



Concepts and Elements of Industrial Ecology

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First Edition, 2012

ISBN 978-81-323-3730-0

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Published by:
University Publications
4735/22 Prakashdeep Bldg,
Ansari Road, Darya Ganj,
Delhi - 110002
Email: info@wtbooks.com

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Chapter- 1

History of Industrial Ecology

The birth of industrial ecology is commonly attributed to an article devoted to industrial ecosystems, written by Frosch and Gallopoulos, which appeared in a 1989 special issue of Scientific American. But the field's fundamentals appeared much earlier. Industrial Ecology emerged out of several ideas and concepts, some of which date back to the 19th century.

Industrial Ecology before the '60s

The term "Industrial Ecology" has been used along-side "Industrial Symbiosis" since the 1940s. Economic geography was perhaps one of the first fields to use these terms. One of the oldest appearances of the term is found in a 1947 article by George T. Renner, who refers to "The General Principle of Industrial Location" as a "Law of Industrial Ecology". Briefly stated this is:

"Any industry tends to locate at a point which provides optimum access to its ingredients or component elements. If all these component elements be juxtaposed, the location of the industry is predetermined. If, however, they occur widely separated, the industry is so located as to be most accessible to that element which would be the most expensive or difficult to transport and which, therefore, becomes the locative factor for the industry in question."

In the same article we defines and describes industrial symbiosis:

"Often the location of an industry cannot be fully understood solely in terms of its locative ingredient elements. There are relationships between industries, sometimes simple, but often quite complex, which enter into and complicate the analysis. Chief among these is the phenomenon of industrial symbiosis. By this is meant the consorting together of two or more of dissimilar industries. Industrial Symbiosis, when scrutinized, is seen to be of two kinds, disjunctive and conjunctive."

It appears that the concept of Industrial Symbiosis was not new for the field of economic geography, since the same categorization is used by Walter G. Lezius in his 1937 article

"Geography of Glass Manufacture at Toledo, Ohio" published also in the journal of Economic Geography .

The term Industrial Ecology can also be found in a 1958 paper concerned with the relationship between ecological changes caused by increased urbanization, and the value orientations of the people undergoing these changes. The case study is in Lebanon :

"The central ecological variable in the present research is ecological mobility, or the movement of men in space. It is patent that modern Industrial Ecology requires more such adaptive mobility than does traditional folk-village organization."

Industrial Ecology in the '60s

In 1963, we find the term Industrial Ecology (defined as the "complex ecology of the modern industrial world") being used to describe the social nature and complexity of (and within) industrial systems :

"...industrial organisations are social rather than mechanical systems. A firm is not only a working organisation with a working purpose. It is rather a community with its own 'politics', in so far as it is involved in problems concerned with the proper distribution of power between individuals and groups of individuals and with questions of individual and group prestige, influence, status and standing... [and he concludes that] the understanding which the student of management is expected to gain is no less than the attainment of insight into an Industrial Ecology of great complexity."

In 1967, the President of the American association for the advancement of science writes in "The experimental city" that *"There are examples of industrial symbiosis where one industry feeds off, or at least neutralizes, the wastes of another..."* The same author in 1970 talks about "The Next Industrial Revolution" The concept of material and energy sharing and reuse is central to his proposal for a new industrial revolution and he cites agro-industrial symbiosis as a practical way for achieving this:

"The object of the next industrial revolution is to ensure that there will be no such thing as waste, on the basis that waste is simply some substance that we do not yet have the wit to use... The next industrial revolution is this generating of a huge new [industry that]... will not produce products, it will rather reprocess the things we call wastes so they may be reproduced in the factories into the things we need... Having the city near the rural area will enable waste heat to be used to speed up the biological processes of treating the organic wastes before they go back into the land. This might end in an elegant arrangement-the power plants located close enough to the center of use, to the people who need the power, but also, within the economics, close enough to the agriculture lands so that the waste heat may be used there. This is an example of agro-industrial symbiosis, if you like to call it that"

Notice that in these early articles, the term "Industrial Ecology" is not used to describe a concept or a practice or a research field. It is used in its literal sense - as a system of interacting industrial entities. The relation to natural ecosystems (through either metaphor or analogy) is not explicit. Industrial Symbiosis on the other hand, is already clearly defined as a type of industrial organization, and the term symbiosis is borrowed from the ecological sciences to describe an analogous phenomenon in industrial systems.

Industrial Ecology in the '70s

Industrial Ecology has been a research subject of the Japan Industrial Policy Research Institute since 1971. Their definition of Industrial Ecology is "research for the prospect of dynamic harmonization between human activities and nature by a systems approach based upon ecology (JIPRI, 1983)". This programme has resulted to a number of reports that are available only in Japanese.

One of the earliest definitions of Industrial Ecology was proposed by Harry Zvi Evan at a seminar of the Economic Commission of Europe in Warsaw (Poland) in 1973 (an article was subsequently published by Evan in the *Journal for International Labour Review* in 1974 vol. 110 (3), pp. 219–233). Evan defined Industrial Ecology as a systematic analysis of industrial operations including factors like: Technology, environment, natural resources, bio-medical aspects, institutional and legal matters as well as the socio-economic aspects.

In 1974 the term of Industrial Ecology is perhaps for the first time associated with a cyclical production mode (rather than a linear one, resulting to waste). Here, the necessity for a transition to an "open-world Industrial Ecology", is used as argument for the need to establish lunar industries :

"Low living standards provide one strong motive for most developing countries to increase their productivity and grow economically. Population increase (while it lasts) is a still more powerful driver for increased world consumption. Thus the pressure on resources will continue to grow. Instead of deploring it, we better grow with it. Only through transition to an open-world Industrial Ecology - which includes both benign industrial revolution on Earth and extraterrestrial industrialization - can the present apparent limits to growth be overcome."

Many elements of modern Industrial Ecology were commonplace in the industrial sectors of the former Soviet Union. For example, "kombinirovaniia produktsia" (combined production) was present from the earliest years of the Soviet Union and was instrumental in shaping the patterns of Soviet industrialization. "Bezotkhodnoyi tekhnologii" (waste-free technology) was introduced in the final decades of the USSR as a way to increase industrial production while limiting environmental impact. Fiodor Davitaya, a Soviet scientist from the Republic of Georgia, described in 1977 the analogy relating industrial systems to natural systems as a model for a desirable transition to cleaner production:

Nature operates without any waste products. What is rejected by some organisms provides food for others. The organisation of industry on this principle—with the waste products of some branches of industry providing raw material for others—means in effect using natural processes as a model, for in them the resolution of all arising contradictions is the motive force of progress.

Industrial Ecology in the '80s

By the 80s Industrial Ecology was already "promoted" to a research subject, which several institutes around the globe embraced. In a 1986 article published in the Journal of Ecological Modeling, there is a full description of Industrial Ecology and the analogy to natural ecosystems is clearly stated :

"The structure and inner-working of an industrial society resemble those of a natural ecosystem. The concepts in ecology such as habitat, succession, trophic level, limiting factors and community metabolism can also apply to the study of the ecology of an industrial society. For instance, an industry in a society may grow or decline as a consequence of dynamic changes in exogenous limiting resources and in the hierarchical and/or metabolic structure of that society. When studying the ecology of an industrial society (henceforth termed 'Industrial Ecology'), these concepts and methodologies employed in ecosystems analyses are useful."

In fact, in the above article there is an attempt to model an "industrial ecological system". The model is composed of seven major sections: industry, population, labor force, living state, environment and pollution, general health, and occupational health. Notice the rough similarity with Evan's factors as stated in the above section.

During the 80s the emergence of another related term, "Industrial Metabolism", is observed. The term is used as a metaphor for the organization and functioning of industrial activity . In an article defending the "biological modulation of terrestrial carbon cycle", the author includes an extraordinary parenthetical note :

"Parenthetically, it should be noted that it is an intrinsic property of life to proliferate exponentially until the encounter of limits set by (1) the availability of biologically utilizable reducing power, or (2) the exhaustion of some critical nutrient, or (3) an autotoxic effect imposed by life on its own environment. These limits are universal, applying to microbial ecosystems as well as to the population dynamics of a seemingly unrestricted biological superdominant such as Homo Sapiens (here, the ultimate limit is likely to be placed by an autotoxic effect exerted by the "extrasomatic" (industrial) metabolism of the human race)."

1989 – Industrial Metabolism and Strategies for Manufacturing

In 1989 two articles were released that played a decisive role in the history of industrial ecology. The first one was titled "Industrial Metabolism" by Robert Ayres. Ayres essentially lays the foundations of Industrial Ecology, although the term is not to be found here.

"We may think of both the biosphere and the industrial economy as systems for the transformation of materials. The biosphere as it now exists is nearly a perfect system for recycling materials. This was not the case when life on earth began. The industrial system of today resembles the earliest stage of biological evolution, when the most primitive living organisms obtained their energy from a stock of organic molecules accumulated during prebiotic times. It is increasingly urgent for us to learn from the biosphere and modify our industrial metabolism, the energy - and value - yielding process essential to economic development... we should not only postulate, but indeed endorse, a long-run imperative favoring an industrial metabolism that results in reduced extraction of virgin materials, reduced loss of waste materials, and increased recycling of useful ones."

The term "Industrial Ecology" gains mainstream attention later the same year (1989) through a "Scientific American" article named "Strategies for Manufacturing". Here, R.Frosch and N.Gallopoulos wonder "why would not our industrial system behave like an ecosystem, where the wastes of a species may be resource to another species? Why would not the outputs of an industry be the inputs of another, thus reducing use of raw materials, pollution, and saving on waste treatment?"

This vision gave birth to the concept of the Eco-industrial Park, the industrial complex that is governed by Industrial Ecology principles. A notable example resides in a Danish industrial park in the city of Kalundborg. There, several linkages of byproducts and waste heat can be found between numerous entities such as a large power plant, an oil refinery, a pharmaceutical plant, a plasterboard factory, an enzyme manufacturer, a waste company and the city itself.

Frosch's and Gallopoulos' thinking was in certain ways simply an extension of earlier ideas, such as the efficiency and waste-reduction thinking announced by Buckminster Fuller and his students (e.g., J. Baldwin), and parallel ideas about energy cogeneration, such as those of Amory Lovins and the Rocky Mountain Institute.

Industrial Ecology in the '90s

In 1991, C. Kumar Patel organized a seminal colloquium on Industrial Ecology, held on May 20 and 21, 1991, at the National Academy of Sciences in Washington D.C. The papers were later published in the Proceedings of the National Academy of Sciences USA, and they form an excellent reference on Industrial Ecology. Papers include "Industrial Ecology: Concepts and Approaches," "Industrial Ecology: A Philosophical

Introduction," "The Ecology of Markets," and "Industrial Ecology: Reflections on a Colloquium." All twenty three papers are available online.

Industrial Ecology in the 21st century

The scientific field Industrial Ecology has grown fast in recent years. The Journal of Industrial Ecology (since 1997), the International Society for Industrial Ecology (since 2001), and the journal Progress in Industrial Ecology (since 2004) give Industrial Ecology a strong and dynamic position in the international scientific community. Industrial Ecology principles are also emerging in various policy realms such as the concept of the Circular Economy that is being promoted in China. Although the definition of the Circular Economy has yet to be formalized, generally the focus is on strategies such as creating a circular flow of materials, and cascading energy flows. An example of this would be using waste heat from one process to run another process that requires a lower temperature. This maximizes the efficiency of exergy use. The hope is that strategy such as this will create a more efficient economy with fewer pollutants and other unwanted by products.

Chapter- 2

Design for the Environment

Design for the Environment Program (DfE) is a United States Environmental Protection Agency (USEPA) program, created in 1992, that works to prevent pollution, and the risk pollution presents to humans and the environment. The EPA DfE program provides information regarding safer electronics, safer flame retardants, safer chemical formulations, as well as best environmental practices. DfE employs a variety of design approaches that attempt to reduce the overall human health and environmental impact of a product, process or service, where impacts are considered across its life cycle. Different software tools have been developed to assist designers in finding optimized products (or processes/services).



US EPA's Design for the Environment Logo.

The three main goals of DfE are:

- Promoting green cleaning and recognizing safer consumer and industrial and institutional products through safer product labeling.
- Defining Best Practices in areas ranging from auto refinishing to nail salon safety.
- Identifying safer chemicals, including life cycle considerations, through Alternatives Assessment.

Design for Environment

There are three main concepts that fall under the Design for Environment umbrella:

- Design for environmental processing and manufacturing: This ensures that raw material [Resource extraction|extraction] (mining, drilling, etc.), processing (processing reusable materials, metal melting, etc.), manufacturing are done using materials and processes which are not dangerous to the environment or the employees working on said processes. This includes the minimization of waste and hazardous by-products, air pollution, energy expenditure, among others.
- Design for environmental packaging: This ensures that the materials used in packaging are environmentally friendly, which can be achieved through the reuse of shipping products, elimination of unnecessary paper and packaging products, efficient use of materials and space, use of [Recycling|recycled] and/or recycleable materials.
- Design for disposal or reuse: The [End-of-life (product)|end-of-life] of a product is very important, because some products emit dangerous chemicals into the air, ground and water after they are disposed of in a landfill. Planning for the reuse or refurbishing of a product will change the types of materials that would be used, how they could later be disassembled and reused, and the environmental impacts such materials have.

Life cycle assessment (LCA) is employed to forecast the impacts of different (production) alternatives of the product in question, thus being able to choose the environmentally most friendly. A life cycle analysis can serve as a very effective tool when determining the environmental impact of a product or process. Proper LCAs can help a designer compare several different products according to several categories, such as energy, toxicity, acidification, [Carbon dioxide|CO₂ emissions], ozone depletion, resource depletion, and many others. By comparing different products, a designer can make decisions about which environmental hazard he/she should focus on in order to make the product more environmentally friendly.

Safer Product Labeling Program

DfE certifies green cleaning products through its Safer Product Labeling Program. This program offers an opportunity to product manufacturers to partner with DfE and have their products certified by DfE criteria and standards. The DfE scientific review team

screens each ingredient in a cleaning product for potential human health and environmental effects based on the best currently available information, EPA predictive models, and expert judgment. DfE recognized products contain only those ingredients that pose the least concern among chemicals in their class. There are currently 2,000 DfE certified cleaning products.

Alternatives Assessment Program

In order to help industries choose safer chemicals for applications, DfE conducts Alternatives Assessments. This program brings together environmental organizations, industry leaders, academia, and others to evaluate the environmental and health impacts of potential alternatives to problematic chemicals. The program uses a variety of approaches to investigate safer chemistries. Life-cycle assessment can be conducted to understand the phases (e.g., production, use, and disposal) where industry can make changes to realize environmental and health benefits. DfE Hazard-based Alternatives Analyses evaluate the hazards posed by chemicals during relevant phases in the product life cycle. These approaches can be applied to identifying safer alternative chemicals for applications that now use priority chemicals of concern. The outcome of an Alternatives Assessments Partnership provides industry with the information they need to choose safer chemicals, as well as avoid unintended consequences of switching to a poorly understood substitute.

Best Practices Approach

DfE's Best Practices approach is designed to enhance the awareness of health and environmental concerns, minimize pollution, and protect workers and communities by promoting the use of safer alternative chemical products and cleaner, more efficient practices. After a chemical ingredient has been reviewed by a DfE Alternatives Assessment and no clear alternative is available, the industry is encouraged to use the Best Practices approach as formulated by DfE. Currently, there is a Best Practices approach for both the Automotive Refinishing industry and Spray Polyurethane Foam.

Ecodesign

Ecodesign is an approach to design of a product with special consideration for the environmental impacts of the product during its whole lifecycle. In a life cycle assessment the life cycle of a product is usually divided into procurement, manufacture, use and disposal.

Overview



Stainless Steel Table with FSC Teca Wood - Brazil Ecodesign

As the whole product life cycle should be regarded in an integrated perspective, representatives from advance development, design, production, marketing, purchasing and project management should work together on the ecodesign of a further developed or new product as they have together the best chance to predict the holistic effects of changes of the product and their environmental impact. Environmental aspects which ought to be analysed for every stage of the life cycle are:

- Consumption of resources (energy, materials, water or land area)
- Emissions to air, water, and the ground (our Earth) as being relevant for the environment and human health
- Miscellaneous (e.g. noise and vibration)

Waste (hazardous waste and other waste defined in environmental legislation) is only an intermediate step and the final emissions to the environment (e.g. methane and leaching from landfills are inventoried). Equally are all consumables, materials and parts used in the life cycle phases accounted and all indirect environmental aspects linked to their production.

Having made up a list on which phase of the life cycle has which particular environmental aspect, these aspects are evaluated according to their environmental

impact on the basis of a number parameters such as extend of environmental impact potential for improvement or potential of change.

According to this ranking the recommended changes are carried out and are reviewed after a certain time.

Environmental Effect Analysis



An electric wire reel reused like a center table in a Rio de Janeiro decoration fair. The reuse of materials is a very sustainable practice that is rapidly growing among designers in Brazil

One instrument to identify the factors that are important for the reduction of the environmental impact during all lifecycle stages is the Environmental Effect Analysis (EEA).

For an EEA the following are taken into account:

- Customers wishes
- Legal requirements, market requirements (competitors) and
- Data concerning the product and the manufacturing process

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Environmental design

Environmental design is the process of addressing surrounding environmental parameters when devising plans, programs, policies, buildings, or products. Classical prudent design may have always considered environmental factors; however, the environmental movement beginning in the 1940s has made the concept more explicit.

