Design for Sustainability

Sharmistha Banerjee

Stupa of Sanchi

The 'Great Stupa' at Sanchi is the oldest stone structure in India and was originally commissioned by the emperor Ashoka the Great in the 200 BC. Its nucleus was a simple hemispherical brick structure built over the relics of the Buddha. It was crowned by the chatra, a parasol-like structure symbolising high rank, which was intended to honour and shelter the relics.

Iron Pillar near Qutb Minar

The Iron Pillar dates from Gupta King, who ruled from 375 - 413 AD.

FOR the last 1600 years, the rustless wonder called the Iron Pillar of India, near the Qutub Minar at Mehrauli in Delhi, continues to baffle contemporary scientists, who cannot determine the method of manufacture, which prevented the iron from rusting for these last 16 centuries.

Caravan Bridge over the river Meles in Izmir, Turkey

It was built in 850 BC and is the oldest functional bridge in the world at 2865 years.

Mahabodhi Temple, Gaya

Built in 260 BC and is a UNESCO World Heritage Site.

Dujiangyan irrigation system

Dujjangyan (Chinese: 都江堰; pinyin: Dūjiāngyàn) is an irrigation infrastructure built in 256 BC during the Warring States period of China by the Kingdom of Qin. It is located in the Min River (Chinese: 岷江; pinyin: Mínjiāng) in Sichuan province, China, near the capital Chengdu. It is still in use today to irrigate over 5,300 square kilometers of land in the region.

Great Pyramid of Giza, Egypt

Also known as the Pyramid of Khufu is the oldest and largest of the three pyramids in the Giza Necropolis bordering what is now El Giza, Egypt. It is the oldest of the Seven Wonders of the Ancient World, and the only one to remain largely intact. Egyptologists believe that the pyramid was built as a tomb for fourth dynasty Egyptian Pharaoh Khufu over a 10 to 20-year period concluding around 2560 BCE. Initially at 146.5 metres (481 feet), the Great Pyramid was the tallest man-made structure in the world for over 3,800 years.

Sustainability

In ecology, sustainability refers to how biological systems remain diverse and productive. Long-lived and healthy wetlands and forests are examples of sustainable biological systems.

In more general terms, sustainability is the endurance of systems and processes. The organizing principle for sustainability is sustainable development, which includes the four interconnected domains: ecology, economics, politics and culture.

Sustainable Development

The **United Nations** World Commission on Environment and **Development** (WCED) in its 1987 report Our Common Future defines **sustainable development**:

"**Development** that meets the needs of the present without compromising the ability of future generations to meet their own needs."

It contains within it two key concepts:

- the concept of **needs**, in particular the essential needs of the world's poor, to which overriding priority should be given; and
- the idea of limitations imposed by the state of technology and social organization on the environment's ability to meet present and future needs.

- All definitions of sustainable development require that we see the world as a system—***a system that connects space; and a system that connects time***.

- W***orld as a system over space*** - air pollution from North America affects air quality in Asia, and pesticides sprayed in Argentina could harm fish stocks off the coast of Australia.

- ***World as a system over time*** - the decisions our grandparents made about how to farm the land continue to affect agricultural practice today; and the economic policies we endorse today will have an impact on urban poverty when our children are adults.

- ***Quality of life is a system***, too. It's good to be physically healthy, but what if you are poor and don't have access to education? It's good to have a secure income, but what if the air in your part of the world is unclean? And it's good to have freedom of religious expression, but what if you can't feed your family?

Which is more sustainable?


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Europe
Barents Sea
Norwegian Sea
ICELAND
Reykjavik
SWEDEN
FINLAND
NORWAY
Gulf of Bothnia
UNITED KINGDOM
North Sea
Baltic Sea
ESTONIA
LATVIA
North Atlantic Ocean
RUSSIA
Moscow
DENMARK
RUSSIA
LITHUANIA
NETHERLANDS
BELARUS
IRELAND
Amsterdam
Berlin
Warsaw
POLAND
London
GERMANY
Celtic Sea
BELGIUM
LUX.
UKRAINE
Paris
CZECH REP.
SLOVAKIA
LIECH.
MOLDOVA
AUSTRIA
FRANCE
SWITZERLAND
HUNGARY
ROMANIA
Bay of Biscay
ITALY
SERBIA
BULGARIA
Black Sea
MONACO
ANDORRA
PORTUGAL
Madrid
SPAIN
Ankara
TURKEY
Lisbon
GREECE
MALTA
CYPRUS
Map not to scale
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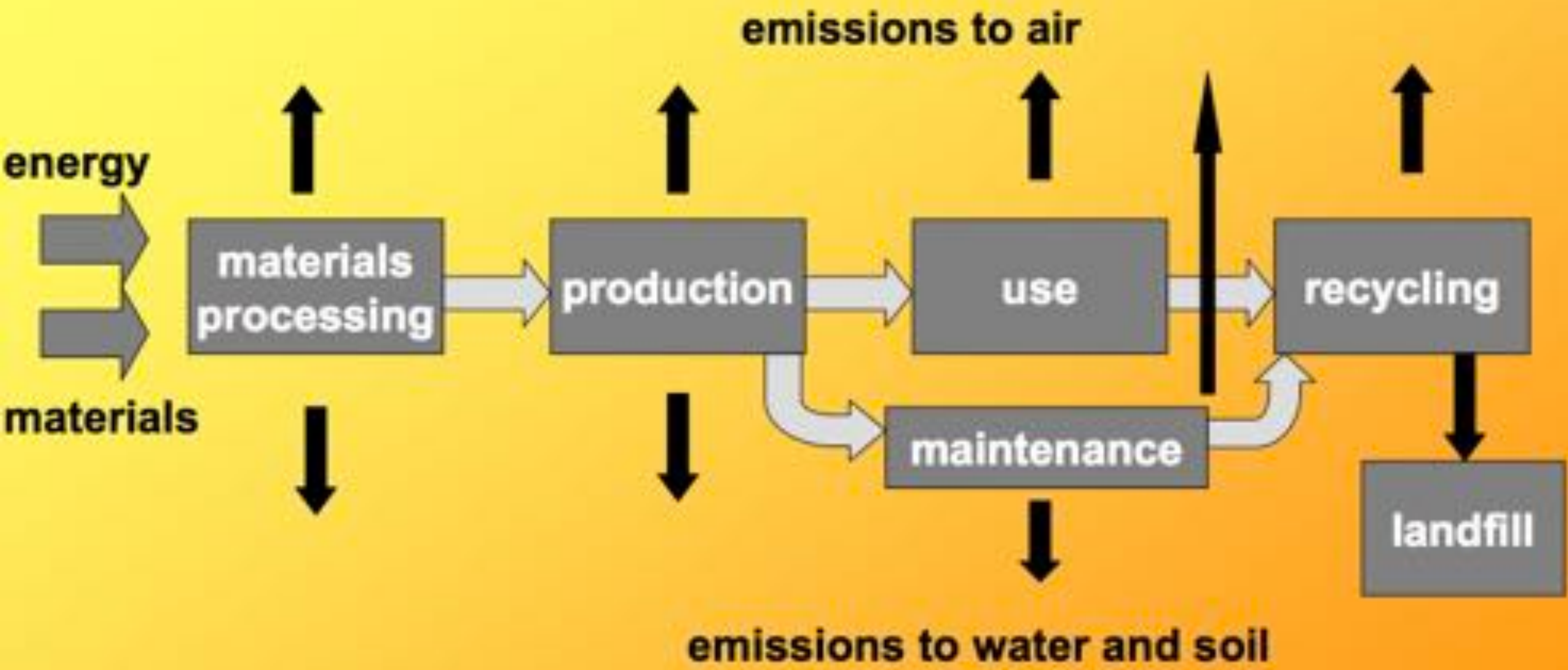
Life Cycle Analysis

