



*Dwight Look College of*

**ENGINEERING**  
TEXAS A&M UNIVERSITY

# Think Like an Engineer – Energy Efficient Coffee Making

Johannes Strobel, Ph.D.  
Director, Educational Outreach Programs  
Associate Professor, ETID & TLAC  
Texas A&M University

NCA's National Coffee Drinking Trends (NCDT) study has been conducted annually by NCA since 1950. It is the longest available statistical series of consumer drinking patterns in the U.S.

Get your  
full report  
today!

**83%**

of Americans say they drink coffee

## Coffee Consumption



### General Trends

## HOW OFTEN?

**3/4**

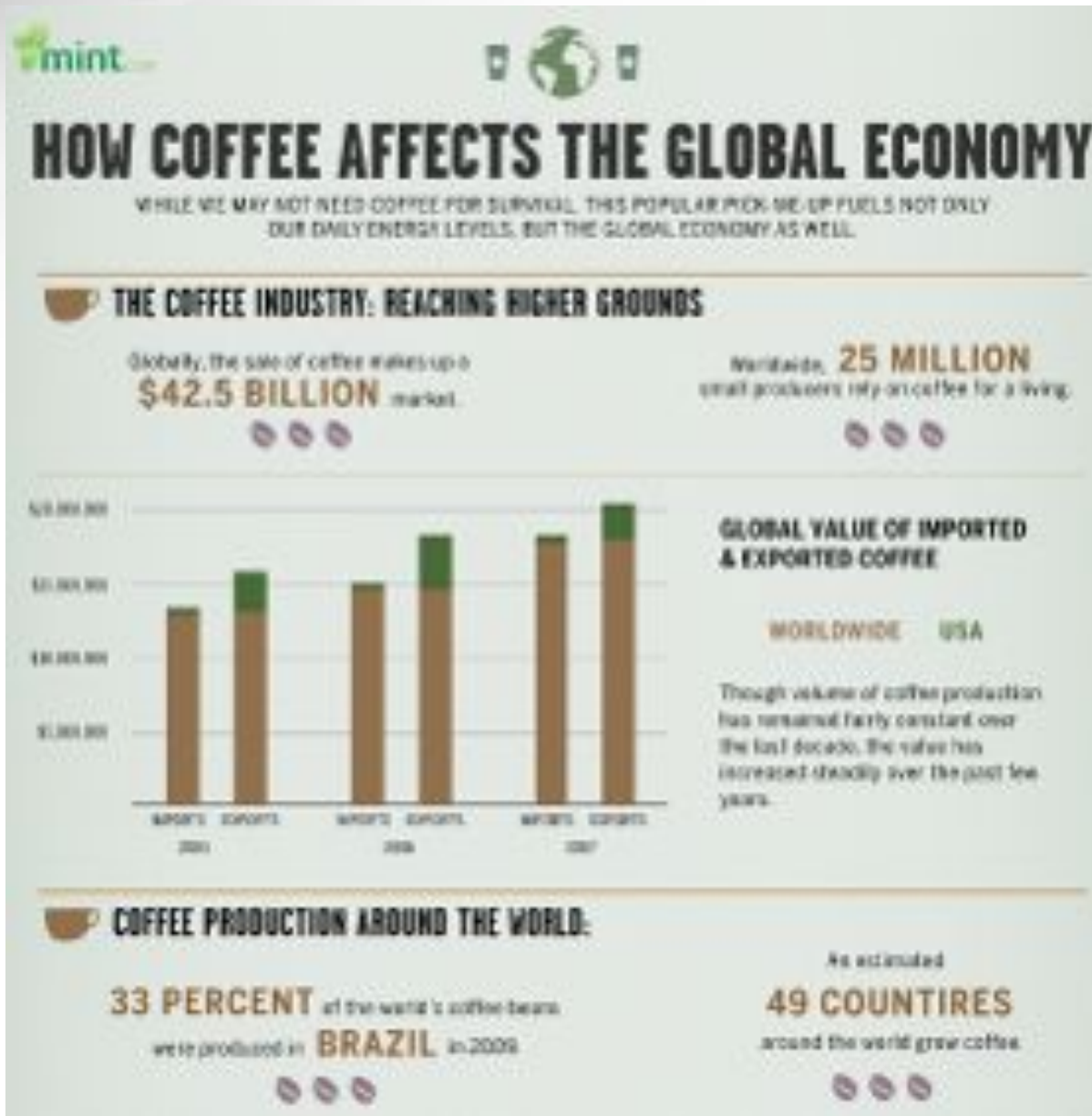
of Americans drink coffee at  
least once per week



Daily coffee consumption remained strong and steady **63%** drink coffee daily

Daily Coffee Consumption  
by Age





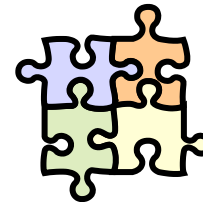
# How much energy does it take to make one cup of coffee?

(1) Brainstorm (2 min)



**Individual  
Reflection**

(2) Discuss (3 min)



**Team work**

Consider:

- How do you define and measure energy?

# Task

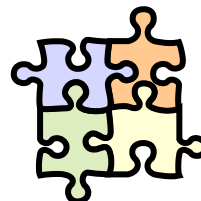
- Your task is to come up with a more energy efficient way of making a cup of coffee.
  - Use science, mathematics, (possibly) engineering concepts that you know
  - Produce a visual to explain your design
  - Make a list of (1) what you know, (2) what you don't know and is important for you to find out and (3) larger questions you might have

(1) Individual Brainstorm  
(5 min)



Individual  
Reflection

(2) Share and develop (10 min)



Team work

(3) Discuss (5 min)



Class  
Discussion

# Did you...?

- |   |   |
|---|---|
| <div></div>   |   |
| 1. Focus on the electrical components of the system?  | <b>(1-3) Electrical</b>                           |
| 2. Make a list of steps (1,2,3,...) on how the device works?  |   |
| 3. Did you draw a block diagram or a flowchart?   |   |
| 4. Focus on the device and its mechanical design (large drawing of the machine)?  | <b>(4-6) Mechanical, Material<br/>Aerospace</b>   |
| 5. Focus on the device itself but especially on its material properties?  |   |
| 6. Did you use terms such as “insulation” and “heat transfer”?  |   |
| 7. Consider a broad scope/system beyond the device itself (harvesting of coffee to cleaning and recycling of the device)? | <b>(7-9) Industrial, Civil,<br/>Environmental</b> |
| 8. Consider various types of coffee makers (e.g., espresso)?  |   |
| 9. Did you focus on improving irrigation system and soil quality?   |   |
| 10. Come up with solutions as simple as placing the coffee maker by a sunny window?                                       | <b>10) Agriculture</b>                            |
|   | <b>Chemical?</b>                                  |



# HOW TO MAKE THE COFFEE MAKER ENERGY EFFICIENT?

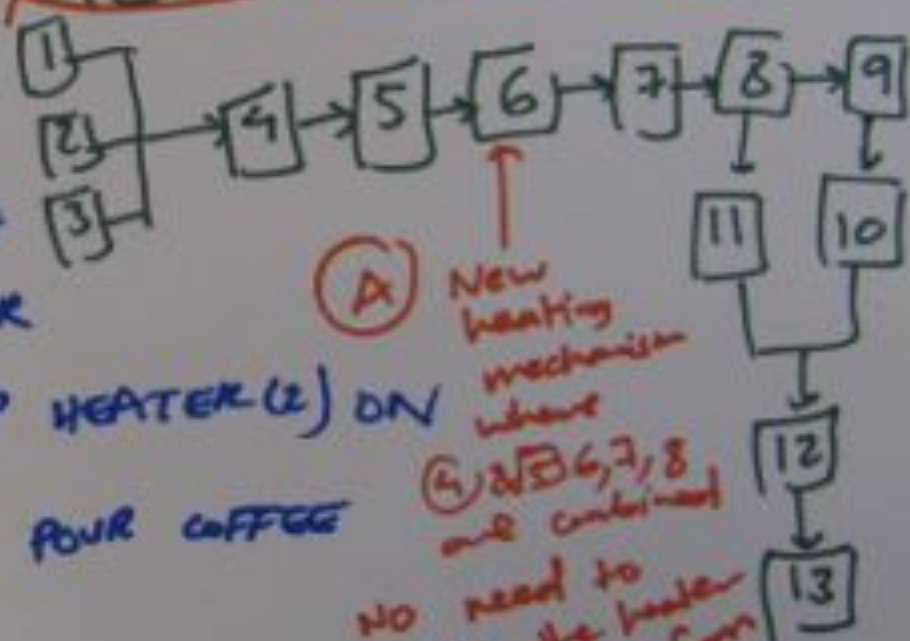
## FUNCTIONAL DECOMPOSITION: (VERB - NOUN)

- 1 - PLUG WIRE
- 2 - PUT WATER
- 3 - PUT COFFEE
- 4 - PRESS "ON" BUTTON
- 5 - TURN HEATER (1) ON
- 6 - HEAT WATER
- 7 - MIX/BIND WATER & COFFEE
- 8 - POUR COFFEE IN CONTAINER
- 9 - KEEP COFFEE HOT; KEEP HEATER (2) ON
- 10 - TAKE CONTAINER OUT TO POUR COFFEE IN CUP
- 11 - TURN HEATER (1) OFF
- 12 - TURN HEATER (2) OFF
- 13 - Clean container

## FUNCTIONAL BLOCK DIAGRAM:



(Q) long process  
can make it shorter  
faster



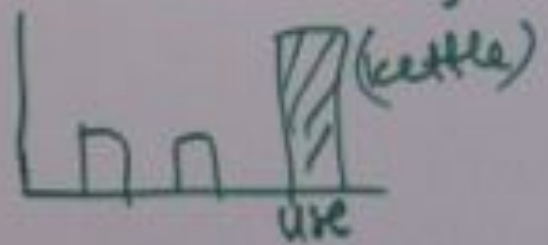
(A) New heating mechanism where

(4) & (5) 6, 7, 8 are combined

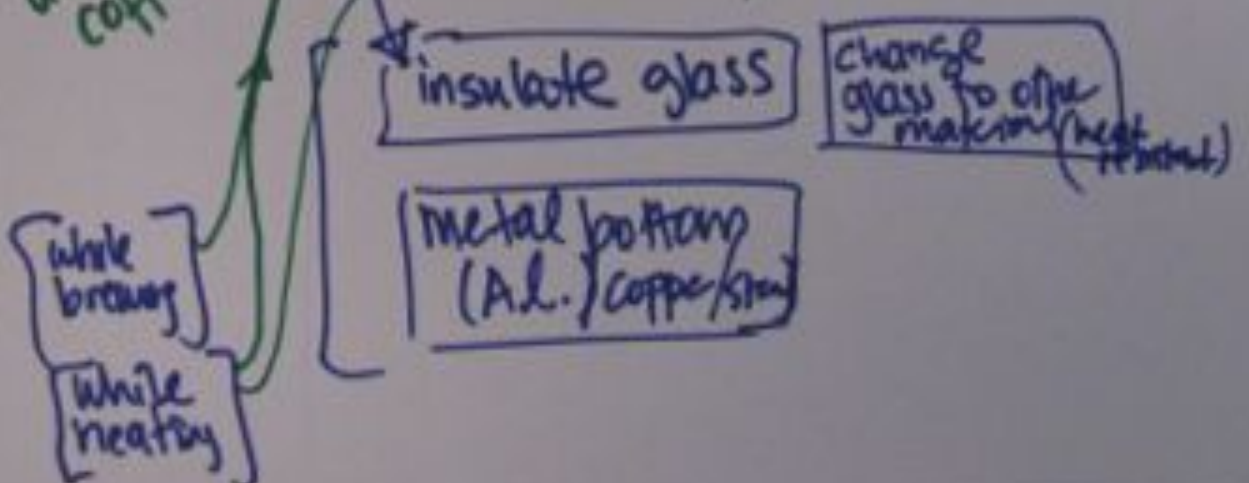
No need to make the heater separate from coffee and water...



- what is the "scope" of the system?  
inputs, outputs.
- where is most energy is used?



- while "using" how is energy lost?
- \* heat loss through glass + top.
- \* conductivity btw glass and heat plate





How to make the coffee maker more energy efficient?

Raw flat  
If ↑ choose  
more energy  
efficient mat

factory

Store

House

Colombia  
Brazil  
France, etc

transportation of coffee  
not energy  
efficient

grow USA

**solved**

solar coffee maker → very expensive  
but cheap  
operation

Near a window  
solar panel

→ constant energy  
fill with water  
only  
not paper  
→ save

only fresh  
water and  
filtered

not better  
Keller

easy to clean

materials  
with as much  
water

→ clean cycle with  
minimum  
water  
the inside  
filter

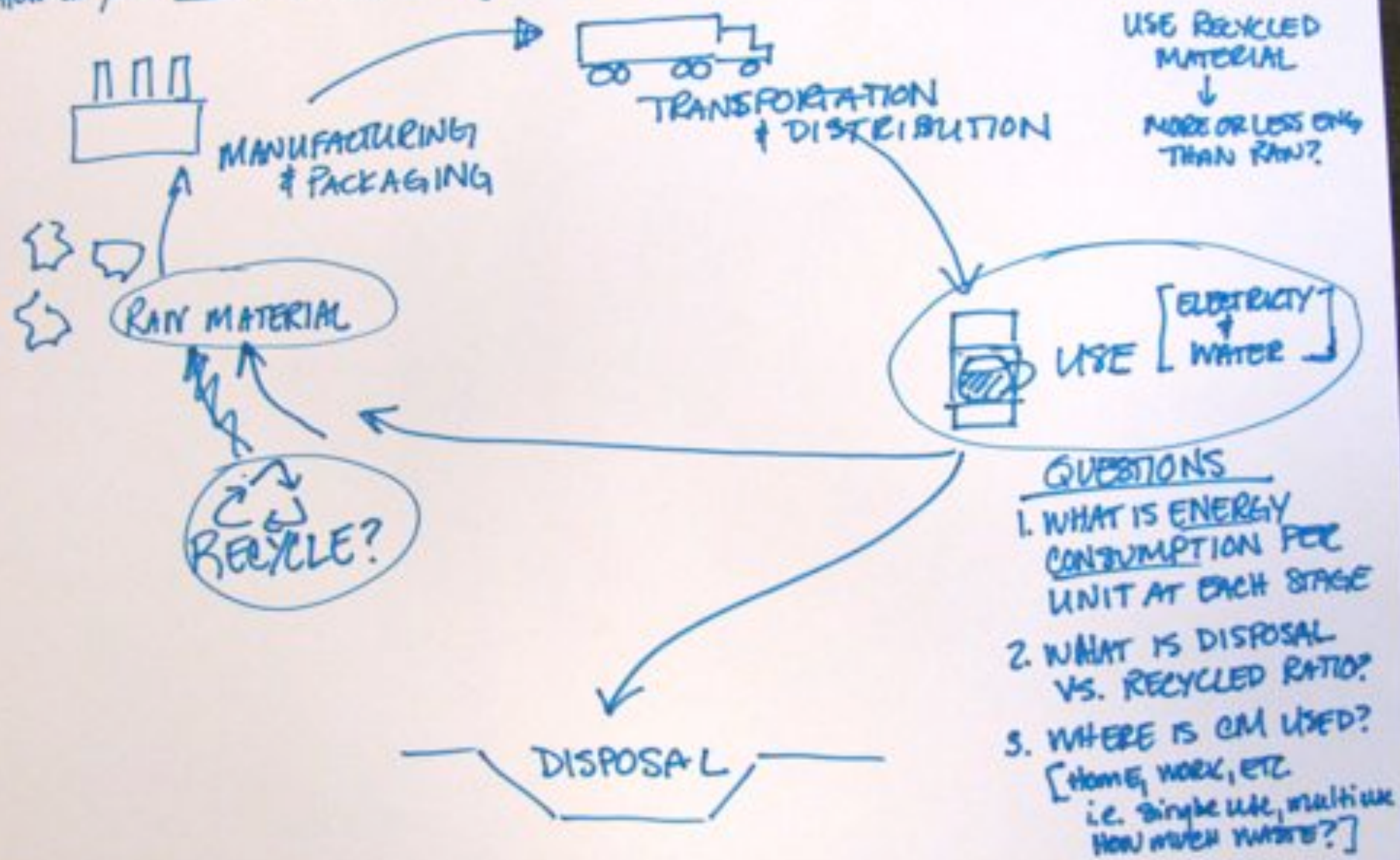
it is sunny  
if it is sunny  
electric  
when no solar  
available

energy saving

keep coffee  
warm at  
day

How do you measure ~~cost~~ energy efficiency?

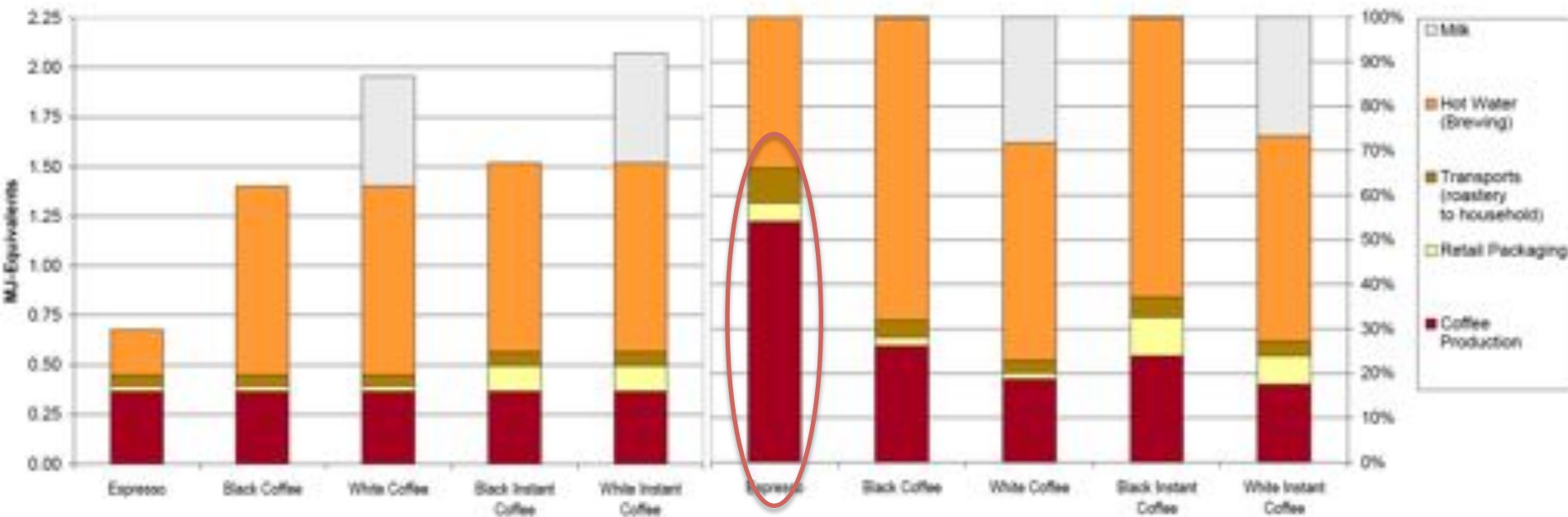
6/29



QUESTIONS

1. WHAT IS ENERGY CONSUMPTION PER UNIT AT EACH STAGE
2. WHAT IS DISPOSAL VS. RECYCLED RATIO?
3. WHERE IS CM USED?  
[Home, work, etc.  
i.e. single use, multiple  
How much waste?]