Environmental design can also refer to the applied arts and sciences dealing with creating the human-designed environment. These fields include architecture, city planning (or urban planning), landscape architecture, and interior design. Environmental design can also encompass interdisciplinary areas such as historical preservation and lighting design. In terms of a larger scope, environmental design has implications for the industrial design of products: innovative automobiles, wind-electricity generators, solar-electric equipment, and other kinds of equipment could serve as examples. Currently, the term has expanded to apply to ecological and sustainability issues.

History



The photo shows a training meeting with factory workers in a stainless steel ecodesign company from Rio de Janeiro, Brazil.

The first traceable concepts of environmental designs focused primarily on solar heating, which began in Ancient Greece around 500 BCE. At the time, most of Greece had exhausted its supply of wood for fuel, leading architects to design houses that would capture the solar energy of the sun. The Greeks understood that the position of the sun varies throughout the year. For a latitude of 40 degrees in summer the sun is high in the south, at an angle of 70 degrees at the zenith, while in winter, the sun travels a lower trajectory, with a zenith of 26 degrees. Greek houses were built with south-facing façades which received little to no sun in the summer but would receive full sun in the winter, warming the house. Additionally, the southern orientation also protected the house from the colder northern winds. This clever arrangement of buildings influenced the use of the grid pattern of ancient cities. With the North-South orientation of the houses, the streets of Greek cities mainly ran East-West.

The practice of solar architecture continued with the Romans, who similarly had deforested much of their native Italian Peninsula by the first century BCE. The Roman *heliocaminus*, literally 'solar furnace', functioned with the same aspects of the earlier Greek houses. The numerous public baths were oriented to the south. Roman architects added glass to windows to allow for the passage of light and to conserve interior heat as it could not escape. The Romans also used greenhouses to grow crops all year long and to

cultivate the exotic plants coming from the far corners of the Empire. Pliny the Elder wrote of greenhouses that supplied the kitchen of the Emperor Tiberius during the year.

Along with the solar orientation of buildings and the use of glass as a solar heat collector, the ancients knew other ways of harnessing solar energy. The Greeks, Romans and Chinese developed curved mirrors that could concentrate the sun's rays on an object with enough intensity to make it burn in seconds. The solar reflectors were often made of silver, copper or polished brass.

Early roots of modern environmental design began in the late 19th Century with writer/designer William Morris, who rejected the use of industrialized materials and processes in wallpaper, fabrics and books his studio produced. He and others, such as John Ruskin felt that the industrial revolution would lead to harm done to nature and workers.

The narrative of Phil Cousineau's documentary film *Ecological Design: Inventing the Future* asserts that in the decades after World War II, "The world was forced to confront the dark shadow of science and industry." From the middle of the twentieth century, thinkers like Buckminster Fuller have acted as catalysts for a broadening and deepening of the concerns of environmental designers. Nowadays, energy efficiency, appropriate technology, organic horticulture and agriculture, land restoration, New Urbanism, and ecologically sustainable energy and waste systems are recognized considerations or options and may each find application.

By integrating renewable energy sources such as solar photovoltaic, solar thermal, and even geothermal energy into structures, it is possible to create zero emission buildings, where energy consumption is self-generating and non-polluting. It is also possible to construct "energy-plus buildings" which generate more energy than they consume, and the excess could then be sold to the grid. In the United States, the LEED Green Building Rating System rates structures on their environmental sustainability.

Examples

Examples of the environmental design process include use of roadway noise computer models in design of noise barriers and use of roadway air dispersion models in analyzing and designing urban highways. Designers consciously working within this more recent framework of philosophy and practice seek a blending of nature and technology, regarding ecology as the basis for design. Some believe that strategies of conservation, stewardship, and regeneration can be applied at all levels of scale from the individual building to the community, with benefit to the human individual and local and planetary ecosystems.

Specific examples of large scale environmental design projects include:

- Boston Transportation Planning Review

- BART - Bay Area Rapid Transit System Daly City Turnback project and airport extension.
- Metropolitan Portland, Oregon light rail system

Chapter- 3

Cradle to Cradle Design

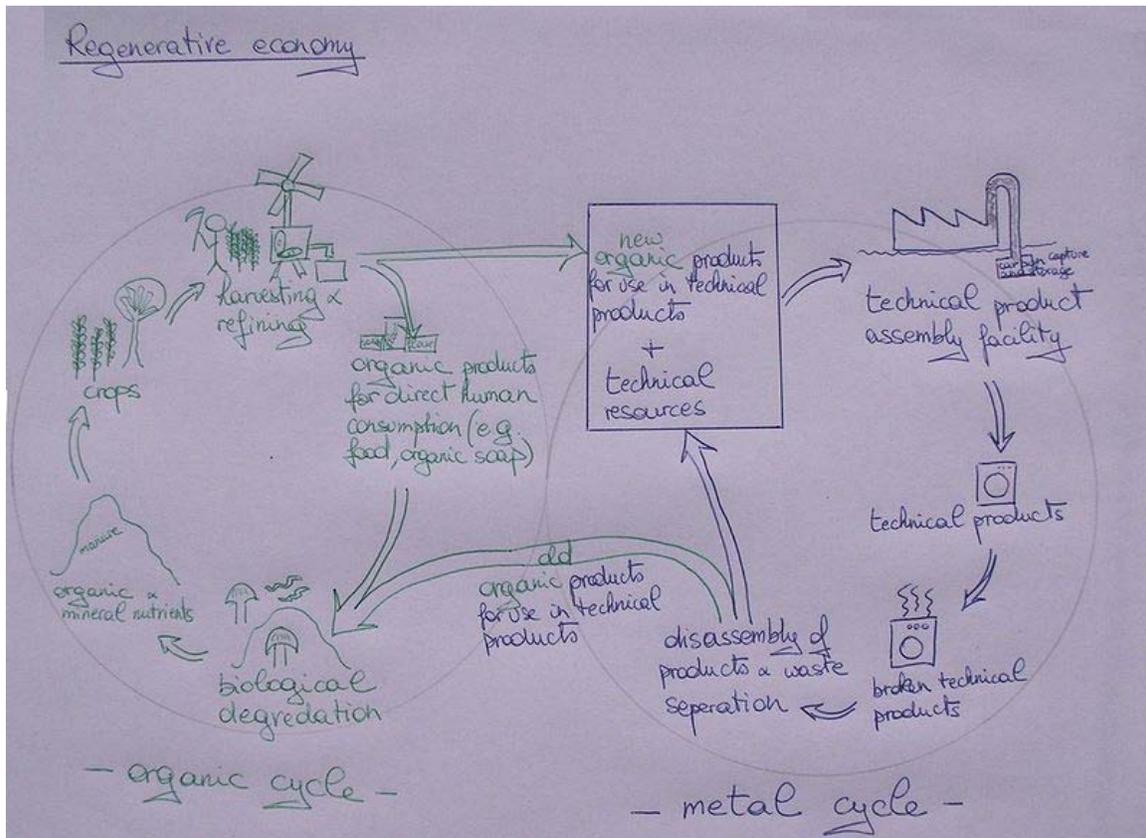
Cradle to Cradle Design (sometimes abbreviated to **C2C**, or **Cradle 2 Cradle**, or in some circles referred to as regenerative) is a biomimetic approach to the design of systems. It models human industry on nature's processes in which materials are viewed as nutrients circulating in healthy, safe metabolisms. It suggests that industry must protect and enrich ecosystems and nature's biological metabolism while also maintaining safe, productive technical metabolism for the high-quality use and circulation of organic and synthetic materials. Put simply, it is a holistic economic, industrial and social framework that seeks to create systems that are not just efficient but essentially waste free. The model in its broadest sense is not limited to industrial design and manufacturing; it can be applied to many different aspects of human civilization such as urban environments, buildings, economics and social systems.

The term 'C2C Certification' is a protected term of the McDonough Braungart Design Chemistry (MBDC) consultants. It is a proprietary system of certification. The phrase "Cradle to Cradle" itself was coined by Walter R. Stahel in the 1970s, and the current model is based on a system of "lifecycle development" initiated by Michael Braungart and colleagues at the Environmental Protection Encouragement Agency (EPEA) in the 1990s and explored through the publication *A Technical Framework for Life-Cycle Assessment*. In partnership with Braungart, William McDonough released the publication *Cradle to Cradle: Remaking the Way We Make Things* in 2002, which is an effective manifesto for Cradle to Cradle Design that gives specific details of how to achieve the model. The model has been implemented by a number of companies, organisations and governments around the world, predominantly in the European Union, China and the United States. Cradle to Cradle has also been the subject matter of many documentary films, including the critically acclaimed *Waste=Food*.

Introduction

In the Cradle to Cradle model, all materials used in industrial or commercial processes—such as metals, fibers, dyes—are seen to fall into one of two categories: "technical" or "biological" nutrients. *Technical nutrients* are strictly limited to non-toxic, non-harmful synthetic materials that have no negative effects on the natural environment; they can be used in continuous cycles as the same product without losing their integrity or quality. In this manner these materials can be used over and over again instead of being "downcycled" into lesser products, ultimately becoming waste. *Biological Nutrients* are

organic materials that, once used, can be disposed of in any natural environment and decompose into the soil, providing food for small life forms without affecting the natural environment. This is dependent on the ecology of the region; for example, organic material from one country or landmass may be harmful to the ecology of another country or landmass.



Biological and technical cycle

The two types of materials each follow their own cycle in the regenerative economy envisioned by McDonough and Braungart.

Structure

The certification criteria in MBDC's C2C certification process are:

- 'Material Health', which involves identifying the chemical composition of the materials that make up the product. Particularly hazardous materials (e.g. heavy metals, pigments, halogen compounds etc.) have to be reported whatever the concentration, and other materials reported where they exceed 100 ppm. For wood, the forest source is required. The risk for each material is assessed against criteria and eventually ranked on a scale with green being materials of low risk, yellow being those with moderate risk but are acceptable to continue to use, and

- red for materials that have high risk and need to be phased out. Grey for materials with incomplete data. The method uses the term 'risk' in the sense of hazard (as opposed to consequence and likelihood).
- The next assessment is of 'Material Reutilization' which is about recovery and recycling at the end of product life.
 - The third assessment is of energy required for production, which for the highest level of certification needs to be based at least 50% on solar for all parts and subassemblies.
 - Fourth is water, particularly usage and discharge quality.
 - The fifth area is 'social responsibility' which refers to fair labour practices.

The certification is available at several levels: basic, silver, gold, platinum, with more stringent requirements at each.

Health

Currently, many human beings come into contact or consume, directly or indirectly, many harmful materials and chemicals on a daily basis. In addition, countless other forms of plant and animal life are also exposed. C2C seeks to remove dangerous *technical nutrients* (synthetic materials such as mutagenic materials, heavy metals and other dangerous chemicals) from current life cycles. If the materials we come into contact with and are exposed to on a daily basis are not toxic and do not have long term health effects, then the health of the overall system can be better maintained. For example, a fabric factory can eliminate all harmful *technical nutrients* by carefully reconsidering what chemicals they use in their dyes to achieve the colours they need and attempt to do so with fewer base chemicals.

Economics

The use of a C2C model often lowers the financial cost of systems. For example, in the redesign of the Ford River Rouge Complex, the planting of native grasses on assembly plant roofs retains and cleanses rain water. It also moderates the internal temperature of the building in order to save energy. The roof is part of an \$18 million rainwater treatment system designed to clean 20 billion gallons (76,000,000 m³) of rainwater annually. This saved Ford \$50 million that would otherwise have been spent on mechanical treatment facilities. If products are designed according to C2C design principles, they can be manufactured and sold for less than alternative designs. They eliminate the need for waste disposal such as landfills.

Definitions

- **Cradle to Cradle** phrase; essentially a play on the "Cradle to Grave" phrase, implying that the C2C model is sustainable and considerate of life in general.
- **Technical nutrients** are basically inorganic or synthetic materials manufactured by humans—such as plastics and metals--that can be used many times over without any loss in quality, staying in a continuous cycle.

- **Biological nutrients** and materials are organic materials that can decompose into the natural environment, soil, water, etc. without affecting it in a negative way, providing food for bacteria and microbiological life.
- **Materials** are usually referred to as the building blocks of other materials, such as the dyes used in colouring fibers or rubbers used in the sole of a shoe.
- **Downcycling** is a term used to describe what is conventionally known as recycling, which is seen as "downcycling" materials into lesser products, a plastic computer housing becomes a plastic cup, which then becomes a park bench, eventually becoming waste.
- **Waste = Food** is a basic concept of organic waste materials becoming food for bugs, insects and other small forms of life who can feed on it, decompose it and return it to the natural environment which we then indirectly use for food ourselves.

Existing synthetic materials

The question of how to deal with the countless existing *technical nutrients* (synthetic materials) that cannot be recycled or reintroduced to the natural environment is dealt with in C2C design. The materials that can be reused and retain their quality can be used within the technical nutrient cycles while other materials are far more difficult to deal with, such as plastics in the Pacific Ocean.

Hypothetical examples

One effective example is a shoe that is designed and mass produced using the C2C model. The sole might be made of "biological nutrients" while the upper parts might be made of "technical nutrients." The shoe is mass produced at a manufacturing plant that utilises its waste material by putting it back into the cycle; an example of this is using off-cuts from the rubber soles to make more soles instead of merely disposing of them (this is dependent on the technical materials not losing their quality as they are reused). Once the shoes have been manufactured, they are distributed to retail outlets where the customer buys the shoe at a fraction of the price they would normally pay for a shoe of comparable aspects; the customer is only paying for the use of the materials in the shoe for the period of time that they will be using the shoe. When they outgrow the shoe or it is damaged, they return it to the manufacturer. When the manufacturer separates the sole from the upper parts (separating the technical and biological nutrients), the biological nutrients are returned to the natural environment while the technical nutrients are used to create the sole of another shoe.

Another example of C2C design is a disposable cup, bottle, or wrapper made entirely out of biological materials. When the user is finished with the item, it can be disposed of and returned to the natural environment; the cost of disposal of waste such as landfill and recycling is eliminated. The user could also potentially return the item for a refund so it can be used again.

Ford's Model U is a design concept of a car, made completely from cradle-to-cradle materials. It also uses hydrogen propulsion.

Finished products

- Cradle-to-cradle shoes have been made through the Nike Considered project.
- The Edag light car
- Rohner Textile AG Climatex-textile
- Biofoam; a cradle-to-cradle alternative to expanded polystyrene
- Sewage sludge processing plants are facilities that create fertiliser from sewage sludge. This approach is green retrofit for the current (inefficient) system of organic waste disposal; as composting toilets are a better approach in the long run.

Implementation

The C2C model can be applied to almost any system in modern society: urban environments, buildings, manufacturing, social systems. 5 steps are outlined in *Cradle to Cradle - Remaking the way we make things*:

- Get "free of" known culprits
- Follow informed personal preferences
- Create "passive positive" lists - lists of materials used categorised according to their safety level

The X List - substances that must be phased out, such as teratogenic, mutagenic, carcinogenic.

The Gray List - problematic substances that are not so urgently in need of phasing out

The P List - the "positive" list, substances actively defined as safe for use

- Activate the positive list
- Reinvent - the redesign of the former system

Products that adhere to all steps can generally be granted a certification. Two certifications used for cradle-to-cradle products include Leadership in Energy and Environmental Design (LEED) and BRE Environmental Assessment Method (BREEAM).

C2C principles were first applied to systems in the early 1990s by Braungart's Hamburger Umweltinstitut (HUI) and The Environmental Institute in Brazil for biomass nutrient recycling of effluent to produce agricultural products and clean water as a byproduct.

Nowadays, the C2C principles are being actively promoted by the Environmental Protection and Encouragement Agency; which is another organisation directed by Michael Braungart.

In 2007, MBDC and the EPEA formed a strategic partnership with global materials consultancy Material ConneXion to help promote and disseminate C2C design principles by providing greater global access to C2C material information, certification and product development.

As of January 2008, Material ConneXion's Materials Libraries in New York, Milan, Cologne, Bangkok and Daegu, Korea started to feature C2C assessed and certified materials and, in collaboration with MBDC and EPEA, the company now offers C2C Certification, and C2C product development.

While the C2C model has influenced the construction or redevelopment of many smaller buildings, several large companies, organisations and governments have also implemented the C2C model and its ideas and concepts:

Major Implementations

- The Lyle Center for Regenerative Studies incorporates cradle to cradle systems throughout the center. The use of the term C2C is replaced with Regenerative.
- The Chinese Government is constructing many cities like Huangbaiyu based on C2C principles, utilising the rooftops for agriculture.
- The Ford River Rouge Complex redevelopment. Cleaning 20 billion gallons (76,000,000 m³) of rainwater annually.
- The Netherlands Institute of Ecology (NIOO-KNAW) will make its laboratory and office complex completely cradle to cradle compliant
- Several private houses and communal buildings in the Netherlands

Coordination with other models

The Cradle to Cradle model can be viewed as a framework that considers systems as a whole or holistically. It can be applied to many aspects of human society, and is related to Life cycle assessment. The Cradle to Cradle model in some implementations is closely linked with the Car-free movement, such as in the case of large scale building projects or the construction or redevelopment of urban environments. It is closely linked with passive solar design in the building industry and with permaculture in agriculture within or near urban environments. An earthship is a perfect example where different re-use models are used, cradle to cradle and permaculture.

