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INDUSTRIAL DEVELOPMENT ORGANIZATION

**GREEN
CHEMISTRY**



SUSTAINABILITY



Image: Flickr, The Glenium Sky admixture, Author: BASF - We create chemistry

DAY 1 SESSION I
4-DAY PRESENTATION

www.greenchemistry-toolkit.org



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Topics To Be Covered

1. Sustainability – Myths and Facts
2. Society, Economy, and the Environment
3. Business and Sustainability
 - Applying Green Chemistry to Management
4. Different Models of Sustainability
5. Case Study: The Interface Company
6. Green Washing
7. Life-Cycle Assessment

When a word becomes so popular you begin hearing it everywhere, in all sorts of marginally related or even unrelated contexts, it means one of two things. Either the word has devolved into:

1. A meaningless cliché, or
2. It has real conceptual heft.



For example, the phrase “Green” or “Going Green” is a meaningless cliché. It has been used so frequently that it led to Green Washing. Anything or anyone can “be green” these days.



“Sustainable“, which at first conjures up a similarly vague sense of environmental virtue, actually belongs in the second category:

It has real conceptual heft.

Despite its simplicity sustainability is a concept many people have a difficult time wrapping their minds around.



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THE TOP TEN SUSTAINABILITY MYTHS

MYTH #1:

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Nobody knows what
sustainability really means.

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WHAT IS SUSTAINABILITY?

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Take a moment to write a sentence or two about what sustainability is.

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UN World Commission on Environment and Development: “Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs.”

Sustainability presumes that resources are finite and should be used conservatively and wisely with a view to long-term priorities and consequences of the ways in which resources are used.

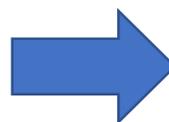
In simplest terms, sustainability is about our children and our grandchildren, and the world we will leave them.

- The Brundtland Report (Our Common Future)

THE DEFINITION OF SUSTAINABILITY



Sustainability wants to avoid this



While also making sure we can lead comfortable lives.

Image Source: Wikipedia

MYTH #2:

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Sustainability is all about
the environment.

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SUSTAINABILITY IS NOT JUST ABOUT THE ENVIRONMENT



Sustainability include a broad group social and economic development issues including: poverty, hunger, health, education, climate change, water, sanitation, energy, and environment.

This requires giving all countries access to natural resources such as water, energy, and food - all of which come, one way or another, from the environment.

www.unep.org



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SUSTAINABILITY IS NOT JUST ABOUT THE ENVIRONMENT

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Sustainability has transformed into an environmental term because the economy is driven by natural resources.

If too many of us use resources inefficiently or generate waste too quickly for the environment to absorb and process, future generations won't be able to meet their needs.

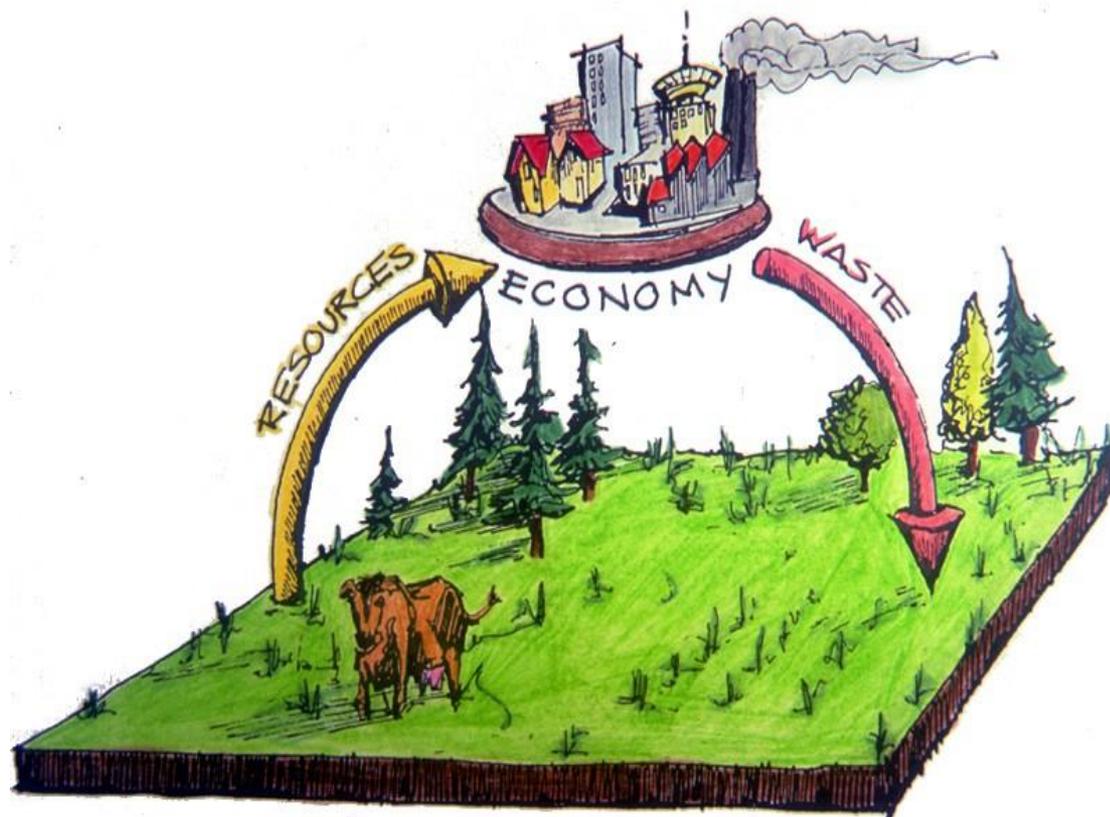


Image Source: Wikipedia



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MYTH #3:



“Sustainable” is a synonym for “green”.

SUSTAINABILITY ≠ GREEN



Although there's a fair amount of overlap between the terms, “green” can suggest to the public a preference for the natural over the artificial.

With more than six billion people on the planet today, and another three billion expected by the middle of the century, society cannot hope to give future generations a comfortable standard of living without a heavy relying on technology and innovations such as genetically altered food products.



MYTH #4:

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Sustainability is all about recycling.

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A question we need to ask:

Is recycling sustainable?

Recycling

- Converting waste materials into new materials and objects.
- Available for metals, plastic, paper, glass.

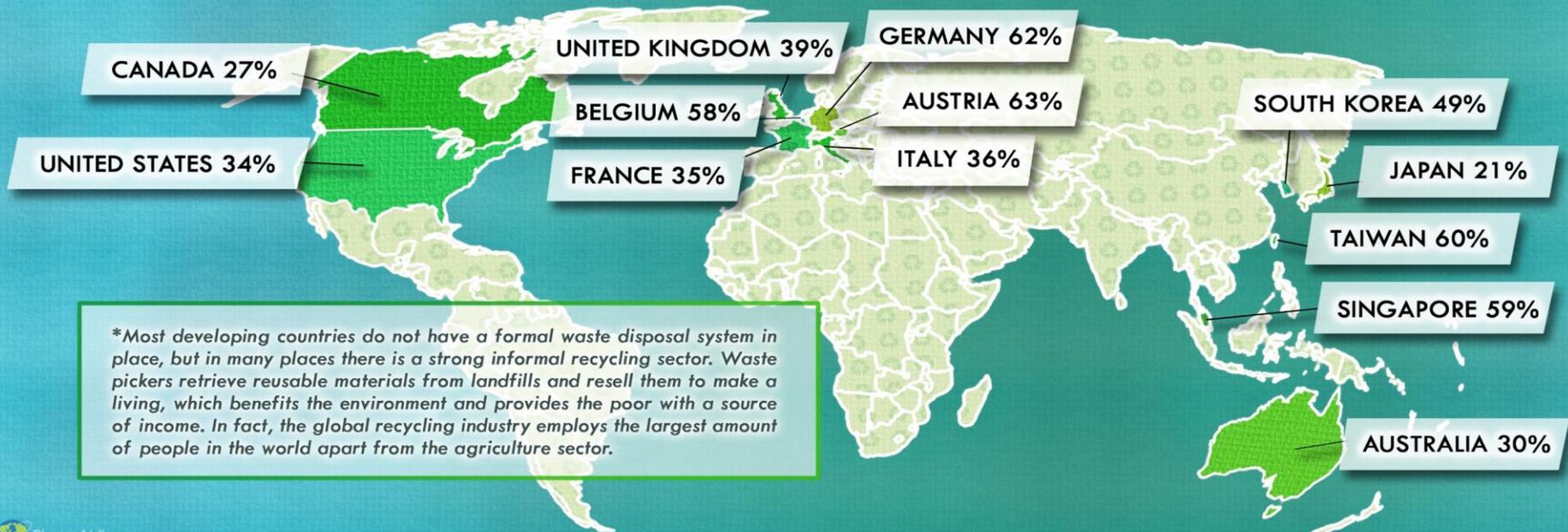
Material	Energy savings
Aluminum	95%
Cardboard	24%
Glass	5-30%
Paper	40%
Plastics	70%
Steel	60%

Cost-benefit of recycling: energy savings



RECYCLING RATES around the world

DID YOU KNOW? → Austria has the highest recycling rate in the world, with 63% of all waste diverted from the landfill. **The United States produces 25% of the world's waste.** Humans have consumed more resources in the last 50 years than in all previous history. **75% of the nearly 1 billion tons of aluminium ever produced has been recycled and is still in productive use.** About 1% of the urban population in developing countries (at least 15 million people) survives by salvaging recyclables from the waste stream.*



*Most developing countries do not have a formal waste disposal system in place, but in many places there is a strong informal recycling sector. Waste pickers retrieve reusable materials from landfills and resell them to make a living, which benefits the environment and provides the poor with a source of income. In fact, the global recycling industry employs the largest amount of people in the world apart from the agriculture sector.

MYTH #5:

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Sustainability is too expensive.

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If there is an 800-pound gorilla in the room of sustainability, this myth is it. That's because there's a grain of truth to it.

But only a grain. It's only true in the short term and under certain circumstances, but certainly is not true in the long term.



More sustainable ways of doing things usually costs less over the life-time of a product or service.

It is the upfront costs that can sometimes be higher.



Image: Wikimedia Commons, Solar panels installed in Baja Sur California, Author: BishopBandita

MYTH #6:

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Sustainability means lowering our
standard of living.

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Once we start becoming organized and innovate, the breakthroughs can be extraordinary.

These innovations will allow us to use resources more productively, which in turn will allow us to be prosperous, fed, entertained, and secure.

The innovation at the heart of sustainable living will be a powerful economic engine.

MYTH #7:

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Consumer choices and grassroots activism, not government intervention, offer the fastest and most efficient routes to sustainability.

www.rhmkalliance.org



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Popular grassroots actions are helpful and essential to creating change. But progress on some reforms, such as curbing CO₂ emissions, can only happen if central authorities commit to making it happen. That is why tax credits, mandatory fuel-efficiency standards, and other government regulations are both practical and necessary.

MYTH #8:

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New technology is always the answer.

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IS NEW TECHNOLOGY THE ANSWER TO SUSTAINABILITY?

WATER TREATMENT TECHNOLOGIES FOR DEVELOPING WORLD



MYTH #9:



Sustainability is ultimately a population problem.

This is not a myth, but it represents a false solution.

Every environmental problem is ultimately a population problem. If the world's population were only 100 million people, we would be hard-pressed to generate enough waste to overwhelm nature's cleanup systems. We could dispose all our trash in a landfill in some remote area, and nobody would notice.



Population experts agree that the best way to limit population is to educate women and raise the standard of living overall in developing countries.

But that strategy cannot possibly happen quickly enough to put a dent in the population on any useful timescale.

The U.N. projects that the planet will have to sustain another 2.6 billion people by 2050. But even at the current population level of 7 billion people, we're using up resources at an unsustainable rate.

MYTH #10:



Once you understand the concept,
living sustainably is easy to figure out.

All too often, a choice that seems sustainable turns out on closer examination to be problematic.

Probably the best current example is the rush to produce ethanol for fuel from corn.

What are the issues with ethanol?

Corn Cultivation:

- Competition with food supply
- Land demand
- Nutritional needs
- Diseases
- Initial investment

Ethanol Demand and Corn Prices:

- Large increase in demand for corn for ethanol production.
 - Current production capacity is at over 5 billion gallons.
 - It is projected to increase to over 9 billion gallons with current plants currently under construction.
- Bushels of corn sold for over \$8 (USD) each in July 2012.
- Corn prices continue to fluctuate.



You cannot really declare any practice “sustainable” until you have done a complete life-cycle analysis of its environmental costs.

Even then, technology and public policy keep evolving, and that evolution can lead to unforeseen and unintended consequences.

