Life Cycle Assessment

Okala Practitioner Chapter 10

Life Cycle Assessment

Life cycle assessment (LCA) is objective (based on quantified measurements) and comprehensive (including the entire lifecycle of the system and including most impacts categories).

International standards (ISO 14040 series) guide the proper practice of LCA. International institutions and companies use LCA.

Single-figure LCA

Single-figure LCA is a form of LCA that combines all the necessary LCA steps in one multiplication impact factor. Single-figure LCA reports one numerical score per material or process. The science of LCA is described in more detail in chapter 14.

Okala Impact Factors are single-figure LCA that designers can use to quickly model the overall impacts of products.

Ways to use Okala Impact Factors

Okala Impact Factors can be used in different ways to understand the environmental performance of a design concept.

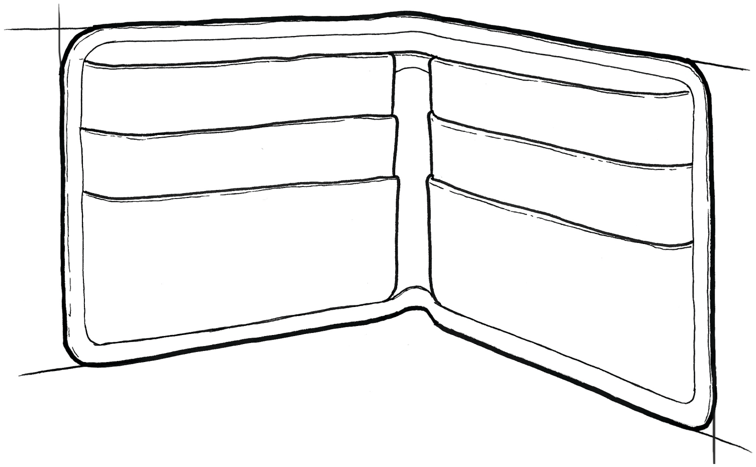
Any of these approaches may be instructive if you need to compare two or more design alternatives:

1. Simple Screening
2. Subassembly comparison
3. Complete System LCA

1. Simple Screening

Simple screening compares one material or process to another material or process for a specific application.

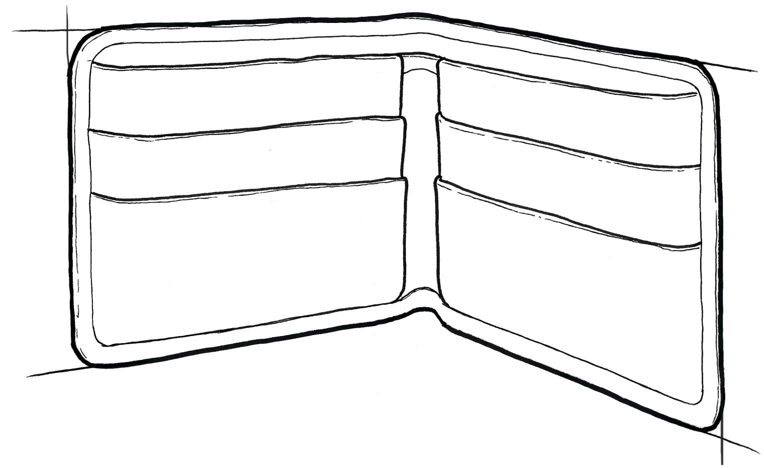
In this example, we compare materials that could be used in a wallet.
We estimate the weight of each material, find the Okala Impact Factor value (pages 44-48), and multiply these to estimate the resulting impact.



ELEMENT	IMPACT FACTOR	QTY.	IMPACT
NYLON FABRIC	11 P/LB	X 0.10 LB?	= 1.1 P
HEMP FABRIC	2.9 P/LB	X 0.14 LB	= 0.4 P
LEATHER	9 P/FT^2	X 26 IN^2/144 IN^2	= 1.6 P

1. Simple Screening

Alternative materials (or processes) have different mechanical, durability, economic and aesthetic characteristics. The designer decides which lower impacting alternative best meets the needs of the application.