Criticism

Criticism has been advanced on the fact that McDonough and Braungart keep C2C consultancy and certification in their inner circle. The authors argue that this lack of competition prevents the model fulfilling its potential. They plead for a public-private partnership overseeing the C2C concept, thus enabling competition and growth of practical applications and services.

Experts in the field of environment protection have questioned the practicability of the concept. Friedrich Schmidt-Bleek, head of the German Wuppertal Institute called his assertion, that the "old" environmental movement had hindered innovation with its pessimist approach "pseudo-psychological humbug".

I can feel very nice on Michael's seat covers in the airplane. Nevertheless I am still waiting for a detailed proposal for a design of the other 99.99 percent of the Airbus 380 after his principles.

Schmidt-Bleek believes it to be completely out of the question that the concept can be realized on a bigger scale.

Moreover, several Life Cycle Assessment (LCA) practitioners, eco-design engineers and recycling experts tell their doubts about the technical implementation of the Cradle-to-Cradle concept.

Indeed, some claims (from some C2C representatives) pretend that C2C-certified products can be either compostable, or indefinitely recyclable with very minimal quality losses. According to several experts, this assertion should be re-discussed, especially because recycling conditions are much more complicated than what is defined and marketed by the C2C certification. In addition to this recycling issue, the fact that transportation criteria are not part of the certification's demand is also a potential source of discussions.

Some claim that C2C certification may not be entirely sufficient in all eco-design approaches. Quantitative methodologies (LCAs) and more adapted tools (regarding the product type which is considered) could be used in tandem.

It is safe to say that every production step or resource-transformation step needs a certain amount of energy (Newton's second law). Cradle to cradle approach does not consider this energy requirement nor where or how the energy is created to do so.

Regenerative Design

Regenerative Design (sometimes referred to as Cradle to Cradle Design) is a process-oriented systems theory based approach to design. The term "regenerative" describes processes that restore, renew or revitalize their own sources of energy and materials, creating sustainable systems that integrate the needs of society with the integrity of nature. The basis is derived from systems ecology with a closed loop input-output model or a model in which the output is greater than or equal to the input with all outputs viable and all inputs accounted for. Regenerative design is the biomimicry of ecosystems that provide for all human systems to function as a closed viable ecological economics system for all industry. It parallels ecosystems in that organic (biotic) and synthetic (abiotic) material is not just metabolized but metamorphosed into new viable materials. Ecosystems and Regeneratively designed systems are holistic frameworks that seeks to

create systems that are absolutely waste free. The model is meant to be applied to many different aspects of human habitation such as urban environments, buildings, economics, industry and social systems. Simply put, it is the design of ecosystems and human behavior, or culture that function as human habitats.

Whereas the highest aim of sustainable development is to continue growth without harm, the end-goal of Regenerative design is to redevelop systems with absolute efficiency, that allows for the co-evolution of the human species along with other thriving species.

History

During the late 1970's, John T. Lyle (1934-1998), a landscape architecture professor, challenged graduate students to envision a community in which daily activities were based on the value of living within the limits of available renewable resources without environmental degradation. Over the next few decades an eclectic group of students, professors and experts from around the world and crossing many disciplines developed designs for an institute to be built at Cal Poly Pomona. In 1992 the Lyle Center for Regenerative Studies was built over two years and opened in 1994. In that same year Lyle's book "Regenerative Design for Sustainable Development" was published by Wiley. In 1995 Lyle worked with William McDonough at Oberlin College for the Adam Joseph Lewis Center for Environmental Studies completed in 2000. In 2002 McDonough's book, the more popular and successful, "Cradle to Cradle: Remaking the Way We Make Things" was published reiterating the concepts developed by Lyle.

Lyle saw the connection between concepts developed by Bob Rodale of the Rodale Institute for regenerative agriculture and the opportunity to develop regenerative systems for all other aspects of the world. While regenerative agriculture focused solely on agriculture, Lyle expanded its concepts and use to all systems. With regenerative agriculture, the concepts are very straight forward and simple but Lyle understood that when developing for other types of systems, more complicated ideas such as entropy and emergy must be taken into consideration.

Swiss architect Walter R. Stahel developed approaches entirely similar to Lyle's also in the late 1970's but instead coined the term Cradle to Cradle Design made popular by McDonough and Michael Braungart

Regenerative vs. Sustainable

Regenerative and Sustainable are essentially the same thing except for a one key point, if the world were to become regenerative or sustainable, under the term sustainable, lost ecological systems are not returned to existence. Under regenerative those lost systems can ultimately begin "regenerating" back into existence.

There is also a linguistic problem with the word "sustainable." The use of the word "sustainable," by experts in the field, is meant to mean "self-sustaining". However, an

attempt to change this definition to mean self sustaining is not fairing well with the general public. Because the root word "sustain" means only "last" or "endure," the general public and even many non-experts in the industry define the word only as "able to last" or "the capacity to endure." The term sustainable is becoming a universal term to not refer to inequality in environmental, social and economic systems but for anything that has the capacity to endure. Under this term a plastic bottle buried in a landfill is sustainable because it has the capacity to endure.

"Regenerative" also has a linguistic problem, however a very different one, the term is still competing with the biological community in terms of its use for the re-growth of limbs. However once the word itself gains wide usage, it may become a non-specialized word and thus be applicable to all fields, much like the term "sustainable" has experienced. When this occurs it may not suffer the same fate as the term "sustainable" because a system or item must be renewable in order to be regenerated. Regenerative's root words are "re" and "generate" respectively meaning "again" and "to bring into existence." Thus the base meaning of regenerative means the "capacity to bring into existence again." So if an item or system is regenerative the item or system has the capacity to bring itself into existence again.

Ecology vs. Environmentalism

Regenerative Design recognizes the major problems in common environmentalist arguments. Many environmentalists pull what supports their arguments but ignore what might be detrimental to their argument. Regenerists utilize all systems of ecology in order to design systems including ones that may seem destructive such as evolution.

Preservation vs. Conservation

Regenerists place more importance on conservation than on preservation. It is recognized in Regenerative Design that humans are a part of natural ecosystems. To exclude people is to create dense areas that destroy pockets of existing ecosystems while preserving pockets of ecosystems without allowing them to change naturally over time. By incorporating people into ecosystems all inputs are pulled from local areas and all outputs are accounted for creating a waste-less system. When human systems cease to create waste, what would once have been considered waste becomes a resource for the input in which the output comes from.

Food Systems

Regenerists call for the creation of demand on agricultural systems to produce regenerative foods. This is often compared to the creation of the demand for organic food. Organic foods have a relation to regenerative foods in that regenerative food is all organic, but not all organic food is regenerative. Organic food is not regenerative if the byproduct of the food crop is not a resource for the next seasons crops and if other inputs for the crop did not come from other resources within the farm which it is grown in.

Size of Regenerative Systems

The size of the regenerative system effects its regenerativity. The smaller a system is designed the more likely it is to be stable and regenerative. Multiple small regenerative systems that are put together to create larger regenerative systems help to create supplies for multiple human-inclusive-ecological systems.

Quantifying Regenerativity

No system can be absolutely regenerative, in other words there can be no system that is 100 % regenerative. Due to evolution and the continuing and largely unpredictable changes that occur over the lifetime of Earth, it is impossible to create a 100 % regenerative system. One can only reach 99.999 % efficiency, the ultimate goal. However, with the energy material interchange, it is possible to create enough energy to potentially create the equivalent amount of material used to create the system in the first instance. See example below.

A completed object (an object with emergy, or embodied energy) can however create more energy than was used to create it. I.e. a solar panel outputting more energy than its given embodied energy. However the system used to make up the solar panel: the inputs such as the materials for the object (silicone) and the solar radiation can only be regenerated if enough energy is produced to generate the materials used to make up the solar panel. However, the solar energy absorbed by the solar panels is still lost or at the very least converted into something else.

Education

Currently Cal Poly Pomona home to the Lyle Center for Regenerative Studies is the only University to offer a degree in regenerative design. The degree is offered as a Masters of Science in Regenerative Studies, (MSRS) and focuses on ideas developed by John T. Lyle and his books *Regenerative Design for Sustainable Development* and *Design for Human Ecosystems*. Cal Poly Pomona also offers a minor in regenerative studies through the College of Environmental Design

The Regenerative Design Institute offers courses in permaculture, nature awareness, wildcrafting, and health and wellness.

Chapter- 4

Life Cycle Assessment

A **life cycle assessment (LCA)**, also known as **life cycle analysis**, **ecobalance**, and **cradle-to-grave analysis**) is a technique to assess each and every impact associated with all the stages of a process from cradle-to-grave (i.e., from raw materials through materials processing, manufacture, distribution, use, repair and maintenance, and disposal or recycling). LCA's can help avoid a narrow outlook on environmental, social and economic concerns. . This is achieved by:

- Compiling an inventory of relevant energy and material inputs and environmental releases;
- Evaluating the potential impacts associated with identified inputs and releases;
- Interpreting the results to help you make a more informed decision.

Goals and purpose of LCA

The goal of LCA is to compare the full range of environmental and social damages assignable to products and services, to be able to choose the least burdensome one. At present it is a way to account for the effects of the cascade of technologies responsible for goods and services. It is limited to that, though, because the similar cascade of impacts from the commerce responsible for goods and services is unaccountable because what people do with money is unrecorded. As a consequence LCA succeeds in accurately measuring the impacts of the technology used for delivering products, but not the whole impact of making the economic choice of using it.

The term 'life cycle' refers to the notion that a fair, holistic assessment requires the assessment of raw material production, manufacture, distribution, use and disposal including all intervening transportation steps necessary or caused by the product's existence. The sum of all those steps – or phases – is the life cycle of the product. The concept also can be used to optimize the environmental performance of a single product (ecodesign) or to optimize the environmental performance of a company.

Common categories of assessed damages are global warming (greenhouse gases), acidification (soil and ocean), smog, ozone layer depletion, eutrophication, ecotoxicological and human-toxicological pollutants, habitat destruction, desertification, land use as well as depletion of minerals and fossil fuels.

The procedures of life cycle assessment (LCA) are part of the ISO 14000 environmental management standards: in ISO 14040:2006 and 14044:2006. (ISO 14044 replaced earlier versions of ISO 14041 to ISO 14043.)

Four main phases

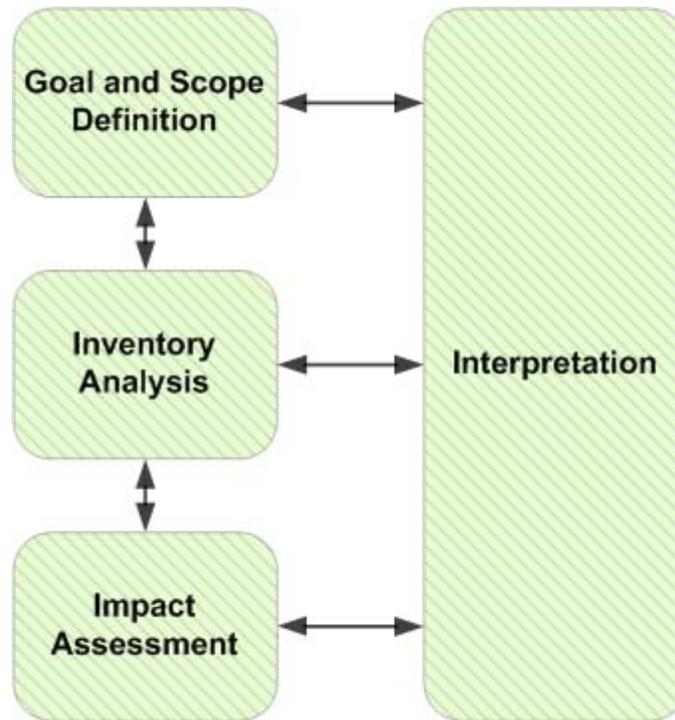


Illustration of LCA phases. These are often interdependent in that the results of one phase will inform how other phases are completed.

According to the ISO 14040 and 14044 standards, a Life Cycle Assessment is carried out in four distinct phases.

Goal and scope

In order to make efficient use of time and resources and outline how the study will be conducted and what final results will be obtained, the following six decisions must be made at the beginning of the LCA process: (1) Define the goal(s) of the project (2) Determine what type of information is needed to inform the decision-makers (3) determine the required specificity (4) Determine how the data should be organized and the results displayed (5) Define the scope of the study (6) Determine the ground rules for performing the work. In the first phase, the LCA-practitioner formulates and specifies the goal and scope of study in relation to the intended application. The object of study is described in terms of a so-called *functional unit*. Apart from describing the functional unit, the goal and scope should address the overall approach used to establish the system boundaries. The system boundary determines which unit processes are included in the

LCA and must reflect the goal of the study. In recent years, two additional approaches to system delimitation have emerged. These are often referred to as 'consequential' modeling and 'attributorial' modeling. Finally the goal and scope phase includes a description of the method applied for assessing potential environmental impacts and which impact categories that are included.

Life cycle inventory

The second phase of Life Cycle Inventory (LCI) involves data collection and modeling of the product system, as well as description and verification of data. This encompasses all data related to environmental (e.g., CO₂) and technical (e.g., intermediate chemicals) quantities for all relevant unit processes within the study boundaries that compose the product system. Examples of inputs and outputs quantities include inputs of materials, energy, chemicals and 'other' – and outputs of air emissions, water emissions or solid waste. Other types of exchanges or interventions such as radiation or land use can also be included.

Usually, Life Cycle Assessment inventories and modeling are carried out using a dedicated software package, such as SimaPro or GaBi . The National Renewable Energy Laboratory and partners created the United States Life Cycle Inventory (LCI) Database to help LCA practitioners understand environmental impact through individual gate-to-gate, cradle-to-gate and cradle-to-grave accounting of the energy and material flows into and out of the environment that are associated with producing a material, component, or assembly. . All LCA software attempts to analyze every stage of the product's life cycle, based on data input by the decision-maker. Again, a life cycle analysis is only as valid as its data. Thus, it is necessary for the decision-maker to first have an extensive knowledge or access to the details of the product "cradle-to-grave": resource extraction, product manufacture, use, and disposal. Depending on the software package employed, it is possible to model not only the environmental impacts of each stage in the product's life, but also the underlying costs and social impacts. The software program can be designed to assess the life cycle holistically or with a specific aspect in mind, such as optimal recyclability or waste minimization.

The data must be related to the functional unit defined in the goal and scope definition. Data can be presented in tables and some interpretations can be made already at this stage. The results of the inventory is an LCI which provides information about all inputs and outputs in the form of elementary flow to and from the environment from all the unit processes involved in the study.

Life cycle impact assessment

The third phase 'Life Cycle Impact Assessment' is aimed at evaluating the contribution to impact categories such as global warming, acidification, etc. The first step is termed characterization. Here, impact potentials are calculated based on the LCI results. The next steps are normalization and weighting, but these are both voluntary according the ISO standard. Normalization provides a basis for comparing different types of environmental

impact categories (all impacts get the same unit). Weighting implies assigning a weighting factor to each impact category depending on the relative importance. The weighting step is not always necessary to create a so called “single indicator”.

Interpretation

The phase stage 'interpretation' is an analysis of the major contributions, sensitivity analysis and uncertainty analysis. This stage leads to the conclusion whether the ambitions from the goal and scope can be met. Life Cycle Interpretation is a systematic technique to identify, quantify, check, and evaluate information from the results of the life cycle inventory (LCI) and/or the life cycle impact assessment (LCIA)... The purpose of performing life cycle interpretation is to determine the level of confidence in the final results and communicate them in a fair, complete, and accurate manner. Interpreting the results of a life cycle assessment (LCA) is not as simple as 3 is better than 2, therefore Alternative A is the best choice! Interpreting the results of an LCA starts with understanding the accuracy of the results, and ensuring they meet the goal of the study. This is accomplished by identifying the data elements that contribute significantly to each impact category, evaluating the sensitivity of these significant data elements, assessing the completeness and consistency of the study, and drawing conclusions and recommendations based on a clear understanding of how the LCA was conducted and the results were developed.

LCA uses and tools

Based on a survey of LCA practitioners carried out in 2006 most life cycle assessments are carried out with dedicated software packages. 58% of respondents used GaBi Software, developed by PE International, 31% used SimaPro developed by PRÉ Consultants, and 11% a series of other tools. According to the same survey, LCA is mostly used to support business strategy (18%) and R&D (18%), as input to product or process design (15%), in education (13%) and for labeling or product declarations (11%). The importance of LCA study is in progress and can be measured by the companies implementing these studies:

- 3M
- Agfa
- Alcan
- BlueScope Steel
- BCorporation
- CANFOR
- Continental
- Daimler
- Electrolux
- Fujitsu
- General Motors
- Hewlett Packard
- Kennecott Utah Copper

- Levi
- Loup Valley Dairy
- Nissan
- Procter & Gamble
- Rio Tinto Borax
- Toyota
- Volvo
- Unilever
- Wharington

An example of LCAs application to labelling is the International Organization of Standardization's "ecolabelling" program, which identifies environmental preference for a product or service based on life cycle considerations. Specifically, type III "ecolabelling" requires an LCA with parameters set by a third party in order to elucidate environmental data for the product or service. Another example of an application of LCAs being performed in industry is through Levi 501 jeans. Through a life cycle assessment, Levi Jeans found that 60% of their climate impact occurs during the consumer phase of these jeans with 80% of this impact is stemming just from using a dryer to dry them instead of air drying.

Data analysis

A life cycle analysis is only as valid as its data; therefore, it is crucial that data used for the completion of a life cycle analysis is accurate and current. When comparing different life cycle analyses with one another, it is crucial that equivalent data is available for both products or processes in question. If one product has a much higher availability of data, it cannot be justly compared to another product which has less detailed data.

