.24E+02
EU	g PO ₄ ³⁻ eq/ hair drier	2.60E-01				9.72E-03	7.84E-03	2.69E-01	2.67E-01
POC	g ethene eq/ hair drier	1.57E+00	1.04E-03	1.95E-02	3.19E-01	1.08E-02	7.30E-03	1.92E+00	1.92E+00
ARD	g/ hair drier-yr	7.51E+00	5.54E-02	9.93E-01	1.70E+01	5.52E-02	-1.21E+00	2.56E+01	2.44E+01

3) Normalization

a) Normalization reference (N_i)

Impact category	Geographical boundary	Value	Unit
GW	Global	5.66E+06	g CO ₂ eq/pe·yr
AD	Regional	5.64E+04	g SO ₂ eq/pe·yr
EU	Regional	8.90E+03	g PO ₄ ³⁻ eq/pe·yr
POC	Regional	7.37E+03	g ethene eq/pe·yr
ARD	Global	1.87E+04	g/pe·yr ²

Note:

1. Reference year = 1995
2. World population = 5,675,675,676
3. Regional population (certain region in Eastern China) = 45,093,000

b) Normalized Impact

Normalized Impact (NI_i) = CI_i / N_i

Impact category		Life cycle stage						Total	
		Upstream	Manu- facturing	Distri- bution	Use	Disposal			
						Scenario A	Scenario B	Scenario A	Scenario B
GW	pe·yr/ hair drier	2.27E-04	1.74E-05	2.33E-05	5.34E-03	6.80E-05	-1.11E-05	5.67E-03	5.59E-03
AD	pe·yr/ hair drier	9.49E-05	6.80E-06		2.09E-03	2.20E-06	1.02E-06	2.20E-03	2.19E-03
EU	pe·yr/ hair drier	2.92E-05				1.09E-06	8.81E-07	3.03E-05	3.00E-05
POC	pe·yr/ hair drier	2.13E-04	1.41E-07	2.65E-06	4.33E-05	1.47E-06	9.91E-07	2.61E-04	2.61E-04
ARD	pe·yr/ hair drier	4.01E-04	2.96E-06	5.31E-05	9.10E-04	2.95E-06	-6.48E-05	1.37E-03	1.30E-03

4) Weighting

a) Weight of impact categories (W_i) based on the panel method

Impact category	GW	AD	EU	POC	ARD
Weight (W_i)	0.29	0.16	0.14	0.13	0.28

Note: weighting factors given here are for illustrative purpose only. Readers should not use these factors for their own work.

b) Weighted impact (WI_i) = $NI_i \times W_i$

Impact category	Normalized impact (NI_i) = CI_i/N_i (pe-yr/ hair drier)		Weighted Impact (WI_i) (pe-yr/hair drier)	
	Scenario A	Scenario B	Scenario A	Scenario B
GW	5.67E-03	5.59E-03	1.67E-03 (68.6%)	1.65E-03 (68.9%)
AD	2.20E-03	2.19E-03	3.46E-04 (14.2%)	3.46E-04 (14.4%)
EU	3.03E-05	3.00E-05	4.35E-06 (0.2%)	4.32E-06 (0.2%)
POC	2.61E-04	2.61E-04	3.30E-05 (1.4%)	3.29E-05 (1.4%)
ARD	1.37E-03	1.30E-03	3.81E-04 (15.6%)	3.62E-04 (15.1%)
Total			2.44E-03 (100.0%)	2.39E-03 (100.0%)

c) Weighted impact per life cycle stage

	Upstream	Manu- facturing	Distri- bution	Use	Disposal		Total	
					Scenario A	Scenario B	Scenario A	Scenario B
GW	6.70E-05	5.12E-06	6.86E-06	1.57E-03	2.01E-05	-3.28E-06	1.67E-03	1.65E-03
AD	1.50E-05	1.07E-06		3.30E-04	3.47E-07	1.61E-07	3.46E-04	3.46E-04
EU	4.19E-06				1.57E-07	1.27E-07	4.35E-06	4.32E-06
POC	2.70E-05	1.78E-08	3.35E-07	5.47E-06	1.86E-07	1.25E-07	3.30E-05	3.29E-05
ARD	1.11E-04	8.22E-07	1.47E-05	2.53E-04	8.20E-07	-1.80E-05	3.81E-04	3.62E-04
Total	2.25E-04	7.03E-06	2.19E-05	2.16E-03	2.16E-05	-2.09E-05	2.44E-03	2.39E-03

Sum of WI_i = WI of the hair drier system for Scenario A = 2.44E-03

for Scenario B = 2.39E-03

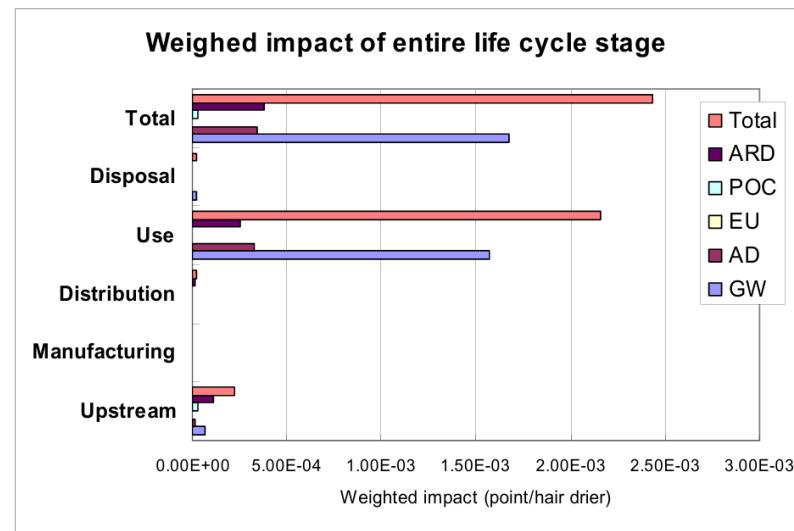


Figure E5.1 Weighted Impact of life cycle stage

Industry (Life Cycle of a PET bottle)

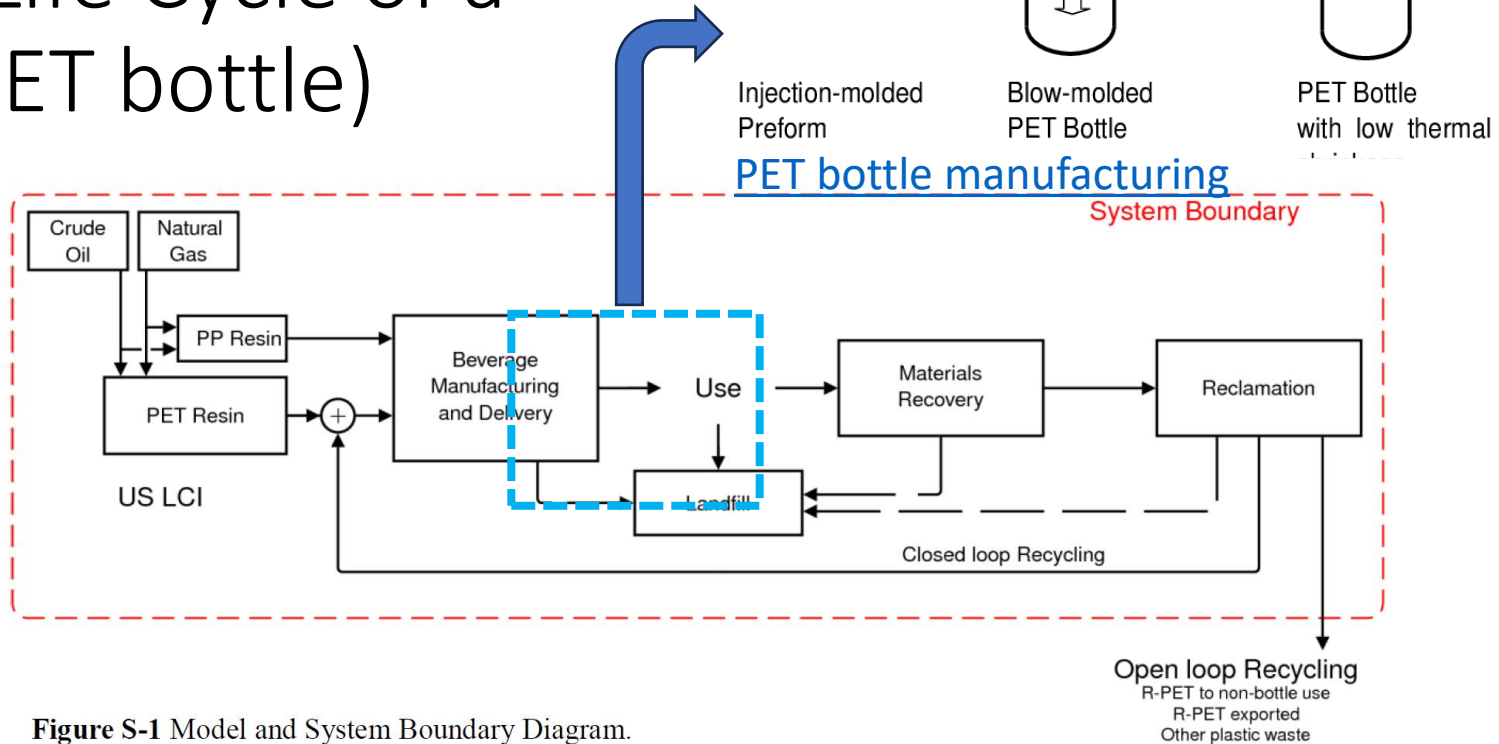


Figure S-1 Model and System Boundary Diagram.