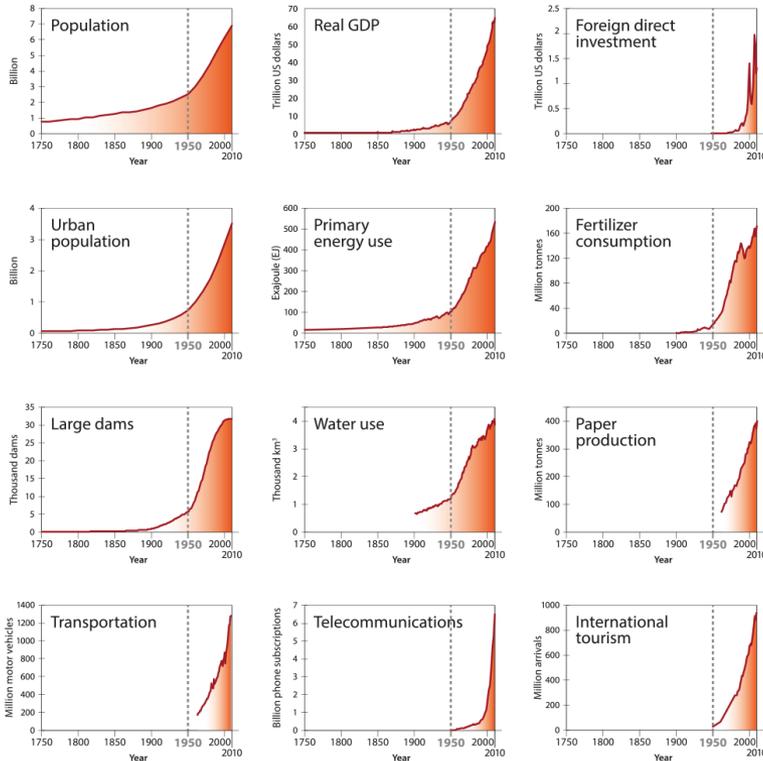
The admirable goal of living sustainably requires plenty of thought on an ongoing basis.

WHY ARE BUSINESSES PAYING ATTENTION?

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Socio-economic trends



Pollution, contamination, and waste are increasing along with population.

We blame society and corporations for encouraging increased customer demand, pushing consumption of life supporting resources further and further.

Even as these resources decline, consumption of these resources is still rising.

www.thankalliance.org



WHY ARE BUSINESSES PAYING ATTENTION?



The problem of declining resources is not felt as acutely in developed areas as it is in less developed parts of the world.

The UN Human Development Report from 2012 suggests that the richest 1% of the world, approximately 70 million people, receive as much income as the poorest 56%, or 4 billion people.

Companies are at risk of losing access to raw materials and to employees.

Unfortunately, we are not acting upon knowledge that we have as quickly as we need to in order to prevent the continuous degradation of the Earth and our ability to survive. This creates a sense of urgency in today's corporate boardroom.

Green Chemistry & Chemical Stewardship Online Certificate Program:

<https://osha.washington.edu/pages/green-chemistry-chemical-stewardship-online-certificate-program>





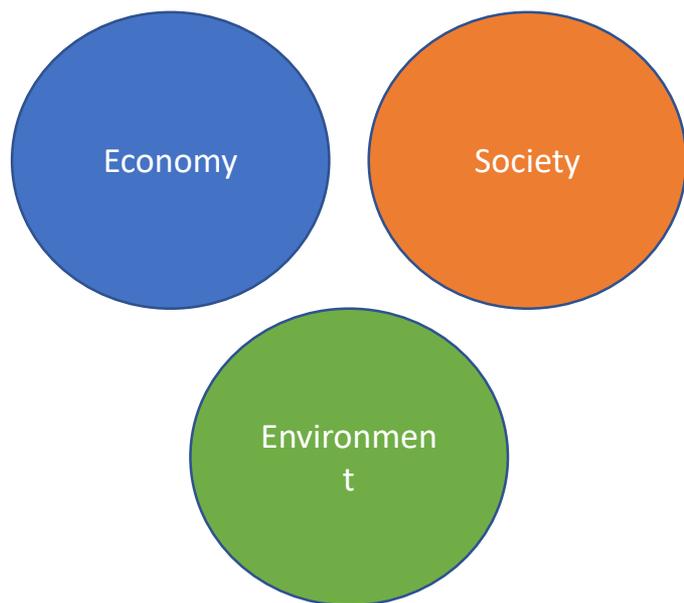
Society, economy, and the environment are the key dimensions of sustainability.

Why?

Economic or physical water scarcity, poor air quality, and destroyed ecosystems that sustain life not only in terms of food but also employment, are all signs that we lack sustainability in day-to-day practices.



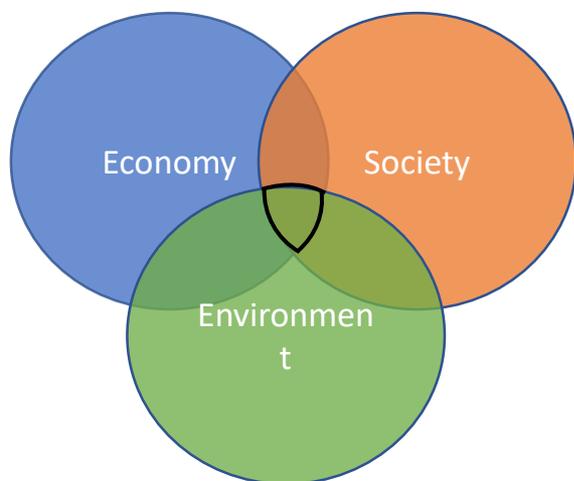
The traditional view of economy, society, and the environment:



When society, economy, and the environment are viewed as separate unrelated parts of a community, the community's problems are also viewed as isolated issues. Economic development councils try to create more jobs. Social needs are addressed by health care services and housing authorities. Environmental agencies try to prevent and correct pollution problems.



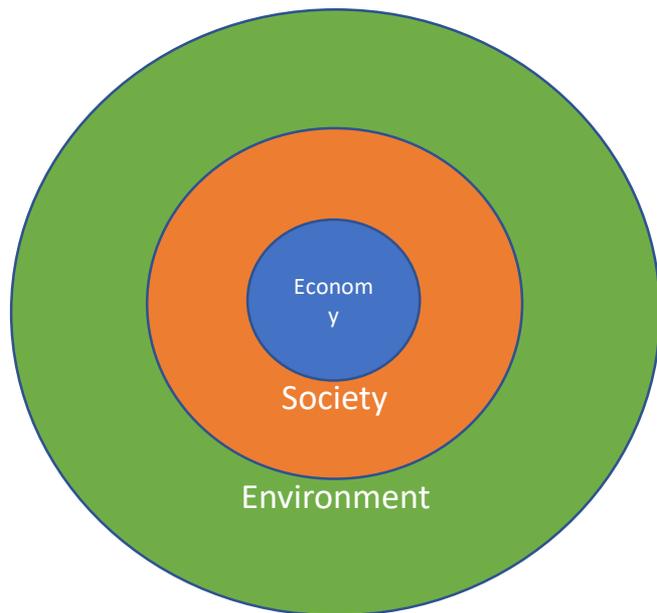
The current view of economy, society, and the environment: The Triple Bottom Line



Understanding the three parts and their links is key to understanding sustainability, because sustainability is about more than quality of life. It is about balancing society, economy, and the environment.



A representation of the ideal economy, society, and the environment:

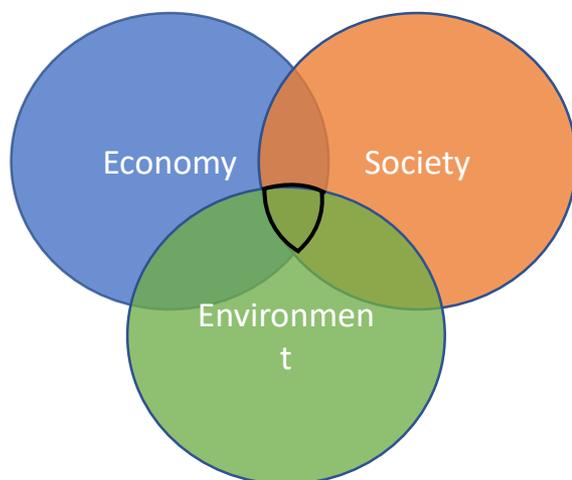


The economy exists entirely within society because all parts of the human economy require interaction among people. However, society is much more than just the economy. Friends and families, music and art, religion and ethics are all important elements of society, but are not primarily based on the exchanging of goods and services.

Society, in turn, exists within the environment. Our basic requirements – air, food, and water – come from the environment as do the energy and raw materials for housing, transportation, and the products we depend on.



Triple Bottom Line (TBL)



TBL measures the impact of an organization's activities on the world by looking at profitability and shareholder values through its social, financial, and environmental capital.

Most of major companies that include sustainability in their business plan use this model.

Pressures that companies are facing:

Fiduciary responsibility to make profit: CEOs in public companies have a fiduciary responsibility to shareholders. It is the law for them to deliver profits. Even private companies and small companies have a fiscal responsibility to investors or venture capitalists to return profit on their investment. While there may be a desire to be more sustainable, it has not yet been included within the scope of fiduciary responsibility.

Fear of increased costs, process complexity, and reduced quality of the end product: There is an underlying assumption that being sustainable will drive up costs, erode profits, and threaten the ability of the company to maintain standards and ultimately survive in a competitive marketplace.

Measurement and Monitoring: Challenges surround what to measure along the three dimensions of the Triple Bottom Line. This includes internal agreement as to what to measure, how to measure, and finally how to put auditing procedures in place. Even if a company wanted to be sustainable, the methodology for setting objectives and measuring the results are often in nascent states.

Green Chemistry & Chemical Stewardship Online Certificate Program:

<https://osha.washington.edu/pages/green-chemistry-chemical-stewardship-online-certificate-program>





Sustainability and Green Chemistry are imperative to business practices, can provide solutions at lower costs, use fewer resources, and the processes and results can be measured.

How?

With the ability to establish multiple value creation levers over the short and long term such as:

- Stronger brand and greater pricing power.
 - Increased margins, producing greater profits and maximizing total shareholder return.
- Improve customer loyalty and reduce the rate of churn.
 - Boosting market share and revenue growth.

Create the culture aligned with sustainability goals: “maximize resource efficiency”, “eliminate and minimize hazards and pollution”, and “design systems holistically and use life cycle thinking” by focusing on design.

B. Torok and T. Dransfield (eds), 1st edn, JAN 2018, Elsevier, Amsterdam, The Netherlands, ISBN-13: 978-0128092705, 1058 pp.

www.thinkalliance.org



Who?

- ❑ An awareness of the Principles of GC&GE should not be limited to the members of the design teams of sustainable and innovative products and processes.
- ❑ Green chemistry requires top-down implementation of sustainable innovation from managers and leaders in addition to the bottom-up (emergence) implementation from designers (followers).
 - Managers must be aware of the principles in order to implement sustainable approaches across multiple scales.
 - Leaders must be aware of the principles in order to develop business models and strategies that are sustainable in the long term.

B. Torok and T. Dransfield (eds), 1st edn, JAN 2018, Elsevier, Amsterdam, The Netherlands, ISBN-13: 978-0128092705, 1058 pp.





Framework of Innovation Management Process: Seven Opportunities to Apply Green Chemistry

1. Inputs

Human - The multidisciplinary approach requires innovative teams with diverse skill sets and knowledge. Actors require the ability to network and collaborate within the departments of an organization and beyond.

Physical/Natural - Renewable materials and energy; designing new materials, products, processes, and systems that are benign to human health and the environment.

Financial - A positive impact on value creation levers (stronger brand and greater pricing power) that can lead to increased total shareholder return.

B. Torok and T. Dransfield (eds), 1st edn, JAN 2018, Elsevier, Amsterdam, The Netherlands, ISBN-13: 978-0128092705, 1058 pp.

www.routledge.com



Framework of Innovation Management Process: Seven Opportunities to Apply Green Chemistry

2. Innovation Strategy

Companies that follow a sustainable business should be able to derive competitive advantages that are based on a sustainable value proposition.

- ❑ By reducing the costs associated with waste, companies can improve operational efficiencies and gain a competitive advantage via a cost advantage.
- ❑ A greener product that's certified as sustainable can be sold at a higher price.

B. Torok and T. Dransfield (eds), 1st edn, JAN 2018, Elsevier, Amsterdam, The Netherlands, ISBN-13: 978-0128092705, 1058 pp.