The validity of data should always be a concern with life cycle analyses. Since we are living in a global world and economy, new processes, manufacturing methods, and materials are introduced to various processes and products. Therefore, it is important to have current data when performing a LCA. If data from 5 to 10 years in the past is used, the LCA will not be accurate, because the quantitative analysis will not reflect the current methods utilized in the process or product. Therefore, drawing conclusions from a report using such data will be ineffective, since the data is unavailable. Some products, whose processes have not changed in 5 to 10 years (if there are any) will be exempt from this. When analyzing electronics, such as cell phones or computers, for example, the most current data is necessary. Since new computer and cell phone models are created every few months, the results of a life cycle analysis of a 3-year-old computer system will often not be applicable to current systems.

One of the most important parts of LCA data analysis is determining the most costly portion of the life cycle. The life cycle considered usually consists of four stages: embedded energy due to processing raw materials, materials processing and manufacturing, product use, and product disposal. If the most costly of these four stages can be determined, then impact on the environment can be efficiently reduced by

focusing on making changes of that particular phase. For example, the most energy-intensive life phase of an airplane or car is during use due to fuel consumption. One of the most effective ways to increase fuel efficiency is to decrease vehicle weight, and thus, car and airplane manufacturers can decrease environmental impact in a significant way by replacing aluminum with lighter materials such as carbon fiber reinforced fibers. The reduction during the use phase should be more than enough to balance additional raw material or manufacturing cost.

Variants

Cradle-to-grave

Cradle-to-grave is the full Life Cycle Assessment from manufacture ('cradle') to use phase and disposal phase ('grave'). For example, trees produce paper, which can be recycled into low-energy production cellulose (fiberised paper) insulation, then used as an energy-saving device in the ceiling of a home for 40 years, saving 2,000 times the fossil-fuel energy used in its production. After 40 years the cellulose fibers are replaced and the old fibers are disposed of, possibly incinerated. All inputs and outputs are considered for all the phases of the life cycle.

Cradle-to-gate

Cradle-to-gate is an assessment of a *partial* product life cycle from manufacture ('cradle') to the factory gate (i.e., before it is transported to the consumer). The use phase and disposal phase of the product are usually omitted. Cradle-to-gate assessments are sometimes the basis for environmental product declarations (EPD) defined as "quantified environmental data for a product with pre-set categories of parameters based on the ISO 14040 series of standards, but not excluding additional environmental information".

Cradle-to-Cradle

Cradle-to-cradle is a specific kind of cradle-to-grave assessment, where the end-of-life disposal step for the product is a recycling process. It is a method used to minimize the environmental impact of products by employing sustainable production, operation, and disposal practices and aims to incorporate social responsibility into product development. From the recycling process originate new, identical products (e.g., asphalt pavement from discarded asphalt pavement, glass bottles from collected glass bottles), or different products (e.g., glass wool insulation from collected glass bottles). Products can now obtain a cradle-to-cradle certification level. Cradle-to-cradle certification evaluates products based on 5 categories including material health, material reutilization, renewable energy use water stewardship, and social responsibility. The ideal cradle-to-cradle product would have little to no human health risk, be recycled in a closed loop design, be created using solar or other renewable energy, have no impact on local water sources, and be designed in a way that respects the rights of the people of our planet.

Gate-to-gate

Gate-to-gate is a partial LCA looking at only one value-added process in the entire production chain. Gate-to-gate modules may also later be linked in their appropriate production chain to form a complete cradle-to-gate evaluation.

Well-to-wheel

Well-to-wheel is the specific LCA of the efficiency of fuels used for road transportation. The analysis is often broken down into stages titled "well-to-station", or "well-to-tank", and "station-to-wheel, or "tank-to-wheel". The first stage, which incorporates the feedstock and fuel processes is sometimes called the "upstream" stage, while the latter stage that deals with vehicle operation is sometimes called the "downstream" stage.

The factor " T_p = Petroleum refining and distribution efficiency = 0.830" from the DOE regulation accounts for the "well-to-station" portion of the gasoline fuel cycle in the USA. To convert a standard Monroney sticker value to a full cycle energy equivalent, convert with T_p . For example, the Toyota Corolla is rated at 28 mpg station-to-wheel. To get the full cycle value, multiply mpg by $T_p=0.83$ to account for the refining and transportation energy use - **23.2 mpg full cycle**. The same adjustment applies to all vehicles fueled completely with gasoline, therefore, Monroney sticker numbers can be compared to each other with or without the adjustment. A recent study examined well-to-wheels energy and emission effects of various vehicle and fuel systems.

The well-to-wheel variant has a significant input on a model developed by the Argonne National Laboratory. The Greenhouse gases, Regulated Emissions, and Energy use in Transportation (GREET) model was developed to evaluate the impacts of new fuels and vehicle technologies. The model evaluates the impacts of fuel use using a well-to-wheel evaluation while a traditional cradle-to-grave approach is used to determine the impacts from the vehicle itself. The model reports energy use, greenhouse gas emissions, and six additional pollutants such as volatile organic compounds (VOCs) and carbon monoxide (CO).

Economic input–output life cycle assessment

Economic input–output LCA (EIO-LCA) involves use of aggregate sector-level data on how much environmental impact can be attributed to each sector of the economy and how much each sector purchases from other sectors. Such analysis can account for long chains (for example, building an automobile requires energy, but producing energy requires vehicles, and building those vehicles requires energy, etc.), which somewhat alleviates the scoping problem of process LCA; however, EIO-LCA relies on sector-level averages that may or may not be representative of the specific subset of the sector relevant to a particular product and therefore is not suitable for evaluating the environmental impacts of products. Additionally the translation of economic quantities into environmental impacts is not validated.

Ecologically-based LCA

While a conventional LCA uses many of the same approaches and strategies as an Eco-LCA, the latter considers a much broader range of ecological impacts. It was designed to provide a guide to wise management of human activities by understanding the direct and indirect impacts on ecological resources and surrounding ecosystems. Developed by Ohio State University Center for resilience, Eco-LCA is a methodology that quantitatively takes into account regulating and supporting services during the life cycle of economic goods and products. In this approach services are categorized in four main groups: supporting, regulating provisioning and cultural services.

Life cycle energy analysis

Life cycle energy analysis (LCEA) is an approach in which all energy inputs to a product are accounted for, not only direct energy inputs during manufacture, but also all energy inputs needed to produce components, materials and services needed for the manufacturing process. An earlier term for the approach was *energy analysis*.

With LCEA, the *total life cycle energy input* is established.

Energy production

It is recognized that much energy is lost in the production of energy commodities themselves, such as nuclear energy, photovoltaic electricity or high-quality petroleum products. *Net energy content is the energy content of the product minus energy input used during extraction and conversion, directly or indirectly.* A controversial early result of LCEA claimed that manufacturing solar cells requires more energy than can be recovered in using the solar cell. The result was refuted. Another new concept that flows from life cycle assessments is Energy Cannibalism. Energy Cannibalism refers to an effect where rapid growth of an entire energy-intensive industry creates a need for energy that uses (or cannibalizes) the energy of existing power plants. Thus during rapid growth the industry as a whole produces no energy because new energy is used to fuel the embodied energy of future power plants. Work has been undertaken in the UK to determine the life cycle energy (alongside full LCA) impacts of a number of renewable technologies. .

Energy recovery

If materials are incinerated during the disposal process, the energy released during burning can be harnessed and used for electricity production. This provides a low-impact energy source, especially when compared with coal and natural gas. While incineration produces more greenhouse gas emissions than landfilling, the waste plants are well-fitted with filters to minimize this negative impact. A recent study comparing energy consumption and greenhouse gas emissions from landfilling (without energy recovery) against incineration (with energy recovery) found incineration to be superior in all cases except for when landfill gas is recovered for electricity production.

LCEA criticism

A criticism of LCEA is that it attempts to eliminate monetary cost analysis, that is replace the currency by which economic decisions are made with an energy currency. It has also been argued that energy efficiency is only one consideration in deciding which alternative process to employ, and that it should not be elevated to the only criterion for determining environmental acceptability; for example, simple energy analysis does not take into account the renewability of energy flows or the toxicity of waste products; however the life cycle assessment does help companies become more familiar with environmental properties and improve there environmental system. . Incorporating **Dynamic LCAs** of renewable energy technologies (using sensitivity analyses to project future improvements in renewable systems and their share of the power grid) may help mitigate this criticism.

A problem the energy analysis method cannot resolve is that different energy forms (heat, electricity, chemical energy etc.) have different quality and value even in natural sciences, as a consequence of the two main laws of thermodynamics. A thermodynamic measure of the quality of energy is exergy. According to the first law of thermodynamics, all energy inputs should be accounted with equal weight, whereas by the second law diverse energy forms should be accounted by different values.

The conflict is resolved in one of these ways:

- value difference between energy inputs is ignored,
- a value ratio is arbitrarily assigned (e.g., a joule of electricity is 2.6 times more valuable than a joule of heat or fuel input),
- the analysis is supplemented by economic (monetary) cost analysis,
- exergy instead of energy can be the metric used for the life cycle analysis .

Critiques

Life cycle assessment is a powerful tool for analyzing commensurable aspects of quantifiable systems. Not every factor, however, can be reduced to a number and inserted into a model. Rigid system boundaries make accounting for changes in the system difficult. This is sometimes referred to as the boundary critique to systems thinking. The accuracy and availability of data can also contribute to inaccuracy. For instance, data from generic processes may be based on averages, unrepresentative sampling, or outdated results . Additionally, social implications of products are generally lacking in LCAs. Comparative life-cycle analysis is often used to determine a better process or product to use. However, because of aspects like differing system boundaries, different statistical information, different product uses, etc., these studies can easily be swayed in favor of one product or process over another in one study and the opposite in another study based on varying parameters and different available data . There are guidelines to help reduce such conflicts in results but the method still provides a lot of room for the researcher to decide what is important, how the product is typically manufactured, and how it is typically used.

The Agroecology tool "agroecosystem analysis" offers a framework to incorporate incommensurable aspects of the life cycle of a product (such as social impacts, and soil and water implications). This tool is specifically useful in the analysis of a product made from agricultural materials such as corn ethanol or soybean biodiesel because it can account for an ecology of contexts interacting and changing through time. This analysis tool should not be used instead of life-cycle analysis, but rather, in conjunction with life-cycle analysis to produce a well-rounded assessment.

Dynamic life cycle assessment

In recent years, the literature on life cycle assessment of energy technology has begun to reflect the interactions between the current electrical grid and future energy technology. Some papers have focused on energy life cycle , while others have focused on carbon dioxide and other greenhouse gases . The essential critique given by these sources is that when considering energy technology, the growing nature of the power grid must be taken into consideration. If this is not done, a given class of energy technology may emit more carbon dioxide over its lifetime than it mitigates.

Chapter- 5

Sustainable Design

Sustainable design (also called environmental design, environmentally sustainable design, environmentally conscious design, etc.) is the philosophy of designing physical objects, the built environment, and services to comply with the principles of economic, social, and ecological sustainability.

Intentions

The intention of sustainable design is to "eliminate negative environmental impact completely through skillful, sensitive design". Manifestations of sustainable design require no non-renewable resources, impact the environment minimally, and relate people with the natural environment.

Applications

Applications of this philosophy range from the microcosm — small objects for everyday use, through to the macrocosm — buildings, cities, and the Earth's physical surface. It is a philosophy that can be applied in the fields of architecture, landscape architecture, urban design, urban planning, engineering, graphic design, industrial design, interior design, and fashion design.

Sustainable design is mostly a general reaction to global environmental crises, the rapid growth of economic activity and human population, depletion of natural resources, damage to ecosystems, and loss of biodiversity.

The limits of sustainable design are reducing. Whole earth impacts are beginning to be considered because growth in goods and services is consistently outpacing gains in efficiency. As a result, the net effect of sustainable design to date has been to simply improve the efficiency of rapidly increasing impacts. The present approach, which focuses on the efficiency of delivering individual goods and services, does not solve this problem. The basic dilemmas include: the increasing complexity of efficiency improvements; the difficulty of implementing new technologies in societies built around old ones; that physical impacts of delivering goods and services are not localized, but are distributed throughout the economies; and that the scale of resource use is growing and not stabilizing.

Sustainable Design Principles

While the practical application varies among disciplines, some common principles are as follows:

- Low-impact materials: choose non-toxic, sustainably produced or recycled materials which require little energy to process
- Energy efficiency: use manufacturing processes and produce products which require less energy
- Quality and durability: longer-lasting and better-functioning products will have to be replaced less frequently, reducing the impacts of producing replacements
- Design for reuse and recycling: "Products, processes, and systems should be designed for performance in a commercial 'afterlife'."
- Design Impact Measures for total carbon footprint and life-cycle assessment for any resource used are increasingly required and available. Many are complex, but some give quick and accurate whole-earth estimates of impacts. One measure estimates any spending as consuming an average economic share of global energy use of 8,000btu per dollar and producing CO₂ at the average rate of 0.57 kg of CO₂ per dollar (1995 dollars US) from DOE figures.
- Sustainable Design Standards and project design guides are also increasingly available and are vigorously being developed by a wide array of private organizations and individuals. There is also a large body of new methods emerging from the rapid development of what has become known as 'sustainability science' promoted by a wide variety of educational and governmental institutions.
- Biomimicry: "redesigning industrial systems on biological lines ... enabling the constant reuse of materials in continuous closed cycles..."
- Service substitution: shifting the mode of consumption from personal ownership of products to provision of services which provide similar functions, e.g., from a private automobile to a carsharing service. Such a system promotes minimal resource use per unit of consumption (e.g., per trip driven).
- Renewability: materials should come from nearby (local or bioregional), sustainably managed renewable sources that can be composted when their usefulness has been exhausted.
- Healthy Buildings: sustainable building design aims to create buildings that are not harmful to their occupants nor to the larger environment. An important emphasis is on indoor environmental quality, especially indoor air quality.
- Robust eco-design: robust design principles are applied to the design of a pollution sources).

Bill of Rights for the Planet

A model of the new design principles necessary for sustainability is exemplified by the "Bill of Rights for the Planet" or "Hannover Principles" - developed by William McDonough Architects for EXPO 2000 that was held in Hannover, Germany.

The Bill of Rights:

1. Insist on the right of humanity and nature to co-exist in a healthy, supportive, diverse, and sustainable condition.
2. Recognize Interdependence. The elements of human design interact with and depend on the natural world, with broad and diverse implications at every scale. Expand design considerations to recognizing even distant effects.
3. Respect relationships between spirit and matter. Consider all aspects of human settlement including community, dwelling, industry, and trade in terms of existing and evolving connections between spiritual and material consciousness.
4. Accept responsibility for the consequences of design decisions upon human well-being, the viability of natural systems, and their right to co-exist.
5. Create safe objects of long-term value. Do not burden future generations with requirements for maintenance or vigilant administration of potential danger due to the careless creations of products, processes, or standards.
6. Eliminate the concept of waste. Evaluate and optimize the full life-cycle of products and processes, to approach the state of natural systems in which there is no waste.
7. Rely on natural energy flows. Human designs should, like the living world, derive their creative forces from perpetual solar income. Incorporate this energy efficiently and safely for responsible use.
8. Understand the limitations of design. No human creation lasts forever and design does not solve all problems. Those who create and plan should practice humility in the face of nature. Treat nature as a model and mentor, not an inconvenience to be evaded or controlled.
9. Seek constant improvement by the sharing of knowledge. Encourage direct and open communication between colleagues, patrons, manufacturers and users to link long term sustainable considerations with ethical responsibility, and re-establish the integral relationship between natural processes and human activity.

These principles were adopted by the World Congress of the International Union of Architects (UIA) in June 1993 at the American Institute of Architect's (AIA) Expo 93 in Chicago. Further, the AIA and UIA signed a "Declaration of Interdependence for a Sustainable Future." In summary, the declaration states that today's society is degrading its environment and that the AIA, UIA, and their members are committed to:

- Placing environmental and social sustainability at the core of practices and professional responsibilities
- Developing and continually improving practices, procedures, products, services, and standards for sustainable design

- Educating the building industry, clients, and the general public about the importance of sustainable design
- Working to change policies, regulations, and standards in government and business so that sustainable design will become the fully supported standard practice
- Bringing the existing built environment up to sustainable design standards

In addition, the Interprofessional Council on Environmental Design (ICED), a coalition of architectural, landscape architectural, and engineering organizations, developed a vision statement in an attempt to foster a team approach to sustainable design. ICED states: The ethics, education and practices of our professions will be directed to shape a sustainable future. . . . To achieve this vision we will join . . . as a multidisciplinary partnership."

These activities are an indication that the concept of sustainable design is being supported on a global and interprofessional scale and that the ultimate goal is to become more environmentally responsive. The world needs facilities that are more energy efficient and that promote conservation and recycling of natural and economic resources.

