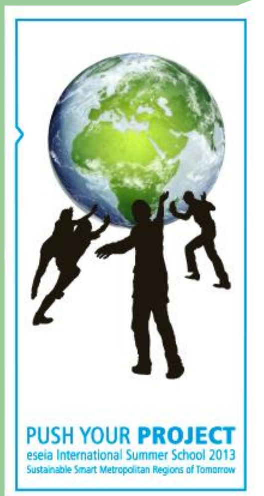

SUSTAINABLE INDUSTRIAL PRODUCTION AND WASTE MINIMIZATION

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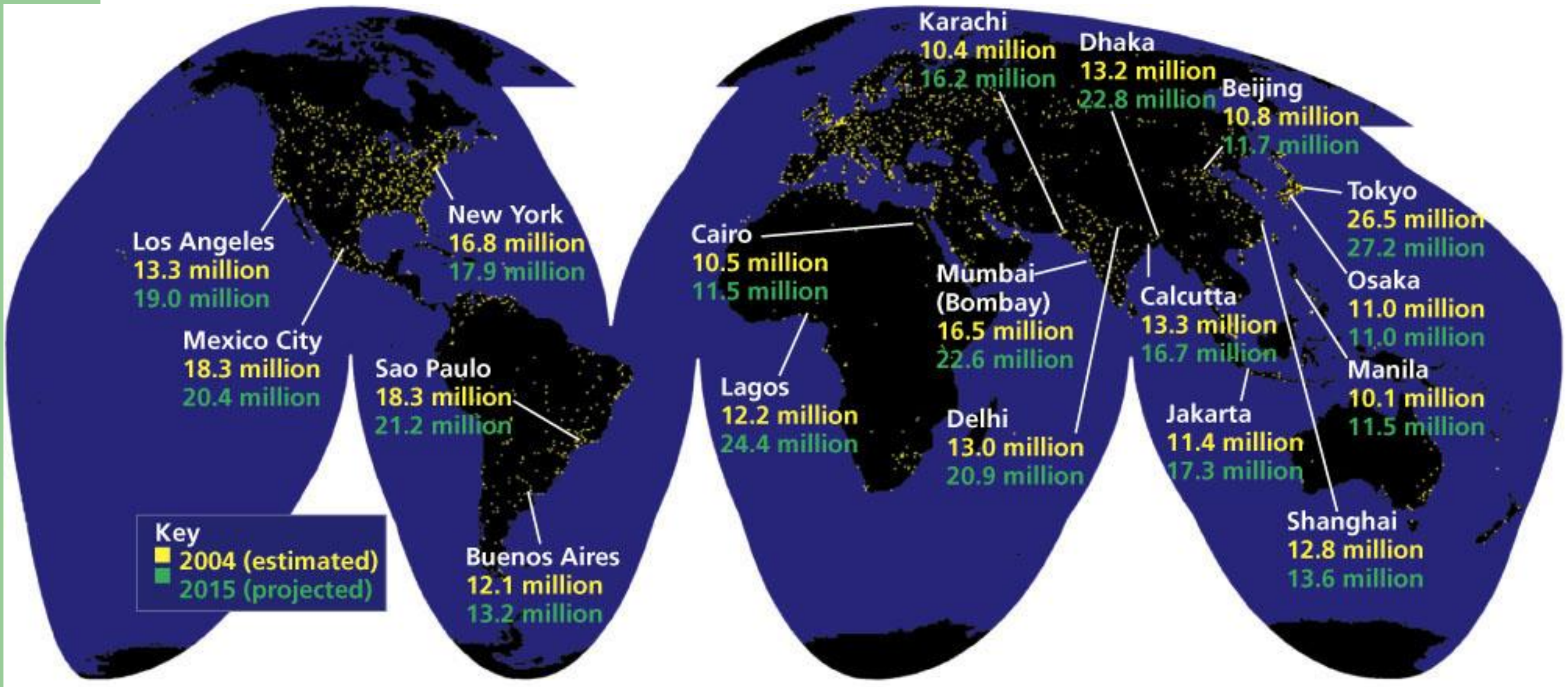
Faculty of Chemical Engineering and Environmental Protection

Department of *Environmental Engineering and Management*

General outline

- Sustainable city in the context of sustainable development
- Short history of industrial production and its role and impact for humanity development
- Sustainability of industrial production system in the context of global sustainability: indicators and tools
- Key measures and alternatives for sustainable industrial development

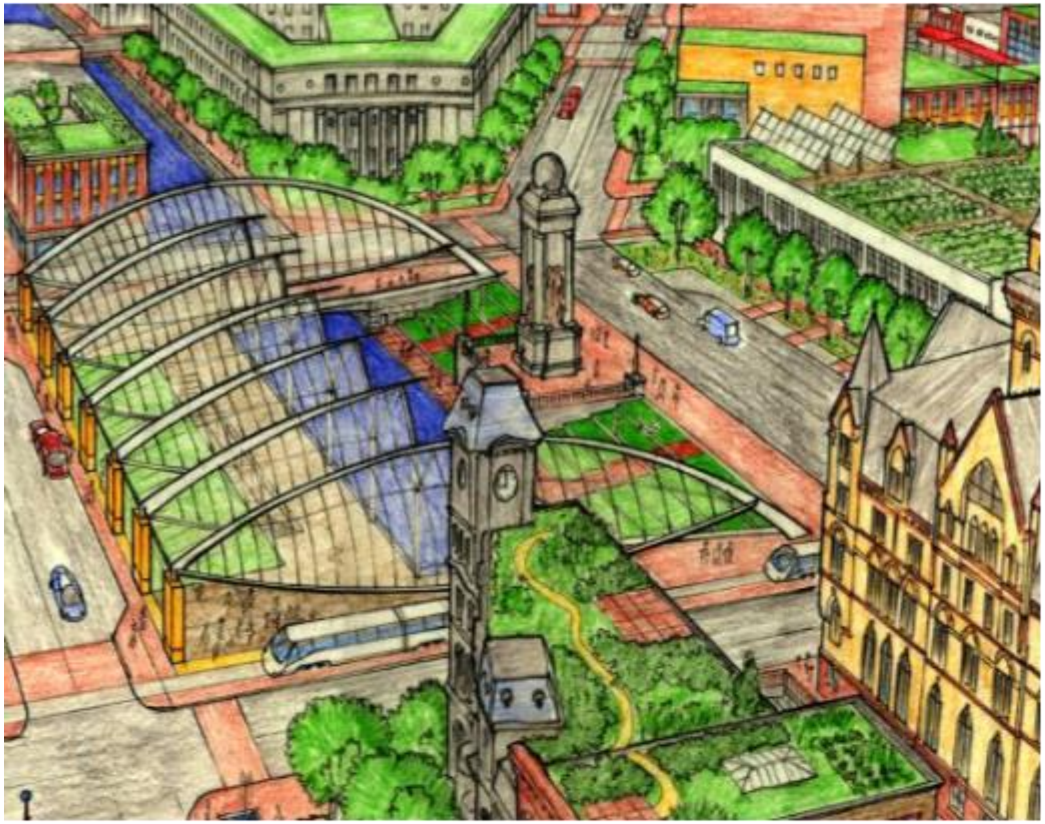
Global Outlook: Satellite Image of Major Urban Areas Throughout the World



We need cities to ***satisfy human needs***
(utility, amenity, livability, security, comfort, urban services, health, opportunity, community, quality of life)
and ***minimize the human impact on the environment***.
(ecological footprint)

Cities need to be
sustainable.

A sustainable city will use less resources and produce less waste than a unsustainable city. This concept can be built into the design of cities and buildings.



SUSTAINABLE DEVELOPMENT – MEASURING SUSTAINABILITY

What is sustainable development?

Development that meets the needs of current generations without compromising the ability of future generations to meet their needs and aspirations.

United Nations-sponsored World Commission on Environment and Development (WCED), chaired by the former Prime Minister of Norway, Gro Harlem Brundtland

(Our Common Future)

It comprises two dimensions:

development (to make better)

sustainability (to maintain).

SD includes two key concepts:

- the concept of **'needs**`: human societies cannot remain static, and the aspirations and expectations that comprise a part of ‘needs’ constantly shift

- the idea of **‘limitations’** imposed by the state of technology and social organization on the environment's ability to meet present and future needs.

From an anthropocentric point of view, sustainability comprises all three elements:

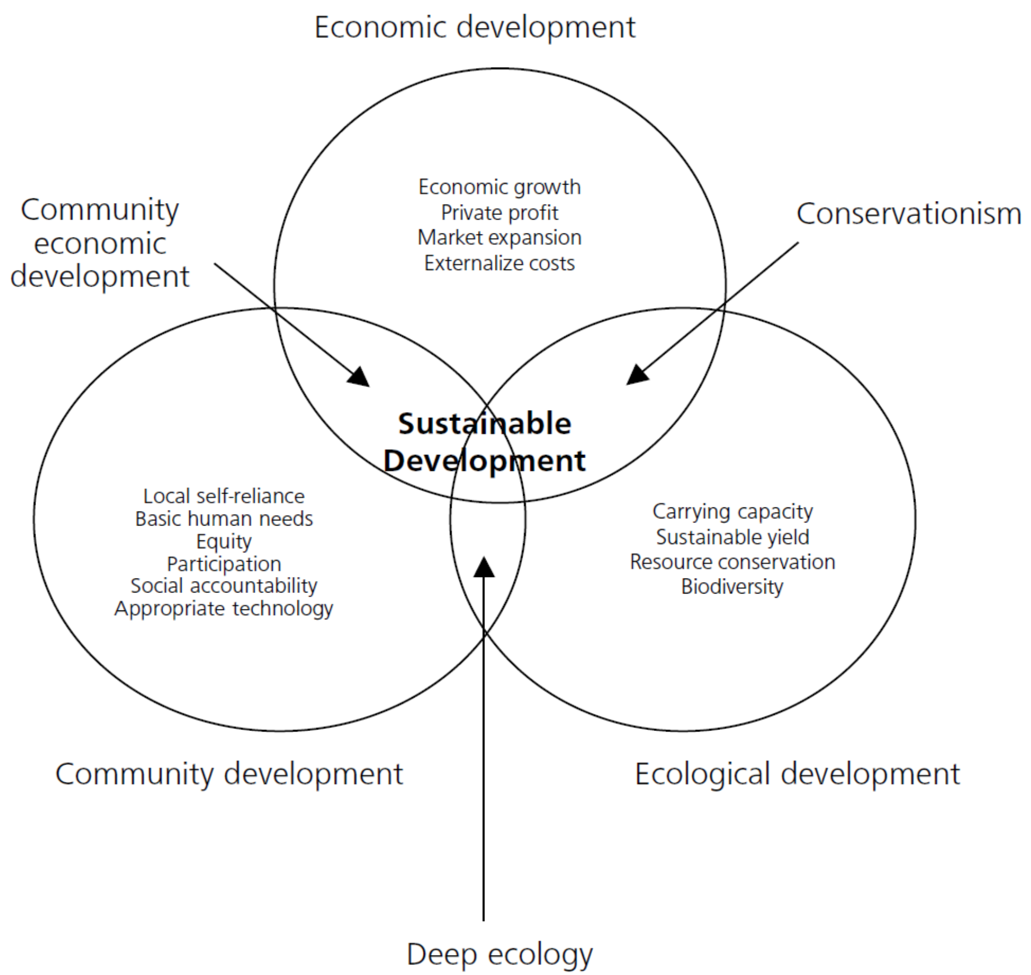
1. **depletion of resources** - in order not to leave future generations empty-handed
2. **environmental and ecological aspects** - in order to enable present and future generations to live in a clean and healthy environment, in harmony with nature
3. **quality of life** - in order to ensure human well-being for present and future generations.

Geurt van de Kerk, Arthur R. Manuel A comprehensive index for a sustainable society: *The SSI – the Sustainable Society Index, http://www.romaniadurabila.net/Manuscript_31%20January%202008.pdf*

A study of the visual devices used in the literature (SD art) and the ideas behind them could be a fascinating topic for analysis in itself.

Various representations for the interactions among the components of the sustainable development have been visually presented.

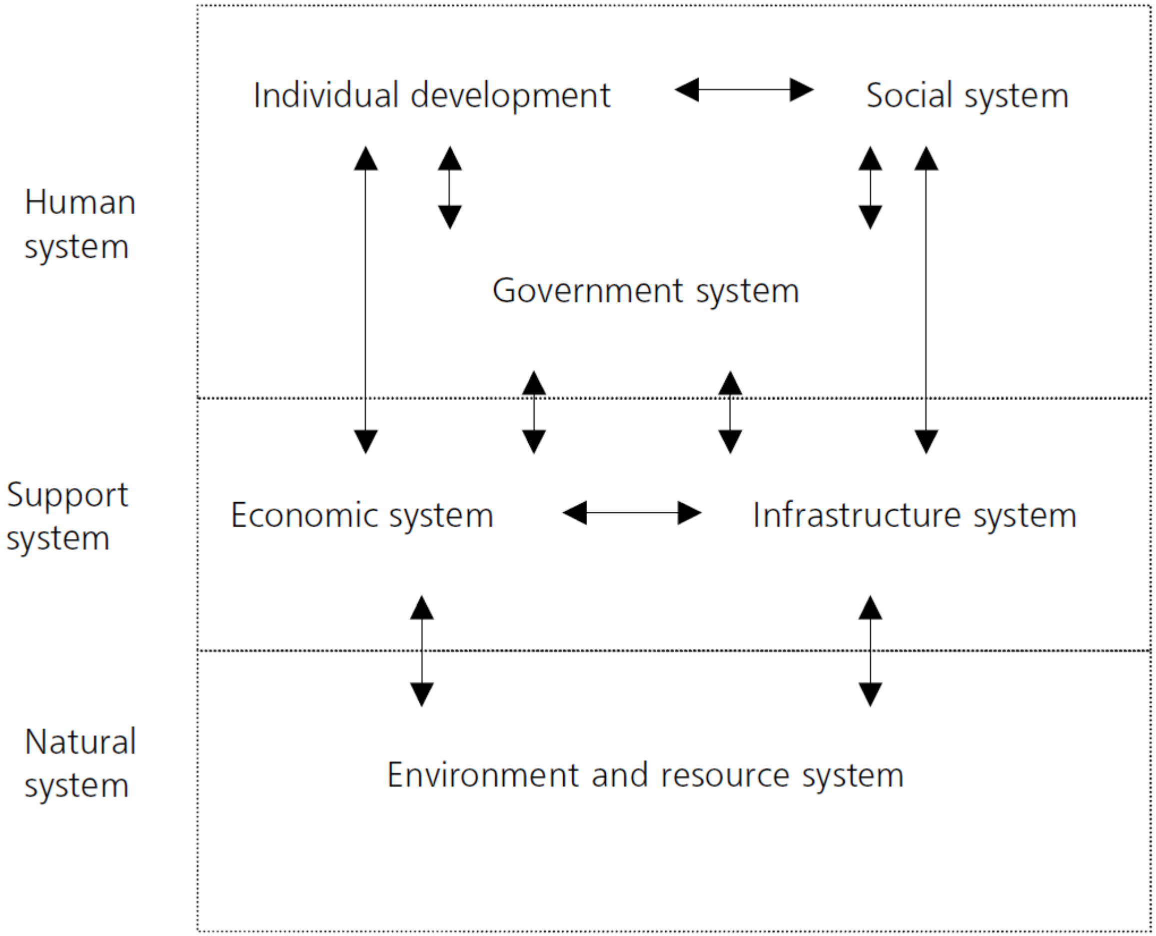
In **Figure,** perhaps the most common type of presentation of SD, there are three interlocking circles, with SD representing the point where all three overlap. This diagram has had much appeal in the literature, perhaps because of its stress on circularity and non-linear inter-linkage.



The interactions between ecological, economic and social (community) development

The components and relationships can presented in a more mechanistic form, as boxes and arrows respectively.

Here we see an emphasis on linear, almost mechanical, linkages.



The six key sub-systems of human society and development

Sustainable development (SD) is classically portrayed as the interface between environmental, economic and social sustainability.

- **Environmental protection**
  - Less wastes and emissions
  - Lower energy, water and materials use
- **Economic prosperity**
  - Cost savings
  - Project investments
  - New businesses
- **Social advancement**
  - Jobs and skills
  - Enhance amenity
  - Health


EHS&S Performance
Environmental Footprint
Product Stewardship
R&D
Process Safety
Energy Efficiency
Process Optimization
Sustainability

SD is participatory: it should involve people from the very beginning.

This is embodied within **Principle 10 of the Rio Declaration on Environment and Development:**

Environmental issues are best handled with the participation of all concerned citizens. Each individual should have . . . [information], and the opportunity to participate in decision-making processes.

Some principles and ideas which contributed to the development of SD approach at a common understanding of SD:

- Rates of utilization of renewable resources must not be greater than rates of regeneration.
- Waste emissions must not be greater than the assimilation capacities of the environment.
- Rates of use of non-renewables must not be greater than the rate of creation of renewable substitutes.

Most cities are unsustainable because of high levels of resource use, waste, pollution, and poverty.

But – what's the alternative?

What is a "sustainable city"?

~ a provisional definition:

"a city designed, built, and managed in a manner where all its citizens are able to meet their own needs without endangering the well-being of the natural world or the living conditions of other people, now or in the future"

The absolutely necessary actions for SD:

- learn how to manage renewable resources for the long term;
- reduce waste and pollution;
- learn how to use energy and materials more efficiently (including more use of solar energy);
- invest in repairing the damage done to the Earth.

Inputs

Energy

Food

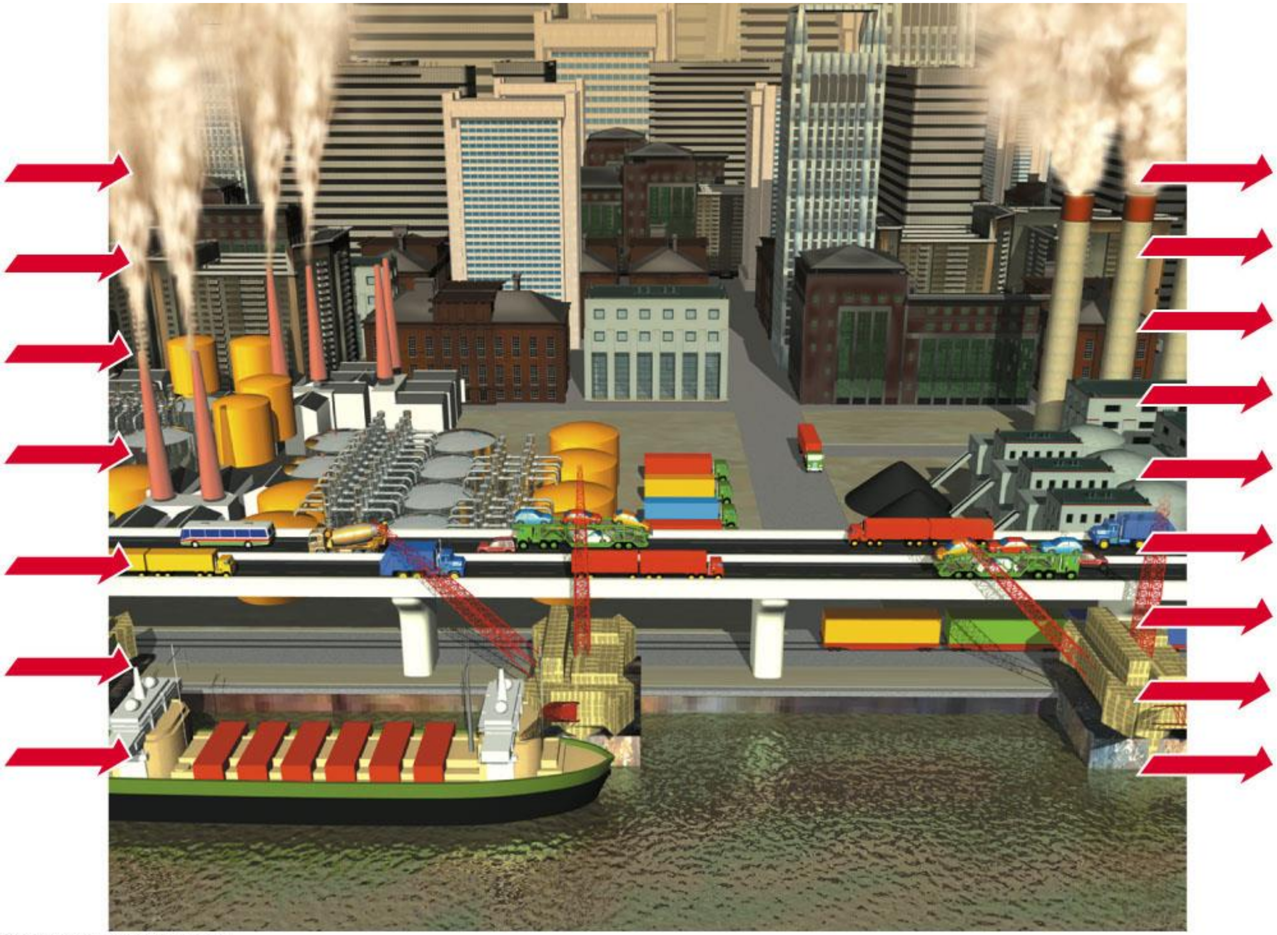
Water

Raw materials

Manufactured goods

Money

Information



Outputs

Solid wastes

Waste heat

Air pollutants

Water pollutants

Greenhouse gases

Manufactured goods

Noise

Wealth

Ideas

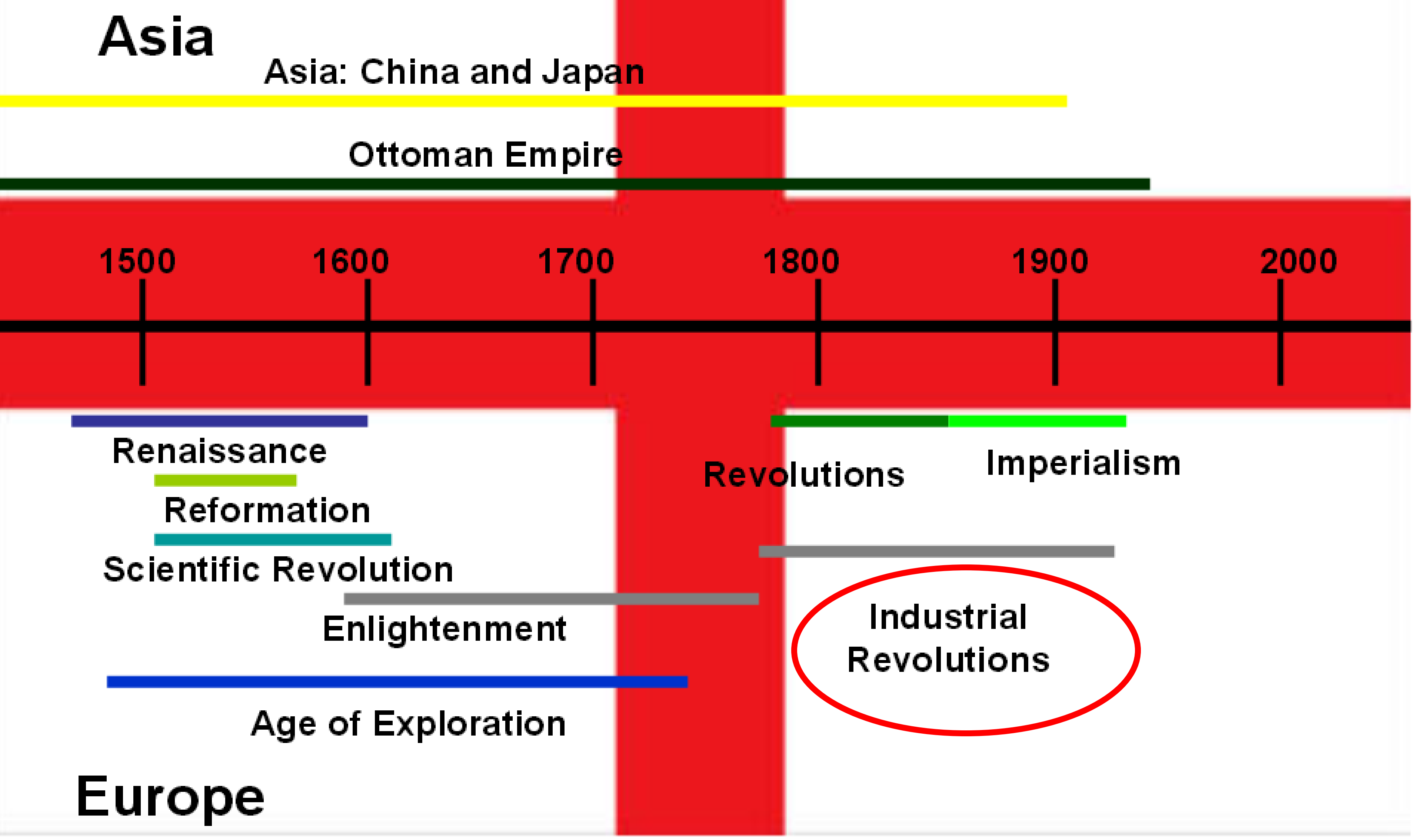
Sample list of environmental impacts of industrial activities

Issue	*Impacts (to measure)*
Resources	raw materials uptake energy consumption
Waste emissions (water)	biochemical oxygen demand (BOD) total suspended solids acidity/alkalinity (pH) concentration of phosphates, nitrates, heavy metals, etc
Waste emissions (air)	carbon dioxide, nitrous/nitric oxides, sulphur dioxide
Waste emissions (other)	solid wastes toxic wastes noise
Further impacts	impacts on landscape impacts on biodiversity contribution to the greenhouse effect contribution to ozone layer depletion contribution to acid rain deposition

Cities development

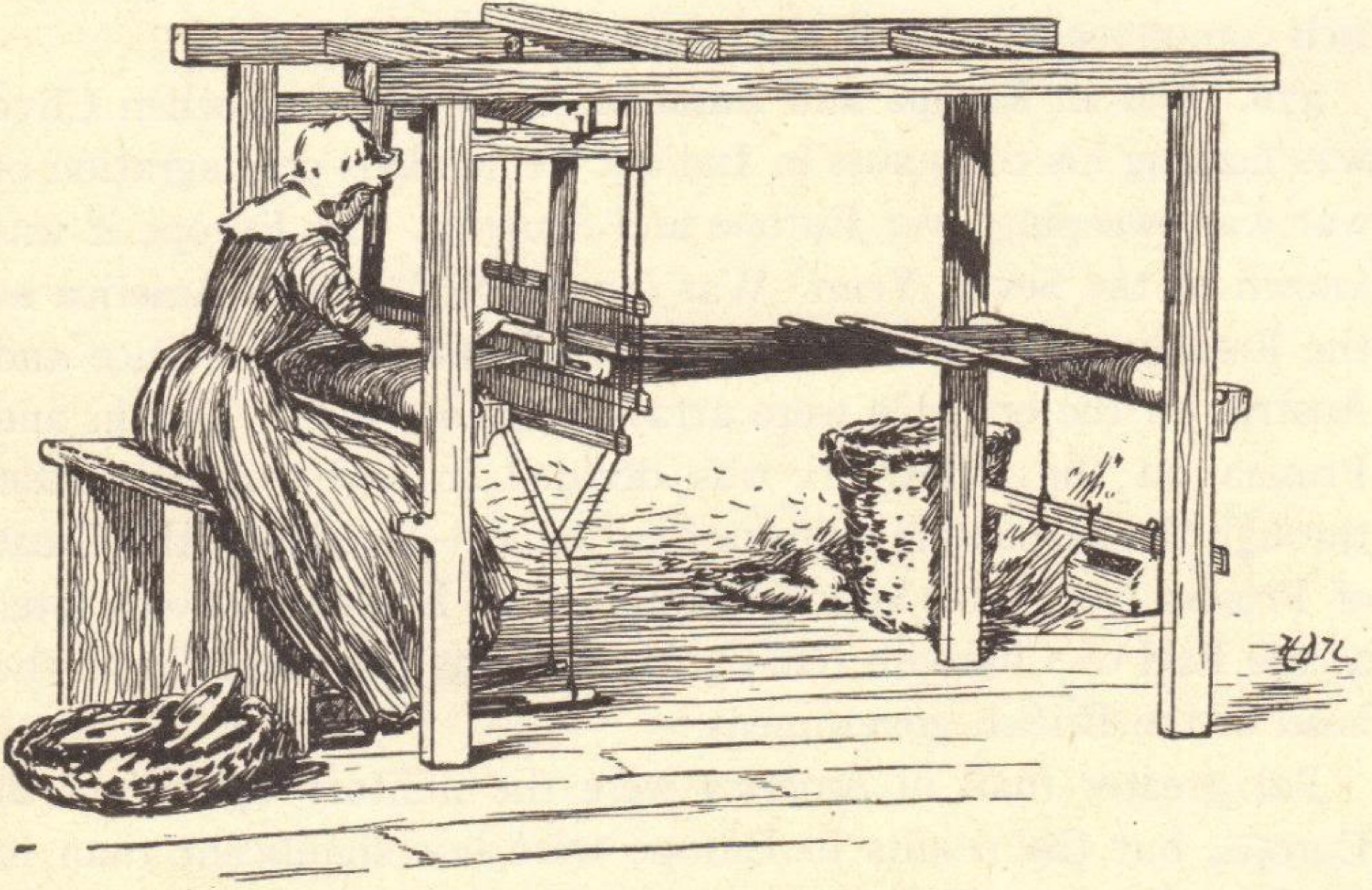
- ***Cultural development***
- ***Social development***
- ***Economic development***

Modern World History

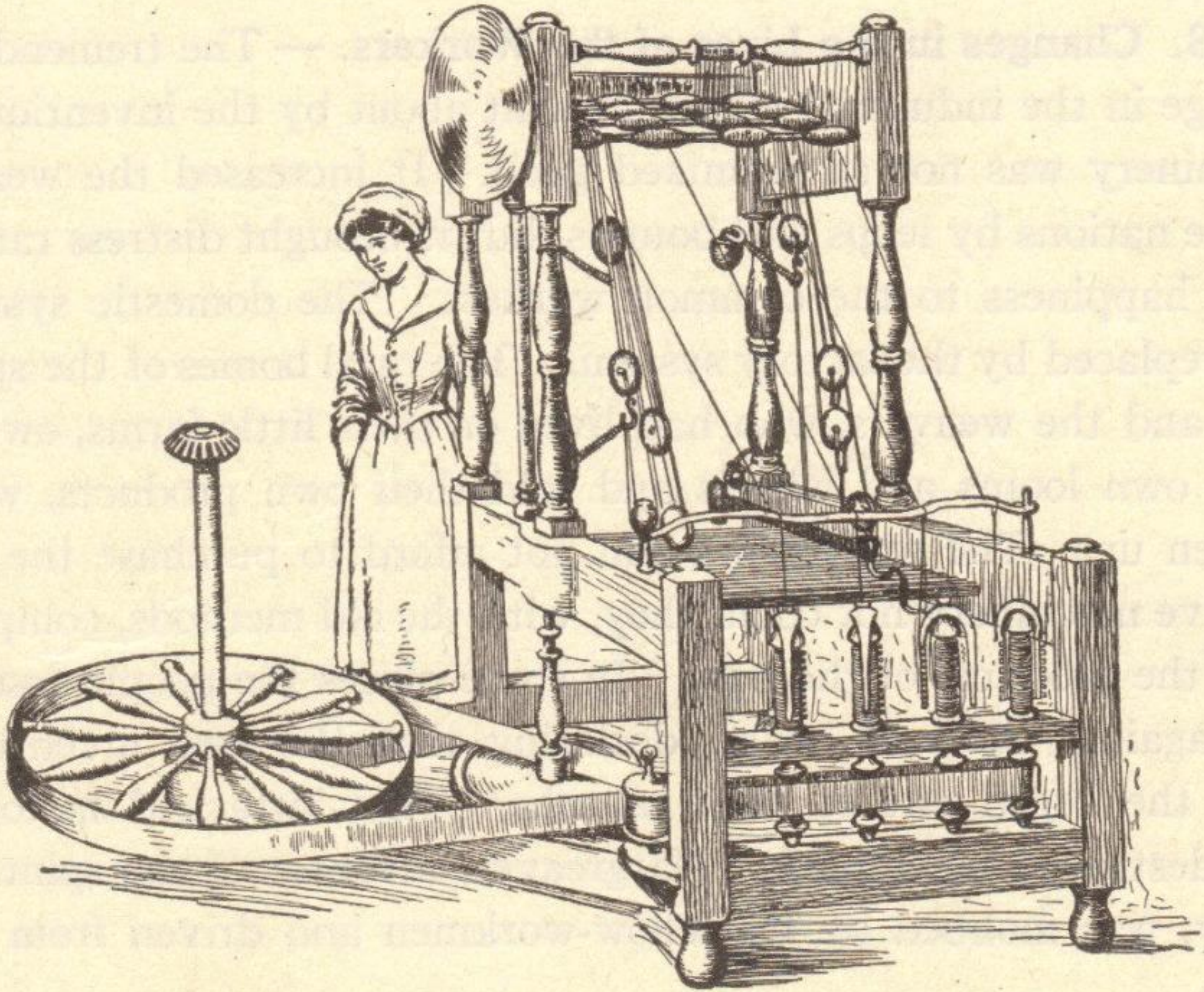


Historical Significance of the Industrial Revolution

- An ancient Greek or Roman would have been just as comfortable in Europe in 1700 because daily life was not much different – agriculture and technology were not much changed in 2000+ years
- **The Industrial Revolution changed human life drastically**
- More was created in the last **250+ years** than in the previous **2500+ years** of known human history



A Hand Loom, such as was used before 1785



ARKWRIGHT'S FIRST SPINNING FRAME

Background of the Industrial Revolution

- Commercial Revolution
  - 15th, 16th, and 17th centuries
  - Europeans expanded their power worldwide
  - Increased geographic knowledge
  - Colonies in the Americas and Asia
  - Increased trade and commerce
  - Guild system could not meet the demands of increasing numbers goods

Development of the Domestic System of Production

- Domestic system developed in England
- Late **1600s-late 1800s**
- Domestic system of production – “putting out” system
  - Business people delivered raw materials to workers’ homes
  - Workers manufactured goods from these raw materials in their homes (typically articles of clothing)
  - Business people picked up finished goods and paid workers wages based on number of items
- Domestic system could not keep up with demand

Factory System

- Developed to replace the domestic system of production
- Faster method of production
- Workers concentrated in a set location
- Production anticipated demand
  - For example: Under the domestic system, a woman might select fabric and have a businessperson give it to a home-based worker to make into a dress. Under the factory system, the factory owner bought large lots of popular fabrics and had workers create multiple dresses in common sizes, anticipating that women would buy them.