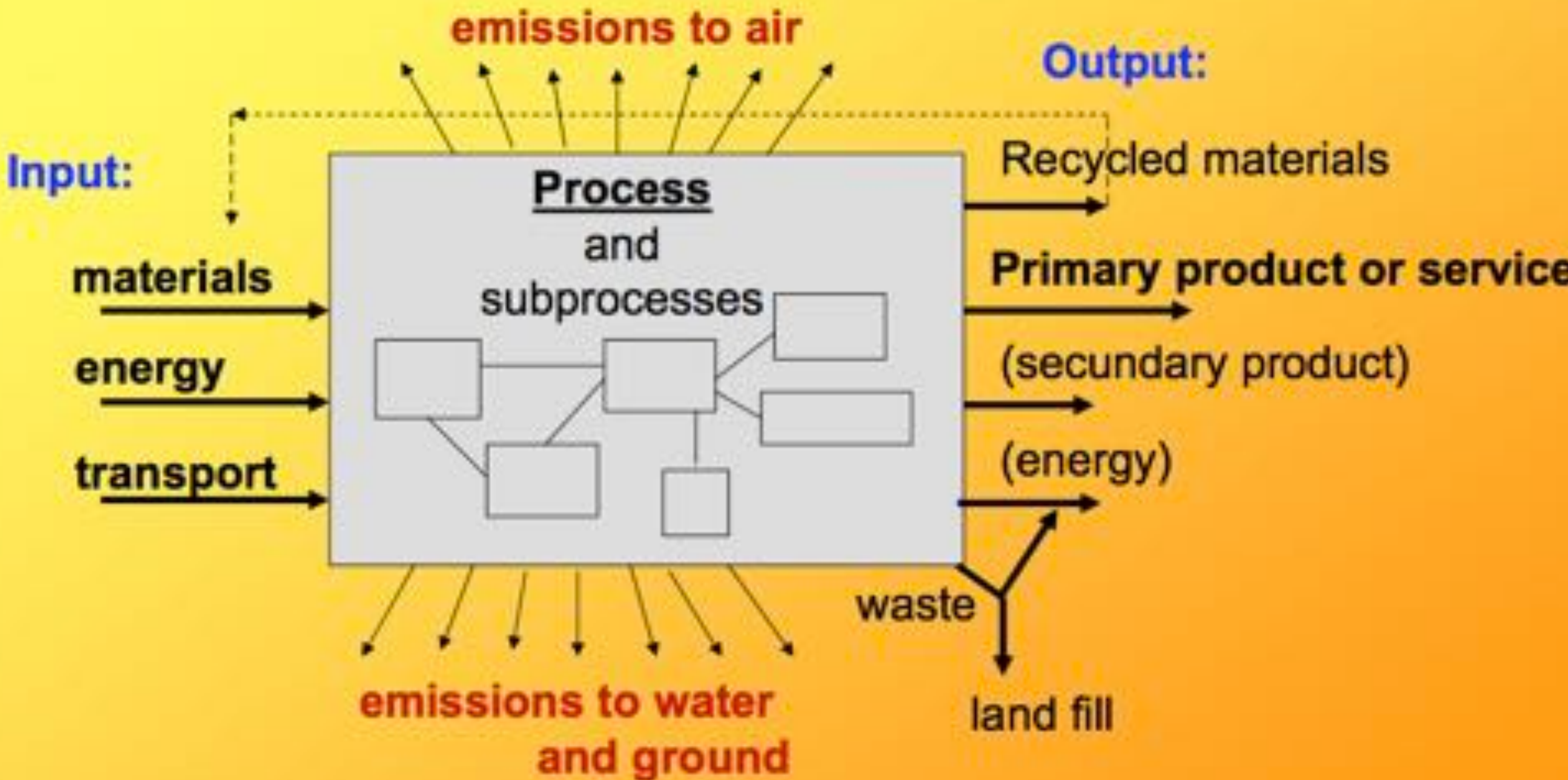
- Eco-costs
- CO_2 equivalents
- Carbon footprint
- Eco-efficient value creation

An LCA provides data on the environmental burden "from cradle to grave"

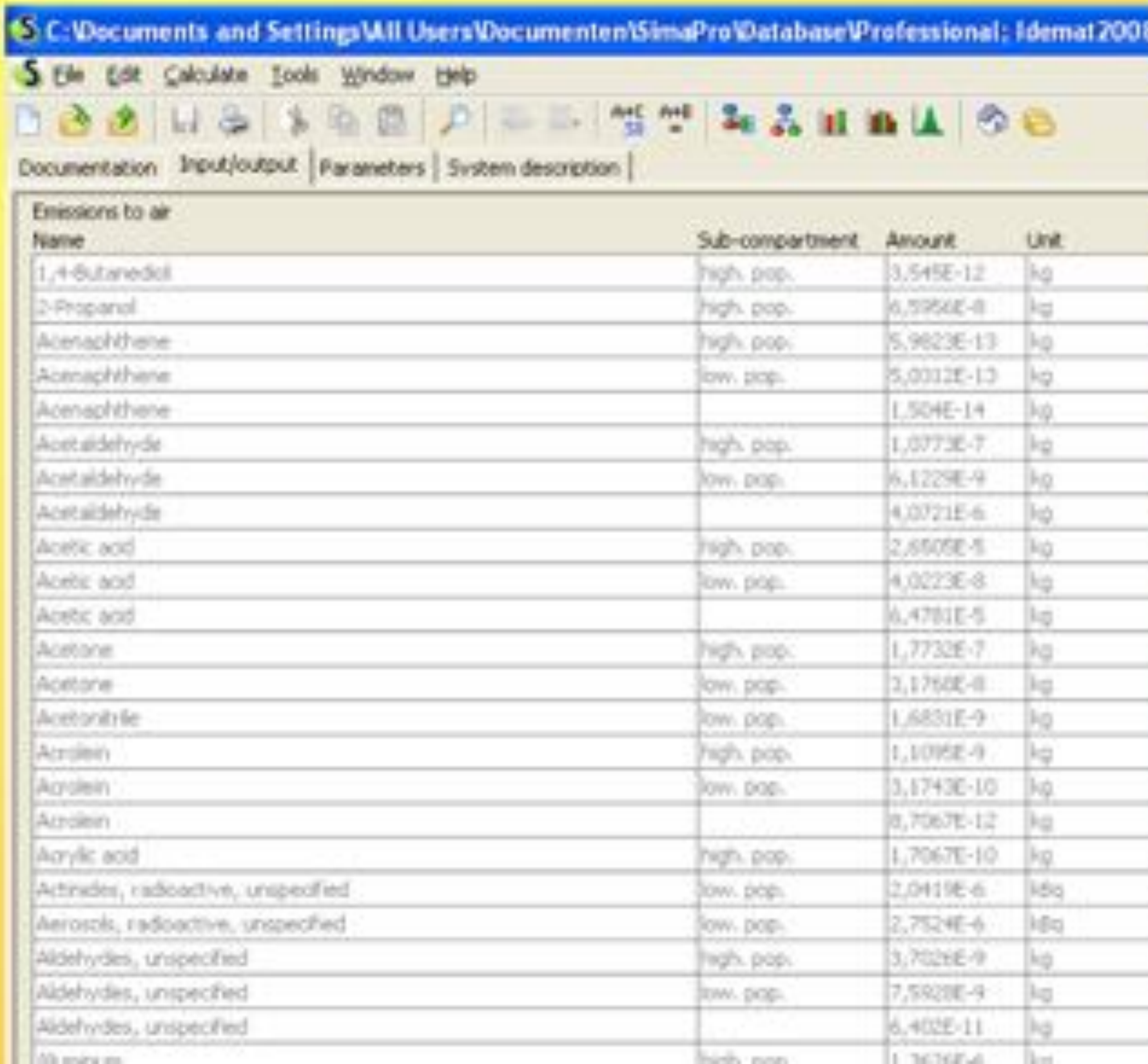


First step: LCI = life cycle inventory
Second step: LCIA = life cycle inventory analysis

The Life Cycle Inventory
The basic structure



There are LCIs of 5000 (!) processes in the ecoinvent v2 and Idemat databases in Simapro



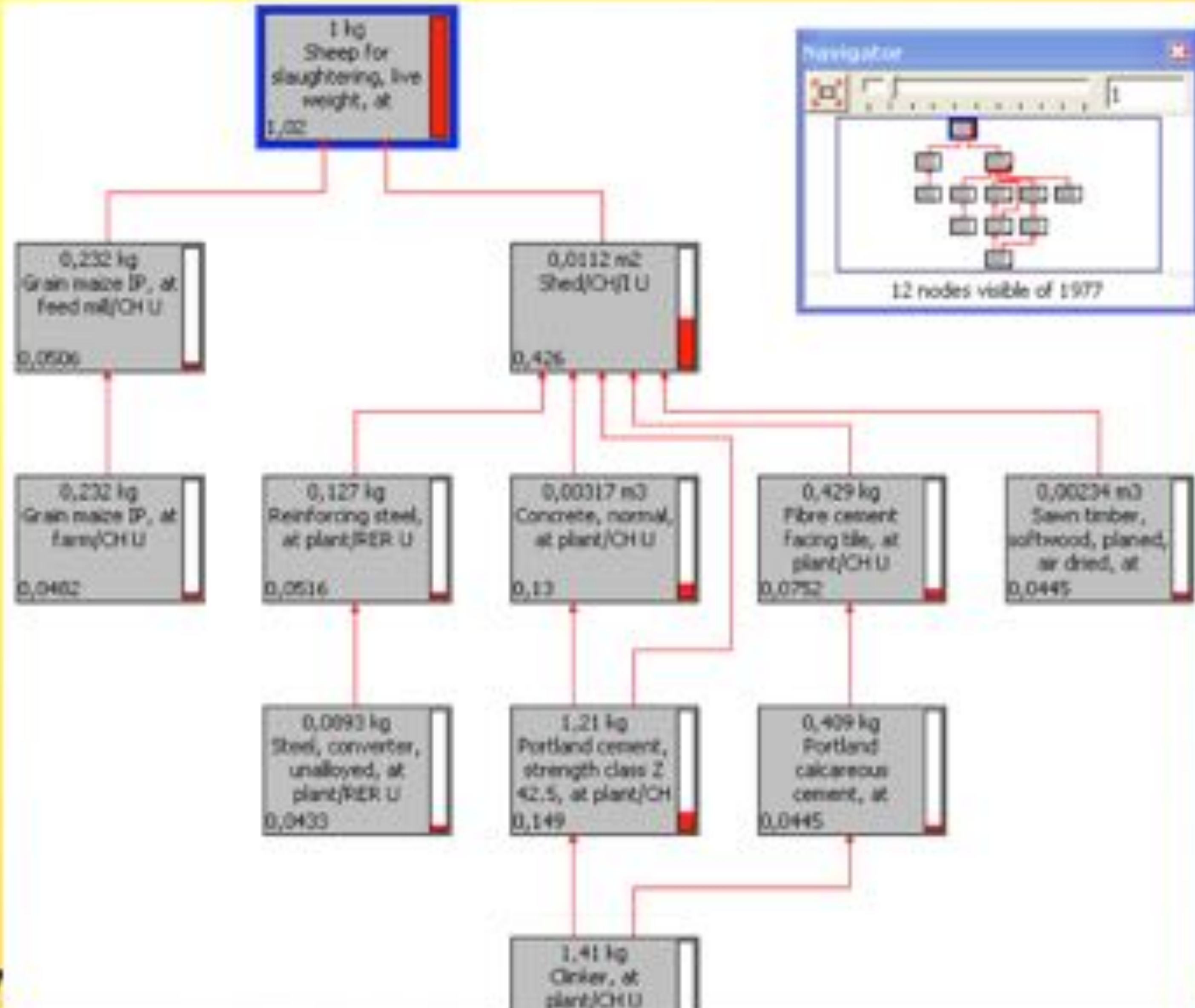
Name	Sub-compartment	Amount	Unit
1,4-Butanediol	high. pop.	3,545E-12	kg
2-Propanol	high. pop.	6,5956E-8	kg
Acenaphthene	high. pop.	5,9823E-13	kg
Acenaphthene	low. pop.	5,0012E-13	kg
Acenaphthene		1,504E-14	kg
Acetaldehyde	high. pop.	1,0773E-7	kg
Acetaldehyde	low. pop.	6,1229E-9	kg
Acetaldehyde		4,0721E-6	kg
Acetic acid	high. pop.	2,6505E-5	kg
Acetic acid	low. pop.	4,0223E-8	kg
Acetic acid		6,4781E-5	kg
Acetone	high. pop.	1,7732E-7	kg
Acetone	low. pop.	3,1768E-8	kg
Acetonitrile	low. pop.	1,6831E-9	kg
Acrolein	high. pop.	1,1095E-9	kg
Acrolein	low. pop.	3,1743E-10	kg
Acrolein		8,7067E-12	kg
Acrylic acid	high. pop.	1,7067E-10	kg
Actinides, radioactive, unspecified	low. pop.	2,0419E-6	kBq
Aerosols, radioactive, unspecified	low. pop.	2,7524E-6	kBq
Aldehydes, unspecified	high. pop.	3,7026E-9	kg
Aldehydes, unspecified	low. pop.	7,5928E-9	kg
Aldehydes, unspecified		6,402E-11	kg