Conceptual Problems to Solve

- **Diminishing Returns:** The principle that all directions of progress run out, ending with diminishing returns, is evident in the typical 'S' curve of The Technology Life Cycle and in the useful life of any system as discussed in Industrial Ecology and Life Cycle Assessment. It's as reliable an expectation as any principle of science that diminishing returns signal natural limits. Common office and business management practice is to read diminishing returns in any direction of effort as an indication of diminishing opportunity, a potential for accelerating their decline and signal to turn elsewhere.
- **Unsustainable Investment:** A problem arises when the limits of a resource are hard to see, so increasing investment in response to diminishing returns may seem profitable as in the Tragedy of the Commons, but may lead to a collapse. This problem of increasing investment in diminishing resources has also been studied in relation to the causes of civilization collapse by Joseph Tainter among others. This natural error in investment policy contributed to the collapse of both the Roman and Mayan, among others. Relieving over-stressed resources requires reducing pressure on them, not continually increasing it whether more efficiently or not

Waste Prevention

Negative Effects of Waste About 80 million tonnes of waste in total are generated in the U.K. alone, for example, each year. And with reference to only household waste, between 1991/92 and 2007/08, each person in England generated an average of 1.35 pounds of waste per day.

Experience has now shown that there is no completely safe method of waste disposal. All forms of disposal have negative impacts on the environment, public health, and local economies. Landfills have contaminated drinking water. Garbage burned in incinerators has poisoned air, soil, and water. The majority of water treatment systems change the local ecology. Attempts to control or manage wastes after they are produced fail to eliminate environmental impacts.

The toxic components of household products pose serious health risks and aggravate the trash problem. In the U.S., about eight pounds in every ton of household garbage contains toxic materials, such as lead, cadmium, and mercury from batteries, insect sprays, nail polish, cleaners, and other products. When burned or buried, toxic materials also pose a serious threat to public health and the environment.

The only way to avoid environmental harm from waste is to prevent its generation. Pollution prevention means changing the way activities are conducted and eliminating the source of the problem. It does not mean doing without, but doing differently. For example, preventing waste pollution from litter caused by disposable beverage containers does not mean doing without beverages; it just means using refillable bottles.

Waste Prevention Strategies In planning for facilities, a comprehensive design strategy is needed for preventing generation of solid waste. A good garbage prevention strategy would require that everything brought into a facility be recycled for reuse or recycled back into the environment through biodegradation. This would mean a greater reliance on natural materials or products that are compatible with the environment.

Any resource-related development is going to have two basic sources of solid waste — materials purchased and used by the facility and those brought into the facility by visitors. The following waste prevention strategies apply to both, although different approaches will be needed for implementation:

- use products that minimize waste and are nontoxic
- compost or anaerobically digest biodegradable wastes
- reuse materials onsite or collect suitable materials for offsite recycling

Examples of sustainable design

Sustainable planning



Cohousing community illustrating greenspace preservation, tightly clustered housing, and parking on periphery, Ann Arbor, Michigan, 2003.

Urban planners that are interested in achieving sustainable development or sustainable cities use various design principles and techniques when designing cities and their infrastructure. These include Smart Growth theory, Transit-oriented development, sustainable urban infrastructure and New Urbanism. Smart Growth is an urban planning and transportation theory that concentrates growth in infill sites within the existing infrastructure of a city or town to avoid urban sprawl; and advocates compact, transit-oriented development, walkable, bicycle-friendly land use, including mixed-use development with a range of housing choices. Transit-oriented development attempts to maximise access to public transport and thereby reduce the need for private vehicles. Public transport is considered a form of Sustainable urban infrastructure, which is a design approach which promotes protected areas, energy-efficient buildings, wildlife corridors and distributed, rather than centralized, power generation and waste water treatment. New Urbanism is more of a social and aesthetic urban design movement than a green one, but it does emphasize diversity of land use and population, as well as walkable communities which inherently reduce the need for automotive travel.

Both urban and rural planning can benefit from including sustainability as a central criterion when laying out roads, streets, buildings and other components of the built environment. Conventional planning practice often ignores or discounts the natural configuration of the land during the planning stages, potentially causing ecological damage such as the stagnation of streams, mudslides, soil erosion, flooding and pollution. Applying methods such as scientific modelling to planned building projects can draw attention to problems before construction begins, helping to minimise damage to the natural environment.

Cohousing is an approach to planning based on the idea of intentional communities. Such projects often prioritize common space over private space resulting in grouped structures that preserve more of the surrounding environment.

Watershed assessment of carrying capacity; estuary, riparian zone restoration and groundwater recharge for hydrologic cycle viability; and other opportunities and issues about Water and the environment show that the foundation of smart growth lies in the protection and preservation of water resources. The total amount of precipitation landing on the surface of a community becomes the supply for the inhabitants. This supply amount then dictates the carrying capacity - the potential population - as supported by the "water crop."

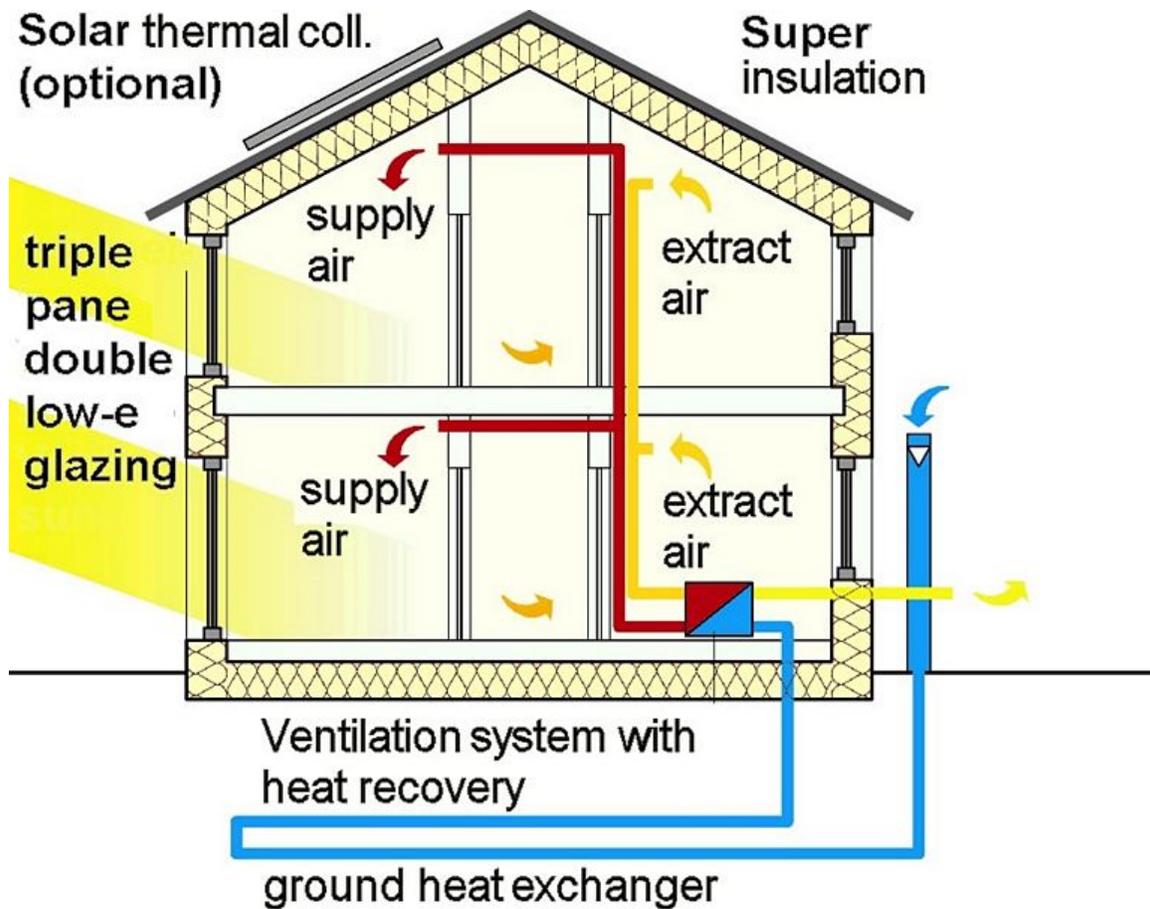
Sustainable architecture

Sustainable architecture is a general term that describes environmentally conscious design techniques in the field of architecture. Sustainable architecture is framed by the larger discussion of sustainability and the pressing economic and political issues of our world. In the broad context, sustainable architecture seeks to minimize the negative environmental impact of buildings by enhancing efficiency and moderation in the use of materials, energy, and development space. Most simply, the idea of sustainability, or ecological design, is to ensure that our actions and decisions today do not inhibit the opportunities of future generations. This term can be used to describe an energy and ecologically conscious approach to the design of the built environment.

Sustainable energy use



K2 sustainable apartments in Windsor, Victoria, Australia by Hansen Yuncken (2006) features passive solar design, recycled and sustainable materials, photovoltaic cells, wastewater treatment, rainwater collection and solar hot water.



The passivhaus standard combines a variety of techniques and technologies to achieve ultra-low energy use.



Following its destruction by a tornado in 2007, the town of Greensburg, Kansas (USA) elected to rebuild to highly stringent LEED Platinum environmental standards. Shown is the town's new art center, which integrates its own solar panels and wind generators for energy self-sufficiency.

Energy efficiency over the entire life cycle of a building is the single most important goal of sustainable architecture. Architects use many different techniques to reduce the energy needs of buildings and increase their ability to capture or generate their own energy.

Heating, Ventilation and Cooling System Efficiency

The most important and cost effective element of an efficient heating, ventilating, and air conditioning (HVAC) system is a well insulated building. A more efficient building requires less heat generating or dissipating power, but may require more ventilation capacity to expel polluted indoor air.

Significant amounts of energy are flushed out of buildings in the water, air and compost streams. Off the shelf, on-site energy recycling technologies can effectively recapture energy from waste hot water and stale air and transfer that energy into incoming fresh cold water or fresh air. Recapture of energy for uses other than gardening from compost leaving buildings requires centralized anaerobic digesters.

Site and building orientation have some major effects on a building's HVAC efficiency.

Passive solar building design allows buildings to harness the energy of the sun efficiently without the use of any active solar mechanisms such as photovoltaic cells or solar hot water panels. Typically passive solar building designs incorporate materials with high thermal mass that retain heat effectively and strong insulation that works to prevent heat escape. Low energy designs also requires the use of solar shading, by means of awnings, blinds or shutters, to relieve the solar heat gain in summer and to reduce the need for artificial cooling. In addition, low energy buildings typically have a very low surface area to volume ratio to minimize heat loss. This means that sprawling multi-winged building designs (often thought to look more "organic") are often avoided in favor of more centralized structures. Traditional cold climate buildings such as American colonial saltbox designs provide a good historical model for centralized heat efficiency in a small scale building.

Windows are placed to maximize the input of heat-creating light while minimizing the loss of heat through glass, a poor insulator. In the northern hemisphere this usually involves installing a large number of south-facing windows to collect direct sun and severely restricting the number of north-facing windows. Certain window types, such as double or triple glazed insulated windows with gas filled spaces and low emissivity (low-E) coatings, provide much better insulation than single-pane glass windows. Preventing excess solar gain by means of solar shading devices in the summer months is important to reduce cooling needs. Deciduous trees are often planted in front of windows to block excessive sun in summer with their leaves but allow light through in winter when their leaves fall off. Louvers or light shelves are installed to allow the sunlight in during the winter (when the sun is lower in the sky) and keep it out in the summer (when the sun is high in the sky). Coniferous or evergreen plants are often planted to the north of buildings to shield against cold north winds.

In colder climates, heating systems are a primary focus for sustainable architecture because they are typically one of the largest single energy drains in buildings.

In warmer climates where cooling is a primary concern, passive solar designs can also be very effective. Masonry building materials with high thermal mass are very valuable for retaining the cool temperatures of night throughout the day. In addition builders often opt for sprawling single story structures in order to maximize surface area and heat loss. Buildings are often designed to capture and channel existing winds, particularly the especially cool winds coming from nearby bodies of water. Many of these valuable strategies are employed in some way by the traditional architecture of warm regions, such as south-western mission buildings.

In climates with four seasons, an integrated energy system will increase in efficiency: when the building is well insulated, when it is sited to work with the forces of nature, when heat is recaptured (to be used immediately or stored), when the heat plant relying on fossil fuels or electricity is greater than 100% efficient, and when renewable energy is utilized.

Renewable energy generation

Solar Panels

Active solar devices such as photovoltaic solar panels help to provide sustainable electricity for any use. Electrical output of a solar panel is dependent on orientation, efficiency, latitude, and climate—solar gain varies even at the same latitude. Typical efficiencies for commercially available PV panels range from 4% to 28%. The low efficiency of certain photovoltaic panels can significantly affect the payback period of their installation. A good rule of thumb for the cost of installing solar panels is roughly about \$4.30/Watt.

Roofs are often angled toward the sun to allow photovoltaic panels to collect at maximum efficiency. For any solar panel, a true-south facing orientation maximizes yield. If true-south is not possible, solar panels can produce adequate energy if aligned within 30° of south. However, at higher latitudes, winter energy yield will be significantly reduced for non-south orientation.

To maximize efficiency in winter, the collector should be angled above horizontal Latitude + 15°. To maximize efficiency in summer, the angle should be Latitude - 15°. However, for an annual maximum production, the angle of the panel above horizontal should be equal to its latitude.

Wind Turbines

Undersized wind turbines (normal turbines are often over 250 feet) may have been oversold and do not always provide the returns promised, particularly for North American households. The use of undersized wind turbines in energy production in

sustainable structures requires the consideration of many factors. In considering costs, small wind systems are generally more expensive than larger wind turbines relative to the amount of energy they produce. For small wind turbines, maintenance costs can be a deciding factor at sites with marginal wind-harnessing capabilities. At low-wind sites, maintenance can consume much of a small wind turbine's revenue. Wind turbines begin operating when winds reach 8 mph, achieve energy production capacity at speeds of 32-37 mph, and shut off to avoid damage at speeds exceeding 55 mph. The energy potential of a wind turbine is proportional to the square of the length of its blades and to the cube of the speed at which its blades spin. Though wind turbines are available that can supplement power for a single building, because of these factors, the efficiency of the wind turbine depends much upon the wind conditions at the building site. For these reasons, for wind turbines to be at all efficient, they must be installed at locations that are known to receive a constant amount of wind (with average wind speeds of more than 15 mph), rather than locations that receive wind sporadically. A small wind turbine can be installed on a roof. Installation issues then include the strength of the roof, vibration, and the turbulence caused by the roof ledge. Small-scale rooftop wind turbines have been known to be able to generate power from 10% to up to 25% of the electricity required of a regular domestic household dwelling. Turbines for residential scale use are available. They are usually approximately 7 feet (2 m) to 25 feet (8 m) in diameter and produce electricity at a rate of 900 watts to 10,000 watts at their tested wind speed. In the United States, residential wind turbines with outputs of 2-10 kW, typically cost between \$12,000 and \$55,000 installed (\$6 per watt), although there are incentives and rebates available in 19 states that can reduce the purchase price for homeowners by up to 50 percent, to (\$3 per watt).

Solar Water Heating

Solar water heaters—also called solar domestic hot water systems—can be a cost-effective way to generate hot water for your home. They can be used in any climate, and the fuel they use—sunshine—is free.

There are two types of solar water systems- active and passive. An active solar collector system will cost approximately \$2,500 to \$3,500 installed and produce about 80 to 100 gallons of hot water per day. A passive system will cost about \$1,000 to \$2,000 installed but will have a lower capacity .

There are also two types of circulation, direct circulation systems and indirect circulation systems. Direct circulation systems loop the domestic water through the panels. They should not be used in climates with temperatures below freezing. Indirect circulation loops glycol or some other fluid through the solar panels and uses a heat exchanger to heat up the domestic water.

The two most common types of collector panels are Flat-Plate and Evacuated-tube. The two work similarly except that evacuated tubes do not convectively lose heat, which greatly improves their efficiency (5%-25% more efficient). With these higher

efficiencies, Evacuated-tube solar collectors can also produce higher-temperature space heating, and even higher temperatures for absorption cooling systems

Electric-resistance water heaters that are common in homes today have an electrical demand around 4500 kW·h/year. With the use of solar collectors, the energy use is cut in half. The up-front cost of installing solar collectors is high, but with the annual energy savings, payback periods are relatively short

Heat Pumps

Air-source heat pumps (ASHP) can be thought of as reversible air conditioners. Like an air conditioner, an ASHP can take heat from a relatively cool space (e.g. a house at 70°F) and dump it into a hot place (e.g. outside at 85°F). However, unlike an air conditioner, the condenser and evaporator of an ASHP can switch roles and absorb heat from the cool outside air and dump it into a warm house.

Air-source heat pumps are inexpensive relative to other heat pump systems. However, the efficiency of air-source heat pumps decline when the outdoor temperature is very cold or very hot; therefore, they are only really applicable in temperate climates .

For areas not located in temperate climates, ground-source (or geothermal) heat pumps provide an efficient alternative. The difference between the two heat pumps is that the ground-source has one of its heat exchangers placed underground—usually in a horizontal or vertical arrangement. Ground-source takes advantage of the relatively constant, mild temperatures underground, which means their efficiencies can be much greater than that of an air-source heat pump. The in-ground heat exchanger generally needs a considerable amount of area. Designers have placed them in an open area next to the building or underneath a parking lot.

Energy Star ground-source heat pumps can be 40% to 60% more efficient than their air-source counterparts. They are also quieter and can also be applied to other functions like domestic hot water heating

In terms of initial cost, the ground-source heat pump system costs about twice as much as a standard air-source heat pump to be installed. However, the up-front costs can be more than offset by the decrease in energy costs. The reduction in energy costs is especially apparent in areas with typically hot summers and cold winters .

Other types of heat pumps are water-source and air-earth. If the building is located near a body of water, the pond or lake could be used as a heat source or sink. Air-earth heat pumps circulate the building's air through underground ducts. With higher fan power requirements and inefficient heat transfer, Air-earth heat pumps are generally not practical for major construction.

