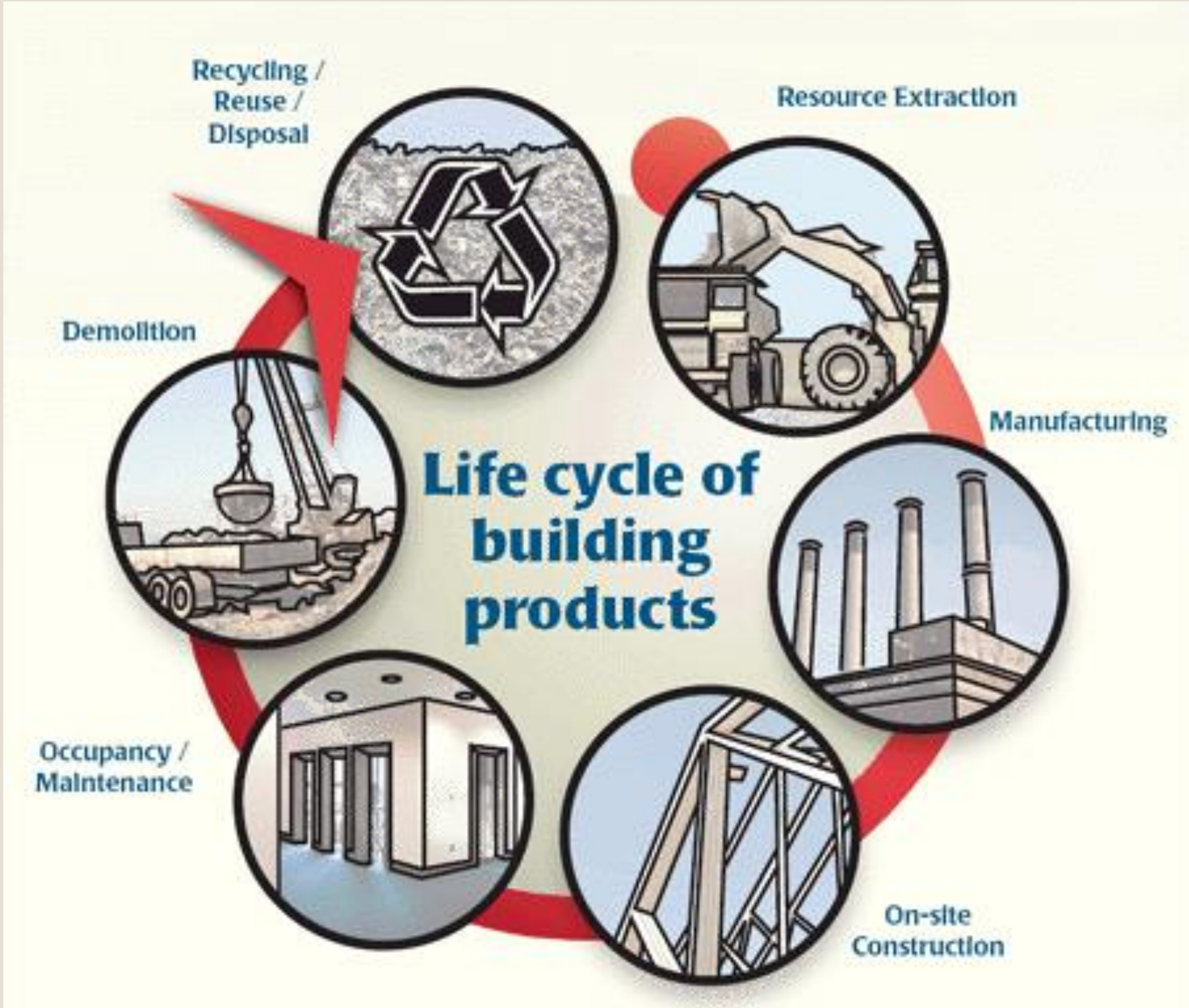
Applying LCA in Building Design – Easier Than You Think! – Part I

Applying LCA in Building Design – Easier Than You Think! - Part I

- LCA – what is it?
- Why use of LCA is essential to creating environmentally better buildings.
- Summary



LCA – What Is It?

Life Cycle Assessment (LCA)

As an introduction, the following is a brief description of what life cycle assessment is, and a summary of the steps that are taken by life cycle practitioners in developing LCA information.

A discussion of how this information can be used in creating environmentally better buildings is addressed later in the presentation.

Life Cycle Assessment

Four phases

1. **Project initiation**
2. **Life cycle inventory**
3. **Impact assessment**
4. **Improvement assessment**

Project Initiation

<u>Define:</u>

- **Purpose and Scope**
- **System Boundaries**
- **Data Categories**
- **Review Process**

Life Cycle Inventory (LCI)

A life cycle inventory involves use of a sophisticated accounting system to track inputs and outputs in manufacturing a product, and sometimes in tracking use, maintenance, and disposal of that product.

Life Cycle Inventory (LCI)

Examination of all measurable:

- **Raw material inputs**
- **Products and by-products**
- **Emissions**
- **Effluents**
- **Wastes**

Life Cycle Inventory (LCI)