What was the Industrial Revolution?

- The Industrial Revolution was a fundamental change in the way goods were produced, from human labor to machines
- The more efficient means of production and subsequent higher levels of production triggered far-reaching changes to industrialized societies

England: Birthplace of the Industrial Revolution

- No concrete start date for the Industrial Revolution
- Marked by gradual, slow changes
- After 1750 – these changes were noticeable first in England

Why the Industrial Revolution Started in England

Capital for investing in the means of production	Colonies and Markets for manufactured goods	Raw materials for production
Workers	Merchant marine	Geography

Benefits of The Industrial Revolution

- **Machines** were invented which replaced human labor
- **New energy sources** were developed to power the new machinery – water, steam, electricity, oil (gas, kerosene)
  - Some historians place advances in atomic, solar, and wind energy at the later stages of the Industrial Revolution
- **Increased use** of raw materials (metals, minerals …………)

Benefits of The Industrial Revolution

- **Transportation improved**
  - Ships
    - Wooden ships → Iron ships → Steel ships
    - Wind-powered sails → Steam-powered boilers
  - Trains
  - Automobiles
- **Communication improved**
  - Telegraph
  - Telephone
  - Radio

Developments

- **Mass production of goods**
  - Increased numbers of goods
  - Increased diversity of goods produced
- **Development of factory system of production**
- **Rural-to-urban migration**
  - People left farms to work in cities
- **Development of capitalism**
  - Financial capital for continued industrial growth
- **Development and growth of new socio-economic classes**
  - Working class, bourgeoisie, and wealthy industrial class
- **Commitment to research and development**
  - Investments in new technologies
  - Industrial and governmental interest in promoting invention, the sciences, and overall industrial growth

The First and Second Industrial Revolutions

- **The first, or old, Industrial Revolution took place between about 1750 and 1870**
  - Took place in England, the United States, Belgium, and France
  - Saw fundamental changes in agriculture, the development of factories, and rural-to-urban migration

- **The second Industrial Revolution took place between about 1870 and 1960**
  - Saw the spread of the Industrial Revolution to places such as Germany, Japan, and Russia
  - Electricity became the primary source of power for factories, farms, and homes
  - Mass production, particularly of consumer goods
  - Use of electrical power saw electronics enter the marketplace (electric lights, radios, fans, television sets)

The Spread of the Industrial Revolution

- Mid-1800s – Great Britain, the world leader in the Industrial Revolution, attempted to ban the export of its methods and technologies, but this soon failed
- 1812 – United States industrialized after the War of 1812
- After 1825 – France joined the Industrial Revolution following the French Revolution and Napoleonic wars
- Circa 1870 – Germany industrialized at a rapid pace, while Belgium, Holland, Italy, Sweden, and Switzerland were slower to industrialize
- By 1890 – Russia and Japan began to industrialize

Results of the Industrial Revolution

Economic Changes

- Expansion of world trade
- Factory system
- Mass production of goods
- Industrial capitalism
- Increased standard of living
- Unemployment

Political Changes

- Decline of landed aristocracy
- Growth and expansion of democracy
- Increased government involvement in society
- Increased power of industrialized nations
- Nationalism and imperialism stimulated
- Rise to power of businesspeople

Social Changes

- Development and growth of cities
- Improved status and earning power of women
- Increase in leisure time
- Population increases
- Problems – economic insecurity, increased deadliness of war, urban slums, etc.
- Science and research stimulated

Some other results of Industrial revolution at the end of 19th

Child labor

Emerging middle/working class

Capitalism vs. communism

Sharp increase in the population

Pollution and unsanitary conditions

Social Changes: Population Increases

Agricultural Revolution → Increased food production → Lower food prices → People ate more → More healthy babies were born → Population skyrocketed

Europe

- 1750 – 144,000,000
- 1900 – 325,000,000

England

- 1750 - 11,000,000
- 1900 - 30,000,000

- **Many people immigrated to industrialized countries**
  - Numerous nationalities to the United States
  - Irish to Manchester and Liverpool in England
- **Population growth in industrialized nations required growing even more food**

The New Industrial City

Staffordshire, England

Problems of Pollution

The Silent Highwayman - 1858

The 'Silent Highway' - Man. 'Your money or your life'. Cartoon published in ***Punch magazine***, **10 July 1858**, No. 35. This cartoon refers to the problems caused by the very hot summer of 1858. The summer heat together with a very high level of sewage and pollution, caused a very bad smell coming from the river Thames. This cartoon depicts the allegorical figure of death rowing a boat on the polluted and foggy river where dead animals float by. Death is here associated with pollution and disease. St. Paul's Cathedral can be seen side by side with a smoky factory in the distance.

Present context ………….

Industrial system has been responsible for raising the quality of life of peoples around the world

The current system is creating unintended and serious consequences for the environment at a global level

The **benefits** for some centers of affluent industrial production are **apparent**, but also are **the growing consequences for the planet**, **its ecosystems and the natural capital** on which future prosperity and indeed human survival depend.

Importance of industry

- Manufacturing value chain, including associated business services
- High industrial productivity creates wealth
- Manufacturing accounts for 75% of exports and 80% of R&D
- Industry as solution-provider helping to tackle societal challenges

Manufacturing industries nevertheless have the **potential to become a driving force for the creation of a sustainable society**.

They **can design and implement integrated sustainable practices** and **develop products and services that contribute to better environmental performance.**

This **requires a shift in the perception and understanding of industrial production and the adoption of a more holistic approach to conducting business.**

The problem remains…………

Some experts suggest the industrial system can account for **30% or more of greenhouse gas generation** in industrialized countries

Today, the global community faces serious challenges, where demand for resources is outstripping supply and where emissions and waste have accumulated to levels that endanger the current quality of life

Processes of economic decision making and governance must shift towards long term analysis and evaluation, incorporating whole life-cycle social and environmental impacts.

Our current industrial system

appears to have been designed to:

" -put billions of pounds of toxic materials into the air, water and soil every year,
-produce materials so dangerous that they will require constant vigilance from future generations,
-result in gigantic amounts of waste,
-put valuable materials in holes all over the planet, where they cannot be easily retrieved,
-require thousands of complex regulations – not to keep people and natural systems safe, but rather to keep them from being poisoned too quickly,
-measure productivity by how few people are working,
-create prosperity by digging up or cutting down natural resources and then burying or burning them,
-erode the diversity of species and cultural practices."

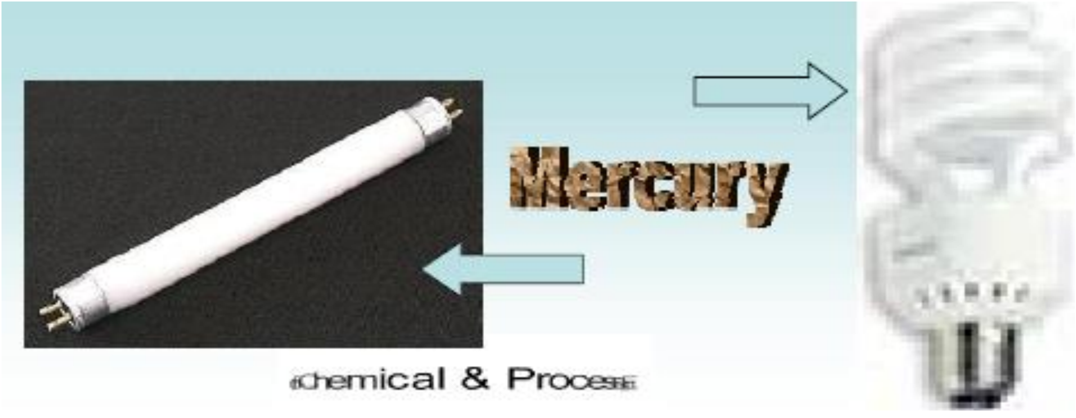
McDonough and Braungart, 2002

Pollution

- Introduction by man, waste matter or surplus energy into the environment, which directly or indirectly causes damage to man and his environment.

Pollutant

- A substance or effect which adversely alters the environment by changing the growth rate of species, interferes with the food chain, is toxic, or interferes with health, comfort amenities or property values of people.



TYPES OF POLLUTION

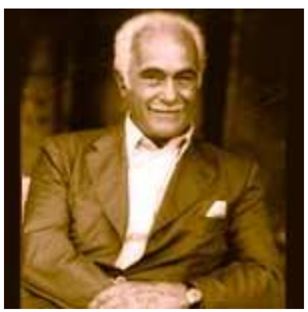
- Water Pollution
- Air Pollution
- Land Pollution
- Noise Pollution
- Thermal Pollution
- Electro Pollution (electronic waste)
- Visual Pollution
- ……………………..

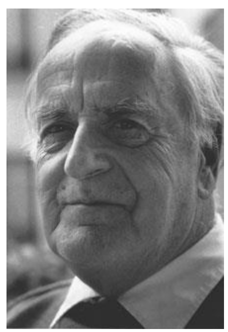
Warnings, attitudes …..

Club of Rome

Founded in 1968 at **Accademia dei Lincei in Rome, Italy,**

by Aurelio Peccei and Alexander King



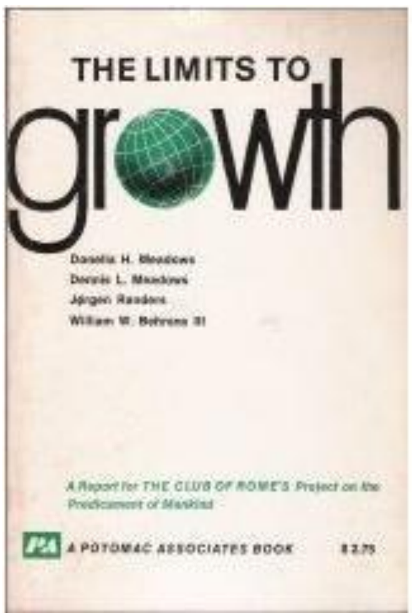


THE CLUB OF ROME

describes itself as **"a group of world citizens, sharing a common concern for the future of humanity."**

The club states that its mission is "**to act as a global catalyst for change through the identification and analysis of the crucial problems facing humanity and the communication of such problems to the most important public and private decision makers as well as to the general public”**

- considerable public attention in **1972** with its report *The Limits to Growth*,
- *authors* ***Donella H. Meadows*, *Dennis L. Meadows*, *Jørgen Randers*, and *William W. Behrens III***



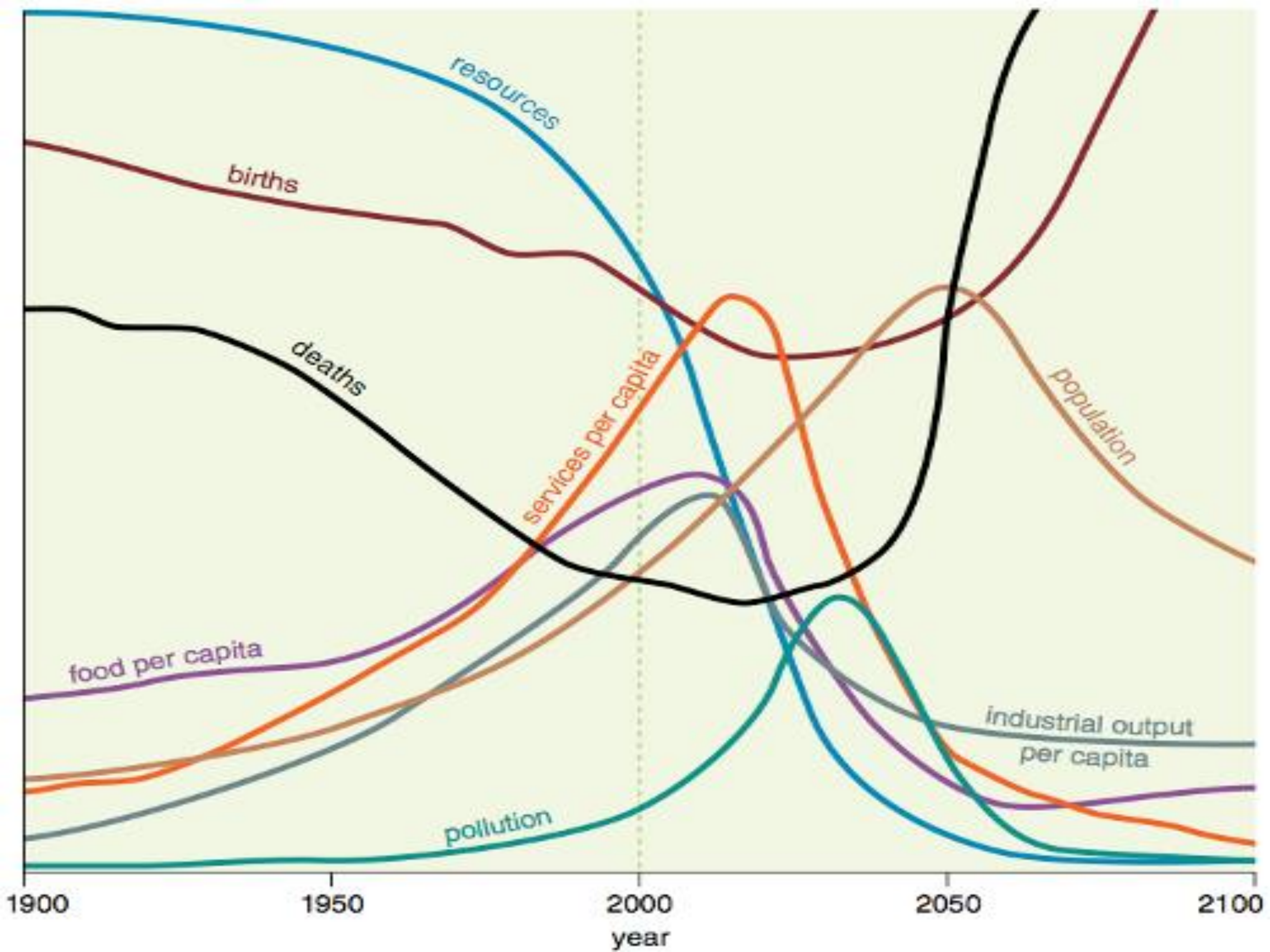
explore the possibility of a sustainable feedback pattern that would be achieved by altering growth trends among the five variables under three scenarios

Purpose

- To explore how exponential growth interacts with finite resources.
- The size of resources is not known, only the general behaviour can be explored.
- It is predicted that the limits to growth would be reached by 2070.

The Variables

- World Population.
- Industrialization.
- Pollution.
- Food Production.
- Resource Depletion.


resources
births
deaths
services per capita
population
food per capita
industrial output per capita
pollution
1900
1950
2000
2050
2100
year

The Club of Rome – basic conclusion….in ’70s

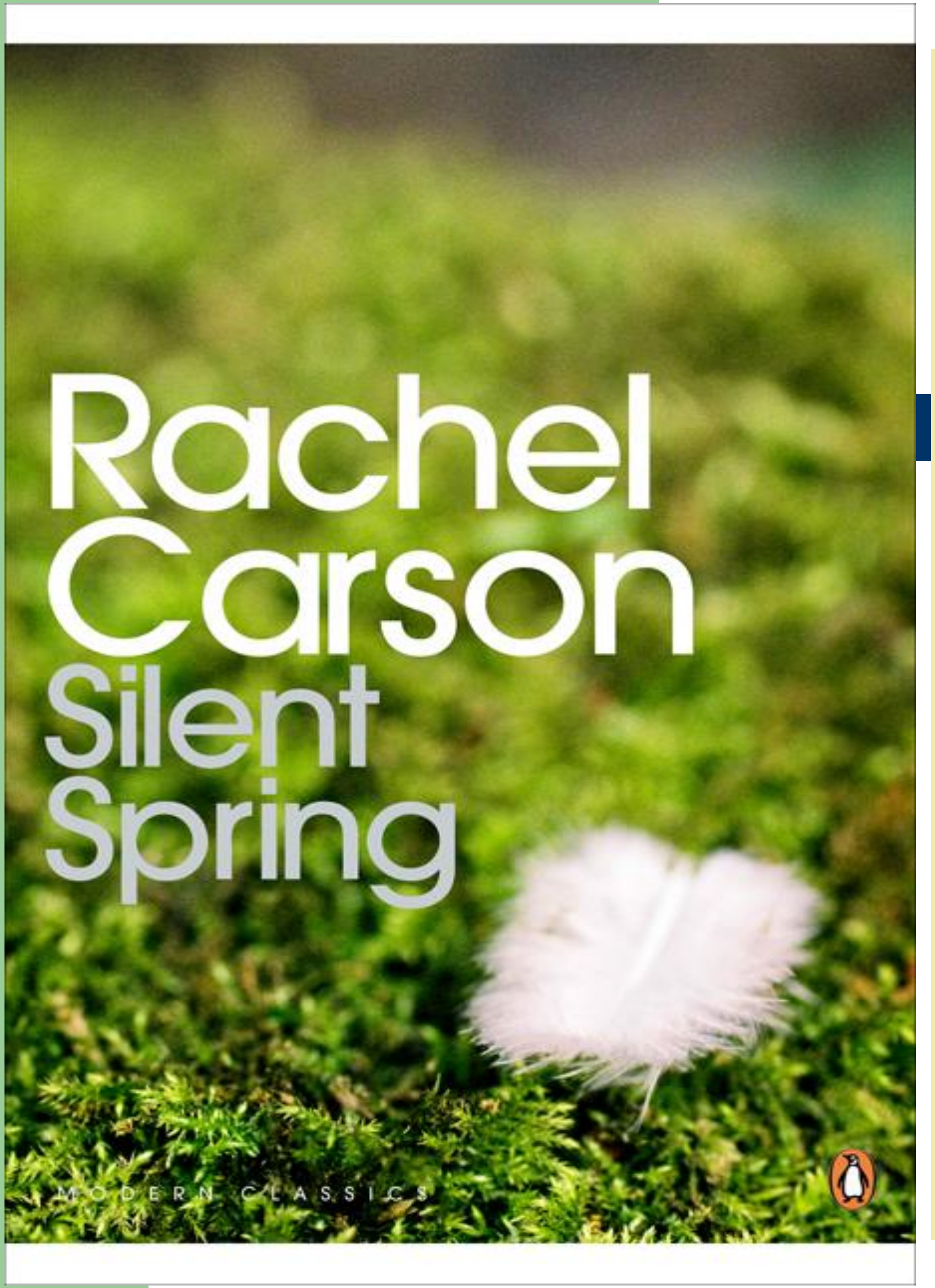
- If present growth trends in world population continue and if associated industrialization, pollution, food production and resource depletion continue unchanged, the limits to growth on this planet will be reached sometime in the next 100 years.
- The most probable result will be sudden and uncontrollable decline in both population and industrial capacity

"… Indeed, Rachel Carson was one of the reasons that I became so conscious of the environment and so involved with environmental issues …Carson has had as much or more effect on me that any, and perhaps than all of them together."

RACHEL CARSON

May 27, 1907 – April 14, 1964

Marine Biologist**, Ecologist, Writer**



"The book that birthed modern environmentalism"

"This book was a shaft of light that for the first time illuminated what is arguably the most important issue of our era."

- Al Gore

"Our Common Future"

also known as the **Brundtland Report**, from the United Nations World Commission on Environment and Development (WCED) was published in 1987 (Oxford University Press).

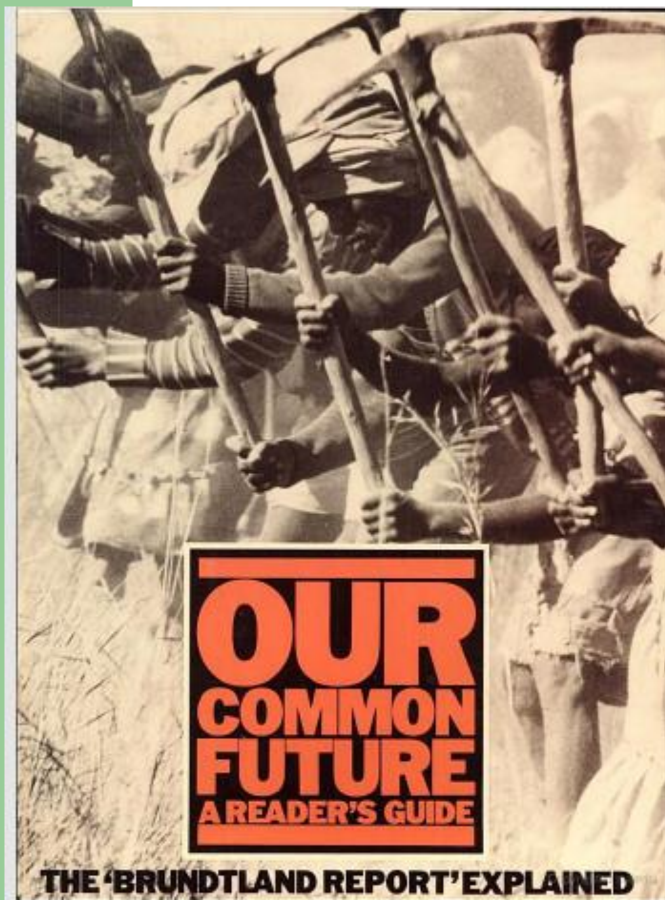
Gro Harlem Brundtland

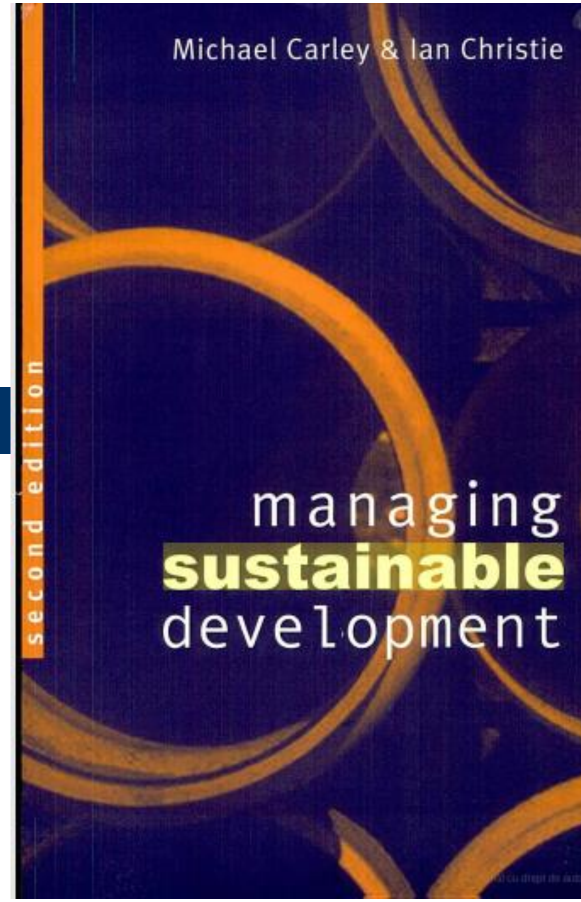
- Norwegian Minister for Environmental Affairs from 1974 to 1979
- Norway's first, and to date only, female Prime Minister. from February to October in 1981.

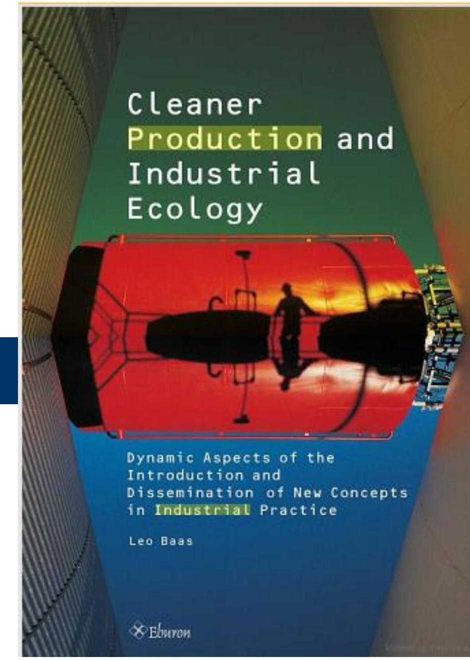
In 1983, **Brundtland:**

- was invited by then United Nations Secretary-General Javier Pérez de Cuéllar **to establish and chair the World Commission on Environment and Development (WCED)** (widely referred to as the *Brundtland Commission)*
- developed the broad political concept of sustainable development in the course of extensive public hearings
- the commission, which published its report, *Our Common Future*, in April 1987, provided the momentum for the 1992 Earth Summit/UNCED, which was headed by Maurice Strong, who had been a prominent member of the commission.
- The Brundtland Commission also provided momentum for Agenda 21.

The *Brundtland Commission* draws upon several notions in its **definition of sustainable development**, which is the most frequently cited definition of the concept to date.







Gro Harlem Brundtland

Relevant existing sustainability indicators

Human Development Index, HDI
Environmental Sustainability Index, ESI-2005
Environmental Performance Index, EPI-2006
Commitment to Development Index, CDI-2006
Index for Sustainable Economic Welfare, ISEW
Genuine Progress Indicator, GPI
Ecological Footprint
Wellbeing of Nations
Millennium Development Indicators
Indicators for the EU Sustainable Development Strategy
CSD indicators
Sustainable Society Index

Ecological footprint and the biocapacity of the planet

a way of comparing the demand on ecological services to the available supply is necessary

clear metrics are needed to change these ideological debates into discussions based on empirical facts.

Responding to this need for a metric, the Ecological Footprint was developed over 20 years ago.

the metrics are usually expressed as sustainability indicators/indexes

The first academic publication about the ecological footprint was by William Rees in 1992.