Example:

Sheep for slaughtering at farm gate

emissions to air
480 (!) lines

There are LCIs of 4500 (!) processes in the ecoinvent v2 database

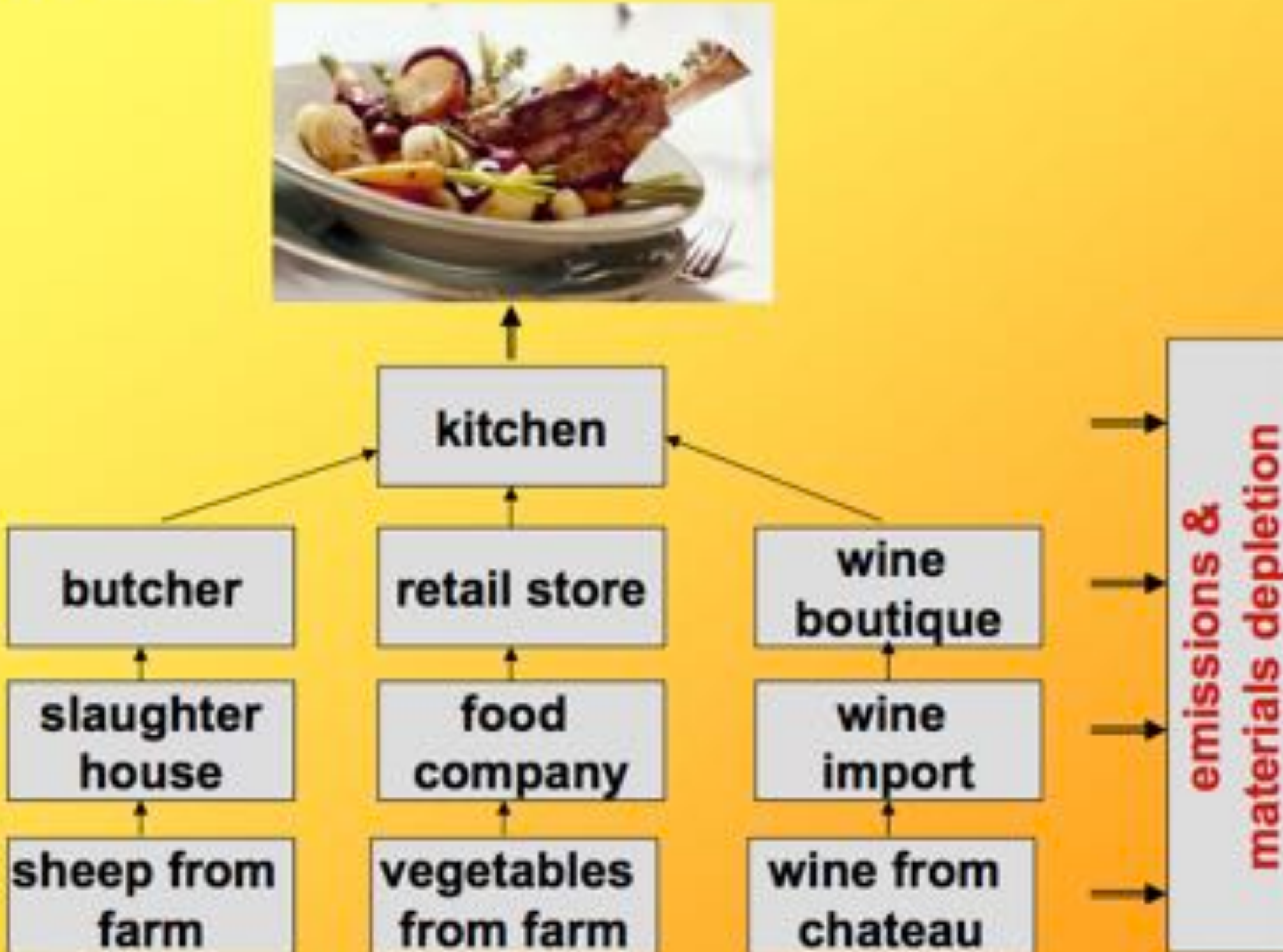


Example:

Sheet for slaughtering at farm gate

(the first level only)

The "tree" of a meal



Which one is more sustainable?

Design for Sustainability Approaches

- Selection of resources with low environmental impact
- Design of products with low environmental impact
- Product-Service System Design for eco-efficiency
- Design for social equity and cohesion

D4S has over the years changed from

- Intervention after process-caused damages (e.g. clean up a polluted lake), ***to***
- Intervention in processes (e.g. use clean technologies to avoid polluting the lake), ***to***
- Intervention in products and services (e.g. design product and services that do not necessitate processes that could pollute a lake), ***to***
- Intervention in consumption patterns (e.g. understand which consumption patterns do not (or less) require products with processes that could pollute that lake)

Product Life Cycle Design or Eco-design

Since the 1990s, attention has partially moved to the product level, i.e. to the design of products with low environmental impact, usually referred as product ***Life Cycle Design, Eco-design*** or ***Design for the Environment***.

New methods of assessing the environmental impact of products were developed; from among them the most accepted is ***Life Cycle Assessment (LCA)***.

Two main approaches were introduced:

- ***life cycle approach***—from designing a product to designing the product life cycle stages, i.e. all the activities needed to produce the materials and then the product, to distribute it, to use it and finally to dispose of it—are considered in a holistic approach.

- ***functional approach*** was reconceptualised from an environmental point of view, i.e. to design and evaluate a product's environmental sustainability, beginning from its function rather than from the physical embodiment of the product itself. It has been understood that environmental assessment, and therefore also design, must have as its reference the function provided by a given product. The design must thus consider the product less than the 'service/result' procured by the product.

D4S – Engineering Design Criteria and Guidelines

1. Minimize Materials Consumption

1.1 Minimize material content:

- Dematerialize the product or some of its components
- Digitalize the product or some of its components
- Miniaturize
- Avoid over-sized dimensions
- Reduce thickness
- Apply ribbed structures to increase structural stiffness
- Avoid extra components with little functionality

1.2 Minimize scraps and discards

- Select processes that reduce scraps and discarded materials during productions
- Engage simulation systems to optimize transformation processes

1.3 Minimize or avoid packaging

- Avoid packaging
- Apply materials only where absolutely necessary
- Design the package to be part (or become a part) of the product

1.4 Engage more consumption efficient systems

- Design for more efficient consumption of operational materials
- Design for more efficient supply of raw materials
- Design for more efficient use of maintenance materials
- Design systems for consumption of passive materials

- Design for cascading recycling systems
- Facilitate the user to reduce materials consumption
- Set the product’s default state at minimal materials consumption

1.5 Engage systems of flexible materials consumption

- Engage digital support systems with dynamic configuration
- Design dynamic materials consumption for different operational stages
- Engage sensors to adjust materials consumption according to differentiated operational stages
- Reduce resource consumption in the product’s default state

1.6 Minimize materials consumption during the product development phase

- Minimize the consumption of stationary goods and their packaging
- Engage digital tools in designing, modeling and prototype creation
- Engage digital tools for documentation, communication and presentation