# What if?

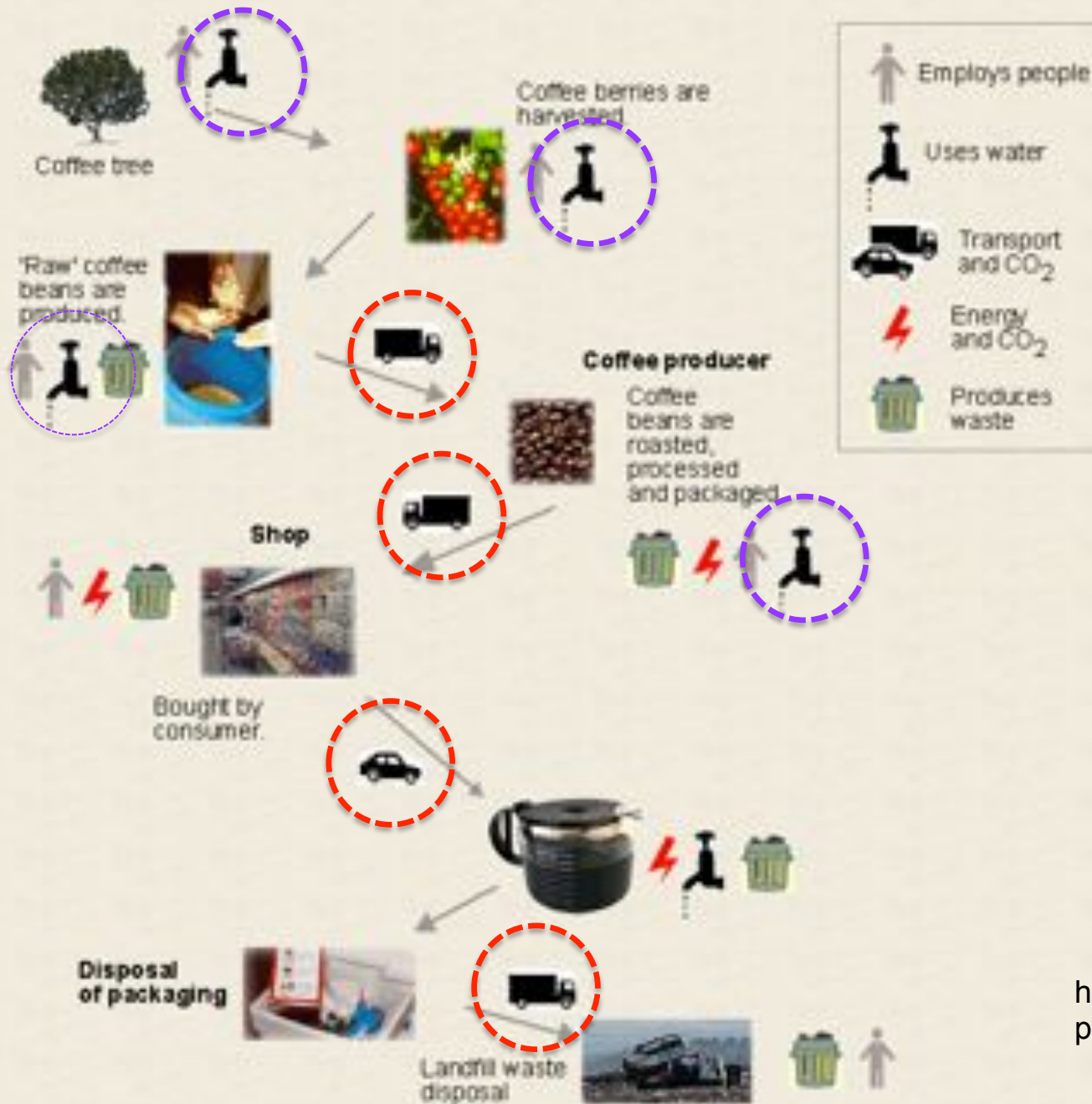


Results of the standard case for a cup of coffee with regard to the non-renewable cumulative energy demand. Left are shown the absolute values and on the right side the results are scaled to 100 %.

Source: [http://www.alufoil.org/tl\\_files/sustainability/ESU\\_-\\_Coffee\\_2008\\_-\\_Exec\\_Sum.pdf](http://www.alufoil.org/tl_files/sustainability/ESU_-_Coffee_2008_-_Exec_Sum.pdf)



## Life cycle of a cup of coffee



# What if?

## Systems Thinking

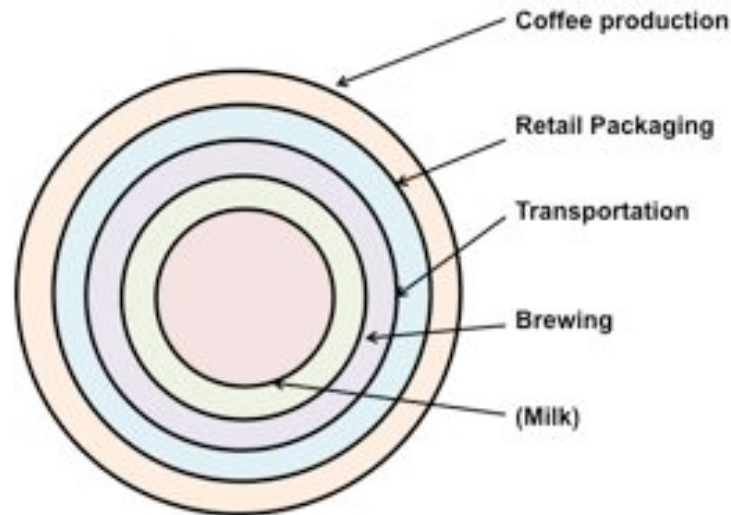
<http://www.sustainability-ed.org/pages/look4-1.htm>

## How much energy does it take to make one cup of coffee?

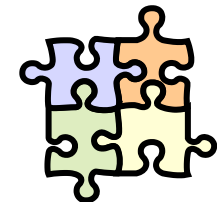
(1) Brainstorm (2 min)



Individual  
Reflection



(2) Discuss (3 min)



Team work

Consider:

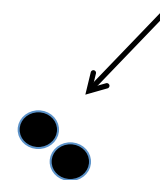
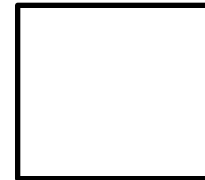
- How do you define and measure energy?
- What goes into making coffee?