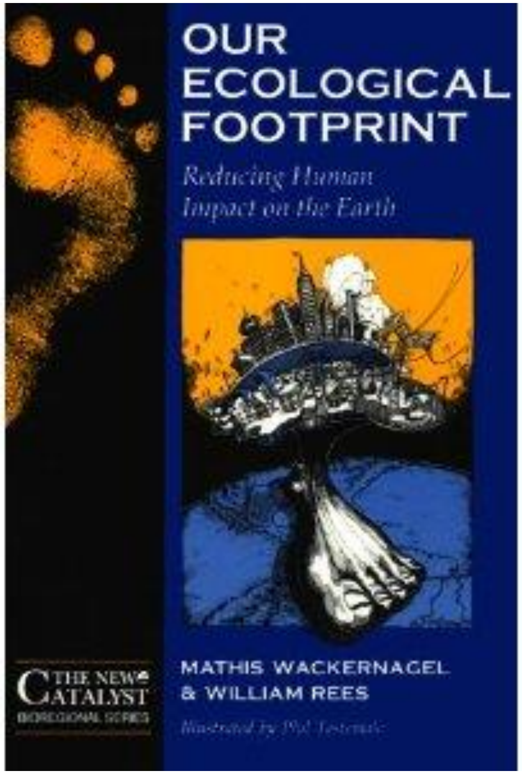
The ecological footprint concept and calculation method was developed as the PhD dissertation of ***Mathis Wackernagel, under Rees' supervision*** *at the* ***University of British Columbia in Vancouver, Canada, from 1990–1994****.*

*Originally, Wackernagel and Rees called the concept "****appropriated carrying capacity".***

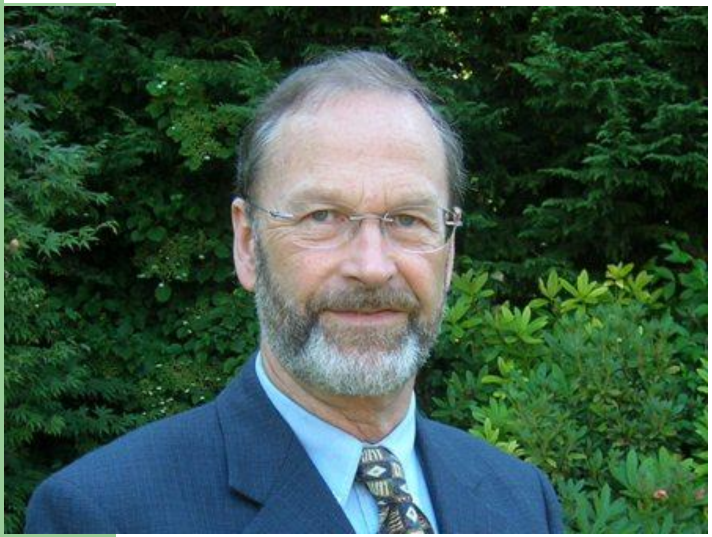
To make the idea more accessible, Rees came up with the term ***"ecological footprint"*** *inspired by a computer technician who praised his new computer's "small footprint on the desk."*

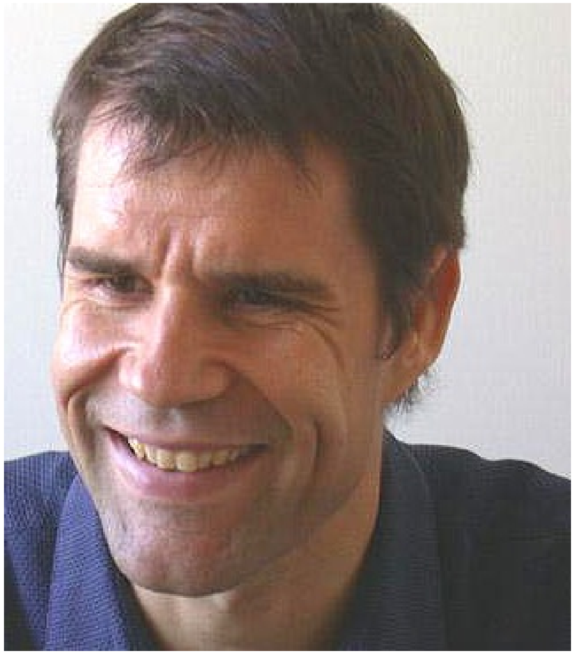
In early 1996, Wackernagel and Rees published the book

Our Ecological Footprint: Reducing Human Impact on the Earth



William Rees





Mathis Wackernagel

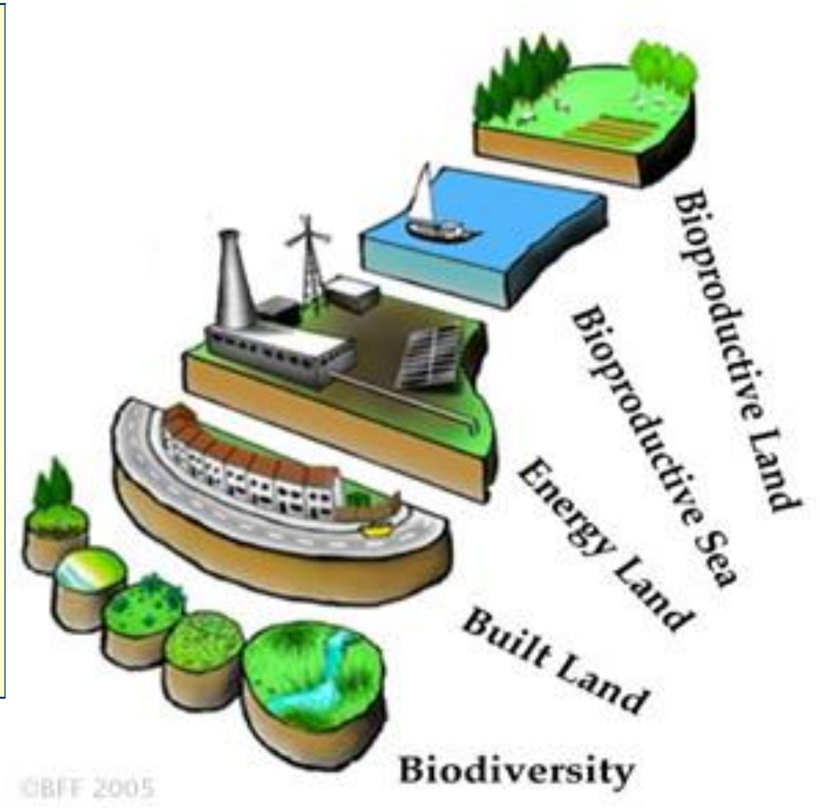
The Ecological Footprint is a measure of the pressure human activity puts on the biosphere.

Ecological footprint *measures*

the amount of biologically productive land and water area

required to produce all the resources an individual, population, or activity consumes*,*

and ***to absorb the waste they generate,*** *given prevailing technology and resource management practices.*



The *Ecological Footprint is*

a resource accounting tool

that can reveal

ecological limits

by comparing

human demand on the Earth’s regenerative capacity

with

the available supply.

Land and water area is scaled according to its biological productivity. This scaling makes it possible to compare ecosystems with differing bioproductivity and in different areas of the world in the same unit,

a global hectare.

A global hectare represents a hectare with world average productivity.

Global hectare (gha):

A productivity weighted area ***used to report both the biocapacity of the Earth, and the demand on biocapacity (the Ecological Footprint).***

The global hectare is normalized to the area-weighted ***average productivity of biologically productive land and water in a given year.***

Global hectares allow Ecological Footprint results to be globally comparable.

The demand on the biosphere can be compared to the available **biocapacity.**

This area can then be compared with **biological capacity (biocapacity),** ***the amount of productive area that is available to generate these resources and to absorb the waste.***

Biological capacity or biocapacity: the capacity of ecosystems to produce useful biological materials and to absorb waste materials generated by humans, using current management schemes and extraction technologies.

Biocapacity is usually expressed in units of global hectares.

The Ecological Footprint is a measure of human demand for biocapacity.

The biocapacity of an area is calculated by multiplying the actual physical area by the yield factor and the appropriate equivalence factor.

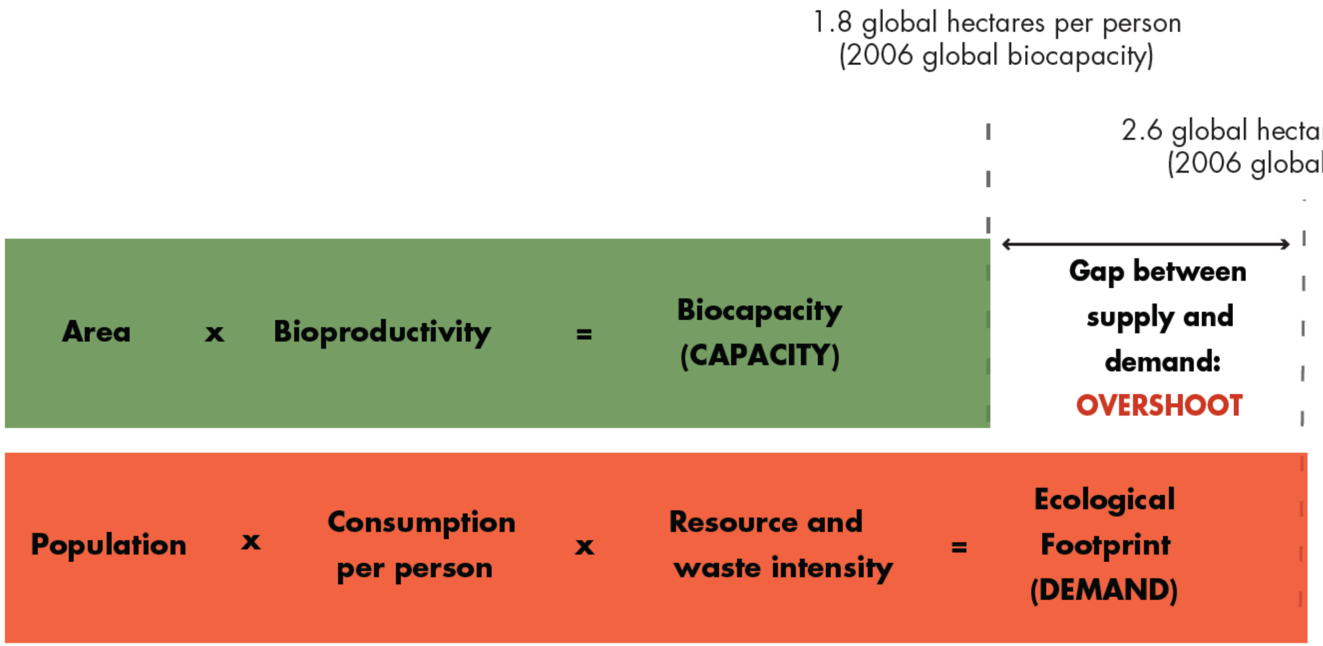
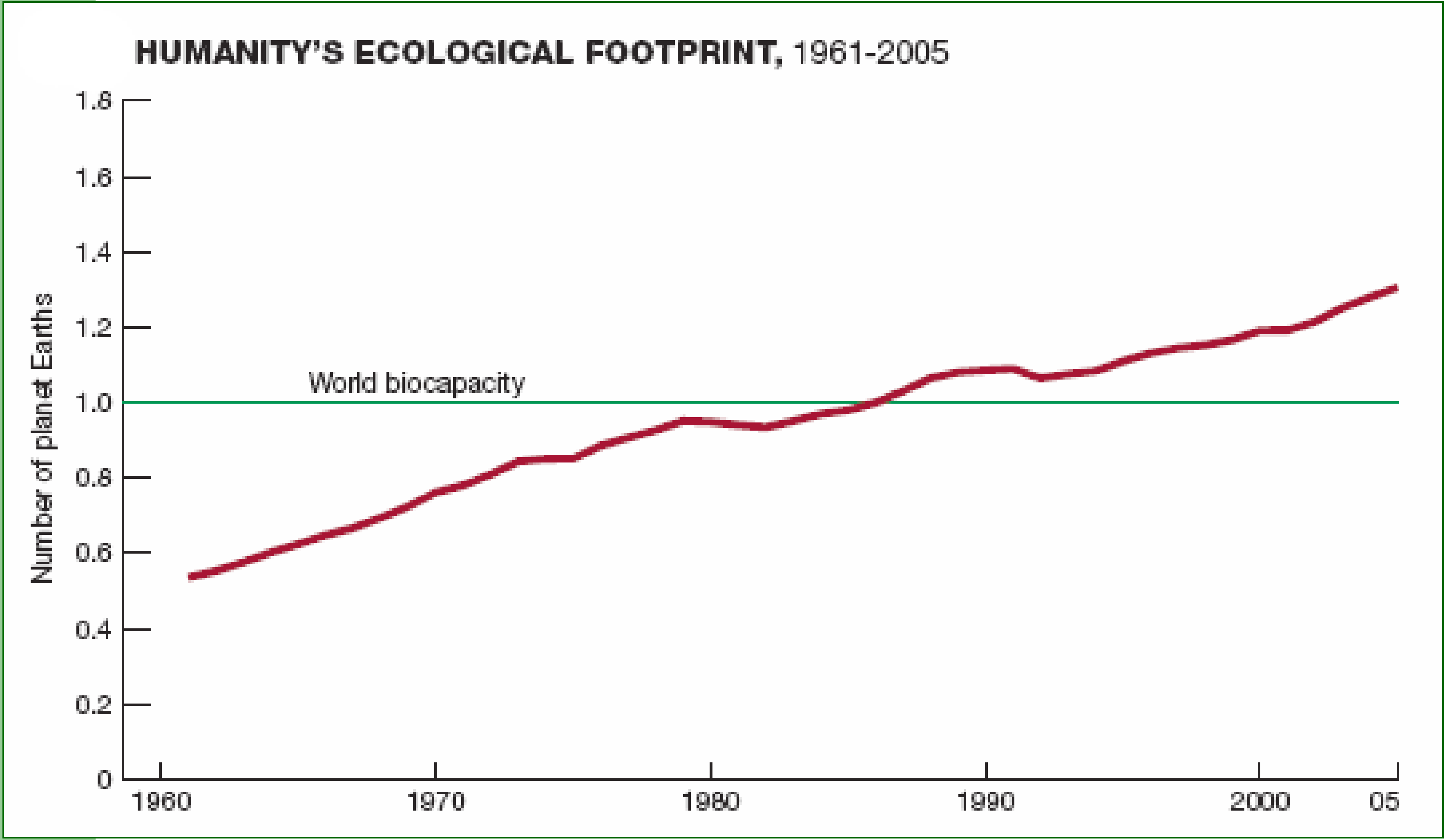


Figure 1.3. Footprint and biocapacity factors that determine global overshoot

In 2006, the planet's total biocapacity was **13.6 billion global hectares**, **or 1.8 global hectares per person, while the demand was 2.6 global hectares per person.** Demand therefore exceeded supply by a **0.8 global hectare deficit per person**. *This 40 percent overshoot meant that it took the Earth almost 16 months to regenerate the resources humanity used in 12 months*



HUMANITY'S ECOLOGICAL FOOTPRINT, 1961-2005
Number of planet Earths
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0
World biocapacity
1960
1970
1980
1990
2000
05

A graphical representation of humanity's ecological footprint, showing humanity are currently using 1.3 planets to provide the resources people use and to absorb waste. This could increase to nearly two planets' worth by 2030 and nearly two and a half by 2050, if no action is taken.

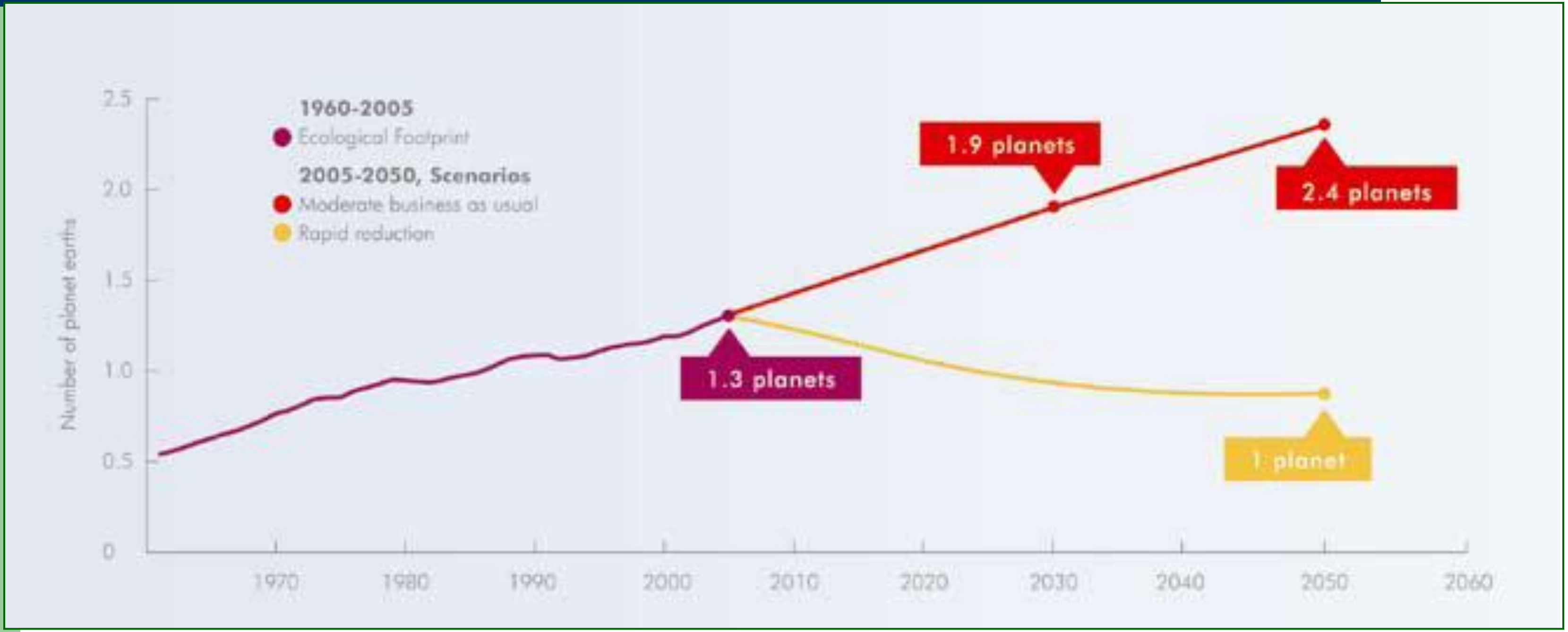


Figure 1.4. The need of resources for the humanity, following the current model of consume

Regions and countries differ greatly in both their demand on biocapacity, and on the biocapacity they have available within their borders.

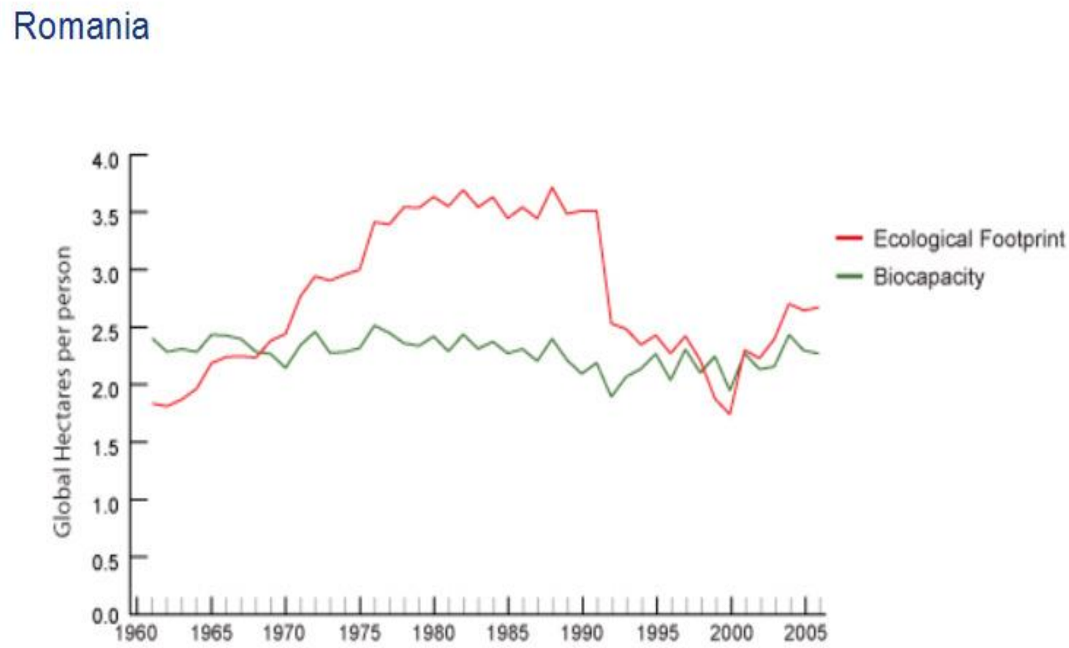
Many countries use more biocapacity than are available within their boundaries.

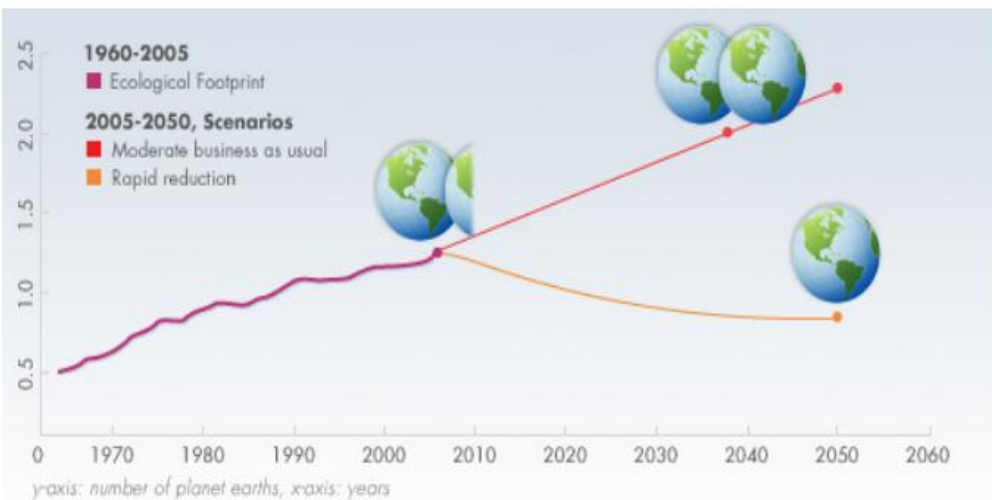
If everyone in the world lived like an average resident of the **United States or the United Arab Emirates,** the biocapacity of more than **4.5 Earths** would be required to support humanity's consumption rates.

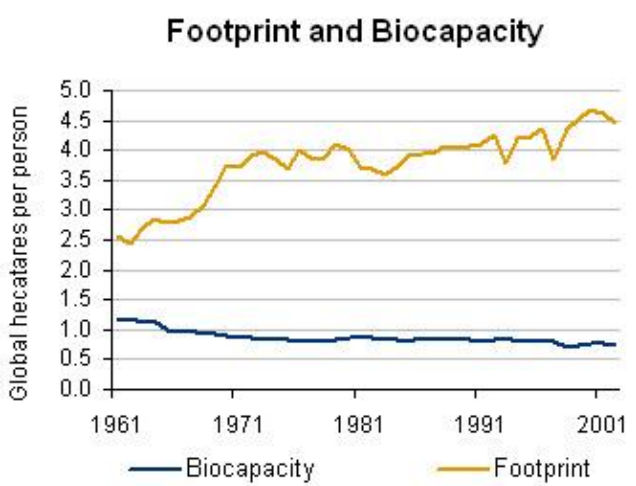
If instead the world were to live like the average **South Korean**, **only 1.8 planets** would be needed. And if the world lived like the average person in **India** did in 2006 (0.4-0.6 planets), humanity would be using **less than half the planet's biocapacity**.

Tracks the per-person resource demand (Ecological Footprint) and resource supply (Biocapacity) in Romania since 1961.

Biocapacity (the amount of productive area that is available to generate these resources and to absorb the waste) varies each year with ecosystem management, agricultural practices (such as fertilizer use and irrigation), ecosystem degradation, and weather.



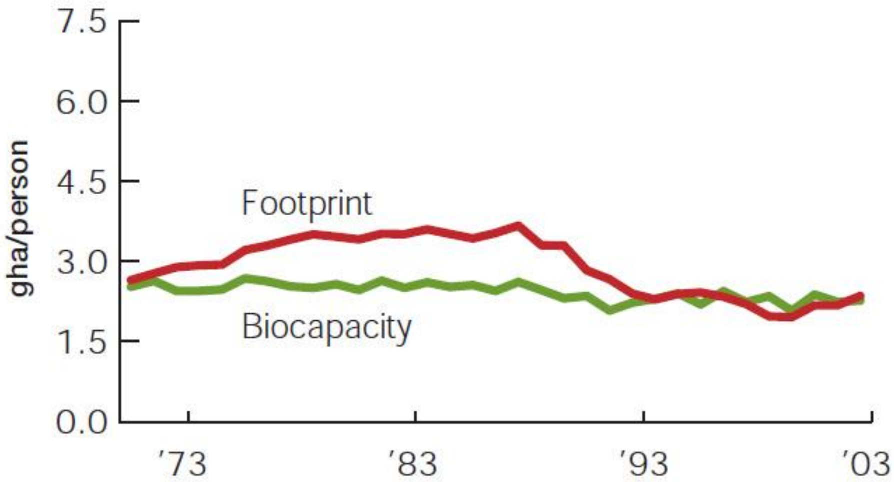




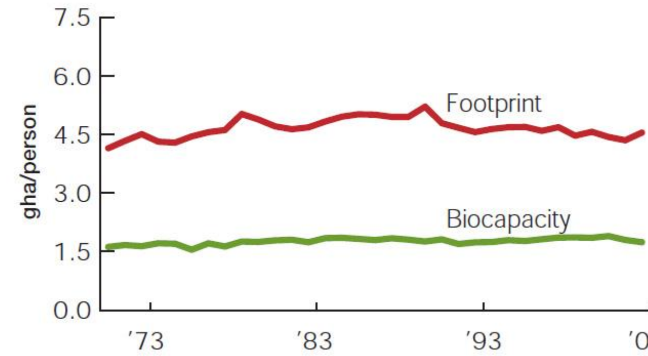
The World

The Netherlands

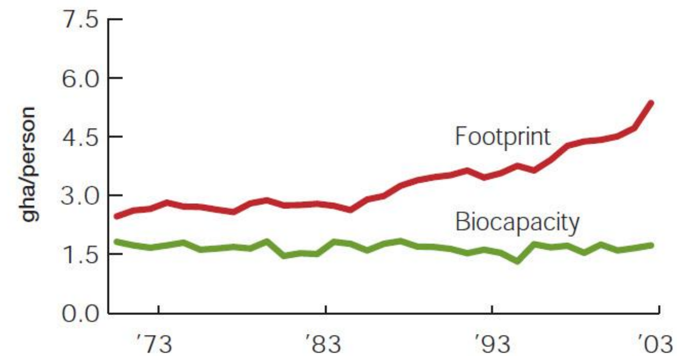
Romania's Ecological Footprint and biocapacity per person, 1971-2003



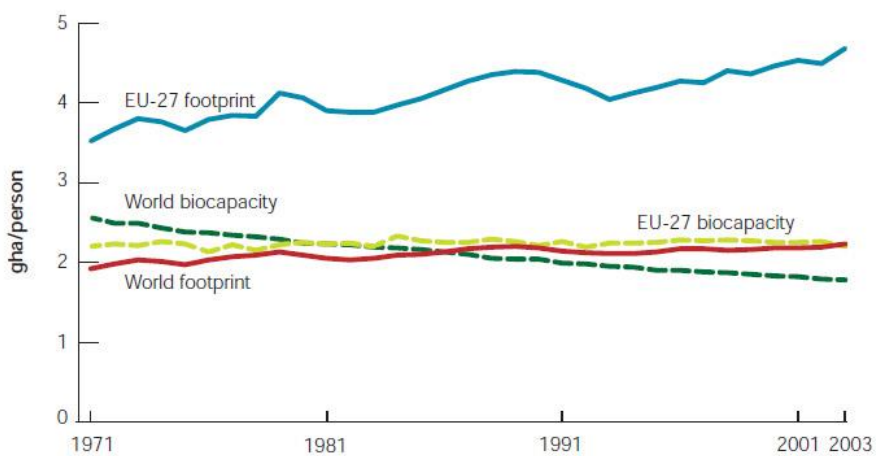
Germany's Ecological Footprint and biocapacity per person, 1971-2003



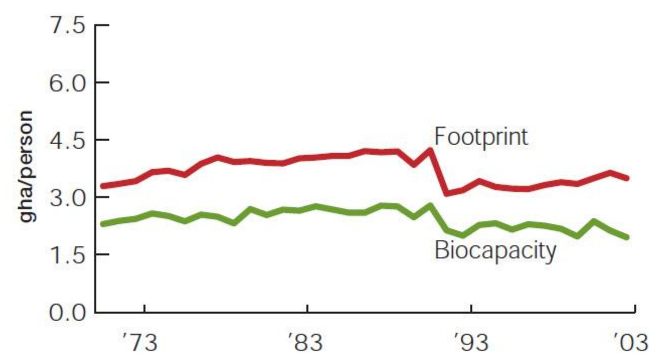
Spain's Ecological Footprint and biocapacity per person, 1971-2003



EU countries and world average Ecological Footprint, 1971-2003 (global hectares per person)



Hungary's Ecological Footprint and biocapacity per person, 1971-2003



http://www.footprintnetwork.org/images/uploads/europe_2007_gdp_and_ef.pdf

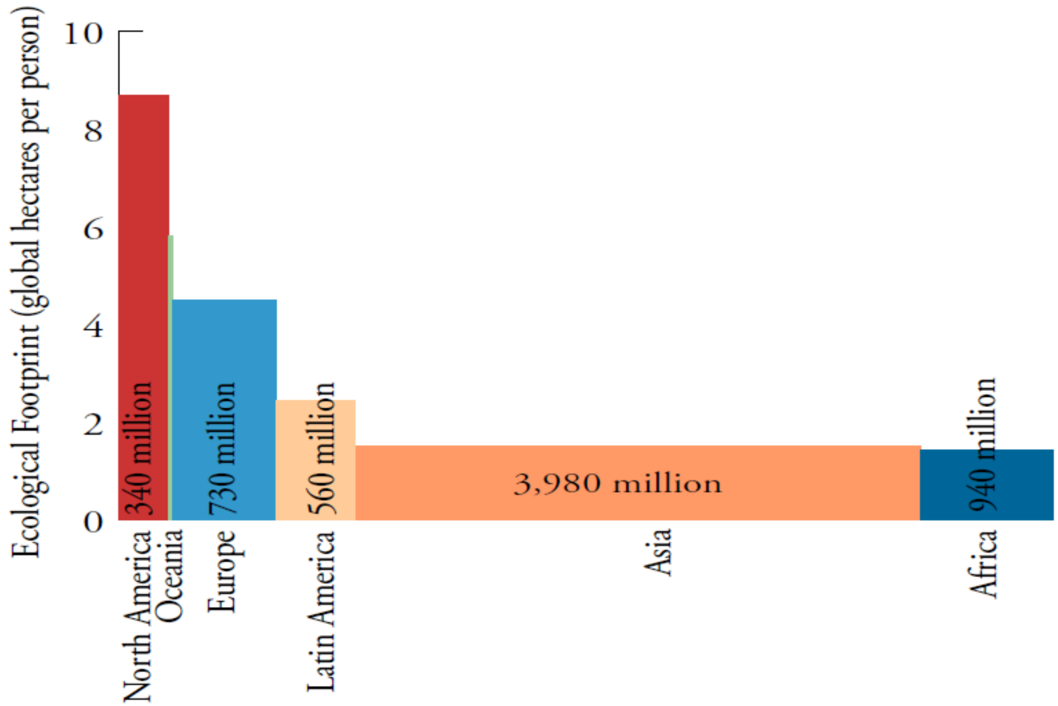


Figure 1.5. Ecological Footprint by region, 2006

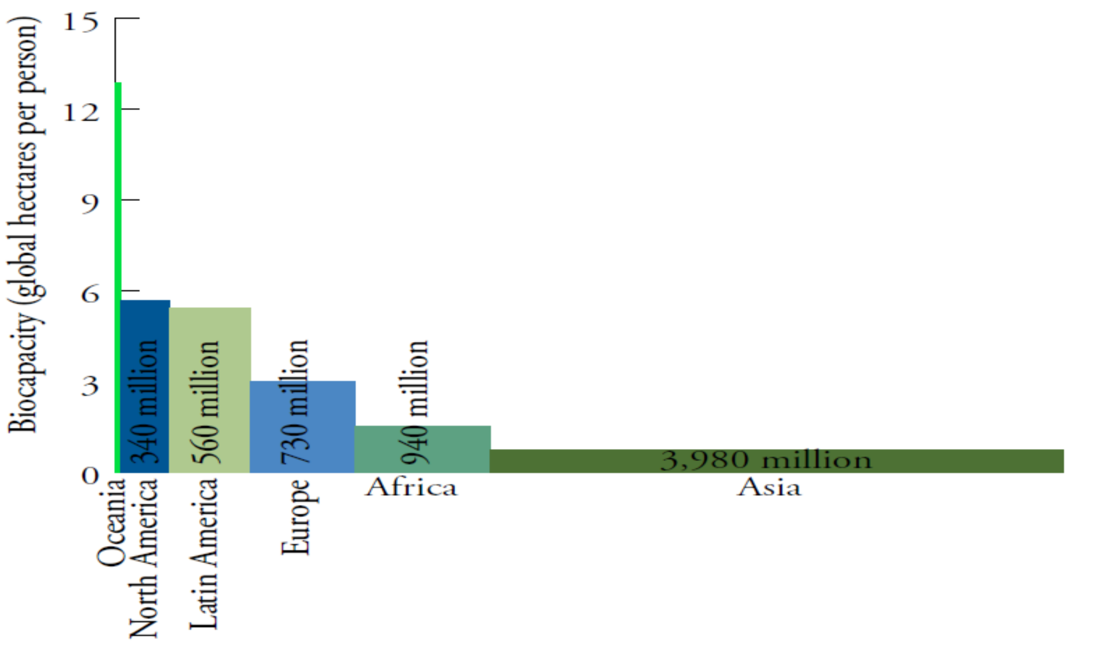
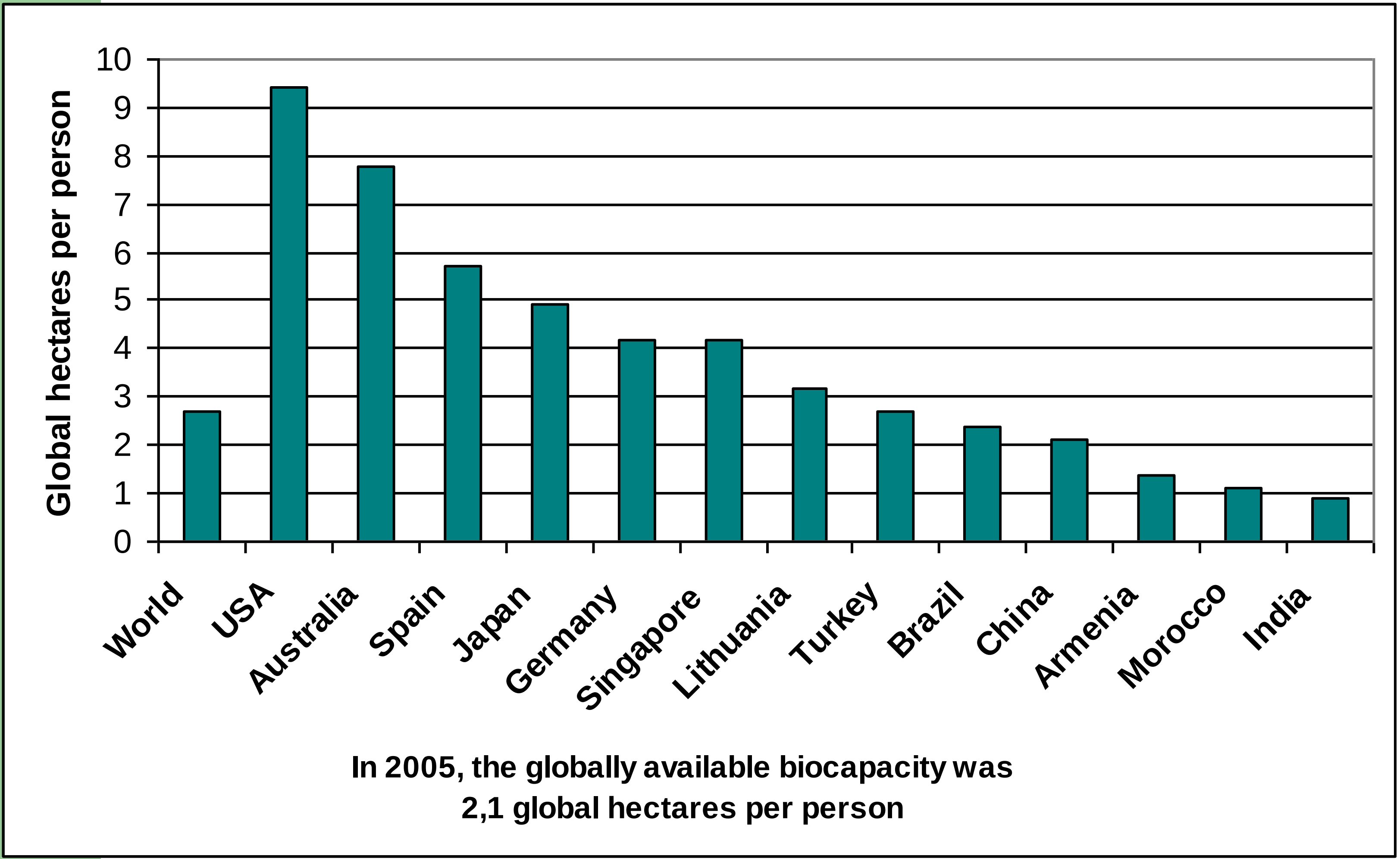


