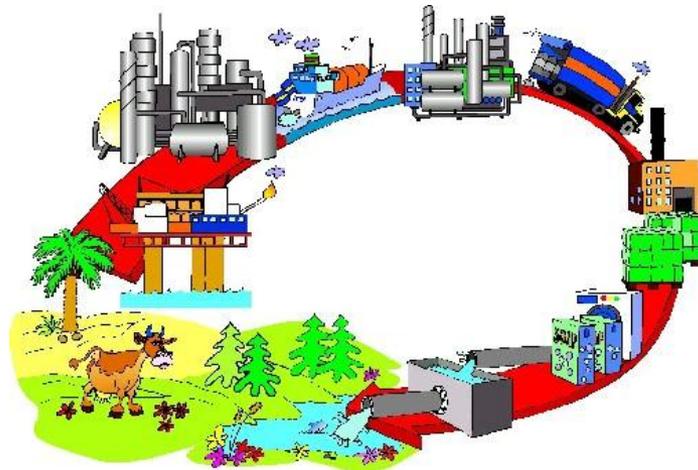


# Environmental Life Cycle Assessment

## PSE 476/WPS 576/WPS 595-005

### Lecture 7: Life Cycle Inventory: LCA Stages: Raw Materials and Energy



Fall 2012

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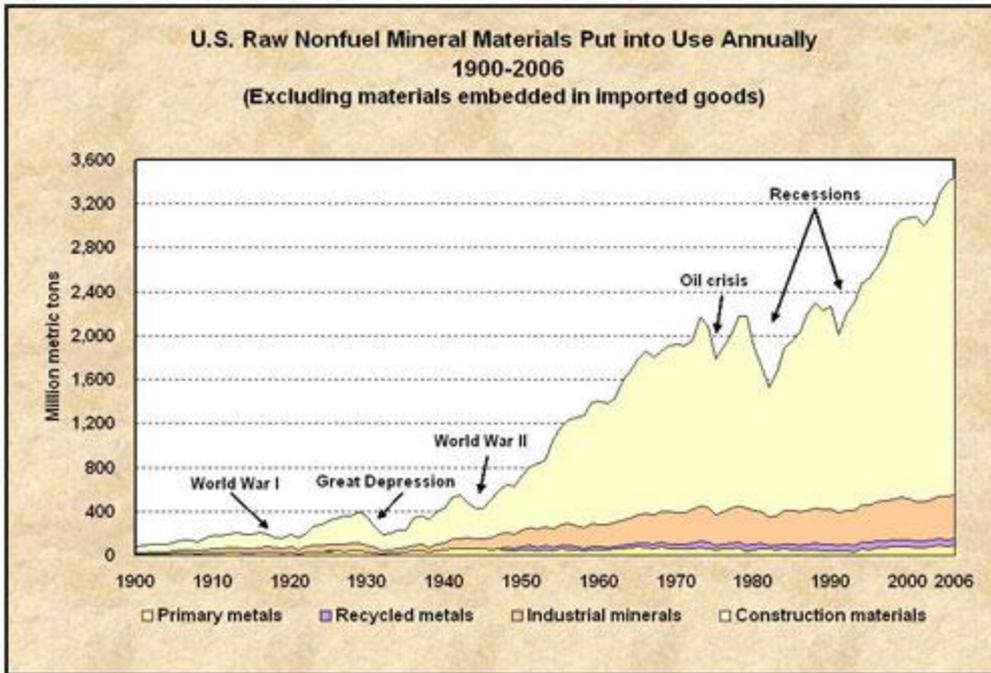
# Raw Materials:

- Primary materials: materials that have not been recycled/reused
- Secondary materials: materials have been recycled/reused
- Secondary materials are of especial importance since they can:
  - Reduce the requirements of primary materials
  - Have significantly different acquisition processes relative to primary materials: with different environmental impacts
    - Different transportation modes
    - Different collection baskets
    - Different quality and purity
  - Reduce waste

# Renewable vs Non-renewable Materials:

- A **nonrenewable resource** is a natural resource which cannot be reproduced, grown, generated, or used on a scale which can sustain its consumption rate, once depleted there is no more available for future needs.
- A **renewable resource** is a natural resource with the ability to reproduce through biological or natural processes and replenished with the passage of time.