Framework of Innovation Management Process: Seven Opportunities to Apply Green Chemistry

3. Knowledge Management

The leaders and managers of sustainability will require new core competencies that include sustainability literacy, external collaboration, and systems thinking.

Project teams that pursue sustainability initiatives, or that are involved in the creation of a new product or process, will require diverse skill sets.

B. Torok and T. Dransfield (eds), 1st edn, JAN 2018, Elsevier, Amsterdam, The Netherlands, ISBN-13: 978-0128092705, 1058 pp.



Framework of Innovation Management Process: Seven Opportunities to Apply Green Chemistry

4. Organization and Culture

At the executive level, prioritization decisions based on values take the form of decisions to invest, or not, in new products, services, and processes.

Employees should prioritize decisions that lead to sustainable innovation and ultimately sustainable development.

Organization and culture can also attract top talent that pays close attention to a firm's behavior and could reduce employee turnover.

B. Torok and T. Dransfield (eds), 1st edn, JAN 2018, Elsevier, Amsterdam, The Netherlands, ISBN-13: 978-0128092705, 1058 pp.





Framework of Innovation Management Process: Seven Opportunities to Apply Green Chemistry

5. Project Management

Awareness of Green Chemistry can guide project managers as they operate within the multiple levels of reporting (middle, upper manager, and executive levels).

As for project management, designers and managers should consider the entire life cycle of a product, including those of the materials and energy inputs.

B. Torok and T. Dransfield (eds), 1st edn, JAN 2018, Elsevier, Amsterdam, The Netherlands, ISBN-13: 978-0128092705, 1058 pp.





Framework of Innovation Management Process: Seven Opportunities to Apply Green Chemistry

6. Portfolio Management

Leaders and managers can evaluate the sustainability of the projects that make up a portfolio in the context of the Green Chemistry

A challenge for leadership is the development of performance metrics for sustainability efforts that are different from the usual metrics of portfolio management, such as patent portfolio size and R&D expenditure.

B. Torok and T. Dransfield (eds), 1st edn, JAN 2018, Elsevier, Amsterdam, The Netherlands, ISBN-13: 978-0128092705, 1058 pp.

www.routledge.com





Framework of Innovation Management Process: Seven Opportunities to Apply Green Chemistry

7. Commercialization

The most effective methods of ideation for product innovation are customer visit teams, ethnographic research, leader user analysis, and focus groups.

Feedback from marketing and sales teams involved in the diffusion stage will help the designers of new products in the ideation phase since these teams will best understand market orientation or pull.

B. Torok and T. Dransfield (eds), 1st edn, JAN 2018, Elsevier, Amsterdam, The Netherlands, ISBN-13: 978-0128092705, 1058 pp.

www.routledge.com





Nike – low carbon, closed loop model

The company is reducing the use of petroleum-derived solvents (PDSs) across the manufacturing process of their footwear product lines. Since 1995, there has been an actual 96% reduction in the use of PDSs per pair of shoes through the adoption of water-based adhesives.

<https://news.nike.com/news/sustainable-innovation>

Unilever

As a result of their sustainability initiatives, Unilever factories are releasing 37% less emissions than in 2008, and waste is down 85%. The example highlights how innovators are attempting to utilize matter and energy in a way that enhances performance and value while protecting the environment.

https://www.nytimes.com/2015/11/22/business/unilever-finds-that-shrinking-its-footprint-is-a-giant-task.html?_r=0



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THE INTERFACE COMPANY CASE STUDY

DOES RUNNING A BUSINESS BY
CONVICTION MEAN SACRIFICING PROFIT?

Prepared by
Abigail Enghirst ~ Karen Schenck ~ Justin Vickerman ~ Karen Wisont

A Sizeable Global Industry

Market Value

- **Global:**
\$150 billion
(2012)
- **US:**
>\$10 billion
(2010)
- **Interface:**
\$927 million
(2010)

Production and Waste

- **Produced annually:**
3 million tons
(6 billion pounds)
- **Discarded annually:**
~2 million tons
(4 billion pounds)
- **Municipal solid waste:** 1% (by weight)
2% by volume

Interface Waste

- **1996:** 15 million lbs
- **2009:** 3.4 million lbs
- 75% reduction
- \$372 million cumulative avoided waste cost



CASE STUDY: THE INTERFACE COMPANY

GREEN CHEMISTRY

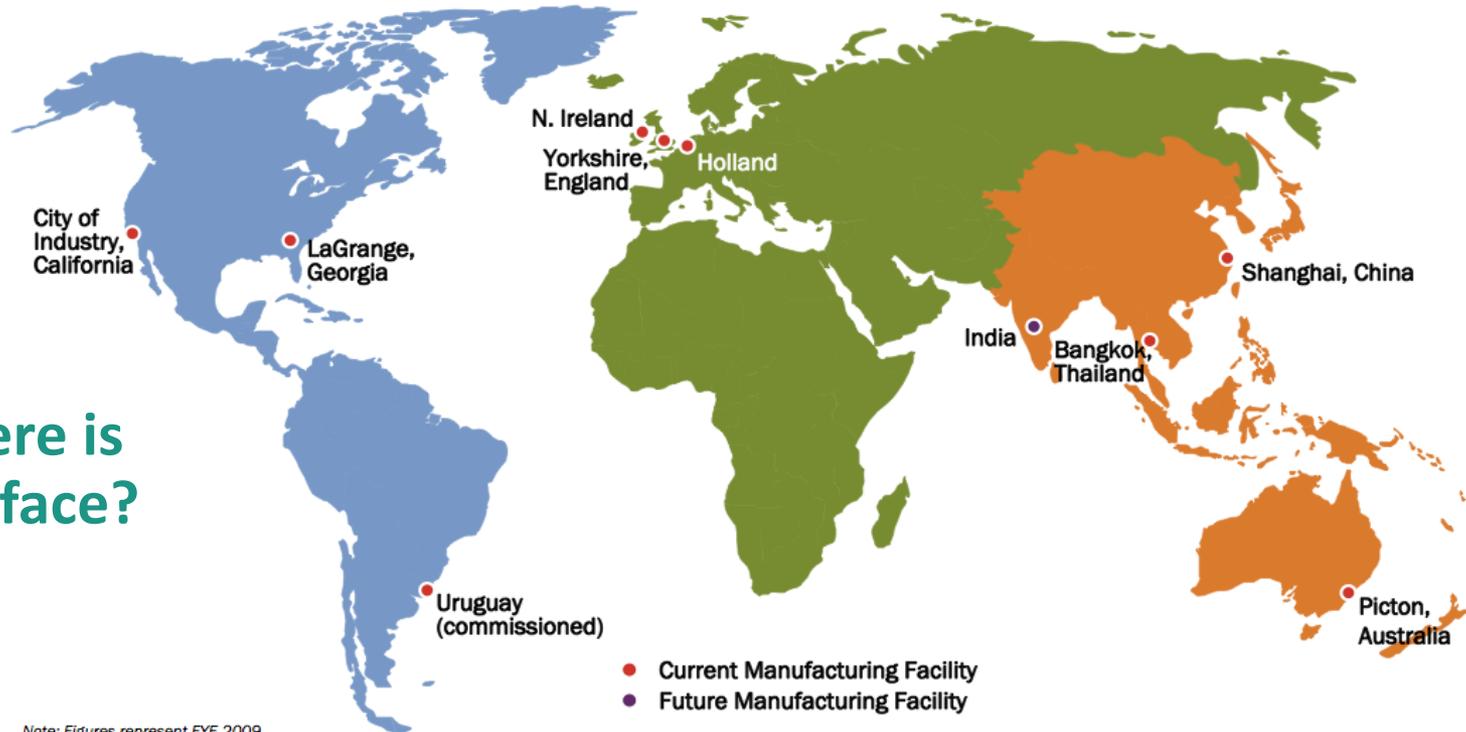


Americas	
Sales	58%
Production	51%
Employees	54%

Europe & MEA	
Sales	30%
Production	34%
Employees	27%

Asia-Pacific	
Sales	12%
Production	15%
Employees	19%

Where is Interface?



Note: Figures represent FYE 2009

www.interfaceinc.com



CASE STUDY: THE INTERFACE COMPANY

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A “Spear in the Chest”



“I stood indicted as a plunderer, a destroyer of the earth, a thief of my grandchildren’s future. And I thought, my God, someday what I do here will be illegal. Someday they’ll send people like me to jail.”

“I was so wrong, for so long...There is a better way to make a bigger profit...and at the same time do it honestly and legitimately, not at the expense of the earth.”

www.interfaceinc.org



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CASE STUDY: THE INTERFACE COMPANY

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Profitable company



Ray Anderson decided to become first truly sustainable company
\$780 million in sales (1994)



\$50 million cost savings (1994-1997)
\$1.2 billion in sales (1998)



Drop in sales, cumulative losses
Anderson replaced (as President 1997, as CEO 2001)



Must a company sacrifice profit to pursue conviction?



CASE STUDY: THE INTERFACE COMPANY



“To be the first company that, by its deeds, shows the entire industrial world what sustainability is in all its dimensions:

people, process, product, place and profits — by 2020 —

and in doing so we will become restorative through the power of influence.”

www.interface.com



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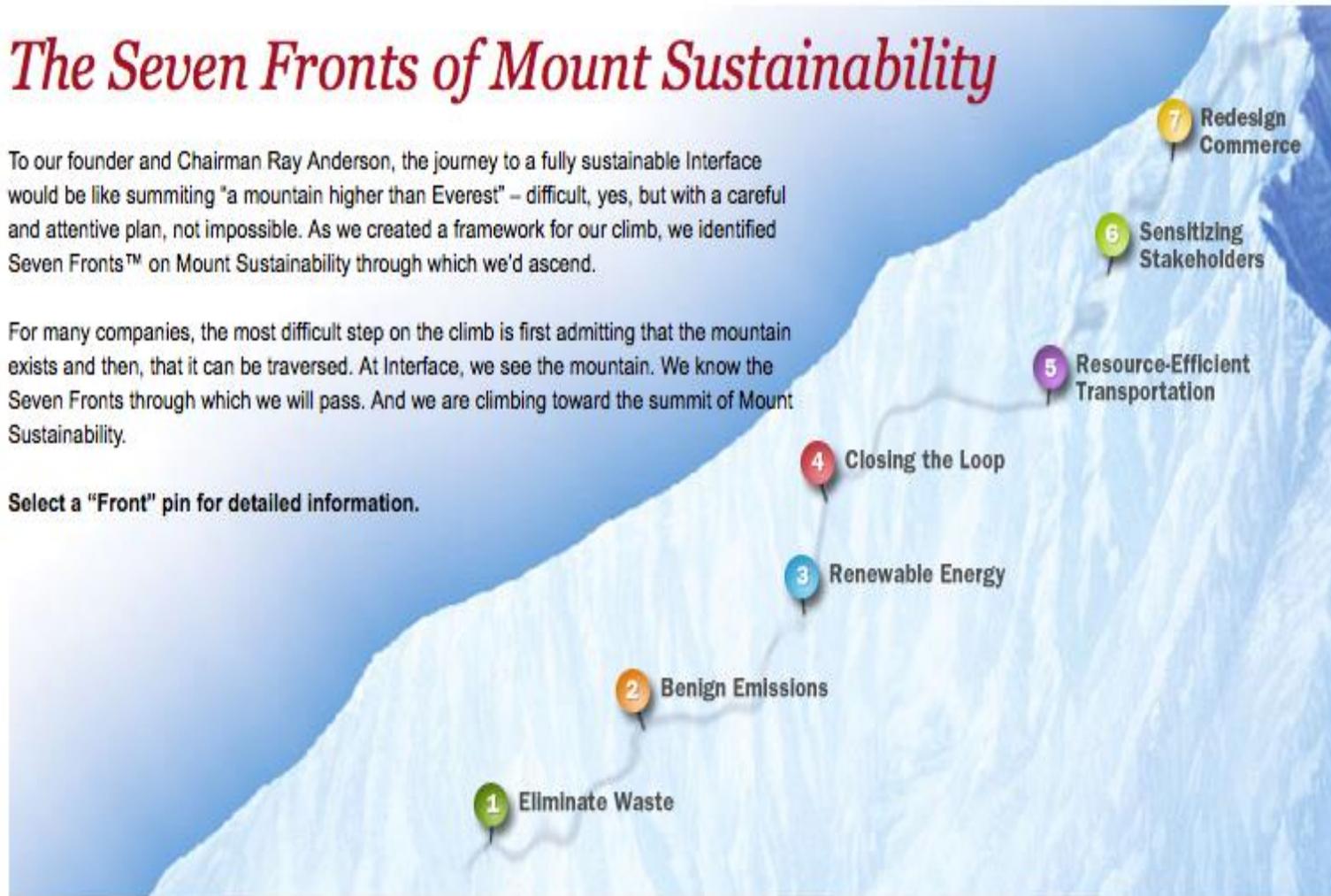


The Seven Fronts of Mount Sustainability

To our founder and Chairman Ray Anderson, the journey to a fully sustainable Interface would be like summiting "a mountain higher than Everest" – difficult, yes, but with a careful and attentive plan, not impossible. As we created a framework for our climb, we identified Seven Fronts™ on Mount Sustainability through which we'd ascend.