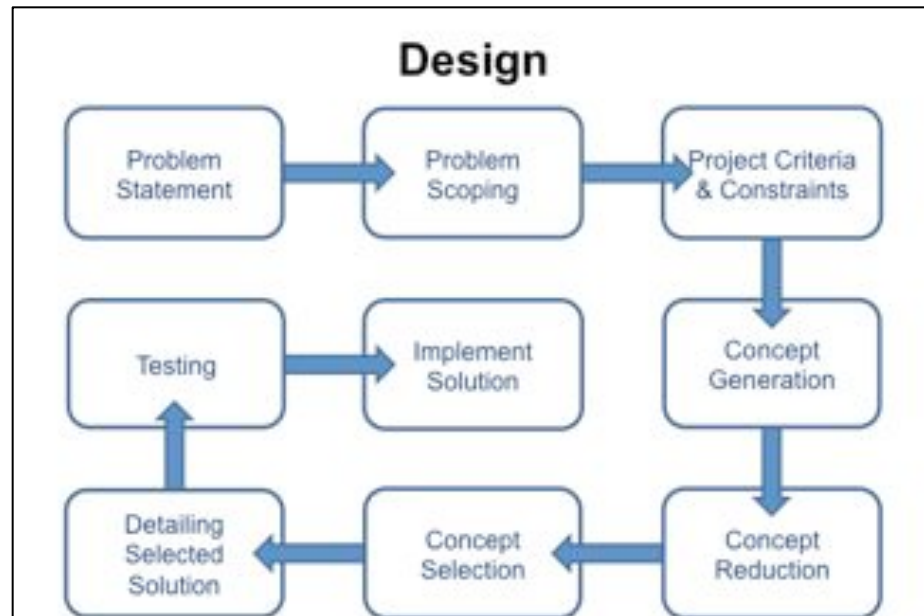
# Engineering Thinking



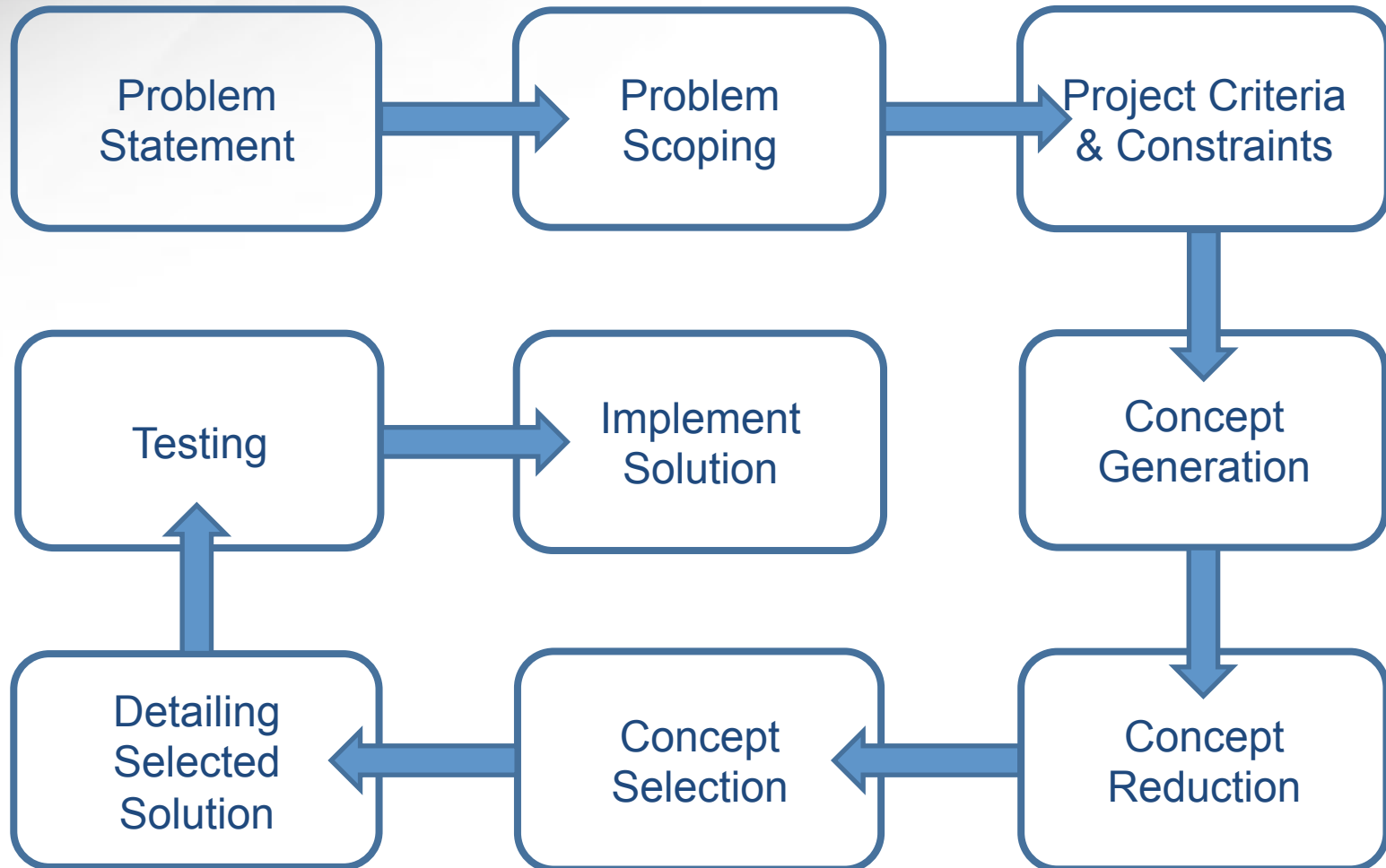
**Sustainability  
Triple Bottom Line**



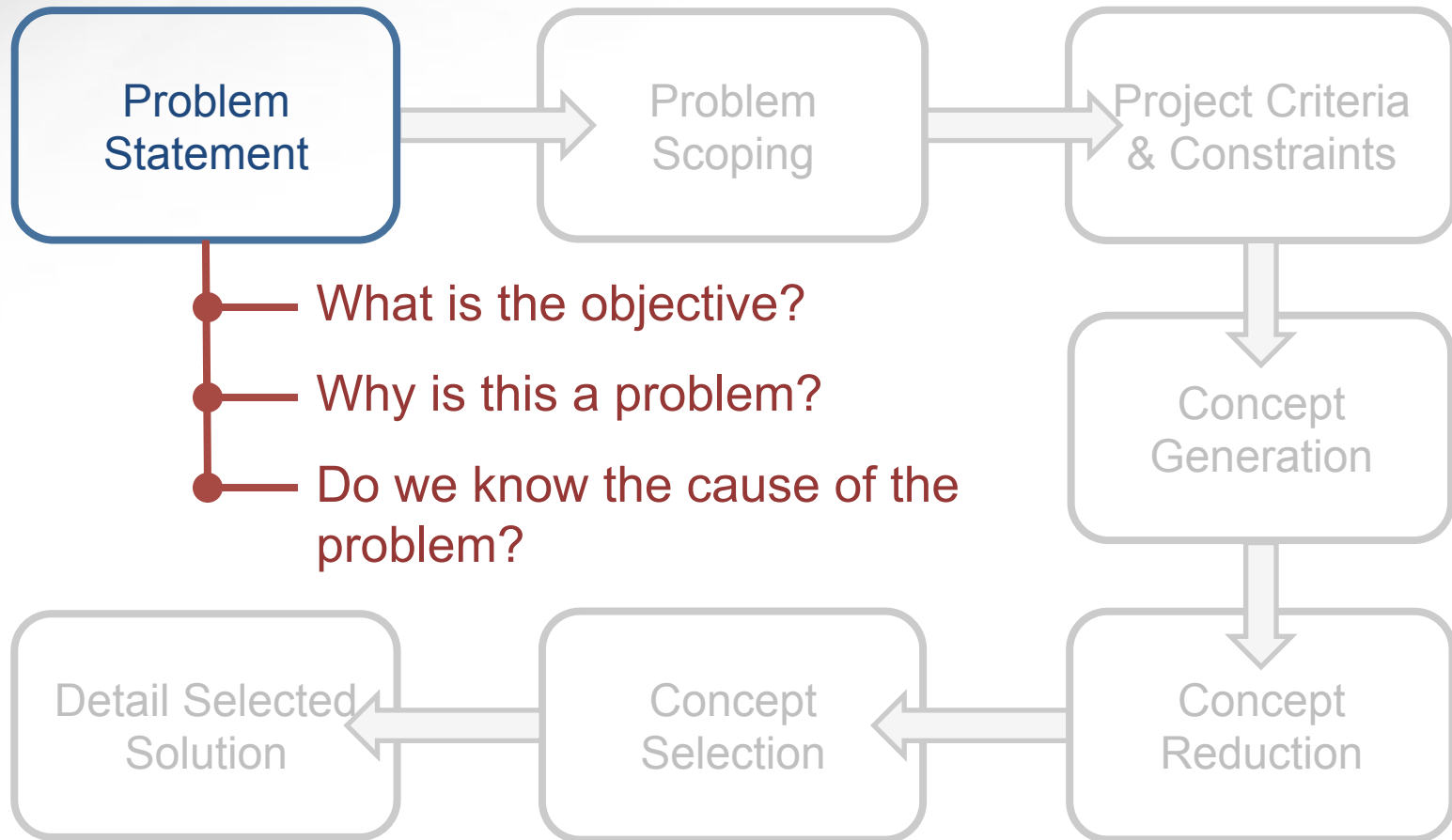
Engineers are  
here



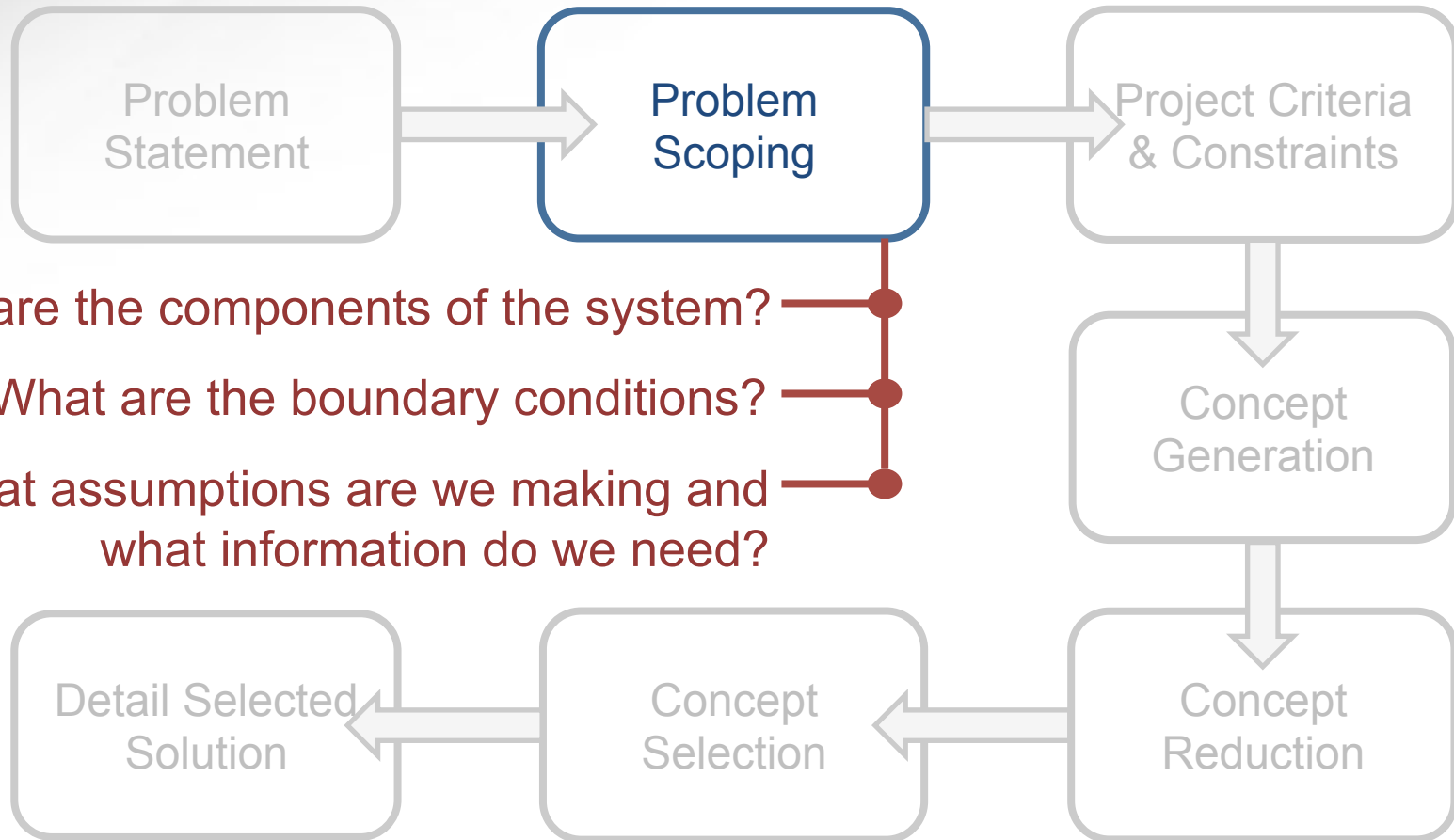
# Design Process



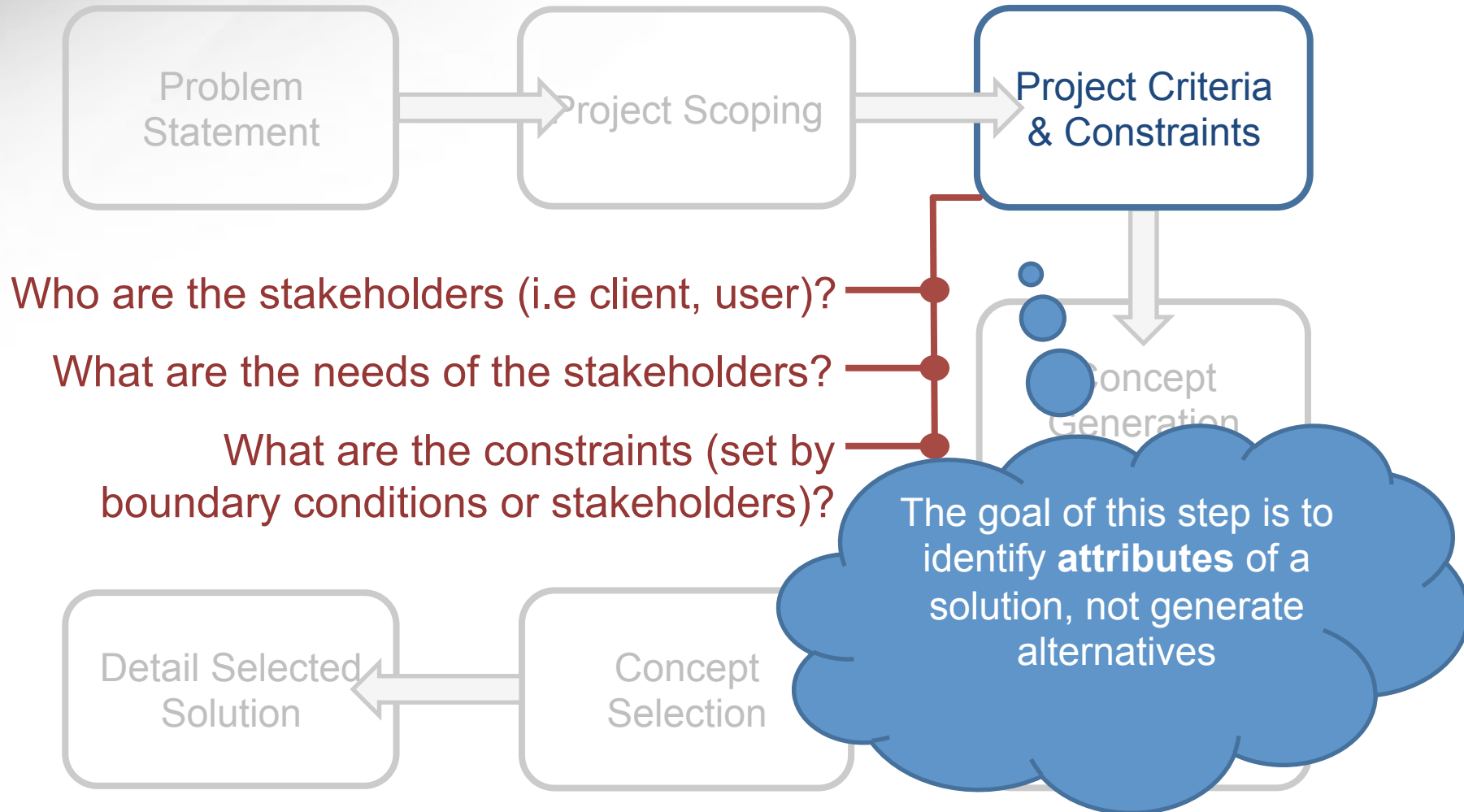
# Problem Statement



# Problem Scoping

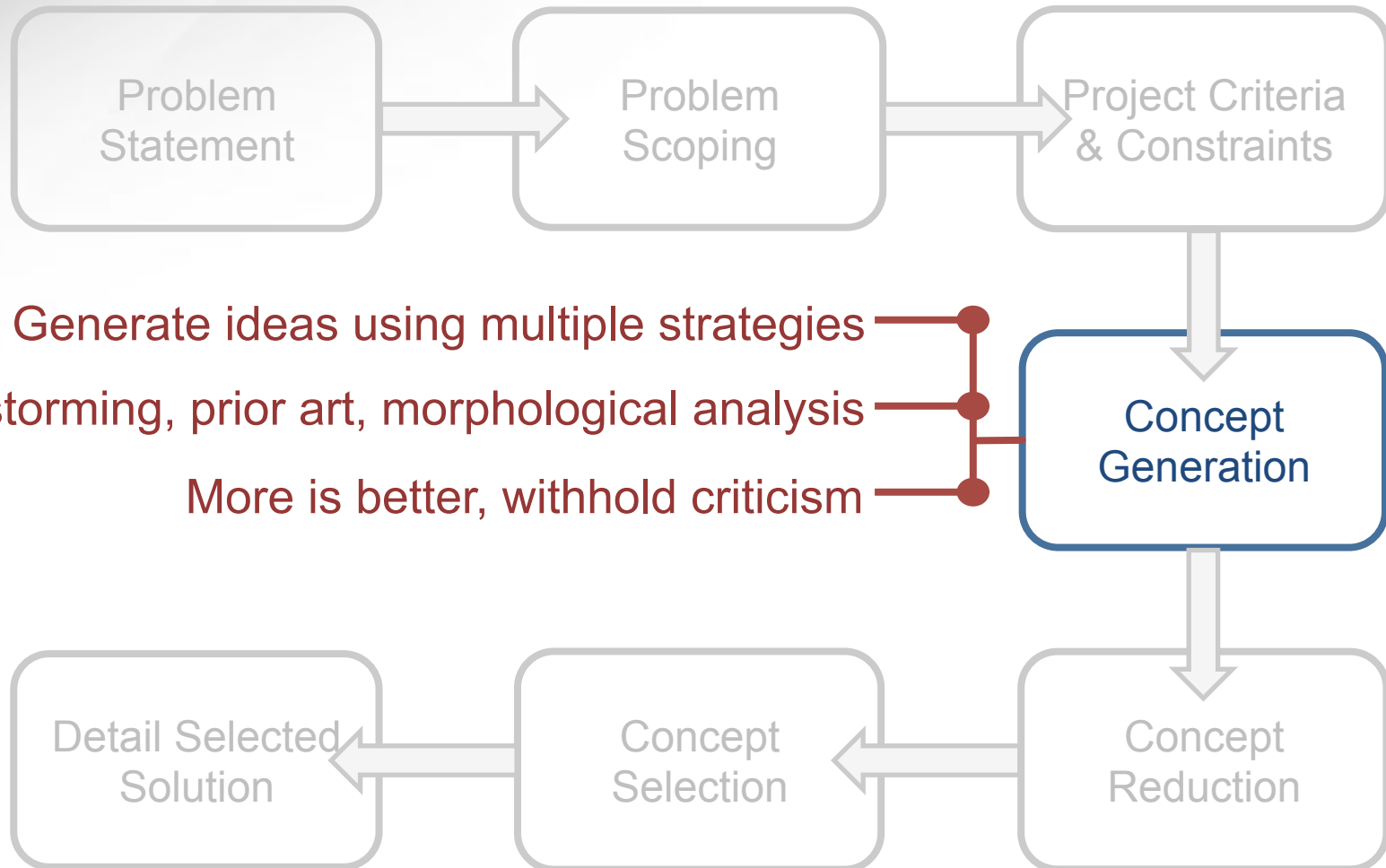


# Project Criteria and Constraints

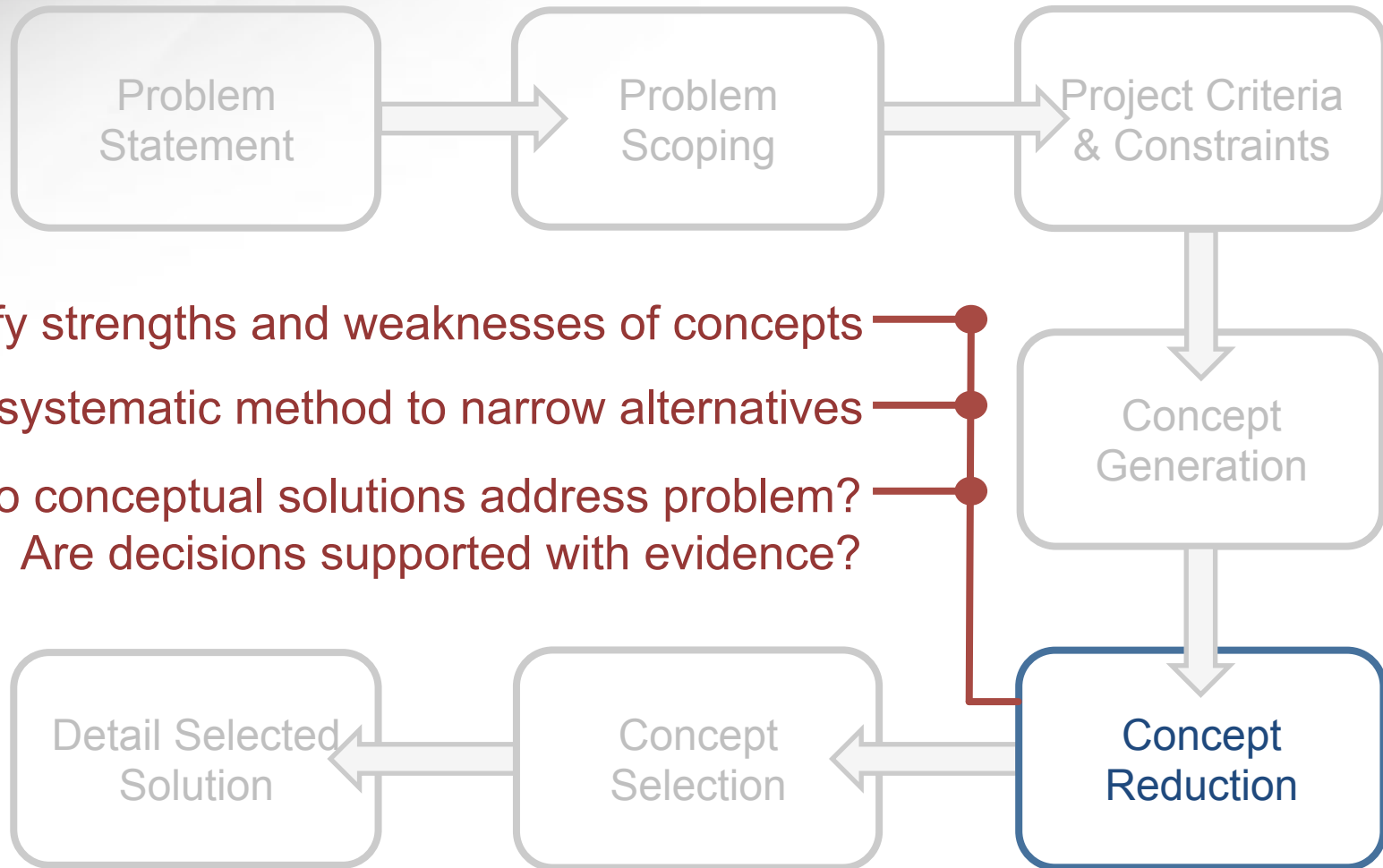




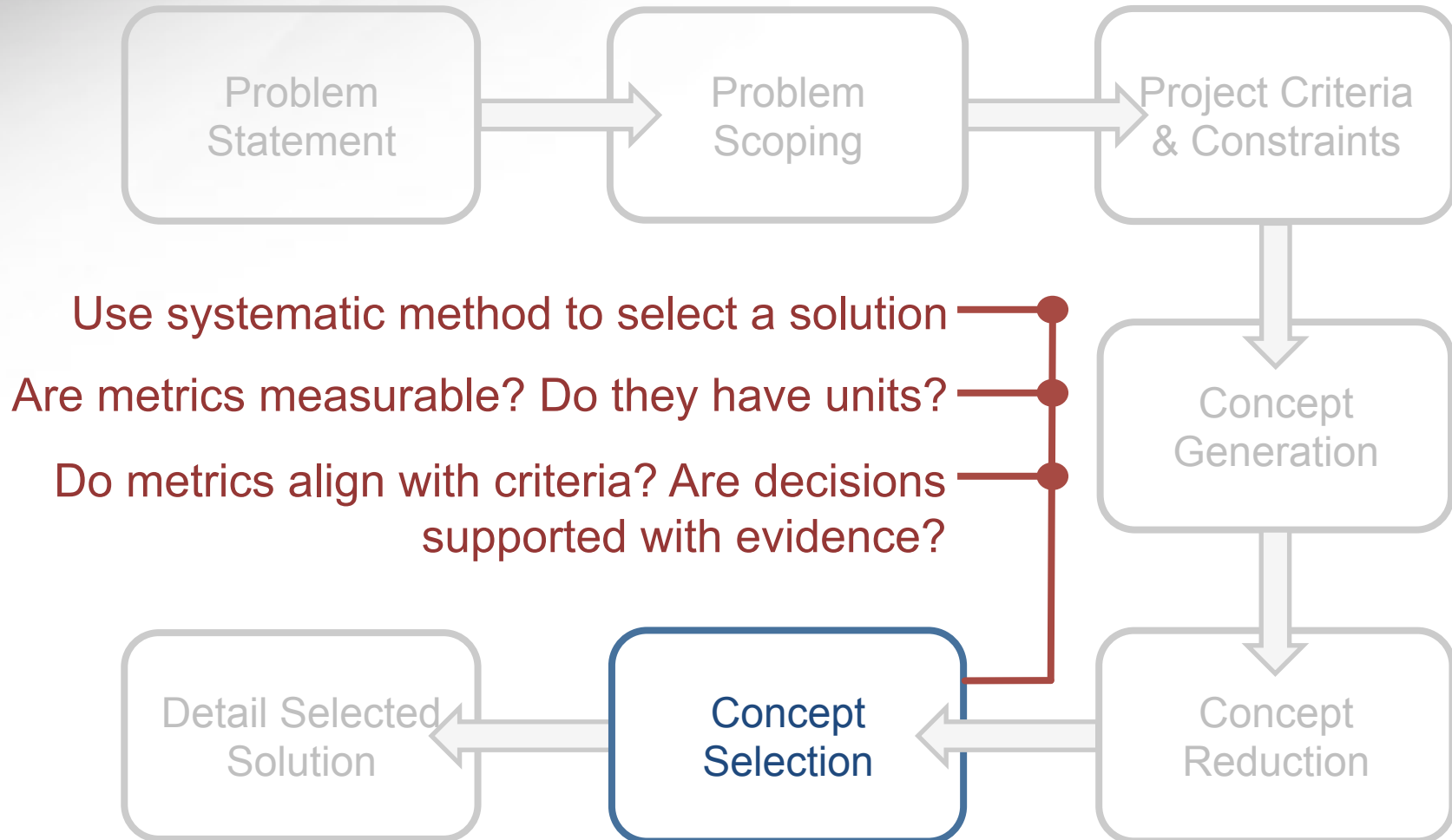
# Concept Generation



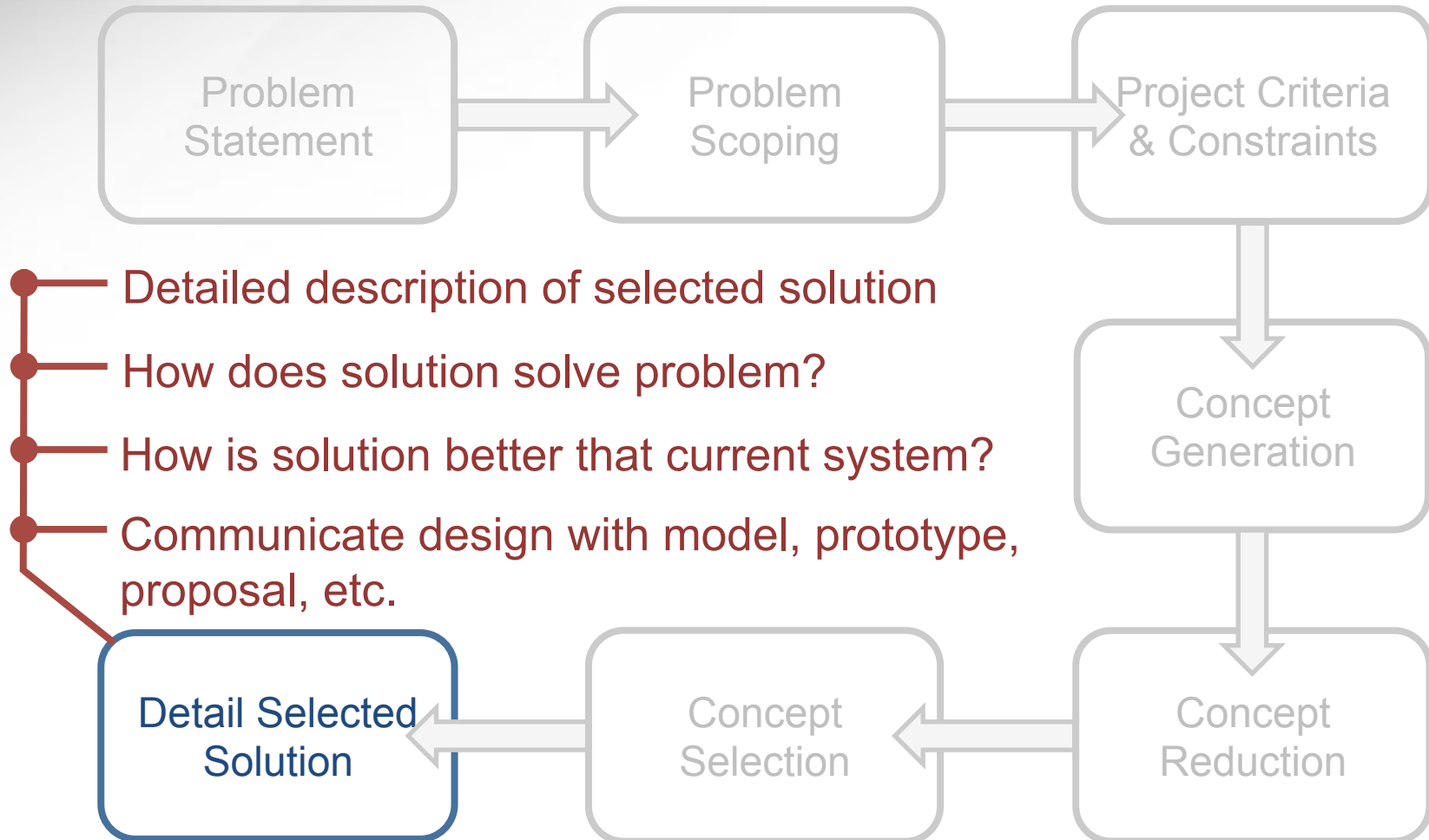
# Concept Reduction



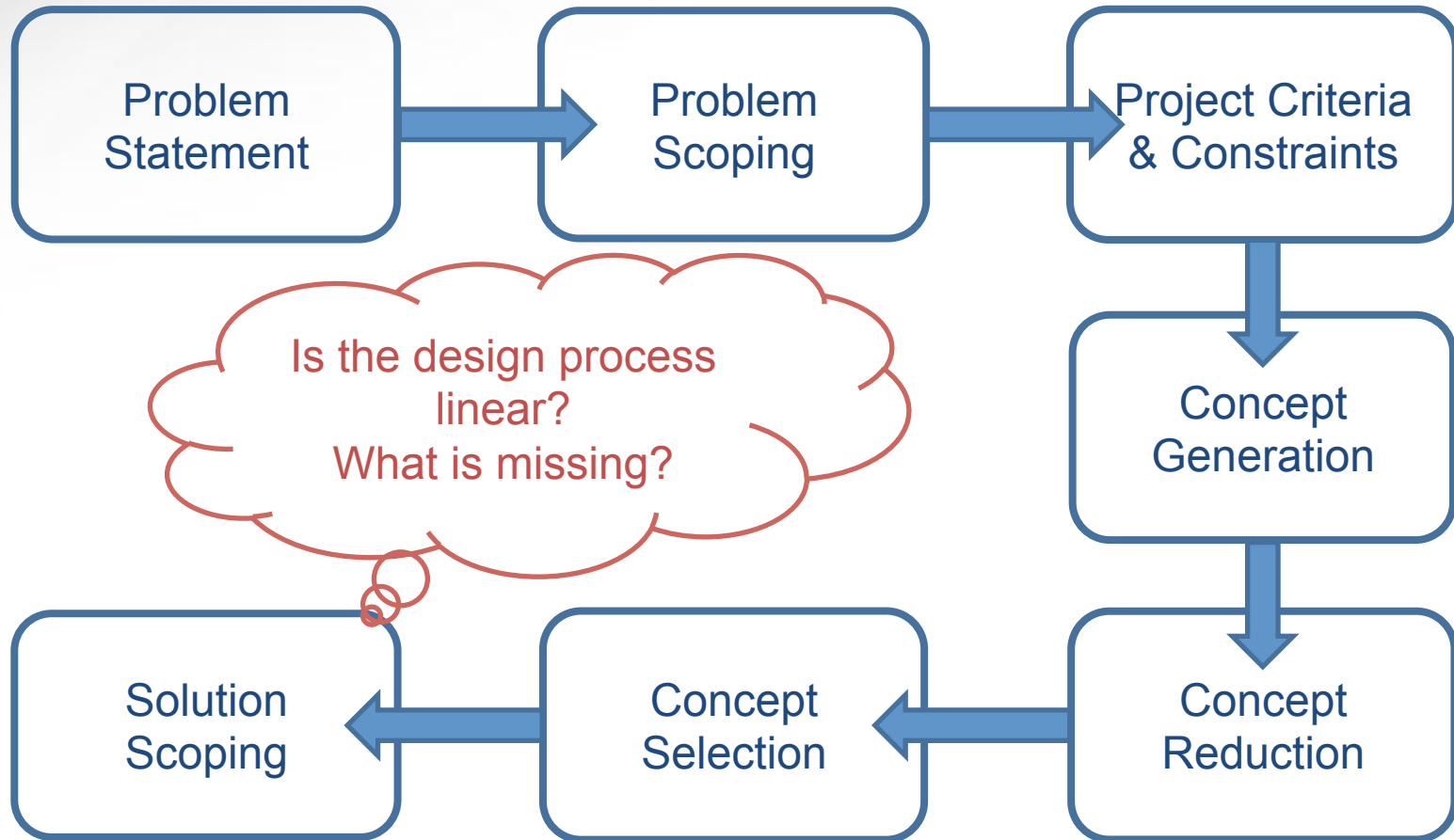
# Concept Selection



# Detailing Selected Solution



# Flow of the Design Process





## Task

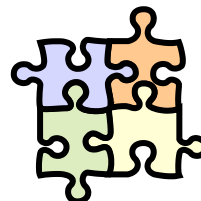
- Your task is to come up with a more energy efficient way of making a cup of coffee.
  - Use science, mathematics, (possibly) engineering concepts that you know
  - Produce a visual to explain your design
  - Make a list of (1) what you know, (2) what you don't know and is important for you to find out and (3) larger questions you might have

(1) Individual Brainstorm  
(5 min)



Individual  
Reflection

(2) Share and develop (10 min)



Team work

(3) Discuss (5 min)



Class  
Discussion



*Dwight Look College of*

**ENGINEERING**  
TEXAS A&M UNIVERSITY

Johannes Strobel, Ph.D.  
[jstrobel@tamu.edu](mailto:jstrobel@tamu.edu)

# Resources

## Images

- <http://www.sustainability-ed.org/pages/look4-1.htm>
- <http://www.rogersfamilyco.com/index.php/u-s-specialty-coffee-consumption-facts/>

## LCA data

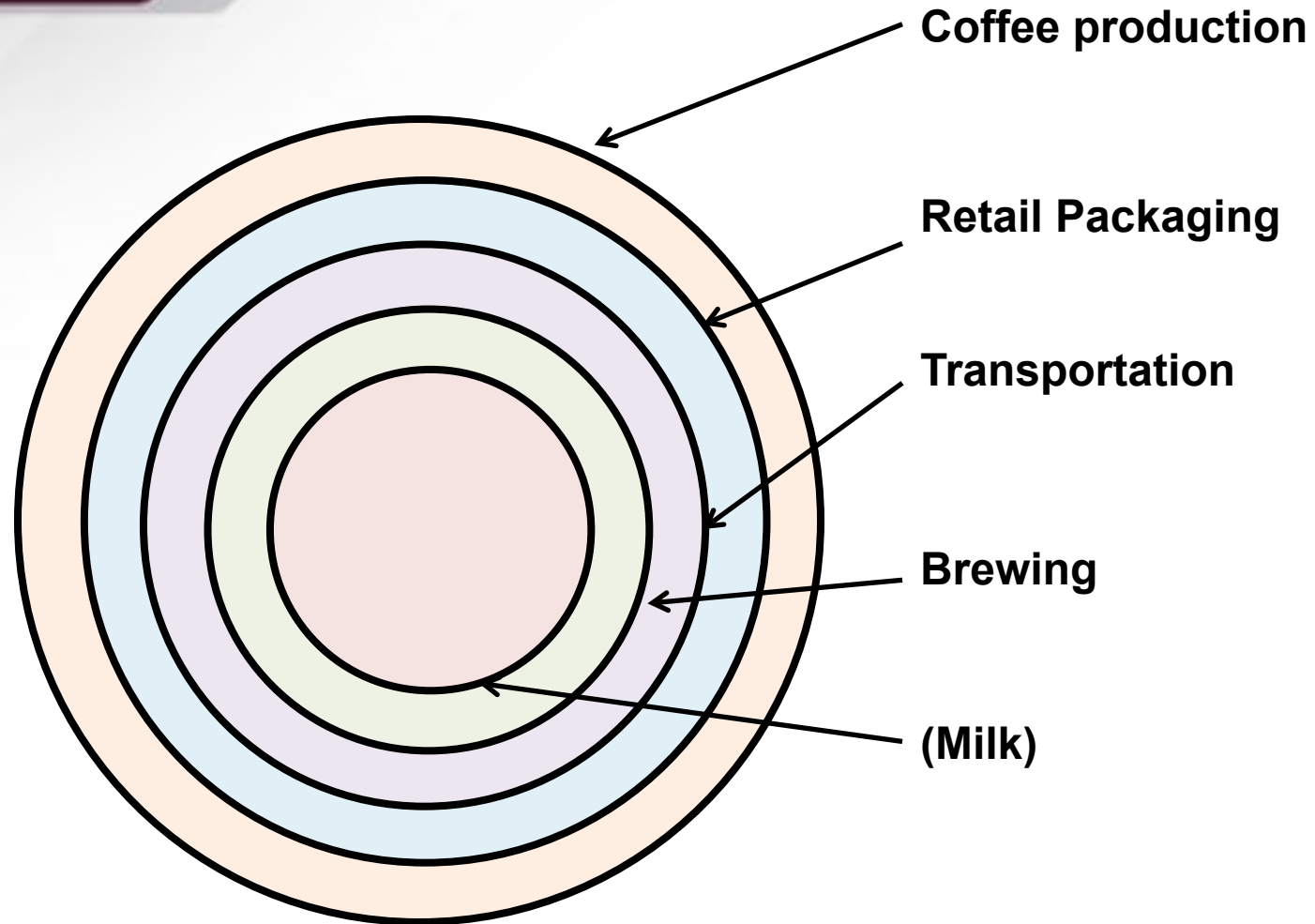
- [http://www.alufoil.org/tl\\_files/sustainability/ESU\\_-\\_Coffee\\_2008\\_-\\_Exec\\_Sum.pdf](http://www.alufoil.org/tl_files/sustainability/ESU_-_Coffee_2008_-_Exec_Sum.pdf)
- <http://bsalinas.com/life-cycle-assessment-of-coffee-production/>

## Cost of making a coffee

- <http://drpennypincher.hubpages.com/hub/How-Much-Does-it-Cost-to-Make-Coffee>

## How long would you have to yell to heat a cup of coffee?

- <http://www.physicscentral.com/explore/poster-coffee.cfm>



# LCA of Packed Food Products

– the function of flexible packaging –  
– Case Study: Coffee –

Sybille Büsser

Roland Steiner

Niels Jungbluth

ESU-services Ltd., Uster, Switzerland

Commissioner

Flexible Packaging Europe (FPE)

Uster, January 2008

Executive Summary

ESU-services Ltd.  
Rolf Frischknecht  
Niels Jungbluth  
Sybille Büsser  
Matthias Tuchschrnid  
[www.esu-services.ch](http://www.esu-services.ch)

Kanzleistrasse 4  
T +41 44 940 61 91  
T +41 44 940 61 32  
T +41 44 940 61 35  
T +41 44 940 67 94  
F +41 44 940 61 94

CH - 8610 Uster  
[frischknecht@esu-services.ch](mailto:frischknecht@esu-services.ch)  
[jungbluth@esu-services.ch](mailto:jungbluth@esu-services.ch)  
[buesser@esu-services.ch](mailto:buesser@esu-services.ch)  
[tuchschrnid@esu-services.ch](mailto:tuchschrnid@esu-services.ch)



Imprint	
Title	<b>LCA of Packed Food Products: the function of flexible packaging</b>
Authors	Sybille Büsser Roland Steiner Niels Jungbluth ESU-services GmbH, fair consulting in sustainability Kanzleistr. 4, CH-8610 Uster www.esu-services.ch Phone +41 44 940 61 35
Customer	Flexible Packaging Europe (FPE) Stefan Glimm Am Bonneshof 5, D - 40474 Düsseldorf enquiries@flexpack-europe.org www.flexpack-europe.org Phone +49 211 4796 150; Fax +49 211 4796 25 168
Steering Group	Gerald Rebitzer (Alcan Packaging Food Europe) John Fairweather (Amcor Flexibles) Jörg Schäfer (Gesamtverband der Aluminiumindustrie) Hans-Jürgen Schmidt (Hydro Aluminium) Jean-Paul Duquet (Novelis)
Copyright	ESU-services Ltd. owns the life cycle inventory data shown in this study.