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

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

[Open LCA PET bottles](#)

[LCA of PET bottles – Indian perspective](#)

Generative AI tool use: chatGPT for a PET bottle

PROMPT: Please share a cradle to grave life cycle assessment of greenhouse gas emissions of a PET bottle in India.

Total GHG Emissions from Cradle to Grave

Summarizing emissions across all stages, the total GHG emissions for a PET bottle from cradle to grave in India can be estimated as follows:

1. Cradle (Raw Material Extraction and Processing): 3-5 kg CO₂e per kg of PET
2. Manufacturing: 1-2 kg CO₂e per kg of PET
3. Distribution and Retail: 0.2-0.6 kg CO₂e per kg of PET
4. Use Phase: Negligible
5. Grave (Waste Management and Recycling): 0.3-1 kg CO₂e per kg of PET

Total Estimated GHG Emissions: 4.5 to 8.6 kg CO₂e per kg of PET from cradle to grave.

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

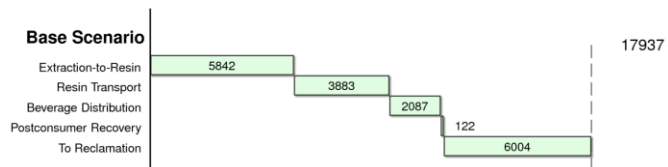
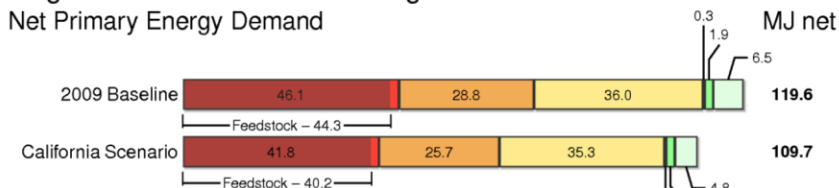


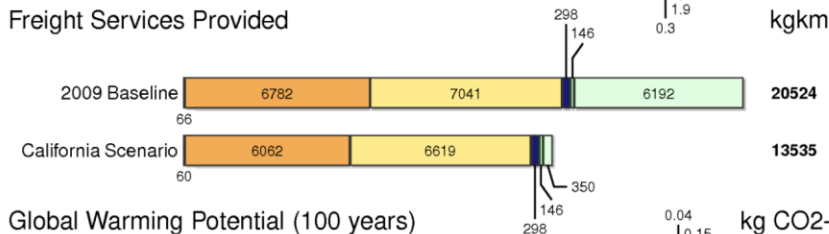
Figure S-5 Freight services used in transporting the product over its life cycle, by transportation step (freight services required upstream in the supply chain and for the fuel production cycle are excluded).

1 kg PET resin – 27.9 L Beverage Delivered

Net Primary Energy Demand



Freight Services Provided



Global Warming Potential (100 years)

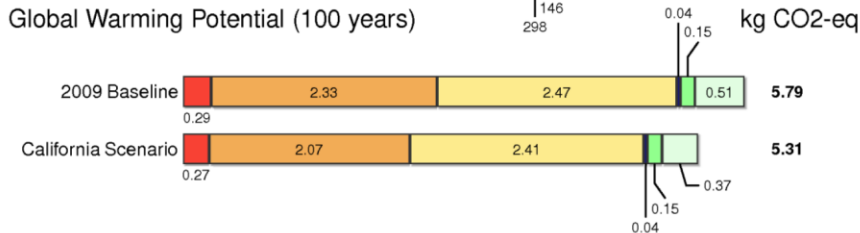


Figure S-4 Comparison of the Baseline and California alternative scenarios under three different indicators.

Life Cycle Model (GaBi)

PET Bottle Layout

GaBi 4 process plan: Mass [kg]

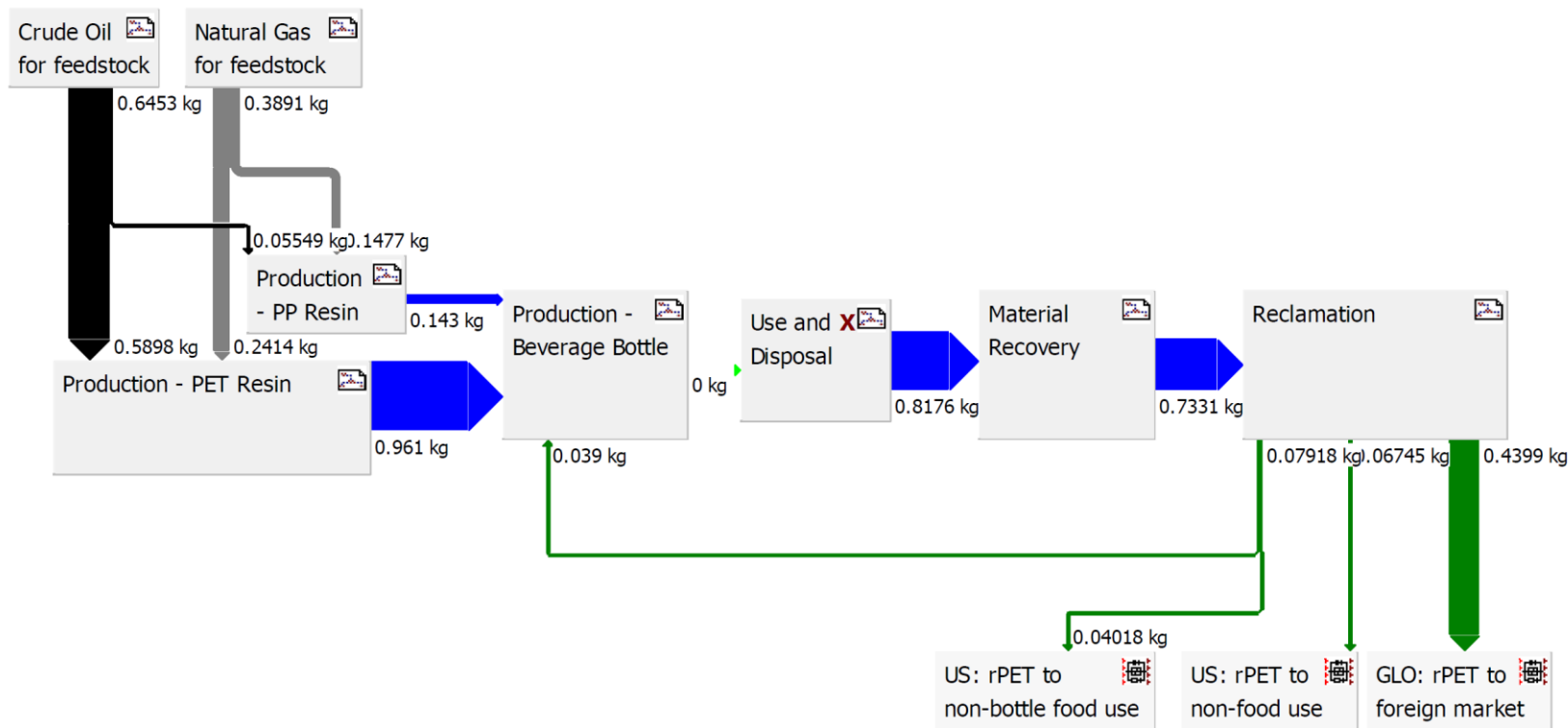
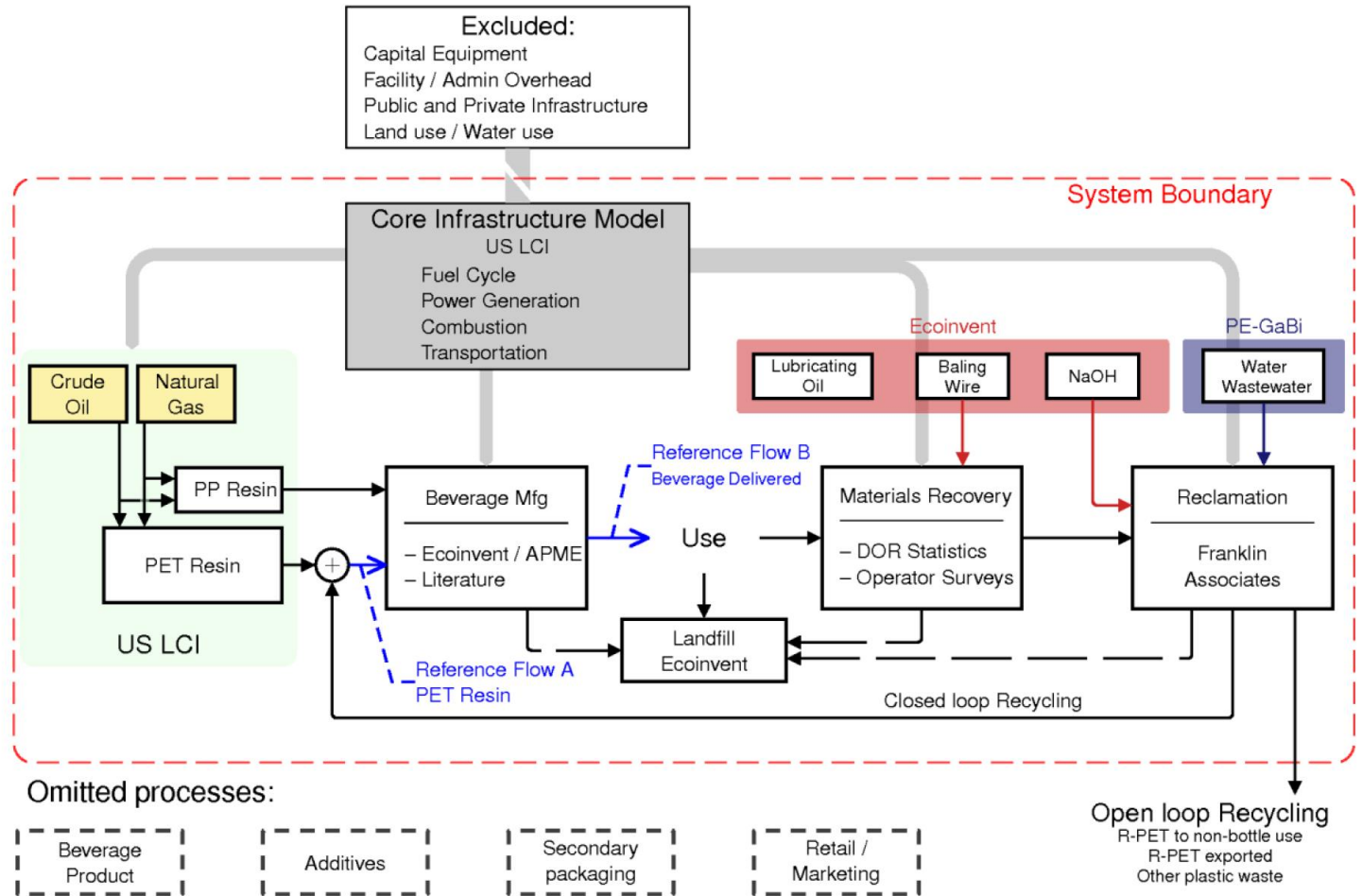