For many companies, the most difficult step on the climb is first admitting that the mountain exists and then, that it can be traversed. At Interface, we see the mountain. We know the Seven Fronts through which we will pass. And we are climbing toward the summit of Mount Sustainability.

Select a "Front" pin for detailed information.





A 20th Century Company

Center

- Common to all companies
- Values are core

Suppliers

- Materials for capital

Customers

- Capital for products
- Used products to landfill

Biosphere

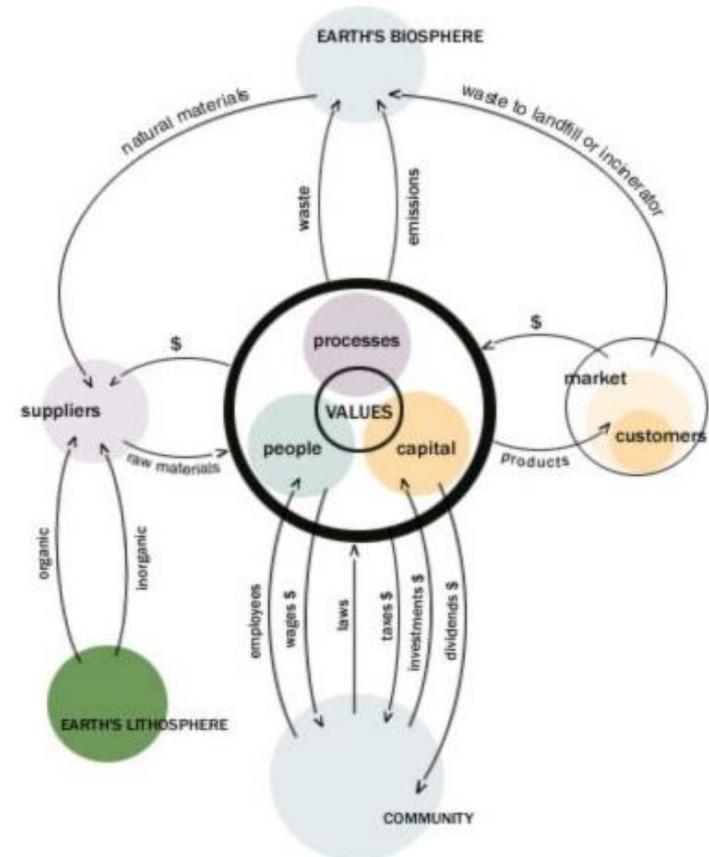
- Collects waste and emissions

Lithosphere

- Suppliers take materials (oil)

Community

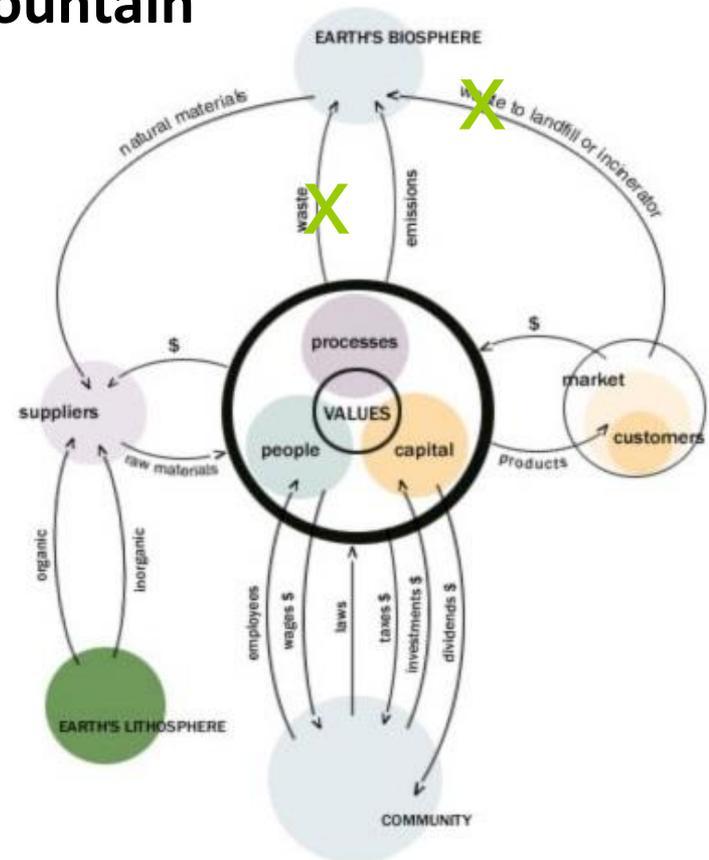
- Employees for wages
- Capital exchange
- Regulation





...to A Prototypical 21st Century Company Climbing the Mountain

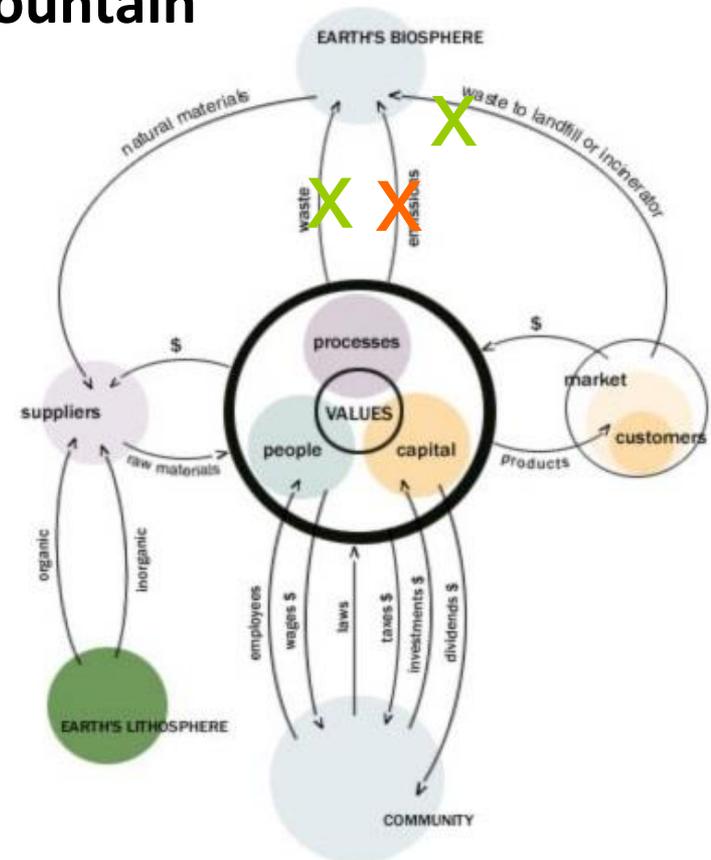
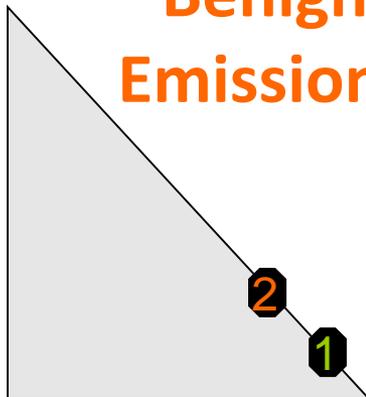
Step 1
Eliminate
Waste





...to A Prototypical 21st Century Company Climbing the Mountain

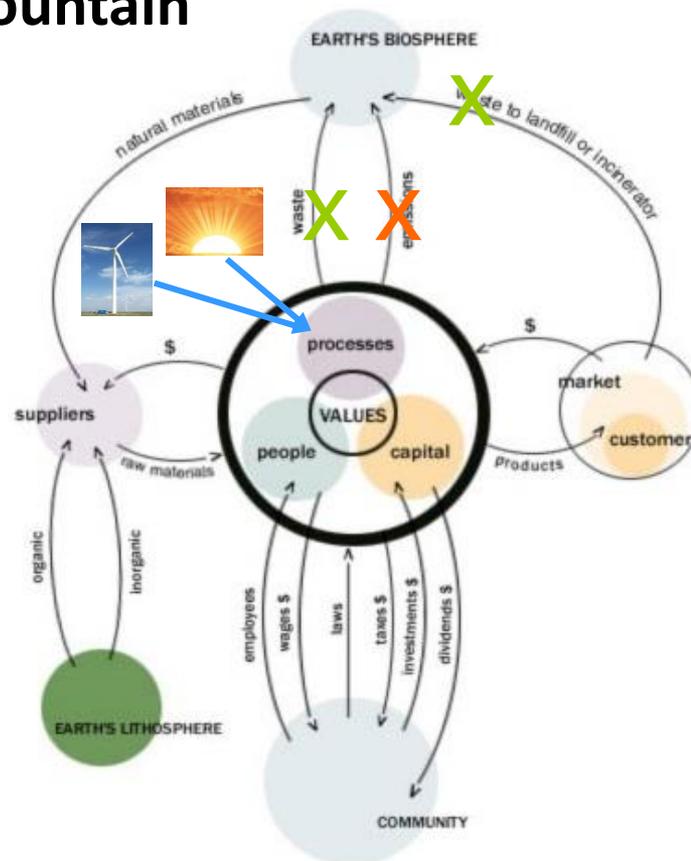
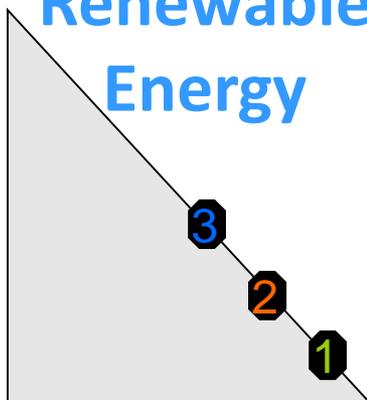
Step 2 Benign Emissions





...to A Prototypical 21st Century Company Climbing the Mountain

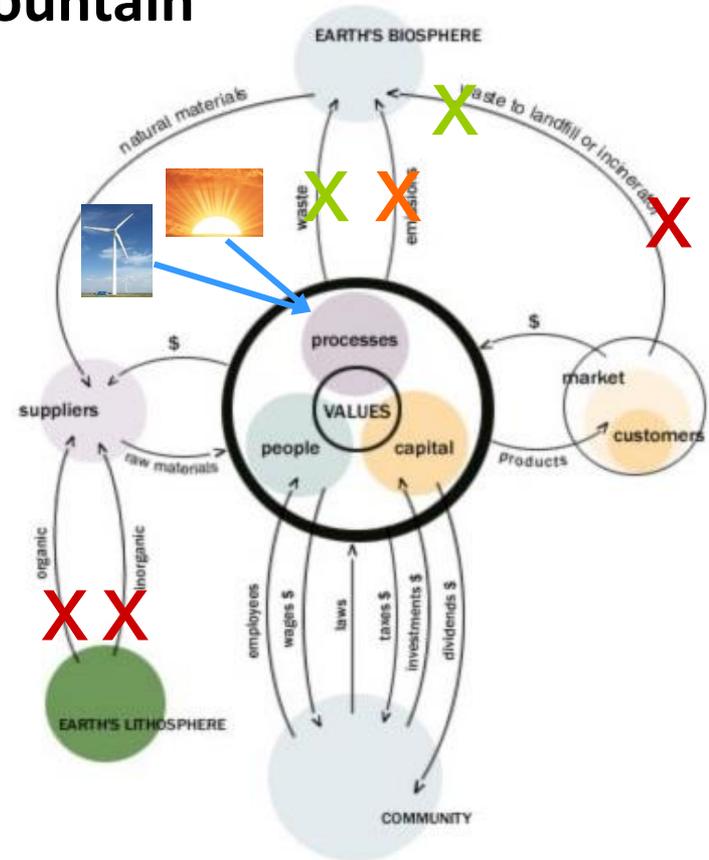
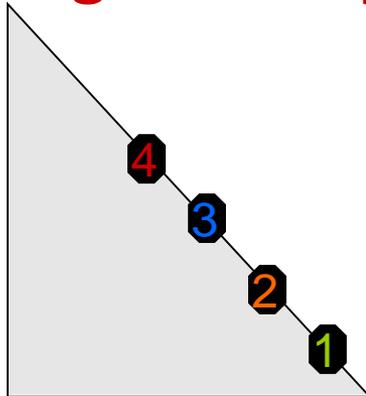
Step 3 Renewable Energy