# Non-renewable Materials: Minerals



**Every American born in 2008 is estimated to use the following amounts of nonfuel mineral commodities in their lifetime for their necessities, lifestyles, and health.**

Mineral commodity	Amount required over a lifetime
Aluminum (bauxite)	5,677 pounds
Cement	65,480 pounds
Clays	19,245 pounds
Copper	1,309 pounds
Gold	1,576 ounces
Iron ore	29,608 pounds
Lead	928 pounds
Phosphate rock	19,815 pounds
Stone, sand, and gravel	1.61 million pounds
Zinc	671 pounds

Data from U.S. Geological Survey and U.S. Energy Information Administration; statistical analysis by National Mining Association. Source of information: <http://www.mii.org/pdfs/CalculationsfmiiBaby.pdf>.

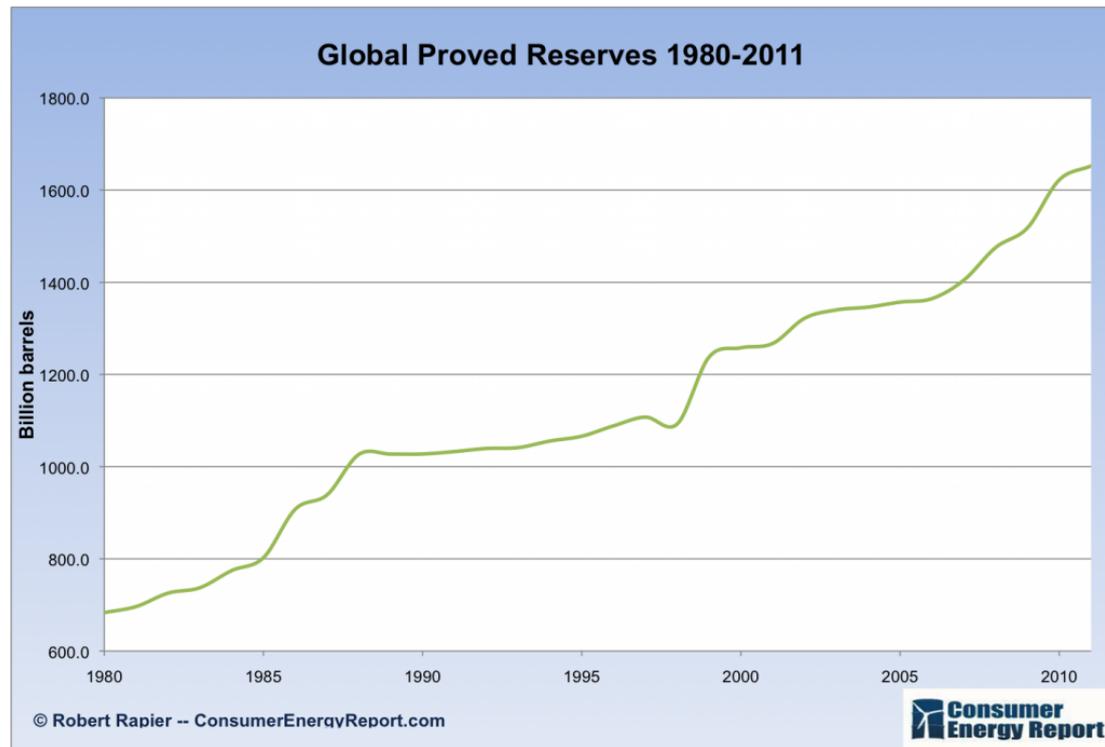
<http://minerals.usgs.gov/granted.html>

# How much copper ore do we have left?

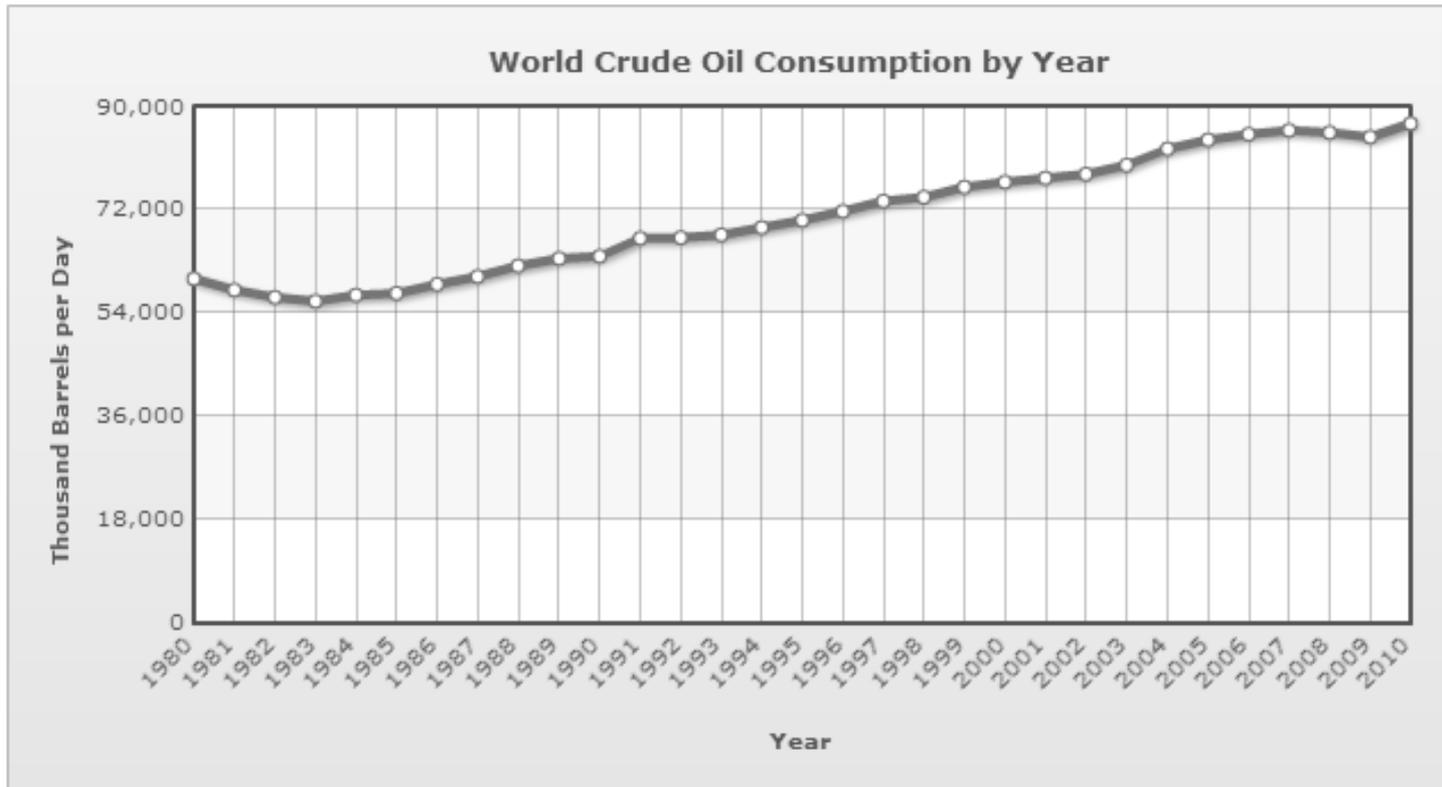
- It is not possible to know exactly.
  - known deposits are being worked and new methods of copper extraction are being developed e.g. using bacteria to 'eat' the copper out of low grade ore
  - some deposits do not contain enough copper to make them economic to extract
  - there are many copper deposits that have not yet been found
  - deposits are still being built up on the seabed

# Non-renewable Materials: Crude Oil

Crude Oil Definition: A mixture of hydrocarbons that exists in liquid phase in natural underground reservoirs and remains liquid at atmospheric pressure after passing through surface separating facilities.



# Non-renewable Materials: Crude Oil



Source: [United States Energy Information Administration](#)

# Non-renewable Materials: Crude Oil

At present consumption, when would proved reserves of crude oil run out?

# Renewable Materials:

- Agricultural products
- Forest biomass
- Fish and animals
- Water
- However, note that any of these materials can be non-renewable in specific situations/locations under specific conditions (non-sustainable consumption practices)

# Non-Renewable and Renewable Energy Resources:

- Non-renewable
  - Fossil fuels (coal and oil)
  - Natural Gas
  - Nuclear Power
- Are there examples of renewables for the above list?
- Renewable
  - Solar energy
  - Geo thermal
  - Wind
  - Hydropower
  - Biomass
- What are the issues with renewables?