2. Minimizing Energy Consumption

2.1 Minimize energy consumption during pre-production and production

- Select materials with low energy inensity
- Select processing technologies with the lowest energy consumption possible
- Engage efficient machinery
- Use heat emitted in processes for preheating other determined process flows
- Engage pump and motor speed regulators with dynamic configuration
- Equip the machinery with intelligent power-off utilities
- Optimize the overall dimensions of the engines
- Facilitate engine maintenance
- Define accurately the tolerance parameters
- Optimize the volumes of required real estate
- Optimize stock taking systems
- Optimize transportation systems and scale down the weight and dimension of all transportable materials and semi-products
- Engage efficient general heating, illumination and ventilation in buildings

2.2 Minimize energy consumption during transportation and storage

- Design compact products with high storage density
- Design concentrated products
- Equip products with onsite assembly
- Scale down the product weight
- Scale down the packaging weight
- Decentralize activities to reduce transportation volumes
- Select local material and energy sources

2.3 Select systems with energy efficient operation stages

- Design attractive products for collective use
- Design for energy efficient operational stages
- Design for energy efficient maintenance
- Design systems for consumption of passive energy sources
- Engage highly efficient conversion systems
- Design/ engage highly efficient engines
- Design/ engage highly efficient power transmission
- Use highly caulked materials and technical components
- Design for localized energy supply
- Scale down the weight of transportable goods
- Design energy recovery systems
- Design energy savings systems

2.4 Engage dynamic consumption of energy

- Engage digital dynamic support systems
- Design dynamic energy consumption systems for differentiated operational stages
- Engage sensors to adjust consumption during differentiated operationals stages
- Equip machinery with intelligent power-off utilities
- Programs product's default at minimal energy consumption

2.5 Minimize energy consumption during product development

- Engage efficient workplace heating, illumination and ventillation
- Engage digital tools for communicating with remote working sites

3. Minimizing Toxic Emissions

3.1 Select non-toxic and harmless materials

- Avoid toxic or harmful materials for product components
- Minimize the hazard of toxic and harmful materials
- Avoid materials that emit toxic and harmful substances during pre-production
- Avoid additives that emit toxic or harmful materials
- Avoid toxic or harmful surface treatments
- Design products that do not consume toxic and harmful materials
- Avoid toxic and harmful surface treatments
- Design products that don’t consume toxic and harmful materials
- Avoid materials that emit toxic or harmful substance during usage
- Avoid materials that emit toxic or harmful substance during disposal

3.2 Select non-toxic and harmless energy resources

- Select energy resources that reduce dangerous emissions during
  - Pre-production
  - Distribution
  - Usage
- Select energy resources that reduce dangerous residues and toxic and harmful waste

4. Renewable and Bio-compatible Resources

4.1 Select renewable and bio-compatible materials

- Use renewable materials
- Avoid exhaustive materials
- Use residual materials of production processes
- Use retrieved components from disposed products
- Use recycled materials, alone or combined with primary materials
- Use bio-degradable materials

4.2 Select renewable and bio-compatible energy resources

- Use renewable energy resources
- Engage the cascade approach
- Select energy resources with high second order efficiency

5. Optimization of Product Lifespan

5.1 Design appropriate lifespan

- Design components with co-extensive lifespan
- Design lifespan of replaceable components according to scheduled duration
- Select durable materials according to the product performance and lifespan
- Avoid selecting durable materials for temporary products or components

5.2 Reliability design

- Reduce overall number of components
- Simplify the products
- Eliminate weak liasions

5.3 Facilitate upgrading and adaptability

- Enable and facilitate software
- Enable and facilitate hardware upgrading
- Design modular and dynamically configured products to facilitate their adaptability for changing environments
- Design multifunctional and dynamically configured products to facilitate their adaptability for changing cultural and physical individual backgrounds
- Design onsite upgradeable and adaptable products
- Design complementary tools and documentation for products
- Design complementary tools and documentation for product upgrading and adaptation

5.4 Facilitate maintenance

- Simplify access and disassembly to components to be maintained
- Avoid narrow slits and holes to facilitate access for cleaning
- Prearrange and facilitate the substitution of short-lived components
- Equip the product with easily usable tools for maintenance
- Equip products with diagnostic and/ or auto - diagnostic systems for maintainable components
- Design products for easy on-site maintenance
- Design complementary maintenance tools and documentation
- Design products that need less maintenance

5.5 Facilitate repairs

- Arrange and facilitate disassembly and re-attachment of easily damageable components
- Design components according to standards to facilitate substitution of damaged parts
- Equip products with automatic damage diagnostic system
- Design products for facilitated on-site repair
- Design complementary repair tools, materials and documentation

5.6 Facilitate re-use

- Increase the resistance of easily damaged and expandable components
- Arrange and facilitate access and removal of retrievable components
- Design modular and replaceable components
- Design components according to standards to facilitate replacement
- Design re-usable auxiliary parts
- Design the re-filling and re-usable packaging
- Design products for secondary use

5.7 Facilitate re-manufacture

- Design and facilitate removal and substitution of easily expandable components
- Design structural parts that can be easily separated from external/ visible ones
- Provide easier access to components to be re-manufactured
- Calculate accurate tolerance parameters for easily expandable connections
- Design for excessive use of materials in places more subject to deterioration
- Design for excessive use of materials for easily deteriorating surfaces

6. Improve Lifespan of Materials

6.1 Adopt the cascade approach

- Arrange and facilitate recycling of materials in components with lower mechanical requirements
- Arrange and facilitate recycling of materials in components with lower aesthetical requirements
- Arrange and facilitate energy recovery from materials throughout combustion

6.2 Select materials with most efficient recycling technologies

- Select materials that easily recover after recycling the original performance characteristics
- Avoid composite materials or, when necessary, choose easily recyclable ones
- Engage geometrical solutions like ribbing to increase polymer stiffness instead of reinforcing fibres
- Prefer thermoplastic polymers to fireproof additives
- Design considering the secondary use of the materials once recycled

6.3 Facilitate end-of-life collection and transportation

- Design in compliance with product retrieval system
- Minimize overall weight
- Minimize cluttering and improve stackability of discarded products
- Design for compressibility of discarded products
- Provide the user with information about the disposing modalities of the product or its parts

6.4 Material identification

- Codify different materials to facilitate their identification
- Provide additional information about the material's age, number of times recycled in the past and additives used
- Indicate the existence of toxic or harmful materials
- Use standardized materials identification systems
- Arrange codification in easily visible places
- Avoid codifying after component production stages

6.5 Minimize the number of different incompatible materials

- Integrate functions to reduce the overall number of materials and components
- Monomaterial strategy: only one material per product or per sub-assembly
- Use only one material, but processed in sandwich structures
- Use compatible materials (that could be recycled together) within the product or sub-assembly
- For joining use the same or compatible materials as in components (to be joined)

6.6 Facilitate cleaning

- Avoid unnecessary coating procedures
- Avoid irremovable coating materials
- Facilitate removal of coating materials
- Use coating procedure compliant with coating materials
- Avoid adhesives or choose ones that comply with materials to be recycles
- Prefer the dyeing of internal polymers, rather than surface painting
- Avoid using additional materials for marking or codification
- Mark and codify materials during moulding
- Codify polymers using laser

6.7 Facilitate composting

- Select materials that degrade in the expected end-of-life environement
- Avoid combining non-degradable materials with products that are going to be composted
- Facilitate the separation of non-degradable materials

6.8 Facilitate combustion

- Select high energy materials for products that are going to be incinerated
- Avoid materials that emit dangerous substance during incineration
- Avoid additives that emit dangerous substance during incineration
- Facilitate the separation of materials that would compromise the efficiency of combustion (with low energy value)

7. Design for Disassembly

7.1 Reduce and facilitate operations of disassembly and separation

- ***Overall architecture***
  - Prioritize the disassembly of toxic and dangerous components or materials
  - Prioritize the disassembly of components or materials with higher economic value
  - Prioritize the disassembly of more easily damageable components
  - Engage modular structures
  - Divide the product into easily separable and manipulatable sub-assemblies
  - Minimize overall dimensions of the product
  - Minimize hierarchically dependent connection between components
  - Minimize different directions in the disassembly route of components and materials

- Increase the linearity of the disassembly route
- Engage a sandwich system of disassembly with central joining elements

- ***Shape of components and parts***
  - Avoid difficult to handle components
  - Avoid asymmetrical components, unless required
  - Design leaning surfaces and grabbing features in compliance with standards
  - Arrange leaning surfaces around the product’s center of gravity
  - Design for easy centering on the component base

- ***Shape and accessibility of joints***
  - Avoid joining systems that require simultaneous interventions for opening
  - Minimize the overall number of fasteners
  - Minimize the overall number of different fasteners types (that demand different tools)

- Avoid difficult to handle fasteners
- Design accessible and recognizable entrances for dismantling

- ***Engage reversible joining systems***
  - Employ two-way snap-fit
  - Employ joints that are opened with common tools
  - Employ joints that are opened with special tools, when opening could be dangerous
  - Design joints made of materials that become reversible only in determined conditions
  - Use screws with hexagonal heads
  - Prefer removable nuts and clips to self-tapping screws
  - Use screws made of materials compatible with joint components, to avoid their separation before recycling
  - Use self-tapping screws for polymers to avoid using metallic inserts

7.2 Engage easily collapsible permanent joining systems

- Avoid rivets on incompatible materials
- Avoid staples on incompatible materials
- Avoid additional materials while welding
- Weld with compatible materials
- Prefer ultrasonic and vibration welding with polymers
- Avoid gluing with adhesives
- Employ easily removable adhesives

7.3 Co-design special technologies and features for crushing separation

- Design thin areas to enable the taking off of incompatible inserts, by pressurised demolition
- Co-design cutting or breaking paths with appropriate separation technologies for incompatible materials separation
- Equip the product with a device to separate incompatible materials
- Employ joining elements that allow their chemical or physical destruction
- Make the breaking points easily accessible and recognizable
- Provide the products with information for the user about the characteristics of crushing separation
- Use materials that are easily separable after being crushed
- Use additional parts that are easily separable after crushing of materials

Biomimetic Approaches

Build the way nature builds.