...to A Prototypical 21st Century Company Climbing the Mountain

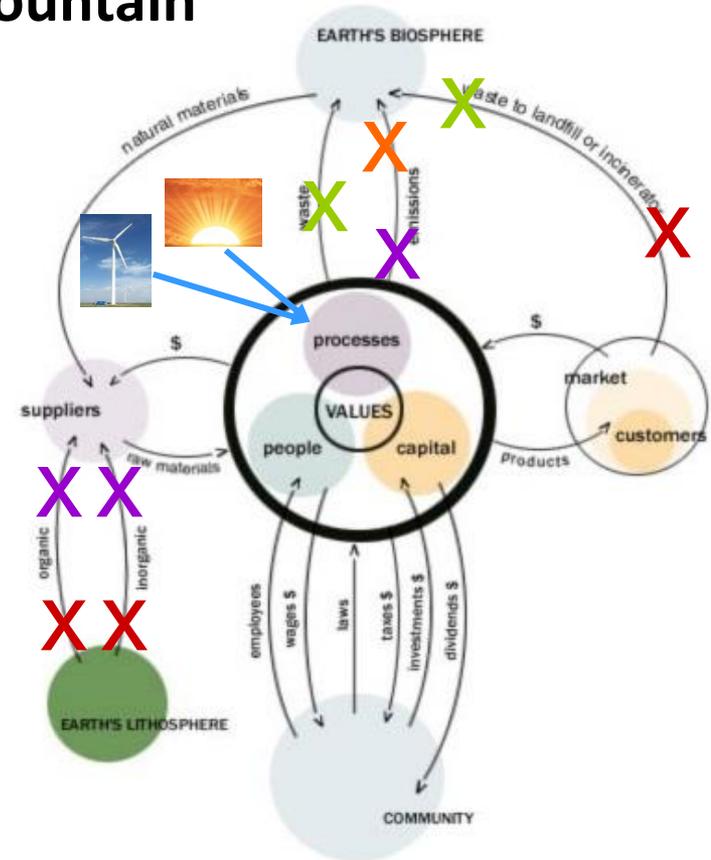
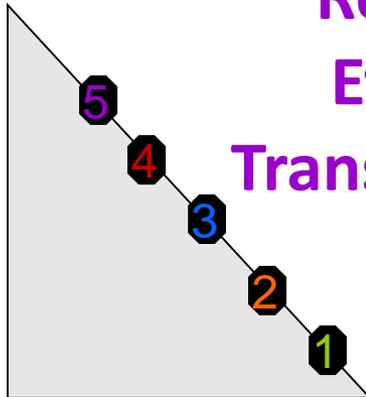
Step 4 Closing The Loop





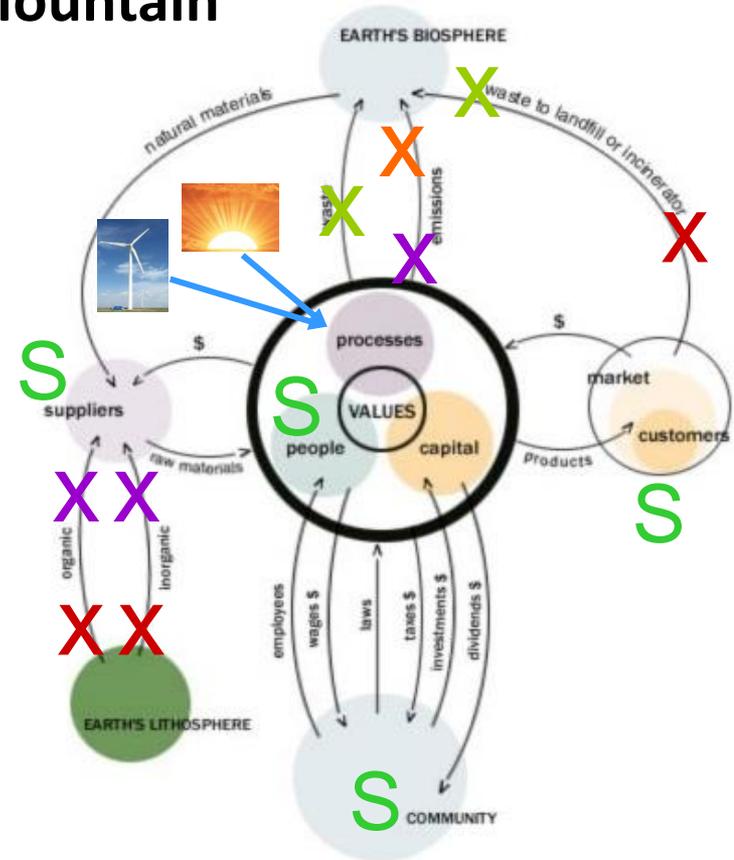
...to A Prototypical 21st Century Company Climbing the Mountain

Step 5 Resource Efficient Transportation



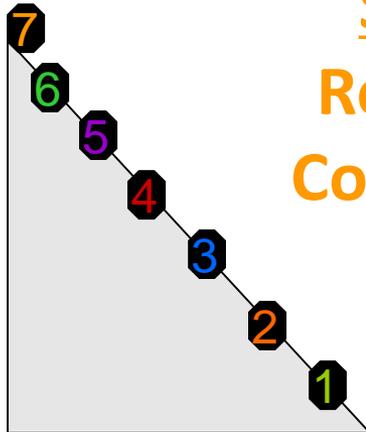


...to A Prototypical 21st Century Company Climbing the Mountain

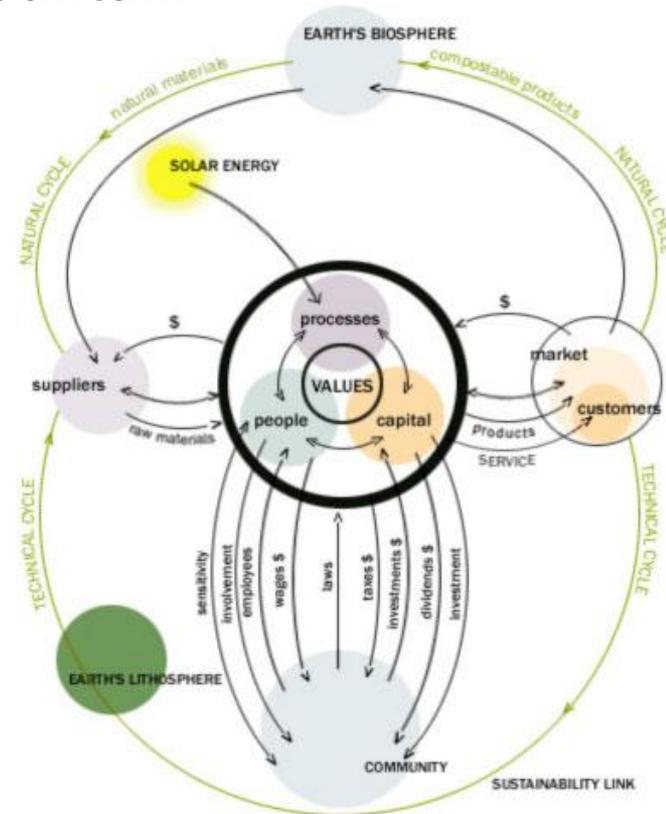




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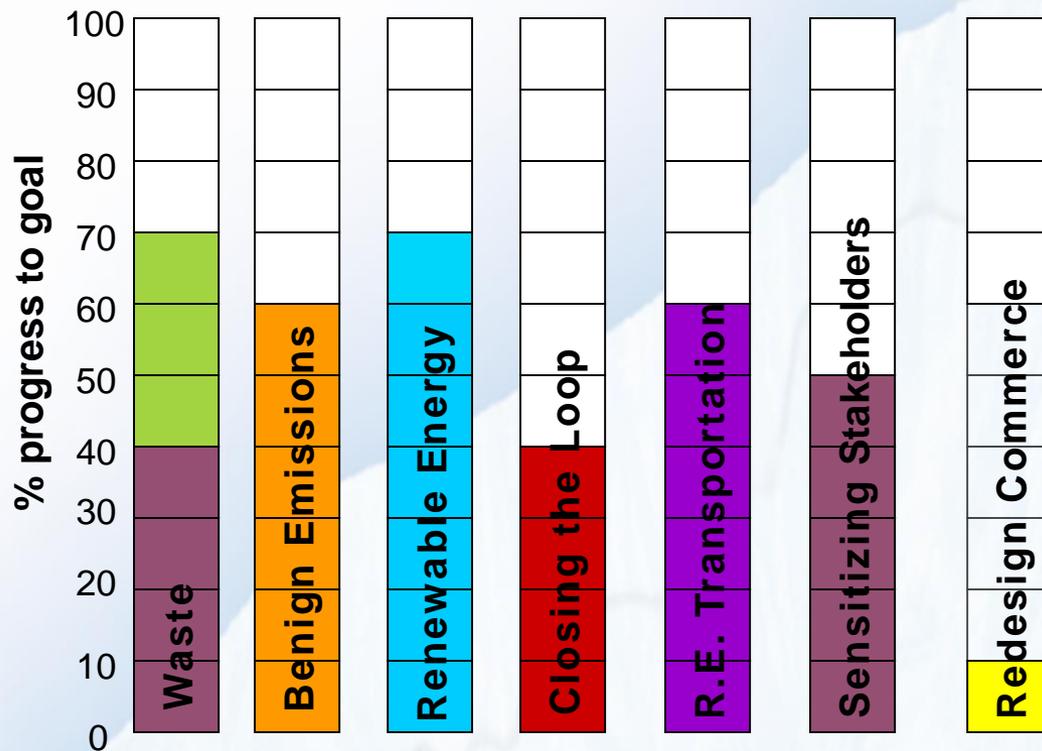