Figure 1.6. Biocapacity by region, 2006

Country	EF (hectares per person)	Proportion relative to world average	Proportion relative to world area available	Gross Domestic Product (GDP) per capita in US dollars
Colombia	1.3	0.23	0.73 (1.3/1.78)	6,370
Sweden	7	3.14	3.93	26,050
Bangladesh	0.6	0.27	0.34	1,700
United Arab Emirates	9.9	4.44	5.56	18,250
Thailand	1.4	0.63	0.78	7,010
Mexico	2.5	1.12	1.4	8,970
Australia	7.7	3.45	4.32	28,260
World Average	**2.23**	**1.0 (2.23/2.23)**	**1.25 (2.23/1.78)**	
Slovenia	3.8	1.7	2.13	18,540
China	1.5	0.67	0.84	4,580
Italy	3.8	1.7	2.13	26,430
Egypt	1.5	0.67	0.84	3,810
Brazil	2.2	0.98	1.24	7,770

Ecological Footprint of Nations

Ecological footprint per person, by country, 2005



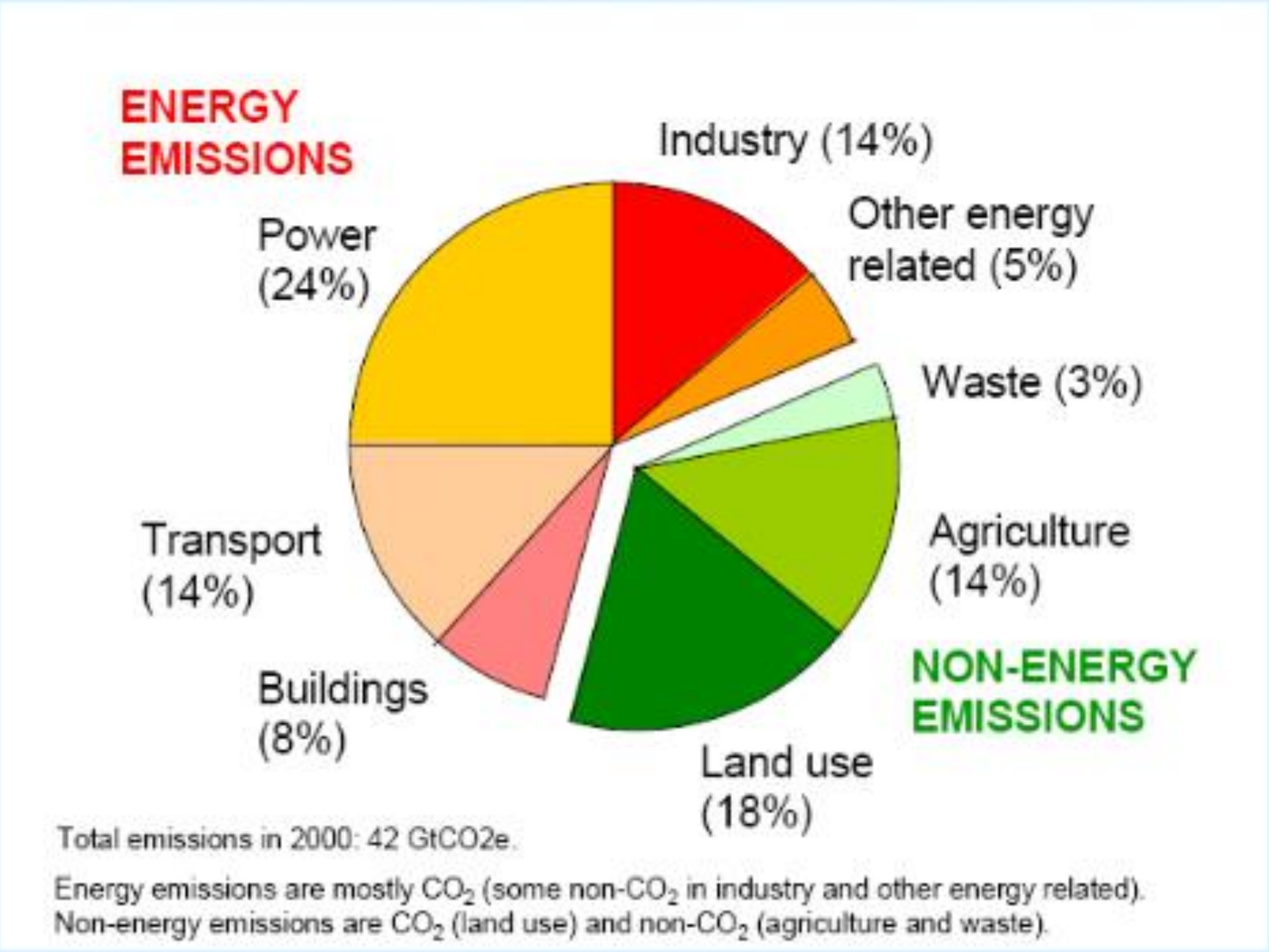
Source: WWF, Living Planet Report, 2008

Carbon Footprint

A **carbon footprint** is a measure of the **impact our activities have on the environment**, and **in particular climate change**.

It relates to **the amount of greenhouse gases** produced in our day-to-day lives through burning fossil fuels for electricity, heating and transportation etc.

The carbon footprint **is a measurement of all greenhouse gases we individually produce and has units of tonnes (or kg) of carbon dioxide equivalent.**

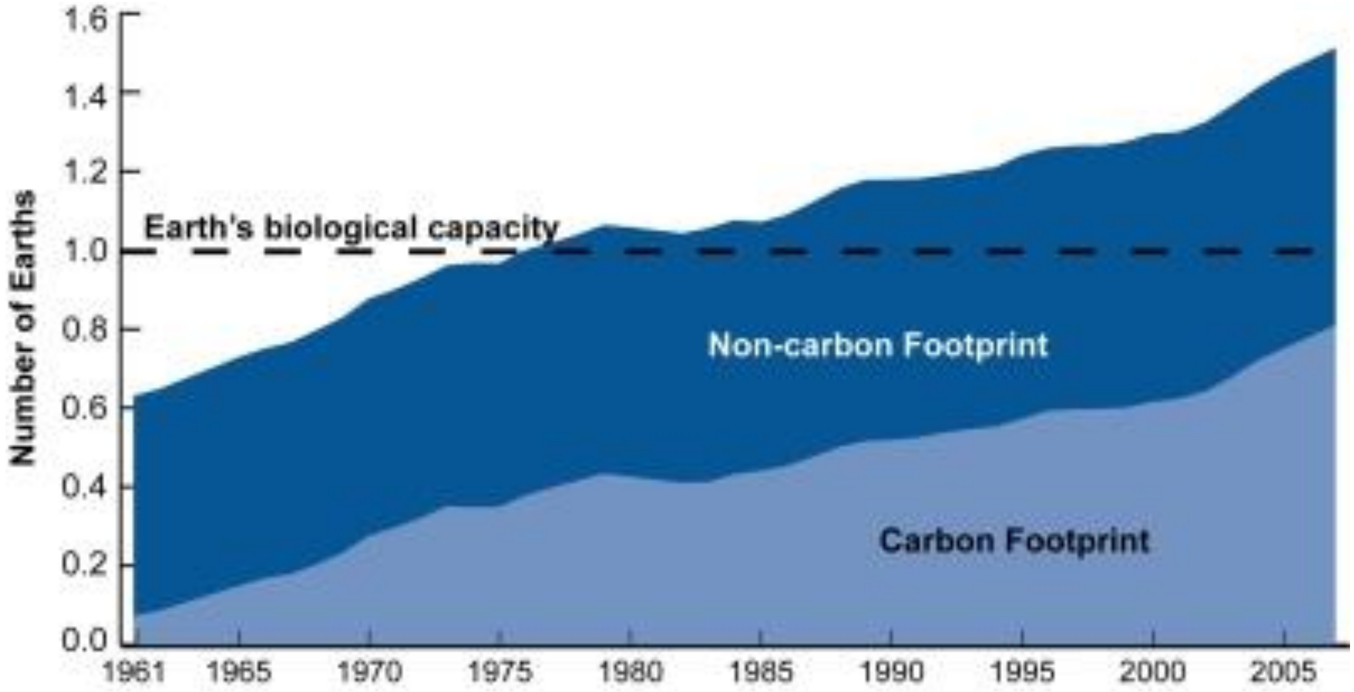


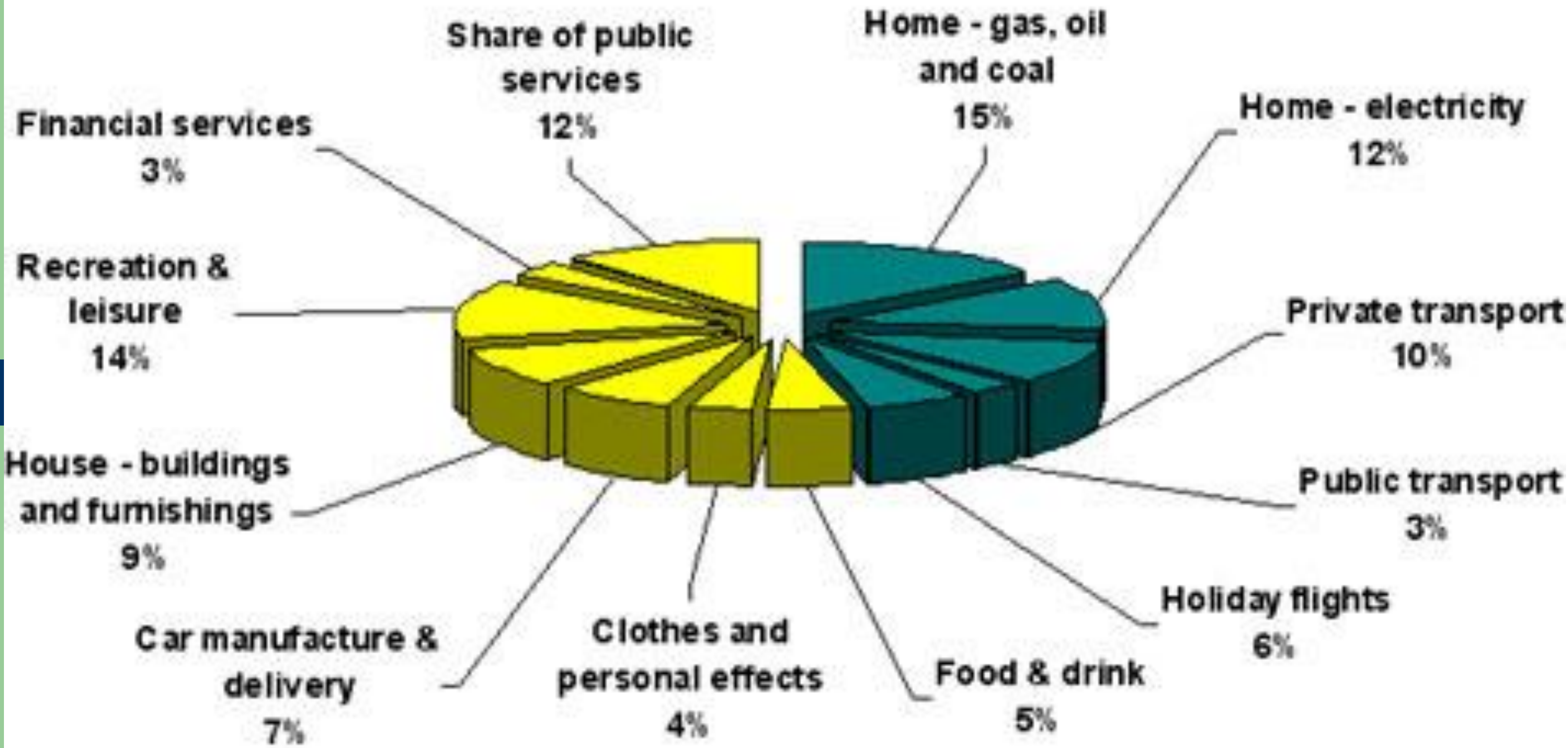
Source: Prepared by Stern Review, from data drawn from World Resources Institute Climate Analysis Indicators Tool (CAIT) on-line database version 3.0.

Global GHG Emissions at 42 GtCO_2e per annum are 5 times higher than the Earth can absorb …

The **carbon component** of the **Ecological Footprint** takes a slightly differing approach, **translating the amount of carbon dioxide into the amount of productive land and sea area required to sequester carbon dioxide emissions.**

This tells us the demand on the planet that results from burning fossil fuels.





A carbon footprint is made up of the sum of two parts,

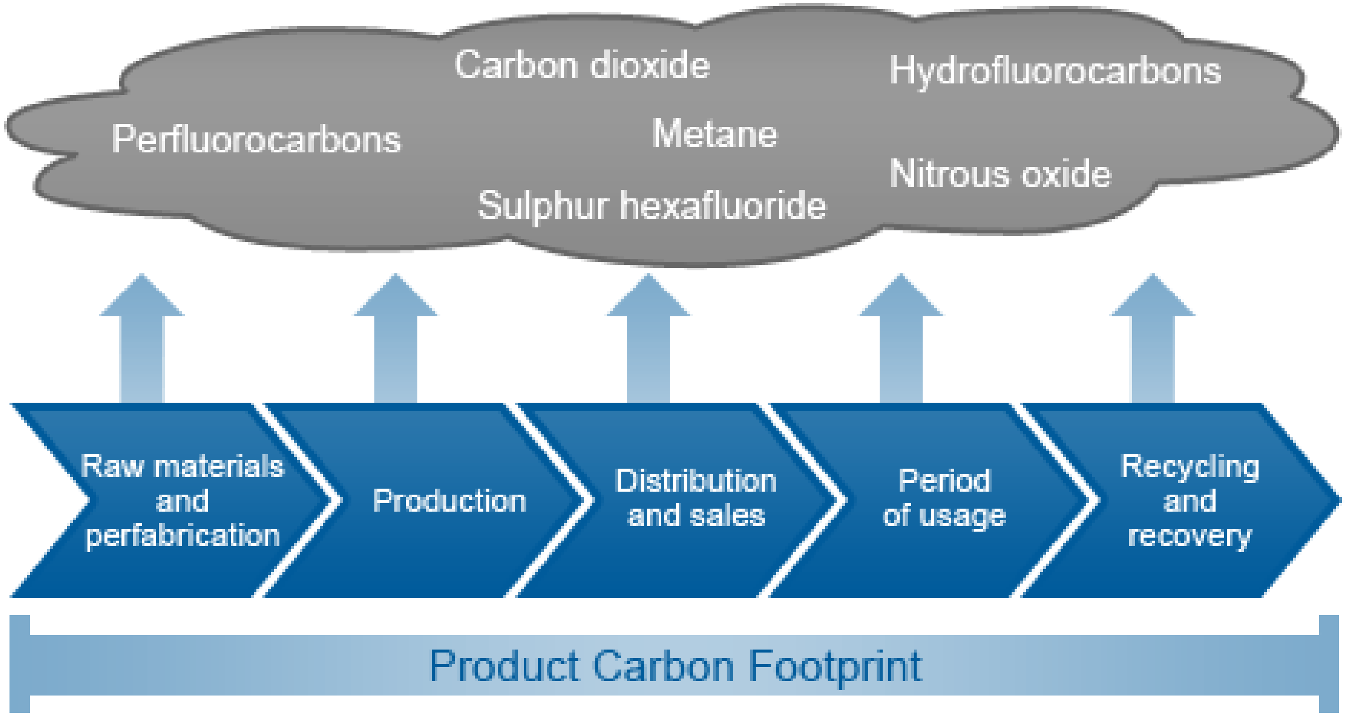
• the primary footprint (shown by the green slices of the pie chart, *direct emissions of carbon dioxide*)

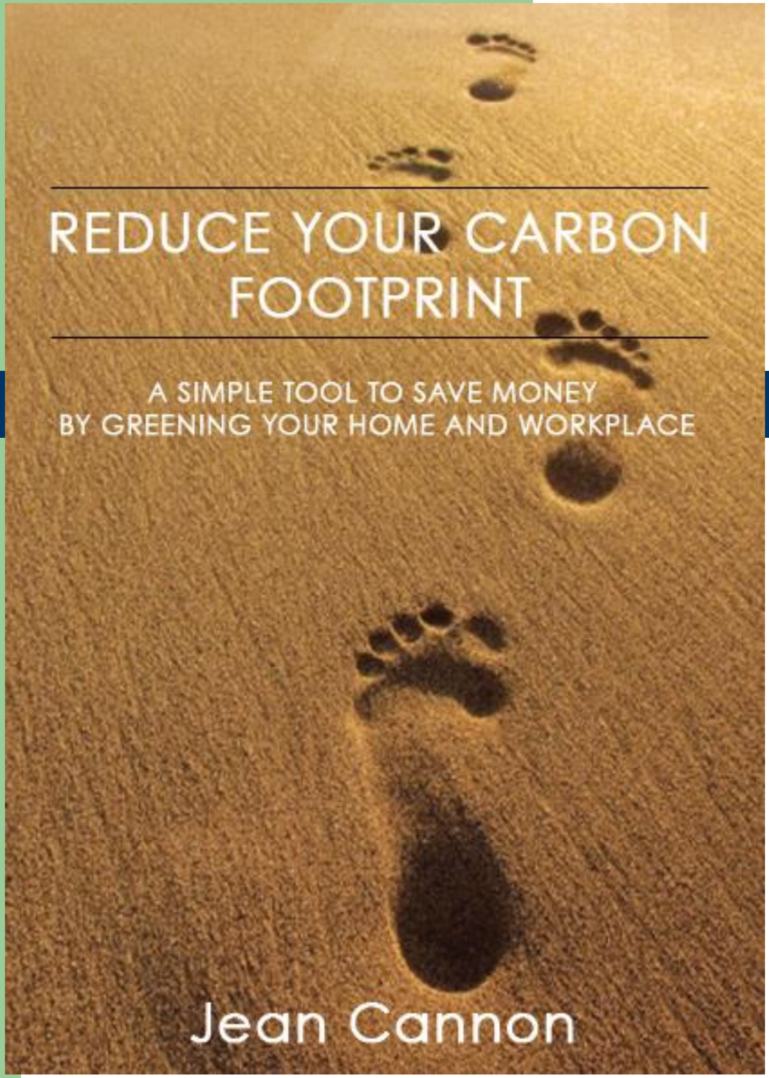
and

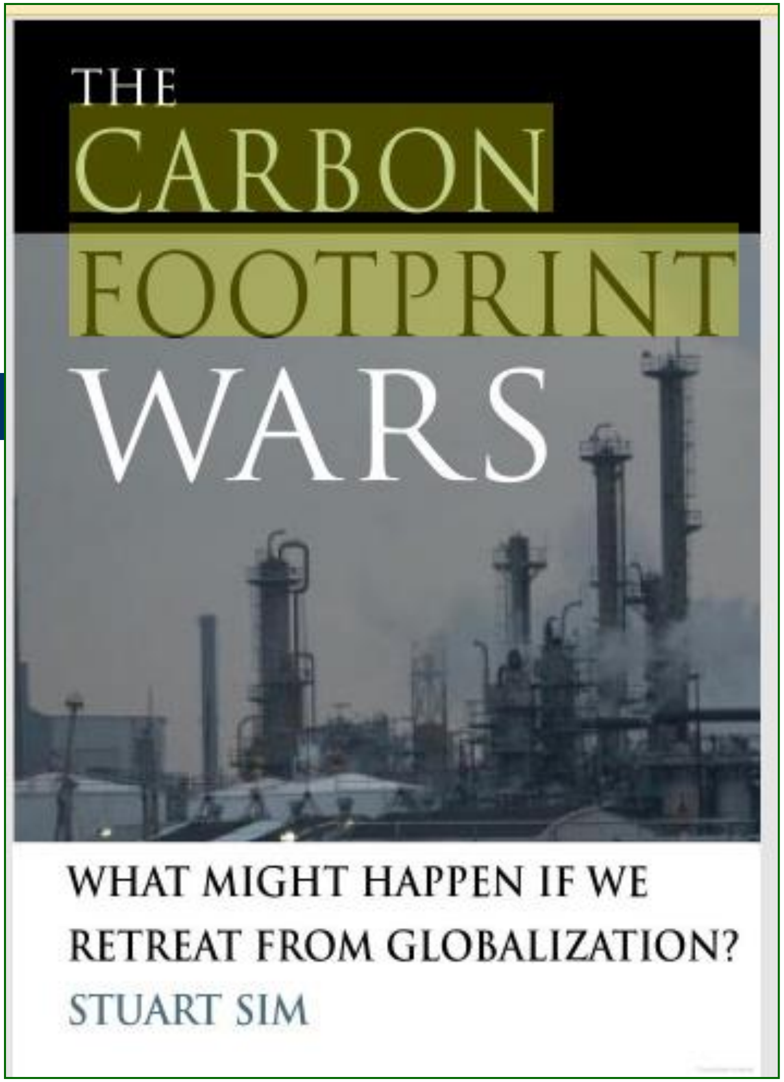
• the secondary footprint (shown as the yellow slices, *indirect emissions of carbon dioxide*).

1. The **primary footprint** is a measure of our direct emissions of CO_2 from the burning of fossil fuels including domestic energy consumption and transportation (e.g. car and plane), in a given time frame. We have direct control of these.

2. The **secondary footprint** is a measure of the indirect CO_2 emissions from the whole lifecycle of products we use - those associated with their manufacture and eventual breakdown.




REDUCE YOUR CARBON FOOTPRINT
A SIMPLE TOOL TO SAVE MONEY BY GREENING YOUR HOME AND WORKPLACE
Jean Cannon


THE CARBON FOOTPRINT WARS
WHAT MIGHT HAPPEN IF WE RETREAT FROM GLOBALIZATION?
STUART SIM

Water Footprint

The **water footprint is an indicator of water use** that looks at both **direct and indirect water use of a consumer or producer.**

The water footprint of an individual, community or business **is defined as the total volume of freshwater that is used to produce the goods and services consumed by the individual or community or produced by the business.**

The ‘water footprint’ **is a measure of human’s appropriation of freshwater resources.**

Freshwater appropriation is measured in terms of water volumes consumed (evaporated or incorporated into a product) or polluted per unit of time.

A water footprint has three components: green, **blue** and **grey.**

The water footprint is a geographically explicit indicator, showing not only volumes of water consumption and pollution, but also the locations.

Water Footprint

The blue water footprint

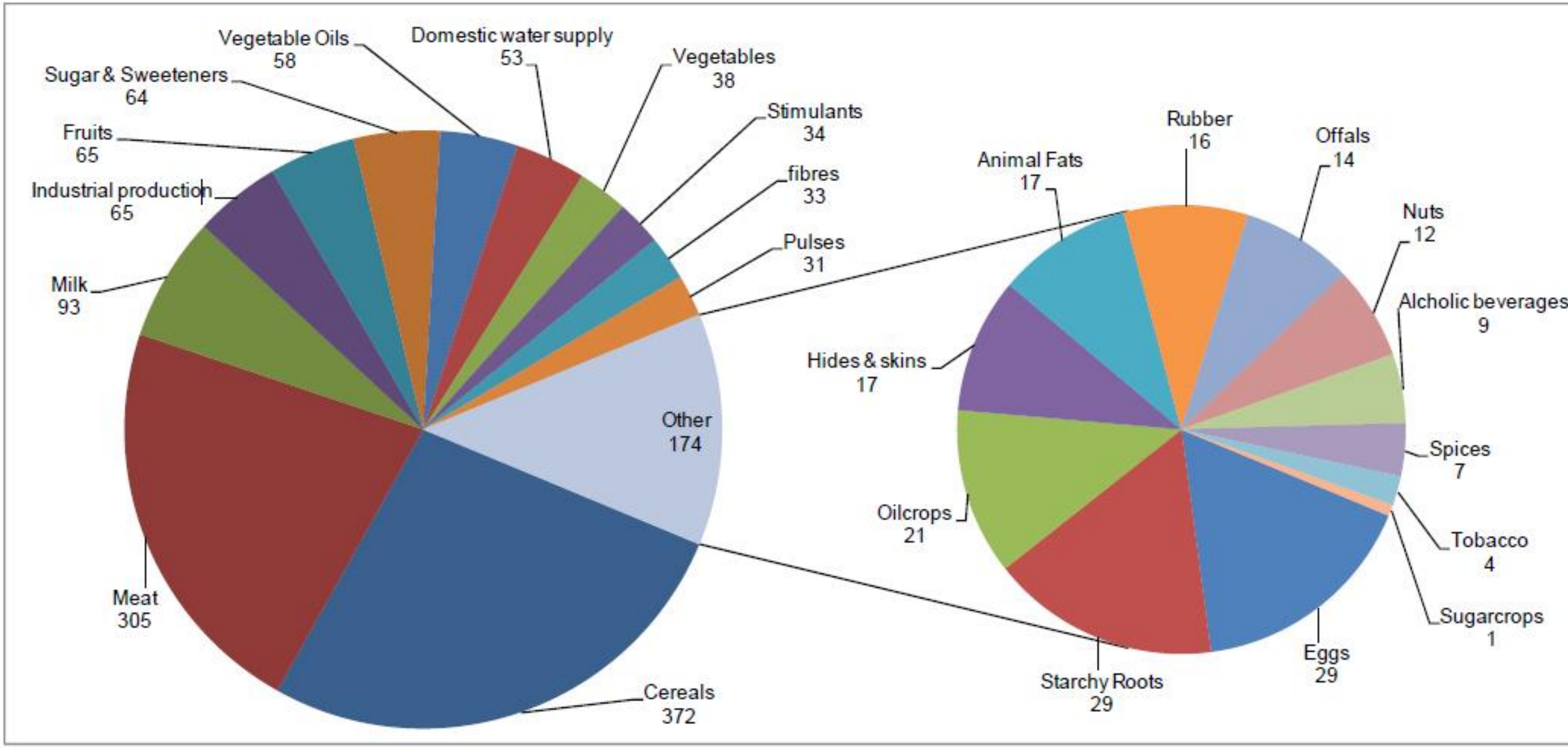
refers to consumption of blue water resources (**surface and ground water**).