Liability Statement	Information contained herein have been compiled or arrived from sources believed to be reliable. Nevertheless, the authors or their organizations do not accept liability for any loss or damage arising from the use thereof. Using the given information is strictly your own responsibility.

## Executive Summary - Case Study: Coffee

### “LCA of Packed Food Products: the function of flexible packaging”

*Büsser S., Steiner R. and Jungbluth N. (2008) LCA of Packed Food Products: the function of flexible packaging. ESU-services Ltd. commissioned by Flexible Packaging Europe, Düsseldorf, DE and Uster, CH.*

The evaluation of the environmental performance of packaging usually concentrates on a comparison of packaging materials. Other aspects including sustainable consumption and production of packed goods are often neglected. The same applies to the functional role of flexible packaging, which is the distribution of goods to society to satisfy human needs.

Broader approaches, which focus on the life cycle of packed goods, including the entire supply system and the consumption of goods, are necessary to get an environmental footprint of the food supply system with respect to sustainable production and consumption.

And as the only reason to produce packaging is to enable the consumer to consume products the relevant question from a sustainability point of view can be only to optimize the sustainability along the total supply chain of consumer goods rather than focussing on parts of it.

The three main targets of this study are:

- the investigation of the environmental performance of flexible packaging with respect to its function within the life cycle of goods, i.e. within the supply chain and consumption of goods,
- the investigation of the role of flexible packaging in view of resource efficiency and prevention of spoilage of packed goods, and
- the investigation of the environmental relevance of stages and interdependencies within the life cycle of goods while taking consumers' patterns and portion sizes into consideration.

The study illustrates the environmental relevance of flexible packaging within the supply chain. While the results of this study are not immediately transferable to other packaging systems or types of products this study shows that the environmental impact from the packaging of the investigated sample products is minor in comparison to the impact from the production of the product, its processing and the consumer behaviour in the use of the product. Additionally, depending on the product, packaging can contribute to minimise the environmental impact of production, processing and use by reducing spoilage and overconsumption.

The results of this study are calculated for eight environmental indicators based on the CML 2001 method. The main impact assessment and discussion is based on five indicators which are:

- Cumulative energy demand (CED), non-renewable (MJ eq.)
- Global warming (kg CO<sub>2</sub> eq.)
- Ozone layer depletion (ODP) (kg CFC-11 eq.)
- Acidification (kg SO<sub>2</sub> eq.)
- Eutrophication (kg PO<sub>4</sub><sup>3-</sup> eq.)

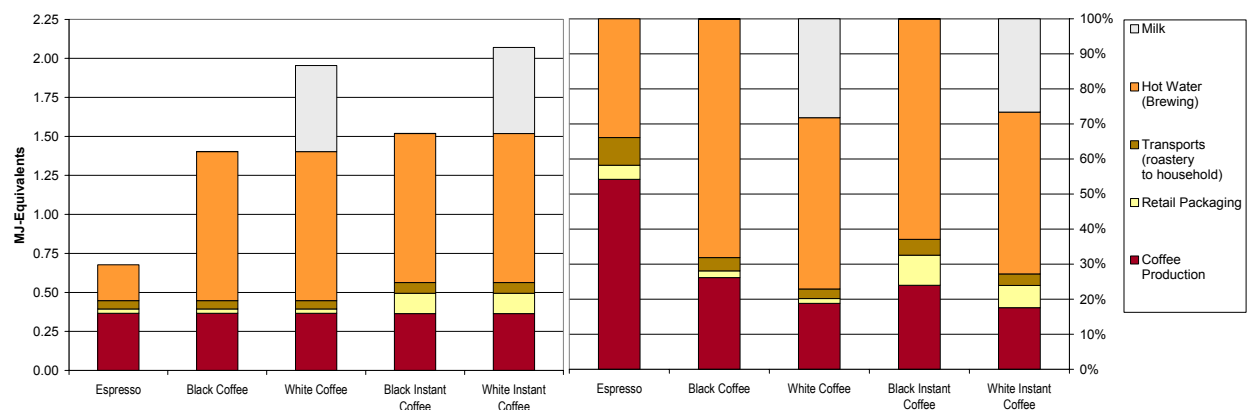
The life cycle inventory for coffee encompasses the whole food supply system from the cultivation, processing, packaging, and transportation of the coffee beans to production and packaging of ground and soluble coffee, transport to retailers and households, and the brewing ending with a cup of coffee ready to drink. The growing as well as the first stages of coffee processing occurs commonly in countries near the equator due to climatic reasons. Most of the coffee, however, is going to be consumed in the industrialised countries (e.g. Europe).