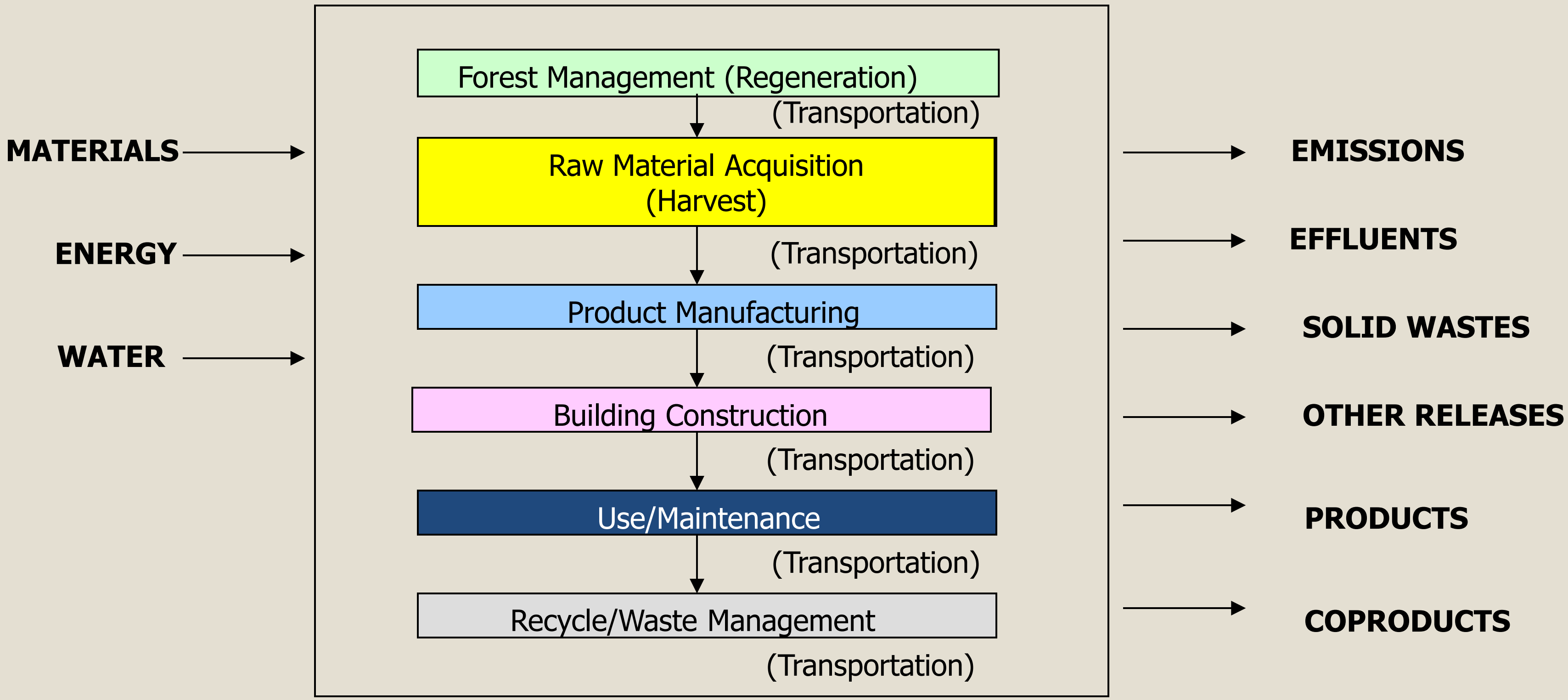
May involve all stages in production, use, and disposal, including:

- **Extraction**
- **Transportation**
- **Primary processing**
- **Conversion to semi-finished products**
- **Incorporation into finished products**
- **Maintenance**
- **Disposal/reuse**

Life Cycle Inventory (LCI)

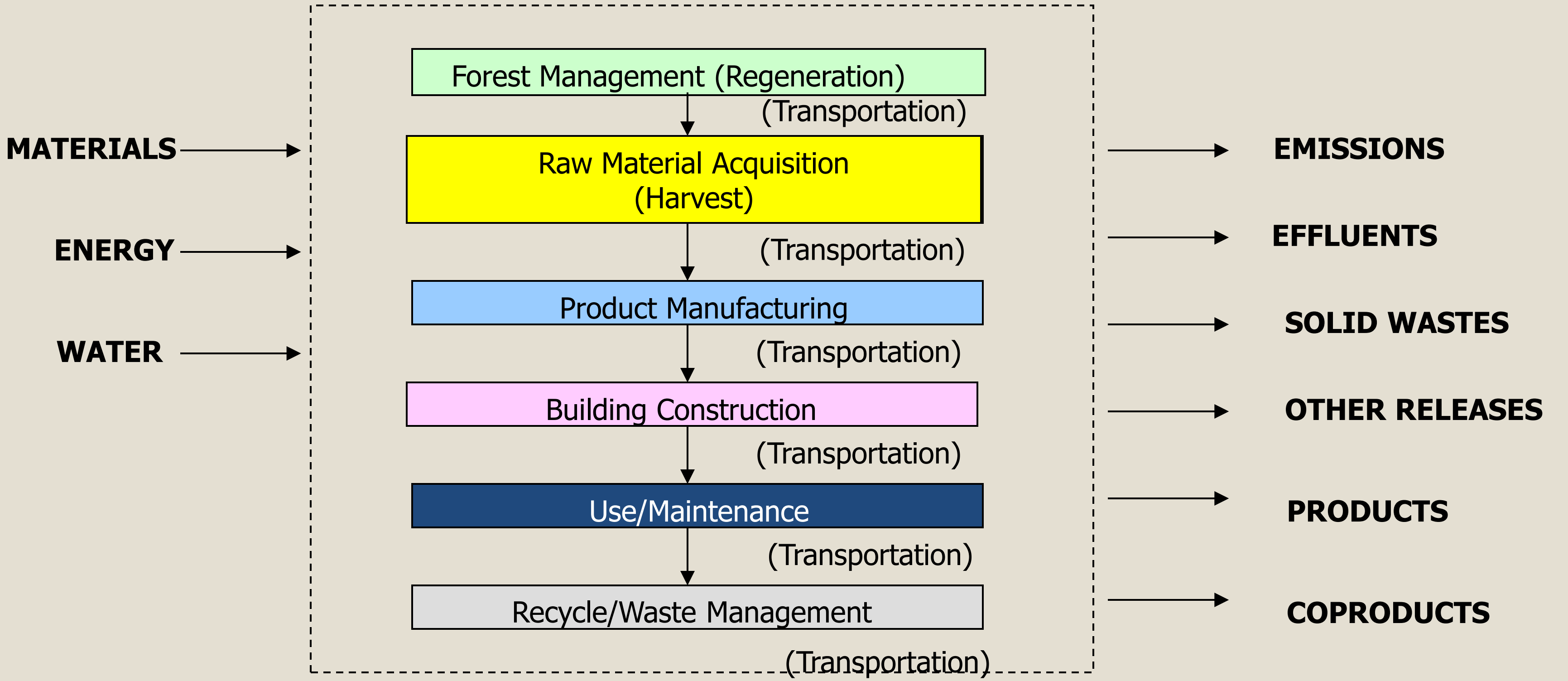
Analyses are conducted using a uniform set of international guidelines and procedures as published by the International Organization for Standardization (ISO).