# Primary Raw Materials:

- Cultivation, harvesting, replenishing
  - Farm products
  - Forest products
  - Wildlife
- Mined/Collected
  - Fossil fuels
  - Ores
  - Water
  - Air

# Inputs for Basic Raw Materials:

- Energy Utilization
  - Electrical energy in kWh
  - Other energy sources in appropriate units, gallons of fuel, cubic feet of gas
  - Renewable energy
  - Non-renewable energy
- Materials Consumed
  - Pesticides, fertilizers, water, ...
- Harvesting/Processing/Transportation
- Infrastructures required
  - Roads, buildings, drilling rigs,
  - Equipment to explore, mine, extract, harvest materials

# Outputs for Basic Raw Materials:

- Air emissions
- Waterborne emissions
- Solid waste
- Other environmental releases
- Habitat changes
- Land use changes
- Aesthetic changes
- Raw material consumption

# LCA Information for Basic Raw Materials:

- US Life Cycle Inventory Database, [www.nrel.gov/lci/](http://www.nrel.gov/lci/)



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## U.S. Life Cycle Inventory Database

More Search Options  SEARCH  
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Database ▶

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NREL's Buildings research supports the U.S. Department of Energy's [Building Technologies Program](#).



### U.S. Life Cycle Inventory Database

NREL and its partners created the U.S. Life Cycle Inventory (LCI) Database to help life cycle assessment (LCA) practitioners answer questions about environmental impact. This [database](#) provides individual gate-to-gate, cradle-to-gate and cradle-to-grave accounting of the energy and material flows into and out of the environment that are associated with producing a material, component, or assembly in the U.S.

The goals of the U.S. LCI Database project are:

- Maintain data quality and transparency
- Cover commonly used materials, products, and processes in the United States with up-to-date, critically reviewed LCI data
- Support the expanded use of LCA as an environmental decision-making tool
- Maintain compatibility with international LCI databases
- Provide exceptional data accessibility
- Be fully and sustainably supported
- Support U.S. industry competitiveness.

Read the plan to achieve the goals of the LCI Database Project in the [U.S. Life Cycle Inventory Database Roadmap](#) .

### EVENTS

**Energy Efficiency in Homes & Buildings, By Paul Kreischer, Lightly Treading Energy and Design**

October 9, 2012, 6:00 - 8:00  
MDT  
Golden, CO

**Northeast Sustainable Energy Association (NESEA) - Green Buildings Open House ▶**

October 13, 2012  
Maine to Pennsylvania

▶ More Events

U.S. Life Cycle Inventory Database Roadmap



U.S. Life Cycle Inventory Database Dataset Additions



# LCA Information for Basic Raw Materials:

- Ecoinvent, European LCI database

The screenshot shows the Ecoinvent Centre website. At the top left is the Ecoinvent Centre logo, a red circle with the text 'ecoinvent Centre' and 'Swiss Centre for Life Cycle Inventories' below it. To the right of the logo is a navigation bar with the text 'a Competence Centre of' followed by logos for ART, PSI, EPFL, ETH, and EMPA. Below the navigation bar is a login section with 'Direct access to database', 'Username:' and 'Password:' fields, a 'Login' button, and a link for 'Forgot your password?'. Below the login section is a horizontal menu with five red buttons: 'Organisation', 'Database', 'Documentation', 'News', and 'ecoinvent v3'. Below the menu is a 'Latest News' section with three news items, each with a title, a short description, and a date. The first news item is 'ecoinvent v3 further postponed ...' dated 09.10.2012. The second is 'ecoinvent v3 – release date shifts to September 2012!' dated 24.07.2012. The third is 'DF LCA 48 "ecoinvent v3" - presentations online available' dated 18.06.2012. Below the news section is a 'Welcome to the ecoinvent Centre portal' section with a paragraph of text and a list of bullet points describing the database and its uses.

ecoinvent Centre  
Swiss Centre for Life Cycle Inventories

a Competence Centre of ART PSI EPFL ETH EMPA

Direct access to database  
Username:   
Password:   
 [Forgot your password?](#)

**Organisation Database Documentation News ecoinvent v3**

**Latest News**

**ecoinvent v3 further postponed ...**  
Due to some technical problems, the release of ecoinvent v3 is unfortunately further postponed...  
[\[more\]](#) 09.10.2012

**ecoinvent v3 – release date shifts to September 2012!**  
In the last month, the ecoinvent Centre team together with the editorial board worked very hard to...  
[\[more\]](#) 24.07.2012

**DF LCA 48 "ecoinvent v3" - presentations online available**  
All presentations from the one-day conference "ecoinvent v3 - an introduction to the new...  
[\[more\]](#) 18.06.2012

**Welcome to the ecoinvent Centre portal**

The ecoinvent Centre - a Competence Centre of ETHZ, EPFL, PSI, Empa and ART - is the world's leading supplier of consistent and transparent life cycle inventory (LCI) data of known quality with the **database ecoinvent data v2.2** and offers science-based, industrial, international life cycle assessment (LCA) and life cycle management (LCM) data and services.

ecoinvent data v2.2 ...