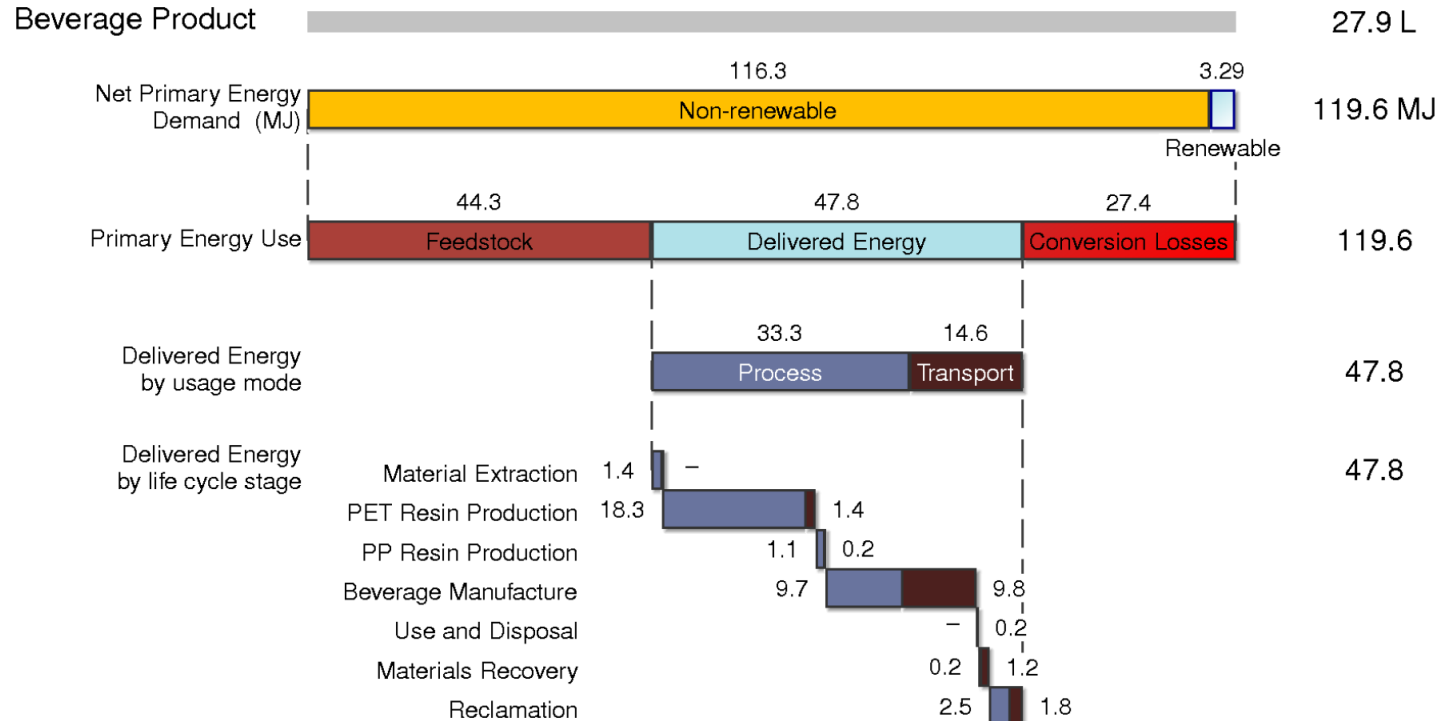
Figure 1.1 GaBi Life cycle model showing mass flows under the 2009 baseline scenario, for bottles made from 1 kg of PET resin.

System
Diagram
with data
and model
boundaries



Detail of energy usage in the product system

1 kg PET Resin



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](#)

Most commonly used products in our life?



Spreadsheet with kgCO2e for products used in households

Ecochain Mobius – ecoinvent database

[Product LCA preference form](#)