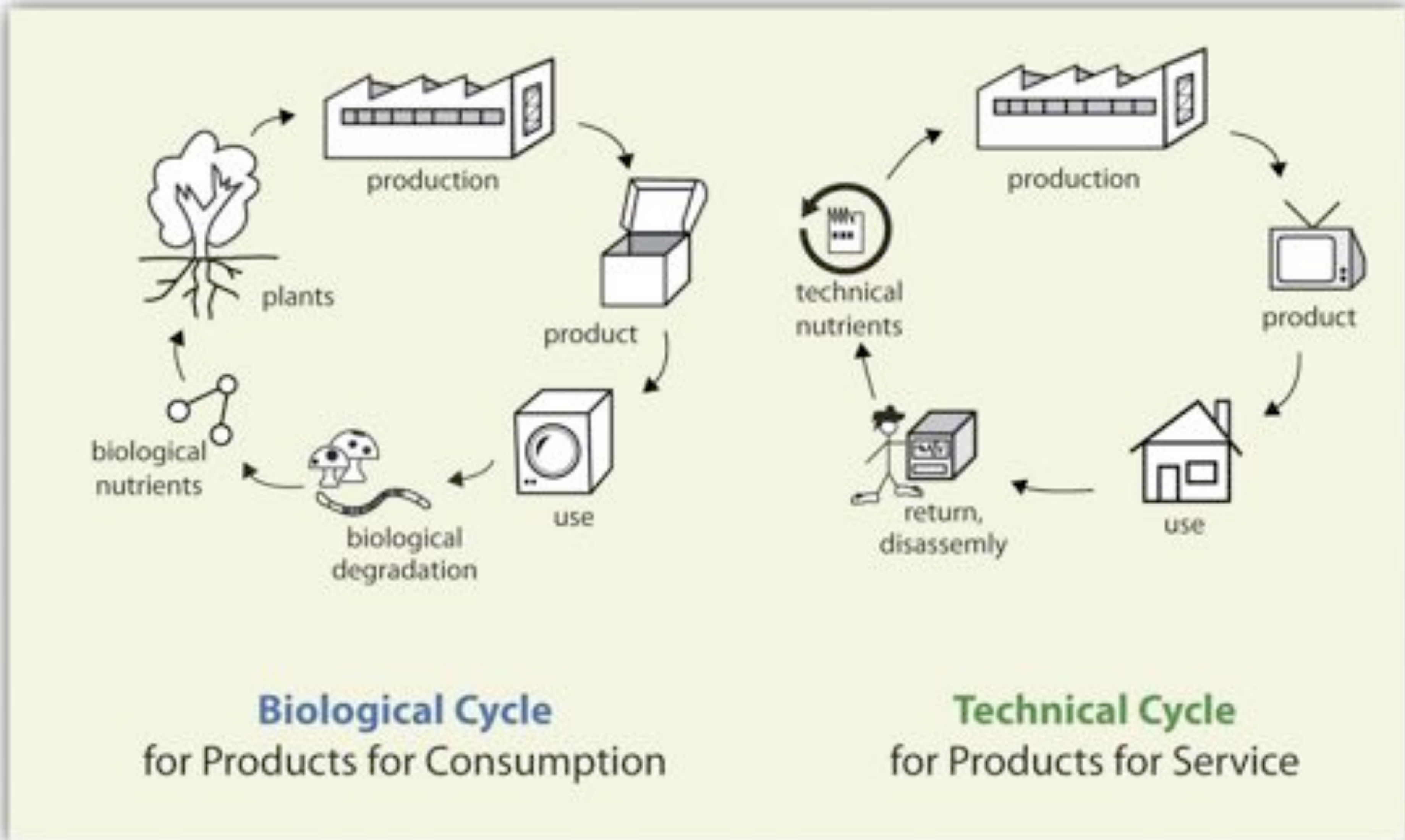
- Cradle to Cradle
- Blue Economy

Cradle to Cradle

- Cradle to Cradle Design 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.


production
plants
product
biological
nutrients
biological
degradation
use
production
technical
nutrients
product
return,
disassemly
use
Biological Cycle
for Products for Consumption
Technical Cycle
for Products for Service

Example -Cradle to Cradle Ink


cradle to cradle
garment industry
organic/fibre (products)
biodegradeable fibre
decomposition
fibre extrusion
polymer production
nutrients
(pesticides herbicides)
elimination of toxic materials
plants
(photo-synthesis)
decompose
biological
biodegradeable fibre
raw materials -fibres
disassembly waste-seperation
biodegradable waiste = food
organic+synthetic fabrics/metal
recycling
natural/ man-made fibres
elimination of toxic materials
dyes, bleaching
technical
metal zippers
buttons
man-made fibres
rivets, buttons zippers
products/ garments
manufacture/ production
Illustrations Kenneth buddha Jeans

Blue Economy

- ***The Blue Economy: 10 years - 100 innovations - 100 million jobs*** is a book by Gunter Pauli. The book expresses the ultimate aim that a Blue Economy business model will shift society from scarcity to abundance "with what we have", by tackling issues that cause environmental and related problems in new ways.

- The book highlights potential benefits in ***connecting and combining seemingly disparate environmental problems with open-source scientific solutions based upon physical processes common in the natural world, to create solutions that are both environmentally beneficial and which have financial and wider social benefits***.

- The book suggests that we can alter the way in which we run our industrial processes and tackle resultant environmental problems, refocusing from the use of rare and high-energy cost resources to instead seek solutions based upon simpler and cleaner technologies.

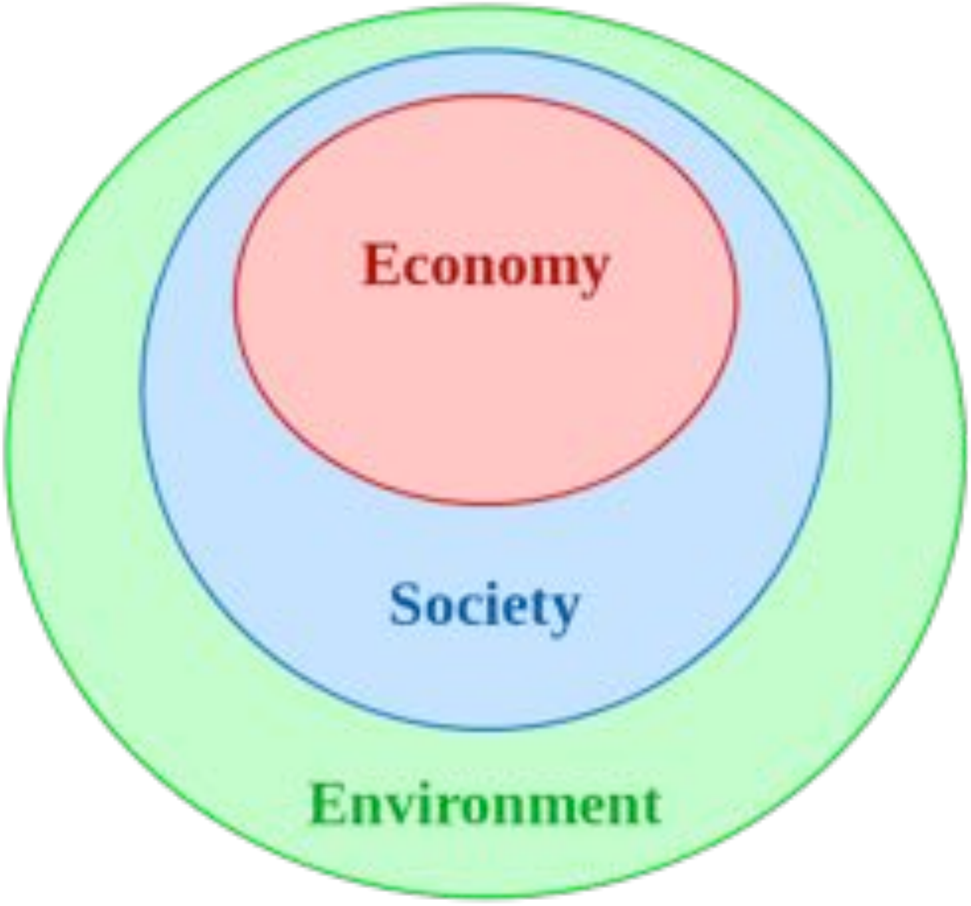
- The book aims to inspire entrepreneurs to adopt its insights, by demonstrating ways in which this can create economic benefits via job creation, reduced energy use, and more revenue streams from each step of the process, at the same time benefiting the communities involved.