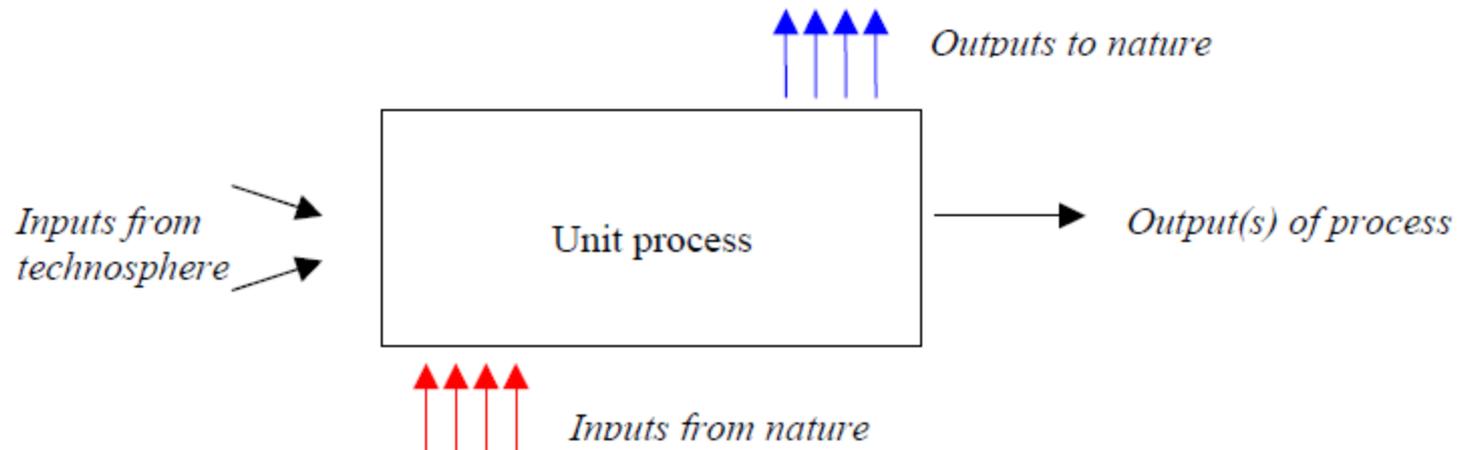
- contains international industrial life cycle inventory data on energy supply, resource extraction, material supply, chemicals, metals, agriculture, waste management services, and transport services.
- is used by around 4'500 users in more than 40 countries worldwide and is included in the leading LCA software tools as well as in various eco-design tools for building and construction, waste management or product design.
- is our solution for your data needs in Integrated Product Policy (IPP), Environmental Product Declaration (EPD), Life Cycle Assessment (LCA), Life Cycle Management (LCM), Design for Environment (DfE).

# LCA Information for Basic Raw Materials: US LCI: Overall Theme

- Which has the least impact on the environment, plastic or paper, cellulose insulation or fiberglass insulation, carpet or wood flooring?
- No final answer, each product has advantages and disadvantages when it comes to its environmental impact.
- The science of sustainability is not exact, but we are working on tools to give us better answers to environmental impact questions.
- The U.S. Life-Cycle Inventory (LCI) Database project is providing essential data to support those tools.

# LCA Information for Basic Raw Materials: US LCI

- Database is composed of LCI data modules.
  - Inputs from technosphere (The part of the physical environment affected through building or modification by humans.)
  - Inputs from nature
  - Outputs to nature
  - Outputs of process (products)
- Modules can be cradle-to-gate or gate-to-gate or cradle to grave