As water vapour and oxygen reduce the quality of coffee its packaging material consists of laminate with a number of layers made of different materials to prevent the diffusion of these substances through the packaging. This study investigates packaging where the barrier layer consists of aluminium foil (typically 6 to 12  $\mu\text{m}$ , in this study 7  $\mu\text{m}$ ).

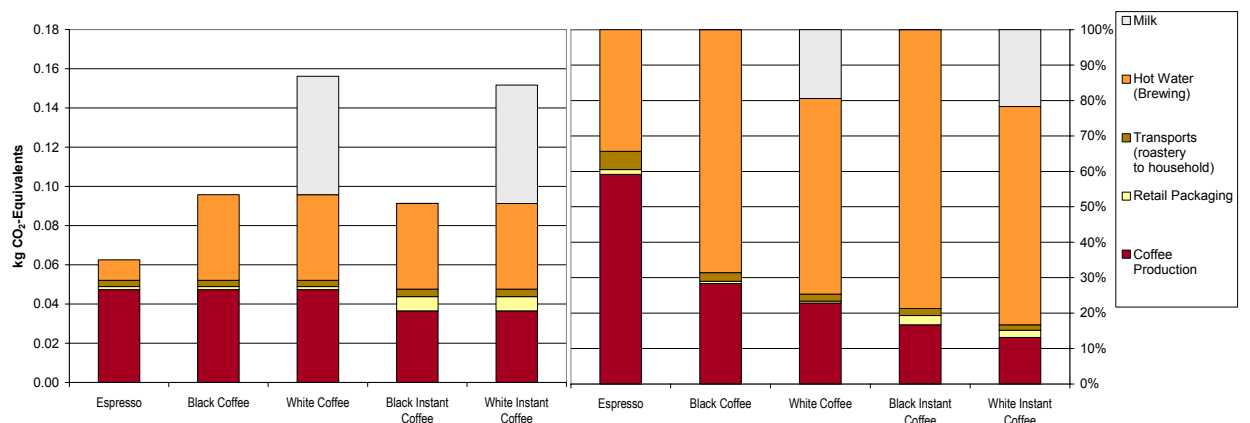
The functional unit for the coffee life cycle is defined as ‘to prepare one cup of coffee ready to drink at home’.

The impact assessment of coffee consumption includes a standard scenario for coffee made from ground or instant coffee with water and eventually milk as well as different spoilage, packaging disposal, and consumer behaviour scenarios.

The standard case assumes: average roasted coffee in a roastery with emission control, brewing the coffee or heating the water by an automatic coffee machine, normal user behaviour concerning coffee machine switch off, and PET/Al/PE bag.



**Figure 1: Results of the standard case for a cup of coffee with regard to the non-renewable cumulative energy demand. Left are shown the absolute values and on the right side the results are scaled to 100 %.**



**Figure 2: Results of the standard case for a cup of coffee with regard to the global warming potential. Left are shown the absolute values and on the right side the results are scaled to 100 %.**

The study shows: the most relevant environmental aspects for a cup of coffee is brewing (i.e. the heating of water) and coffee production compared to transport and retail packaging which are of minor importance. Brewing and coffee production have a considerable impact share between 82 percent (ozone layer depletion, black instant coffee) and 99 percent (eutrophication, black coffee) In the case of white coffee the milk added is of great environmental relevance. The instant coffee in the one-portion stick-pack needs more packaging material per cup of coffee and leads, as a consequence, to higher shares of the retail packaging in all indicators. On the other hand: a one-portion stick-pack can prevent spoilage or over-consumption, and even when in this case hot water is also wasted resources related to coffee production can be saved.

A sensitivity analysis was conducted regarding the following parameters: brewing behaviour, i.e. normal (75% water excess) vs. economical (10%) resp. negligent (150%), brewing device (coffee machine vs. kettle), spoilage (no leftovers vs. 33% spoilage of coffee in case of ground coffee resp. hot water in case of instant coffee), packaging disposal (incineration vs. landfill), grocery shopping (average distances vs. urban resp. countryside scenario), adding up: best case / worst case.

The sensitivity analysis has shown the following results: the influence of packaging disposal is very small due to the general low influence of packaging. In contrast, the brewing behaviour is highly relevant for the environmental impact of a cup of coffee. That applies similarly to the type of heating device – i.e. using a kettle or an automatic coffee machine. Spoilage leads to a significant increase of all indicators. Under the spoilage scenario the coffee from one-portion stick-packs has a better environmental performance concerning all indicators, because in case of instant coffee spoilage of hot water and in case of ground coffee spoilage of prepared coffee has been predicted. Regardless of urban or countryside distances, grocery shopping has low impact.

In the best case scenario a kettle is used to prepare the coffee, the user behaves in an economic way regarding the brewing, the coffee packaging is incinerated resp. recycled (cardboard box) and the urban transport scenario is chosen for bringing the coffee from the supermarket to the household. In the worst-case scenario a coffee machine is used, the user behaves in a negligent way (switch-on time 24 h/d), the coffee packaging is landfilled and the countryside transport scenario is chosen.

Conclusions for the consumption of coffee: the most important factors concerning the environmental impact from the whole supply chain of a cup of coffee are the brewing of coffee, its cultivation and production, and the milk production in case of white coffee. The optimisation potential in the cultivation and production of coffee was not analysed. Against this background, the study highlights consumer behaviour and packaging related measures to reduce the environmental impact of a cup of coffee:

- Economic user behaviour, e.g. switching the machine on only when needed and reducing the stand-by usage.
- Using a kettle instead of an automatic coffee machine contributes to the reduction of electricity consumption, however, convenience and coffee experience aspects may not always allow to substitute a kettle for a coffee machine.
- Reducing leftovers of brewed coffee and hot water by preparing the coffee on a cup per cup basis. This avoids wastage of coffee in its drinking form including all the previously resources needed to produce and allocating the coffee and wastage of hot water.
- Minimising the amount of packaging – the cardboard box for the instant coffee packaging is not to be neglected in view of some indicators.
- Optimising the amount of packaging by choosing adequate packaging sizes.

Concluding remarks: Packaging has an environmental impact, though low, in relation to those along the full life cycle relevant to evaluate the sustainable consumption of drinking coffee. While single serving packaging normally needs more packaging per filling, tailor-made packaging, on the other hand, can reduce spoilage, thus improving overall resource efficiency along the food supply chain. However, com-

pared to the reduction potential of other measures (e.g. economic coffee machine utilisation) packaging is not considered to be of primary importance for this type of product. Consumer's behaviour influences the environmental impacts of coffee consumption much more than the type of common packaging.

## **Summary**

It should be the aim of every type of industry to minimize the environmental impacts directly related to their products. This study shows that in case of packaging industry this goal can only be reached if also aspects indirectly influenced by the product are taken into account. Thus, the packaging industry does not only aim to improve the production process of their packages, but also to provide packages whose functionality helps to reduce other more relevant environmental impacts in the life cycle. Depending on the product tailor-made packaging may also help to increase overall resource efficiency.

# How Much Does it Cost to Make Coffee?

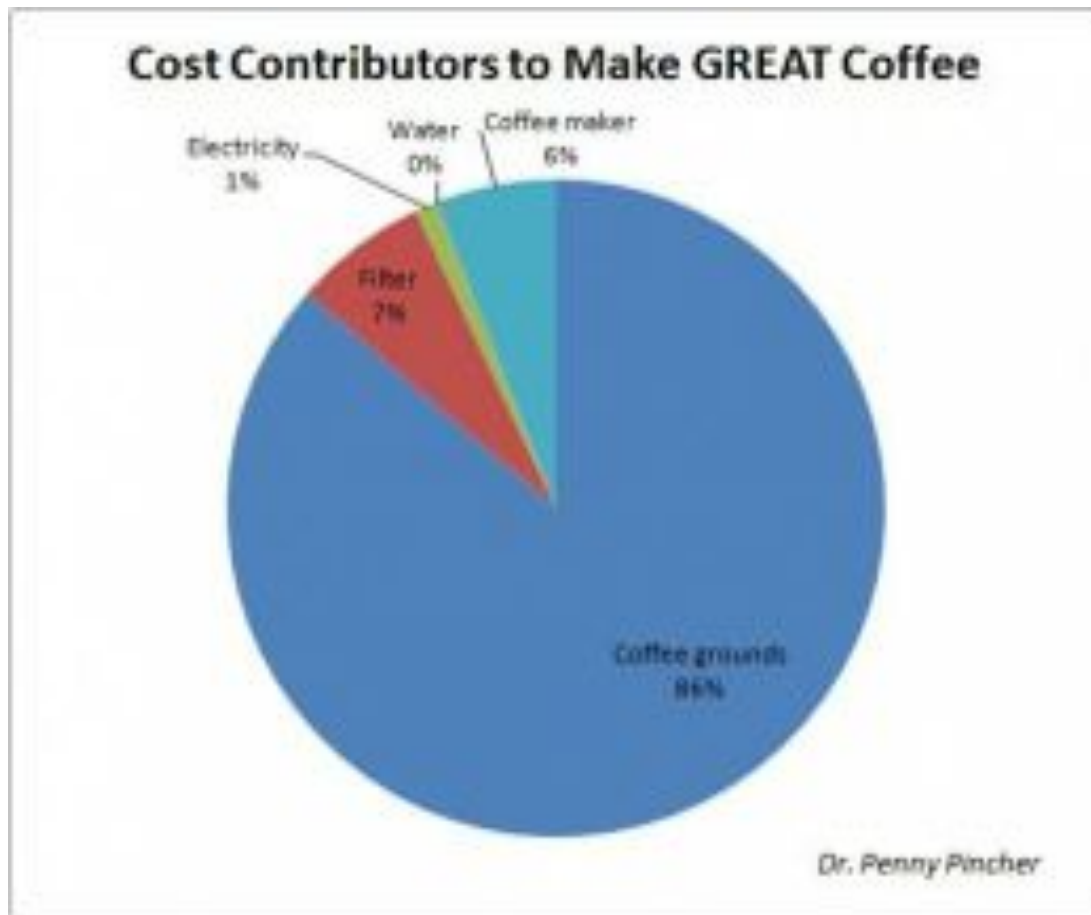
by [drpennypincher](#)  
53 Followers

## How Much Does It Cost To Make Coffee?

When I ask people how much they spend to make coffee, the answer is usually based only on the cost of ground coffee. Take the price of a can of coffee, divide by the number of servings, and that is how much it costs to make coffee- right?

There are some additional factors to consider in accurately determining the cost to make coffee. We will consider electricity, coffee filters, water, and the cost of the coffee maker in addition to the cost of the coffee grounds.

When you consider all of these costs to make coffee, the cost of making 16 oz of coffee can range from about 11 cents to about \$1.80. This is a wide range- let's see why the cost of making a cup of coffee can vary so much.



Cost contributors to make great coffee: coffee grounds, coffee filter, water, electricity, and coffee maker

Source: Dr. Penny Pincher

I am interested in 16oz of coffee since this is how much my excellent [Contigo travel coffee mug](#) holds. A "cup of coffee" is defined as 4 ounces, so 16 ounces of coffee is 4 cups. This is about 1/2 a pot of coffee.



Contigo AUTOSEAL Stainless Steel Vacuum Insulated Tumbler, 16 Ounces, Silver

**Amazon Price:** \$16.99

List Price: \$20.99

Cost to make 16 oz cup of coffee			
	cheap	medium	high
Coffee grounds	\$ 0.08	\$ 0.12	\$ 0.52
Filter	\$ 0.01	\$ 0.02	\$ 0.04
Electricity	\$ 0.01	\$ 0.01	\$ 0.01
Water	\$ 0.00	\$ 0.14	\$ 1.13
Coffee maker	\$ 0.01	\$ 0.04	\$ 0.11
Cost for 16 oz:	\$ 0.11	\$ 0.32	\$ 1.80
		Dr. Penny Pincher	

Cost to make coffee ranges from 11 cents to \$1.80 per 16 oz cup- why can the cost vary so much?

Source: Dr. Penny Pincher

## How Much Electricity Does It Take To Make Coffee?

Making coffee requires heating water from about 50 degrees F to about 200 degrees F for brewing- that takes a lot of energy. How much does the electricity to run a coffee maker cost?

My coffee maker runs at 1025 Watts, maximum. Let's use 1000W as the power required during brewing. I used a stopwatch to time how long it takes to brew 16oz of coffee. The time required was 3 minutes and 52 seconds.

Electricity is billed in kilowatt hours. Typical rates for electricity run at about 10 to 12 cents per kilowatt hour. We'll use 10 cents per kilowatt number since the rate in my area is closer to this, and since it is a nice round number. So how many kilowatt hours is used to brew coffee at 1000W for 3.87 minutes?

The coffee maker is using 1000W which is equivalent to 1kW. The brewing time of 3.87 minutes is 0.0645 hours. So the electricity used to brew 16oz of coffee is 0.0645 kilowatt hours. At 10 cents per kilowatt hour, this is 0.645 cents for electricity.

Coffee makers may vary in the heating capacity and time to brew, but 0.645 cents is a typical electricity cost for most auto drip coffee makers to brew 16 oz of coffee.

## How Much Does a Coffee Filter Cost?

The main types of coffee filters are basket filters and cone filters. Basket filters are the cheapest and cost about 1 cent each for generic and 1.5 cents each for name

brand. Name brand cone filters are a bit more expensive at about 4 cents per coffee filter. I prefer [cone filters over basket filters](#) since the shape helps extract maximum flavor from the coffee grounds, but cone filters do cost a bit more.

Of course, you may be able to purchase in large quantities and get a better deal- these are typical prices.

## **How Much Does Water To Make Coffee Cost?**

There is a wide range in the cost of water used to make coffee. In most places, tap water costs about 2 cents per 1000 gallons. If you use filtered water, this costs about \$1 per gallon if you buy it in a store and somewhat less if you filter it yourself. If you use bottled water at \$1 per 16oz bottle, the water cost is \$8 per gallon!

Why would anyone use bottled water to make coffee? I did this for a short time when I had a problem with my well water and it was not safe to drink. All I had available was bottled water and I really wanted to make coffee. That was some expensive coffee!

## **What is the Cost of a Coffee Maker to Make Coffee?**

The cost of your coffee maker also contributes to your cost to make coffee. Let's assume that your coffee maker will have a life of 5 years and that you brew 16oz once per day. Over this lifetime, a \$20 coffee maker costs about 1 cent per 16oz, a \$65 coffee maker costs about 3.5 cents per 16oz of coffee, and a \$200 coffee maker costs about 11 cents per 16oz of coffee made.

You can see that an expensive coffee maker is a significant contributor to the cost of making a cup of coffee.

## **How Much Do Coffee Grounds Cost to Make Coffee?**

Coffee grounds are by far the biggest contributor to the cost of making coffee, representing about 75% to 86% of the cost of making coffee. Inexpensive generic coffee grounds cost about 8 cents per 16 oz of coffee. Folgers or equivalent coffee grounds cost about 12 cents per 16 oz of coffee. Starbucks or other premium coffee grounds cost about 52 cents per 16 oz of coffee.

The directions for making coffee on a bag of Starbucks coffee grounds call for 2 tablespoons of ground coffee per 6 oz of cold water. I calculated the cost of coffee grounds based on using 18 oz of cold water. The Folgers and generic coffee grounds container indicates to use 1 tablespoon of coffee grounds per 6 oz of water. I used these directions to calculate the cost- it takes twice as much coffee grounds to make Starbucks or coffee shop style coffee.

## **How Much Does it Cost to Make Great Coffee?**

In the table above for the "high" cost column, bottled water is used which greatly increases the cost of making coffee. The coffee that I make every day uses filtered water rather than bottled water which is much less expensive. I use the water filter



in my refrigerator.

Also, the coffee maker I use is a [Melitta with thermal carafe- a \\$65 coffee maker](#) rather than a \$200 coffee maker, which further reduces the cost. The table below shows my cost to make 16oz of great coffee. I use fresh ground coffee from whole beans, and my Melitta uses a cone filter to extract maximum flavor.



[Melitta 46894 10-Cup Thermal Coffeemaker with Standard Packaging](#)

**Amazon Price:** \$56.99

List Price: \$99.00

Great 16 oz Coffee Cost		
Coffee grounds	\$	0.52
Filter	\$	0.04
Electricity	\$	0.01
Water	\$	0.00
Coffee maker	\$	0.04
Cost for 16 oz:	\$	0.60
Dr. Penny Pincher		

Cost to make great coffee is about 60 cents for 16 ounces

Source: Dr. Penny Pincher

As you can see, the cost of the coffee grounds is the largest contributor to the cost of great coffee, about 68% of the total cost.