[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



www.vigyanashram.com

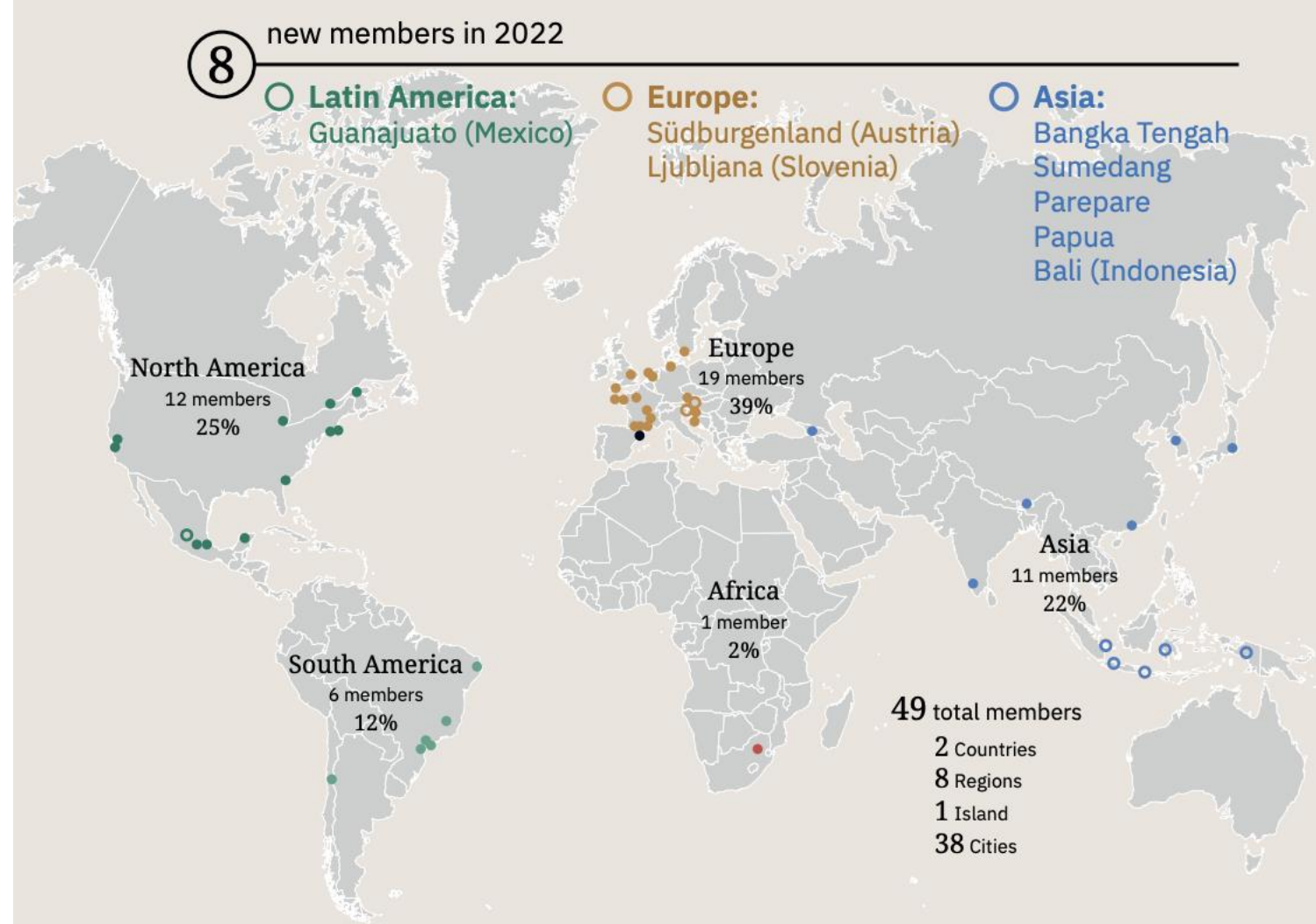
Vigyan Ashram: self sufficient village

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/>



Fab City Network



The cities network share working practices and knowledge with the wider network as well as a deep alignment of purpose and culture.

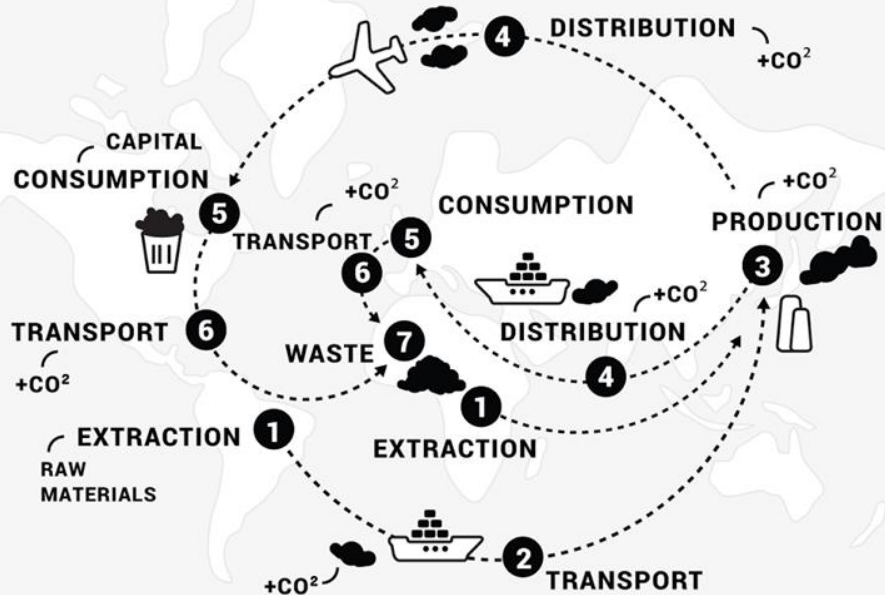
The cities network share working practices and knowledge with the wider network as well as a deep alignment of purpose and culture.

FAB CITY WANTS TO BRING BACK PRODUCTION TO CITIES AND BIOREGIONS...

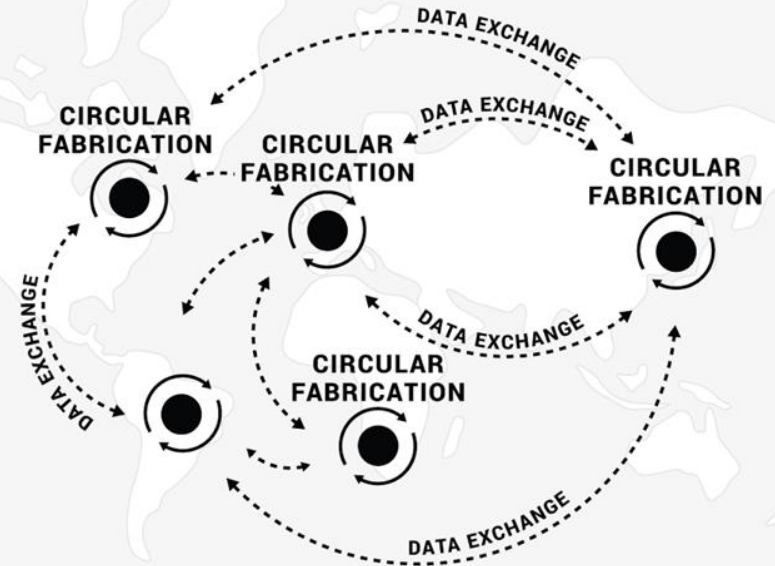


Fab City approach: From PITO to DIDO

PITO - PRODUCT IN TRASH OUT

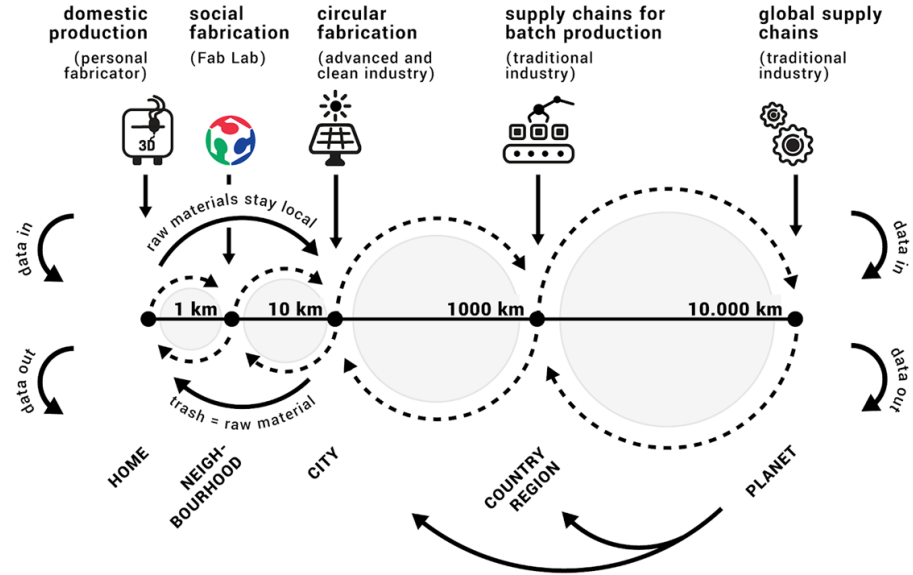


DIDO - DATA IN DATA OUT



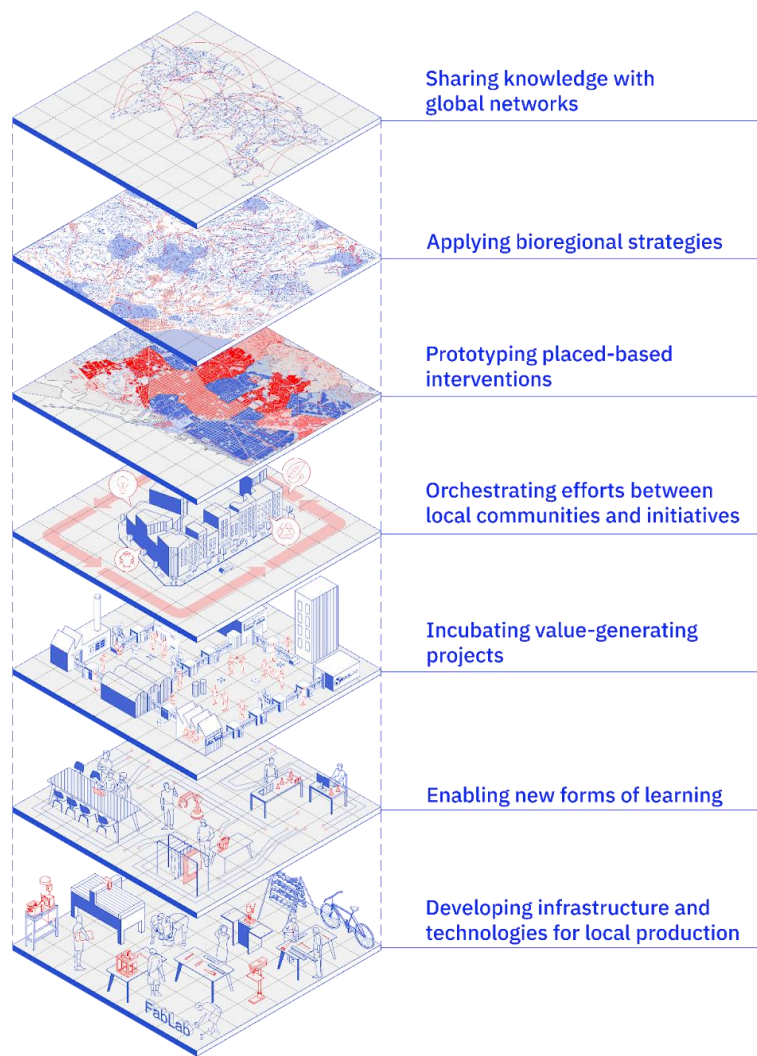
The Fab City Global Initiative proposes for cities and regions to look at their production infrastructure as an ecosystem, that is complementary, and multiscalar.