Example - The Vortex

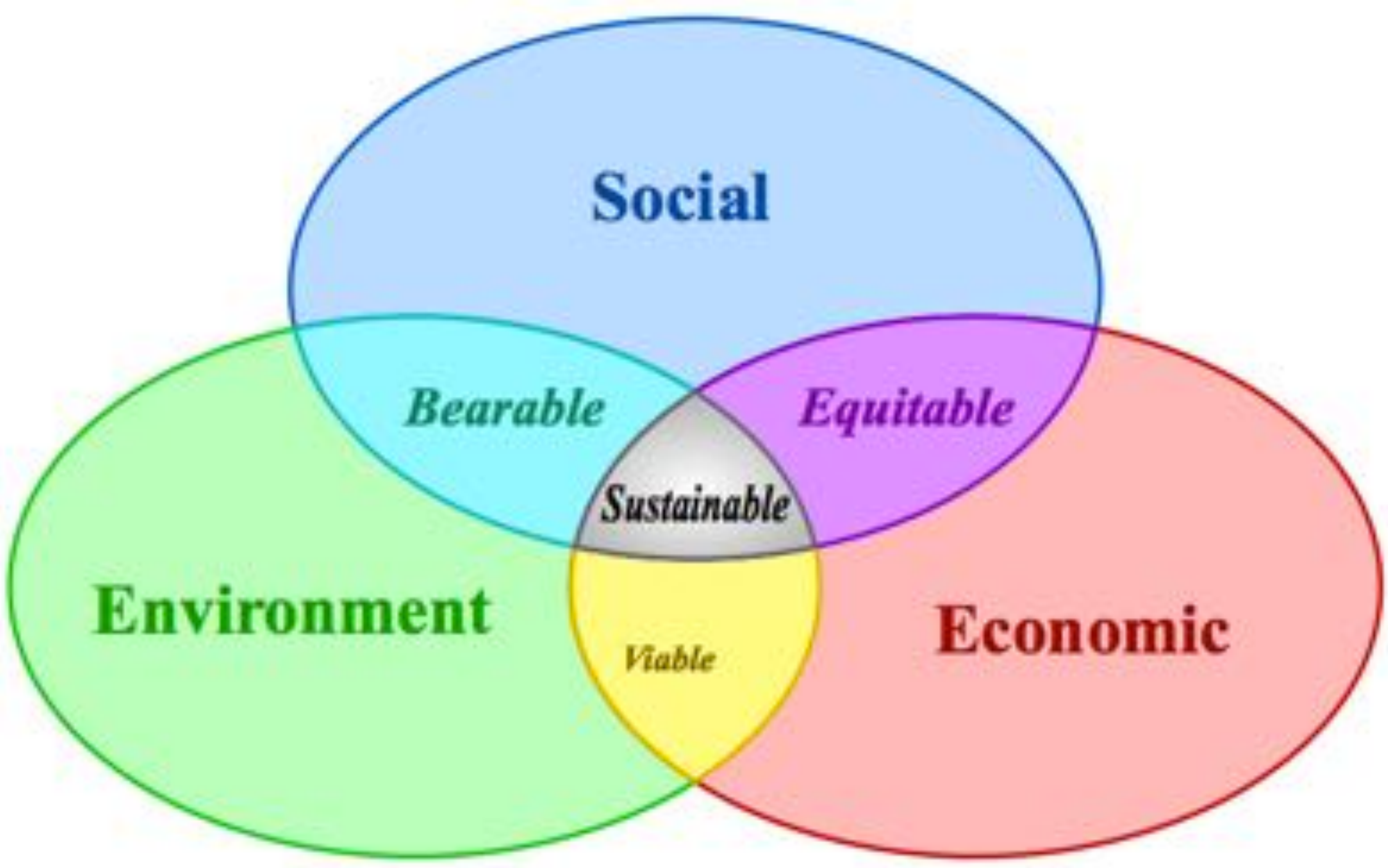
Example – The Maggots

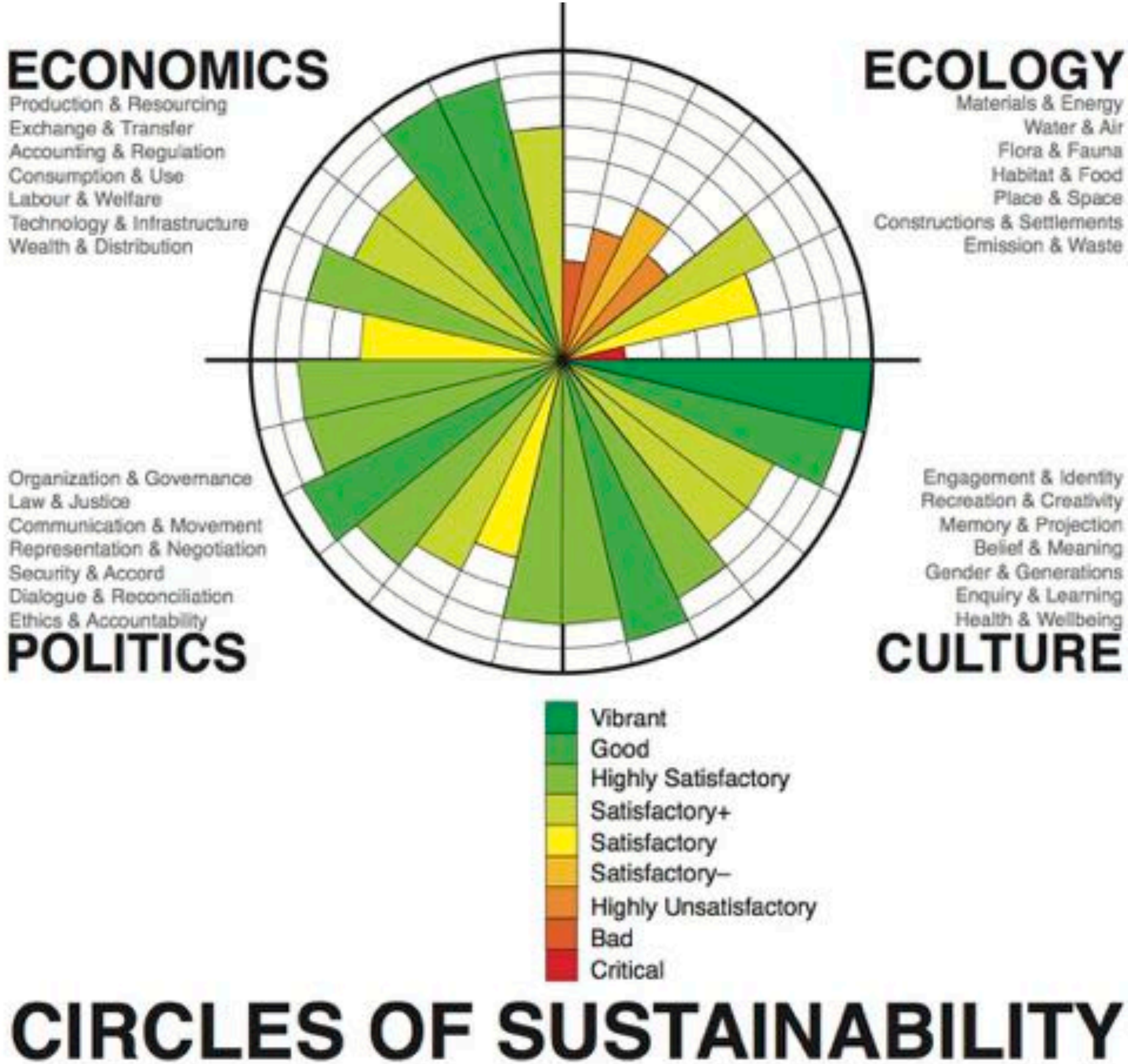
Example – Coffee & Mushrooms

Circles of Sustainability

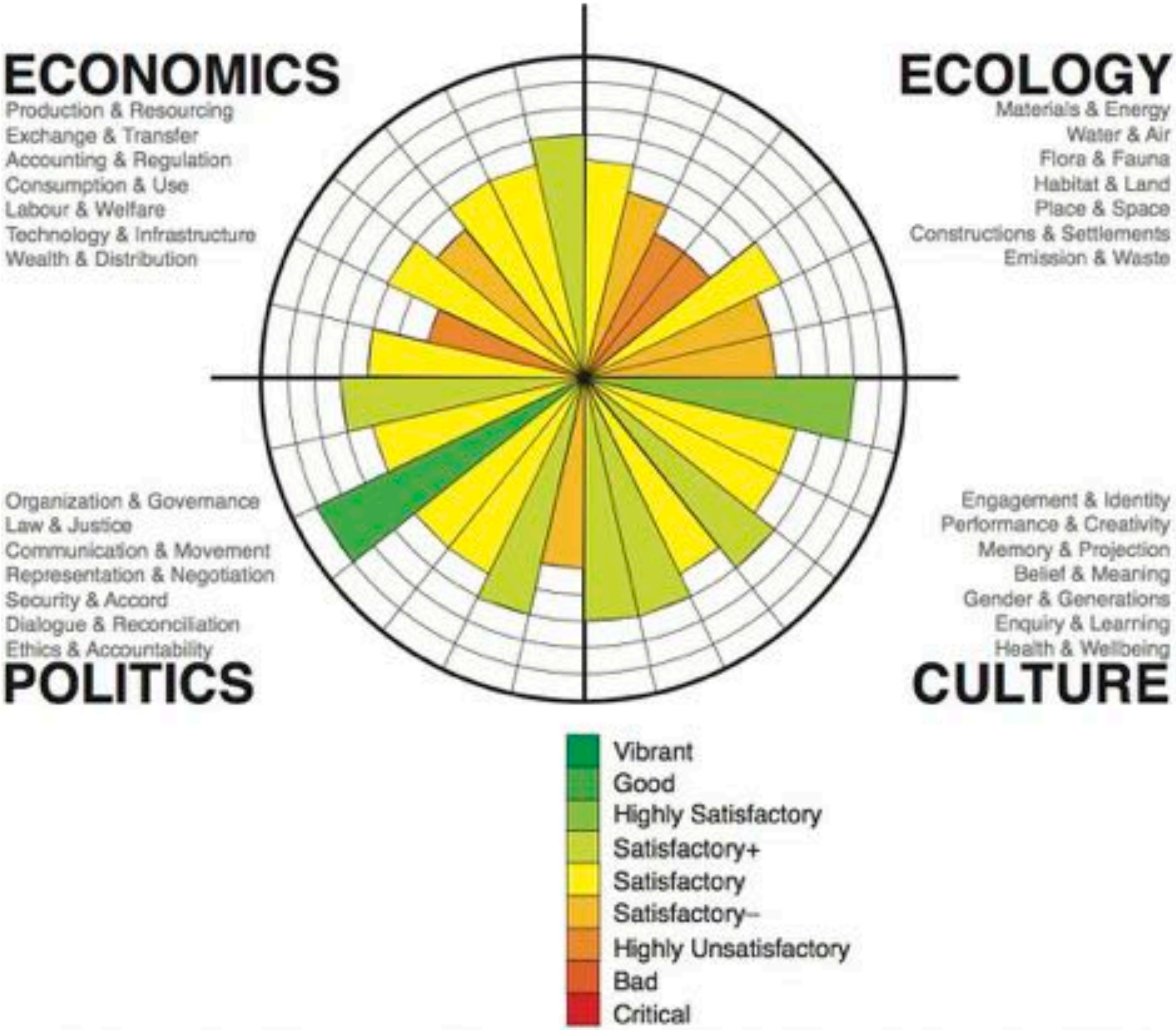


Sustainable Development at the Confluence of 3 Constituent parts

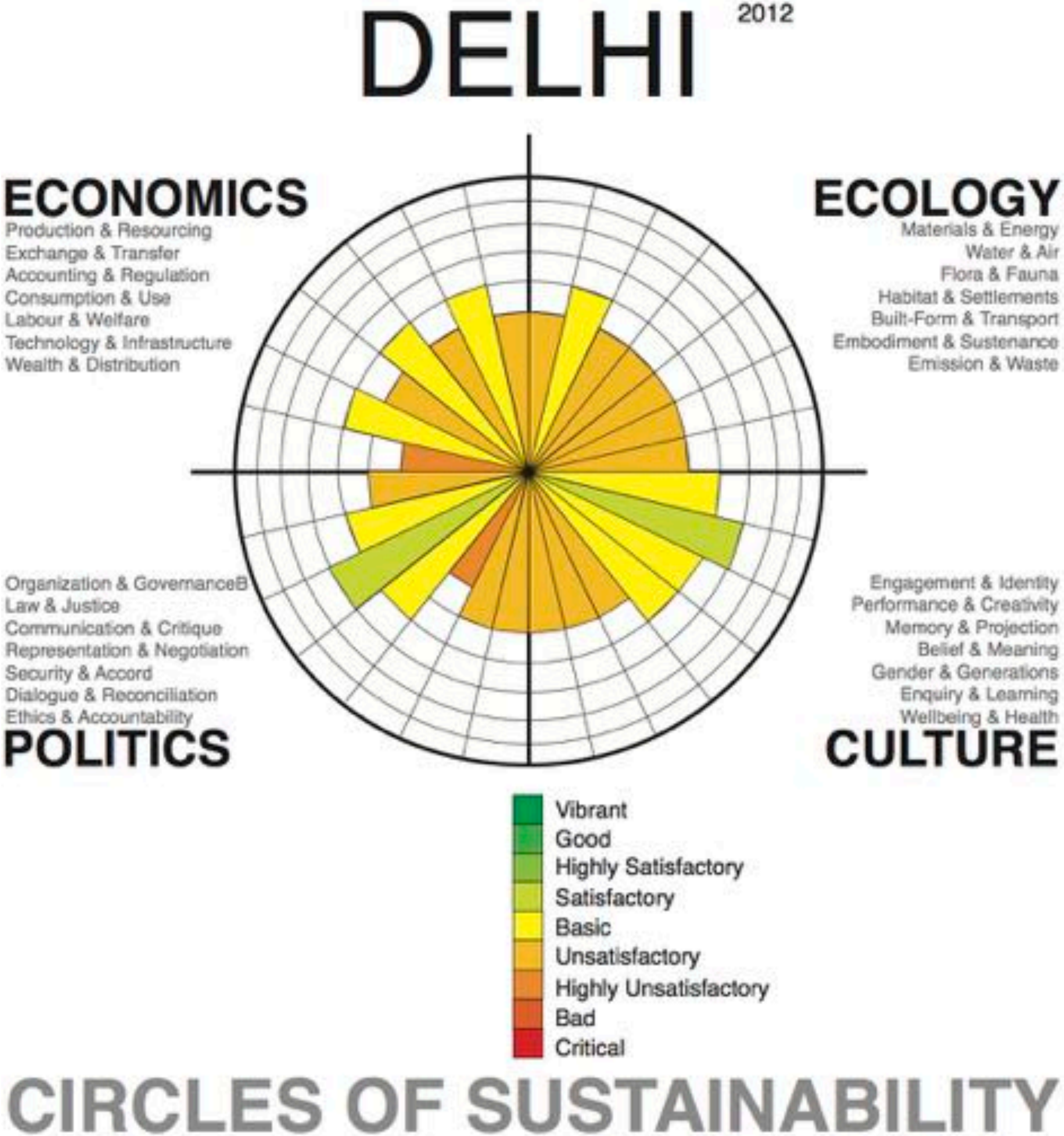



ECONOMICS
Production & Resourcing
Exchange & Transfer
Accounting & Regulation
Consumption & Use
Labour & Welfare
Technology & Infrastructure
Wealth & Distribution
ECOLOGY
Materials & Energy
Water & Air
Flora & Fauna
Habitat & Food
Place & Space
Constructions & Settlements
Emission & Waste
Organization & Governance
Law & Justice
Communication & Movement
Representation & Negotiation
Security & Accord
Dialogue & Reconciliation
Ethics & Accountability
POLITICS
Engagement & Identity
Recreation & Creativity
Memory & Projection
Belief & Meaning
Gender & Generations
Enquiry & Learning
Health & Wellbeing
CULTURE
Vibrant
Good
Highly Satisfactory
Satisfactory+
Satisfactory
Satisfactory–
Highly Unsatisfactory
Bad
Critical
CIRCLES OF SUSTAINABILITY

HYDERABAD 2012



CIRCLES OF SUSTAINABILITY


DELHI
2012
ECONOMICS
Production & Resourcing
Exchange & Transfer
Accounting & Regulation
Consumption & Use
Labour & Welfare
Technology & Infrastructure
Wealth & Distribution
ECOLOGY
Materials & Energy
Water & Air
Flora & Fauna
Habitat & Settlements
Built-Form & Transport
Embodiment & Sustenance
Emission & Waste
Organization & GovernanceB
Law & Justice
Communication & Critique
Representation & Negotiation
Security & Accord
Dialogue & Reconciliation
Ethics & Accountability
POLITICS
Engagement & Identity
Performance & Creativity
Memory & Projection
Belief & Meaning
Gender & Generations
Enquiry & Learning
Wellbeing & Health
CULTURE
Vibrant
Good
Highly Satisfactory
Satisfactory
Basic
Unsatisfactory
Highly Unsatisfactory
Bad
Critical
CIRCLES OF SUSTAINABILITY