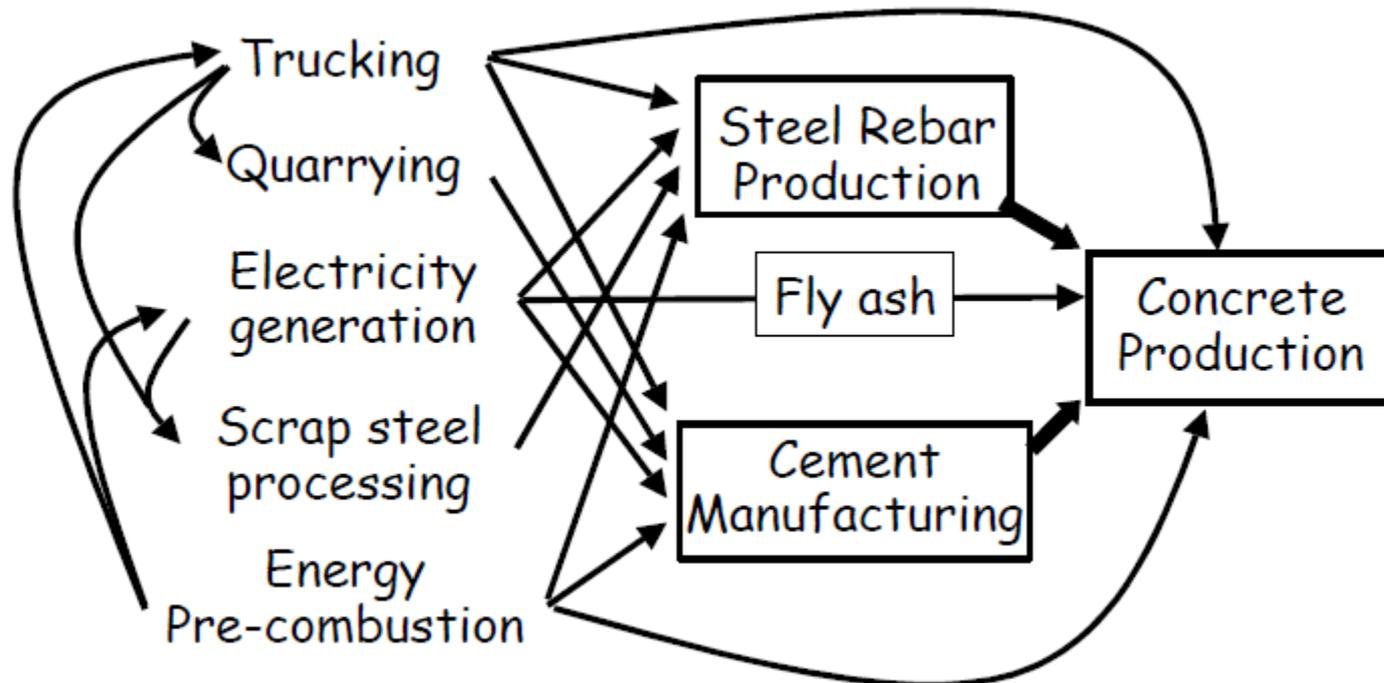
# LCA Information for Basic Raw Materials: US LCI

- Note, in some cases, inputs/outputs to nature are qualified

Flow Type	Category	Sub Category
Input from Nature	Resource	Biotic In air In ground In water Land
	Water	Lake Ocean Protected area River River, long-term Unspecified
	Other	Unspecified
Output to Nature	To Air	High population density Low population density Low population density, long-term Protected area Stratosphere Unspecified
	To Water	Fossil Ground Ground, long-term Lake Ocean Protected area River River, long-term Unspecified
	To Waste Management	Building demolition Hazardous waste incineration Inert material landfill Land farming Municipal incineration Recycling Residual material landfill Sanitary landfill Underground deposit Wastewater treatment Others
	Other	Unspecified

# LCA Information for Basic Raw Materials: US LCI

- Modules as building blocks
- The scrap steel processing module calls for electricity per unit reference flow of product, and obtains inventory data for that electricity from the electricity generation module