RESCALING GLOBAL PRODUCTION



↳ Model: DIDO - Data In / Data Out

Full Stack Seven Layers



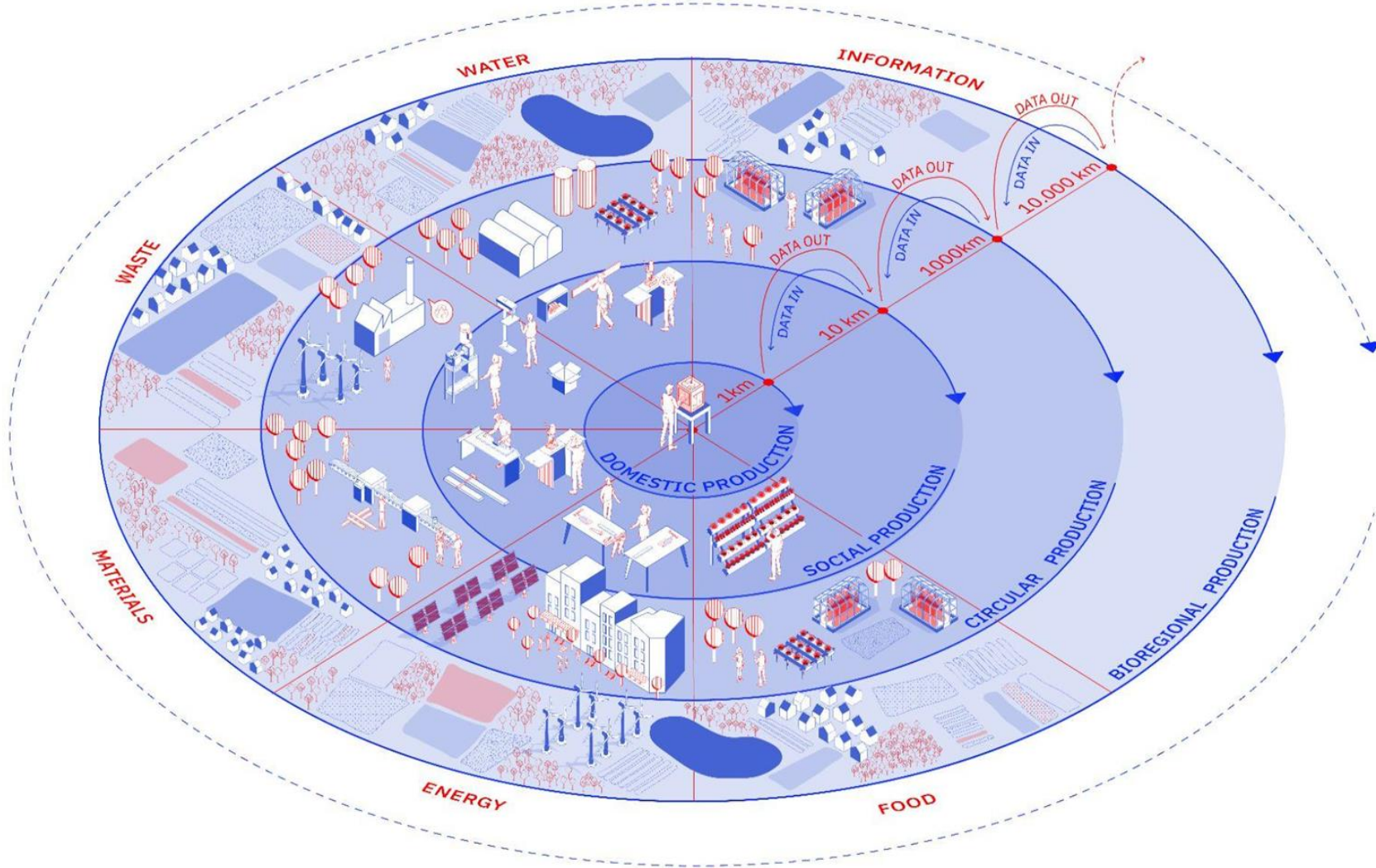
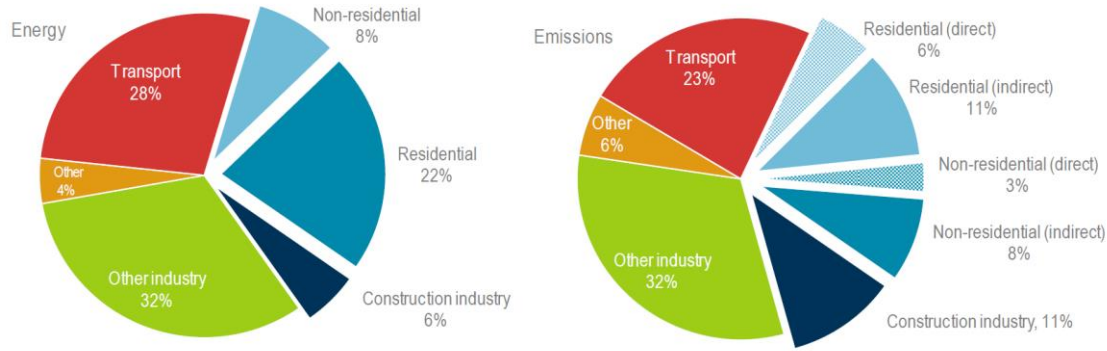


Figure 1 • Global share of buildings and construction final energy and emissions, 2017



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.

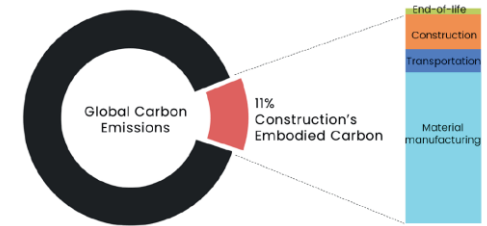


Fig. 2. Contribution of embodied carbon

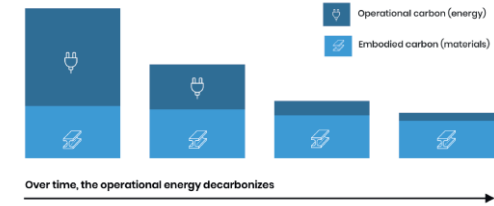
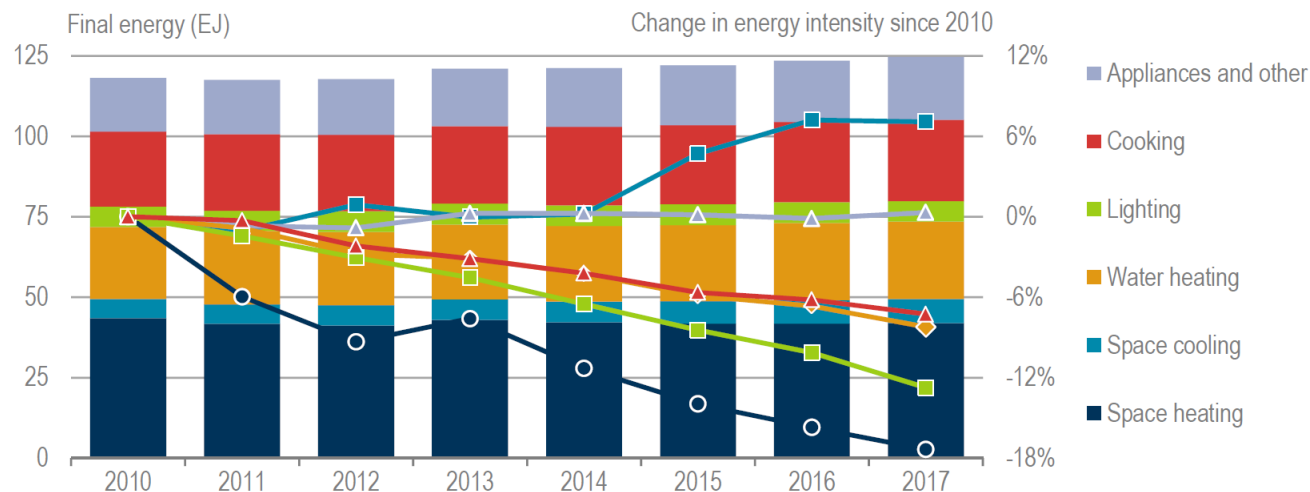