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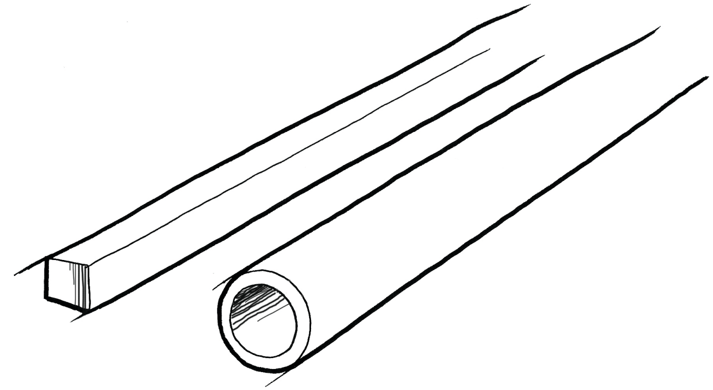
2. Subassembly comparison

Subassembly comparison estimates the materials, processes, transport and end-of-life treatment of one subassembly compared to another subassembly. It requires more time than simple screening but it gives more accurate results.

Here we consider two chair legs. One is made of powder coated steel and the other subassembly is made of anodized aluminum tubes. Both are transported the same distance via the same transport methods. With different weights, their transport impacts differ.



STEEL LEG

ELEMENT	QTY.	IMPACT FACTOR	IMPACT
STEEL	3 LB.	3.5/LB.	10.5
EXTRUSION		1.1/LB.	3.3
POWDER COAT	2 FT²	2.2/FT²	4.4
TRANSPORT	3 TON-M	0.7/TON-M	2.1
TO LANDFILL	3 LB.	0.02/LB.	0.06

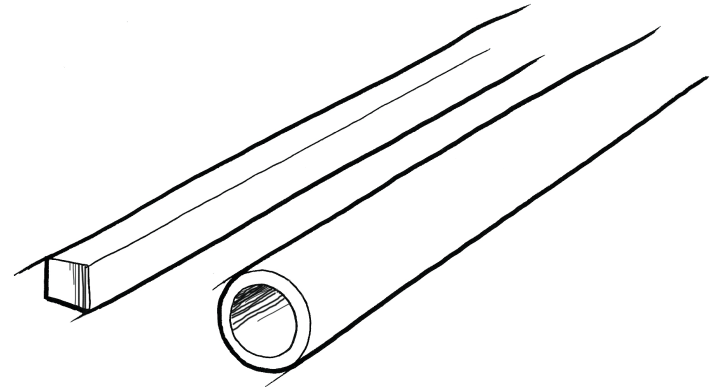
ALUMINUM LEG

ELEMENT	QTY.	IMPACT FACTOR	IMPACT
ALUMINUM	0.9 LB.	13/LB.	11.7
EXTRUSION		0.64/LB.	0.58
ANODIZING	3 FT²	0.56/FT²	1.68
	1.4 TON-M	0.7/TON-M	0.98
TO RECYCLE			0

2. Subassembly comparison

This approach models many elements of the subassembly, but excludes use phase energy and material consumption, and amount of service delivered over the life cycle.

The overall product system is usually not optimized by the optimization of a subassembly.



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ELEMENT	QTY.	IMPACT FACTOR	IMPACT
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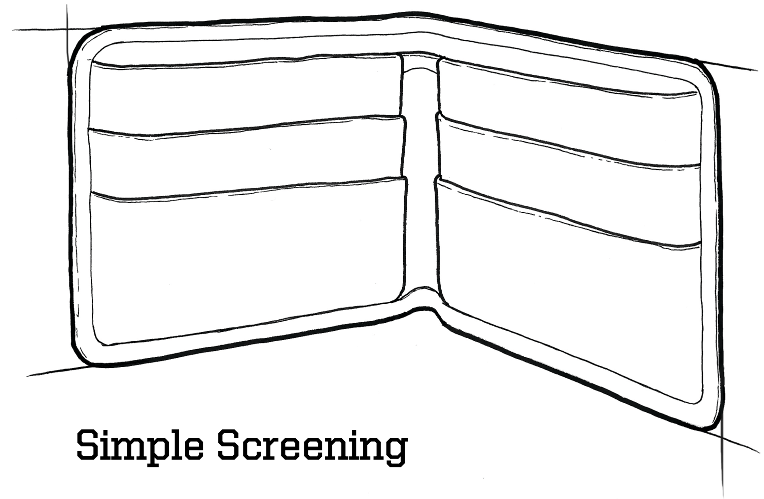
EXTRUSION		1.1/LB.	3.3
POWDER COAT	2 FT²	2.2/FT²	4.4
TRANSPORT	3 TON-M	0.7/TON-M	2.1
TO LANDFILL	3 LB.	0.02/LB.	0.06
		TOTAL	20.4 P