Design for eco-efficient Product-Service Systems

- From the end of the 1990s, starting with a more stringent interpretation of sustainability that called for more radical changes in production and consumption models, attention has partially moved to design for ***eco-efficient Product-Service Systems***, a wider dimension than that of the single product.

- From among several converging definitions, the one given by the United Nations Environment Programme (UNEP 2002) states that a Product-Service System (PSS) is '***the result of an innovative strategy that shifts the centre of business from the design and sale of (physical) products alone, to the offer of product and service systems that are together able to satisfy a particular demand***'.

- In this context, it has therefore been argued (Vezzoli 2003a) that the design conceptualisation process needs to expand ***from a purely functional approach to a satisfaction approach***, in order to emphasize and to be more coherent with the enlargement of the design scope from a single product to a wider system fulfilling a given demand related to needs and desires, i.e. satisfaction.

The main characteristics of eco-efficient PSS innovations are:

- They are rooted in a ***satisfaction-based*** economic model, i.e. each offer is developed/designed and delivered in relation to a particular customer satisfaction.

- They are ***stakeholder interaction-based innovation***, i.e. radical innovations, less so technological ones, as new interactions and partnerships between the stakeholders of a particular satisfaction production chain.

- They have ***intrinsic eco-efficiency system potential***, i.e. innovation in which it is the company/companies' economic and competitive interest that leads to an environmental impact reduction, where the creation of value is decoupled from resource consumption.