## How Much Does it Cost to Make Cheap Coffee?

You can make coffee for much less than 26 cents for 16 ounces:

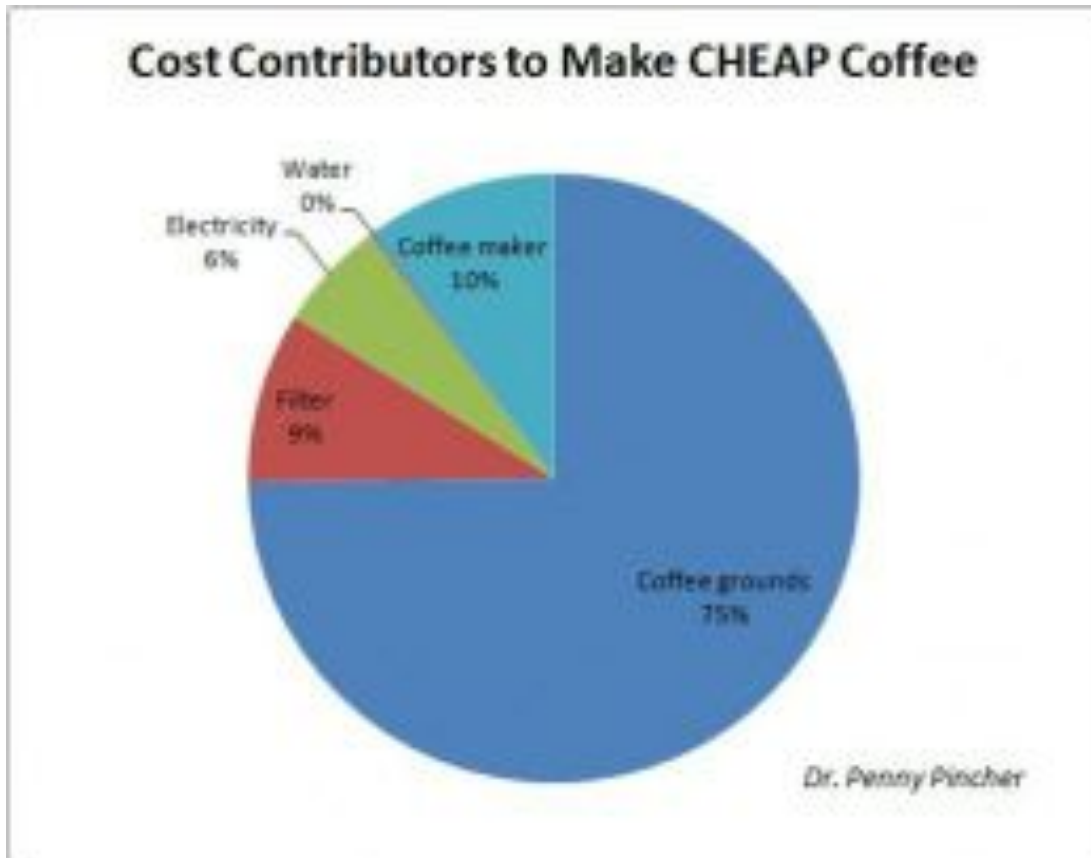
- You can use a less expensive coffee maker, \$20 instead of \$65.
- You can use less expensive basket filters instead of cone filters.
- The biggest savings- use less expensive coffee grounds and make weaker coffee using 1 tbsp per 6 oz of coffee instead of 2 tbsp per 6 oz of coffee.
- Spend less on water by using tap water instead of filtered water.

If you do all of these things, you can make some really cheap coffee at about 5.5 cents per 16 ounces.

Cheap coffee uses lower cost ingredients. The cost of the coffee grounds contributes about 50% of the cost of making cheap coffee.

Cheap 16 oz Coffee Cost		
Coffee grounds	\$	0.08
Filter	\$	0.01
Electricity	\$	0.01
Water	\$	0.00
Coffee maker	\$	0.01
Cost for 16 oz:	\$	0.11
Dr. Penny Pincher		

Cheap coffee can be made for about 11 cents per 16 oz serving  
Source: Dr. Penny Pincher



Cost contributors for making really cheap coffee for 11 cents per 16 ounces  
Source: Dr. Penny Pincher

## Even Great Coffee is a Great Deal!

As you can see, the difference between making cheap coffee and making great coffee is 11 cents per 16 ounces vs 60 cents per 16 ounces. Even paying 60 cents to make a great cup of coffee seems like a bargain. A cup of coffee like this at a coffee shop costs about \$2 or more.

If you want the convenience of using a single serve coffee maker such as a Keurig, the [cost of the coffee pod is typically between 45 to 65 cents](#) just for the coffee pod, which increases the cost quite a bit. Also, each coffee pod brews only 4 to 10 ounces of coffee, not a full 16 ounces. You would need 2 K-cups to brew 16 ounces of coffee.

Brewing fresh coffee with an auto drip coffee maker at home is a bargain even if

you make the good stuff.

## **Recommended Reading**

[Why is cake so expensive when cake mix is so cheap?](#)

© 2013 Dr. Penny Pincher Last updated on August 30, 2013

# The role of flexible packaging in the life cycle of coffee and butter



## Introduction

The evaluation of packaging's environmental performance usually concentrates on a comparison of different packaging materials or designs [1, 2]. Another important aspect in LCA studies on packaging is the recycling or treatment of packaging wastes [3]. LCA studies of packed food include the packaging with specific focus on the contribution of the packaging to the total results [4]. The consumption behaviour is often assessed only roughly. Packaging is facilitating the distribution of goods to the society.

A full life cycle assessment study has been conducted for two food products [5, 6]:

- Ground and instant coffee in pouches and stick-packs made of plastic laminate with an aluminium foil layer as a barrier.
- A family and single portion pack of butter wrapped in a laminate with an aluminium foil layer.

The study looks at the environmental relevance of stages and interdependencies – especially packaging – within the life cycle of goods while taking consumers' behaviour and portion sizes into consideration. This study was commissioned by Flexible Packaging Europe.

## Life Cycle Inventory

Investigated were different kinds of coffee preparation within espresso made from ground coffee and white coffee made from instant coffee. A sensitivity analyses was conducted regarding packaging disposal, brewing behaviour, brewing device, wastage and different grocery shopping scenarios.

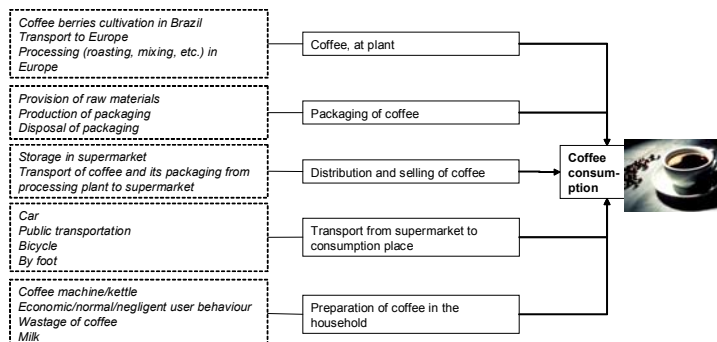


Fig. 1 Scheme of the included processes in the life cycle of coffee.

The inventory of butter production is calculated based on an environmental report of a dairy producing different milk products and an economic allocation. To produce 1 kilogramme of butter an average of 22.5 litres milk is used [7].

## Impact Assessment

Fig. 2 shows the results of the standard case for a cup of coffee with regard to the non-renewable cumulative energy demand. The large differences between different options can mainly be explained by different amounts of water and milk used for the preparation and the brewing device (coffee machine vs. kettle). The instant coffee in the one-portion stick-pack is prepared by a kettle with lower energy

demand as a coffee machine but needs more packaging material per cup of coffee, thus leads to higher shares of the retail packaging in all indicators.

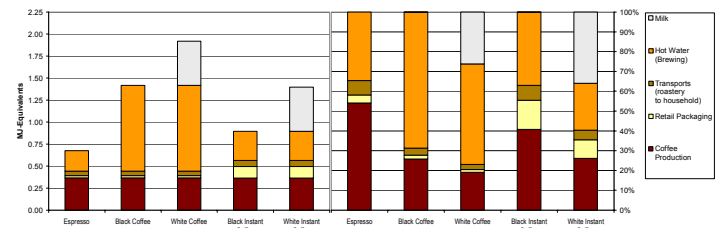


Fig. 2 Results of the standard case for a cup of coffee with regard to the non-renewable cumulative energy demand.

Regarding the life cycle of butter consumption, provision of milk is the main important issue. The distribution and selling stage influences the indicators CED and ODP distinctly. Domestic storage is important in the indicator CED. Other life cycle stages are not of primary importance.

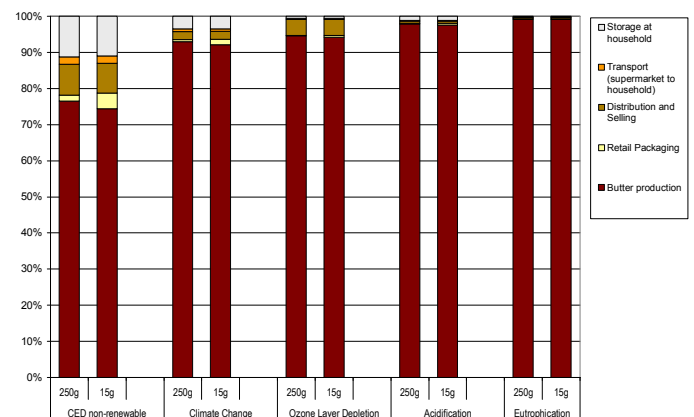


Fig. 3 Results of the standard case for one kilogramme butter with regard to the selected five indicators. The results are scaled to 100 %.

## Conclusions

It should be the aim of every type of industry to minimize the environmental impacts directly related to their products. This study shows that in case of packaging industry this goal can only be reached if also aspects indirectly influenced by the product are taken into account. Thus, the packaging industry should not only aim to improve its production processes and minimize material use, but also to provide packages whose functionality helps to reduce other more relevant environmental impacts in the life cycle as e.g. losses. Depending on the product, tailor-made packaging may help to increase overall resource efficiency. This applies to coffee served in single serving stick. It was not possible to determine if small packaging for butter does avoid wastage or has any other clear environmental advantage or disadvantage.

## References

- 1 De Monte M, Padoano E, Pozzetto D (2005): Alternative Coffee Packaging: an Analysis from a Life Cycle Point of View. Journal of Food Engineering 66, 405-411
- 2 Plinke E, Schonert M, Meckel H, Detzel A, Giegrich J, Fehrenbach H, Ostermayer A, Schorb A, Heinisch J, Luxenhofer K, Schmitz S (2000): Ökobilanz für Getränkeverpackungen II. 37/00, Umweltbundesamt, Berlin, retrieved from: [www.umweltbundesamt.de/luba-info-daten/daten/bil.htm](http://www.umweltbundesamt.de/luba-info-daten/daten/bil.htm)
- 3 Heyde M, Kremer M (1999): Recycling and recovery of plastics from packagings in domestic wastes. LCA Documents, 5. Eco-Informa Press, Bayreuth
- 4 Jungbluth N, Tietje O, Scholz R (2000): Food Purchases: Impacts from the Consumers' Point of View Investigated with a Modular LCA. Int J LCA 5, 134-142, retrieved from: [www.esu-services.ch](http://www.esu-services.ch)
- 5 Büsser S. and Jungbluth N. (2008c) LCA of food products and the role of flexible aluminium packaging. In: *Int. J. LCA*, submitted, pp.
- 6 Büsser S, Steiner R, Jungbluth N (2008): LCA of Packed Food Products: the function of flexible packaging: coffee, spinach and butter, ESU-services Ltd. im Auftrag von Flexible Packaging Europe, Düsseldorf, DE and Uster, CH, retrieved from: [http://www.flexpack-europe.org/front\\_content.php?idcat=170](http://www.flexpack-europe.org/front_content.php?idcat=170)
- 7 Schweizer Milchproduzenten (2007): Butter, retrieved from: <http://www.swissmilk.ch/>

# The Environmental Impact of Coffee

Ben Salinas

## Abstract

A Life Cycle Assessment (LCA) was performed of coffee production and consumption. The analysis of these results, generated using the Eco-Indicator 99 LCA tool, showed that the majority of the impact in production of coffee occurred during transportation. When compared to the impact due to other coffee processes such as roasting and brewing coffee as espresso, it was determined that the farming of coffee is a small percentage of the overall impact.

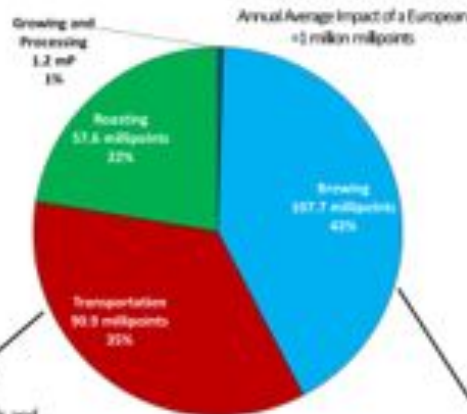
Finca Vista Hermosa is a sustainability minded coffee farm in Guatemala.



### By The Numbers

- Annual Production: ~40,000 kg
- 17,800 trees
- Coffee Tree Age: 30-55 years
- Pesticides/Fungicide Usage: None
- Fertilizer: Offset 30% by reusing coffee cherry waste

## Overall Environmental Impact



Materials and Manufacturing  
2.2 mPt (0%)

105.5 mPt (98%)

## System Map



## The Journey of a Coffee Bean



## Key Findings: Transport

- Air shipping coffee across the United States triples the overall environmental impact.
- Ground transportation should be minimized as transport via boat is 3-15 times more efficient.

## Electricity



## Key Findings: Brewing

- Commercial espresso machines are poorly designed. At least 50% of the daily power use is due to heat loss.
- Most commercial espresso machines are left on 24 hours per day.
- Over its 10 year life, an espresso machine will cost \$15,000 in electricity—as much as the machine itself.

## Conclusion

More than 95% of the environmental impact of coffee occurs in the country of consumption, where 98% of the economic value of coffee is realized.

More information available on request:  
ben.salinas@gmail.com





## HOW COFFEE AFFECTS THE GLOBAL ECONOMY

WHILE WE MAY NOT NEED COFFEE FOR SURVIVAL, THIS POPULAR PICK-ME-UP FUELS NOT ONLY OUR DAILY ENERGY LEVELS, BUT THE GLOBAL ECONOMY AS WELL.

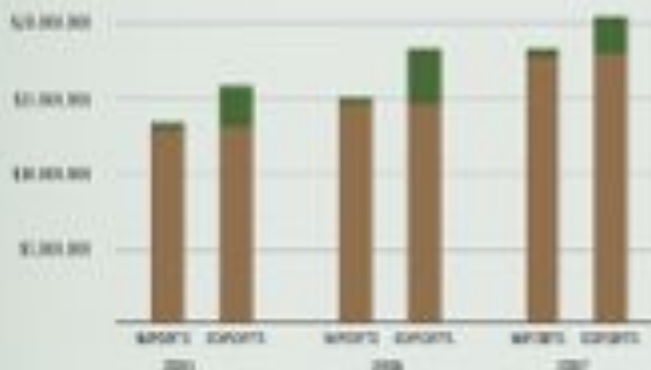


### THE COFFEE INDUSTRY: REACHING HIGHER GROUNDS

Globally, the sale of coffee makes up a  
**\$42.5 BILLION** market.



Worldwide, **25 MILLION**  
small producers rely on coffee for a living.



### GLOBAL VALUE OF IMPORTED & EXPORTED COFFEE

WORLDWIDE USA

Though volume of coffee production has remained fairly constant over the last decade, the value has increased steadily over the past few years.



### COFFEE PRODUCTION AROUND THE WORLD:

**33 PERCENT** of the world's coffee beans  
were produced in **BRAZIL** in 2009.



As estimated  
**49 COUNTRIES**  
around the world grow coffee.





# The role of flexible packaging in the life cycle of coffee and butter



## Introduction

The evaluation of packaging's environmental performance usually concentrates on a comparison of different packaging materials or designs [1, 2]. Another important aspect in LCA studies on packaging is the recycling or treatment of packaging wastes [3]. LCA studies of packed food include the packaging with specific focus on the contribution of the packaging to the total results [4]. The consumption behaviour is often assessed only roughly. Packaging is facilitating the distribution of goods to the society.

A full life cycle assessment study has been conducted for two food products [5, 6]:

- Ground and instant coffee in pouches and stick-packs made of plastic laminate with an aluminium foil layer as a barrier.
- A family and single portion pack of butter wrapped in a laminate with an aluminium foil layer.

The study looks at the environmental relevance of stages and interdependencies – especially packaging – within the life cycle of goods while taking consumers' behaviour and portion sizes into consideration. This study was commissioned by Flexible Packaging Europe.

## Life Cycle Inventory

Investigated were different kinds of coffee preparation within espresso made from ground coffee and white coffee made from instant coffee. A sensitivity analyses was conducted regarding packaging disposal, brewing behaviour, brewing device, wastage and different grocery shopping scenarios.

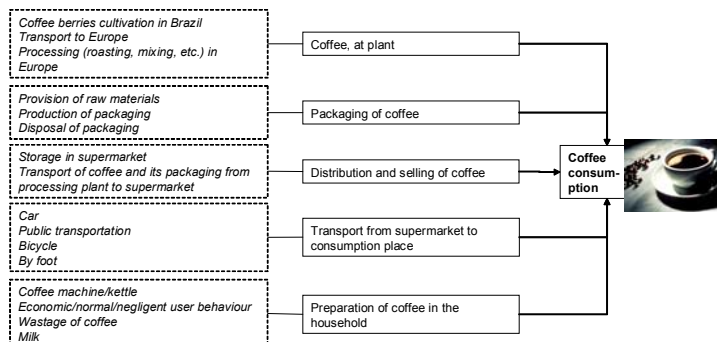


Fig. 1 Scheme of the included processes in the life cycle of coffee.

The inventory of butter production is calculated based on an environmental report of a dairy producing different milk products and an economic allocation. To produce 1 kilogramme of butter an average of 22.5 litres milk is used [7].

## Impact Assessment

Fig. 2 shows the results of the standard case for a cup of coffee with regard to the non-renewable cumulative energy demand. The large differences between different options can mainly be explained by different amounts of water and milk used for the preparation and the brewing device (coffee machine vs. kettle). The instant coffee in the one-portion stick-pack is prepared by a kettle with lower energy

demand as a coffee machine but needs more packaging material per cup of coffee, thus leads to higher shares of the retail packaging in all indicators.

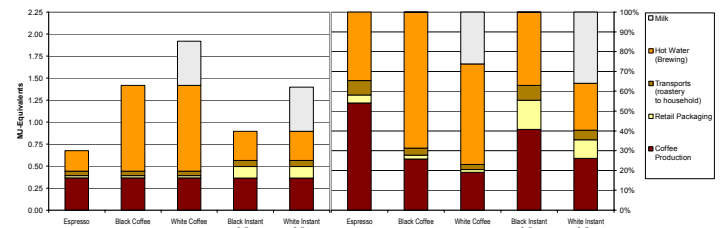


Fig. 2 Results of the standard case for a cup of coffee with regard to the non-renewable cumulative energy demand.

Regarding the life cycle of butter consumption, provision of milk is the main important issue. The distribution and selling stage influences the indicators CED and ODP distinctly. Domestic storage is important in the indicator CED. Other life cycle stages are not of primary importance.