ALUMINUM LEG

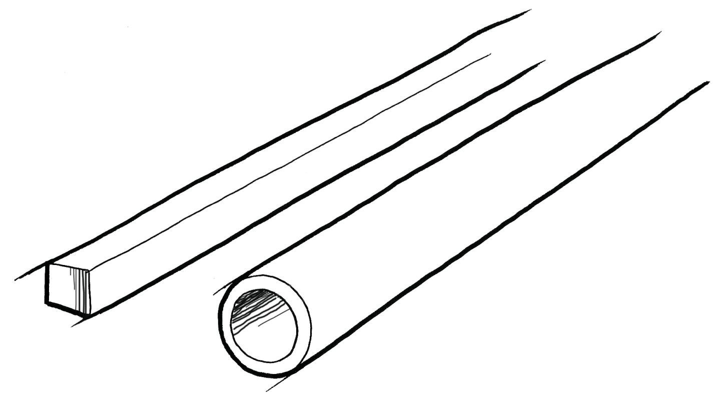
ELEMENT	QTY.	IMPACT FACTOR	IMPACT
ALUMINUM	0.9 LB.	13/LB.	11.7
EXTRUSION		0.64/LB.	0.58
ANODIZING	3 FT²	0.56/FT²	1.68
	1.4 TON-M	0.7/TON-M	0.98
TO RECYCLE			0
			14.9 P

lower total impact →

A subassembly comparison is faster to calculate than complete system LCA, but as with simple screening, **the whole system should eventually be assessed to compute the overall impacts over the entire life cycle.**



Simple Screening



Subassembly comparison

3. Complete System LCA

Complete system LCA is the most reliable assessment method for capturing impacts over the entire life cycle.

It should be used when a comprehensive understanding of the system's impacts is needed.

Complete system LCA requires you to clearly define system characteristics listed on the right.

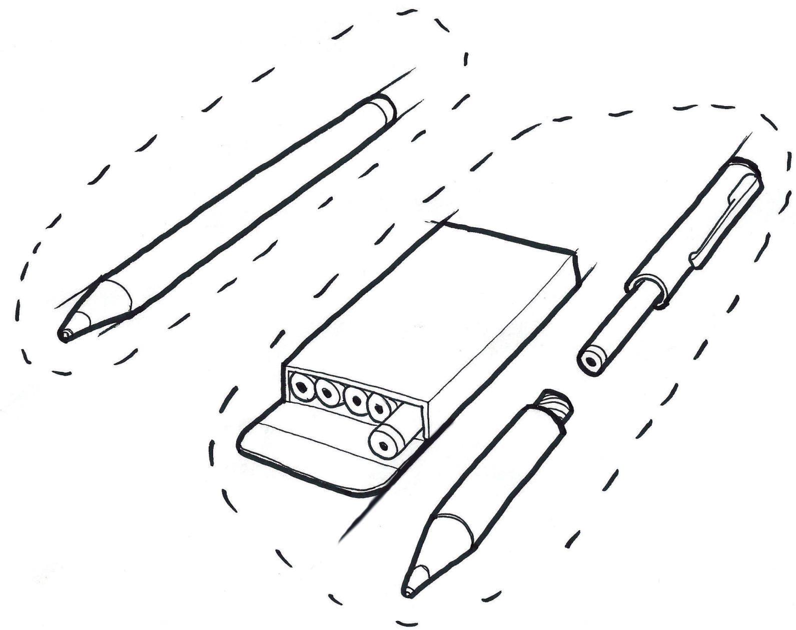
a. System boundary
b. Product lifetime
c. Functional unit
d. System bill of materials

Complete System LCA

a. System boundary

A system boundary specifies what is and is not included in the assessment. We include as much of the product system as possible, but we can lack data for items with complex compositions (detergent, toothpaste, etc.). These are typically left out of this level of assessment.

Other items, such as the energy required to wash a drinking glass in a washing machine, can usually be accurately estimated.

