

LCA equations and parameters

Parameters and value:

E_{rm}	— the energy consumption of raw materials;
E_w	— the energy consumption of waste materials in manufacture;
E_m	— the energy consumption in the material phase;
m	— the mass of raw materials;
M_{cf}	— the mass correcting factor to compensate the mass loss in manufacture;
H_v	— the embodied energy constant of virgin raw materials;
H_{rc}	— the embodied energy constant of the recycled part in raw materials;
R_c	— the fraction of the recycled part in raw materials;
H_c	— the energy constant of waste collection;
H_{rw}	— the embodied energy constant of waste materials;
N	— the total number of ingredients in the formulation;
Z_i	— the number of processes for ingredient i ;
H_R	— the energy constant of a raw material manufacture process;
m_{Ri}	— the mass of ingredient i ;
$M_{cfRi,j}$	— the mass correction factor of process number j for ingredient i ;
Y	— the total process number of a semi-finished product;
p	— the percentage of the cut-off materials in a process;
H_P	— the energy constant of a semi-finished product manufacture process;
$Cf_j(m)$	— the mass conversion factor of the process number j of the semi-finished product;
E_{mfR}	— the manufacture energy of raw materials;
E_{mfP}	— the manufacture energy of the semi-finished product;
E_{mf}	— the energy consumption in manufacture stage;
E_t	— the energy consumption in transport stage;
n	— the number of transports;
H_{tj}	— the energy constant of transport number j ;
D_j	— the distance of transport number j ;
E_u	— the energy consumption in use stage;
H_u	— the energy constant of use depending on the vehicles it is applied;
C_e	— the energy equivalence for electric transporting tools depending on countries;
DL	— the lifelong working days of the product;
D_{day}	— the average moving distance per day of the transporting tool in life cycle;
E_d	— the energy consumption of disposal;
EOL	— the way of end-of-life;
E	— the total energy consumption in lifecycle;
CF	— the total CO ₂ footprint in lifecycle;
α	— the conversion factor between energy and CO ₂ ;

CF_m , CF_{mf} , CF_{mf} , CF_u and CF_d are corresponding parameter of CO₂ footprint in the material, manufacture, transport, use and disposal phase, respectively. The detail parameters labeled ‘CF’ for CO₂ footprint has the same meaning as labeled with ‘E’ for energy consumption. For example, H_v means the energy constant of virgin raw materials, while CF_v represents the CO₂ constant of virgin raw materials.

Table 1: Key parameter values for LCA calculation.

Energy	parameters	H_v (MJ/kg)	H_{R1} (MJ/kg)	H_{R2} (MJ/kg)	H_c (MJ/kg)	H_{rc} (MJ/kg)	H_{t1} (MJ/kg)	H_{t2} (MJ/kg)	H_u (MJ/kg)			
	Recycled powder	0.92	0	0.3	0.2	0.92	0.35	0.82	1.7			
	Phenolic resin	92.6	0	0.3	0.2	92.5	0.35	0.82	1.7			
	formula materials	Not listed										
CO ₂	parameters	CF_v (g/kg)	CF_{R1} (g/kg)	CF_{R2} (g/kg)	CF_c (g/kg)	CF_{rc} (g/kg)	CF_{t1} (g/kg)	CF_{t2} (g/kg)	CF_u (g/kg)			
	Recycled powder	81	0	23	14	81	25	59	72			
	Phenolic resin	4310	0	23	14	4210	25	59	72			
	formula materials	Not listed										
Common	parameters	R_c	m (g)	p_1	p_2	D_1 (km)	D_2 (km)	C_e	α	DL	D_{day} (km)	EOL
	Recycled powder	0	145.5	5%	0	500	50	1	0.07	3000	15	landfill
	Phenolic resin	0	12.7	5%	0	500	50	1	0.07	3000	15	landfill
	formula materials	Not listed										

Equations:

$$E_{rm} = m \cdot M_{cf} \cdot (H_v \cdot (1 - R_c) + H_{rc} \cdot R_c) \quad (1)$$

$$E_w = m \cdot (M_{cf} - 1) \cdot (H_c + H_{rw}) \quad (2)$$

$$E_m = E_{rm} + E_w \quad (3)$$

$$E_{mfr} = \sum_{i=1}^N \sum_{j=1}^{Z_i} H_{Ri,j} \cdot m_{Ri} \cdot M_{cfRi,j} \quad (4)$$

$$M_{cfRi,j} = \prod_{k=1}^{Z_i+Y-j+1} \frac{1}{1-p_k} \quad (5)$$

$$E_{mfp} = \sum_{j=1}^Y H_{pj} \cdot Cf_j(m) \cdot \prod_{k=1}^{Y-j+1} \frac{1}{1-p_k} \quad (6)$$

$$E_{mf} = E_{mfr} + E_{mfp} \quad (7)$$

$$E_t = \sum_{j=1}^n H_{tj} \cdot m \cdot D_j \quad (8)$$

$$E_u = H_u \cdot m \cdot C_e \cdot DL \cdot D_{day} \quad (9)$$

$$E_d = H_c \cdot m \quad (10)$$

$$E = E_m + E_{mf} + E_t + E_u + E_d \quad (11)$$

$$CF_m = m \cdot M_{cf} \cdot (CF_v \cdot (1 - R_c) + CF_{rc} \cdot R_c) + m \cdot (M_{cf} - 1) \cdot (CF_c + CF_{rw}) \quad (12)$$

$$CF_{mf} = \sum_{i=1}^N \sum_{j=1}^{Z_i} CF_{Ri,j} \cdot m_{Ri} \cdot \prod_{k=1}^{Z_i+Y-j+1} \frac{1}{1-p_k} + \sum_{j=1}^Y H_{pj} \cdot Cf_j(m) \cdot \prod_{k=1}^{Y-j+1} \frac{1}{1-p_k} \quad (13)$$

$$CF_t = \sum_{j=1}^n CF_{tj} \cdot m \cdot D_j \quad (14)$$

$$CF_u = CF_u \cdot m \cdot C_e \cdot DL \cdot D_{day} \quad (15)$$

$$CF_d = \alpha \cdot E_d \quad (16)$$

$$CF = CF_m + CF_{mf} + CF_t + CF_u + CF_d \quad (17)$$