The green water footprint

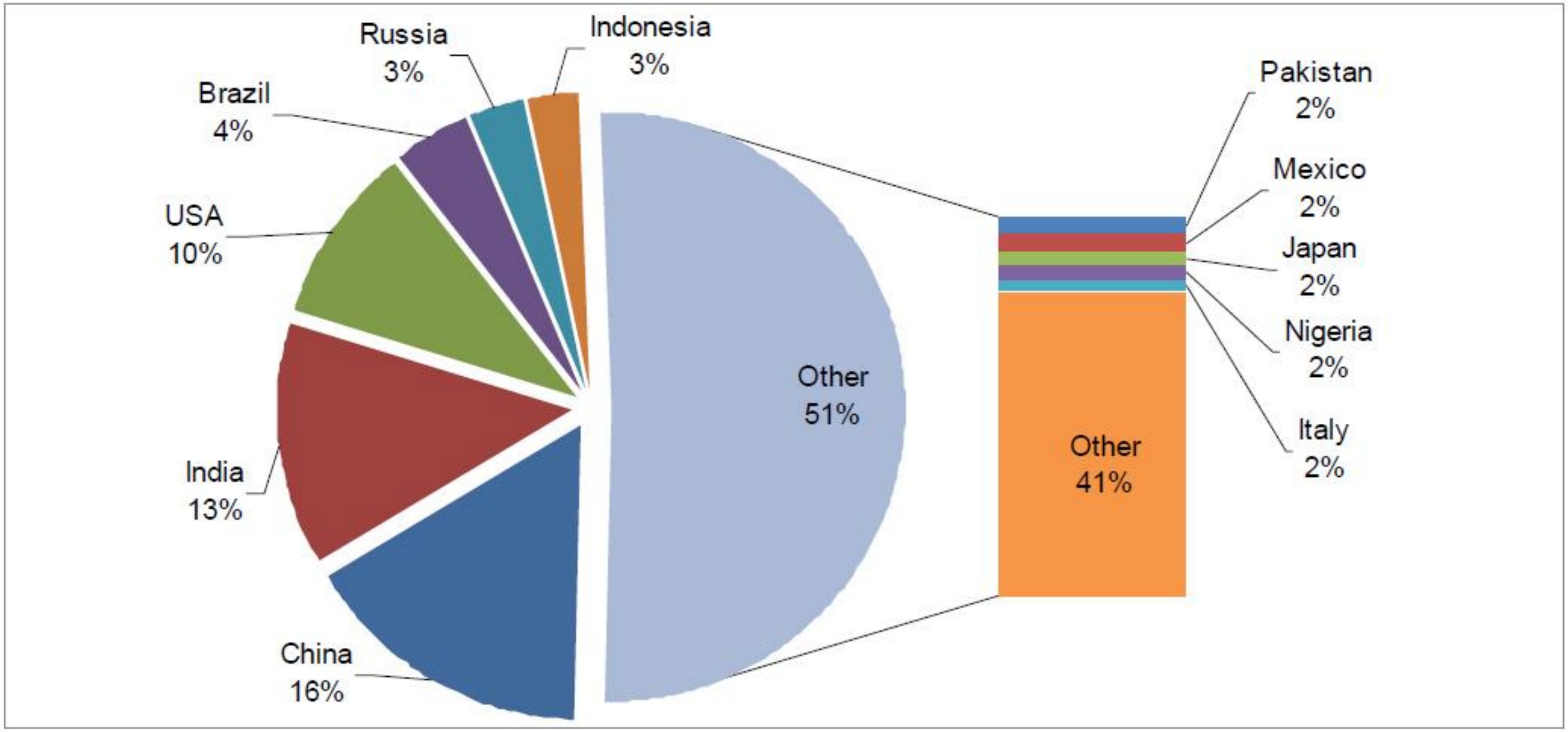
is the volume of green water (**rainwater)** consumed, which is particularly relevant in crop production.

The grey water footprint

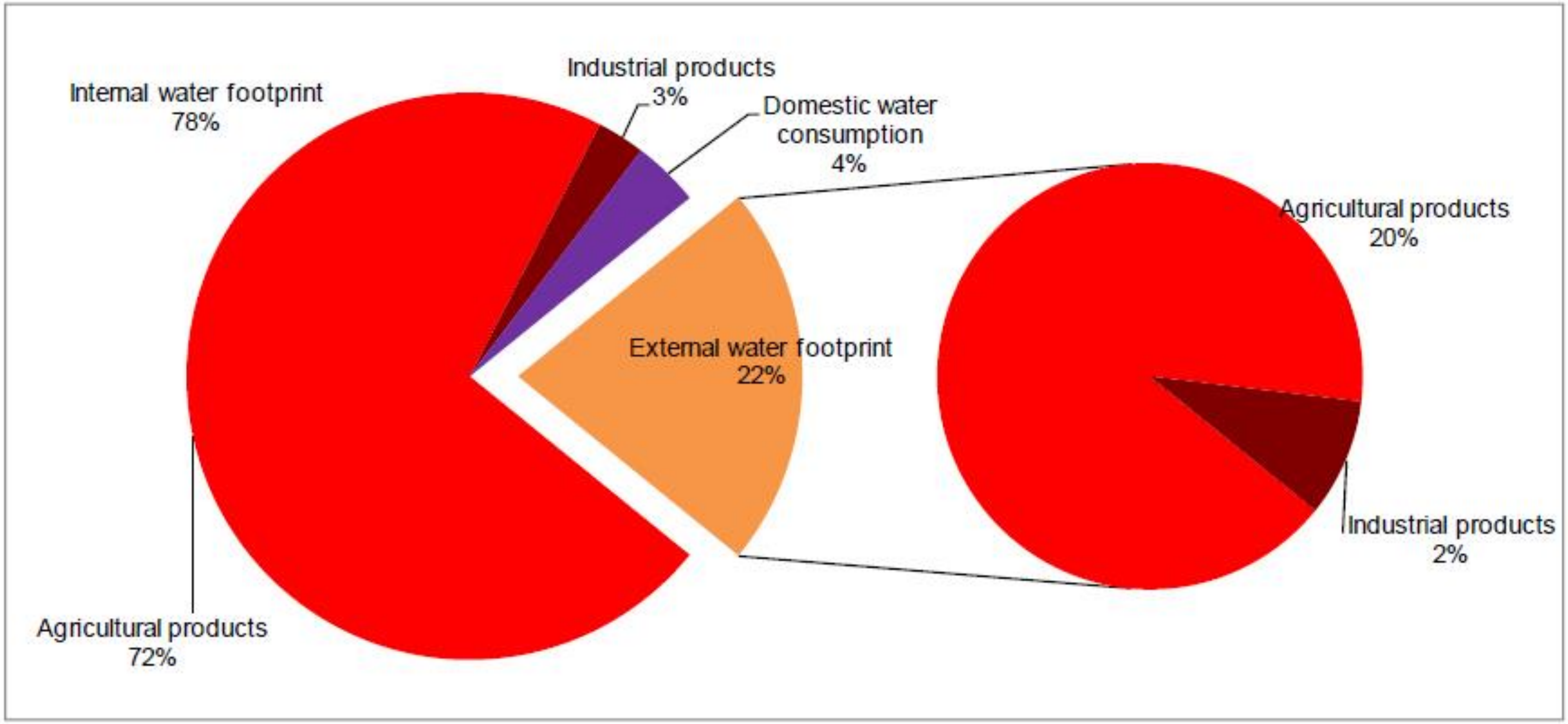
is an indicator of **the degree of freshwater pollution** and is defined as **the volume of freshwater that is required to assimilate the load of pollutants based on existing ambient water quality standards.**



Contribution of different product categories to the global water footprint of consumption (in m3/yr/cap).



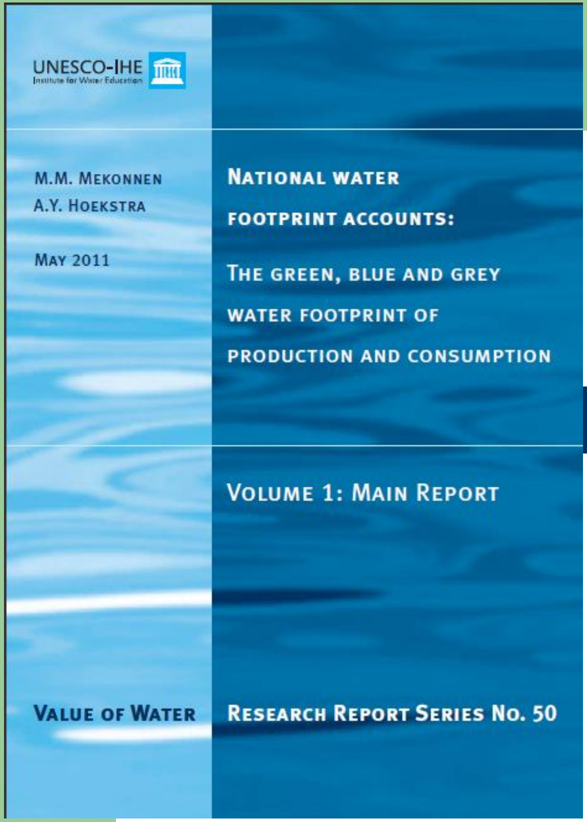
Contribution of different countries to the global water footprint of consumption.

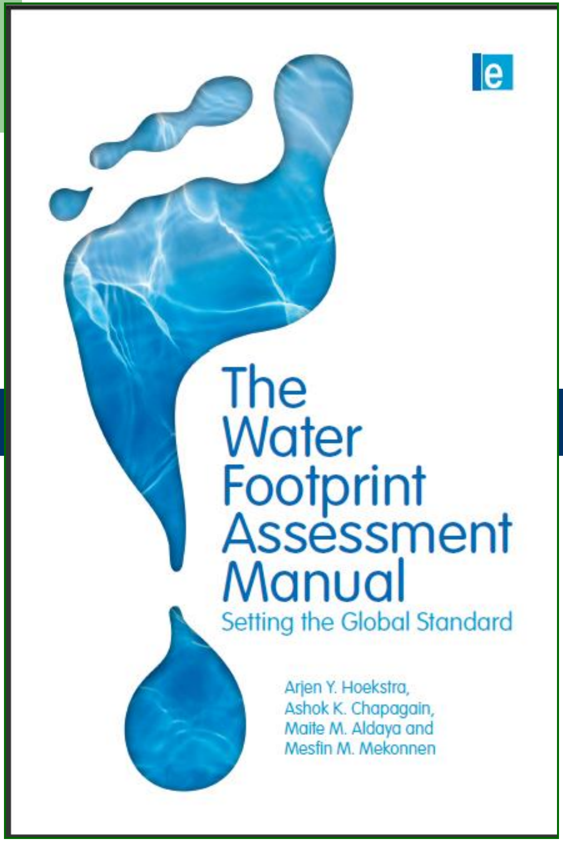


Contribution of different consumption categories to the global water footprint, split into internal and external water footprint.

The internal water footprint is defined as the use of domestic water resources to produce goods and services consumed by the nation's population.
It is the sum of the water footprint within the nation minus the volume of virtual-water export to other nations related to the export of products produced with domestic water resources.

The external water footprint is defined as the volume of water resources used in other nations to produce goods and services consumed by the population in the nation under consideration.
It is equal to the virtual-water import into the nation minus the volume of virtual-water export to other nations as a result of re-export of imported products.





Arjen Y. Hoekstra

Life Cycle Assessment (LCA), a tool in sustainability evaluation

(EN ISO 14040, EN ISO 14044)

ISO = International Organization for Standardization
Ensures that an LCA is completed in a certain way.

"Compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle"

This establishes an environmental profile of the system!

WHAT CAN BE DONE WITH LCA?

1. Product or project development and improvement
2. Strategic planning
3. Public policy making
4. Marketing and eco-declarations

USEPA

LCA: to examine product environmental impacts over their entire life cycle, from raw materials extraction to manufacturing, use, & disposal.

What Makes Up LCA

- **Goal & Scope Definition**

  What is the purpose of the LCA and who is the audience?

- **Inventory Analysis (LCI)**

1. What is the function & functional unit?
2. Where are the boundaries?
3. What data do you need?
4. What assumptions are you making?
5. Are there any limitations?

- **Impact Assessment (LCIA)**

  What are the environmental, social, and economic affects?

- **Interpretation**

  Ways to reduce environmental impacts.

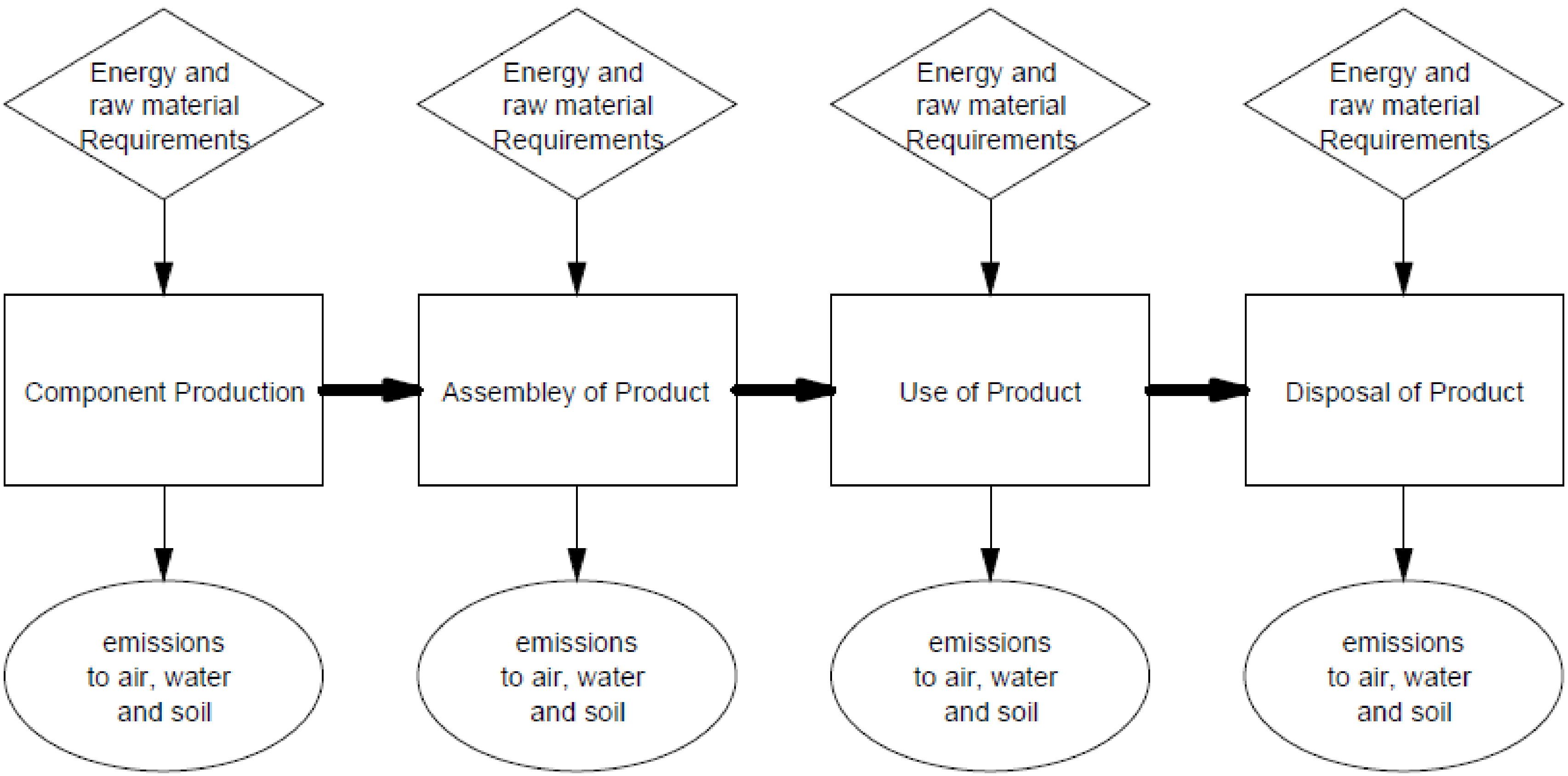
  What conclusions can you draw from the study?

  What recommendations can be made?

An Effective Life Cycle Assessment

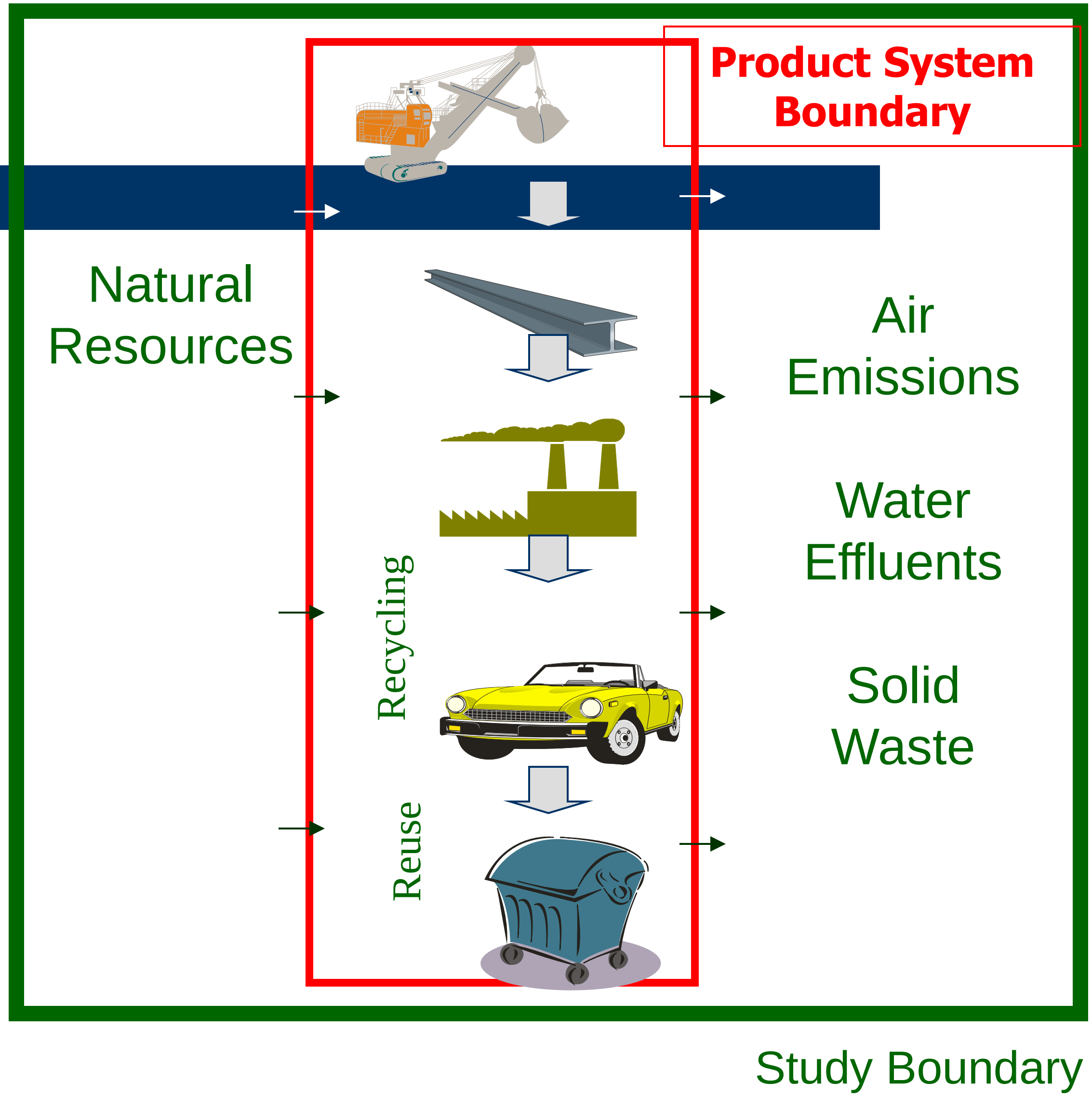
- Examines system-wide effects (cradle-to-grave)
- Analyzes multi-media (air, water, waste, etc.)
- Analyzes multi-attributes (all impacts)
- Helps identify *trade-offs* among alternatives
- Identifies opportunities for *improvement*
- Supports environmental *decision making*
- Provides the cornerstone of Sustainability

What's considered in an LCA?



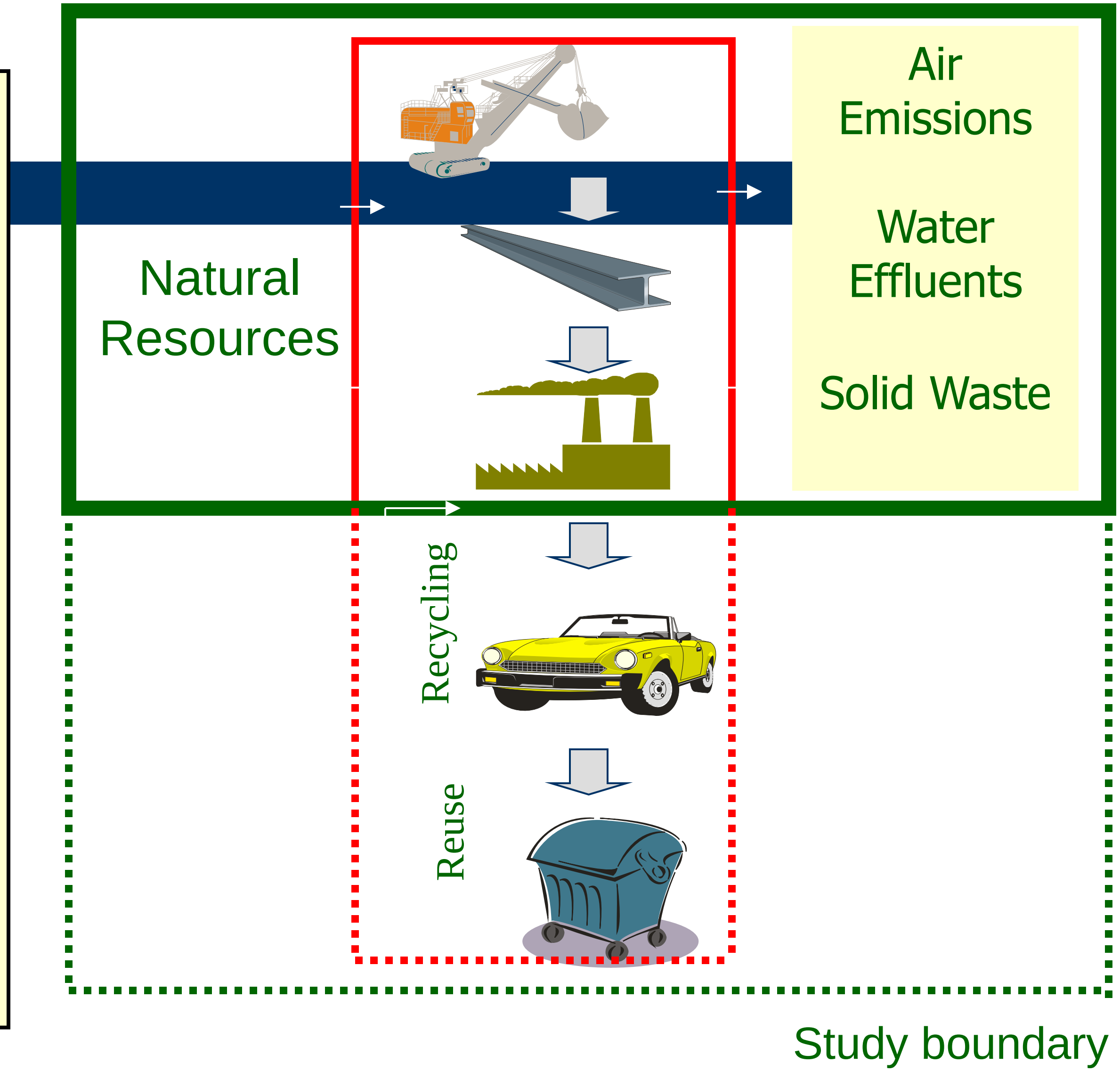
Life Cycle Stages

- Raw Material Acquisition
- Material Processing
- Production
- Use and Maintenance
- End-of-Life



Cradle-to-gate boundaries – excluding downstream activities past product manufacture – can be called an LCA **BUT** claims must relate to what was studied and not be overstated.

Such studies are helpful in improving the product supply chain, but may miss important impacts that occur at end of life.



ISO Standards for LCA

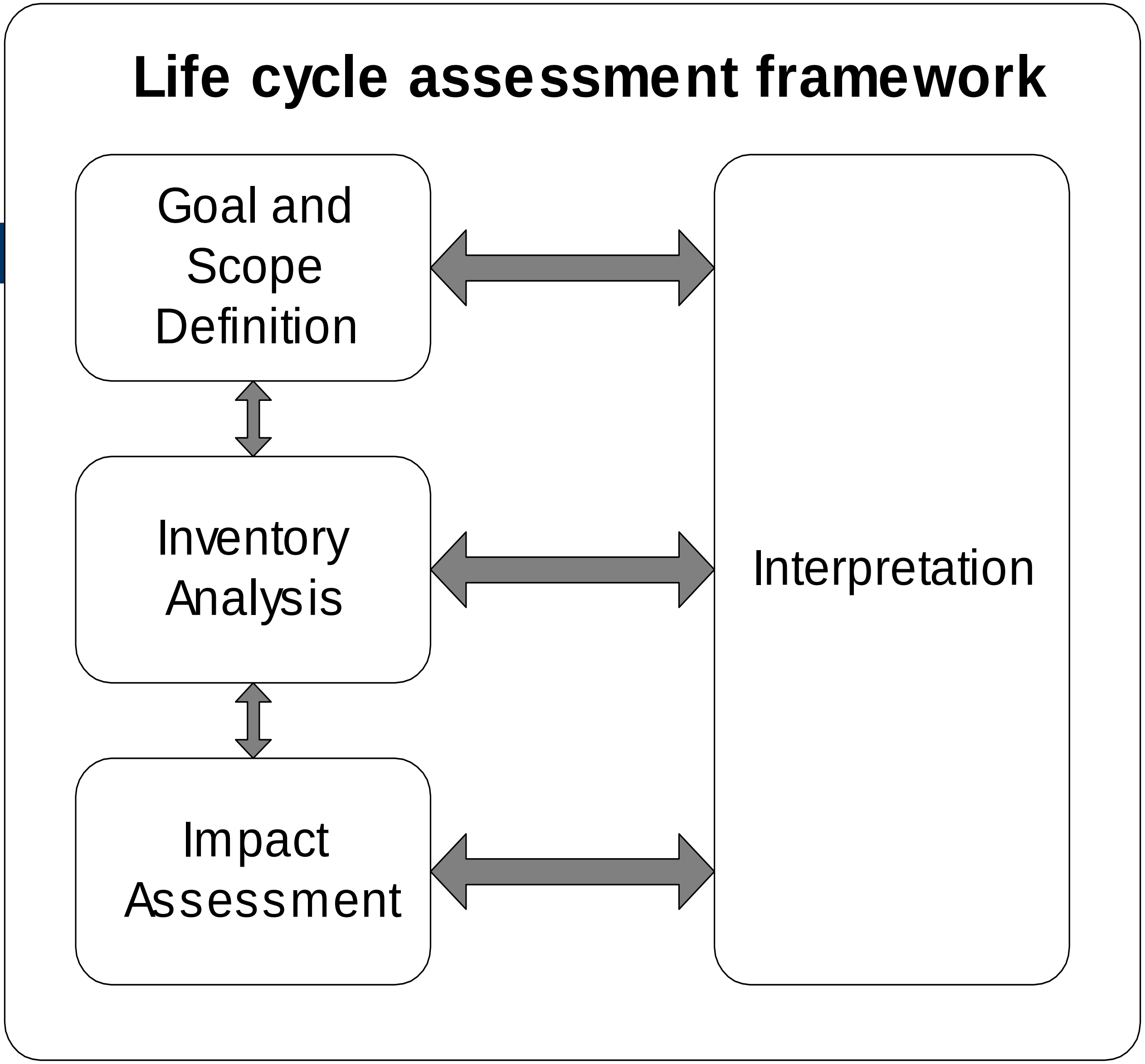
ISO provides a standardized methodology for conducting multi-media, cradle-to-grave environmental assessments:

ISO 14040 “Life Cycle Assessment – Principles and Framework” 1997

ISO 14044 “Life Cycle Assessment – Requirements and Guidelines” 2006

* ISO – International Standards Organization

ISO 14040

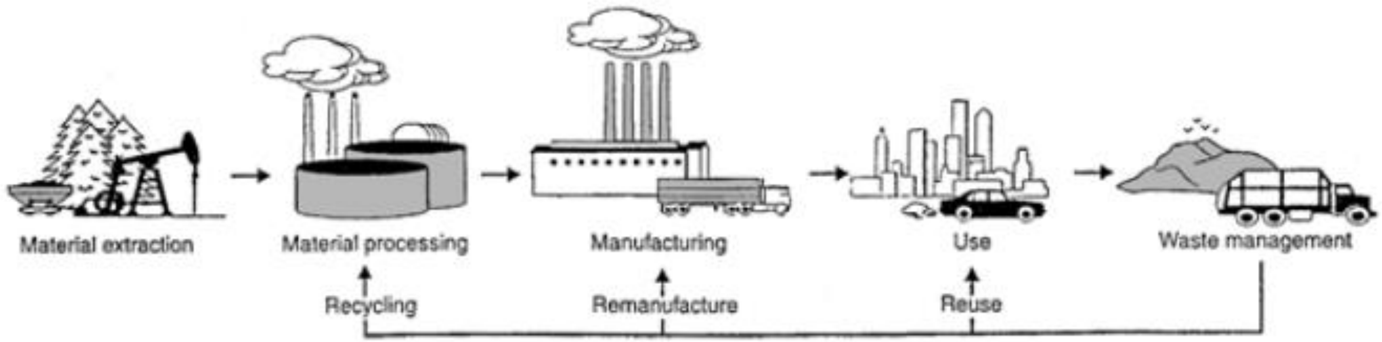

Life cycle assessment framework
Goal and Scope Definition
Inventory Analysis
Impact Assessment
Interpretation

Life Cycle Impact Assessment
Indicators of Potential Impact

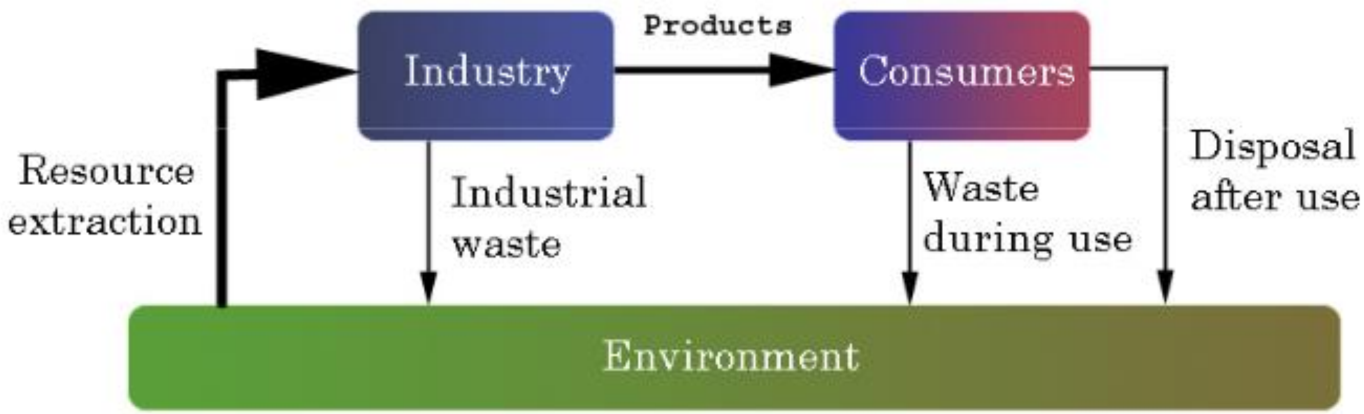
Impact Category Measurement	Indicator
• Global Warming	kg CO_2 equivalents
• Ozone Depletion	CFC-11 equivalents
• Acidification	kg SO_2 equivalents
• Eutrophication	kg PO_4^{3-} equivalents
• Smog Formation	kg Ethene equivalents
• Human Toxicity	HTx equivalents
• Eco-toxicity	ETx equivalents
• Waste	kg Waste
• Resource Use	kg Scarce Resources
• Water	m^3 Water
• Land Use	being developed

A typical industrial system

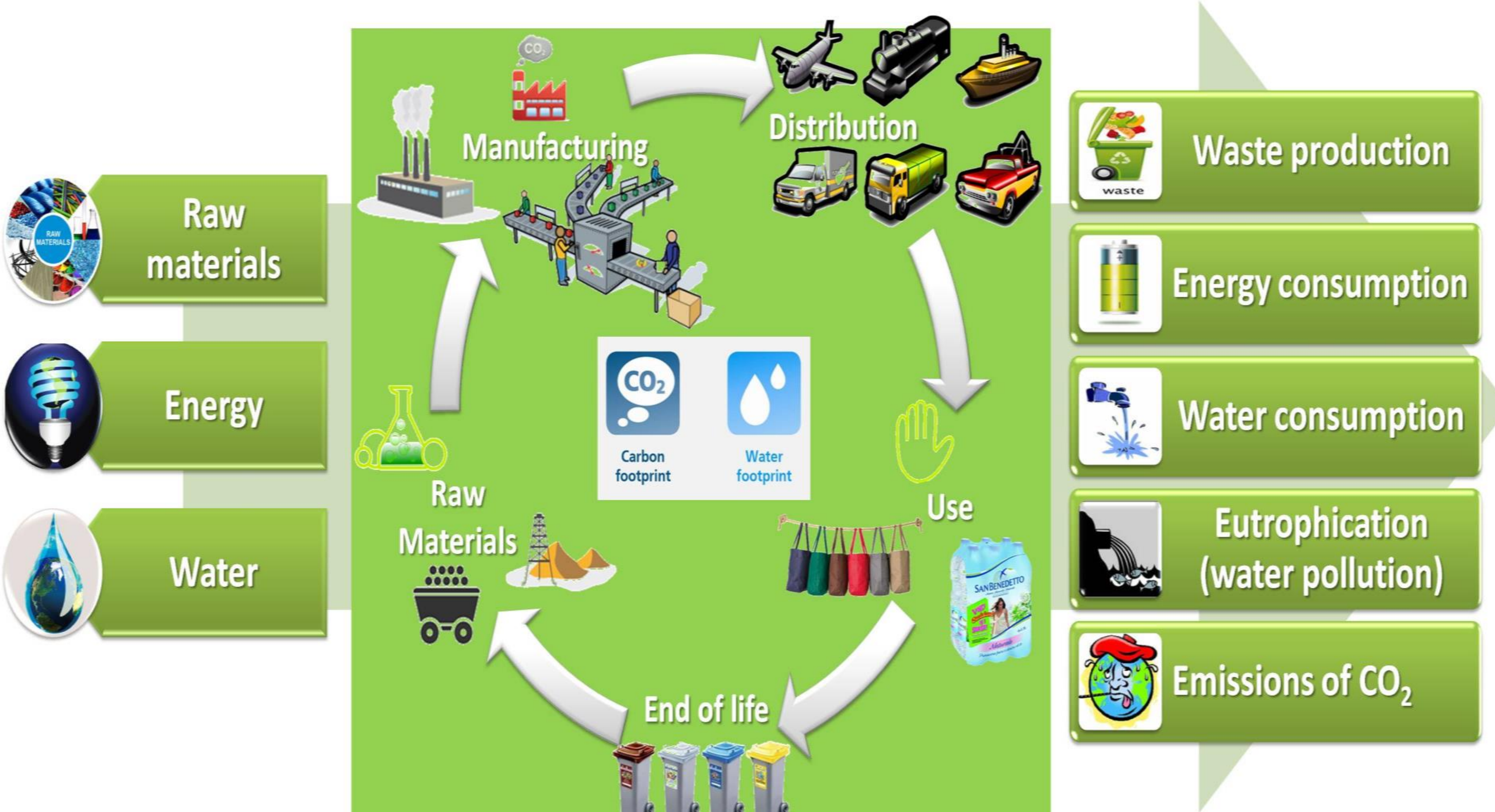
Example



Generic view



… mostly a one-way, open system !