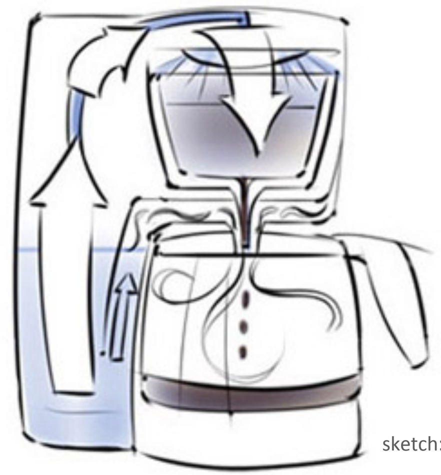


SYSTEM BOUNDARY

Complete System LCA

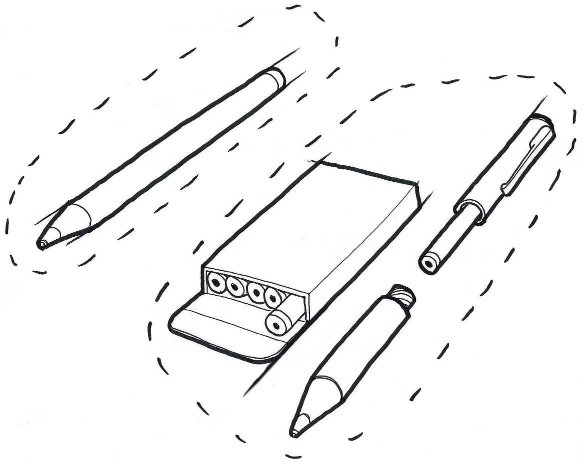
a. System boundary

Example 1:
A coffee making machine may or may not include: materials in product and packaging, electricity use, coffee filters, water and coffee. We can include all of this except the coffee, given the available impact factors.



sketch: Teams Design

Example 2:
In a comparison of writing pens, the system boundary of one pen is the disposable ballpoint pen, while the boundary for the competitor is a refillable pen plus the refill cartridges.



Complete System LCA

b. Product lifetime

The product lifetime is the total number of hours that the product will be used in its lifetime. This can be estimated by multiplying the number of years that the product will be used by the number of hours/year that the product will be used.

Manufacturers rarely divulge the lifetimes of their products. Designers teams therefore need to agree on a realistic estimation of product system lifetime.

Examples	*years*	*x hrs/year =*	***Lifetime hours***
Ink-jet printer:	6	94	576
Packaging:	quickly consumed		~
Automobile:	12	350	4200
Chair:	18	600	10800
House:	50	5000	250,000

Table A (chapter 10)

Typical lifetimes of common products

Wear-out life is used to calculate the life-cycle impacts of products. The technology cycle indicates how soon the technology used in the product is significantly modified. Most products will usually find new homes and be used through the duration of their wear-out life. Determining the life of products not on this list may require speaking with product manufacturers.

Source: Catherine Rose, A method for formulating Product End-of-life Strategies, Stanford U., 2001

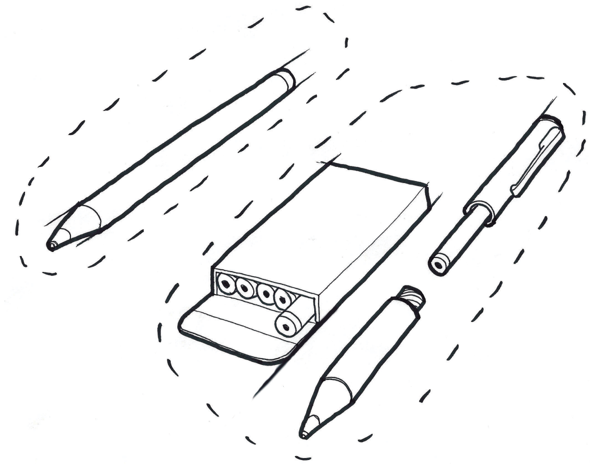
Product	Wear-out life, years	Technology cycle, years
audio system	9	4
automobile	20	7
bubblejet printer	8	5
cellular phone	3	1
computer	6	2
computer mouse	6	4
cordless phone	10	5
CRT display	6	3
digital copier	5	2
fax machine	6	2
hand held vacuum	4	6
inkjet printer	4	2
laserjet printer	8	5
LCD display	5	2
miniature robot	5	5
photocopier	5	5
portable CD player	5	10
portable radio	10	2
single use camera	2	4
telephone	5	2
television	11	4
typerwiter	15	9
vacuum cleaner	8	7
video projector	5	2
washing machine	10	5

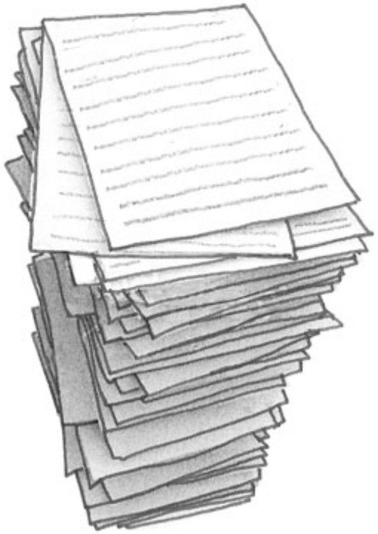
Complete System LCA

b. Product lifetime

Sometimes the product lifetime can be discovered through testing.