Fig. 3. Operational carbon emissions will decrease over time

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

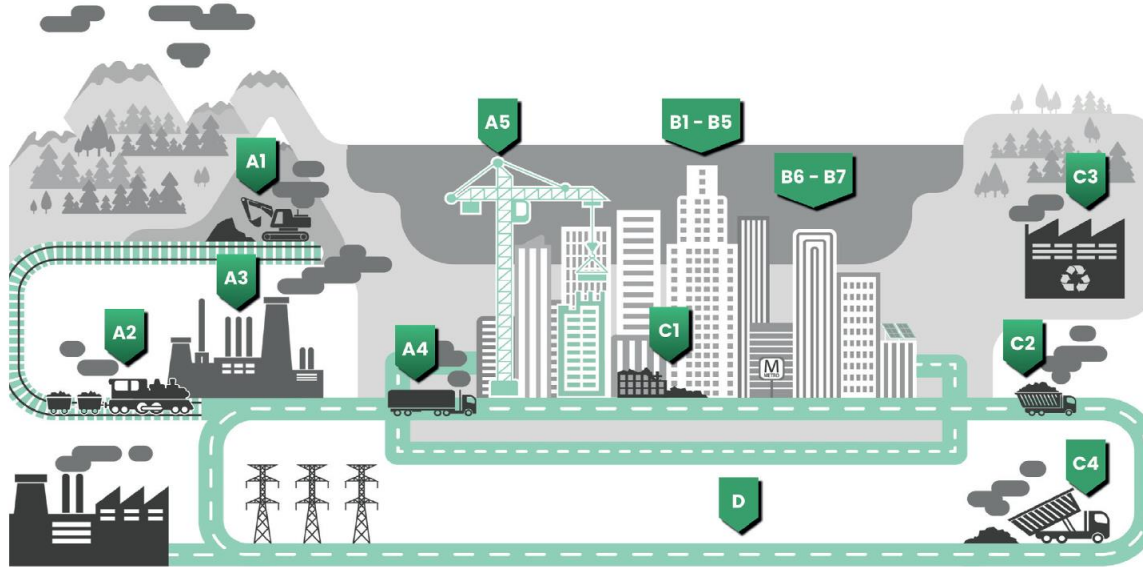


Notes: *Energy intensity* is final energy per unit floor area. *Appliances and other* includes household appliances (e.g. refrigerators, washers and televisions), smaller plug loads (e.g. laptops, phones and electronics) and other services equipment.

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

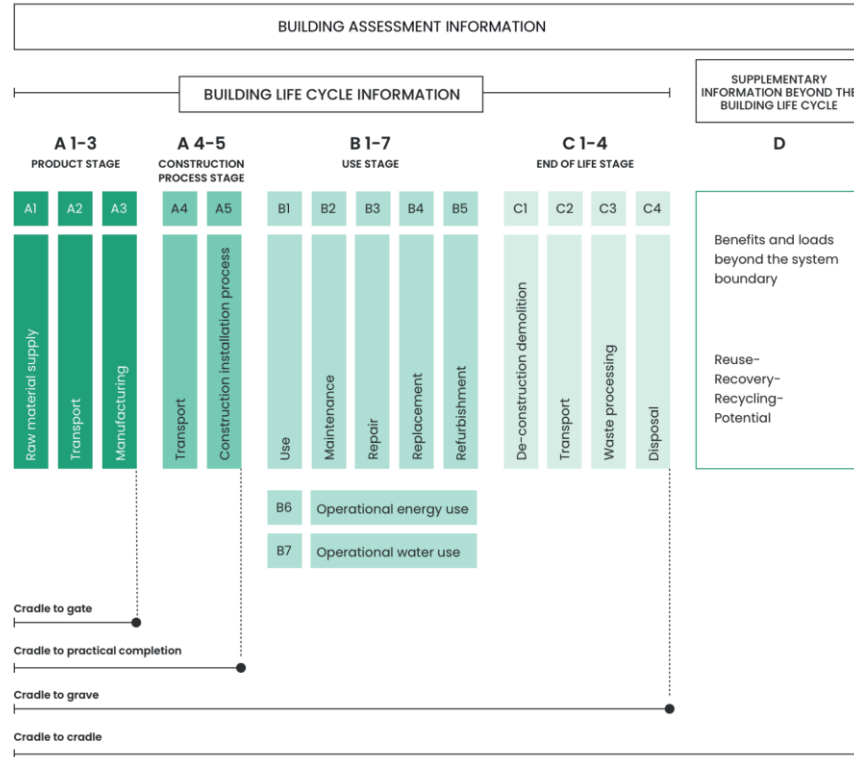
C1 – C4 End of life stage

- 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

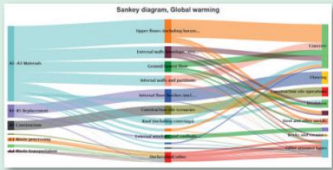
	INVENTORY	X	IMPACT	=	TOTAL
Process	Quantities of materials and processes in building	X	Environmental impacts for each material and process	=	Total environmental impact of building
Example	100 kg steel 	X	1.5 kg per kg steel 	=	150 kg CO ₂ e 

Fig. 11. Example of impact assessment calculations

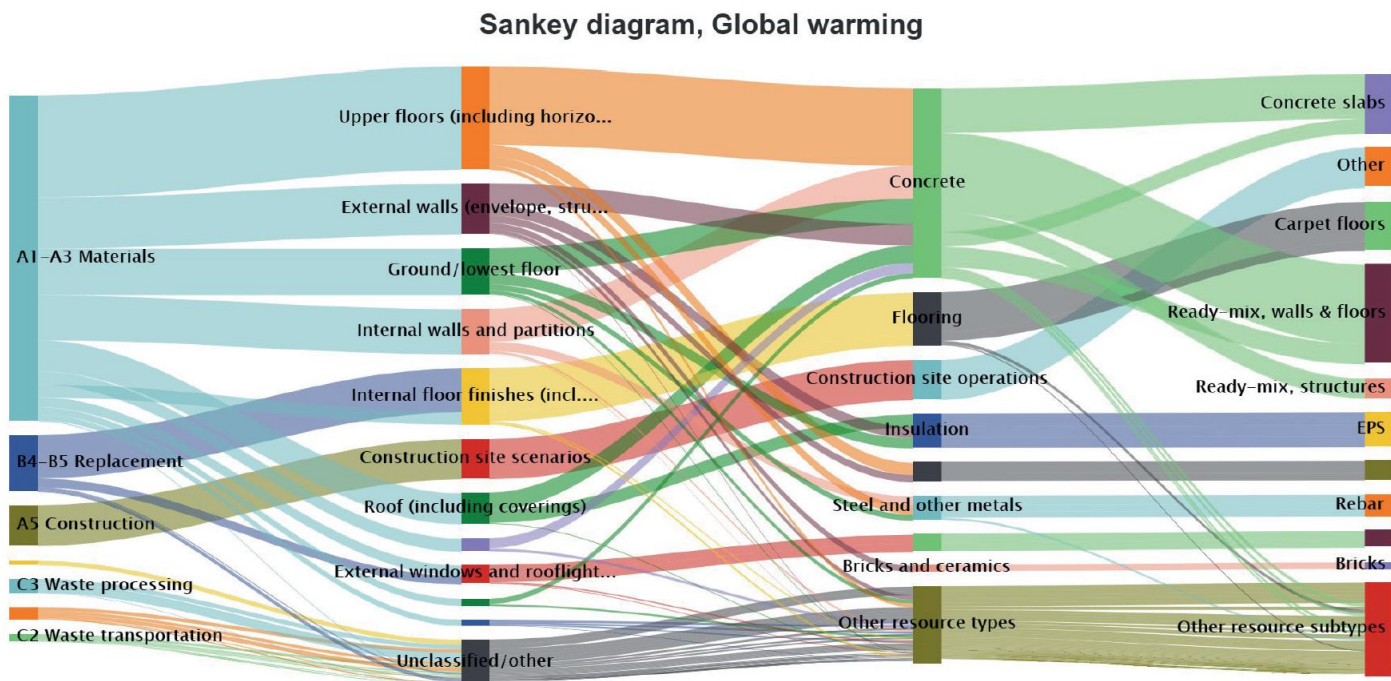
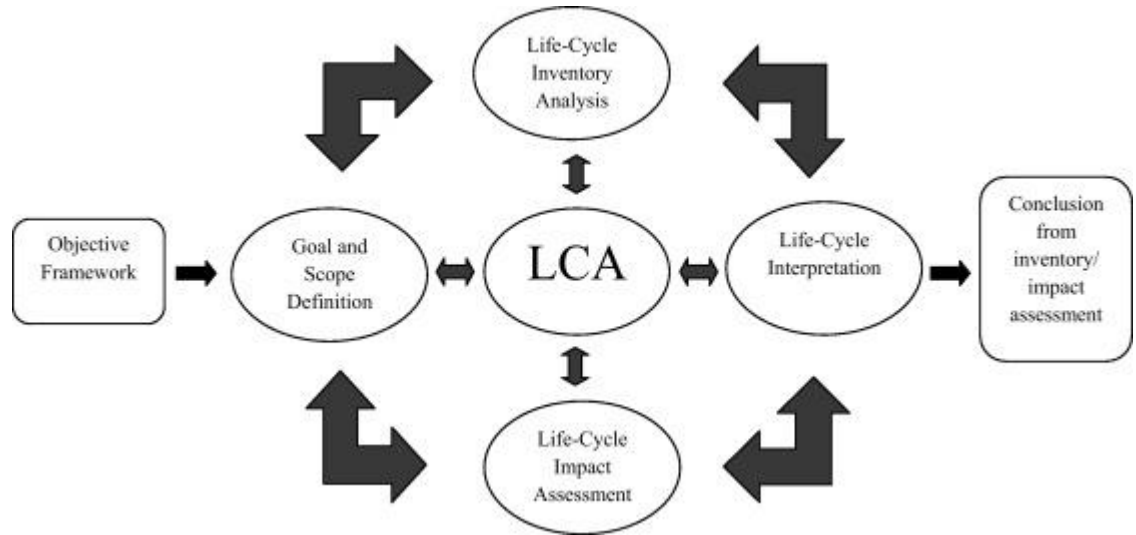