Step 7 Redesign Commerce



MISSION ZERO GOALS: APPROXIMATELY 60% PROGRESS AS ASSESSED IN 2010

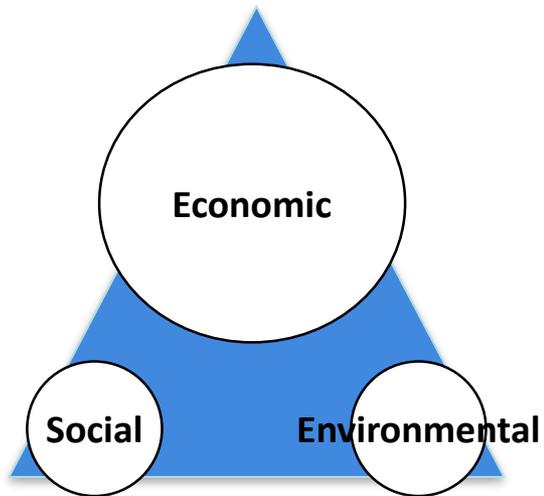
GREEN CHEMISTRY



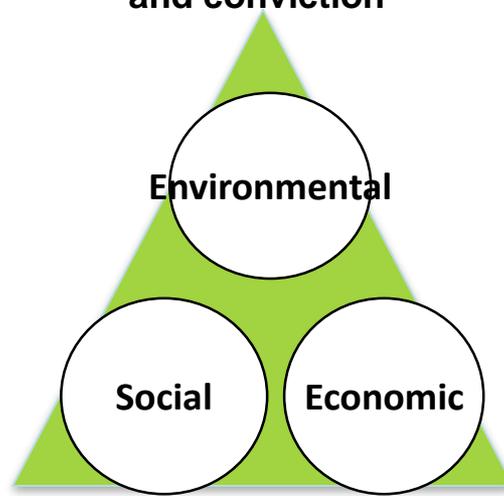
FINDING BALANCE BETWEEN CONVICTION AND PROFIT



Focus on profit



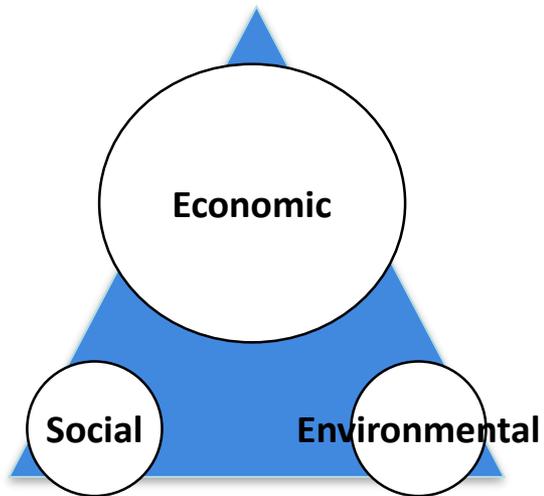
**Balance of profit
and conviction**



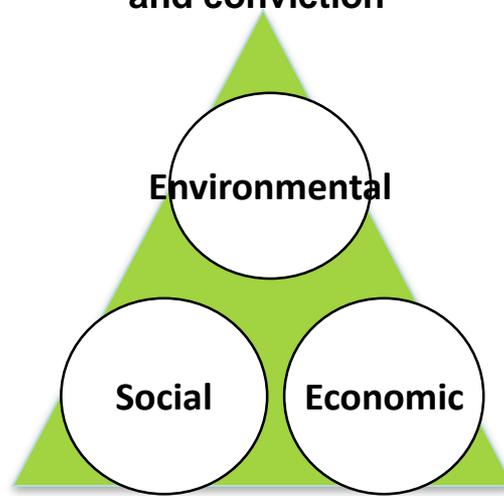
FINDING BALANCE BETWEEN CONVICTION AND PROFIT



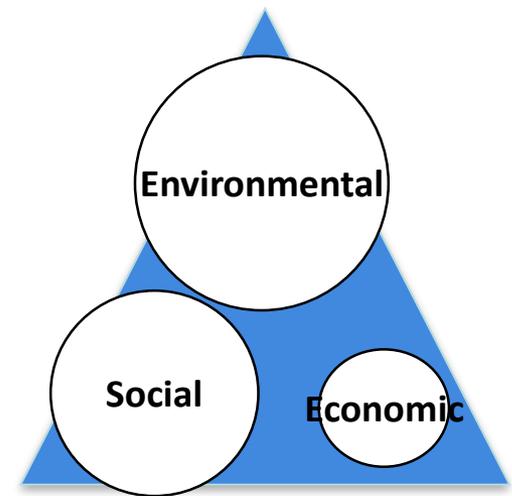
Focus on profit



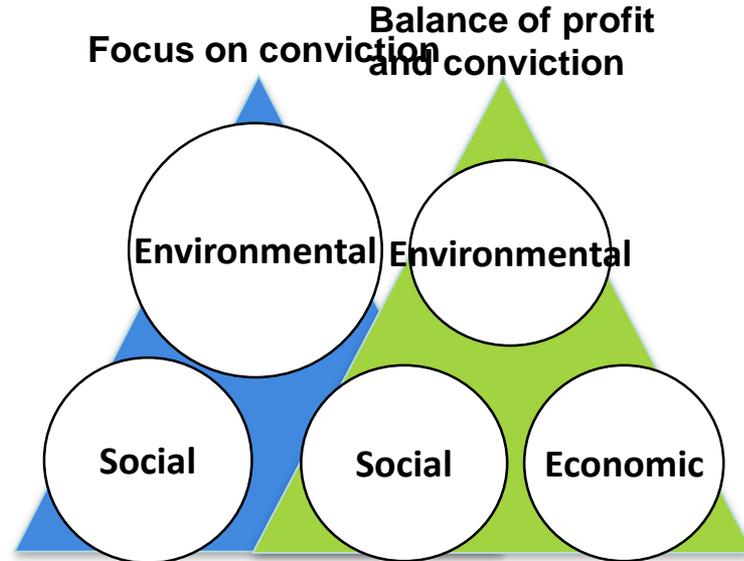
**Balance of profit
and conviction**



Focus on conviction



FINDING BALANCE BETWEEN CONVICTION AND PROFIT



FINDING BALANCE BETWEEN CONVICTION AND PROFIT

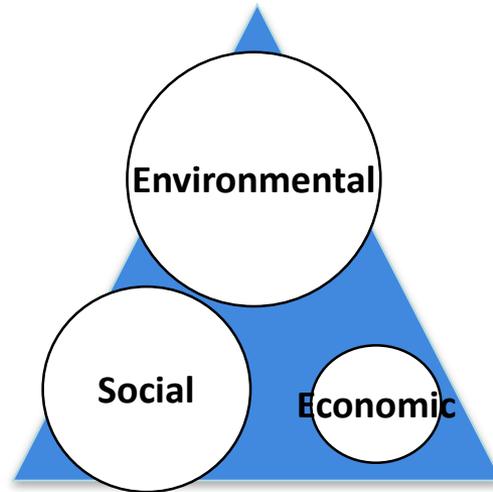


of profit
ction

mental

Economic

Focus on conviction



FINDING BALANCE BETWEEN CONVICTION AND PROFIT

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“Innovative business models and products must work **financially**, or it won’t matter how good they are ecologically and socially.” -Senge

f profit
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mental

Economic



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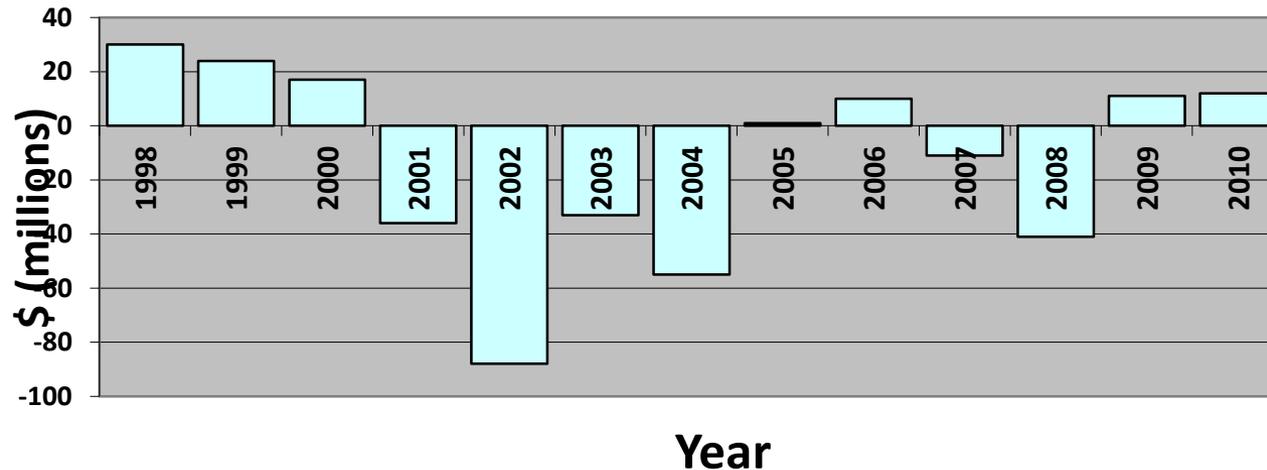
www.greenchemistry.org



“Ultimately there is only one bottom line.”

- Ben Packard, former VP of Global Responsibility, Starbucks

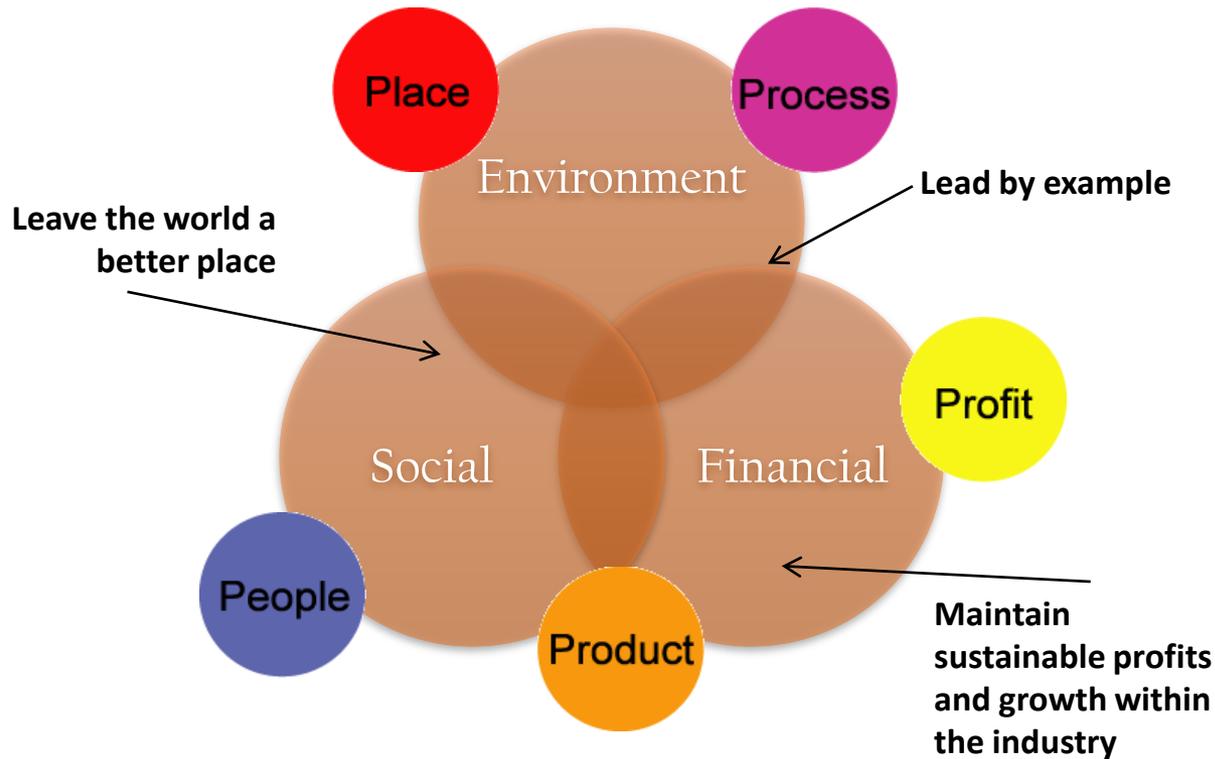
Interface Net Income



“But for those who think that business exists to make a profit, I suggest they think again. Business makes a profit to exist.” -Anderson



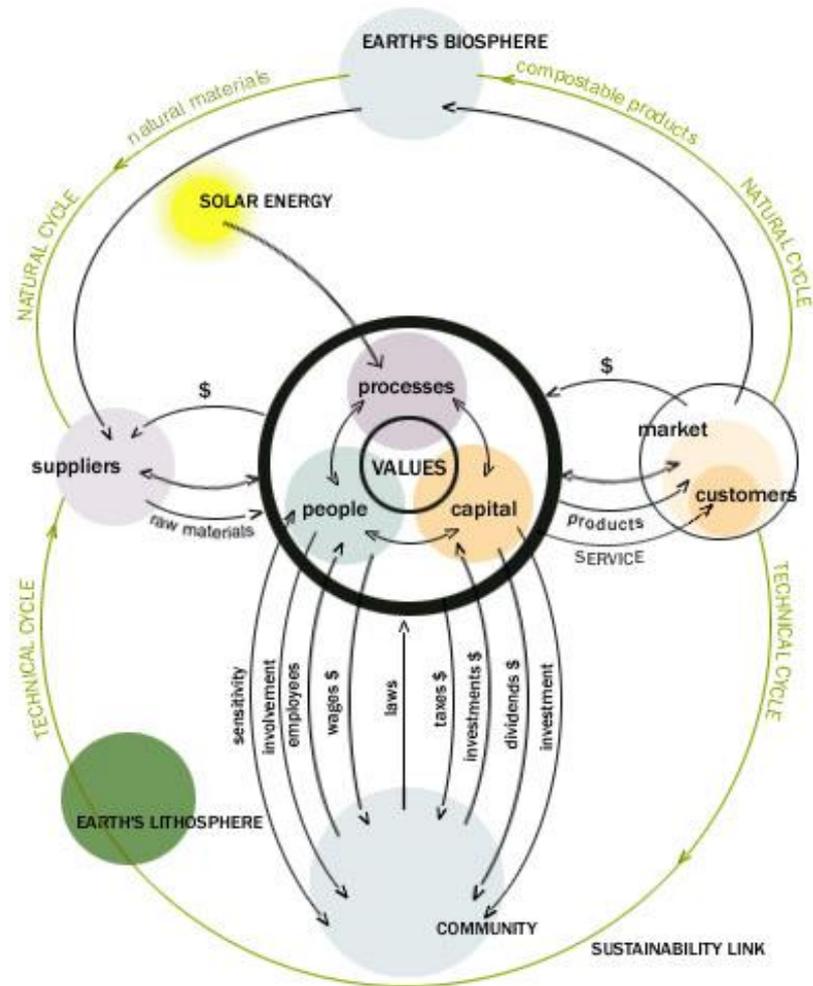
The Ingredients of Prototypical 21st Century Success



www.bankalleasing.org



THE INTERFACE MODEL Prototypical Company of the 21st Century



CASE STUDY: THE INTERFACE COMPANY

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“The choice between conviction and profits is a false choice; more creativity is required.”