Life Cycle Inventory (LCI)



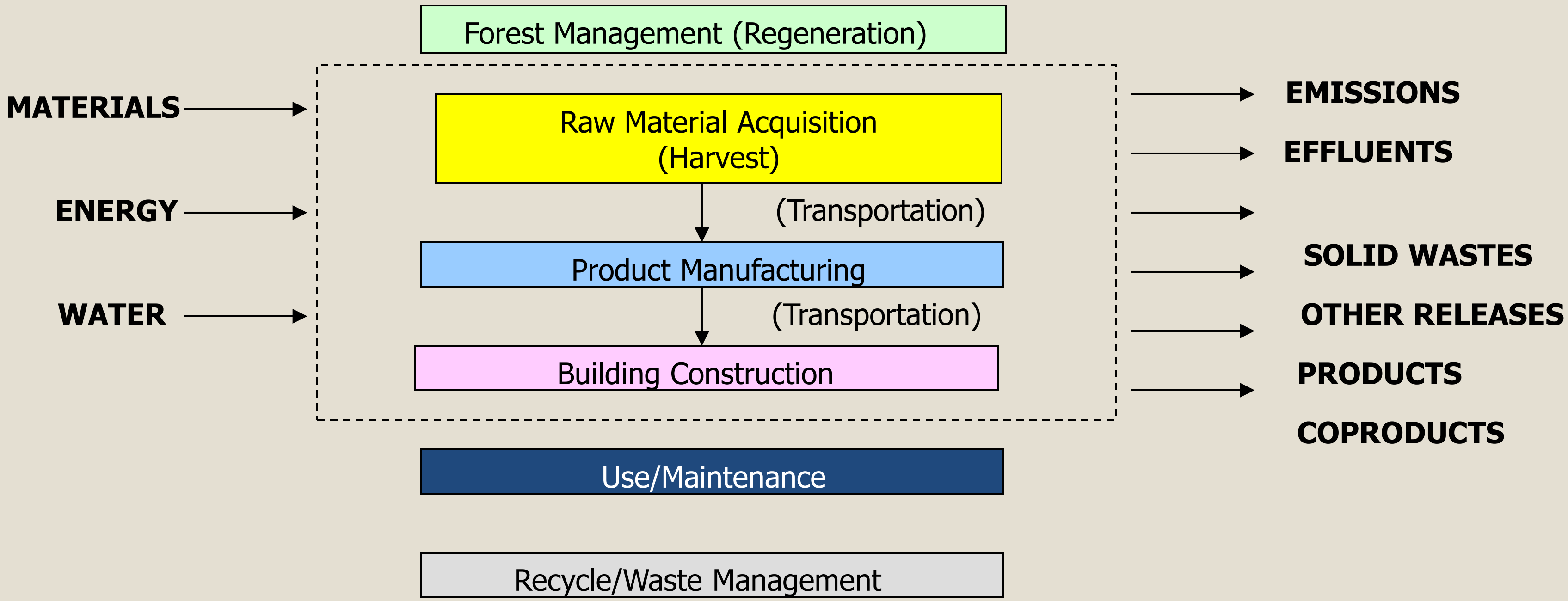
Conceptually, an LCI looks like this. In this case a wood building is analyzed beginning with raw material extraction through end of building life, with all inputs and outputs considered.

Life Cycle Inventory (LCI)



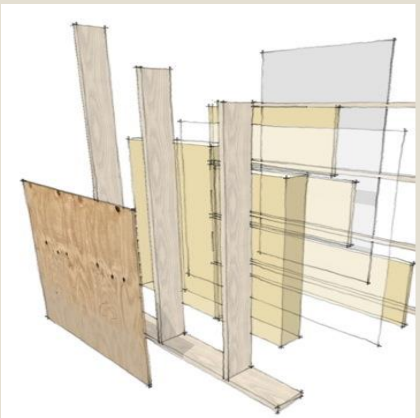
The dashed line above defines the system boundary for this analysis, defining what is to be considered. In this case, all steps in building materials production, transport, building construction, use and maintenance, and deconstruction or demolition are included.

Life Cycle Inventory (LCI)



This analysis could be conducted as shown above, with consideration given to forest harvesting (but not forest restoration), production and transport of building materials, and all aspects of building construction. Use/maintenance and end-of-building-life are not included.