Fig.15. Embodied carbon breakdown by key building elements (Treemap and Sankey diagram)

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>.

Generative AI tool use: chatGPT for a residential building

PROMPT: Please share a cradle to grave life cycle assessment of greenhouse gas emissions of a residential building in India.

Phase	Approximate Emissions (kgCO ₂ e/m ²)
Raw Material Extraction	200-300
Material Manufacturing	300-400
Transportation to Construction	10-20
Construction Phase	20-50
Operational Phase (50 years)	2050-3300
Maintenance and Renovation	50-100
End-of-Life (Demolition)	30-60
Total	2660-4230 kgCO ₂ e/m ²

Embodied carbon footprint: 600-900 kgCO₂e/m²

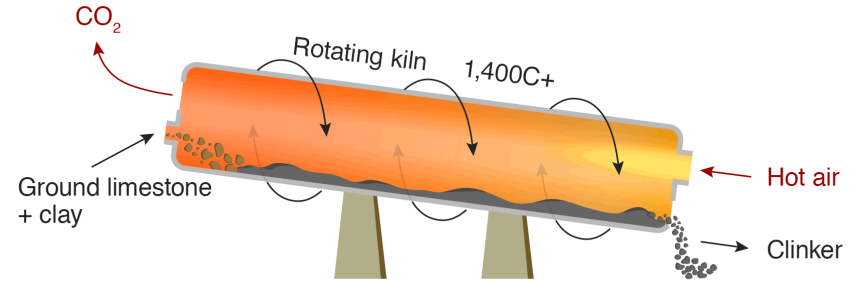
How Cement is made

Introduction to cement chemistry

Chapter 5: How we make things

How to Avoid a Climate Disaster – Bill Gates

How cement is made

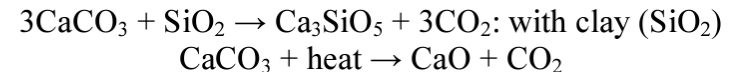


Source: Carbon Brief, Chatham House

BBC

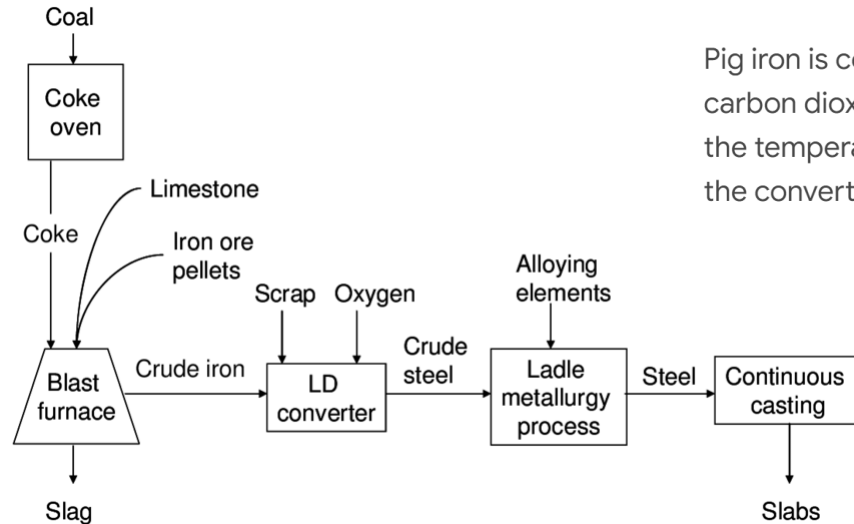
The chemical reaction that releases carbon dioxide (CO₂) during cement production is $\text{CaCO}_3(\text{s}) \rightarrow \text{CaO}(\text{s}) + \text{CO}_2(\text{g})$. This reaction occurs when limestone (CaCO₃) is heated to high temperatures during the process of calcination, which is an intermediate step in cement production. [🔗](#)

Typical reactions for the production of clinker include:



[How is iron made Link2](#) [Bessemer Process for steel](#) [Stainless Steel production](#)

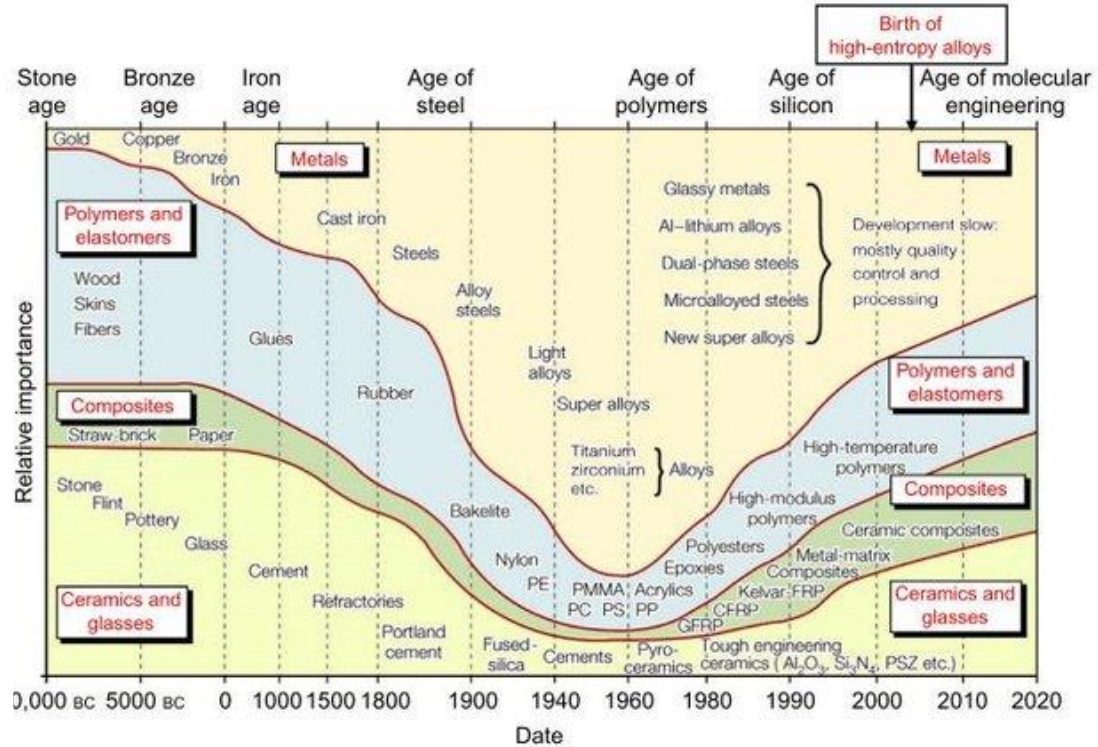
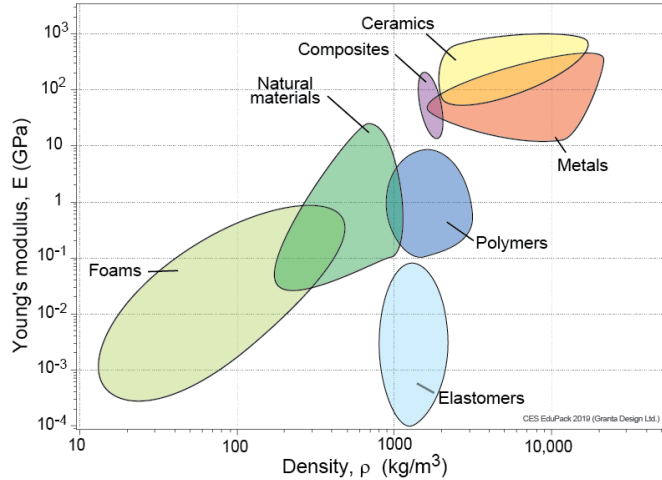
Chapter 5: How we make things How to Avoid a Climate Disaster – Bill Gates



In large part, the carbon is put there to smelt the iron from its ore. The carbon first burns, producing carbon monoxide (CO): $2\text{C} + \text{O}_2 \rightarrow 2\text{CO}$. This then reacts with the iron oxide, producing pig iron: $\text{Fe}_2\text{O}_3 + 3\text{CO} \rightarrow 2\text{Fe} + 3\text{CO}_2$. A very interesting chemical process is the creation of molten iron in the blast furnace. 29 Jan 2018

Pig iron is converted into steel **by heating in a converter**. A blast of oxygen diluted with carbon dioxide is blown through the converter. Oxygen reacts with impurities and raises the temperature to 2173 K. Carbon gets oxidised to CO which burns off at the mouth of the converter. 9 Jan 2020

Which materials do we use the most today?



https://www.researchgate.net/publication/340967691_HEAs_High_Entropy_Alloys_for_advanced_systems_and_engines_Examination_Committee/figures?lo=1, Michael Ashby, ANSYS

Can we improve the TSG carbon footprint estimate?