In the case of the writing pens example, the fact that the disposable ballpoint pen dried up after covering 75 sheets of paper with writing established the lifetime of ‘per 75 sheets of paper’.





Complete System LCA

c. Functional unit

The functional unit describes the impacts/primary service of the product. A functional unit enables the comparison of different products that deliver similar services.

Strict standards exist do not exist for how large a functional units should be, although the quantity that one person would use at a time is often used.

If the product system is used for a long period of time (such as a house) a unit of time should be included, (such as square foot - year).

Examples:

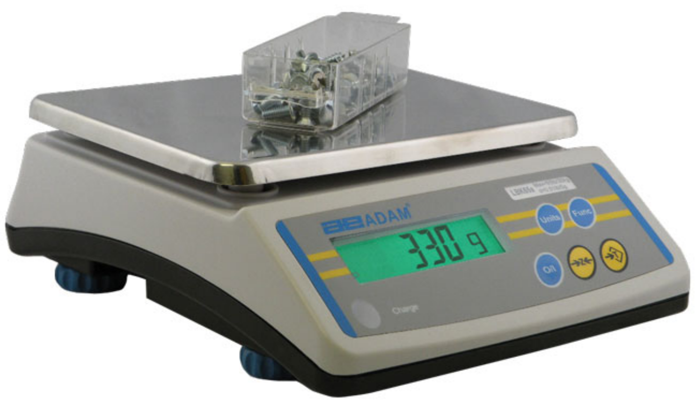
Ink-jet printer:	1000 prints
Packaging:	package
Automobile:	10,000 miles
Chair:	1000 hrs. of sitting
House:	square feet - year

Complete System LCA

d. System bill of materials

The system bill of materials (SBOM) quantifies every physical input in the lifetime of the product. It includes all materials in the product and packaging, major material processing steps in manufacturing, energy, fuel and any materials consumed during use, transport in the phases and, for each of the material inputs, end-of life information such as land-filling, incineration or recycling.

Making a SBOM can require disassembling an existing product, weighing each component and determining the materials and manufacturing processes for the major components.



Complete System LCA

Example: Molded Plastic Chair

We apply these steps to a chair designed by Charles Eames and manufactured by Herman Miller.

This example shows the calculation steps in the complete system LCA process.

Step 1. Define
a. system boundary
b. product lifetime
c. functional unit

The system boundary, lifetime, and functional unit are defined. The chair is used 600 hours/year for 12 years, which delivers a lifetime of 7,200 hours.

System boundary:	excludes: cleaning during use
Lifetime:	600 hour/yr x 12 year = 7,200 hour
Functional unit:	impacts/ hour used

This example is also found on page 38 of Okala Practitioner.

Step 2:
Make system bill of materials

The SBOM must be thorough. It lists:

All components in the product, noting weight and material per component,

Major processing steps (such as injection molding) per component,

Additional materials (fuel, coffee filters, cleaning) needed in the product' s life,

Energy use in primary and secondary modes (such as stand-by mode),

End-of-life scenario (recycling, composting, landfill, incineration),

and **Transportation** of components and product among all these phases.

Step 2:
SBOM for the chair

All materials, processing and energy use over the product's entire lifecycle must be included. Items used in the chair are listed.

material	*quantity*	*processing*
Polypropylene (PP)	4.3 lb.	Injection molded
Steel legs and connectors	5.6 lb.	Extruded, nickel plated

Step 2:
Transportation

Transportation

The distance from the factory to the user plus from the user to the landfill (or incinerator) should be included. Distances from raw resource to factory are already included in the impact factors. Units for transportation are calculated with:

$$\frac{\text{Total Lbs. X miles}}{\text{2000 lbs. / ton}} = \text{ton-miles}$$

The chair is manufactured in Michigan and transported by truck an average of 1215 miles. The ton miles for the chair are thus:

$$\frac{\text{12.5 lbs. X 1040 miles}}{\text{2000 lbs. / ton}} = \text{7.6 ton-miles}$$