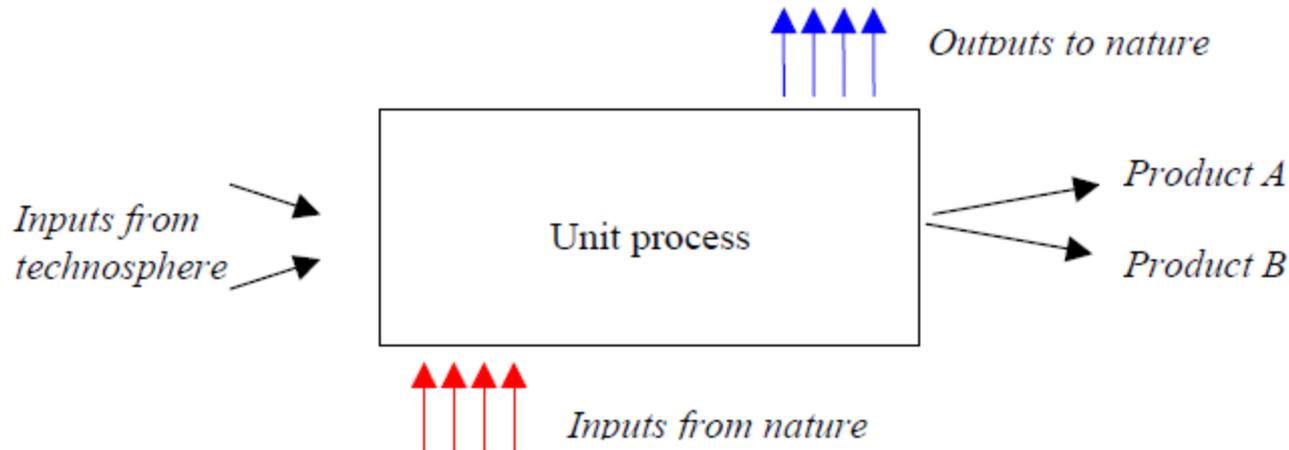


# LCA Information for Basic Raw Materials: US LCI

- Aggregate Modules: combined data for several modules into one
  - Convenience
  - Only available at an aggregated level
- Example: kiln dried softwood lumber from the Pac. NW combines
  - Forest resources (forest mgmt and harvesting)
  - Sawing
  - Kiln drying
  - Planning
  - Energy Production
  - Transportation
- Since the individual modules are also available, then a user can pick and choose individual modules to produce a specific “aggregated module” correct for a certain application

# LCA Information for Basic Raw Materials: US LCI

- Modules supplied without allocations between co-products
- Allows the users to apply allocation methods as they see fit and to undertake sensitivity analysis on allocation methods



# LCA Information for Basic Raw Materials: US LCI

- Database: <https://www.lcacommons.gov/nrel/search>

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## U.S. Life-Cycle Inventory Database

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**DATASET TYPE**

Flows (1334)

Process (633)

**CATEGORY**

Air Transportation (1)

Chemical Manufacturing (84)

Crop Production (34)

Elec. Equip., Appliance, and Comp. Mnf. (2)

Fabricated Metal Product Manufacturing (1)

Forestry and Logging (80)

Mining (except Oil and Gas) (6)

Nonmetallic Mineral Product Mnf. (2)

Oil and Gas Extraction (3)

Paper Manufacturing (1)

Petroleum and Coal Products Mnf. (2)

Primary Metal Manufacturing (23)

Rail Transportation (1)

Transit and Ground Passenger Trans. (46)

Transportation Equipment Manufacturing (5)

Truck Transportation (102)

Utilities (125)

Waste Management and Remediation Service (22)

Water Transportation (6)

Wood Product Manufacturing (60)

biomass (21)

Search for ([Advanced Search](#)) ([New search](#))

Order results by: Relevance

1,967 records found 1 2 3 4 5 6 .. 57 Next

<b>Transport, single unit truck, short-haul, diesel powered, West</b>	General Freight Trucking	
<b>Transport, motorcycle, gasoline powered</b>	Other Transit and Ground Passenger Tran	
<b>Phenol formaldehyde, at plant</b>	Plastics Material and Resin Mnf.	
<b>Soybean oil, crude, degummed, at plant</b>	unspecified	
<b>Palm kernels, at plant</b>	Oilseed (except Soybean) Farming	
<b>Polystyrene, high impact, resin, at plant, CTR</b>	Petrochemical Manufacturing	
<b>Electricity, at eGrid, HIMS, 2008</b>	Utilities	
<b>Forest residue, processed and loaded, at landing system</b>	Logging	
<b>Anode, at plant</b>	Misc. Fabricated Metal Product Mnf.	
<b>Combustion, wet wood residue, AP-42</b>	Other Electric Power Generation	
<b>Dry veneer, at plywood plant, US SE</b>	Softwood Veneer and Plywood Mnf.	
<b>Soybean grains, at field</b>	Soybean Farming	
<b>Delimiting, slide boom delimitter</b>	Logging	

# LCA Information for Basic Raw Materials: US LCI

- Example: corn stover, ground and stored

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- Transportation Equipment Manufacturing (5)
- Truck Transportation (102)
- Utilities (125)
- Waste Management and Remediation Service (22)
- Water Transportation (6)
- Wood Product Manufacturing (60)
- biomass (21)

Search for ([Advanced Search](#)) ([New search](#))