Life Cycle Inventory

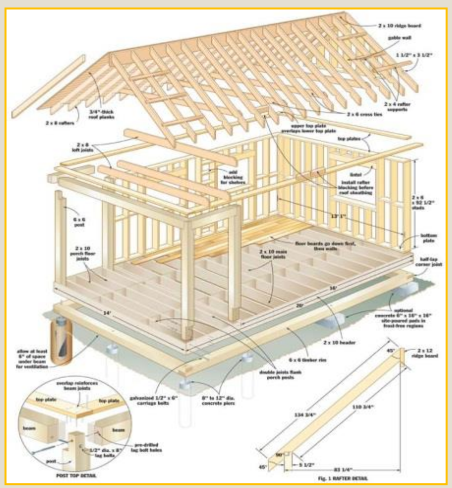


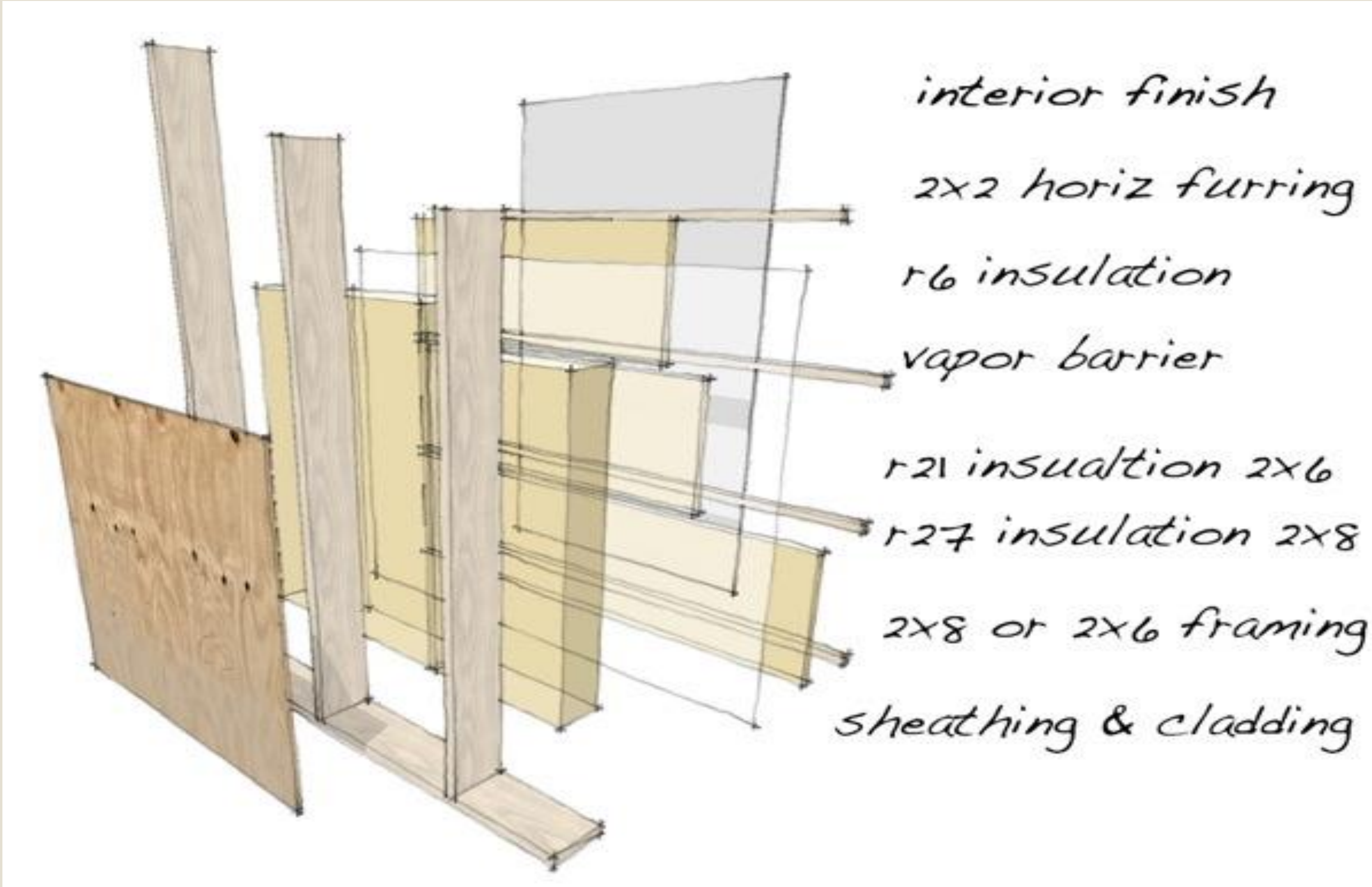
Everything within the system boundary is examined.

(manufacture of individual components, wall sections, impacts linked to construction)

Potential environmental impacts of every component are tracked.

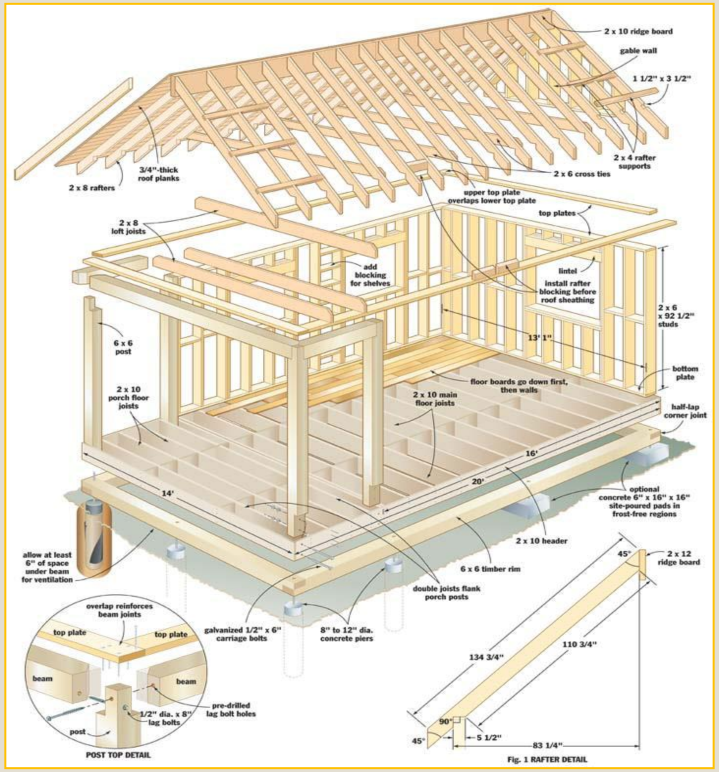
- **Raw material inputs**
- **Energy used at every step**
- **Water consumption**
- **Resulting emissions, effluents, solid wastes**
- **By-products**





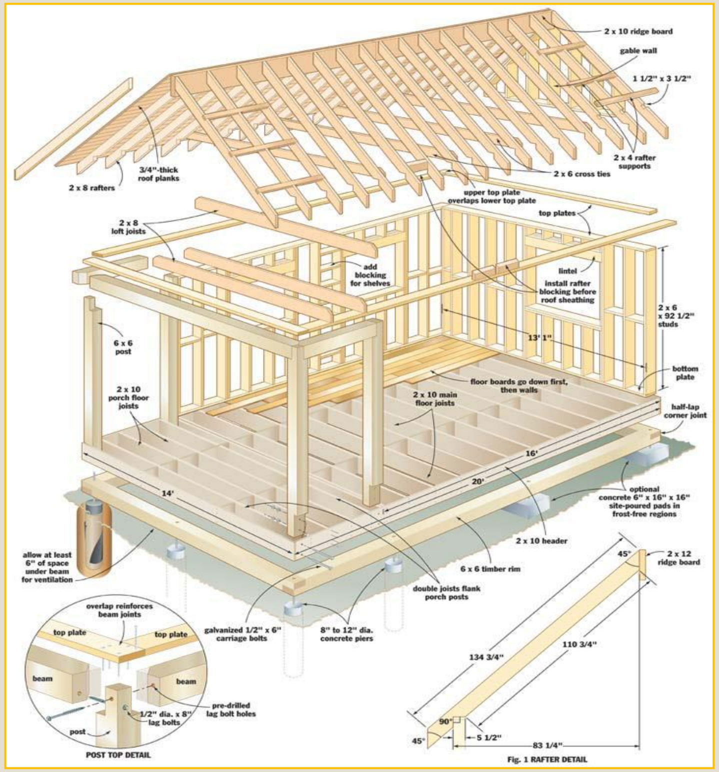
In determining potential environmental impacts, analysis typically includes (depending upon drawing of system boundaries):

- **Raw material extraction**
- **Transportation**
- **All steps in manufacturing**



If the "product" is a component assembled on-site or an entire structure, the following are also assessed :

- **Transport of materials to construction site**
- **Building construction**



In addition, again depending upon system boundaries, impacts related to building operation may be assessed.

