

Life Cycle Assessment: A step-by-step guide to estimating environmental impacts

Life Cycle Assessment (LCA) is a systematic analysis of the potential environmental impacts associated with a product, process or service during its lifetime and is widely applied in commercial settings. A useful handbook on LCA: “*Life Cycle Assessment: Quantitative approach for decisions that matter*”, is available as a free download (Matthews, Hendrickson et al. 2015).

Life Cycle Assessment is an iterative process, as shown in Figure 1 (left), where the definition of the goal and scope can change as you progress through your project. For example, you may be assessing one product made in a factory although others are also made there, so you will need to identify if there are overheads that can be shared and what share is appropriate for the product you are assessing. This will inform the inventory list (a list of items and processes for which you need to find the impact). Establishing the functional unit early and deciding whether you are assessing a product, or a process is fundamental.

Thinking about the Life Cycle Stages, Figure 1 (right) helps to establish the system boundary and a decision about whether to cover the cradle-to-gate or cradle-to-grave will be made. The ‘use’ stage may be long or short; if long, the assessment may need to sum repeated impacts over the lifespan of the product/process. The end-of-life stage covers recycling expectations, you need to think what proportion can be recycled, how often it can be recycled and the likely need for new components or energy needed to recycle. The waste may be compostable or some other form of recovery or disposed in landfill.

The final impact value is usually given as a single figure, but this can be developed in stages to identify the impacts related to each element of the process, this is a useful way to target high impact components and enable the exploration of alternatives which could help to reduce the overall impact. The four steps listed below will help you to gather your requirements before using software. (Alternatively, the tables which follow can be used without using the OpenLCA software.) These have been populated with some impact factors ready for use. The tables are designed to be copied into a spreadsheet, to be used as a template to record your data and build up a basic LCA.

OpenLCA (GreenDelta 2006), is free open-source software for estimating environmental impacts of processes and products; video tutorials exist on YouTube to help users to get started. Databases can be downloaded from various sources and are often free to use.

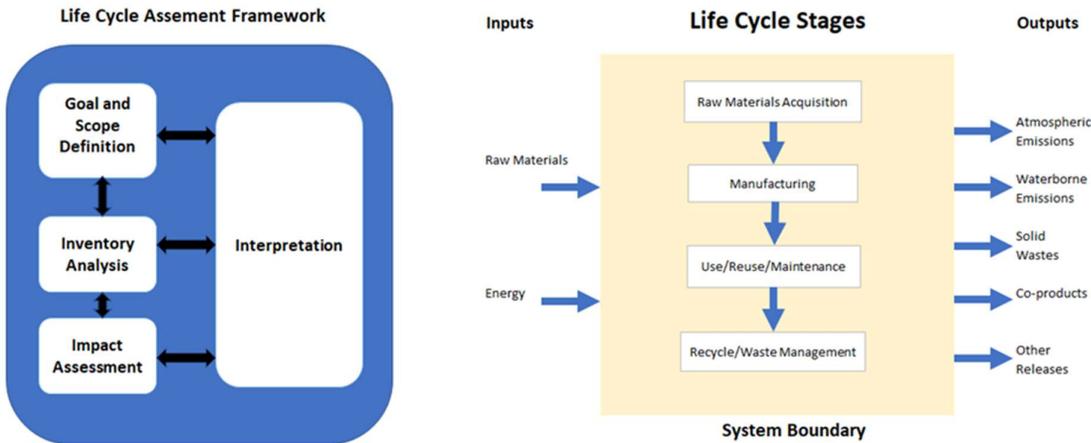


Figure 1. LCA framework and System Boundary diagrams

Reconstructed Soil recipes

Reconstructed soil recipes have been developed by the Reconstructed Soil Project (herein called ReCon Soil). These share basic components such as composted urban green waste and native subsoil or topsoil. Table 1 summarises three recipes by proportional weight. One has been developed in France, two in England; although all can be constructed in either location using locally available materials.