Raw materials
Energy
Water
Manufacturing
Distribution
Use
End of life
Raw Materials
Carbon footprint
Water footprint
Waste production
waste
Energy consumption
Water consumption
Eutrophication (water pollution)
Emissions of CO_2

Technology alone cannot be relied upon to break the link between growing consumption and growing impact on the planet.

Dramatic changes are required to our systems of consumption and of production, with changes to patterns of living in a low-carbon economy.

This will place industry and business systems at the centre of the next industrial revolution.

The industrial system is not just part of the problem it has to be part of the solution.

THE UNSUSTAINABLE CHARACTER OF THE INDUSTRIAL SYSTEM

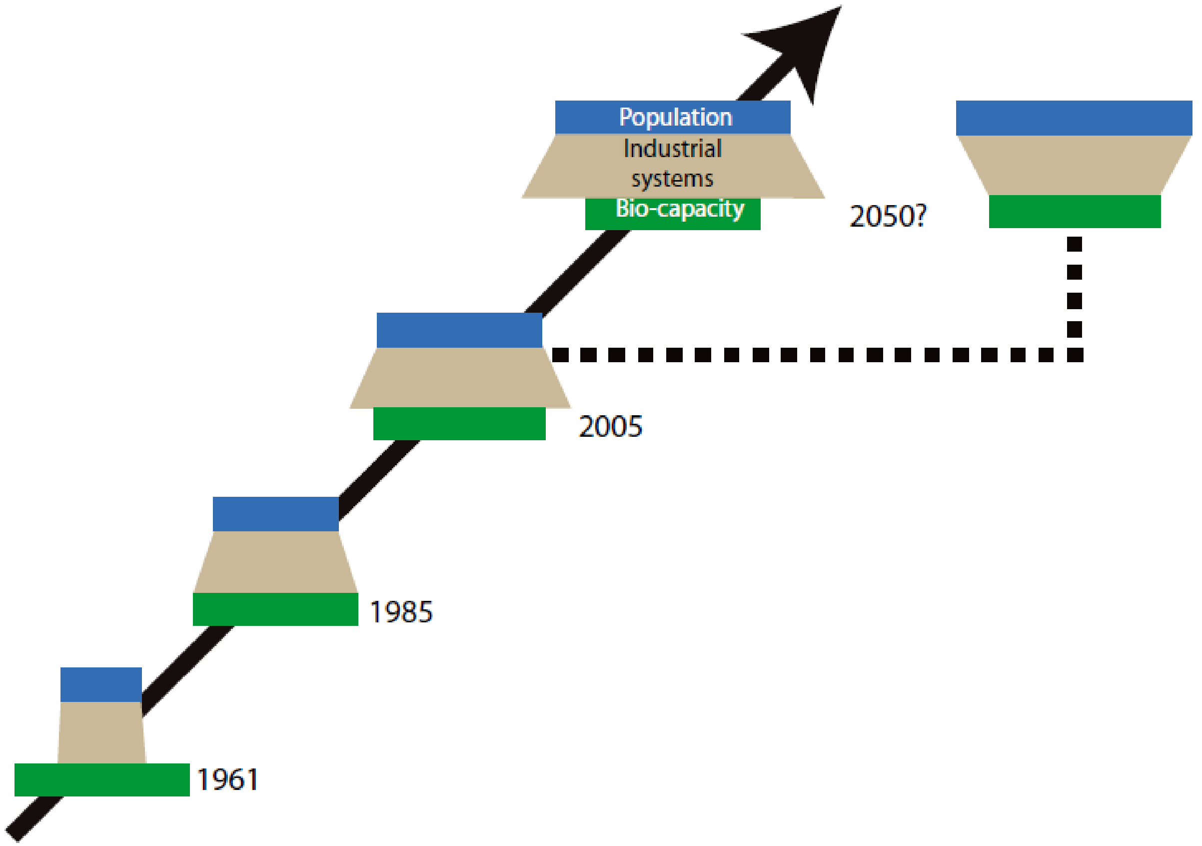
The footprint of the current industrial system

- the current industrial system takes natural capital (mined and grown materials) and turns it into the 'stuff of the world'
- **the efficiency of the total system at converting material into valuable end product is below 10%**, with over 90% of extracted resources failing to reach the customer
- the world is finite, its ecosystem is complex, and we are operating close to the boundary.

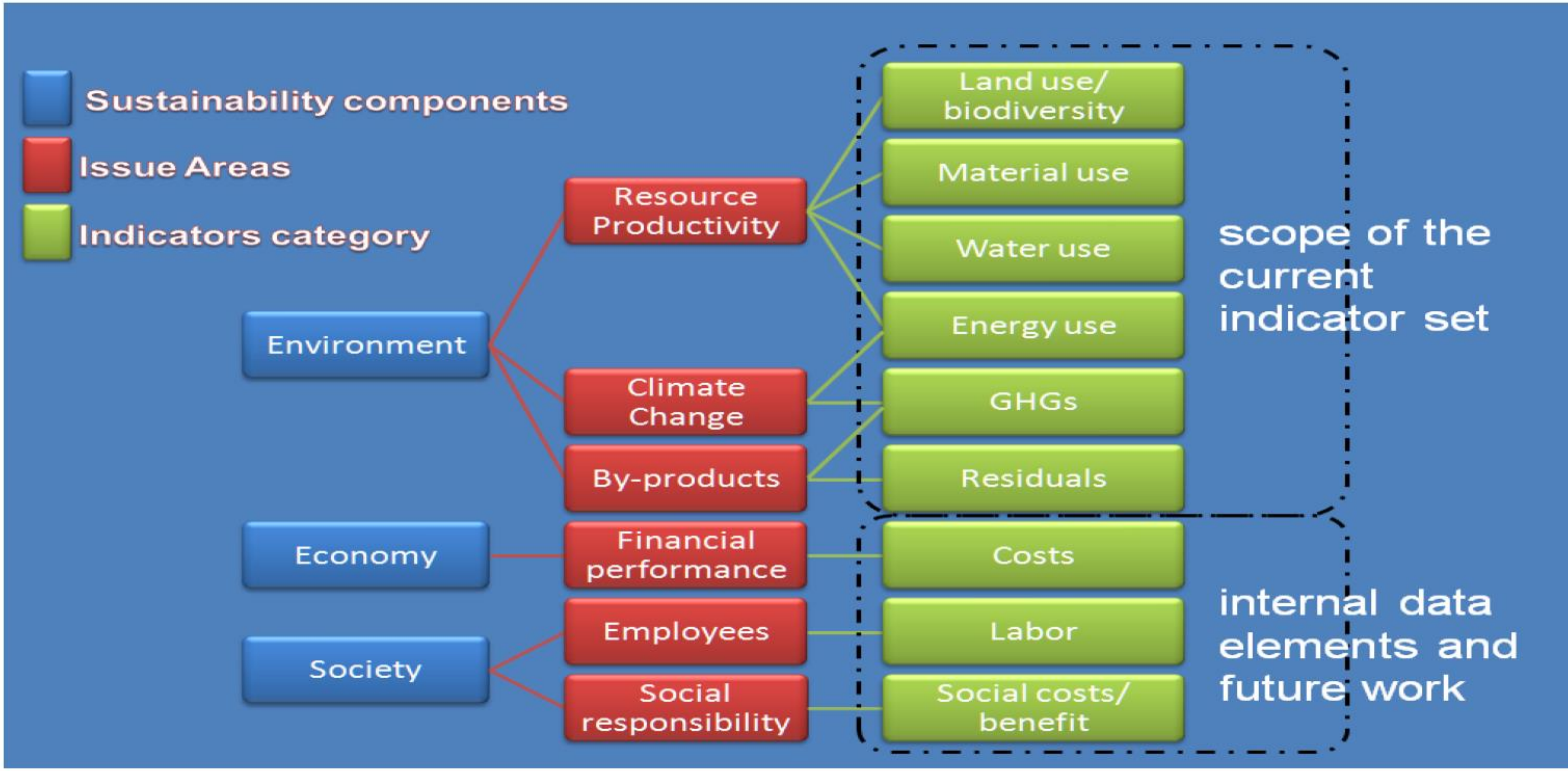
Systems that perform at 10% efficiency, that only extract one use from a preciously extracted material, that use enormous quantities of water and energy are not well-designed systems.

The footprint of the industrial system has expanded several fold in the last 50 years, supporting an improved quality of life for an ever increasing population.

The industrial footprint however now exceeds the globally available bio-capacity .



The footprint of the current industrial system



Framework for initiatives and actions to ensure sustainable production

Source: Michael Bordt, The OECD sustainable manufacturing toolkit, Sustainability and US Competitiveness Summit, October 8, 2009, Directorate of Science, Technology and Industry, OECD, Paris
www.oecd.org/sti/innovation/sustainablemanufacturing

Goals of sustainable industrial production

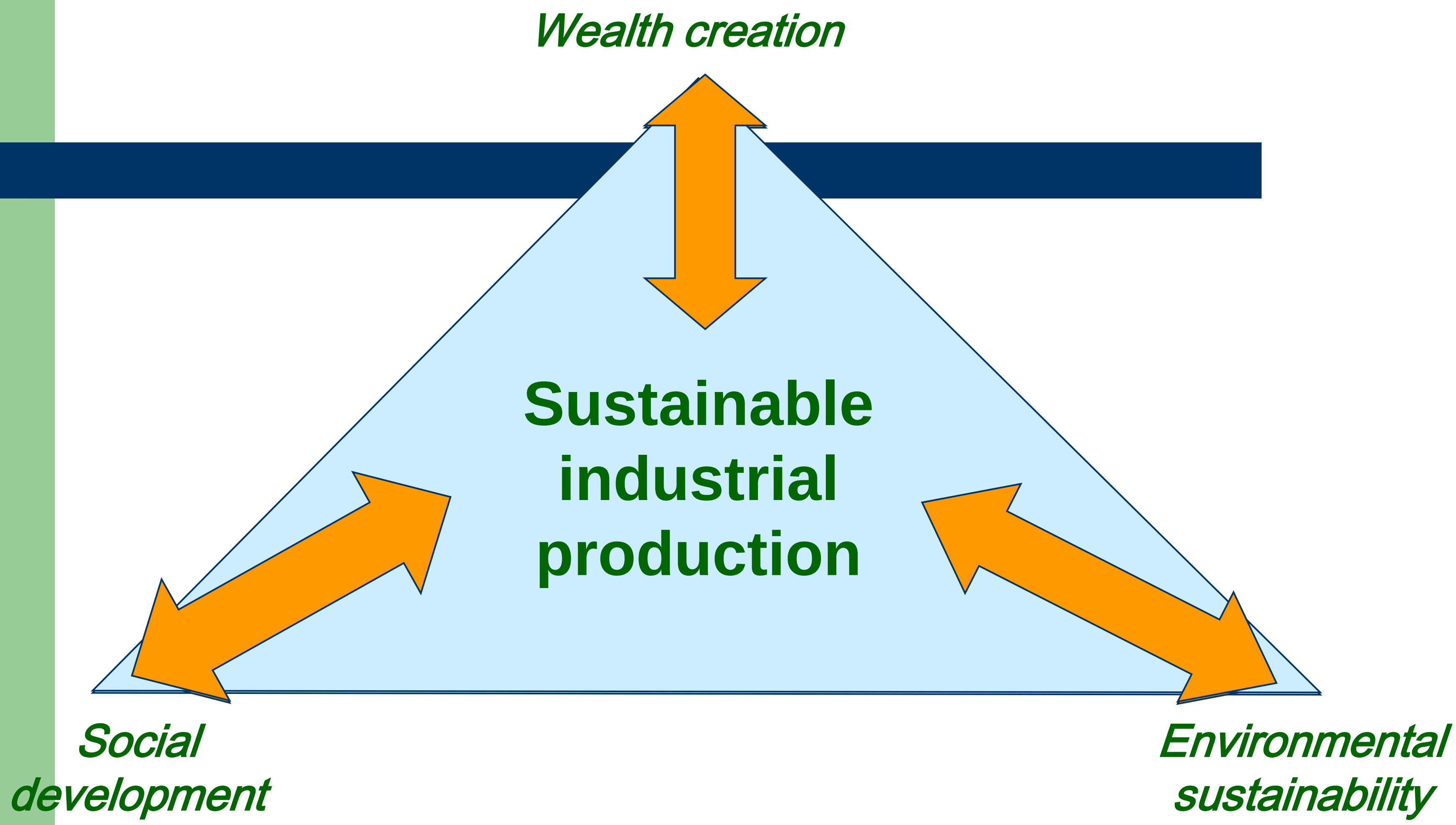
Industrial production is a key area of human activity.

Due to its multi-dimensional importance, it is strongly linked to the three pillars of Sustainable Development:

economic competitiveness,

social importance (employment, quality of life),

environmental impact.


Wealth creation
Sustainable industrial production
Social development
Environmental sustainability

Evolution of environmental issues in industrial systems

1960-70 **pollution**	**1970-80** **limits to growth**	**1980-90** **large systems**	**1990-** **sustainability**

(www.earthportal.org/forum/?cat=28; janne hukkinen; www.solcomhouse.com/nuclear.htm; www.ew.govt.nz/enviroinfo/air/climatechange.htm)

The key sustainable industrial development measures

- Cleaner production
- Environmental and integrated management systems
- Product oriented measures based on life cycle approach
- Sustainability reporting based on performance evaluation

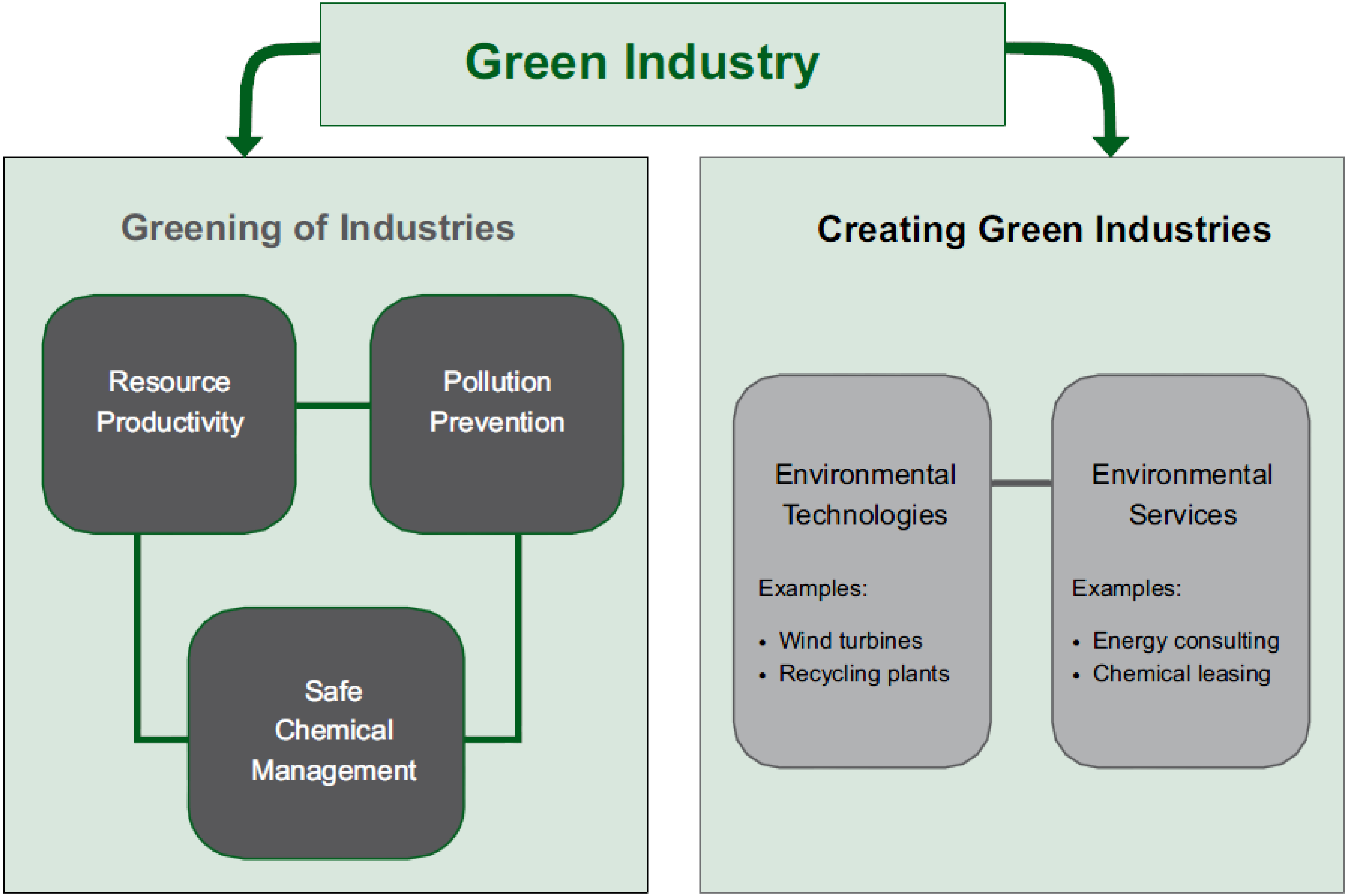
Green Industry

- an important pathway to achieving sustainable industrial development
- by the means of two-pronged strategy

(1) the greening of existing industry

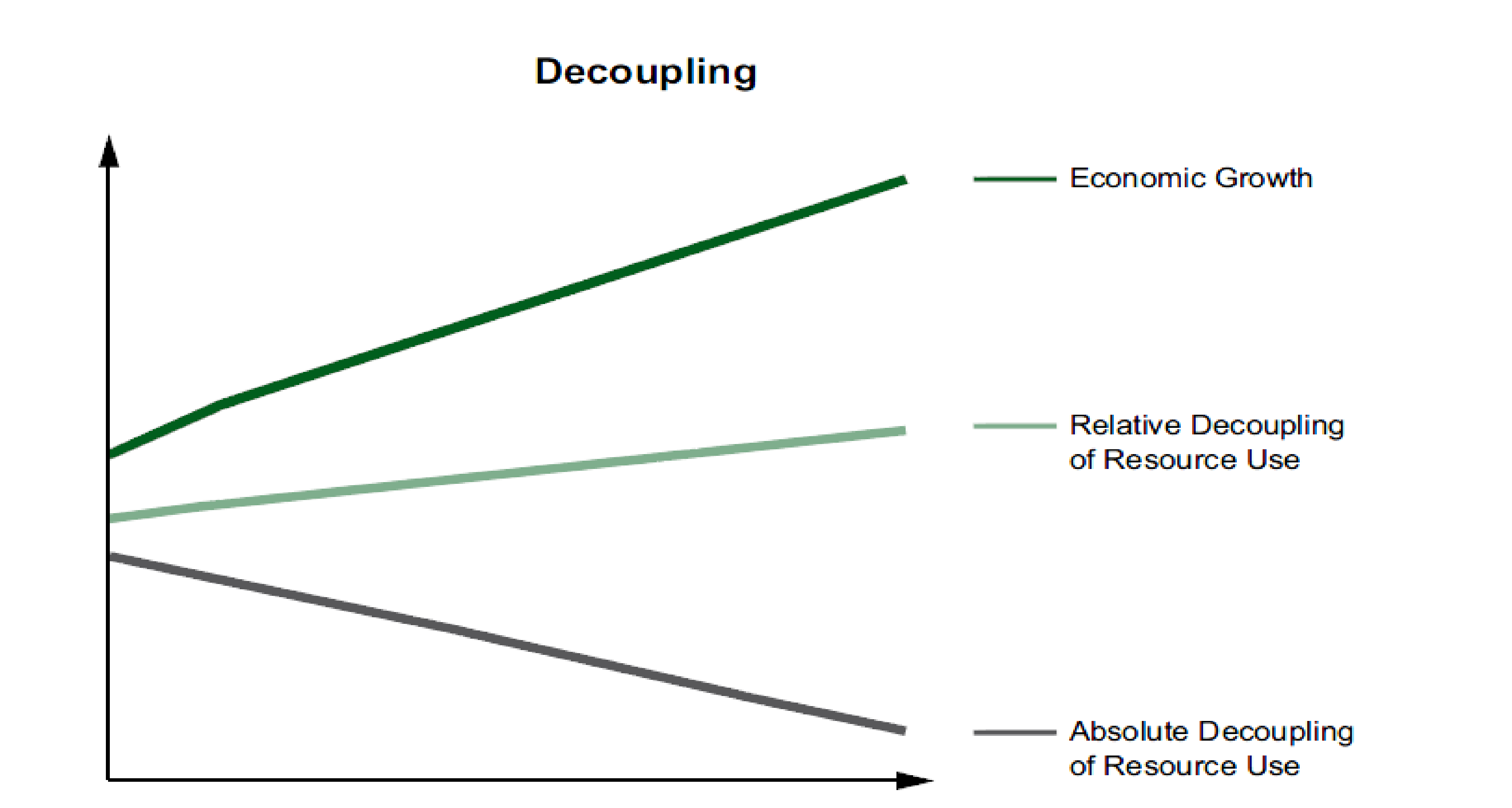
(2) the creation of new “Green industries”

Does not require the ever-growing use of natural resources and pollution for growth and expansion!!


Green Industry
Greening of Industries
Resource Productivity
Pollution Prevention
Safe Chemical Management
Creating Green Industries
Environmental Technologies
Examples:
• Wind turbines
• Recycling plants
Environmental Services
Examples:
• Energy consulting
• Chemical leasing

The Green Industry Challenge:

decoupling economy growth from the use of resources and environmental pressures (pollution)



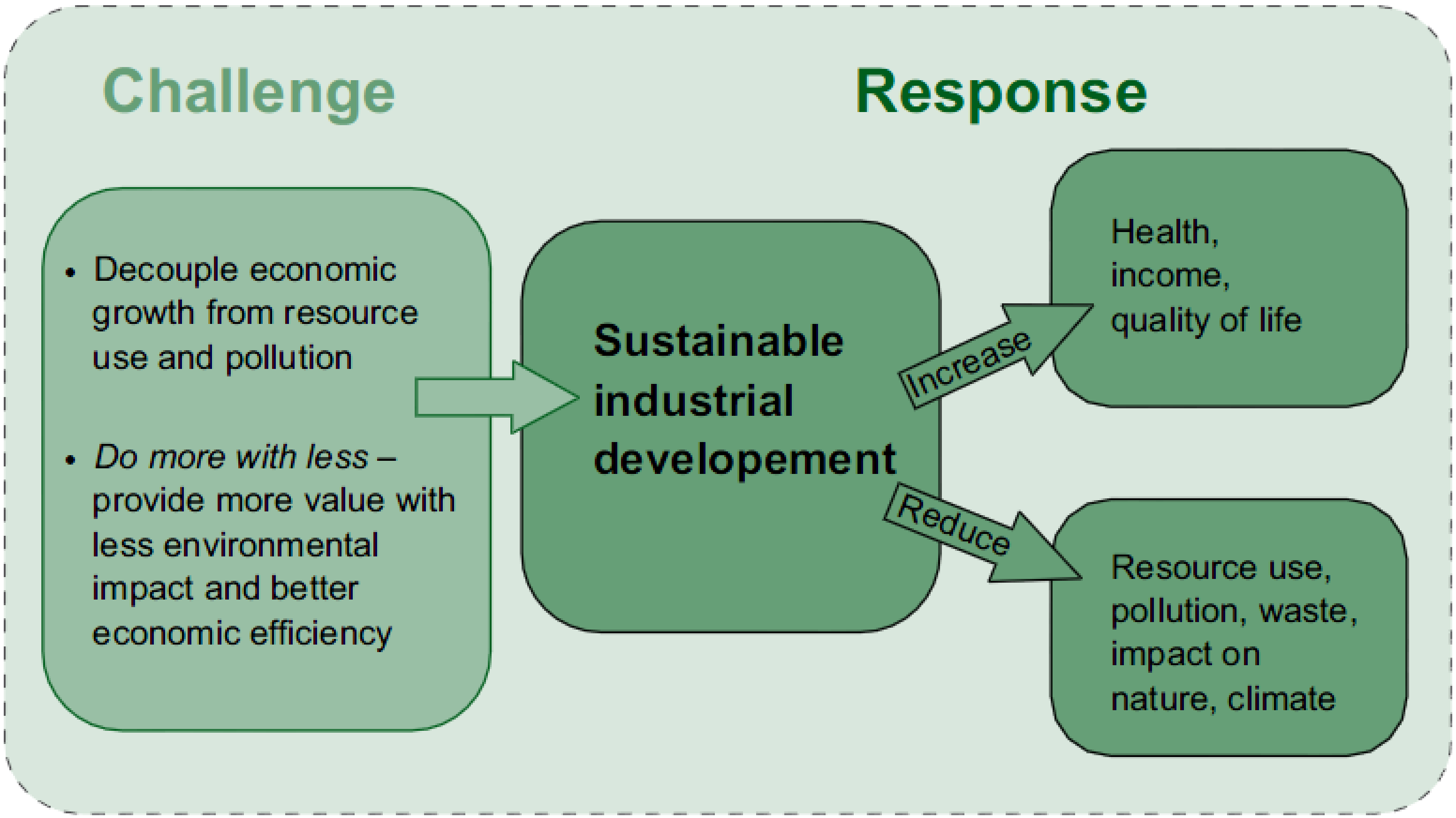
Decoupling . . .

relative: production rises but increases in resource use and pollution do not rise as quickly (gradual increases to resource productivity, increased value creation, and shifts toward less resource-intensive economic activities)

absolute: production is able to increase while resource use and pollution fall (***green growth***: radical changes in terms of technology, production and consumption systems, and culture)

…. **two facets of decoupling:**

the role of technology and the type of output being produced

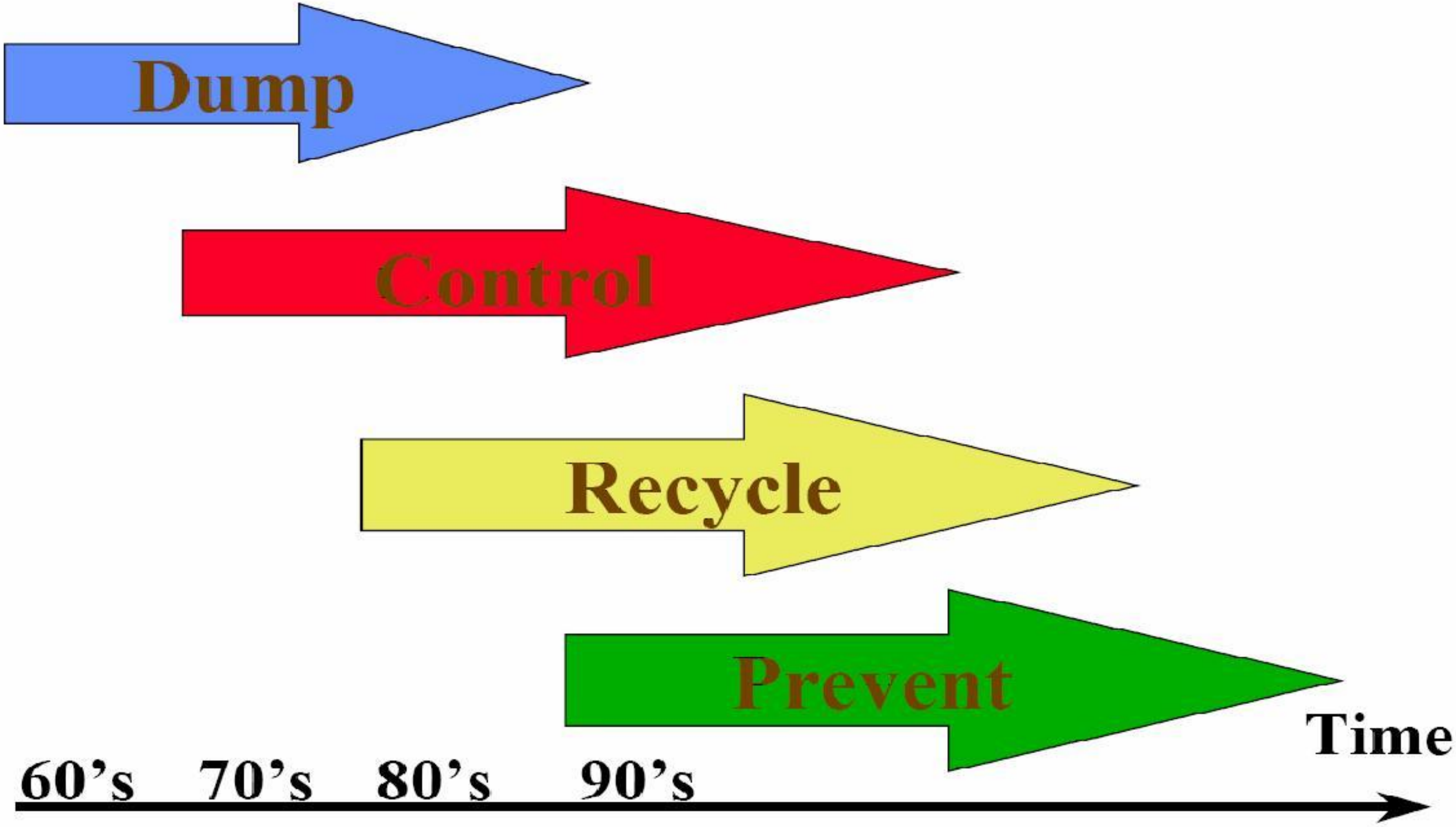


SECTOR	SELECTED INDUSTRIES WITHIN SECTOR
Renewable Energy	Energy generation from solar, wind, geothermal, biomass
Green Building	New construction, retrofitting, weatherization, water recycling, low energy use appliances, stormwater planning
Clean Transportation	Low-carbon fuel R&D, hybrid vehicle development, ride-share, public transit, transit-oriented development
Waste Management	Recycling, municipal waste, materials salvage and reuse, deconstruction, toxics remediation, brownfields clean-up
Land Use	Locally grown food, organic agriculture, carbon sequestration, urban gardening, farmers markets
Green Investment	Carbon trading, green banking, clean-tech investments, green investment services

Green Economy—Six Leading Sectors

Over the past decades, the industrialized nations have responded to pollution and environmental degradation in five characteristic ways:

1. By **not recognizing—or ignoring—the problem** of environmental pollution;
2. By **diluting or dispersing pollution**, so that its effects are less harmful or apparent;
3. By **seeking to control pollution and wastes** (the end-of-pipe or pollution control approach);
4. By **trying to develop and improve environmental technology** that will help close the loops in material flow streams during the production process, and facilitate reuse and recycling
5. By **implementing Cleaner Production** through the **prevention of pollution and waste generation at source.**



Short history of responses to pollution problem

Traditional pollution control solutions proved less effective than they initially appeared, and **there came a point beyond which further requirements became prohibitively expensive**.