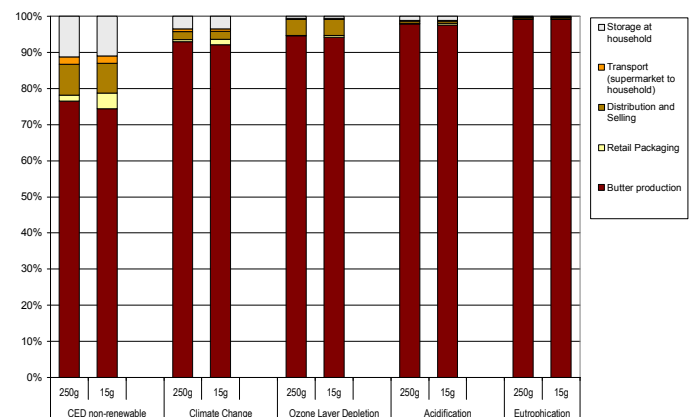


Fig. 3 Results of the standard case for one kilogramme butter with regard to the selected five indicators. The results are scaled to 100 %.

## Conclusions

It should be the aim of every type of industry to minimize the environmental impacts directly related to their products. This study shows that in case of packaging industry this goal can only be reached if also aspects indirectly influenced by the product are taken into account. Thus, the packaging industry should not only aim to improve its production processes and minimize material use, but also to provide packages whose functionality helps to reduce other more relevant environmental impacts in the life cycle as e.g. losses. Depending on the product, tailor-made packaging may help to increase overall resource efficiency. This applies to coffee served in single serving stick. It was not possible to determine if small packaging for butter does avoid wastage or has any other clear environmental advantage or disadvantage.

## References

- 1 De Monte M, Padoano E, Pozzetto D (2005): Alternative Coffee Packaging: an Analysis from a Life Cycle Point of View. Journal of Food Engineering 66, 405-411
- 2 Plinke E, Schonert M, Meckel H, Detzel A, Giegrich J, Fehrenbach H, Ostermayer A, Schorb A, Heinisch J, Luxenhofer K, Schmitz S (2000): Ökobilanz für Getränkeverpackungen II. 37/00, Umweltbundesamt, Berlin, retrieved from: [www.umweltbundesamt.de/luba-info-daten/daten/bil.htm](http://www.umweltbundesamt.de/luba-info-daten/daten/bil.htm)
- 3 Heyde M, Kremer M (1999): Recycling and recovery of plastics from packagings in domestic wastes. LCA Documents, 5. Eco-Informa Press, Bayreuth
- 4 Jungbluth N, Tietje O, Scholz R (2000): Food Purchases: Impacts from the Consumers' Point of View Investigated with a Modular LCA. Int J LCA 5, 134-142, retrieved from: [www.esu-services.ch](http://www.esu-services.ch)
- 5 Büsser S. and Jungbluth N. (2008c) LCA of food products and the role of flexible aluminium packaging. In: *Int. J. LCA*, submitted, pp.
- 6 Büsser S, Steiner R, Jungbluth N (2008): LCA of Packed Food Products: the function of flexible packaging: coffee, spinach and butter, ESU-services Ltd. im Auftrag von Flexible Packaging Europe, Düsseldorf, DE and Uster, CH, retrieved from: [http://www.flexpack-europe.org/front\\_content.php?idcat=170](http://www.flexpack-europe.org/front_content.php?idcat=170)
- 7 Schweizer Milchproduzenten (2007): Butter, retrieved from: <http://www.swissmilk.ch/>

---

# Life Cycle Analysis and Green Design: A Context for Teaching Design, Environment, and Ethics

---

INDIRA NAIR

Department of Engineering and Public Policy  
Carnegie Mellon University

## ABSTRACT

An exercise based on the concepts of green design and life cycle analysis is described. The details of the exercise and references are given to enable its use in classes. The problem provides a useful context in which to teach and discuss design, social relevance, and ethics, as well as to develop group and communication skills.

## I. INTRODUCTION

This paper describes a class exercise that has been used in several diverse courses with success. It involves students in active, project-based learning, fosters their creativity, and enables their learning in context. The exercise lends itself to developing and exercising all levels in Bloom's *Taxonomy of Learning - Knowledge, Comprehension, Application, Analysis, Synthesis, and Evaluator*, and provides a natural learning environment to practice constructivist, or conceptual change based on teaching and learning.<sup>1-3</sup> Some background on the topic, references, and the details of the exercise are described to facilitate the use of this problem in engineering and other courses.

### A. Green Design

Green Design, or design for the environment, is defined as "design that attempts to minimize environmental burdens without compromising functionality."<sup>4</sup> It is a paradigm that has been gaining attention as a way of increasing environmental friendliness of products and processes by introducing considerations about the environment in the design phase. Green design has emerged as a result of a general philosophic shift from waste management to pollution prevention.<sup>4-6</sup> The framework for green design is a systems approach to product design, manufacture, use and disposal. In this framework, environmental considerations such as resource conservation and waste minimization are used at all phases—production, use and disposal—of the product and process life cycle to guide, inform, constrain and select design alternatives.

## II. LIFE CYCLE ANALYSIS

Life cycle assessment (LCA) may be used as a part of design to guide green design. Life cycle analysis has been defined as "an objective process to evaluate the environmental burdens associated with a product, process, or activity by identifying and quantifying

energy and material usage and environmental releases, to assess the impact of those energy and material uses and releases on the environment, and to evaluate and implement opportunities to effect environmental improvement."<sup>7</sup> A simplified life cycle diagram is shown in figure 1.

Historically, the first Life Cycle Analyses were the energy analyses that were popular in the 1960's, which had a resurgence in the early 1970's during the oil shortage energy crisis.<sup>8</sup> With the emergence of a pollution prevention philosophy in Europe and the U.S., life cycle analysis has gained wide attention in the last decade. In 1990, the U.S. Congress Office of Technology Assessment published *Green Products by Design*, emphasizing the importance of the LCA in guiding design, and the need for coherence in regulations to facilitate such an approach. In 1991, the Society of Environmental Toxicology and Chemistry (SETAC) published guidelines for a LCA, based on several workshops which explored the status of the field, and reached consensus on methods for LCA. The SETAC schemes are shown in figure 2. Figure 3 is one of the earliest diagrams representing the entire energy and materials balance system in a comprehensive systems representation.<sup>9</sup>

A complete LCA consists of three major steps:

- Inventory: compiling an inventory of energy and raw materials, all the air emissions, effluents, and solid waste for all the stages of the product life cycle;
- Impact analysis: an assessment of the impacts of the environmental loadings from the inventory; and
- Improvement analysis: design options to reduce the environmental and health impacts. It stands to reason that LCA's have been criticized as being too data-intensive, value-driven and subject to large uncertainties.<sup>10</sup> However, an LCA can provide a good framework to guide materials selection, performance and quality criteria, design for disassembly, and reuse and recycling.

## III. LCA AS A STUDENT EXERCISE

LCA exercises provide a natural vehicle for the student to learn not only the technical details, but also to understand the engineered product in its full context in society including aspects of consumer behavior and preference, industrial decisions about marketing and distribution, ethical considerations in design, and public policy aspects such as regulation. The exercise facilitates teaching about open-ended problems, and collecting "real-world" data. It gives students experience in setting priorities in data collection, making reasonable estimates, identifying uncertainties, and building useful models to guide design. The problem is useful for teaching students a wide range of concepts including: systems analysis; setting problem boundaries; data and performance uncertainty; environmental



and health risk assessment and management; product safety and communication; and engineering ethics. We can routinely incorporate the three basic engineering ethics principles enunciated by Martin and Schinzinger, for example, — awareness (of all phases of a project), accountability (for product safety as well as for environmental aspects), and autonomy (engineer and consumer as the decision maker), and by bringing these principles up explicitly in discussions, integrate ethics into the teaching.<sup>11</sup>

#### A. The Comparative LCA Exercise

Asking students to determine which of two consumer products of equivalent function is the more “environmentally friendly” is the premise of the LCA exercise. Allen and Bakshani have used the specific problem of the environmental impact of paper and plastic grocery sacks as an example of a real problem to motivate students and for incorporating environmental aspects into a chemical engineering course.<sup>12</sup>

We have used a more general version of the problem since 1989. For the sake of clarity, and to promote its use, we have reproduced the assignment almost verbatim in Exhibit 1.

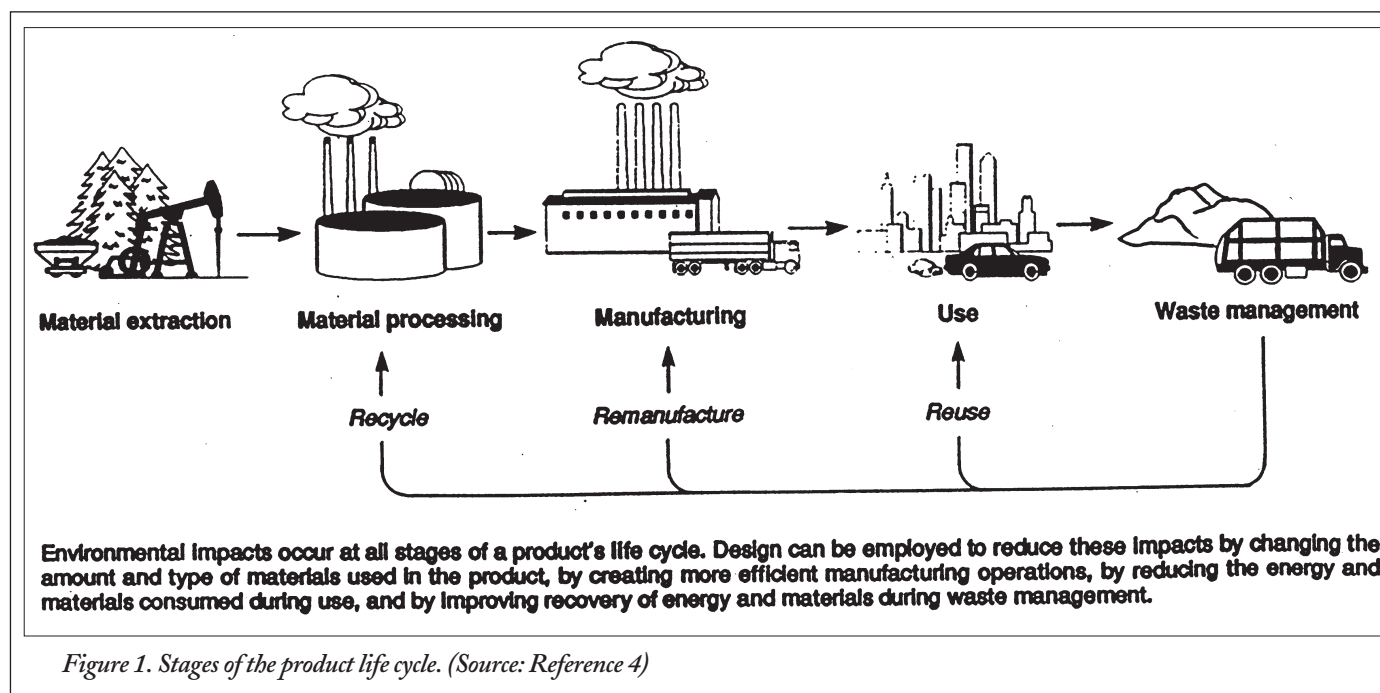
As seen in Exhibit 1, the problem is set up in detail, yet the student has to make various decisions along the way. This is an ideal condition for open-ended problems. We have them work in groups, and as this is a long-term homework assignment in our course, we set aside some time in class once a week or so, to discuss the status of the project, including any difficulty the students are encountering.

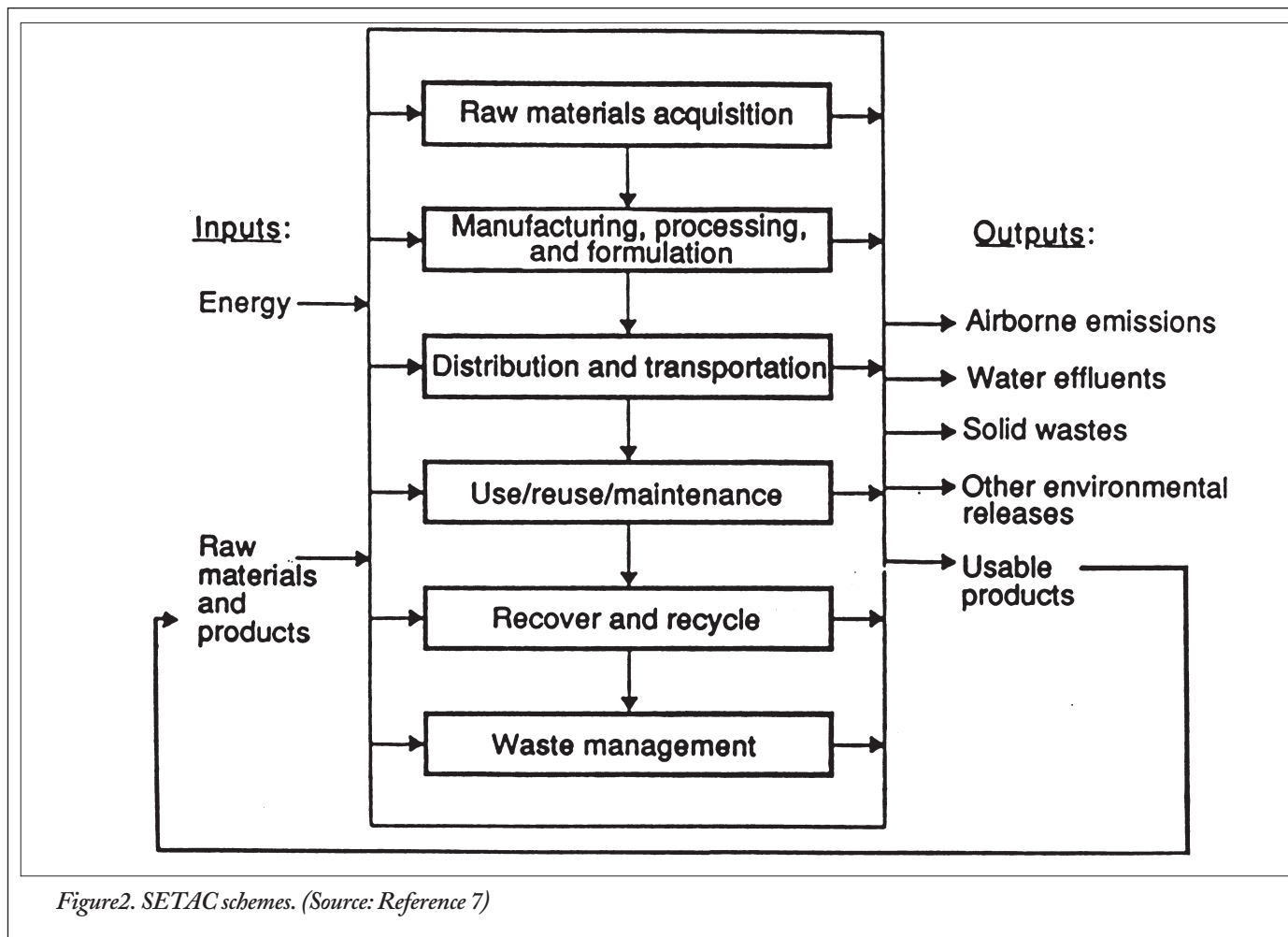
The LCA exercise calls for primarily an inventory analysis, as the impact analysis is much more complicated.<sup>13</sup> The students are encouraged to do the energy and materials inventory in as much detail as possible. Only a qualitative impact assessment is feasible. The students do get an idea of the uncertainties involved in assessing the impacts. In many cases, students also propose an improved design. The extent to which details of a new design are emphasized could depend upon whether the course has design or general environmental analysis as its focus.

One of the techniques we use routinely in teaching environmental issues is to have students draw concept maps of various phases. Concept maps are simply diagrammatic representations of the conceptual framework around an idea or issue.<sup>14,15</sup> Students can use these to express their concepts in a framework of other connected concepts, and teachers can use these as a “language” to monitor progress in building the students’ conceptual framework, and to assess student learning.<sup>3,16,17</sup> The activity of drawing concept maps draws the student’s attention naturally to the fact that his or her learning involves building this cognitive framework and embedding new concepts into the existing framework. For example, in the LCA exercise, we may have students draw a concept map of the use phase of a specific product to clearly identify all the factors that influence and are influenced by the use. Figure 4 shows a concept map of depletion of old growth forests drawn by a student in one of the classes.<sup>18</sup> Burry has developed methods for assessing learning using concept maps.<sup>17</sup>

## IV. RESULTS AND DISCUSSION

Our study of freshmen have shown that they see environmental problems as the most salient technology-society issue.<sup>19</sup> Thus, this is an ideal problem area to evoke student interest as well as to introduce environmental and ethical considerations in an engineering design or policy context. Over the last 7 years, we have used the LCA problem with great student involvement and excitement, in engineering courses as well as courses for humanities students. It is ideal for classes that have a mix of students from diverse disciplines. Students are very creative about the products they choose. An example was a comparative LCA of a wooden pencil with a mechanical pencil. In addition to getting very specific data from the companies that made their selected products, the students also did a survey of other students’ habits and preferences in using pencils to estimate the weights of “various factors in the decision to use a pencil.”<sup>20</sup> Students have compared batteries (disposable and rechargeable), auto-





mobile fuels, tableware, and even tomatoes (organically grown and “regular”)!

#### A. Pedagogical Features of the Exercise

Our observations of students and their work on this problem have highlighted to us numerous features on the value of this exercise. These factors of student learning are outlined below:

**1) Working with Open-Ended Problems:** The problem provides an ideal setting for students to learn to draw problem boundaries and structure the various parts of the problem. While the problem has an overall well-defined goal of comparing two products, numerous decisions have to be made as they work the problem. Students understand the importance and relevance of assumptions made along the way and of approximations and models.

**2) Relevance of Context in Solving Problems:** Estimating the environmental burdens of a product depends upon the assumptions made about various aspects at the different life cycle stages. These range over diverse aspects such as sources of raw material (renewable forests vs. old-growth for wood used), context of use, possible health effects, user preferences and habits, institutional constraints, etc. They also learn that the “best” solution is context-dependent, and may often involve a mixed strategy for use. For example, in comparing plastic and cloth diapers, students come to the strategy of using cloth diapers for most home uses, and plastic diapers for travel and day-care center use. Students realize that any “bottom-line” answers such as “Product A’ is more environmentally friendly than ‘Product B’” contains a number of hidden assumptions and

that environmental friendliness is a tough thing to evaluate. Students see how perspectives, values, and habits influence environmental impacts of a product.

