Sustainability

Sustainability is often on people’s lips nowadays. Everybody seems to have an idea of what it means, and yet it is an elusive concept. Before giving some definition, let us search for what it includes.

For one, sustainability is about the future, making sure that humanity does not follow a path to crisis and doom. We need to take responsibility for our actions toward future generations, and with this responsibility comes a moral imperative. In other words, sustainability is a good to be sought, and not just for us but also for our children and beyond.

Sustainability is also about the environment. None of our activities would be sustainable if it led to environmental demise. So, in sustainability is contained another responsibility, that toward nature. It includes operating within the limits imposed on us by the environment.
Assembling the pieces, we see that the concept of Sustainability implicates our actions, future generations, the environment, responsibility, and limits.

The challenge before us is to identify, and engage in, those responsible actions that make the environment an integral part of our economy and respect environmental limits, so that we and future generations can continue to live on this spaceship called Earth.

My favorite definition of sustainability:

"Sustainability is the ultimate relation of action and consequence."
(Kirsten Childs, in Sustainable Architecture - White Papers, 2004)

Therefore,

“If we want things to stay as they are, things will have to change.”

Jules B. LaPidus, President of the Council of Graduate Schools in 1998 (said in a different context)

In other words, we have no choice. Something’s got to change!
Demand on resources

A thought to ponder...

On the eve of Indian independence, Mahatma Gandhi was interviewed by a British journalist, who asked him whether independent India could follow the British model of industrial development. Gandhi, in his famous response, said:

“It took Britain half the planet's resources to achieve its level of prosperity. How many planets would India require for its development?”

And, there is the “Factor 10”:

- Population is expected to double before it levels off → **Factor 2**
- If everybody in the world aspires to the American standard of living, the rate of resource consumption would have to quintuple (assuming constant ratio between economic activity and material consumption) → **Factor 5**

\[2 \times 5 = 10\]

Thus, one can expect a ten-fold increase in demand for resources. Yet, our mining activities already span the entire planet. So what should be done?

Definition of carrying capacity

"The maximum rate of resource consumption and waste discharge that can be sustained indefinitely in a given region without progressively impairing the functional integrity and productivity of the relevant ecosystems."

(Paul L. Bishop, in *Pollution Prevention: Fundamental and Practice*, 2000, page 574)
Starting with Carrying Capacity

For natural ecosystems, **Sustainability** can be defined as the **carrying capacity**, that is, the amount of use that can be sustained over time without degradation of the system.

A typical example is pasture land: Without fertilizer, a 40-hectare (100-acre) pasture can sustain no more than about 80 dairy cows. More cows would consume grass at a rate faster than soil can regenerate it by natural growth.

Exceeding the carrying capacity leads to a collapsed system, bare land and dead cows.

Two aspects of Sustainability

1) Not the same as **carrying capacity**.

Carrying capacity is a static concept that fits non-evolving or slowly-evolving ecological systems.

Human activities progress by successive inventions on a relatively short time scale. Problems due to excess are not generally solved by reduction but are most often overcome by new tools and new resources.

As the proverb goes: “Necessity is the mother of all inventions.” This leads to the concept of **Sustainable Development**.

2) Three-pronged approach.
Alternative illustration: A three-strand braid going on for ever

For how long?
Time

Profit
People
Planet

Yet, one more way of looking at the three ingredients:
as poles in tension

(Economic Factor)
(Sociocultural Factor)
(Environmental Factor)

(Adapted from Figure 1.1 of F. Giudice, G. La Rosa & A. Risitano, Product Design for the Environment, Wiley, 2006)
Achieving sustainability requires staying within the carrying capacity.

The big question is: What is the carrying capacity of Planet Earth?

There is unfortunately no direct answer. Planetary carrying capacity is nearly impossible to define because of human creativity. Past excesses have generally not been solved by reduction but most often by the invention of new technologies or use of new resources. In other words, instead of staying under the limits, we have constantly pushed the limits upward.

Examples
- The bronze age followed the stone not for lack of stones!
- It was predicted in the 1890s that New York City could not grow any larger because horse manure could not be removed from the streets any faster. (One New York prognosticator of the 1890s concluded that by 1930 the horse droppings would rise to Manhattan’s third-story windows.)

This lack of precise knowledge of planetary capacity leads to the concepts of Ecofootprint and Sustainable Development, to supersede Sustainability as a static concept.

Ecological Footprint

How do we know whether we are operating within the carrying capacity of our ecosystem Earth? One way to find out is to see how much we use and compare it to what is available. In doing so, we face an immediate problem, for we use all kinds of different things, air, water, foods of many types, metals, and on and on.

How can we sum all these apples and oranges?