Recipe /component (proportion/t)	Fr8Ex	E1Bc	E2Bc
Excavated subsoil	0.42		0.21
Green waste compost	0.03	0.14	0.12
Composted bark		0.08	
Composted agricultural residue			0.25
Sand		0.35	
Biochar		0.15	0.12
Lignite clay		0.28	
Native component	0.55		0.3
Fr= France; E= England			

Table 1. Proportions of component material used to create FR8Ex, E1Bc and E2Bc soils.

Fr8Ex is a recipe for a soil amendment (not a fully reconstructed soil) designed to improve soil structure and retain nutrients and thus has a prerequisite of native soil to improve. It is likely that the soil product would be suitable for uses such as land reclamation and urban landscaping. Ideally, waste materials (urban green waste compost, excavated subsoil) should be sourced locally to reduce transport emissions. Compost can be produced either by industrial processing (in vessel composting, IVC) or outside via windrow (WR).

E1Bc makes use of composted materials, derived from urban green waste and bark produced on many agricultural sites through normal operations. These soils accommodate inclusion of biochar as a vehicle to sequester carbon long-term.

E2Bc incorporates both excavated subsoils and biochar. This recipe combines the reuse of excavated subsoils from construction with otherwise waste outputs from agricultural. These last two recipes have the potential for use as a replacement for topsoil in land reclamation, brownfield regeneration or urban landscaping. As with Fr8Ex, compost from urban green waste can be created either on site or off-site via WR or IVC.

The main difference between Fr8Ex and recipes E1Bc and E2Bc is that the latter are fully reconstructed soils which can be made on site or in a soil hub.

Steps to draw up an LCA for ReCon Soils:

Step 1: Identify all the components of a recipe, proportions, and volumes.

Step 2: Identify any mechanical handling, including the time it is used for or the area it covers. The impact from the manufacture of these is apportioned over the expected lifespan, additional maintenance will be included but only as an average. Good maintenance is invaluable in controlling environmental impacts and adds to a circular economy mindset (EC 2015, EC 2020).

Step 3: Identify fuel usage and water for on-site transport/mechanical handling activities. This may include water used to clean vessels/ trucks (be mindful of the source as tap water has a higher impact than rainwater).

Step 4: Put together a table of requirements (an inventory list) in a spreadsheet, like the ones given below. The impact factor has been included in each table for your use. Ensure the formula includes all relevant columns for example for transport loads you need to include the weight and the distance (in tonnes and km as appropriate).

Step 5: If you wish to use the OpenLCA software you will use the inventory list as your inputs. The use of the software involves creating a new process, searching for the appropriate process flow that matches your inventory item, specifying the unit and quantities from your inventory list. You can select an impact model from the ones available and hit the 'calculate' button to get the software to make the calculation. The output is given on several sheets, as a complete breakdown by elements, or summarised to a single value in the list of impact categories, there can be up to 17 impact categories in the output. The 'climate change' output is in kg CO₂ eq/(input qty), reported in Tables 2-4, that follow.

Notes:

Free open-source datasets: Argribalyse (including some ECOINVENT components) (ADEME 2022) is used as the source data. The climate model, ReCiPe 2016 Midpoint (H) (Huijbregts, Steinmann et al. 2017) is used to model the environmental impacts. This uses the Global Warming Potential (GWP) measure, which quantifies the integrated infrared radiative forcing increase of greenhouse gas expressed in kg CO₂-eq. The country of origin used in the databases for the impacts given are based on the regions Europe or France, however some processes may not be available for these countries and an alternative is given. A list of the common regions/countries is given in Table 5. As electricity is generated by a variety of means, it is important to use the appropriate country to reflect the energy mix.