Order results by: Relevance Go

1,967 records found 1 2 3 4 5 6 .. 57 Next

Transport, single unit truck, short-haul, diesel powered, West	General Freight Trucking	<a href="#">P</a>
Transport, motorcycle, gasoline powered	Other Transit and Ground Passenger Tran	<a href="#">P</a>
Phenol formaldehyde, at plant	Plastics Material and Resin Mnf.	<a href="#">P</a>
Soybean oil, crude, degummed, at plant	unspecified	<a href="#">P</a>
Palm kernels, at plant	Oilseed (except Soybean) Farming	<a href="#">P</a>
Polystyrene, high impact, resin, at plant, CTR	Petrochemical Manufacturing	<a href="#">P</a>
Electricity, at eGrid, HIMS, 2008	Utilities	<a href="#">P</a>
Forest residue, processed and loaded, at landing system	Logging	<a href="#">P</a>
Anode, at plant	Misc. Fabricated Metal Product Mnf.	<a href="#">P</a>
Combustion, wet wood residue, AP-42	Other Electric Power Generation	<a href="#">P</a>
Dry veneer, at plywood plant, US SE	Softwood Veneer and Plywood Mnf.	<a href="#">P</a>
Soybean grains, at field	Soybean Farming	<a href="#">P</a>
Delimiting, slide boom delimitter	Logging	<a href="#">P</a>

# LCA Information for Basic Raw Materials: US LCI

- Example: corn stover, ground and stored

Showing details for *corn stover, ground and stored*

 [Back to Results](#)

Activity	Modelling	Admin Info	Exchanges
<b>Name</b>	corn stover, ground and stored		
<b>Category</b>	biomass - production		
<b>Description</b>	Taken from Sheehan, Corn Stover Ethanol LCA. (Directly from TEAM). The corn steep liquor production involves the steeping of harvested corn for a period of from 24 to 48 hours in a light sulfurous acid solution. The production of sulfurous acid was assumed to be negligible. The only emissions were SO <sub>x</sub> from the steeping tanks. Emission factors provided by USA EPA AP-42. All of the production burdens from corn are assumed to be allocated to the production of the steeping liquor.		
<b>Location</b>	RNA		
<b>Geography Comment</b>	North America		
<b>Infrastructure Process</b>	False		
<b>Quantitative Reference</b>	corn stover, ground and stored		

# LCA Information for Basic Raw Materials:

- Example: corn stover, ground and stored

Activity	Modelling	Admin Info	Exchanges		
Inputs					
Flow	Category	Type	Unit	Amount	Comment
corn stover, carted	root/Flows	ProductFlow	t	1.28e+00	comes in wet
Dummy_agricultural machinery, general, production	root/Flows	ProductFlow	kg	9.00e-01	
Dummy_conveyor belt, at plant	root/Flows	ProductFlow	m	3.47e-05	conveyor for storage
Dummy_conveyor belt, at plant	root/Flows	ProductFlow	m	3.47e-05	conveyor for grinder in-feed system
Dummy_dried roughage store, non ventilated	root/Flows	ProductFlow	m3	1.17e-07	
Dummy_fodder loading, by self-loading trailer	root/Flows	ProductFlow	m3	2.78e+00	loading to storage
Dummy_loading bales	root/Flows	ProductFlow	p	1.43e+00	loading bales for grinder. Calculation of number of bales comes from 2000 lbs of corn stover divided by weight per bale. Trailer volume is 2511 ft^3 (INL table 4-5), density is 12 lbs/ft^3 dry (=20 wet at 40% moisture).
Dummy_maize drying	root/Flows	ProductFlow	kg	2.38e+02	
electricity, at grid, US, 2008	root/Flows	ProductFlow	kWh	5.37e+01	Electricity needed for pelletization.
electricity, at grid, US, 2008	root/Flows	ProductFlow	kWh	3.26e+00	Electricity needed for twine removal
electricity, at grid, US, 2008	root/Flows	ProductFlow	kWh	6.13e+01	Electricity needed for dust collection
grinding	root/Flows	ProductFlow	sh tn	9.31e-01	
Outputs					
corn stover, ground and stored	root/Flows	ProductFlow	t	1.00e+00	
Water	air/unspecified	ElementaryFlow	kg	2.80e+02	water dried per ton of final moisture corn stover.

# Summary terms

- Primary materials
- Secondary materials
- Non-renewable
- Renewable
- Technosphere
- Aggregated model
- US LCI
- ecoinvent