-Ray Anderson



www.interface.com



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- What sustainable practices are incorporated in your company?
- Is there a room for improvement?
- How can YOU contribute to sustainability within your organization and what can these contributions be?

- How successful would the Interface model be at your organization?
- Do you have to sacrifice some profit to become a sustainable company?



- The act of misleading consumers regarding practices of a company or the environmental benefits of a product or a service.
- Deceptive use of Green Marketing, or claiming to do good and doing the opposite.

OTHER GREEN WASHING PHRASES TO CONSIDER

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- ❑ Cruelty free, bio, eco, carbon neutral, earth-friendly, true green

www.rhenkullensing.org



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REASONS COMPANIES USE GREEN WASHING



- Using Green Wave for Profit
 - Consumers are likely to buy green products or services and because many consumers can't tell if the product claim is true.
- Keeping with the Green Trend
 - To show competitive advantage over the competitor.
- Public Relations

www.rheinkolleg.de



COMMON FEATURES OF GREEN WASHING

- Suggestive pictures
- Irrelevant claims
- Hidden trade-offs
- Green product
- Distraction from the greater impact made by the product



- Better regulation
- Certifications
- Consumer awareness
- Reporting green washing



Cradle to Grave
Cradle to Shelf

Comprehensive Evaluation of Impact

www.riskalliance.org



- ❑ Two attributes make LCA distinct and useful as an analytical tool:
 - Whole system consideration of the total product life-cycle.
 - Presentation of tradeoffs among multiple environmental issues.

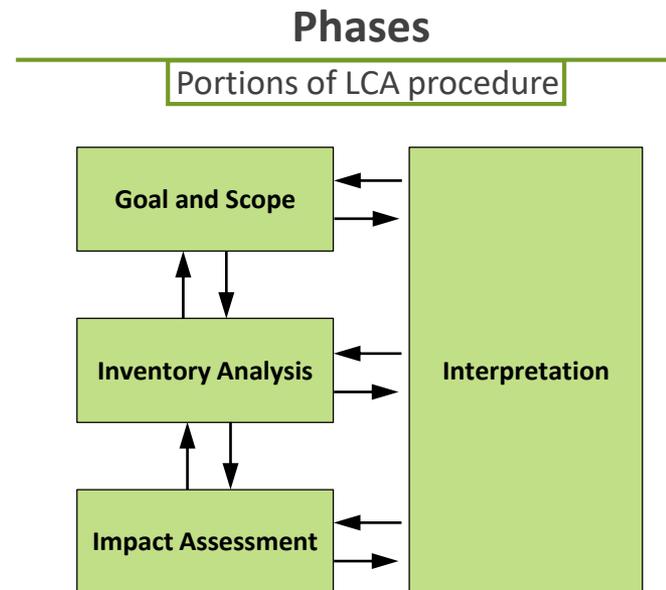
- ❑ LCA is quantitative (within limits)

THE FOUR STEPS OF AN LCA



- ❑ Goal and Scope Definition (**ISO 14040**)
- ❑ The Life-Cycle Analysis (**ISO 14041**) - What are the energy, raw materials, emissions, and wastes? What data is needed?
- ❑ Life-Cycle Impact Assessment (**ISO 14042**) - Assess environmental impacts identified in the life-cycle inventory.
- ❑ Life-Cycle Improvement - (**ISO 14043**) Identify opportunities to reduce the environmental impacts by modification of the life-cycle inventory.

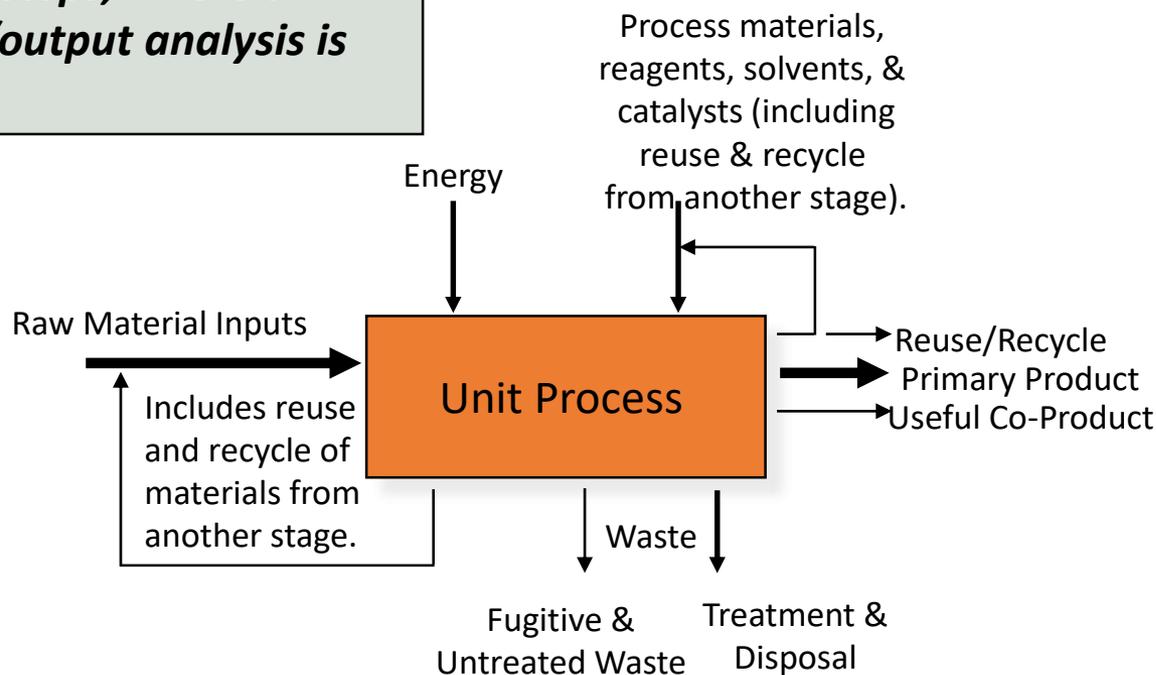
ISO1400 link provided for reference only.



- ❑ ISO is an independent, non-governmental international organization with a membership of 162 national standards bodies.
- ❑ It is an organization setting international standards.
- ❑ ISO also publishes technical reports, technical specifications, publicly available specifications and guides.



Each process is subdivided into the unit processes/steps, where a detailed input/output analysis is conducted.





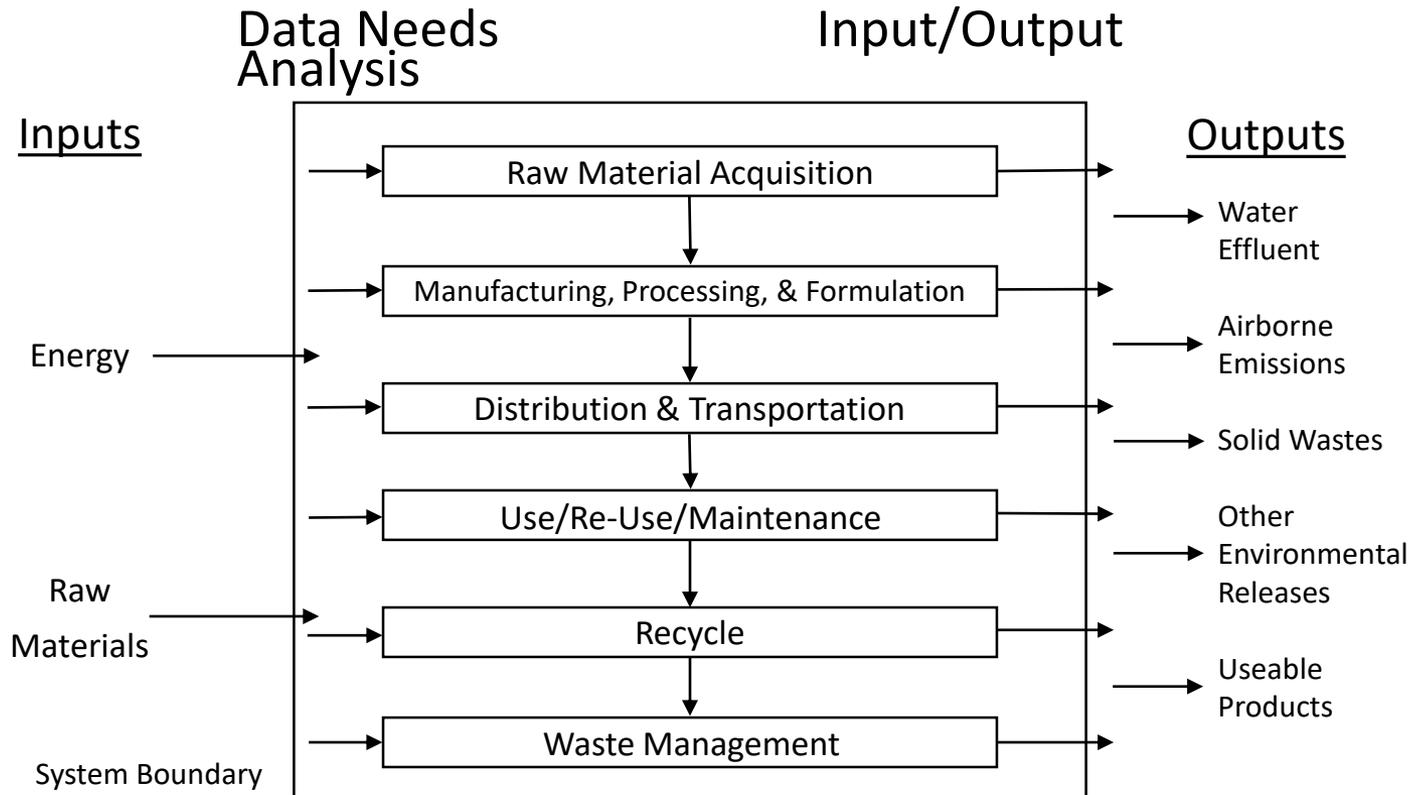
ISO 14040 contains general information on:

- a. Goal and scope of LCA
 - b. LCI phase
 - c. LCIA phase
 - d. Interpretation phase
 - e. Reporting and critical review
 - f. Limitations
 - g. Relationship between phases
 - h. Conditions for use of value choices and optional elements
- Phases of an LCA

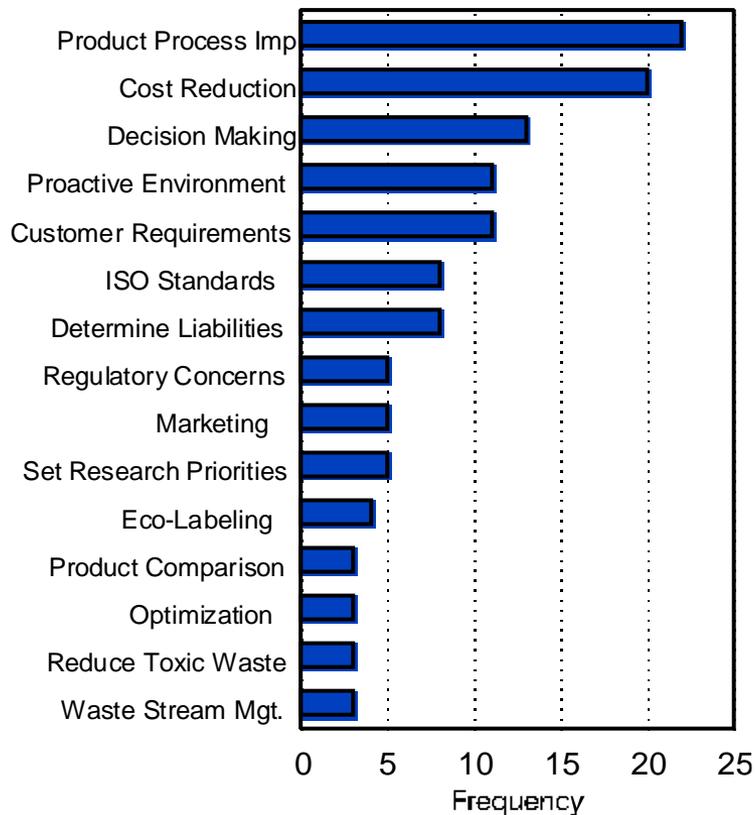
Normative references: Need to use 14044 to apply 14040



An input/output analysis is required for each process.



MOTIVATIONS FOR IMPLEMENTING LCA



LIFE-CYCLE ANALYSIS HELPS AVOID SHIFTING THE ISSUES

- ❑ Looking at the entire life-cycle helps ensure reducing waste at one point does not simply create more waste at another point in the life-cycle.
- ❑ **Issues may be shifted** – intentionally or inadvertently – among:
 - Processes or manufacturing sites
 - Geographic locale
 - Different budgets and planning cycles (first cost)
 - Environmental media – air, water, soil (MTBE)
 - Sustainability dimension: economic, social, environmental burdens
- ❑ Depends on “boundaries”
- ❑ Be conscious of what is shifted and where!