Sustainable building materials

Some examples of sustainable building materials include recycled denim or blown-in fiber glass insulation, sustainably harvested wood, Trass, Linoleum, sheep wool, concrete (high and ultra high performance, roman self-healing concrete), panels made from paper flakes, baked earth, rammed earth, clay, vermiculite, flax linnen, sisal, seegrass, cork, expanded clay grains, coconut, wood fibre plates, calcium sand stone, locally obtained stone and rock, and bamboo, which is one of the strongest and fastest growing woody plants, and non-toxic low-VOC glues and paints.

Recycled Materials



Recycling items for building

Some sustainable architecture incorporates the use of recycled or second hand materials, such as reclaimed lumber. The reduction in use of new materials creates a corresponding reduction in embodied energy (energy used in the production of materials). Often sustainable architects attempt to retro-fit old structures to serve new needs in order to avoid unnecessary development. Architectural salvage and reclaimed materials are used when appropriate. When older buildings are demolished, frequently any good wood is reclaimed, renewed, and sold as flooring. Any good dimension stone is similarly reclaimed. Many other parts are reused as well, such as doors, windows, mantels, and hardware, thus reducing the consumption of new goods. When new materials are employed, green designers look for materials that are rapidly replenished, such as bamboo, which can be harvested for commercial use after only 6 years of growth, sorghum or wheat straw, both of which are waste material that can be pressed into panels, or cork oak, in which only the outer bark is removed for use, thus preserving the tree. When possible, building materials may be gleaned from the site itself; for example, if a new structure is being constructed in a wooded area, wood from the trees which were cut to make room for the building would be re-used as part of the building itself.

Lower Volatile Organic Compounds

Low-impact building materials are used wherever feasible: for example, insulation may be made from low VOC (volatile organic compound)-emitting materials such as recycled denim or cellulose insulation, rather than the building insulation materials that may contain carcinogenic or toxic materials such as formaldehyde. To discourage insect damage, these alternate insulation materials may be treated with boric acid. Organic or milk-based paints may be used. However, a common fallacy is that "green" materials are always better for the health of occupants or the environment. Many harmful substances (including formaldehyde, arsenic, and asbestos) are naturally occurring and are not without their histories of use with the best of intentions. A study of emissions from materials by the State of California has shown that there are some green materials that have substantial emissions whereas some more "traditional" materials actually were lower emitters. Thus, the subject of emissions must be carefully investigated before concluding that natural materials are always the healthiest alternatives for occupants and for the Earth.

Volatile organic compounds (VOC) can be found in any indoor environment coming from a variety of different sources. VOCs have a high vapor pressure and low water solubility and are suspected of causing sick building syndrome type symptoms. This is because many VOCs have been known to cause sensory irritation and central nervous system symptoms characteristic to sick building syndrome, indoor concentrations of VOCs are higher than in the outdoor atmosphere, and when there are many VOCs present, they can cause additive and multiplicative effects.

Green products are usually considered to contain fewer VOCs and be better for human and environmental health. A case study conducted by the Department of Civil, Architectural, and Environmental Engineering at the University of Miami that compared three green products and their non-green counterparts found that even though both the

green products and the non-green counterparts both emitted levels of VOCs, the amount and intensity of the VOCs emitted from the green products were much safer and comfortable for human exposure.

Waste management

Waste takes the form of spent or useless materials generated from households and businesses, construction and demolition processes, and manufacturing and agricultural industries. These materials are loosely categorized as municipal solid waste, construction and demolition (C&D) debris, and industrial or agricultural by-products. Sustainable architecture focuses on the on-site use of waste management, incorporating things such as grey water systems for use on garden beds, and composting toilets to reduce sewage. These methods, when combined with on-site food waste composting and off-site recycling, can reduce a house's waste to a small amount of packaging waste.

Water management

Rainwater harvesting and grey water reuse are some of the possibilities for reducing water demand.

Building placement

One central and often ignored aspect of sustainable architecture is building placement. Although many may envision the ideal environmental home or office structure as an isolated place in the middle of the woods, this kind of placement is often detrimental to the environment. First, such structures often serve as the unknowing frontlines of suburban sprawl. Second, they usually increase the energy consumption required for transportation and lead to unnecessary auto emissions. Ideally, most building should avoid suburban sprawl in favor of the kind of light urban development articulated by the New Urbanist movement. Careful mixed use zoning can make commercial, residential, and light industrial areas more accessible for those traveling by foot, bicycle, or public transit, as proposed in the Principles of Intelligent Urbanism. The study of Permaculture, in its holistic application, can also greatly help in proper building placement that minimizes energy consumption and works with the surroundings rather than against them, especially in rural and forested zones.

Social sustainability in architecture

Public housing is cost effective. This approach lets everyone have their own sleeping/recreation space, yet incorporate communal spaces (e.g. mess halls, Latrines, public showers).

Architectural design can play a large part in influencing the ways that social groups interact. Communist Russia's Constructivist Social condensers are a good example of this

, which are buildings which were designed with the specific intention of controlling or directing the flow of everyday life to "create socially equitable spaces" .

Sustainable design can help to create a sustainable way of living within a community. While the existing social constructs can be seen to influence architecture, the opposite can also be true. An overtly socially sustainable building, if successful, can help people to see the benefit of living sustainably . This can be seen in many of Rural Studio's buildings in and around Hale County, Alabama, and in the design of ALA Himmelwright's "model fireproof farmhouse," located at Rock Lodge Club in Stockholm, New Jersey.

Art can be a powerfully positive social force. It can help to reduce stress in many situations, lowering the risk of stress-related health problems , both physical and mental.

The cohousing movement with a high degree of social sustainability and participation where the majority of participants are non-architects invariably uses traditional architecture that resonates with the general public .

Criticism

Sustainable architecture, it can be argued, does not rigorously form a part of architecture as a discipline . Rather, it is a concern in the building construction industry as a whole, and given the dominance of construction techniques and building subsystems, it should be considered a part of civil engineering as a discipline. There are also conflicting ethical and political orientations depending on the viewpoints. Numerous schools of architecture exclude sustainable architecture as a part of their curriculum, and it is considered to be a fashionable subject at the moment .

Sustainable architecture is the design of sustainable buildings. Sustainable architecture attempts to reduce the collective environmental impacts during the production of building components, during the construction process, as well as during the lifecycle of the building (heating, electricity use, carpet cleaning etc.) This design practice emphasizes efficiency of heating and cooling systems; alternative energy sources such as solar hot water, appropriate building siting, reused or recycled building materials; on-site power generation - solar technology, ground source heat pumps, wind power; rainwater harvesting for gardening, washing and aquifer recharge; and on-site waste management such as green roofs that filter and control stormwater runoff. This requires close cooperation of the design team, the architects, the engineers, and the client at all project stages, from site selection, scheme formation, material selection and procurement, to project implementation.

Sustainable architects design with sustainable living in mind. Sustainable vs green design is the challenge that designs not only reflect healthy processes and uses but are powered by renewable energies and site specific resources. A test for sustainable design is — can the design function for its intended use without fossil fuel — unplugged. This challenge suggests architects and planners design solutions that can function without pollution

rather than just reducing pollution. As technology progresses in architecture and design theories and as examples are built and tested, architects will soon be able to create not only passive, null-emission buildings, but rather be able to integrate the entire power system into the building design. In 2004 the 59 home housing community, the Solar Settlement, and a 60,000 sq ft (5,600 m²) integrated retail, commercial and residential building, the Sun Ship, were completed by architect Rolf Disch in Freiburg, Germany. The Solar Settlement is the first housing community world wide in which every home, all 59, produce a positive energy balance.

Sustainable landscape and garden design

Sustainable landscape architecture is a category of sustainable design and energy-efficient landscaping concerned with the planning and design of outdoor space. Design techniques include planting trees to shade buildings from the sun or protect them from wind, using local materials, on-site composting and chipping to reduce green waste hauling, and also may involve using drought-resistant plantings in arid areas (xeriscaping) and buying stock from local growers to avoid energy use in transportation.

Sustainable graphic design

Sustainable graphic design considers the environmental impacts of graphic design products (such as packaging, printed materials, publications, etc.) throughout a life cycle that includes: raw material; transformation; manufacturing; transportation; use; and disposal. Techniques for sustainable graphic design include: reducing the amount of materials required for production; using paper and materials made with recycled, post-consumer waste; printing with low-VOC inks; and using production and distribution methods that require the least amount of transport.

Sustainable Agriculture

Sustainable agriculture adheres to three main goals:

- environmental health,
- economic profitability,
- social and economic equity.

A variety of philosophies, policies and practices have contributed to these goals. People in many different capacities, from farmers to consumers, have shared this vision and contributed to it. Despite the diversity of people and perspectives, the following themes commonly weave through definitions of sustainable agriculture.

There are strenuous discussions — among others by the agricultural sector and authorities — if existing pesticide protocols and methods of soil conservation adequately protect topsoil and wildlife. Doubt has risen if these are sustainable, and if agrarian reforms would permit an efficient agriculture with fewer pesticides, therefore reducing the damage to the ecosystem.

For more information on the subject of sustainable agriculture: "UC Davis: Sustainable Agriculture Research and Education Program".

Domestic machinery and furniture



Stainless Steel Table with FSC Teca Wood - Brazil sustainable design. Stainless is 100% recyclable and teca wood comes environmental friendly reforestation

Automobiles, home appliances and furnitures can be designed for repair and disassembly (for recycling), and constructed from recyclable materials such as steel, aluminum and glass, and renewable materials, such as Zelfo, wood and plastics from natural feedstocks. Careful selection of materials and manufacturing processes can often create products comparable in price and performance to non-sustainable products. Even mild design efforts can greatly increase the sustainable content of manufactured items.

Improvements to heating, cooling, ventilation and water heating

- Absorption refrigerator
- Annualized geothermal solar
- Earth cooling tubes
- Geothermal heat pump
- Heat recovery ventilation
- Hot water heat recycling
- Passive cooling
- Renewable heat

- Seasonal thermal storage
- Solar air conditioning
- Solar hot water

Disposable products

Detergents, newspapers and other disposable items can be designed to decompose, in the presence of air, water and common soil organisms. The current challenge in this area is to design such items in attractive colors, at costs as low as competing items. Since most such items end up in landfills, protected from air and water, the utility of such disposable products is debated.

Eco fashion and home accessories

Creative designers and artists are perhaps the most inventive when it comes to upcycling or creating new products from old waste. A growing number of designers upcycle waste materials such as car window glass and recycled ceramics, textile offcuts from upholstery companies, and even decommissioned fire hose to make belts and bags. Whilst accessories may seem trivial when pitted against green scientific breakthroughs; the ability of fashion and retail to influence and inspire consumer behaviour should not be underestimated. Eco design may also use bi-products of industry, reducing the amount of waste being dumped in landfill, or may harness new sustainable materials or production techniques e.g. fabric made from recycled PET plastic bottles or bamboo textiles.

Energy Sector

Sustainable technology in the energy sector is based on utilizing renewable sources of energy such as solar, wind, hydro, bioenergy, geothermal, and hydrogen. Wind energy is the world's fastest growing energy source; it has been in use for centuries in Europe and more recently in the United States and other nations. Wind energy is captured through the use of wind turbines that generate and transfer electricity for utilities, homeowners and remote villages. Solar power can be harnessed through photovoltaics, concentrating solar, or solar hot water and is also a rapidly growing energy source.

The availability, potential, and feasibility of primary renewable energy resources must be analyzed early in the planning process as part of a comprehensive energy plan. The plan must justify energy demand and supply and assess the actual costs and benefits to the local, regional, and global environments. Responsible energy use is fundamental to sustainable development and a sustainable future. Energy management must balance justifiable energy demand with appropriate energy supply. The process couples energy awareness, energy conservation, and energy efficiency with the use of primary renewable energy resources.

Water Sector

Sustainable water technologies have become an important industry segment with several companies now providing important and scalable solutions to supply water in a sustainable manner.

Beyond the use of certain technologies, Sustainable Design in Water Management also consists very importantly in correct implementation of concepts. Among one of these principal concepts is the fact normally in developed countries 100% of water destined for consumption, that is not necessarily for drinking purposes, is of potable water quality. This concept of differentiating qualities of water for different purposes has been called "fit-for-purpose". This more rational use of water achieves several economies, that are not only related to water itself, but also the consumption of energy, as to achieve water of drinking quality can be extremely energy intensive for several reasons.

Sustainable technologies

Sustainable technologies use less energy, fewer limited resources, do not deplete natural resources, do not directly or indirectly pollute the environment, and can be reused or recycled at the end of their useful life. There is a significant overlap with appropriate technology, which emphasizes the suitability of technology to the context, in particular considering the needs of people in developing countries. However, the most appropriate technology may not be the most sustainable one; and a sustainable technology may have high cost or maintenance requirements that make it unsuitable as an "appropriate technology," as that term is commonly used.

Encouraging sustainability



Training meeting with factory workers in a stainless steel ecodesign company from Rio de Janeiro - Brazil

The Passivhaus-Institut promotes and establishes standards for the Passive House - Passivhaus international program for Low-energy houses and other low-energy building techniques and structures.

The use of sustainable technologies may be encouraged through means such as reducing the capacity of the electrical cable supplying a home, such as Australia's Crystal Waters Village. In some cases the electricity supplier charges a higher rate for the energy used when the capacity of the supply is increased.

Terminology

In some countries the term *sustainable design* is known as Ecodesign, green design or environmental design. Ecodesign as meant by Victor Papanek, did include social design and social aspects. Over the past years the terms *sustainable design* and *design for sustainability* — besides other new terms — became more accepted globally, including the triple bottom line (people, planet and profit).

Chapter- 6

Eco-Industrial Park



View of the Kalundborg Eco-industrial Park

An **eco-industrial park** (EIP) is an industrial park in which businesses cooperate with each other and with the local community in an attempt to reduce waste and pollution, efficiently share resources (such as information, materials, water, energy, infrastructure, and natural resources), and help achieve sustainable development, with the intention of increasing economic gains and improving environmental quality. An EIP may also be planned, designed, and built in such a way that it makes it easier for businesses to cooperate, and that results in a more financially sound, environmentally friendly project for the developer.

The Eco-industrial Park Handbook states that "An Eco-Industrial Park is a community of manufacturing and service businesses located together on a common property. Members seek enhanced environmental, economic, and social performance through collaboration in managing environmental and resource issues."

Based on the concepts of industrial ecology, collaborative strategies not only include by-product synergy ("waste-to-feed" exchanges), but can also take the form of wastewater cascading, shared logistics and shipping & receiving facilities, shared parking, green technology purchasing blocks, multi-partner green building retrofit, district energy systems, and local education & resource centres. This is an application of a systems approach, in which designs and processes/activities are integrated to address multiple objectives.

EIPs can be developed as greenfield land projects, where the eco-industrial intent is present throughout the planning, design and site construction phases, or developed through retrofits and new strategies in existing industrial developments.

Examples



Example of Industrial Symbiosis. Waste steam from a waste incinerator (right) is piped to an ethanol plant (left) where it is used as input to their production process.

"Industrial symbiosis" is a related but more limited concept in which companies in a region collaborate to utilize each other's by-products and otherwise share resources. In Kalundborg, Denmark a symbiosis network links a 1500MW coal fired power plant with the community and other companies. Surplus heat from this power plant is used to heat 3500 local homes in addition to a nearby fish farm, whose sludge is then sold as a fertilizer. Steam from the power plant is sold to Novo Nordisk, a pharmaceutical and enzyme manufacturer, in addition to a Statoil plant. This reuse of heat reduces the amount thermal pollution discharged to a nearby fjord. Additionally, a by-product from the power plant's sulfur dioxide scrubber contains gypsum, which is sold to a wallboard manufacturer. Almost all of the manufacturer's gypsum needs are met this way, which reduces the amount of open-pit mining needed. Furthermore, fly ash and clinker from the power plant is utilized for road building and cement production.

The industrial symbiosis at Kalundborg was not created as a top-down initiative, but instead evolved gradually. As environmental regulations became stricter, firms were motivated reduce the cost of compliance, and turn their by-products into economic products.

In Canada, eco-industrial parks exist across the country and have enjoyed some success. The best known example is Burnside Park, in Halifax, Nova Scotia. With support from Dalhousie University's Eco-Efficiency Centre, the more than 1,500 businesses have been improving their environmental performance and developing profitable partnerships. Subsequently, two greenfield industrial developments have been started in Alberta: TaigaNova Eco-Industrial Park is in the heart of the Athabasca oil sands, while Innovista Eco-Industrial Park is a gateway to the Rocky Mountains ~300km west of Edmonton.

Other usage

EIPs also refer to industrial parks where a "green" approach has been taken towards the infrastructure and development of the site. This can include green infrastructure related to Renewable Energy Systems; stormwater, groundwater and wastewater management; road surfaces; and transportation demand management. Green building practices can also be encouraged or mandated

EIPs are often used as a stimulus for economic diversification in the community or region where they are located. Anchor tenants, such as bio-based product manufacturers or waste-to-energy facilities, etc., can attract complementary businesses as suppliers, scavengers/recyclers, service providers, downstream users and other businesses that could benefit from eco-industrial strategies.

Suggested usage

It is suggested that EIPs be used as a means of growing the renewable energy sector. In the case of a Solar Photovoltaic (PV) Manufacturing plant, an EIP can increase the manufacturing efficiency to make it more economical, while reducing the environmental

impact of producing the solar cells. In essence, this assists the growth of the renewable energy industry and the environmental benefits that come with replacing fossil-fuels.