- **Transport of materials to construction site**
- **Building construction, and perhaps:**
  - **Operation (heating/cooling)**
  - **Maintenance**
  - **End-of-building-life**

Life Cycle Inventory (LCI)

A life cycle inventory of a single component can result in an enormous amount of data. The next slide summarizes data obtained from analysis of production of 1,000 ft^2 of Douglas-fir plywood.

Inputs are shown on the left (logs, purchased veneer, resin, energy), and outputs are shown on the right (plywood, chips that will be used in making paper, peeler core that may become fence posts, sawdust that will be used to produce energy, emissions and effluents from all processes).

Life-Cycle Inventory results for 1.0 MSF 3/8-in. basis plywood production from the PNW region. Results include plywood production only; no emissions are included for the production and use of electricity, fuel, and phenol-formaldehyde resin.

INPUTS

Materials	Units	Per MSF 3/8-in. basis
Wood resin		
Roundwood (log)	ft.3	6.56E+01
	lb.	1.89E+03
Phenol-formaldehyde	lb.	1.59E+01
Extender and fillers [a]	lb.	8.90E+00
Catalyst [a]	lb.	1.11E+00
Soda ash [a]	lb.	3.30E-01
Bark [b]	lb.	1.98E+02
Dry veneer	lb.	6.81E+00
Green veneer	lb.	1.51E+01
Electrical energy		
Electricity	kWh	1.39E+02
Fuel for energy		
Hog fuel (produced) [b]	lb.	3.83E+02
Hog fuel (purchased) [b]	lb.	3.40E+01
Wood waste	lb.	5.00E-01
Liquid propane gas	gal.	3.59E-01
Natural gas	ft.3	1.63E+02
Diesel	gal.	3.95E-01

a These materials were excluded based on the 2% rule.

b Bark and hogged fuel are wet weights whereas all other wood materials are ovendry weights; bark weight is included in the “hog fuel (produced)” weight.

OUTPUTS

Materials	Units	Per MSF 3/8-in. basis
Bark		
Bark waste	lb.	1.31E+01
Bark ash	lb.	7.75E+00
Total	lb.	2.09E+01
Products		
Plywood	lb.	9.91E+02
Co-products	lb.	
Wood chips	lb.	4.25E+02
Peeler core	lb.	4.62E+01
Green clippings	lb.	3.10E+01
Veneer downfall	lb.	3.44E+00
Panel trim	lb.	1.07E+02
Sawdust	lb.	9.63E+00
Solid dry veneer	lb.	6.68E+01
Total	lb.	6.89E+02
Air emissions		
Acetaldehyde	lb.	1.12E-02
Acetone	lb.	4.80E-03
Acrolein	lb.	4.95E-07
Benzene	lb.	4.77E-04
CO	lb.	1.91E+00
CO_2 fossil	lb.	2.78E+02
CO_2 non-fossil	lb.	2.78E+02
Dust (PM10)	lb.	2.08E-01
Formaldehyde	lb.	1.80E-02
Methanol	lb.	1.28E-01
NO_x	lb.	2.34E-01
Organic substances	lb.	2.20E-02
Particulates	lb.	3.47E-01
Phenol	lb.	8.27E-03
SO_2	lb.	7.74E-04
SO_x	lb.	
VOC	lb.	6.26E-01

Life Cycle Inventory (LCI)

So what could an architect, civil engineer, builder or anyone else seeking to build an environmentally better building reasonably do with this kind of information? Not much!