Table 2: Template for excavated roadside or site materials and transport options

Activity	Inventory item	Volume	Distance	Type/ fuel	Impact factor Kg CO2 eq	Impact (row total)
Site clearance	Excavation, hydraulic digger processing - RER kg Co2 eq/m3				0.534	
Decommissioned road (RER)	Decommissioned road (RER) treatment kg CO2 eq/m2		10		0.032	0.32
Road works	Road maintenance road maintenance kg CO2 eq/m2				2.804	
Fuel for mechanical handling equip	Litres	5		diesel	2.65	13.25
Roadside regrading of subsoils/t	Recycled aggregates (UK) (3.7 @1 00%)	2			3.7	7.4
Water for recycled aggregate	Cubic meter (1000 litres)	0.1		tap	9.036	0.9036
Transport to landfill/other/t/km	Transport, freight, lorry 16-32 metric ton (RER)	10	5	vehicle	0.161	8.05
Transport to landfill/other/t/km	Transport, freight, lorry 7-16 metric ton (RER)			vehicle	0.212	0
Fuel for transport	Litres	0.5		diesel	2.65	1.325
Landfill burden/t	Inert waste, for final disposal (RoW)	1			8.31	8.31
Landfill burden/t	Hazardous/sanitary landfill	0			497.47	0
Import of topsoil/turf						0
Import of virgin aggregate & sand/t	Gravel, round (CH) gravel and sand quarry operation Cut-off, S - from Ecoinvent - CH				2.27	0
Import of virgin aggregate/t	Gravel, crushed (RoW) market for gravel, crushed Cut-off, S - from Ecoinvent				17.81	
Total impact kg CO2 eq/t						39.56

Table 3: Template for ReCon Soil recipe components/tonne

Activity	Inventory item	Volume	Impact factor Kg CO2 eq	Impact (row total)
Processing of cattle manure	Cattle manure, open solid storage/tanker for liquid		10.503	0
Processing for inorganic fertilizers	Inorganic. average mineral fertilizer as N, from regional storehouse FR/U		1522.65	0
Processing for inorganic fertilizers	Inorganic. average mineral fertilizer as KO2, from regional storehouse FR/U		694.07	0
Processing for inorganic fertilizers	Inorganic. average mineral fertilizer as P2O5, from regional storehouse FR/U		982.02	0
Composting	Open windrow		679.39	0
Composting	In vessel composting (IVC)		55.04	0
Biochar	Type and quality	0.1	553	55.3
Water (tap)	Cubic meter (1000 litres)	0.1	9.036	0.9036
Virgin sand		0.2	4.99	0.998
Lignite clay		0.09	13	1.17
Roadside regrading of subsoils	Recycled aggregates (UK) (3.7 @50%)	0.42	1.85	0.777
Avoided landfill for excavated subsoils		0.42	-8.31	-3.4902
Total impact kg CO2 eq/t				55.66

Table 4: Template for transport and mechanical handling operations

Inventory item	Volume	Distance	Type/ fuel	Impact factor Kg CO2 eq	Impact (row total)
Transport, freight, lorry 3.5-7.5 metric ton (GLO)	2	10	diesel	0.515	10.3
Transport, freight, lorry 7.5-16 metric ton (RER)	10	10	diesel	0.212	21.2
Transport, freight, lorry 16-32 metric ton (RER)	20	10	diesel	0.161	32.2
Ploughing/tilling/ha	1	1		118.17	118.17
Fertilizing, solid manure or compost (charging and spreading), with frontal bucket and 5t spreader/day	1			449.16	449.16
Electric fertilizing, solid manure or compost (charging and spreading), with frontal bucket and 5t spreader/FR U/day	1			110.31	110.31
Fertilising, by broadcaster (GLO)/ha	1			26.31	26.31
Transport, tractor and trailer, agricultural processing Europe t/km	10	12		0.35	42
Fuel (for each item)/litre	5		diesel	2.65	13.25
Electricity (dependent on country energy mix) UK (2021)/GWh				254	
Total impact kg CO2 eq/t					822.90

Country or region	Abbreviation	Country or region	Abbreviation
Norway	NO	Global	GLO
Australia	AU	Oceanic	OCE
India	IN	Africa	RAF
China	CN	Asia and the Pacific	RAS
Germany	DE	Europe	RER
Netherlands	NL	Latin America and the Caribbean	RLA
Switzerland	CH	North America	RNA
France	FR	Near East	RNE
United Kingdom	GB	Middle East	RME
United States	US	Rest of the World	RoW
Hong Kong	HK	Russian Federation	RU
Japan	JP	Canada	CA

Table 5. ISO 3166 Country listings used in LCA databases

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