Kalundborg Eco-industrial Park



View from around the Asnaes power station

In Kalundborg, Denmark an Industrial symbiosis network exists where companies in a region collaborate to use each other's by-products and otherwise share resources. At the center is a 1500MW coal fired power plant which has material and energy links with the community and several other companies. Surplus heat from this power plant is used to heat 3500 local homes in addition to a nearby fish farm, whose sludge is then sold as a fertilizer. Steam from the power plant is sold to Novo Nordisk, a pharmaceutical and enzyme manufacturer, in addition to a Statoil plant. This reuse of heat reduces the amount thermal pollution discharged to a nearby fjord. Additionally, a by-product from the power plant's sulfur dioxide scrubber contains gypsum, which is sold to a wallboard manufacturer. Almost all of the manufacturer's gypsum needs are met this way, which reduces the amount of open-pit mining needed. Furthermore, fly ash and clinker from the power plant is used for road building and cement production.

EcoPark

EcoPark (Chinese: 環保園) located in Tuen Mun Area 38, on west side of Hong Kong, is similar to an industrial park exclusively for waste recycling and environmental engineering. This is the first of its kind in Hong Kong.

Introduction

In December 2005, the Hong Kong Government mapped out a strategy on waste management emphasized waste reduction and recovery. Hong Kong currently recycles 48% of its municipal solid waste (MSW), but over 99% of recovered recyclable materials are exported to Mainland China for further re-processing while less than 1% are treated locally and re-manufactured into useful products. With the measures to promote waste recovery, recycling and reuse in place, a local waste management area like EcoPark is a viable option for furthering Hong Kong's recycling program.

EcoPark aims to promote the local recycling industry and jump-start a circular economy to provide a sustainable solution to the city's waste problems. By encouraging and promoting the reuse, recovery and recycling of waste resources and returning them to the consumption loop, the EcoPark will help realize the full potential of the local recycling industry and alleviate the heavy reliance on the export of recyclable materials recovered from Hong Kong.

Design and construction

The EcoPark occupies 200,000 square metres of land in Tuen Mun Area 38 and will be developed in two phases. As pledged in the Policy Framework, the aim is to commission Phase I of EcoPark (80,000 square metres) towards the end of 2006 and Phase II (120,000 square metres) in 2009. Hong Kong Government funding will be used to build the basic infrastructure of EcoPark.

The EcoPark will be divided into lots of different sizes. Lots in EcoPark will be tendered for specific recovered materials and processes that help achieve Hong Kong's government waste management objectives, in particular, in recycling local wastes. Admission criteria will be developed with priority given to processes involving value-added technologies, and target materials of the proposed Producer Responsibility Schemes.

Progress

All six lots in EcoPark Phase I has been allocated for recycling of waste cooking oil, waste computer equipment, waste metals, waste wood, waste plastics and waste car batteries. Some of them are already in operation, while the rest of tenants will start their operation shortly.

Construction works of the EcoPark Phase II have already completed. Two lots have been allocated to non-government organisations for recycling of plastics and waste electrical appliances. The remaining lots in EcoPark Phase II will be available for tendering in late 2010.

Phase I tenants

Champway Technology Limited - Recycling of waste cooking oil into biodiesel
Li Tong Group - Recycling of waste computer equipment
Shiu Wing Steel Limited - Recycling of waste metals
Hong Kong Hung Wai Wooden Board Company - Recycling of waste wood
Hong Kong Telford Envirotech Company Limited - Recycling of waste plastics
Cosmos Star Company Limited - Recycling of car batteries

Phase II lots

Tendering of Phase II lots (with a total area of 100,000 square metres) will start in late 2010.

Visitor Centre

The 1,000-square metre EcoPark Visitor Centre is the first education centre in Hong Kong with a main theme of solid waste management. Admission is free and decent service will be provided. Online and telephone booking can be arranged through the EcoPark Management Office.

Public consultation

Hong Kong Government has consulted the Tuen Mun District Council and members support the development of EcoPark and agree that EcoPark will help promote development of local recycling industry and create job opportunities in Tuen Mun. The Council hopes that EcoPark will become a landmark for Tuen Mun.

Local trade associations and recyclers were also consulted and they support the development of EcoPark, agreeing that by providing long-term land at affordable cost, together with supporting infrastructure, EcoPark will help enhance recycling technology development and improve waste recovery rates in Hong Kong.

Environmental considerations

An Environmental Impact Assessment (EIA) was carried out in respect of air and water quality, waste management, land contamination, landfill gas hazard and hazard to life, in which a wide range of recycling processes for different material types were examined. The assessment recommends a list of materials and processes to be allowed and also

recommends a number of mitigation measures. With these measures in place, the EIA concludes that there will be no significant environmental impacts to the surrounding areas.

Chapter- 7

Eco-Costs

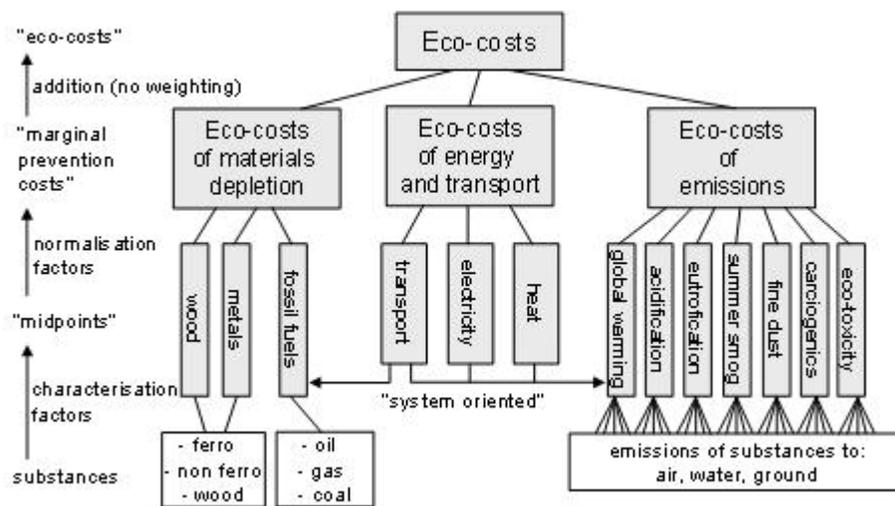


Fig 1: Calculation structure of the eco-costs 2007.

Eco-costs are a measure to express the amount of environmental burden of a product on the basis of prevention of that burden. They are the costs which should be made to reduce the environmental pollution and materials depletion in our world to a level which is in line with the carrying capacity of our earth.

For example: for each 1000 kg CO₂ emission, one should invest € 135,- in offshore windmill parks (or other CO₂ reduction systems at that price or less). When this is done consequently, the total CO₂ emissions in the world will be reduced by 65% compared to the emissions in 2008. As a result global warming will stabilise. In short: "the eco-costs of 1000kg CO₂ are € 135,-".

Similar calculations can be made on the environmental burden of acidification, eutrophication, summer smog, fine dust, eco-toxicity, and the use of metals, fossil fuels and land (nature). As such, the eco-costs are virtual costs, since they are not yet integrated in the real life costs of current production chains (Life Cycle Costs). The eco-costs should be regarded as hidden obligations.

The eco-costs of a product are the sum of all eco-costs of emissions and use of materials and energy during the life cycle "from cradle to cradle". The widely accepted method to

make such a calculation is called Life Cycle Assessment (LCA), which is basically a mass and energy balance, defined in the 14040 and ISO 14044.

The practical use of eco-costs is to compare the sustainability of several product types with the same functionality. The advantage of eco-costs is that they are expressed in a standardized monetary value (€) which appears to be easily understood ‘by instinct’. Also the calculation is transparent and relatively easy, compared to damage based models which have the disadvantage of extremely complex calculations with subjective weighting of the various aspects contributing to the overall environmental burden .

The system of eco-costs is part of the bigger model of the EVR

Background information

The eco-costs system has been introduced in 1999 and published in 2000-2004 in the International Journal of LCA , and in the Journal of Cleaner Production . In 2007 the system was updated.

The method of the eco-costs is based on the sum of the marginal prevention costs (end of pipe as well as system integrated) for toxic emissions, material depletion, energy consumption and transport, and conversion of land. For a visual display of the system see figure 1.

The classical way to calculate a “single indicator” in LCA is based on the damage of the emissions. Pollutants are grouped in “classes”, multiplied by a “characterisation” factor to cope with their relative importance within a class, and totalised to the level of their “midpoint” effect (global warming, acidification, nutrification, etc.). The classical problem is then to determine the relative importance of each midpoint effect. This is done by “normalisation” (= comparison with the pollution in a country or a region) and “weighting” (= giving each midpoint a weight, to take the relative importance into account) by an expert panel.

The calculation of the eco-costs is based on classification and characterisation tables as well (combining tables from IPCC, the Universities of Leiden and the University of Michigan), however has a different approach to the normalisation and weighting steps. Normalisation is done by calculation the marginal prevention costs for a region (i.e. the European Union), to reduce the pollution to the “no observable adverse effect level” (often the threshold level of a toxic substance). The weighting step is not required in the eco-costs system, since the total result is the sum of the eco-costs of all midpoints. The advantage of such a calculation is that the marginal prevention costs are related to the cost of the most expensive Best Available Technology which is required to meet the target, and the corresponding level of future Tradable Emission Rights. Example: For reduction of CO₂ emissions to a sustainable level, the marginal prevention costs is the cost of replacement of coal fired power plants by windmill parks at the sea.

The eco-costs have been calculated for the situation in the European Union. It might be argued that the eco-costs are also an indication of the marginal prevention costs for other

parts of the globe, under the condition of a level playing field for production companies. A group of universities in Japan is developing a set of data for Japan as well.

Eco-costs 2007

The method of the eco-costs 2007 comprises tables of over 3000 emissions, and has been made operational by special database for Simapro, based on LCIs from Ecoinvent v2 and Idemat 2008 (over 5000 materials and processes), and a database for CES (Cambridge Engineering Selector).

For emissions of toxic substances, the following set of multipliers is used in the eco-costs 2007 system:

- prevention of acidification 7.55 €/kg SO_x equivalent
- prevention of eutrophication 3.60 €/kg phosphate equivalent
- prevention of ecotoxicity 802 €/kg Zn equivalent
- prevention of carcinogens 33 €/kg PAH equivalent
- prevention of summer smog (respiratory diseases) 8.90 €/kg C₂H₄ equivalent
- prevention of fine dust 27.4 €/kg fine dust PM_{2.5}
- prevention of global warming (GWP 100) 0.135 €/kg CO₂ equivalent

The eco-costs of abiotic depletion is 0.7 €/kg for fossil fuels. The eco-costs of material depletion of tropical hardwood are based on the change of biodiversity before and after harvesting.

The characterisation tables which are applied in the eco-costs 2007 system:

- IPCC 2007, 100 years, for greenhouse gasses
- CML-2, for acidification, eutrophication and summer smog (respiratory diseases)
- IMPACT 2002+, for aquatic eco-toxicity (inc. heavy metals), fine dust and carcinogens

Prevention costs versus Damage costs

Prevention measures will decrease the costs of the damage, related to environmental pollution (e.g. damage costs related to human health problems in terms of QALYs). The savings which are a result of the prevention measures are of the same order of magnitude as the costs of prevention. So the total effect of prevention measures on our society is that it results in a better environment at virtually no extra costs, since costs of prevention and costs of savings will level out.

Discussion

There are many “single indicators” for LCA. Basically they fall in three categories:

- single issue
- damage based
- prevention based

The best known “single issue” indicator is the carbon footprint: the total emissions of kg CO₂, or kg CO₂ *equivalent* (taking methane and some other greenhouse gasses into account as well). The advantage of a single issue indicator is, that its calculation is simple and transparent, without any complex assumptions. It is easy as well to communicate to the public. The disadvantage is that it ignores the problems caused by other pollutants and it is not suitable for cradle to cradle calculations (because materials depletion is not taken into account).

The most common single indicators are damage based. This stems from the period of the 1990th, when LCA was developed to make people aware of the damage of production and consumption. The advantage of damage based single indicators is, that they make people aware of the fact that they should consume less, and make companies aware that they should produce cleaner. The disadvantage is that these damage based systems are very complex, not transparent for others than who make the computer calculations, need many assumptions, and suffer from the subjective weighting procedure at the end. Communication of the result is not easy, since the result is expressed in “points” (attempts to express the results in money were never very successful, because of methodological flaws).

Prevention based indicators, like the system of the eco-costs, are relatively new. The advantage, in comparison to the damage based systems, is that the calculations are relatively easy and transparent, and that the results can be explained in terms of money and in measures to be taken. The system is focused on the decision taking processes of architects, business people, designers and engineers. The disadvantage is that the system is not focused on the fact that people should consume less.

Eco-costs value ratio

The **EVR model** is a Life Cycle Assessment based method to analyse consumption patterns, business strategies and design options in terms of eco-efficient value creation. Next to this it's used to compare products and service systems (e.g. benchmarking).

The eco-costs/value ratio (EVR) is an indicator to reveal sustainable and unsustainable consumption patterns of people. The eco-costs is an indicator for the environmental pollution of the products people buy, the value is the price they pay for it in our free market economy. Example: When somebody spends 1000 euro per month on housing (in Europe: EVR approx. 0,3) it is less harmful for the environment than when 1000 euro is spend on diesel (in Europe: EVR approx. 1,0).

The EVR is also relevant for business strategies, because companies are facing the slow but inevitable internalization of environmental costs. At the moment the costs of products don't take into account the environmental damage caused by these products. This "pollution is for free" mentality is less and less accepted by communities.

The EVR makes companies aware of the relative importance of the environmental pollution of their products, and the relative risk they run that future production costs will increase because of this internalization of environmental costs. By using the EVR, companies can make decisions for their product portfolio: abandon products with low value and high environmental costs and stimulate products with high value and low environmental costs.

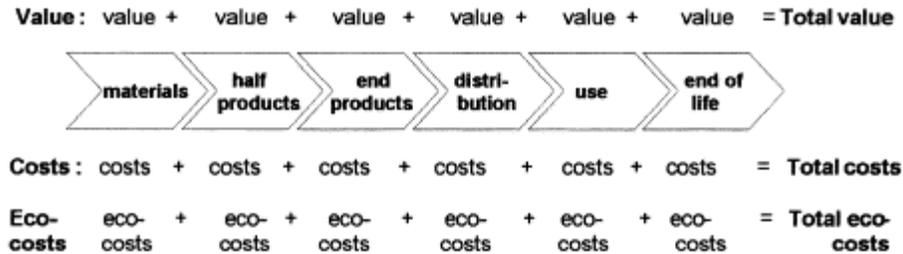


Figure 1: The basic idea of combining the economic and ecological chain: ‘the EVR chain’.

Background information

The EVR model has been introduced in 1998 and published in 2000-2004 in the International Journal of LCA , and in the Journal of Cleaner Production . In 2007 the system was updated. The concept of EVR is based on eco-costs.

Working principle

The model

$EVR = \text{Eco-costs}/\text{value}$. The basic idea of the EVR model is to link the ‘value chain’ to the ecological product chain. In the value chain, the added value (in terms of money) and the added costs are determined for each step of the product ‘from cradle to grave’. Similarly, the ecological impact of each step in the product chain is expressed in terms of money, the so-called ‘eco-costs’ . See figure 1

Eco-costs

Eco-costs express the amount of environmental burden of a product on basis of prevention of that burden. They are the marginal prevention costs (money) which should be made to reduce the environmental pollution and materials depletion in our world to a level which is in line with the carrying capacity of our earth.

As such, the eco-costs are virtual costs, since they are not yet integrated in the real life costs of current production chains (Life Cycle Costs). The eco-costs should be regarded as hidden obligations.

For example: for each 1000 kg CO₂ emission, one should invest € 135,- in offshore windmill parks (or other CO₂ reduction systems at that price or less). When this is done consequently, the total CO₂ emissions in the world will be reduced by 65% compared to the emissions in 2008. As a result global warming will stabilise. In short: "the eco-costs of 1000kg CO₂ are € 135,-". Similar calculations can be made on the environmental burden of acidification, eutrication, summer smog, fine dust, eco-toxicity, and the use of metals, fossil fuels and land (nature).

At this moment eco-costs are used to assess the environmental performance of different materials, processes and End of Life methods.

EVR of products

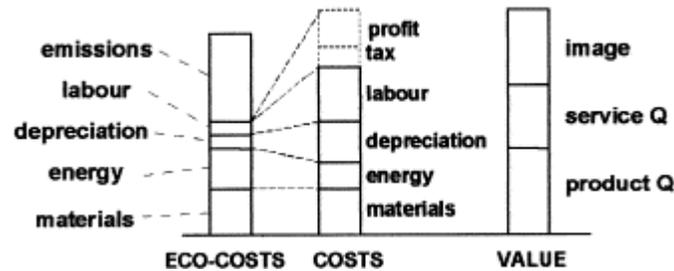


Figure 2: The decomposition of ‘virtual eco-costs’, costs and value of a product.

The EVR combines eco-cost and value to see whether a product will be successful. The product should have low environmental impact in its lifecycle (low eco-costs) and an attractive value for consumers. The value here is the market value (perceived customer value, also called fair price). Figure 2 depicts the three dimensions of a product: the value, the costs and the eco-costs.