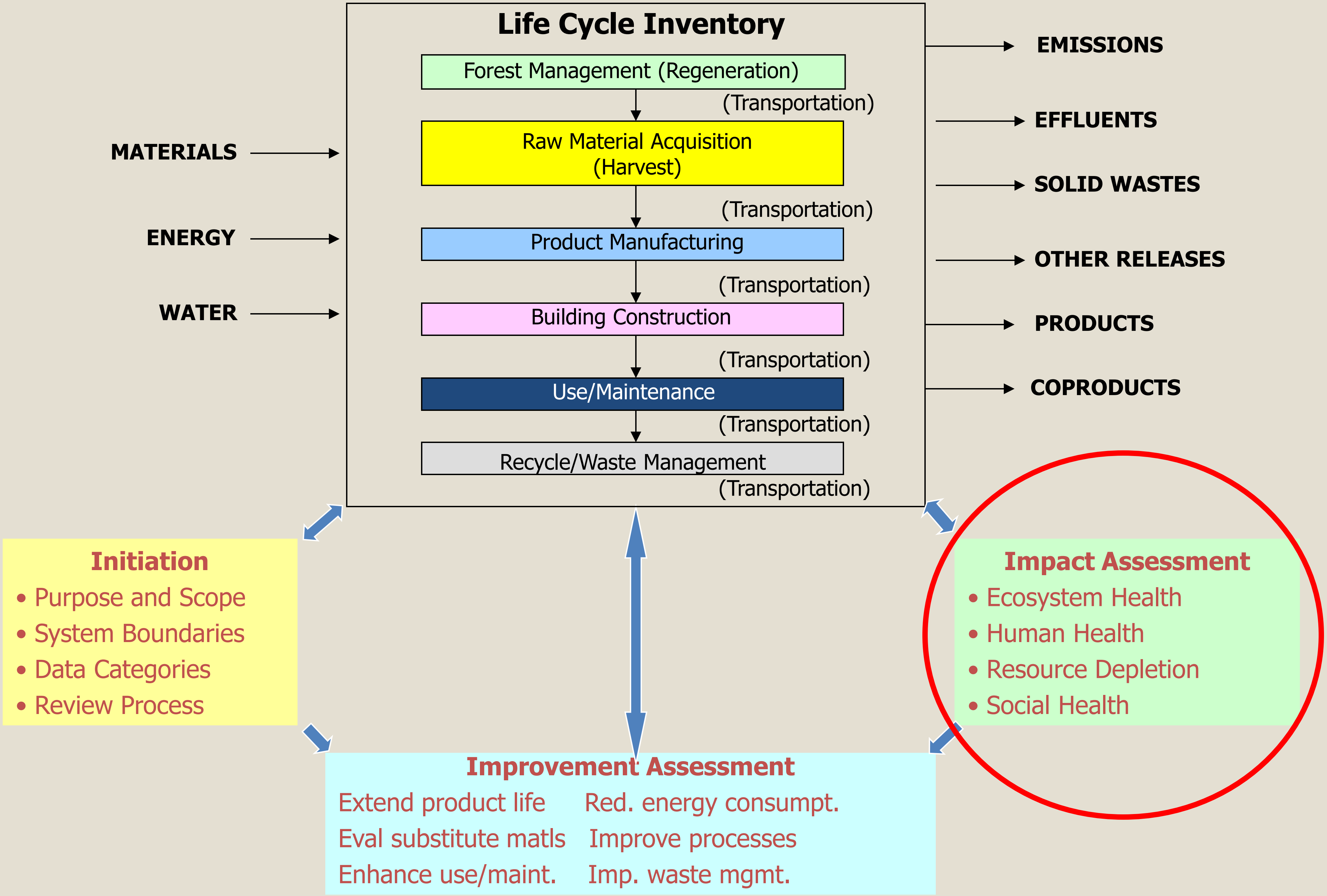
In order to make sense of the large amount of data obtained, the next step is to perform an impact assessment – analyzing data in the context of best available environmental and health science to determine what it means. The result is a much shorter list of impact measures.

Examples of Impact Measures Determined Through an Impact Assessment

Embodied energy (GJ)
GWP (CO_2 kg)
Air emission index
Acidification potential
Human toxicity
Photochemical oxidation
Ozone layer depletion
Depletion of non-renewable resources
Water consumption
Eutrophication
Solid waste (total kg)

Embodied energy is total energy consumption throughout the entire chain of processes considered.

The impact assessment, as part of an LCA, is shown, on the next slide.


Life Cycle Inventory
Forest Management (Regeneration)
(Transportation)
Raw Material Acquisition
(Harvest)
(Transportation)
Product Manufacturing
(Transportation)
Building Construction
(Transportation)
Use/Maintenance
(Transportation)
Recycle/Waste Management
(Transportation)
MATERIALS
ENERGY
WATER
EMISSIONS
EFFLUENTS
SOLID WASTES
OTHER RELEASES
PRODUCTS
COPRODUCTS
Initiation
• Purpose and Scope
• System Boundaries
• Data Categories
• Review Process
Impact Assessment
• Ecosystem Health
• Human Health
• Resource Depletion
• Social Health
Improvement Assessment
Extend product life
Red. energy consumpt.
Eval substitute matls
Improve processes
Enhance use/maint.
Imp. waste mgmt.

Improvement Assessment

Armed with a relatively short list of impact measures, a product manufacturer (or building designer) can now begin to make informed decisions about how to reduce the environmental impacts of product production and use.

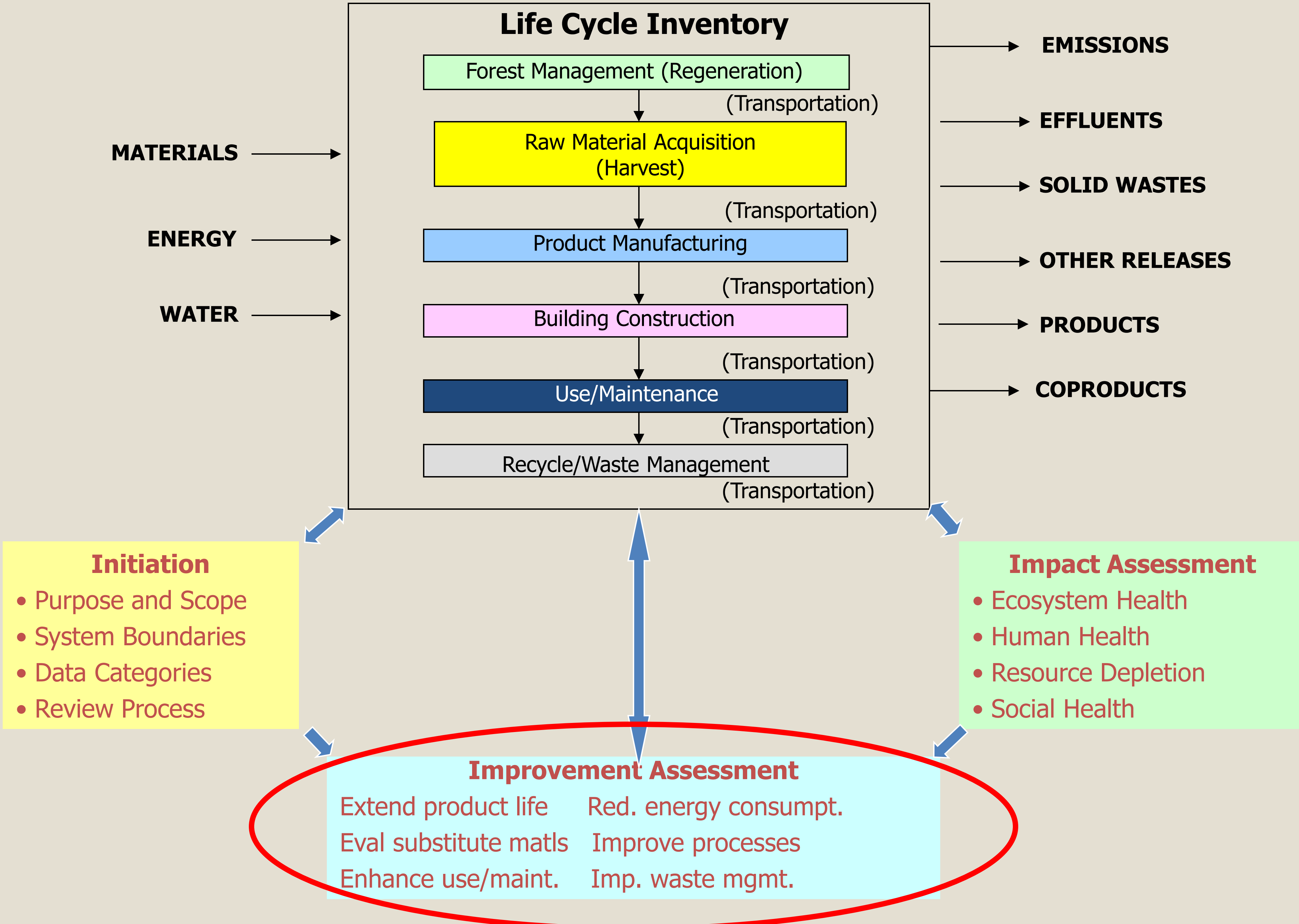
A building designer, for example, can use LCA results to determine the most effective steps that might be taken to reduce the environmental impacts of a building project (see next slide).