End-of-pipe technology simply **shifted waste or pollutants from one environmental medium to another**, as in the case of air and water pollution control devices that produced concentrated hazardous waste for leaking landfills.

All in all, pollution control approaches of the 1970s and 1980s were no longer sufficient, and a **new more flexible approach**, had to be put in place that allowed creative solutions to be developed jointly by industry, government and environmentalists.

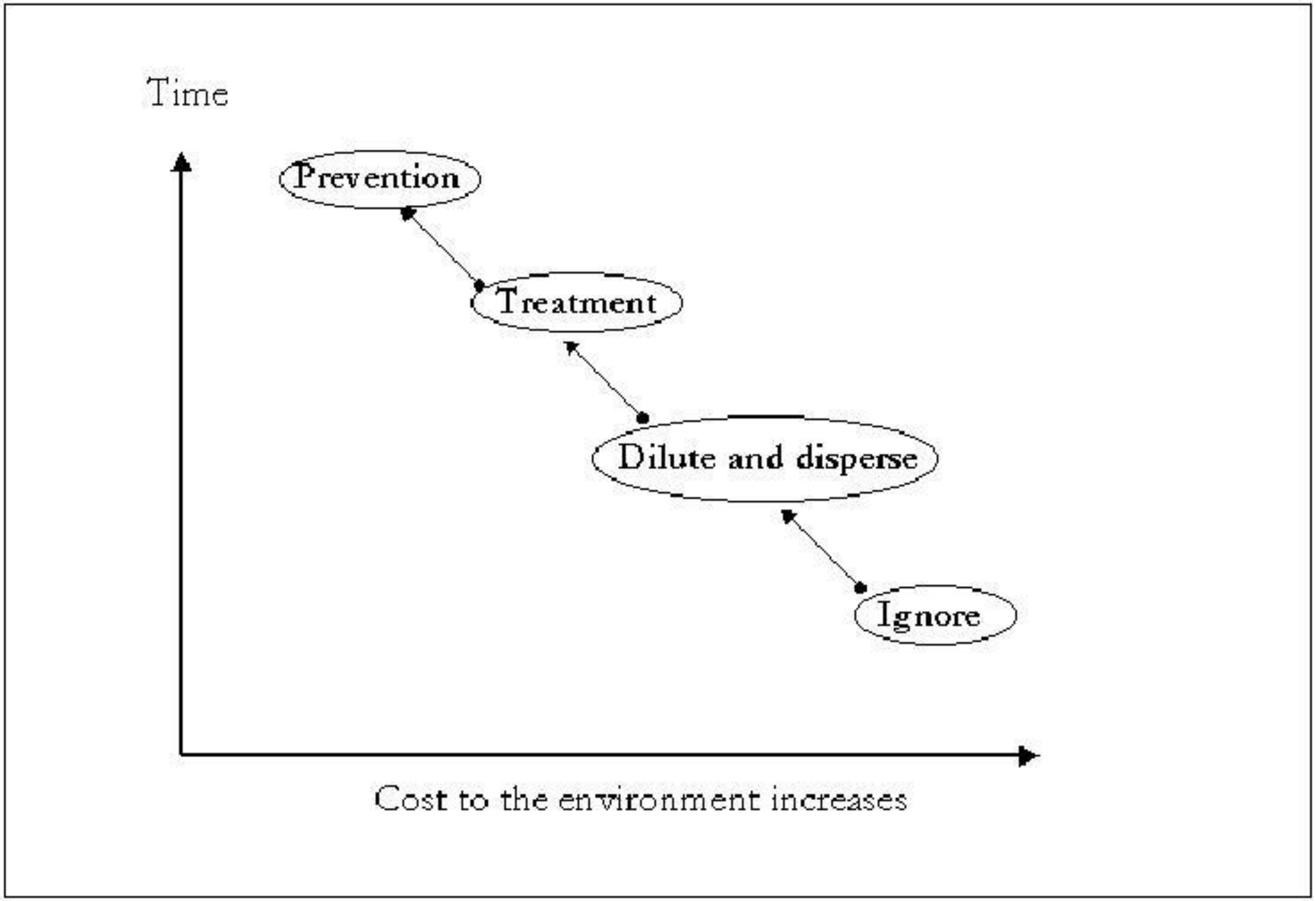
In the mid-eighties, two new methods, **the recycling of waste and energy recovery** came into common use, alongside the traditional pollution control approach.

By the end of the decade, the **common-sense concepts of resource conservation, risk reduction and pollution prevention** became widely accepted by both governments and industry.

Since the beginning of the nineties, the concepts of **Cleaner Production (CP), Pollution Prevention (P2), Waste Minimization and Eco-efficiency** have been gradually gaining popularity and acceptance.

The sequence of ‘ignore, dilute, control, improve processing and prevent generation’ culminated in an activity that combines maximum positive effects on the environment with economic savings both for industry and society.

All these responses are associated with various costs for environmental protection.



Costs for environmental protection associated to various responses to pollution

Evolution of environmental issues

	1960-70	1970-80	1980-90	1990-
dominant environ-mental discourse	***pollution***, carson	limited ***natural resources***, club of rome	complex ***techno-logical systems***, nuclear power	***sustainable development***, brundtland
institution	***environmental officials*** regulate pollution	environmental concern to ***sectoral organi-zations***	***self-regulation*** of complex systems	complex ***institu-tional innovation*** with mix of instruments
techno-logy	***end-of-the-pipe***	***process-specific end-of-the-pipe***	***clean techno-logy*** minimizing material flows	***industrial ecology***

Practices addressing pollution control and prevention, towards sustainable Industrial Production

Pollution control

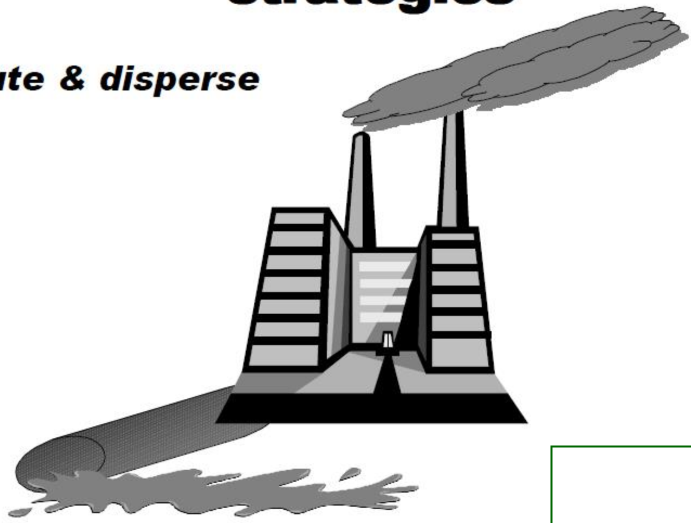
Pollution control refers to the measures taken to manage pollution after it has been generated.

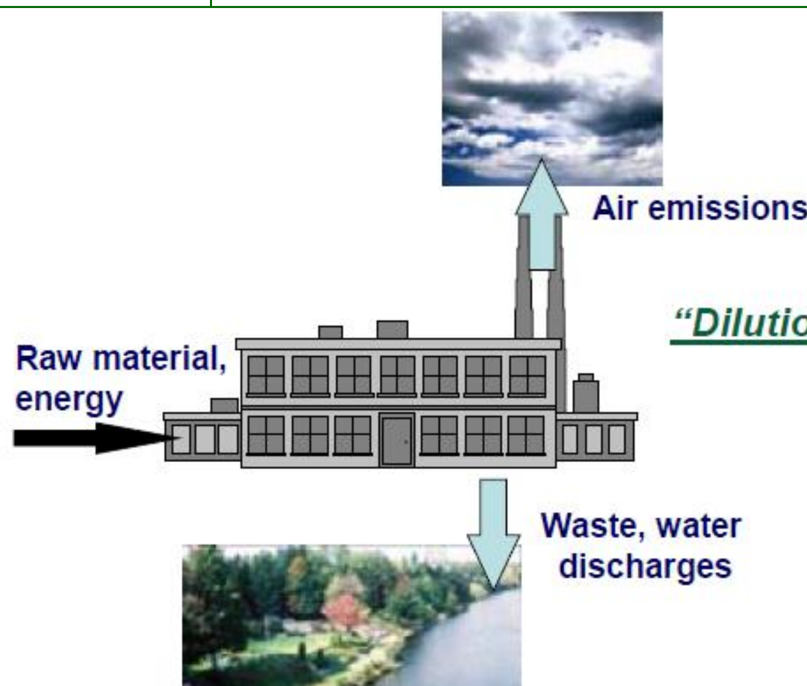
It may include:

- **dilution and dispersion** (passive response)
- **end-of-pipe approaches** (reactive response)

Passive environmental strategies

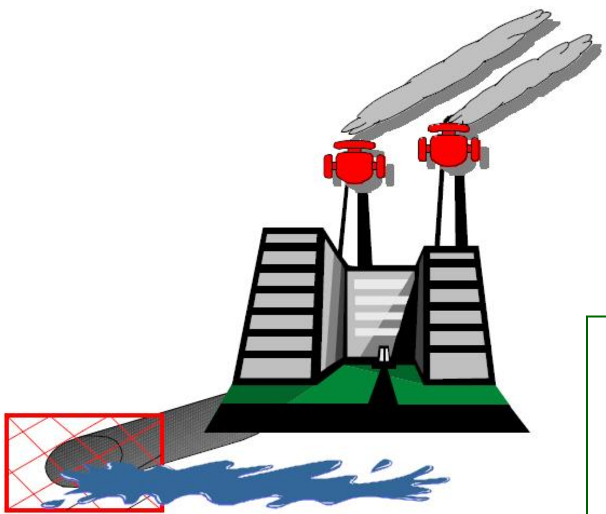
Dilute & disperse

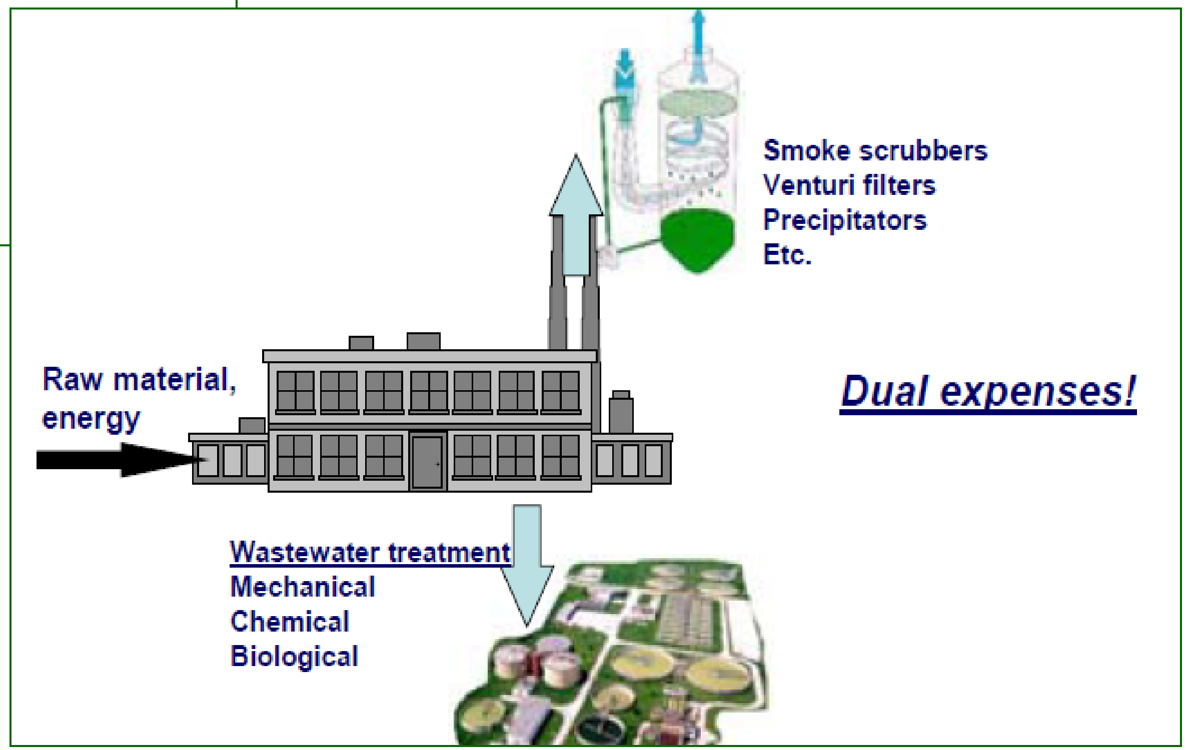




"Dilution as a solution"

Reactive environmental strategies: end-of-pipe approaches





Pollution Prevention/Cleaner production

The concept of Pollution Prevention/Cleaner production was introduced by UNEP in 1989 as a response to the question of how industry could work toward sustainable development.

Unlike in the past when pollution was simply controlled, **P2 and CP programs attempt to reduce and/or eliminate air, water, and land pollution.**

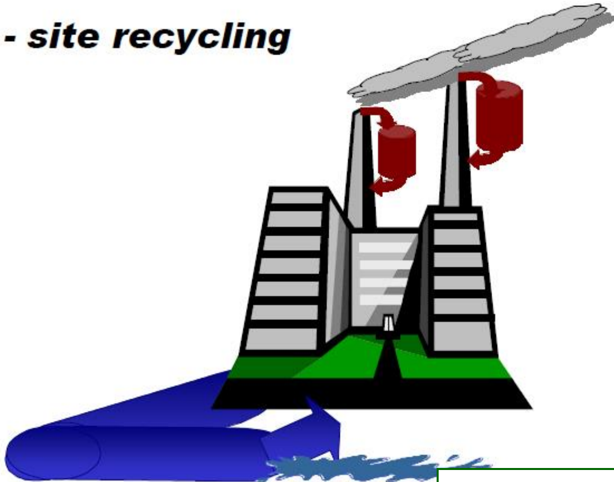
Therefore, the P2 and CP approaches benefit both the environment and society.

Economically, P2 and CP can actually *reduce* costs and in some cases, generate profit.

Both approaches are practical and feasible, and can consequently contribute to a sustainable future.

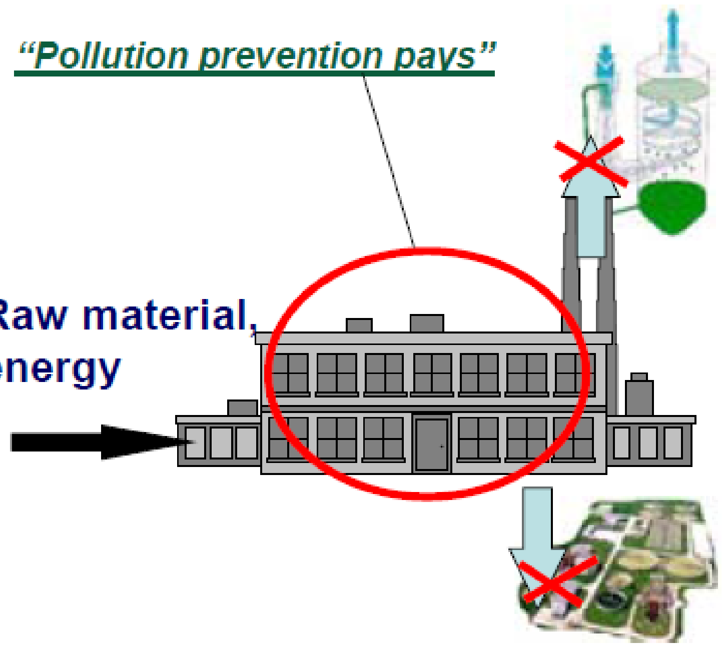
Reactive environmental strategies

On - site recycling



"Pollution prevention pays"

Raw material, energy



PREVENTION !

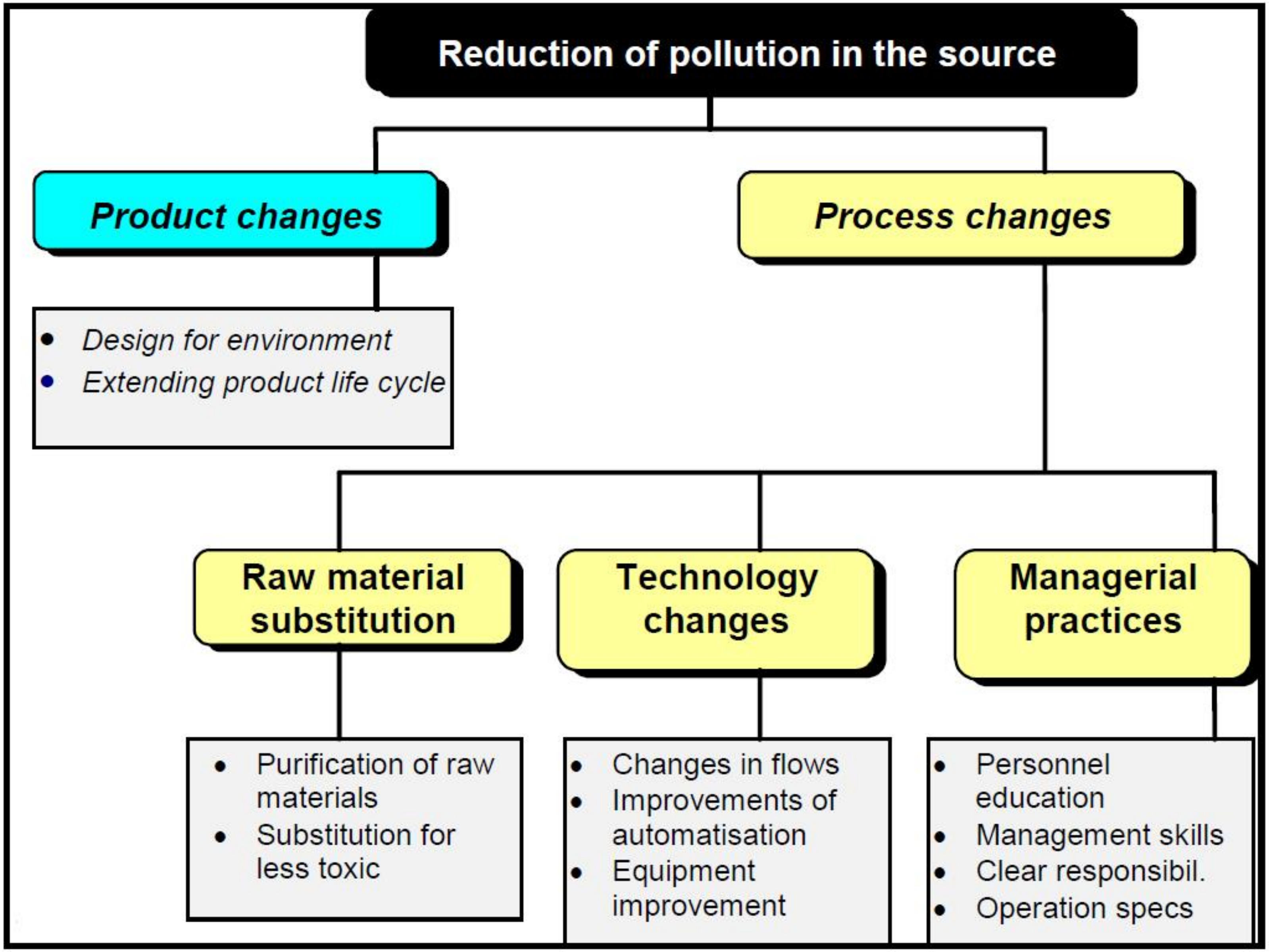
Some of the goals of P2/CP include the following:

- eliminate and/or reduce waste generation.
- conserve natural resources and materials.
- prevent spills and accidental releases.
- prevent product losses.

Proactive environmental strategies: Cleaner Production

Prevention of Waste generation:

- Good housekeeping
- Input substitution
- Better process control
- Equipment modification
- Technology change
- Product modification
- Efficient use of energy resources
- On-site recovery/reuse


Reduction of pollution in the source
Product changes
Process changes
Design for environment
Extending product life cycle
Raw material substitution
Technology changes
Managerial practices
Purification of raw materials
Substitution for less toxic
Changes in flows
Improvements of automatisation
Equipment improvement
Personnel education
Management skills
Clear responsibil.
Operation specs

Pollution Prevention/Cleaner Production is the continuous application of an integrated preventive environmental strategy applied to processes, products and services.

It embodies the more efficient use of natural resources and thereby minimizes waste and pollution as well as risks to human health and safety.

It tackles these problems at their source rather than at the end of the production process; **in other words it avoids the 'end-of-pipe' approach.**

For processes, P2/CP includes conserving raw materials and energy, eliminating the use of toxic raw materials and reducing the quantity and toxicity of all emissions and wastes.

For products, it involves reducing the negative effects of the product throughout its life-cycle, from the extraction of the raw materials right through to the product's ultimate disposal.

For services, the strategy focuses on incorporating environmental concerns into designing and delivering services.

P2/CP can be an efficient way to operate processes, manufacture products and provide services.

It cuts the cost of wastes and emissions, reduces the liabilities associated with adverse environmental and health effects, and can create new markets.

Waste minimization

Sometimes, **Waste Minimization** has a different meaning than either P2 or CP. It generally refers to the generation of hazardous waste, usually in the manufacturing sector.

Waste minimization includes both **waste avoidance** and **waste utilization**.

Waste avoidance refers to the actions taken by the producer *to avoid generating hazardous waste*.

Waste utilization includes a variety of actions which *make that waste a useful input into the production process*.

There is a distinct difference between the terms **reuse, recycling, and recovery**.

Reuse refers to the *repeated use of a "waste" material in the production process*

Recycling occurs when *one producer is able to utilize the waste from another production process*.

Recovery refers to the *extraction of certain components of a "waste" material for the use in another production process.*

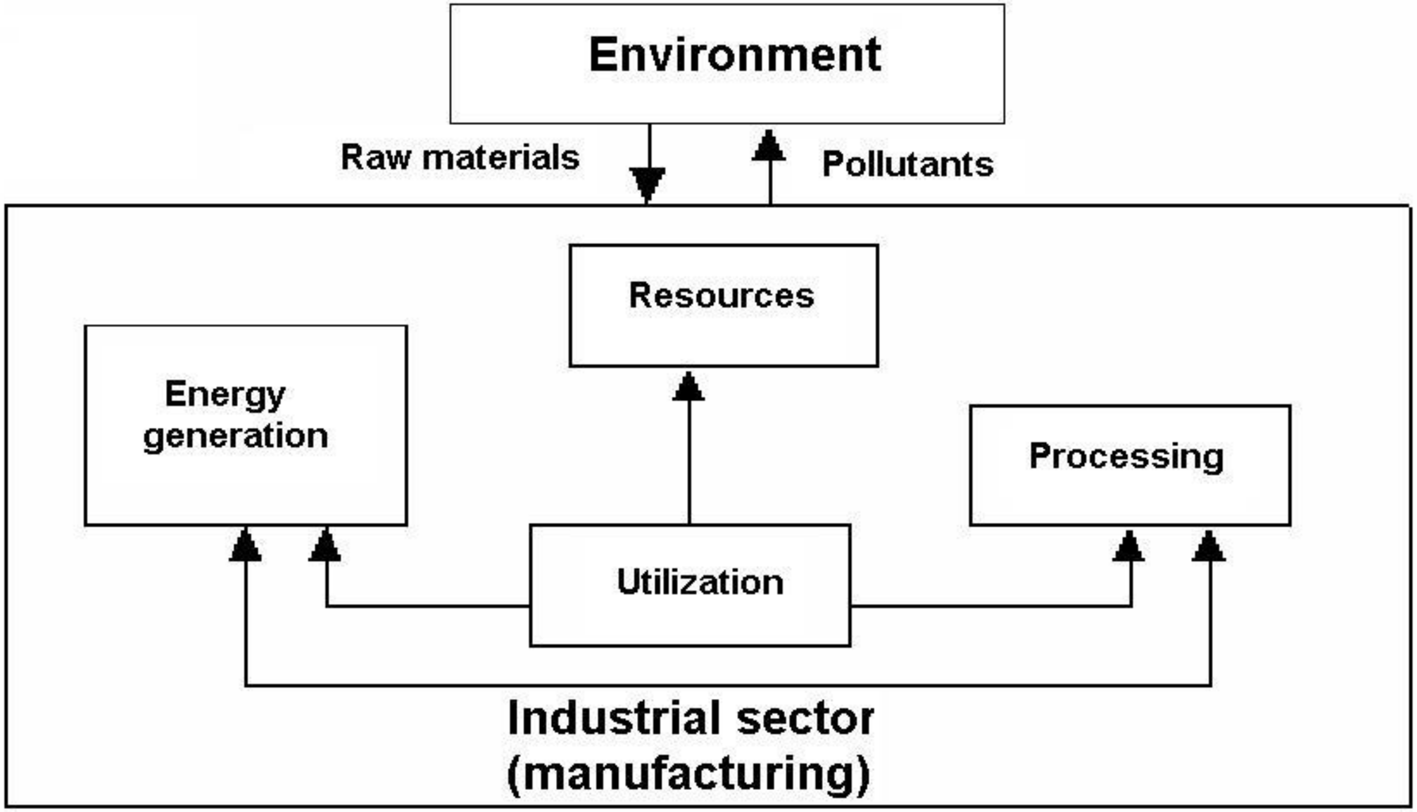
Tiers for the application of PP/CP alternatives