- Measuring energy consumption in buildings
- Understanding travel related emissions
- Estimating food related emissions
- Estimating product related emissions
- **How about internet?**
- Anything else?



Generative AI tool: chatGPT for internet kgCO₂e

PROMPT: Please share a cradle to grave life cycle assessment of greenhouse gas emissions of the use of internet by a user.

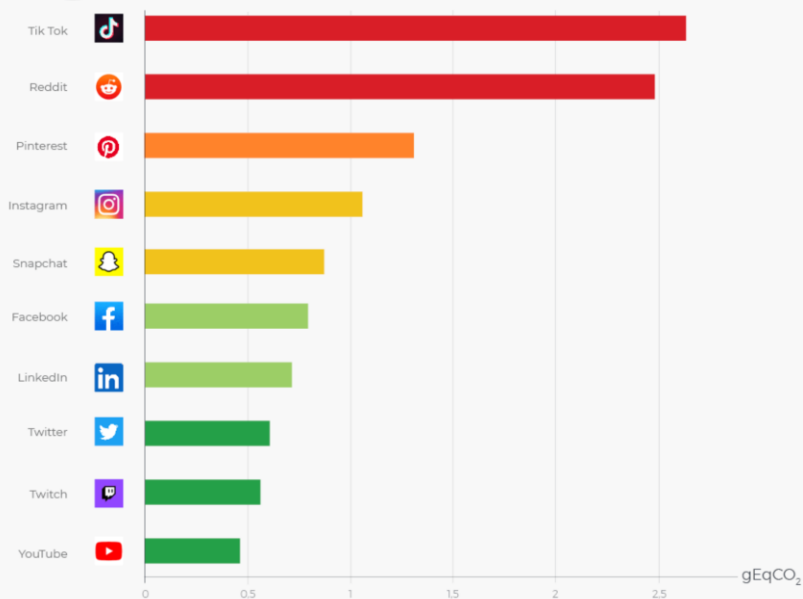
Phase	Approximate Emissions (kgCO ₂ e/year)
Device Manufacturing & Infrastructure	50-100
Data Transmission (Networks)	12-108 (depends on data consumption)
Data Centers	9-58 (depends on data processed)
User Device Energy Consumption	40-100
End-of-Life (Disposal/Recycling)	Offset of 10-20 kgCO ₂ e for recycling
Total	110-366 kgCO ₂ e/year per user



Carbon Impact of social media applications news feed

Greenspector - October 2021

Smaller is better!



Measurements made on a Samsung S7 smartphone (Android)

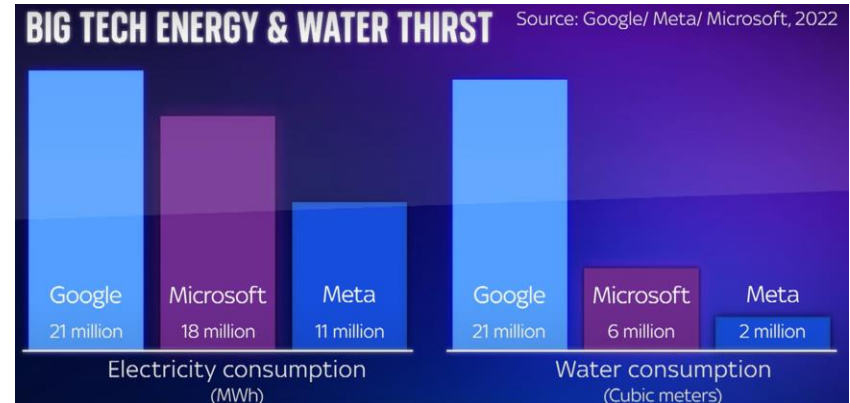
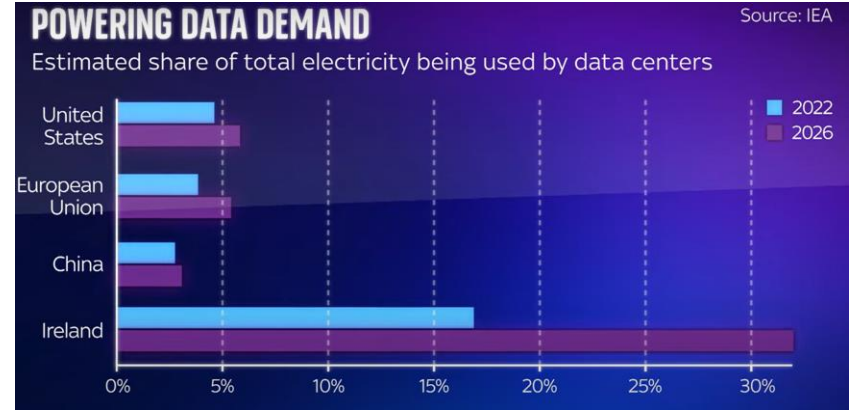
2. Data Transmission Networks

- **Telecommunication Networks:** Data transmission via mobile networks (4G, 5G), fiber-optic cables, and Wi-Fi consumes energy at various stages, from base stations and transmission towers to local exchanges and internet service provider (ISP) networks.
- **Energy Use:** Each gigabyte (GB) of data transmitted over the internet consumes energy across different layers of the network. On average, data transmission via wired networks is more energy-efficient than mobile networks.
 - Wired internet (fiber-optic, broadband): **0.06 - 0.2 kWh per GB.**
 - Mobile networks (4G, 5G): **0.2 - 0.4 kWh per GB**, with 5G being more energy-efficient than 4G.
- **GHG Emissions:** Emissions from data transmission depend on the energy source used in the network. In countries like India, where a significant portion of electricity comes from coal, the carbon intensity is higher.
 - India's electricity carbon intensity: **0.82 kgCO₂/kWh.**
 - Energy consumption for data transmission varies, but for each GB of data, emissions could range from **0.05 to 0.3 kgCO₂e per GB**, depending on the network type and energy source.
- **Emission Estimate:** For an average user consuming **20-30 GB of data per month** (for internet browsing, streaming, etc.), this translates to **12-108 kgCO₂e per year** depending on the network type.

Increasing demand for data putting energy and water supplies at risk

3. Data Centers (Servers and Cooling)

- **Data Center Operations:** Data centers are essential for processing and storing the massive amounts of data generated and accessed through the internet. These facilities host servers, networking equipment, and storage devices, consuming large amounts of energy for both computing and cooling.
- **Energy Use in Data Centers:** The energy intensity of data centers varies, but globally, data centers account for approximately **1-2% of total electricity consumption**.
 - Average energy consumption per GB of data processed: **0.05-0.2 kWh per GB**, depending on data center efficiency and location.
 - Green data centers, which use renewable energy or advanced cooling technologies, can have significantly lower emissions.
- **GHG Emissions:** The carbon footprint of data centers is influenced by the electricity grid's carbon intensity. In countries like India, where coal is still a significant part of the energy mix, data center emissions are higher.
 - Using **0.82 kgCO₂/kWh** (average in India), each GB of data processed in a data center can result in emissions of **0.04 - 0.16 kgCO₂e per GB**.
- **Emission Estimate:** For an average user generating or consuming 20-30 GB of data per month, data center emissions could range from **9-58 kgCO₂e per year**.



- ✓ Avoid arbitrary limitations
- ✓ Consider environmental influences
- ✓ Take regular eye and movement breaks
- ✓ Limit screen time when it causes pain
- ✓ Take extra precautions if you have photophobia

Screen Time Guidelines

HARMFUL EFFECTS OF EXCESSIVE SCREEN TIME

Decline in
Mental
Health

Sleep
Problems

Vision Issues

Decline in
Physical
Health

Friendships
and Family
Connections
Suffer

Learned
Violent
Behavior



Can we improve the TSG carbon footprint estimate?

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