The ecological footprint is a way to systematize the computation. It reduces all our consumption to the land surface that is needed to produce it. For example,

- The footprint associated with frequent eating of meat that is locally grown is 1.32 hectares (3.26 acres), more for meat that needs to be shipped in from some distance away,

- Driving an average car for 240 km (150 miles) per week is equivalent to 0.88 hectares (2.16 acres), counting where the materials came from to manufacture the car, the share of highway and parking spaces, where the fuel comes from, etc.
If we divide the total productive surface on the earth by the population, we arrive at 1.84 hectares (4.7 acres) per person. Anybody who uses more is either depriving someone else or contributing to irreversible damage on Earth.

Footprints of individuals, groups and even nations have been calculated. A finding is that the wealthier the group, the larger the footprint. This is because wealth and consumption are closely related. The general rule is that people in industrialized nations consume 5 to 10 times more than people in poor countries.

See how you are doing...

http://www.ecologicalfootprint.org/Global%20Footprint%20Calculator/GFPCalc.html

http://footprint.wwf.org.uk/
Oooooooooooooooooooooooooooooooooooops!

[Ecological Footprint Chart]

WWF International. Living Planet Report 2006
http://www.panda.org/lpr/7/living_planet_report/index.htm

(http://www.footprintnetwork.org/gfn_sub.php?content=maps)
Sustainable Development

Because sustainability is so hard to define in the presence of human progress, we can approach the concept by not defining *Sustainability* per se but *Sustainable Development*.

In 1987, the Brundtland Commission -- named for its chairwoman, Gro Harlem Brundtland, then Prime Minister of Norway, was one of several unofficial international entities which prepared the way for the U.N. Conference on Environment and Development held in Rio de Janeiro in 1992. It made the claim:

"Humanity has the ability to make development sustainable -- to ensure that it meets the needs of the present without compromising the ability of future generations to meet their own needs."

In this definition, which sounds more like a declaration, note the words:

"has the ability" → reflects optimism, even certainty.

"needs" (twice) → refers to necessities of life, such as shelter, food and basic health care, not whims and wants.

"compromising" → there are limits.

What Sustainable Development entails

Like sustainability, sustainable development can mean different things to different people. There is no universally accepted definition, but the following elements are regarded by essential by most people.

1. Systems view – Integrative approach
2. Environment alongside social welfare and the economy (Triple Bottom Line)
3. Recognition of limits
4. Regenerative systems – Waste of a process to become food for another
5. Use of planetary resources at a rate below regeneration
6. Local production to the extent possible
7. Long-term view – Obligation to future generations
8. Precautionary approach
9. Respect of biological and cultural diversity
10. Social equity
So, the goal is to achieve Sustainability.

But how?

Nature shows us a way: Natural Ecosystems are sustainable.

IDEA: Let’s try to imitate nature and strive to make our industrial systems work in the manner of natural systems.

In other words, let’s engage in **Biomimicry** (imitation / copying of nature).

This is the objective of Industrial Ecology, to render our industrial systems sustainable by making them obey the laws of nature.

Note that Industrial Ecology is one way of working toward Sustainability. There is no proof that it is the only way. For example, the Clinton White House and the US Business Council for Sustainable Development have advocated “eco-efficiency”, meaning “adding maximum value with minimum resource use and minimum pollution.” William McDonough has criticized this approach as “getting better at doing the wrong thing.”

Nature consists of a number of systems called “spheres”:

- The atmosphere (air and what is in it)
- The hydrosphere (water in its liquid form)
- The lithosphere (land, rocks and below)
- The biosphere (all the living organisms)

To this, we now add the anthroposphere, the human system, which includes:

- The built environment (buildings, roads, and other infrastructure)
- Agriculture (also called the Primary Sector)
- The manufacturing industry (also called the Secondary Sector)
- The service industry (also called the Tertiary Sector)
- Energy production infrastructure (power plants)

This anthroposphere includes:

- Materials (raw materials, processed materials, products, solid waste)
- Energy consumption (fossil fuels, nuclear, renewable forms of energy)
- Information (knowledge, inventions, communications, etc.) Each bound by a conservation principle, unlimited supply and growing
Let’s now contrast the way our present industrial systems behave in comparison with natural systems. In other words, we ask the question:

How far are we from having sustainable systems?

List characteristics of natural systems (at least 5 attributes).
Then list the corresponding characteristics of our industrial systems.

**Natural Systems:**
- No waste – Closing of materials loops
  The waste of a process is the food of another activity
- Materials are metabolized
- Use of energy at low temperatures, near thermodynamic reversibility; parcimonious use of energy
- No central control
- Great diversity of species and redundancy
- Nonlinearities in behavior (live or die)

**Industrial Systems:**
- Much waste – Few materials loops closed
  Many resources are extracted from the environment and degraded forms of materials are returned to the environment
- Materials undergo transformations
- Use of energy at high temperatures, away from thermodynamic reversibility; inefficient use of energy
- Weak central control
  (free market tempered by some regulations)
- Moderate diversity of activities and redundancy (competition)
- Nonlinearities in behavior
  (make a profit or go out of business)
How natural ecosystems work

Either looking at a single substance

Or looking at populations

A typical industrial system

Example

Generic view

... a one-way, open system!
A progressive path toward a sustainable industrial system

What imitation of nature should look like

A product's life cycle from cradle to reincarnation.
... and industry may be intertwined with nature, as is already the case for Sulfur.