Improvement Assessment

- Increase energy efficiency of building?
- Reduce embodied energy?
- Use substitute building materials?
- Source building materials locally?
- Improve construction processes?
- Redesign building?
- Enhance building life, durability?
- Reduce building maintenance needs?
- Reduce packaging of materials delivered to building site?
- Improve construction waste management?

Improvement Assessment

The impact assessment, as part of the LCA process, is shown conceptually in the next slide.



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Why Use of LCA is Essential to Creating Environmentally Better Buildings

There are 40 distinctly different green building programs and model codes in North America. The Leadership in Energy and Environmental Design (LEED) program of the US Green Building Council is the best known.

It is for this reason that LEED is used as an example in the following discussion about why use of LCA is essential to creating environmentally better buildings. It is important to recognize that problems identified in the LEED program are not limited to LEED, but found in many of the other programs as well.

Designation of environmentally preferable materials under the LEED program

Within the LEED program there are a number of rating systems: New Construction, Core and Shell, Commercial Interiors, Homes, Schools, among others. In all of these rating systems, a relatively short list of criteria is used to identify environmentally preferable materials.

Most of these criteria appear under the Materials and Resources category (see next slide), with others under the Indoor Environmental Quality category.

As the various LEED rating systems are quite similar, the LEED for New Construction program is used to illustrate issues within all of the rating systems.

Point Distribution within LEED for New Construction (LEED-NC)

	LEED-NC, 2009*
Sustainable sites	26 pts, 1 pr
Water efficiency	10 pts, 1 pr
Energy and atmosphere	35 pts, 3 pr
Materials and resources	14 pts, 2 pr
Indoor environmental quality	15 pts, 2 pr
Innovation and design process	6 pts
Regional bonus credits	4 pts
Homeowner awareness	
TOTAL	100 pts, 9 pr***

* Effective April 27, 2009

** Effective January 1, 2008

*** 10 bonus points also available (Innov. and design & reg.)

The way in which LEED developed its short list of criteria defining environmentally preferable materials was through groups of “experts” who used their collective wisdom (as well as collective biases and intuition) to come up with identifying characteristics. The process was deceptively simple, leading to a few criteria that most could agree on:

- Recycled content
- Low or no VOCs
- Recycled
- Locally or regionally sourced
- Certified (wood only)
- Rapidly renewable

Credits Related to Characteristics of Construction Materials Under the LEED-NC Program

LEED-NC, v. 3 2009	
Materials and Resources	**Indoor Environmental Quality**
Credit MRc 1 – Reuse existing walls, floors	Credit MRc 4.4 – Low emitting materials, composite wood, and agrifiber
Credit MRc 2 – Recycle, reuse demolition, construction waste.	
Credit MRc 3 – Use salvaged, reclaimed materials.	
Credit MRc 4 – Use materials with recycled content.	
Credit MRc 5 - Local/regional materials (extracted, processed, manufactured within 500 miles)	
Credit MRc 6 - Rapidly renewable materials (10-year or less harvesting cycle) – includes bamboo, agrifiber	
Credit MRc 7 - FSC certified wood. must use minimum of 50% FSC wood. [to get the 1 point]	

There were a number of problems with this approach, the first of which is that intuition is famously unreliable especially where complexity may be involved.

Second, no mechanism was established for getting rid of criteria that might later be found to be unsound.

Third, and most glaring, is that the factors most responsible for adverse environmental impact were completely overlooked.