Example – Klüber Lubricants

- Klüber has moved from only selling lubricants to commercial customers to a service providing added value to product use.
- Using a service called S.A.T.E. Klüber analyses the effectiveness of aerosol treatment plants and sewage treatment. For this purpose, Klüber has designed a movable chemical laboratory, a van that is able to monitor a client's industrial machines directly, to determine the performance of lubricants used and their environmental impact. It also controls noise, vibrations, smoke and many other undesirable industrial impacts.
- The additional service Klüber offers clients leads to plant improvement in terms of efficiency, guarantees functionality and durability, and enhances environmental protection.

- Klüber has broken away from the business-as-usual attitude. Its interests do not rely only on the amount of lubricant sold, but also on service.
- There has been a reduction in the overall quantity of lubricant consumed per unit of service and thus a reduction in polluting emissions.
- Other benefits arise from the improved monitoring of performance of various machines, so that any accidental pollution can be avoided.
- Clients perceive they derive added value from this service because it frees them from the costs and the problems associated in the monitoring and checking of their equipment. Achieving better efficiency from lubricants also provides many economic benefits both in production processes and in improving the life of machines, and plant costs are also reduced.

Example - The 'solar heat service'—pay per hot water

- The 'solar heat service' is a full-service providing a final result, consisting of 'selling' hot water as a finished product. Hot water is produced by new equipment that combines sun, energy and methane, with economic and energy savings.

- Solar plants are designed in order to maximise the contribution of solar energy. Hot water is measured by means of a specific heat meter, and the whole system is monitored in order both to control in real time how the system works and also to apply a Guarantee of Solar Results, a specific contract through which the installer makes a commitment to reach a pre-determined level of efficiency.

- AMG has already tested this service in a Tennis Club in Palermo, Italy, providing hot water for the dressing rooms.

- The innovative feature of this Product-Service System is that AMG will not invoice the client for the methane consumed to obtain hot water, but rather, hot water is sold as an entire service.

- AMG sells heat and calculates the thermal kilowatts consumed by its clients.

- With AMG the consumer pays for receiving a comprehensive service, from installation, to the thermal-energy meters, and to the transportation of methane to the boilers. With equipment maintenance provided as well, the customer is overall buying a ‘final result’.

Design for social equity and cohesion

- This potential role for design directly addresses various aspects of a ***'just society with respect for fundamental rights and cultural diversity that creates equal opportunities and combats discrimination in all its forms'*** (EU 2006). Moreover, several writers and researchers urge a movement (and a key role for design) towards harmonizing society such that it is ***not only just and fair, but that people are encouraged to be empathic, kind and compassionate for the benefit of others.***

1. Distributed Economies

- Another approach to DfS is distributed economies. Many authors (Mance 2001; Rifkin 2002; Sachs et al. 2002; Johansson et al. 2005; Vezzoli and Manzini 2006; Crul and Diehl 2006; Rifkin 2010) have argued that this approach is capable of creating favourable economic model to couple socio-ethical and environmental dimensions of sustainability.

- The term has thus been extended to several socio-economic systems: information technologies and distributed computing; energy systems and distributed energy generation; production and the possibilities of distributed manufacturing; and the processes of change and distributed innovation, distributed creativity, and distributed knowledge (Vezzoli, et. al. 2014).

- In all these cases, the term distributed implies that the elements are autonomous but highly connected to other elements of the system.

2. Design for a Sufficiency Economy

- King Bhumibol Adulyadej proposed the philosophy of sufficiency economy (PSE) to people of Thailand in 1997 (Thongpakde, 2005). The concept of PSE can be applied to the individual level, the community level and the national level (Mongsawad, 2010). The following is a synthesis of the philosophy:

*"Sufficiency economy" is a philosophy that stresses the **middle path** as the overriding principle for appropriate conduct by the populace at all levels. This applies to conduct at the level of the **individual**, **families**, and **communities**, as well as to the choice of a balanced development strategy for the **nation** so as to **modernise in line with the forces of globalisation while shielding against inevitable shocks and excesses that arise**. "Sufficiency" means moderation and due consideration in all modes of conduct, as well as the need for sufficient protection from internal and external shocks. To achieve this, the application of knowledge with prudence is essential. In particular, great care is needed in the utilisation of untested theories and methodologies for planning and implementation. At the same time, it is essential to strengthen the moral fibre of the nation, so that everyone, particularly political and public officials, technocrats, businessmen and financiers, adhere first and foremost to the principles of honesty and integrity. In addition, a balanced approach combining patience, perseverance, diligence, wisdom and prudence is indispensable to cope appropriately with the critical challenges arising from extensive and rapid socio-economic, environmental and cultural changes occurring as a result of globalisation."*

- Thus the three principles of PSE are: ***moderation***, ***reasonableness*** and ***immunity***; along with two other conditions: ***knowledge*** and ***morality***, needed to make the principles work (Mongsawad, 2010).

3. Design for Social Enterprise

- A social enterprise is understood as an organisation which applies ***commercial strategies to maximise social and environmental well-being*** rather than only profits for its stakeholders.

- These can be structured as a for-profit or non-profit enterprise.

- They may take various forms like a co-operative, mutual organisation, a social business, a benefit corporation, a community interest company or a charity organisation, depending on, in which country the entity exists (Janelle et. al. 2009).

4. Design with a Capability Approach

- The capability approach stresses that the focus of development should be on ***human development, agency, well-being, and on providing freedoms*** to the people instead of only on economic development or utility maximisation (Sen 1999).

- Economic development is considered as one of the means for human development (Sen 2002) along with ***political freedoms, social opportunities, transparency guarantees, and protective securities*** (Sen 1999).

- The capability approach focuses on ***what people are realistically able to do and to be*** (Nussbaum 2000) ***in a given context***.

In the context of design, Oosterlaken (2009, 2012) argues the use of capability approach as a means for

- ***capability*** (political practices, social institutions, habits, etc.) ***expansion***,
- incorporation of moral values (emerging research field - “***value sensitive design***”; moral values like autonomy, privacy, sustainability, accountability, responsibility, etc.),
- incorporation of “***well-being***” (defined as “an experiential state of people and organizations, which can have many shapes, such as satisfaction, fulfillment, support and inspiration, protection, acknowledgement, comfort, happiness, and involvement.” TU Delft 2007),
- drawing attention to ***human diversity*** (in terms of what we value along with personal and social/environmental characteristics that influence the conversion from resources into capabilities and functioning
- well-articulated, well justified methodology for ***user participation in design processes*** (Participatory Design approaches)

D4S: the current status

- In ***industrialised*** contexts, represented especially by European countries, the choice of ***low impact material/energy*** and the ***Life Cycle Design (LCD)*** or ***eco-design of products*** are positioned at a good level of consolidation (Vezzoli and Manzini 2008a), with a modest level of penetration in design education and practice. For ***eco-efficient PSS design***, the level of consolidation is inferior and education and practice is, logically, far more sporadic.

- Very few design researchers are working on the ***design for social equity and cohesion*** front. It is in fact a new research frontier, meaning that little has been shared in the design community on a theoretical level and few methods and tools have been developed for the operative level.

- For ***emerging countries and contexts***, the landscape of Design for Sustainability research and education is more varied.

- In Brazil, for example, the ***socio-ethical dimension*** of sustainability has garnered attention earlier than product design for environmental sustainability.

- In Thailand ***LCD/Eco-design*** teaching has a longer official history in the curriculum, but new courses have been implemented in higher learning institutes using methods and tools such as ***Design for a Sufficiency Economy*** and ***Design for Social Enterprise***. These address prominent new social movements and discourse in Thailand regarding both social equity and social cohesion and the philosophy of a Sufficiency Economy.

- The differences between Design for Sustainability research in industrialised contexts compared to emerging and low-income contexts is largely due to ***differences in local industry need and innovation climates***.

- In the least industrialised regions, whose economy and labour market are dominated by micro Small and Medium sized Enterprises (MSMEs), ***companies' product development processes are generally unstructured and based on practical experience as well as benchmarking*** what is already familiar. Staff tend to be less educated and operating sectors tend to be low-tech, such as food processing or metal processing.

- The ***drivers*** for Design for Sustainability practice and research therefore ***differ*** when comparing industrialised and low-income or emerging contexts.

- External drivers such as legislation and consumer and supplier demand that play the key role in the European context, for instance, are not present to the same extent in emerging contexts. The main driving forces for Design for Sustainability in less industrialised economies are seen more in ***internal drivers such as cost efficiency, competitiveness and new markets***.

From Human Centered Design to Life Centered Design

- As designers, whether we're creating packaging, products, or places, we usually think first of human purpose and pleasure.

- Nature's elegance inspires us with beautiful forms, folds, spirals, patterns, shapes, layers, materials and colors—immeasurably enriching human imagination.

- But three current opportunities in design prompt us to also seek guidance from nature: environmental impact, complex systems, and new technologies for making.

Gap Areas and Opportunities

- Considering the Indian context, which is a combination of marginalized as well as industrialized sectors, students need to be equipped with the a broader spectrum of DfS skills and knowledge. Based on the current scenario the areas of intervention can be described as follows:
  - Gaps in ***measurement*** of sustainability:
    - No tools and methods for capturing degree of sustainability in traditional practices in rural and urban areas
    - No tools and methods for capturing degree of sustainability of the rural way of life

- Gaps in ***application*** of Sustainability:
    - No tools and methodologies for product development for grassroots
    - No systematic design process tailored for sustainable frugal product design

- Gaps in ***Education*** of Sustainability:
    - Participatory design methods not explored in design for sustainability curriculum

Sustainability and Social Innovation Lab

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Thank You

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