It is a trend in society that heavy pollution of industry is not accepted anymore by the inhabitants of a country. This results in stricter regulations by countries (e.g. tradable emission rights, enforcement of best available technologies, eco-taxes, etc.). Eco-costs will then become part of the internal production costs. This internalizing of eco-costs might be a threat to a company, but it might also be an opportunity: “When my product has less eco-burden than that of my competitor, my product can withstand stricter regulations of the government. So this characteristic of low eco-costs of my product is a competitive edge.” To analyse the short term and the long term market prospects of a product or a product service combination (Product Service System, PSS), each product or PPS can be positioned in the portfolio matrix of Figure 3. The basic idea of the product portfolio matrix is the fact that a product, service or PSS is characterized by:

- its short term market potential: high value/costs ratio
- its long term market requirement: low eco-costs.

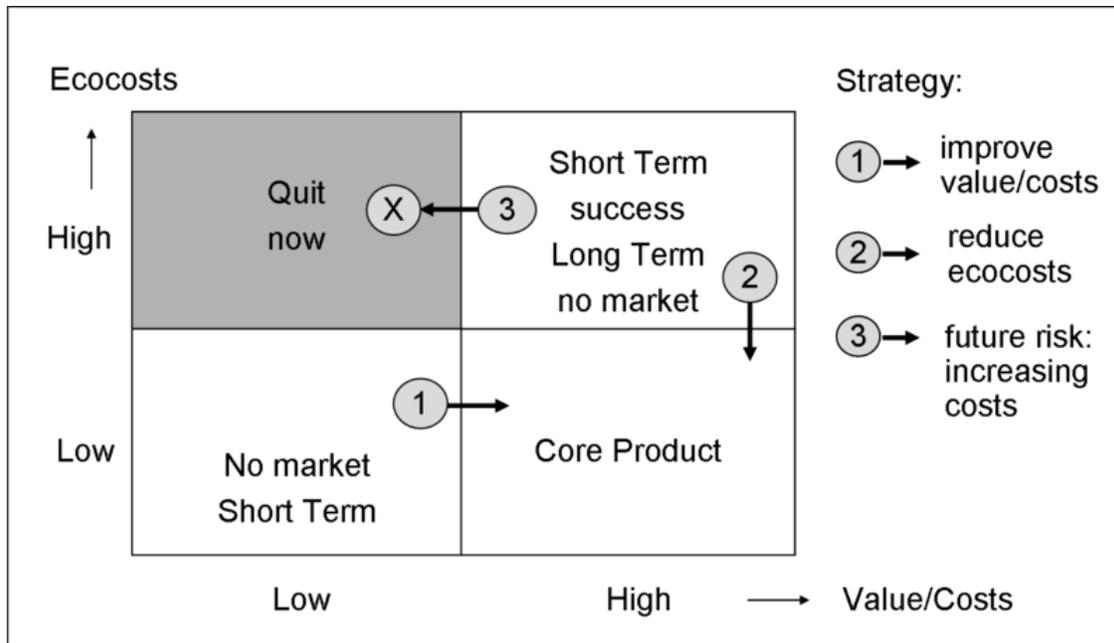


Figure 3: Product portfolio matrix for EVR product strategy of companies.

In terms of product strategy, the matrix results in 3 strategic directions:

1. enhance the value/costs ratio of a green design to create a bigger market
2. lower the eco-costs of current successful products to make it fit for future markets
3. abandon products with a low value/ costs ratio (not much profit, small market) and high eco-costs

For many ‘green designs’, the usual problem is that they have a low current value/costs ratio. In most of the cases the production costs are higher than the production costs of the classic solution, in some cases even the (perceived) quality is poor. There are two ways to do something about it:

- a. enhance the (perceived) quality of the product
- b. attach to the product a service (create a PSS) in a way that the value of the bundle of the product and the service is more than the value of its components.

For a product which has a good present value/costs ratio, but high eco-costs, the product and the production process have to be redesigned to lower the eco-costs. This road towards sustainability is often far more promising than the strategy of enhancing the value/costs ratio of a green design.

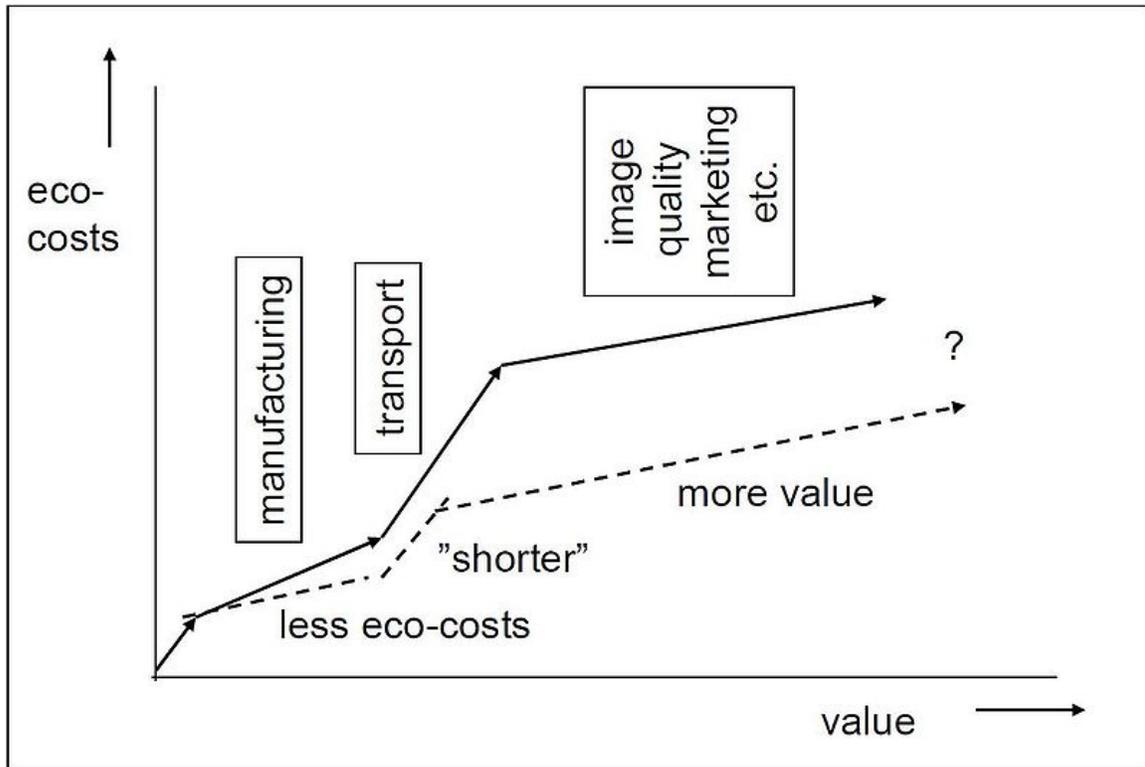


Figure 4: Design strategies to enhance the EVR of a product.

The reason is that the economies of scale for production and distribution are available and that the new product is marketed to an existing client base which is used to the brand name, the quality standards, the service system, etc.

Note: The most common fear of business managers is that their new green products end up with a deteriorated value/costs ratio, and hence will have a cumbersome position in the market. The stability of the governmental policy plays an important role here. When governmental regulations which level the playing field are postponed or even abandoned, proactive companies with sound product strategies are harmed. This can cause severe damage to the transition process and may lead to reluctance of players to move proactively in the future.

The most successful design options are depicted in Figure 4. The best design strategy is:

- to increase value where value is high
- to decrease the eco-costs where the eco-costs are high

Use

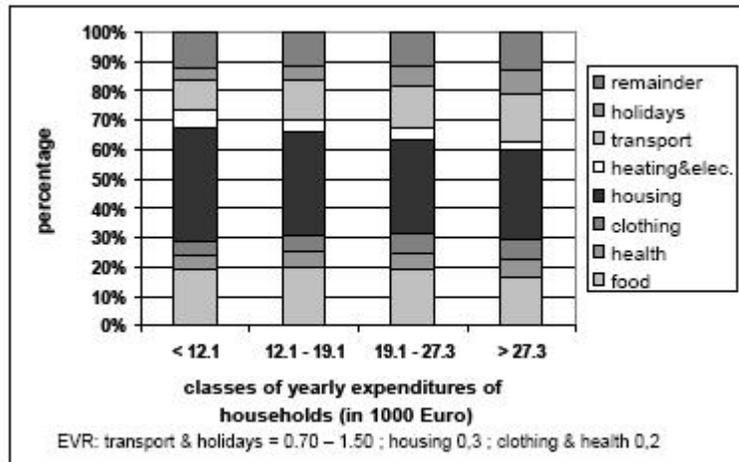


Figure 5. The consumer's side: preference of expenditures in Dutch households.

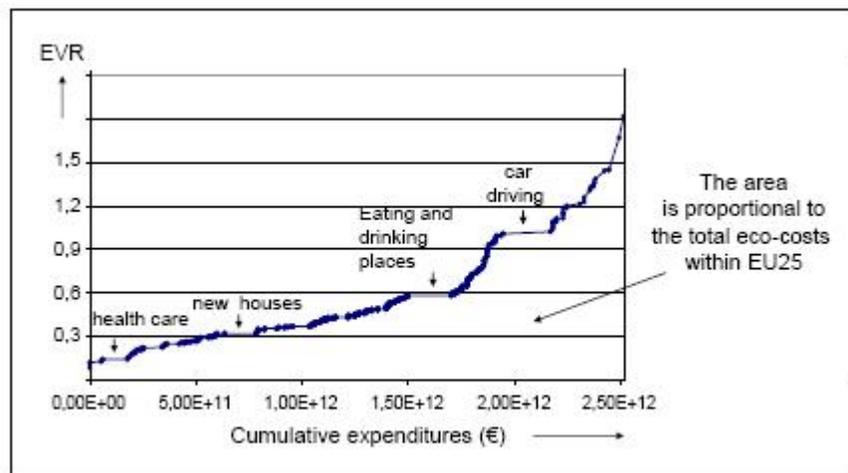


Figure 6. The EVR and the total expenditures of all consumers in the EU25 (from EIPRO)

EVR & de-linking

In economics, de-linking (also known as decoupling) is often used in the context of economic production and environmental quality. In this context, it refers to the ability of an economy to grow without corresponding increases in environmental pressure. In many economies increasing production (GDP) would involve increased pressure on the environment. An economy that is able to sustain GDP growth, without also experiencing a worsening of environmental conditions, is said to be de-linked.

There is a consumer's side of the de-linking of economy and ecology. Under the assumption that most of the households spend in their life what they earn in their life, the total EVR of the spending of households is the key towards sustainability. Only when this total EVR of the spending gets lower, the eco-costs related to the total spending can be reduced even at a higher level of spending. There are two ways of achieving this:

- At the production side: the improvement of eco-efficiency ('lowering EVR') of products and services by the industry
- At the consumer's side: the change of lifestyle of customers in the direction of 'low EVR' products.

At the production side, our society is heading in the right direction: gradually, industrial production is achieving higher levels of the value/costs ratio and is at the same time becoming cleaner. At the consumer's side, however, our society is suffering from the fact that the consumers preferences are heading in the wrong direction: towards products and services with an unfavourable EVR (like driving in SUVs, more kilometres, intercontinental flights for holidays). These unfavourable preferences can be concluded from Figure 5.

Figure 5 shows that people in the Netherlands (and probably in the other EC countries as well) spend relatively more money on cars and holidays when they have more money available. Other studies show that people tend to have intercontinental holidays at the moment they can afford it. This shift in consumer spending will become a big problem in the near future, since the EVR of e.g. housing and health care is much lower than the EVR of transport and (inter)continental holidays by plane. Figure 6 shows the EVR (= ecocosts/price) on the Y-axis as a function of the cumulative expenditures of all products and services of all citizens in the EU 25 on the X-axis. The data is from the EIPRO study of the European Commission (EIPRO = environmental impact of products).

The area underneath the curve is proportional to the total eco-costs of the EU25. Basically there are two strategies to reduce the area under the curve: - ask industry to reduce the eco-costs of their products (this will shift the curve downward) - try to reduce expenditures of consumers in high end of the curve, and let them spend this money at the low end of the curve (this will shift the middle part of the curve to the right). The question is now how designers and engineers can contribute to this required shift towards sustainability and what this means to product portfolio strategies of companies. The solution is Eco-efficient Value Creation.

Eco-efficient Value Creation

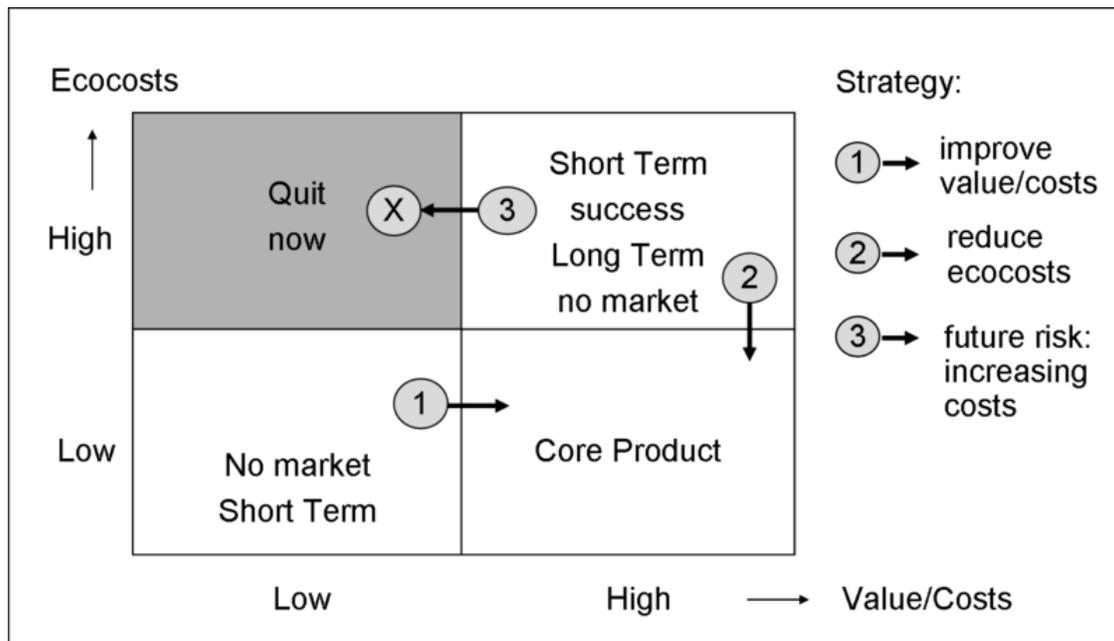


Figure 7: The double objective for design & engineering: less eco-costs, more value.

The way towards sustainability requires a double aim in product innovation, see Figure 7:

- lower eco-costs, and at the same time
- higher value (a higher market price).

We call this: Eco-efficient Value Creation. The reason we need value creation for eco-efficient products is threefold:

1. the higher price in the market is required to cover the higher production cost of green products (note that a higher price is only accepted by the consumer when the perceived value is higher, otherwise the consumer will not buy the product)
2. the higher price prevents the rebound effect
3. lowering the EVR appears the key to a sustainable development at the level of countries (Figure 6)

Below, an example of eco-efficient value creation is given:

The first example is the introduction of the Lexus RX 400h in the USA:

- the customer value has increased, by emphasising its combined power and comfort (from the advertisement in the US: ".....While it may have a V6 engine

- under the hood, the extra boost from the electric-drive motor gives the vehicle the acceleration power of a V8..... and the noise levels in Lexus hybrid vehicles have been reduced even more")
- the eco-costs of driving are lower, since its excellent overall fuel economy

Note that the acceleration of a car is an interesting issue in terms of value. High acceleration is associated with expensive sports cars (Porsche, Ferrari). But people who buy these fast cars hardly use it. For these people acceleration is more part of the image of the product than it is part of the product qualities they use on a daily basis.

Environmental Benchmarking in LCA

Life Cycle Assessment (LCA) is the generally accepted method to compare two (or more) alternative products or services. A prerequisite for such a comparison is that the functionality ('functional unit') and the quality of the alternatives are the same (you cannot compare apples and oranges in the classical LCA). In cases of product design and architecture, however, this prerequisite seems to be a fundamental flaw in the application of LCA: the designer or architect is aiming at a better quality (in the broad sense of the word: including intangible aspects like beauty and image), so the new design never has the same quality. In some cases the functionality of the design is not the same, since the design solution is limited by a maximum budget, in some cases the functionality is the same, but the higher quality results in a higher price. In all these cases a single indicator in LCA (like the eco-costs) is not suitable for environmental benchmarking. In these cases however, it does make sense to compare the design alternatives on the basis of the eco-costs/value ratio (EVR), where the value is the perceived customer value (the fair price).

Example 1. Different types of armchairs differ in terms of comfort, aesthetics, etc. rather than in terms of functionality. A classical LCA (with a single indicator like eco-costs, carbon footprint, etc.) does not make sense here. Selection on the basis of EVR, however, is the key to a sustainable consumption pattern. The chair with the lowest EVR is the best solution in terms of sustainability.

Example 2. In LCA, the comparison of a new building and a renovated building is in the majority of cases not possible, since, in practice, both solutions differ in almost all quality aspects (tangible as well as intangible). However, the solution with lowest EVR is the best in terms of sustainable consumption.

Note that the renovated building is the best solution in most of the cases, because it has the lowest EVR in the production phase. However, in some cases the renovated building is not the best solution, because of unfavourable energy consumption (high EVR) in the use phase.