Goal

Goal statement is the first component of an LCA and guides much of the subsequent analysis

Goal must state:

- Intended use
- Reasons for study
- Audience
- Whether comparative and disclosed to public

Scope

Scope provides background information, details methodological choices, and lays out report format

Scope includes:

- Product system
- Functions of systems
- Functional unit
- System boundary
- Allocation procedures
- Impact categories, assessment method and interpretation type

- Data requirements
- Assumptions
- Limitations
- Initial data quality requirements
- Type of critical review, if any
- Type and format of report



Life Cycle Inventory (LCI) Phase

Data collection

As much input and output data as possible is collected

Can be presented in report or kept private, if confidentiality agreements warrant

Useful for other researchers that could use that data

Life Cycle Impact Assessment (LCIA) Phase

Conversion of inventory data into environmental impact potentials

Impact categories, indication, and characterization models are chosen

Data are grouped based on potential to cause certain environmental impacts (classification)

Input and output quantities converted to potential impacts based on characterization factors (characterization)

Optional steps: Normalization, grouping, weighting

Continually ongoing during assessment to help guide other phases.

Discussion of inventory analysis and impact assessment results in LCA study.

- In an LCI study, only inventory needs to be discussed.

Can be modeled as **conclusions and recommendations** to the decision maker.

Should be consistent with and **based on goal and scope** of the study.

Should **reflect the various uncertainties** inherent in LCA including:

- LCA is based on a relative approach using a functional unit.
- Impacts are “potential”.

❑ Possible Goal:

- Is an electric car greener than a combustion engine vehicle?

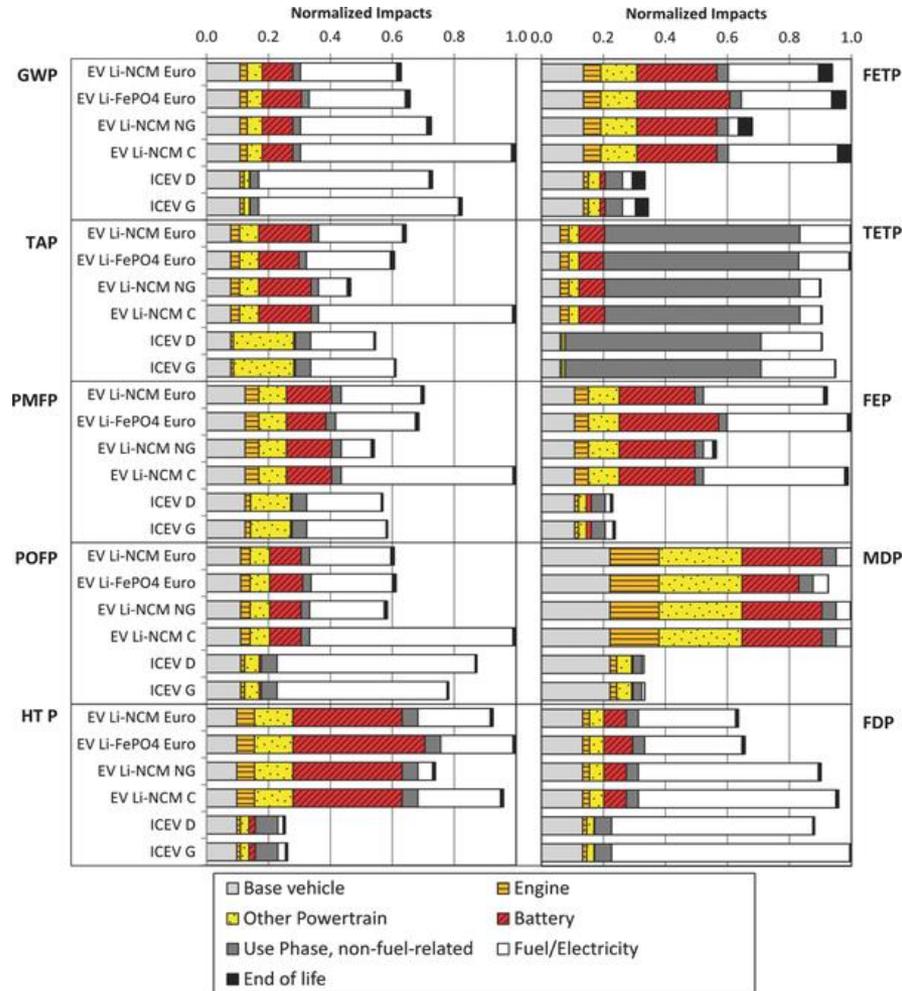
❑ Possible Scope:

- Do analysis on environmental damage and human toxicity.

❑ Output:

- Global warming (GWP), terrestrial acidification (TAP), particulate matter formation (PMFP), photochemical oxidation formation (POFP), human toxicity (HTP), freshwater eco-toxicity (FETP), terrestrial eco-toxicity (TETP), freshwater eutrophication (FEP), mineral resource depletion (MDP), fossil resource depletion (FDP).

COMPARATIVE ENVIRONMENTAL LIFE CYCLE ASSESSMENT OF CONVENTIONAL AND ELECTRIC VEHICLES



ICEV = internal combustion engine vehicle

EV = electric vehicle

LiNCM = lithium nickel cobalt manganese

LiFePO₄ = lithium iron phosphate

PbA = lead acid

The study compares 4 electric cars (with different batteries) and 2 conventional cars in terms of environmental impact

Journal of Industrial Ecology

Volume 17, Issue 1, pages 53-64, 4 OCT 2012 DOI: 10.1111/j.1530-9290.2012.00532.x

<http://onlinelibrary.wiley.com/doi/10.1111/j.1530-9290.2012.00532.x/full#jiec532-fig-0001>





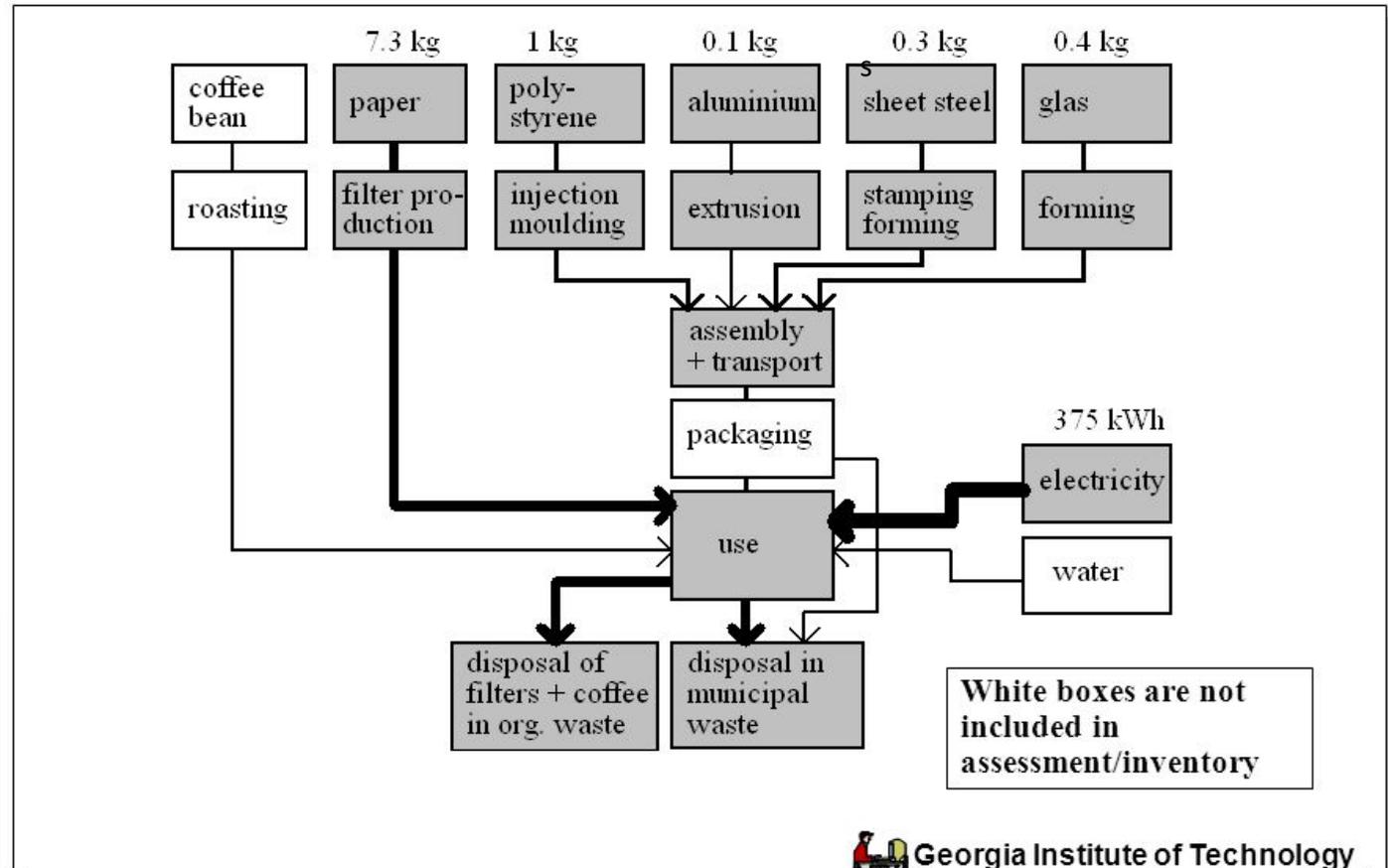
- ❑ Electric cars powered by the present European electricity mix offer a 10% to 24% decrease in global warming potential relative to conventional diesel or gasoline vehicles
- ❑ Electric cars exhibit the potential for significant increases in human toxicity, freshwater eco-toxicity, freshwater eutrophication, and metal depletion impacts, largely emanating from the vehicle supply chain (energy consumption, battery replacement)

- ❑ Recommendation:

Improving the environmental profile of electric cars requires engagement around reducing vehicle production supply chain impacts and promoting clean electricity sources in decision making regarding electricity infrastructure.



Example: Coffee Machine Life-Cycle Inventory





- Not a complete assessment of all environmental issues because only those identified in the goal and scope are considered.
- LCI can rarely, if ever, include every single process and capture every single input and output due to system boundaries, data gaps, cut-off criteria, etc.
- LCI data collected contains uncertainty.
- Characterization models are far from perfect.
- Sensitivity and other uncertainty analyses are not fully developed.



- ❑ Necessary component for comparative studies disclosed to the public.
- ❑ Verifies process and consistency with principles.
 - Not an endorsement.
 - Does not verify or validate goals.
- ❑ Can improve credibility of study.
- ❑ Critical review process is defined in the goal and scope.
- ❑ Requires external independent chair person and at least two other members.



Image: shenandoahchiropractic.com



- Systematic procedure for environmental assessment through product or process life cycle.
- Functional unit basis for comparisons differs from many other environmental management techniques.
- Amenable to data confidentiality needs and proprietary matters.
- Open to updates based on new science and developing techniques.
- Not overly restrictive.
- Impacts identified are all expressed as **potential**.
- LCIA converts LCI results to environmental issues based on characterization factors.
- Systematic approach to identify, check, evaluate, and present information based on goal and scope.
- Iterative process with continual interpretation.
- May link to other environmental management techniques.

Note: Features identified are based on those put forth in ISO 14040:2006





- 1) Use the Input-Output (Embodied Energy & Operating Energy) Quick tool to estimate energy resulting from production of product.
 - a. Use economic activity to derive estimates of materials and energy resources required for that activity, as well as the resulting environmental emissions.
 - b. Online Tool : <http://www.eiolca.net>
 - c. Task: Estimate Embodied energy and emissions associated with manufacturing of an automobile verses a bicycle.
 - i. Use the database – look into energy use for us 2002.
 - 1.Total energy TJ/1million \$ (scale for 1 car worth \$35000).
 - 2.Look at greenhouse gas emissions.
 - 3.Compare automobile and a bicycle.



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Topics To Be Covered

1. Sustainability – Myths and Facts
2. Society, Economy, and the Environment
3. Business and Sustainability
 - Applying Green Chemistry to Management
4. Different Models of Sustainability
5. Case Study: The Interface Company
6. Green Washing
7. Life-Cycle Assessment



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THANK YOU!
QUESTIONS?

This training material was developed in close collaboration with the **Center for Green Chemistry and Green Engineering** at Yale University.

www.greenchemistry-toolkit.org