Step 3:
Calculate impacts/ lifetime

SBOM	amount	Okala factor/unit	impact points
Recycled polyethylene	4.3 lb.	1.9/lb.	8.17
Process: Injection mold	4.3	0.72/lb.	3.1
Steel	3.6 lb.	25/lb.	12.6
Process: extrude	3.6 lb.	11/lb.	3.96
Process: Nickel plate	112 sq. inches	0.57/sq. inch	0.44
Transport 28 ton truck	7.6 ton-mi.	0.32/ton-mi.	2.43
Landfill PP	4.3 lb.	0.26/lb.	1.12
Landfill steel	3.6 lb.	0.02/lb.	0.08
		total lifetime impacts	31.9 Okala points

Step 3:
Calculate impacts/ lifetime

We calculate the impacts in the functional unit (per 1hour that the chair is used) by dividing by the total number of hours that the chair is used.

We round final impact values to two significant figures because this more realistically represents level of precision of the assessment process.

Examples: 4.443 rounds to 4.4 and 0.00155 rounds to 0.0016

$$\frac{\text{Lifetime impacts}}{\text{Lifetime hours}} = \frac{\text{31.9 Okala points}}{\text{7,200 hours}} = 0.00443 = 0.0044 \text{ Okala millipoints/ hour}$$

Discussion

Does anything surprise you about the results of the impact assessment of the chairs?

Should you review any of the steps again?

Did we leave anything out of the bill-of-materials that should have been included?

This example evaluated the environmental performance of a chair.
It was not a comprehensive evaluation of its design qualities.

Conclusion:
A single-figure LCA is a powerful tool for modeling the environmental performance of a product or system, but it does not provide all of the necessary design-related information that a designer usually needs to keep in mind.

Building LCA

Using Okala Impact Factors to make LCAs of buildings is explained on page 40. This requires additional software to model building energy needs for a particular location. Further the system boundary usually excludes some of the building infrastructure (such as electrical and plumbing systems).

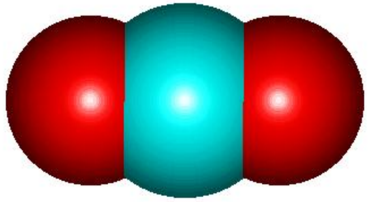
Although Building LCAs model simplified models of a structure, they can provide insightful information about the environmental performance of these large systems.

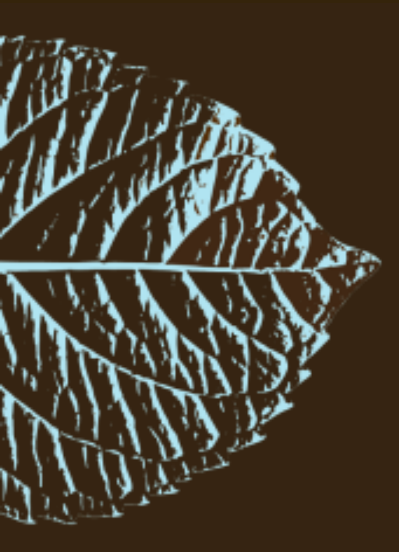
Carbon Footprinting

You can follow a similar calculation process as is used with the Okala Impact Factors to make carbon footprints of product systems. To do this, you use the CO_2 equivalent that is listed at the right edge of each Okala Impact Factor.

Although carbon footprinting is often used, it measures only one impact category (climate change), and does not reflect the multiple impact categories in the Okala Impact Factors.

Depending on the system being assessed and the audience, carbon footprints may be useful.





Okala Practitioner

Integrating Ecological Design

This presentation is part of an educational presentation series that supports teaching from the *Okala Practitioner* guide.

Okala Practitioner and these presentations were created by the Okala Team to disseminate fact-based knowledge about ecological design to the design disciplines and business.

Unless provided in the presentations, Information sources are found in the *Okala Practitioner* guide.

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The Okala Team initiated the collaboration with the US EPA and the Industrial Designers Society of America (IDSA) in 2003. The team developed *Okala Practitioner* with support from Autodesk, IBM, Eastman Chemical and the IDSA Ecodesign Section.

Okala Practitioner is available through amazon.com.

More information and the free Okala Ecodesign Strategy App can be found at Okala.net.

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