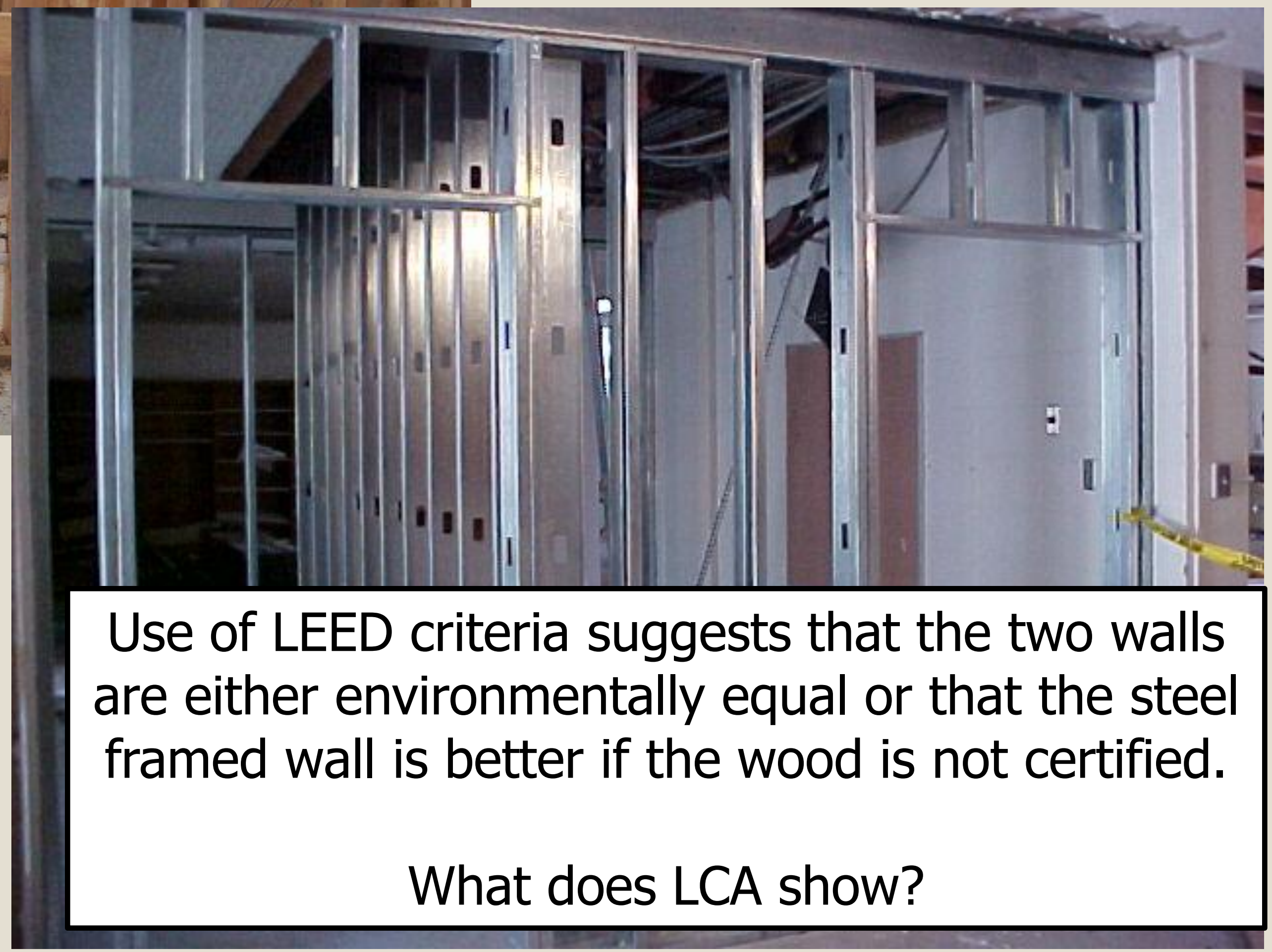
Credits Related to Characteristics of Construction Materials Under the LEED-NC Program

LEED-NC, v. 3 2009	
Materials and Resources	**Indoor Environmental Quality**
Credit MRc 1 – Reuse existing walls, floors	Credit MRc 4.4 – Low emitting materials, composite wood, and agrifiber
Credit MRc 2 – Recycle, reuse demolition, construction waste.	Where are: Embodied energy? Fossil fuel depletion? Resource depletion? Global warming potential? Smog potential? Ozone depletion? Eco-toxicity? Habitat alteration? Emissions to air, water? Water intake? Acidification potential? Eutrophication potential?
Credit MRc 3 – Use salvaged, reclaimed materials.	
Credit MRc 4 – Use materials with recycled content.	
Credit MRc 5 - Local/regional materials (extracted, processed, manufactured within 500 miles)	
Credit MRc 6 - Rapidly renewable materials (10-year or less harvesting cycle) – includes bamboo, agrifiber	
Credit MRc 7 - FSC certified wood. must use minimum of 50% FSC wood. [to get the 1 point]	

Consider the following example of how reliance on a few criteria, not based on any kind of systematic assessment, can result in reward for environmentally poor decisions.

In the LEED program, a "green" credit is awarded for use of recycled-content materials.

Use of steel framing with ≥25% recycled content yields 1 point. No requirement for certification.



If FSC certified wood is used, that gains a project 1 point. If no certification, 0 points.

Use of LEED criteria suggests that the two walls are either environmentally equal or that the steel framed wall is better if the wood is not certified.

What does LCA show?

Interior Non-Load Bearing Wall, Wood vs. Steel

Comparative Energy Use (GJ)

Wood	**Steel***	**Difference**
3.8	11.5	3.0X

* 30% recycled content assumed; the industry-wide average for steel framing is 25-28%.

Source: Athena Sustainable Materials Institute.

Comparative Emissions in Manufacturing Wood vs. Steel-Framed Interior Wall

Emission/Effluent	Wood Wall	Steel Wall	Difference
CO_2 (kg)	305	965	3.2X
CO (g)	2,450	11,800	4.8X
SOX (g)	400	3,700	9.3X
NOX (g)	1,150	1,800	1.6X
Particulates (g)	100	335	3.4X
VOCs (g)	390	1,800	4.6X
Methane (g)	4	45	11.1X

Source: Athena Sustainable Materials Institute.

Comparative Effluents in Manufacturing Wood vs. Steel-Framed Interior Wall

Emission/Effluent	Wood Wall	Steel Wall	Difference
Suspended solids (g)	12,180	495,640	41X
Non-ferrous metals (mg)	62	2,532	41X
Cyanide (mg)	99	4,051	41X
Phenols (mg)	17,715	725,994	41X
Ammonia (mg)	1,310	53,665	41X
Halogenated organics (mg)	507	20,758	41X
Oil and grease (mg)	1,421	58,222	41X
Sulphides (mg)	13	507	39X

Source: Athena Sustainable Materials Institute.

A reasonable question is how a rating system that supposedly helps users identify environmentally better building products could be so far off.

The answer lies in what is missing.

LEED Credits – What is Missing?

- No consideration of total energy consumed in raw materials production, product manufacturing.
- No consideration of emissions to air, water.
- No *capacity* to consider these things.
- No systematic assessment of environmental attributes of construction materials (i.e. no LCA).

Summary

Summary

- Use of LCA is the only way to accurately assess environmental attributes of materials.
- Reliance on intuition-based prescriptive standards is notoriously misleading, sometimes leading to gross errors in identification of environmentally preferable materials.
- Without LCA, assessment of critical measures of environmental impact is not possible.

Questions?

Further information about Life Cycle Assessment and other green building topics can be obtained from Dovetail Partners, Inc.

www.dovetailinc.org