**3) Process of Familiarity and Asking the Right Questions:** Students are also asked to describe the process of their work, particularly assumptions, data collection methods, uncertainties, and approximations. They have to decide the criteria by which they will judge “environmental friendliness.” They have to talk to product manufacturers, and discover how hard it is to get relevant and useful data.

Students discover the importance of recognizing and designing for behavioral aspects. For example, they discover that the product with the least environmental impact may not be really “environment-friendly” if it is not user-friendly, and people’s preferences drive them to use a substitute that pollutes a lot more. In their reports, we ask them to discuss their surprises and “pains” as they went through the process.

**4) Importance of Working in Interdisciplinary Teams:** The interdisciplinary team work fosters mutual respect for strength and relevance of other disciplines and develops group process and communication skills. Status reports of work in progress can be used to provide guidance on the group process.

Concept maps provide a simple but elegant way to foster and enhance interdisciplinary thinking.

**5) Responding to Diversity in Students:** While a lot has been written about teaching for a diverse classroom, it is a challenge to design classroom experiences that give students with diverse styles of learning and diverse backgrounds an opportunity to demonstrate

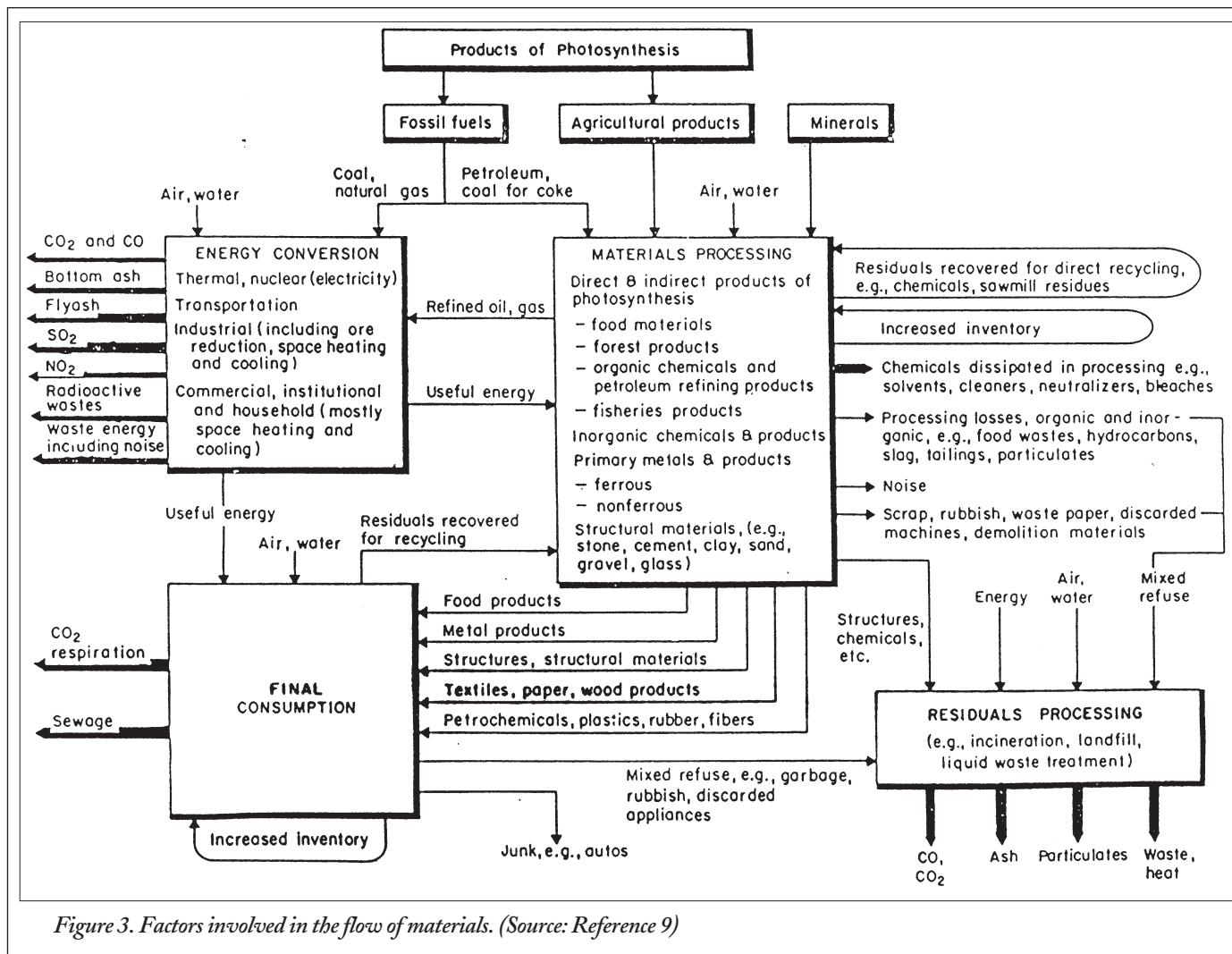


Figure 3. Factors involved in the flow of materials. (Source: Reference 9)

their strengths. This exercise provides such an environment.

**6) Values and Ethics in Decision Making:** Various aspects of values as well as environmental and design ethics are naturally brought into the examinations of decisions in the LCA. The ethical dimensions of awareness (of the engineer, designer, of the consumer, and of society in general), accountability of the various paths involved and autonomy can be invoked and discussed naturally in the project. The influence of societal values on environmental conditions produced by various decisions can be illustrated in terms of the specific problems the students have worked. This lends credence and strength to the discussions and brings home the social responsibility of all the decision makers involved.

For example, depending on the product, the ethical inquiry may focus on the environmental ethics involved in fossil fuel use or deforestation; the role of accurate information, value of information and individual responsibility in seeking information for socially responsible decision making; or the responsibility of the design engineer for conservation of natural resources and pollution prevention. This exercise provides a natural environment to have students reflect on and practice ethical decision making.<sup>21</sup>

**7) Understanding of Details of Design:** This example provides a good context for both students of engineering and students of other disciplines to explore details of design. The interest all students took in the technical details of the design was an unplanned result when we held this exercise in an environmental science course for

humanities majors, which did have a few engineering students. The engineering students became the experts in the domain of design and the other students brought their own disciplinary strengths to it. In this learning experience, all students thought and discussed the various aspects of design in a thorough way.

In summary, this problem presents various facets of environmental science, engineering, and decision making to the student. It develops technical content knowledge, interdisciplinary knowledge, decision making skills, and group interaction and communication skills. Pedagogical and motivational factors such as teaching knowledge in context, learning through trial and error, extended periods of observation, seeing the use of the material learned, and discussion of ethical responsibility as part of the goal of engineering, have been cited as necessary for attracting and retaining all students.<sup>22,23</sup> All these are automatically built into this exercise.

The exercise also lends itself to modification for different levels and stages of students. We have taught versions of it at levels from middle schools through senior college level classes for engineering majors as well as humanities and science majors and for courses involving students from several disciplines. In general, LCA provides a fertile ground for investigations of this type ranging from semester-long project or design courses to homework assignments in a general education course.

## EXHIBIT I

### What is a "green product?"

#### Life Cycle Assessment (LCA) to determine Environmental Friendliness

The concept of "environmentally friendly" or "green" products has gained a lot of attention in the past 5 years or so. As a way of determining which of two equivalent products causes less pollution and environmental impacts, an analysis called the Product Life Cycle Analysis (PLCA, or LCA for short) has been used.

In this project you will conduct a PLCA on two products that are alternatives e.g., paper napkins and cloth napkins. Several readings are enclosed to guide and aid your work.

#### A. Select a pair of alternatives for a consumer product with a life of 0-10 years. Possibilities include:

- glass bottles and plastic bottles for soft drinks
- cloth diapers and plastic diapers
- incandescent and fluorescent light bulbs
- disposable and rechargeable batteries
- liquid and powder detergents
- alternate packaging materials
- automobiles

#### B. Draw a flowchart showing the material, energy, and residual flows for your particular pair of products. Present the materials-energy flow-chart in class.

#### C. Do PLCA for the 2 products.

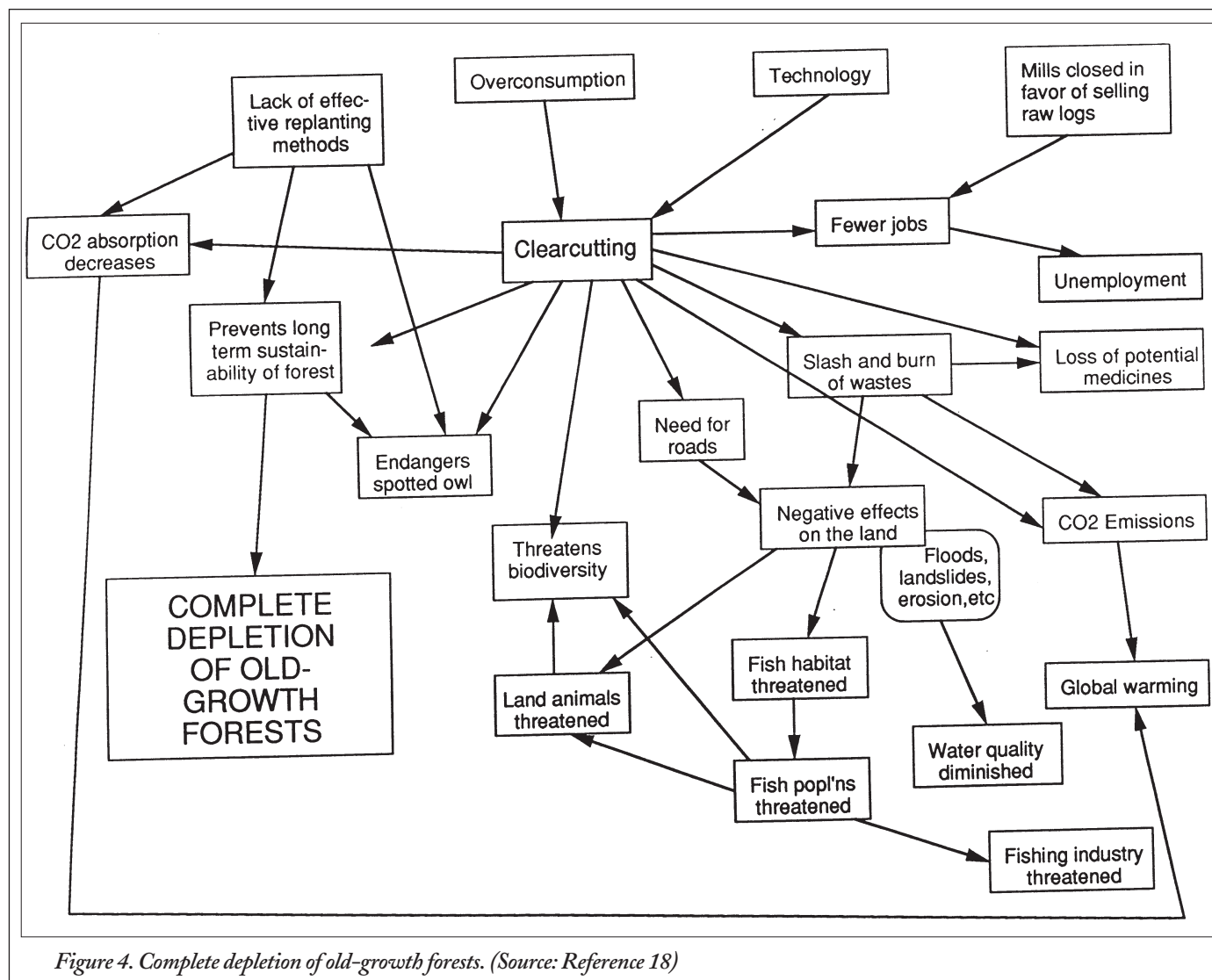
This is to give you experience in estimating:

- (1) the resources—materials and energy—embodied in products we use daily and,
- (2) the waste flows and emissions to the environment during manufacture, use and ultimate disposal of the product.

(Use concept maps, tables, etc., to show the environmental burdens/impacts, as well as other factors consumers usually consider when buying a product.)

#### D. Based on your analysis and personal experience, develop a set of criteria for deciding on the "better product choice" from the point of view of resource conservation and environmental quality. What other factors would you have to consider besides these two?

- Can you propose the weight each of these criteria should have?
- Outline the set of values that you considered in this part.
- How might the criteria (or the weights) change with the culture of the society?





- What may be the problems in implementing the factors determined by these criteria into the design of products?

*E. Determine which is more environmentally friendly.*

*F. Look at two products you have around for any environmental label. Briefly describe what you learn from the labels. Design a logo and short slogan for the green product that you worked on.*

*G. Write and present a report on the project. The project report should show the detailed calculation of the LCA including your assumptions, and approximations, the factors you considered in your assessment, the difficulties and uncertainties in the analysis.*

A detailed discussion at the end should include the problems with doing the LCA, to what extent it helps consumers make informed choices.

*H. Formal oral presentation Present your results in a formal presentation in class. Each group presentation should be no more than 15 minutes. The presentation should be a clear summary of your work, including the uncertainties, assumptions, etc. The discussion on page 25-26 of the SETAC Chapter 2 should provide a good guideline in preparing the presentation.*

Several papers are provided to give you background information on life cycle analysis.<sup>4,7,9,10,24-26</sup>

## ACKNOWLEDGMENTS

I would like to thank Sharon Jones and Victoria Massimino for assistance with this work.

## REFERENCES

(References with asterisks indicate references from which readings are given to students as part of the exercise.)

1. Atman, C.J., and I. Nair, "Constructivism: Appropriate for Engineering Education?," Proceedings, 1992 ASEE Annual Conference, ASEE, 1992, pp. 1310-1312.
2. Cheek, D., Thinking Constructively About Science, Technology and Society Education, State University of New York Press, Albany, NY, 1992.
3. Ausubel, D.P., Educational Psychology: A Cognitive View, Holt, Rinehart, and Winston, New York, NY 1968.
4. \*U.S. Congress Office of Technology Assessment, Executive Summary, Green Products by Design, U.S. Government Printing Office, Washington, DC, 1992.
5. Graedel, T. E., and B.R. Allenby, Industrial Ecology, Prentice Hall, Englewood Cliffs, NJ, 1995.
6. Hendrickson, C., and F.C. McMichael, "Product Design for the Environment," Environmental Science and Technology, vol. 26, no. 5, 1992.
7. \*Fava, J.A., R. Denison, B. Jones, M.A. Curran, B. Vigon, S. Selke, and J. Barnum (eds.), A Technical Framework for Life-Cycle Assessment, Society of Environmental Toxicology and Chemistry (SETAC) Foundation, Washington, DC, 1991.
8. Boustead, I., and G.F. Hancock, Handbook of Industrial Energy Analysis, Ellis Horwood, Chichester & John Wiley, New York, 1979.
9. \*Flowchart from: Ayres, R.U., and A.V. Kneese, "Pollution and En-

vironmental Quality," in Perloff, H. (ed.), Quality of the Urban Environment, Resources for the Future Inc., Washington, DC, p. 37.

10. \*Portney, P.R., "The Price is Right: Making Use of Life Cycle Analysis," Issues in Science and Technology, Winter 1993-94, pp. 69-75.

11. Schinzinger, M.W., and R. Schinzinger, Ethics in Engineering, McGraw-Hill, New York, 1989.

12. Allen, D.T., and N. Bakshani, "Environmental Impact of Paper and Plastic Grocery Sacks: A Mass Balance Problem with Multiple Recycle Loops," Chemical Engineering Education, 1992, pp. 82-86.

13. Ryding, S., "Environmentally-Sound Product Development Based on Life-Cycle Assessments (LCA) - 'From Cradle to Grave'," in S. Ryding (ed.), Environmental Management Handbook, Lewis Publishers, Boca Raton, Florida, 1992, pp. 435-438.

14. Novak, J.D., and D.B. Gowin, Learning How to Learn, Cambridge University Press, Cambridge, MA, 1984.

15. Novak, J.D., "Concept Maps and Vee Diagrams, Two Meta-Cognitive Tools to Facilitate Meaningful Learning," Instruction Science, vol. 19, 1990, pp. 29-52

16. Mason, C.L., "Concept Mapping: A Tool to Develop Reflective Science Instruction," Science Education, vol. 76, 1992, pp. 51-63.

17. Burry, J.A., B. Roskos-Enoldsen, A. Ivan-Nejad, R. Oxford, and L. Bolen, Concept Mapping Rubric, The Evaluation Center, Western Michigan University, Kalamazoo, MI, 1993.

18. Chen, J., "Pacific Northwest Rain Forests," paper submitted to course, "Science, Technology and Environment," May 1995.

19. Atman, C. J., and I. Nair, "A Case for Teaching Engineering in Context: Engineering Freshmen's Views about STS Issues," Proceedings, 1993 ASEE Annual Conference, ASEE, 1993.

20. Nair, I., J. Chen, T. Lumish, A. Gupta, and J. Konrad, "Integrating Science, Technology and Environment: Life Cycle Analysis and Green Design," presented at the Technological Literacy Conference, National Association for Science, Technology and Society Annual Meeting, Arlington, VA, February 1996.

21. Nair, I., "Decision Making in the Engineering Classroom," Journal of Engineering Education, vol. 86, no.4, 1997, pp. 349-356.

22. Rosser, S.V., Female-Friendly Science: Applying Women's Studies Methods and Theories to Attract Students, Pergamon Press, Elmsford, NY, 1990.

23. Nair, I., and S. Majetich, "Physics and Engineering in the Classroom," Chapter 1 (pp. 25-42) in S. Rosser (ed.), Teaching the Majority, Teachers College Press, Teachers College, Columbia University, New York, 1995.

24. \*Hocking, M., "Paper versus Polystyrene," Science, vol. 251, February 1, 1991.

25. \*Salzhauser, A.L., "Obstacles and Opportunities for a Consumer Ecolabel," Environment, vol. 33, no. 9, November 1991.

26. \*Shapiro, K., "Life-Cycle Evaluation of Packaging Materials," Proceedings, IEEE Conference on Electronics and Environment, IEEE, 1993, pp. 106-110.