A natural ecosystem:

Usually quite complex and with many actors and relations

What about industry?

How do industrial systems compare to natural systems?
A better industrial system

Connectance level $C$:

$$C = \frac{\text{number of actual links}}{\text{total possible number of links}} = \frac{L}{S(S-1)/2} = \frac{2L}{S(S-1)}$$

$L = \text{number of links}$  
$S = \text{number of species}$

A diagrammatic representation of an industrial food web. In this diagram, each box represents one of 15 different waste disposal companies. Each box contains a single label for these transactions. The magnitude of the flows is captured on this diagram. All flows and from the point of view of the industrial actors are not shown in this diagram, nor are flows connecting to air, water, and food. (Reproduced with permission from A.S. Sager and R.A. Freck, A perspective on industrial ecology and its application to a social-engineering example, Journal of Cleaner Production, 3, 35-35, 1995.)

Box plots of connectance in different types of food webs. BIO = 113 biological food webs; IND = 19 industrial food webs, consisting of 15 eco-industrial parks (EIP) and 4 integrated biosystems (IBS). (Biological data are from F. Briand and J.E. Cohen. Environmental correlates of food chain length, Science, 238, 956-960, 1987; industrial data are from C. Hardy and T.E. Graedel. Industrial ecosystems and food web theory. Journal of Industrial Ecology, 6, in press, 2003.)
THE BASIS OF INDUSTRIAL ECOLOGY

The Four Laws of Ecology
(Barry Commoner, 1971, 33-48)

1. Everything is connected to everything else.
2. Everything must go somewhere.
4. There is no such thing as a free lunch.

The equivalent of Commoner's "laws" for sustainability in industry are:

Eco-Industrial Principles and Industrial Ecology

1. Industry is an interrelated system of extraction, production, distribution, consumption and disposal.
2. Industrial production must be subject to "life-cycle analysis" so as to identify materials pathways (Industrial Metabolism).
3. The natural world is a source of models of efficiency and of renewable energy and resources.
4. Finite resources must be returned, recycled, reclaimed and/or reused in order to close materials cycles and minimize energy consumption.

Implications of Sustainability for Industrial Ecology

1. Not using renewable resources faster than they are replenished
2. Not using non-renewable, non-abundant resources faster than substitutes can be found.
3. Not releasing waste faster than the planet can assimilate them.
4. Not significantly depleting the diversity of life on the planet.

"The fundamental task of Industrial Ecology is to ... match the inputs and outputs of the man-made world to the constraints of the biosphere."

"The economy is a subsystem of the biosphere, not the other way around."
(David Orr, "Shelf Life", Conservation Biology, Volume 23, No. 2, 2009, quoting Herman Daly)
More definitions of INDUSTRIAL ECOLOGY

1. Improving metabolic pathways (ex: less solvent)
2. Dematerializing the output (ex: lighter product)
3. Systematizing patterns of energy use
4. Balancing industrial in/output with natural capacity
5. Creating loop-closing practices
6. Aligning policy
7. Creating new structures and new linkages

Lowe (1993):
IE = recognition that industrial systems are natural systems
IE’s toolbox:
1. Toward zero waste
2. Design for Environment (DFE)
3. Industrial metabolism (IM) [*big-view approach to materials/energy flows]
4. Management at the industry/nature interface
5. Creation and exploitation of information

Frosch (1994):
IE = force to change from a linear-open system toward a cyclical-closed system
Barriers to IE:
1. Technical hurdles
2. Insufficient information
3. Organizational obstacles
4. Regulatory issues and legal concerns

Graedel & Allenby (1995):
"Industrial Ecology is the science of Sustainability."
1. Optimization of resources (less consumption, less waste)
2. Optimization of energy
3. Optimization of capital (human and monetary)

O’Rourke, Connelly & Koshland (1996):
2 principal goals in IE:
1. Closing loops
2. Paradigm shift (in our view of industry/nature relation)
2 strategies in IE:
1. Getting the information right (ex: LCA, ecofeedback)
2. Getting the price right (ex: Total cost accounting)

Massachusetts Institute of Technology (MIT) architects developed the ultimate tree house – a very unique home that is built from 100% living nutrients including soy-based plastic windows. The building utilizes gray water biological filtration, and the sun for both ventilation and hot water.