LCA Calculation Formulas

1. Overview

Life Cycle Assessment (LCA) quantifies environmental impacts associated with a product or service across its entire life cycle – from raw material extraction to end-of-life.

Goal: Quantify impacts, identify hotspots & support better decisions.

2. LCA Calculation Flow

1. Define Goal & Scope	2. Life Cycle Inventory (LCI)	3. Life Cycle Impact Assessment (LCIA)	4. Interpretation
Define functional unit, system boundary & assumptions	Collect input & output data for all unit processes	Convert inventory data to potential impacts	Analyze results, identify hotspots & draw conclusions

3. Key Principles

- Holistic: Consider the entire life cycle
- Functional Unit Based: All results per functional unit
- Consistent: Same data quality & methodology
- Transparent: Clear methods & assumptions
- Actionable: Support sustainable decisions

4. Core LCA Calculation Formulas

Item	Formula	Description	Notes
LCI Calculation (Flow Amount)	$F_{ij} = A_i \times D_{ij}$	Amount of elementary flow j from activity i	Ai = Activity data Dij = Emission/flow factor
Total Inventory Result	$F_j = \sum_i F_{ij}$	Total amount of elementary flow j	Sum across all unit processes
Characterization (Impact Calculation)	$I_k = \sum_j (F_j \times CF_{jk})$	Impact score for impact category k	CFjk = Characterization factor of flow j for impact category k
Total Impact per Category	$I_k = \Sigma F_j \times CF_{jk}$	Total impact of all flows for category k	Result in category unit (e.g., kg CO2e)
Normalization	$N_k = \frac{I_k}{N_k^{ref}}$	Normalize impact relative to reference	Nkref = Normalization reference value
Weighting (Optional)	$W_k = N_k \times W_k^*$	Weighted impact score	Wk* = Weight of category k
Total Single Score (Optional)	$S = \sum_k W_k$	Overall weighted single score	Higher score = Higher potential impact

5. Key Parameters & Definitions

- A_i : Activity data (e.g., kg, kWh, L)
- D_{ij} : Emission/flow factor per unit of activity i
- F_{ij} : Flow amount of flow j from activity i
- F_j : Total amount of elementary flow j
- CF_{jk} : Characterization factor of flow j for impact category k
- I_k : Impact score for impact category k
- N_k^{ref} : Normalization reference value for category k
- N_k : Normalized impact for category k
- W_k^* : Weight of impact category k
- W_k : Weighted impact for category k
- S : Single score (optional)

6. Impact Assessment Steps

1. **Classification** — Assign inventory flows to impact categories
2. **Characterization** — Multiply flows by characterization factors
3. **Normalization (Optional)** — Compare to reference values
4. **Weighting (Optional)** — Apply weights to reflect priorities
5. **Single Score (Optional)** — Aggregate to a single score

7. Numerical Example

Example Product – 1 kg Steel (Functional Unit)

Input / Output Data (LCI)

Flow (j)	Amount (Fj)	Unit	Category
CO_2 (fossil)	1.80	kg	Climate Change
CH_4	0.005	kg	Climate Change
SO_2	0.010	kg	Acidification
$PM_{2.5}$	0.002	kg	Particulate Matter

Characterization Factors (CFjk)

Flow (j)	Climate Change (kg CO2e/kg)	Acidification (kg SO2e/kg)	Particulate Matter (DALY/kg)
CO_2 (fossil)	1.00	-	-
CH_4	28.0	-	-
SO_2	-	1.00	-
$PM_{2.5}$	-	-	1.10

Step 1: Characterization (Impact Calculation)

Climate Change (kg CO2e)	Acidification (kg SO2e)	Particulate Matter (DALY)
$I_{CC} = (1.80 \times 1.00) + (0.005 \times 28.0)$ = 1.80 + 0.14 = 1.94 kg CO_2e	$I_{AC} = (0.010 \times 1.00) = 0.010\ kg\ SO_2e$	$I_{PM} = (0.002 \times 1.10) = 0.0022\ DALY$

Step 2: Normalization (Assume Reference Values)

$$N_{CC}^{ref} = 10{,}000\ kg\ CO_2e \quad N_{AC}^{ref} = 500\ kg\ SO_2e \quad N_{PM}^{ref} = 100\ DALY$$

$$N_{CC} = \frac{1.94}{10{,}000} = 1.94 \times 10^{-4}$$

$$N_{AC} = \frac{0.010}{500} = 2.0 \times 10^{-5}$$

$$N_{PM} = \frac{0.0022}{100} = 2.2 \times 10^{-5}$$

Step 3: Weighting (Assume Weights)

$$W_{CC}^{*} = 0.5 \quad W_{AC}^{*} = 0.3 \quad W_{PM}^{*} = 0.2$$

$$W_{CC} = 1.94 \times 10^{-4} \times 0.5 = 9.7 \times 10^{-5}$$

$$W_{AC} = 2.0 \times 10^{-5} \times 0.3 = 6.0 \times 10^{-6}$$

$$W_{PM} = 2.2 \times 10^{-5} \times 0.2 = 4.4 \times 10^{-6}$$

Step 4: Single Score (Optional)

$$S = 9.7 \times 10^{-5} + 6.0 \times 10^{-6} + 4.4 \times 10^{-6} = 1.23 \times 10^{-4}$$

8. Common Impact Categories

- Climate Change (kg CO2e)
- Acidification (kg SO2e)
- Eutrophication (kg $PO4^{3-}$e)
- Photochemical Ozone Formation (kg NMVOCe)
- Resource Depletion (kg Sbeq)
- Particulate Matter (DALY)
- Water Scarcity (m^3 world eq.)

9. System Boundary Types

- Cradle to Gate: Raw material extraction to factory gate
- Cradle to Grave: Full life cycle including use & end-of-life
- Cradle to Cradle: Includes recycling & resource recovery

10. Unit Conversions (Common)

- 1 t = 1,000 kg
- 1 kg = 1,000 g
- 1 kWh = 3.6 MJ
- 1 m^3 = 1,000 L
- 1 t CO2e = 1,000 kg CO2e
- 1 ha = 10,000 m^2

11. Good Practice Checklist

✓ Define functional unit clearly
✓ Set appropriate system boundary
✓ Use high-quality, representative data
✓ Apply consistent methods & factors
✓ Document assumptions & data sources
✓ Conduct sensitivity analysis
✓ Perform critical review of results