MACRO SCALE

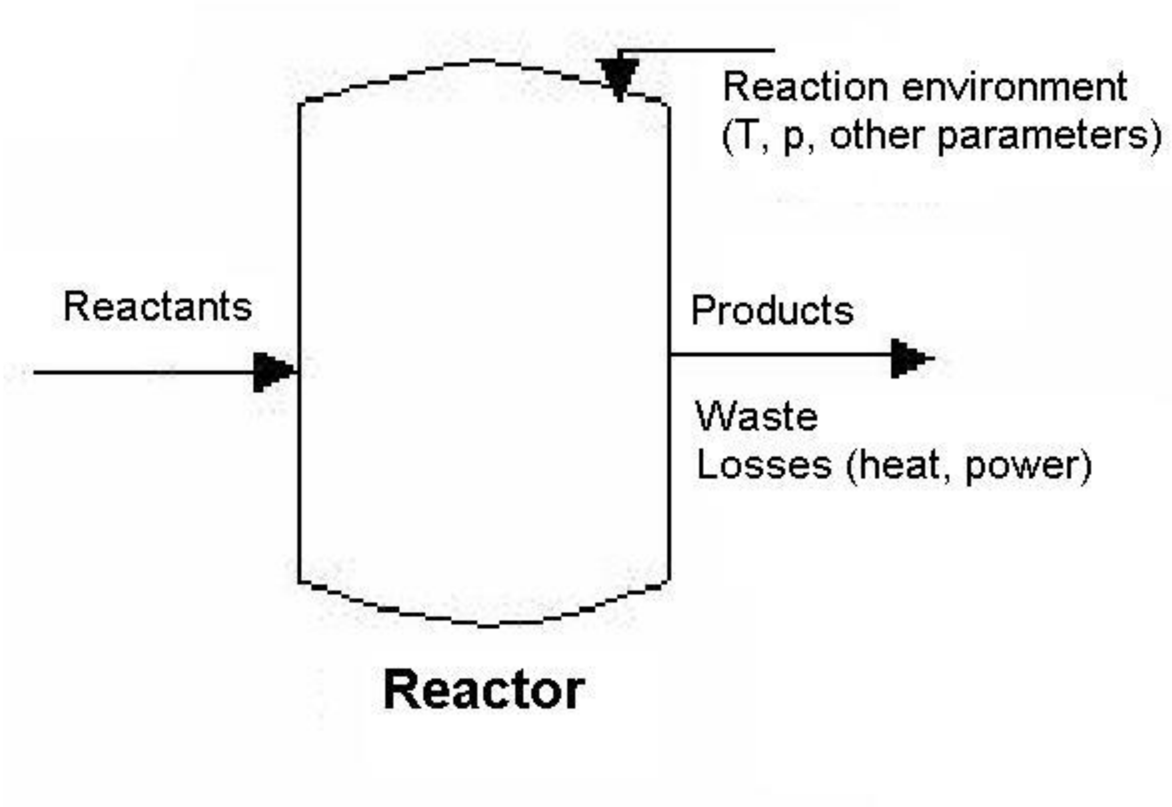
MEZO SCALE

MICRO SCALE

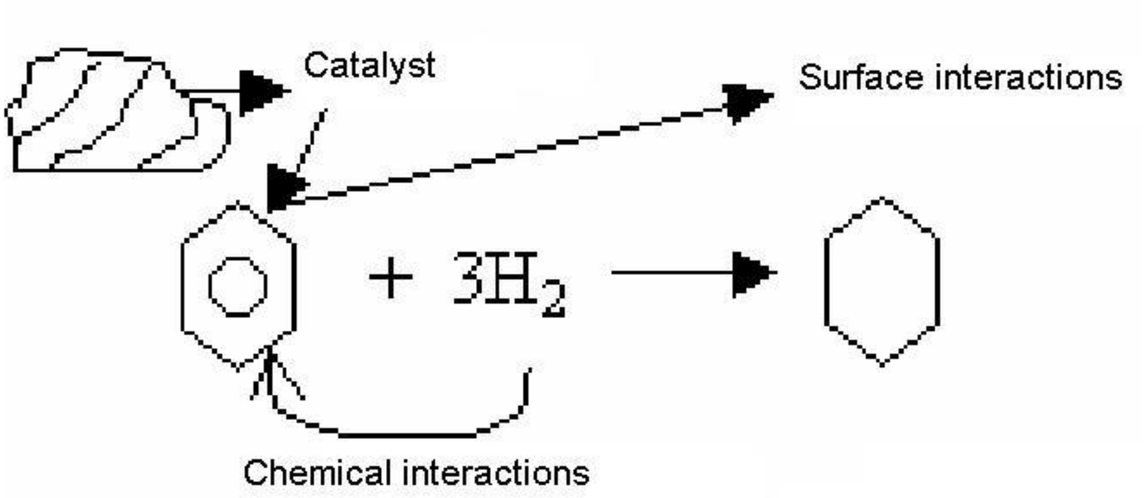
Macro scale (Industrial System)**:**



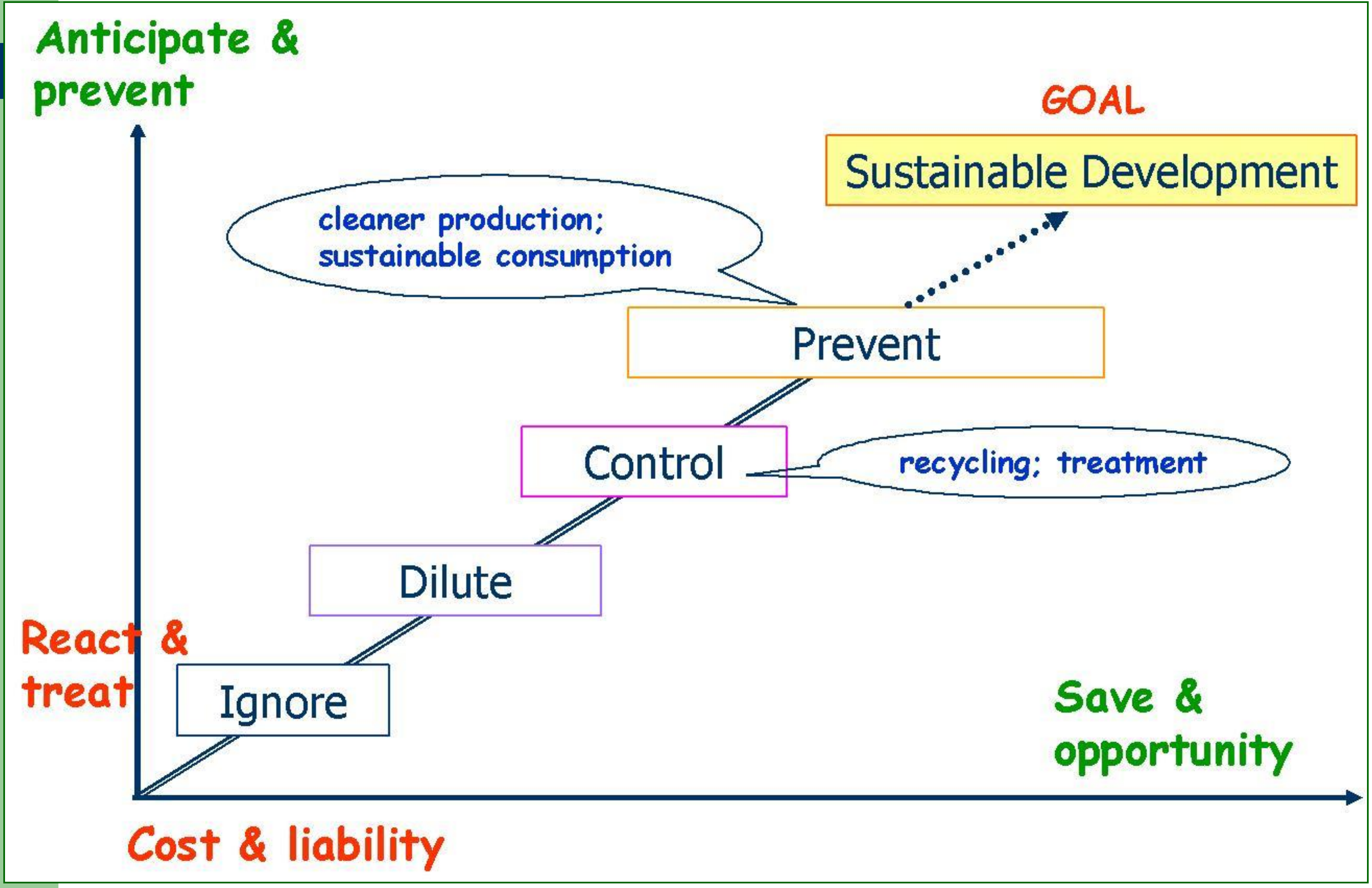
Mezo (chemical reactor)**:**



Micro scale (catalytic reaction)



These practices evolved towards a sustainable development model, which started with pollution prevention/cleaner production tool (Figure 4.8).



- **adoption of more integrated and systematic methods to improve sustainability performance:** has laid the foundation for *new business models or modes of provision which can potentially lead to significant environmental benefits*.

- **efforts to create closed-loop, circular production systems:** have particularly focused on, for example *revitalizing disposed products into new resources for production* (by establishing *eco-industrial parks* , where **economic and environmental synergies** between traditionally unrelated industrial producers can be harnessed).

These practices mentioned above are predominantly process-oriented tools. They outline procedures for conducting a preliminary assessment to identify opportunities for waste reduction or elimination.

In a hierarchy of waste management, pollution prevention is on the top of a pyramid.

Owing to the benefits of this alternative directly coincide with economic, social and environmental interests, the conventional pyramid is inverted.

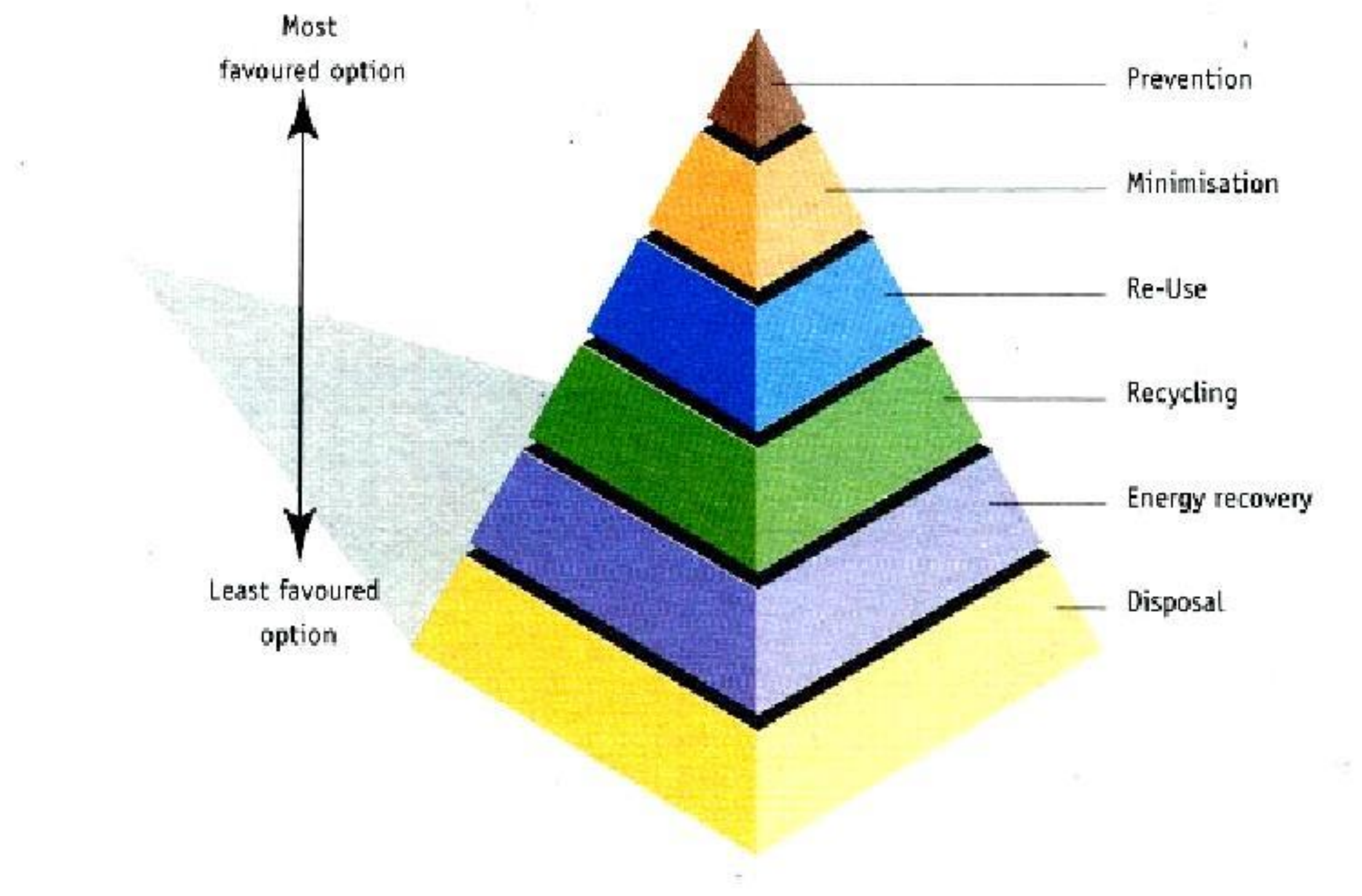


Figure 4.10. The conventional hierarchy of waste management

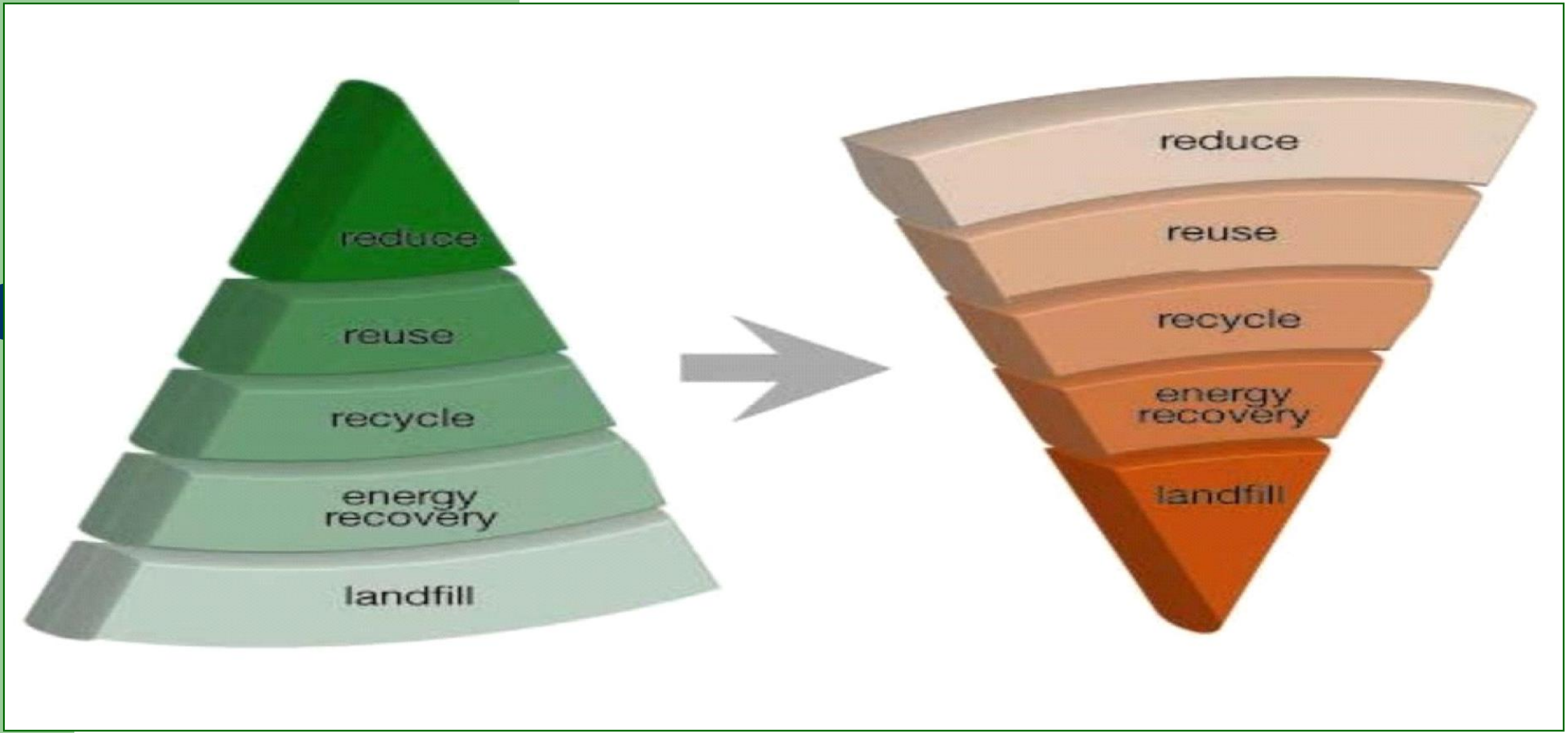
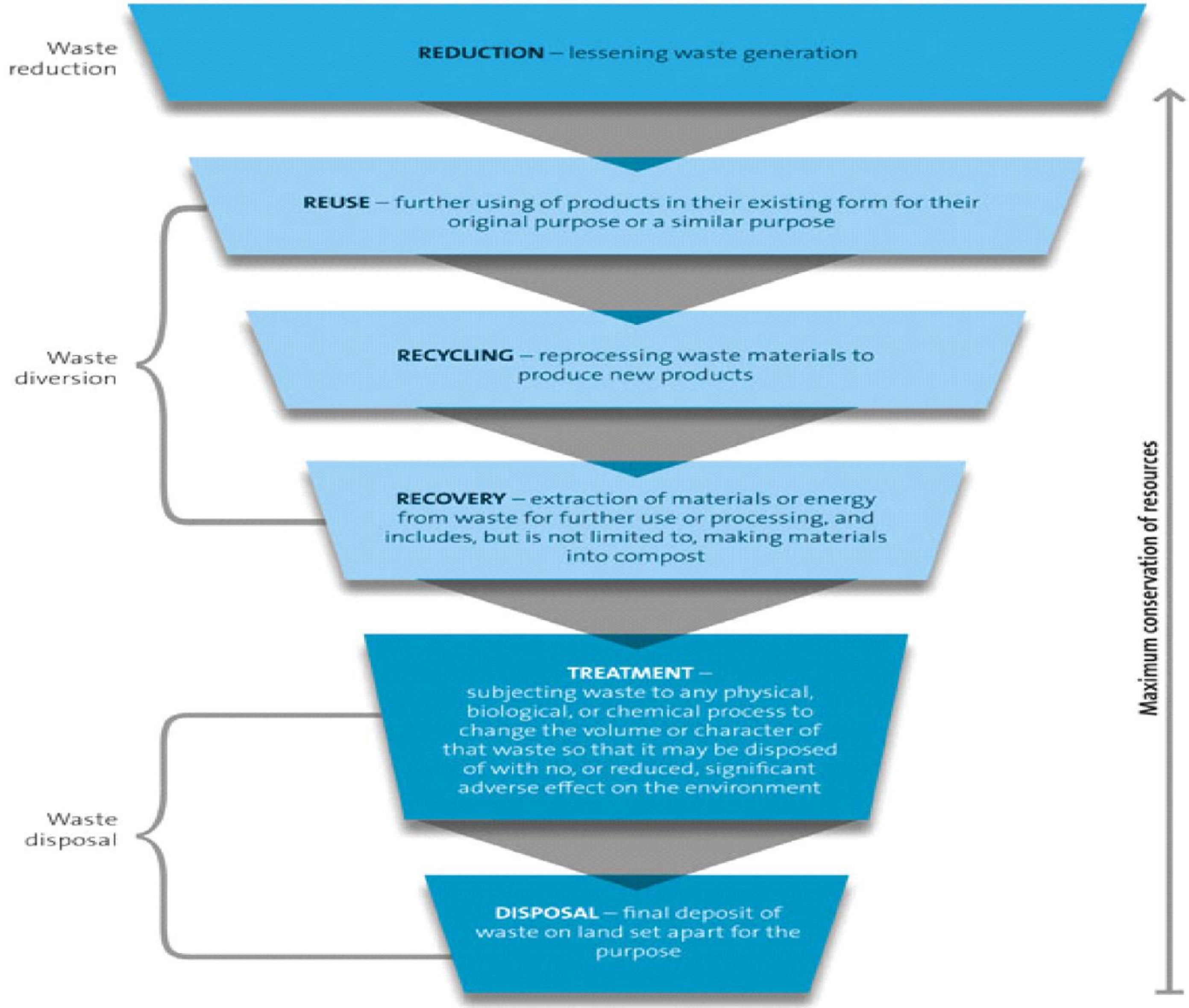
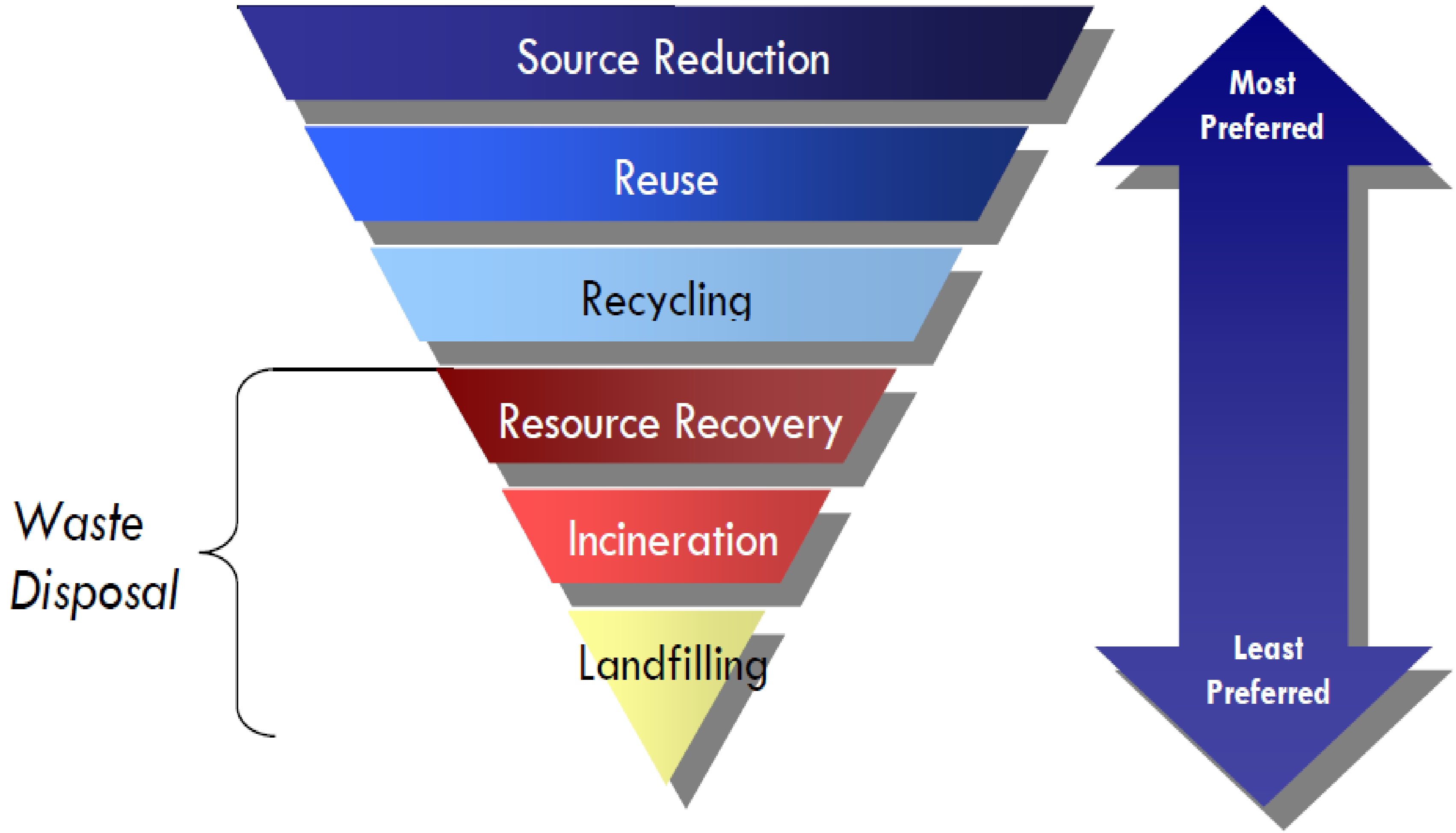


Figure 4.11. The current aspect of the pyramid of waste management hierarchy


Waste reduction
REDUCTION – lessening waste generation
REUSE – further using of products in their existing form for their original purpose or a similar purpose
Waste diversion
RECYCLING – reprocessing waste materials to produce new products
RECOVERY – extraction of materials or energy from waste for further use or processing, and includes, but is not limited to, making materials into compost
TREATMENT – subjecting waste to any physical, biological, or chemical process to change the volume or character of that waste so that it may be disposed of with no, or reduced, significant adverse effect on the environment
Waste disposal
DISPOSAL – final deposit of waste on land set apart for the purpose
Maximum conservation of resources



Source Reduction
Reuse
Recycling
Resource Recovery
Incineration
Landfilling
Waste Disposal
Most Preferred
Least Preferred

Source reduction is the preferred method of waste management since **it prevents the generation of waste in the first place**.

source reduction: the design, manufacture, purchase, or use of materials to reduce their quantity or toxicity before they reach the waste stream (USEPA)

It includes minimizing the production of wastes during any step in the creation or use of a product.

In plant **or** ***in-process recycling*** **or** ***reuse*** **follows source reduction in waste hierarchy**

Sometimes, ***on-site recycling*** **is considered as reusing alternative**

Both source reduction and reuse are considered pollution prevention practice

They decrease resource use, protecting the environment.

Source reduction and reuse also reduce the dependency on traditional methods of waste management (for example landfilling).

Recycling*:* follows source reduction and reuse in the waste hierarchy

- the process by which materials otherwise destined for disposal are collected, processed, and remanufactured (*on site* or *off site*).

Disposal management methods, including **resource recovery (or waste to energy**) and **landfilling** are near the bottom of the hierarchy.

Resource recovery is preferred to landfilling since the method reduces the bulk of municipal waste and can provide the added benefit of energy production.

Based on this hierarchy, the main components of waste management in an industrial system can be structured as:

- **source reduction**
- **in-process recycling**
- **on site recycling**
- **off site recycling**
- **waste treatment**
- **waste landfilling**
- **waste release**

These alternatives can be combined in various schemes.

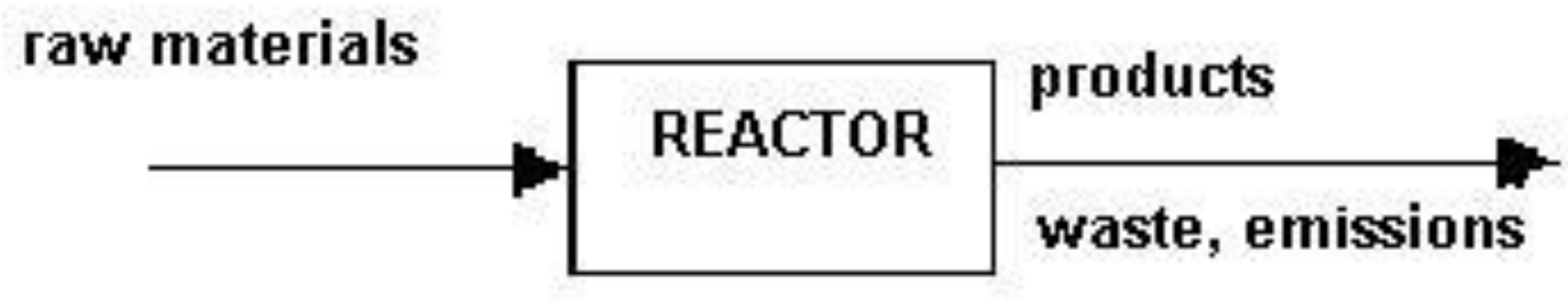


Fig. 5.2. Unsustainable industrial system represented by a reactor

•***source reduction*** can be carried out by changing the reactor conditions so that its performance is improved and the waste quantity and emissions are diminished (Fig.5.3)

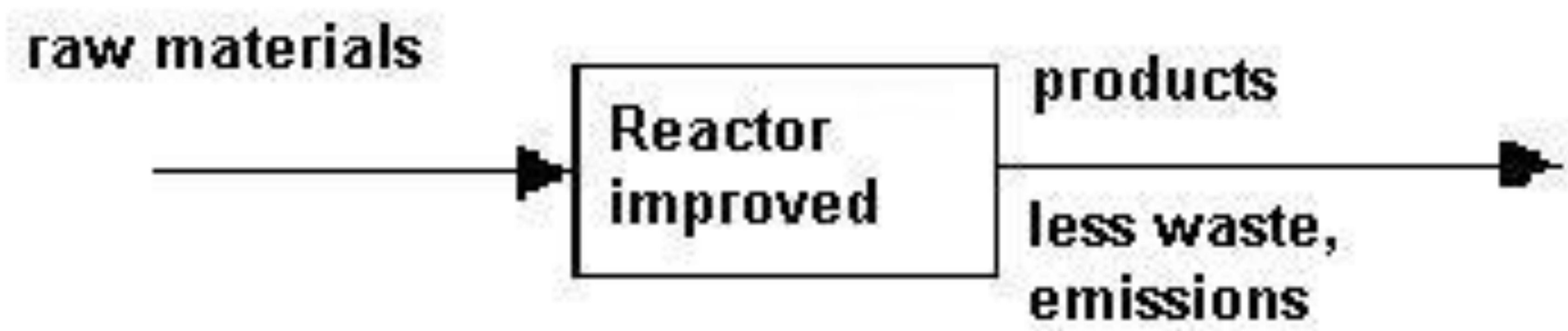


Fig. 5.3. Industrial system represented by a modified reactor, with minimized waste quantity

•**in-process recycling:** the output is sent to a separator, while the unprocessed raw materials are recycled and mixed with fresh raw materials (Fig. 5.4):

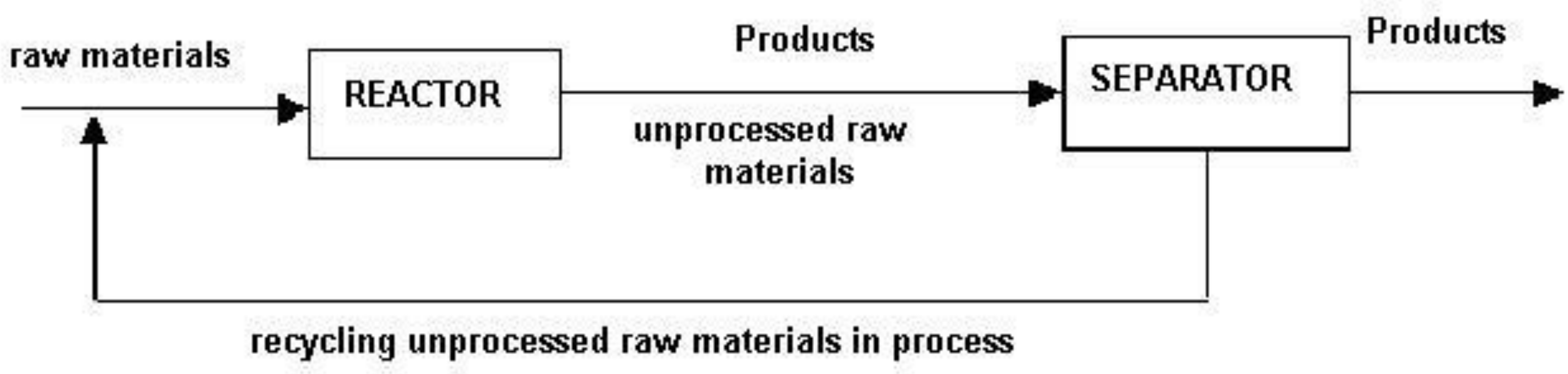


Fig. 5.4. In process recycling

•**on site recycling:** the output is sent to a separator, while the unprocessed raw materials are sent as raw materials to another process (Reactor 1) belonging to the same industrial process, (Fig. 5.5):

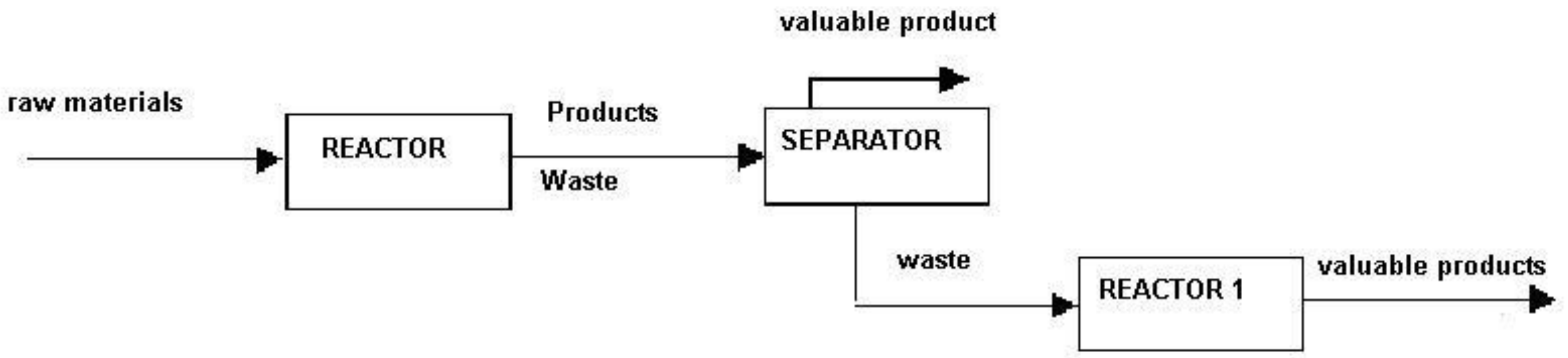


Fig. 5.5. On-site recycling

•**off site recycling:** the output is sent to a separator, while the unprocessed raw materials are transported as raw materials to another process (Reactor 2) belonging to another industrial process, located to another site (Fig. 5.6):

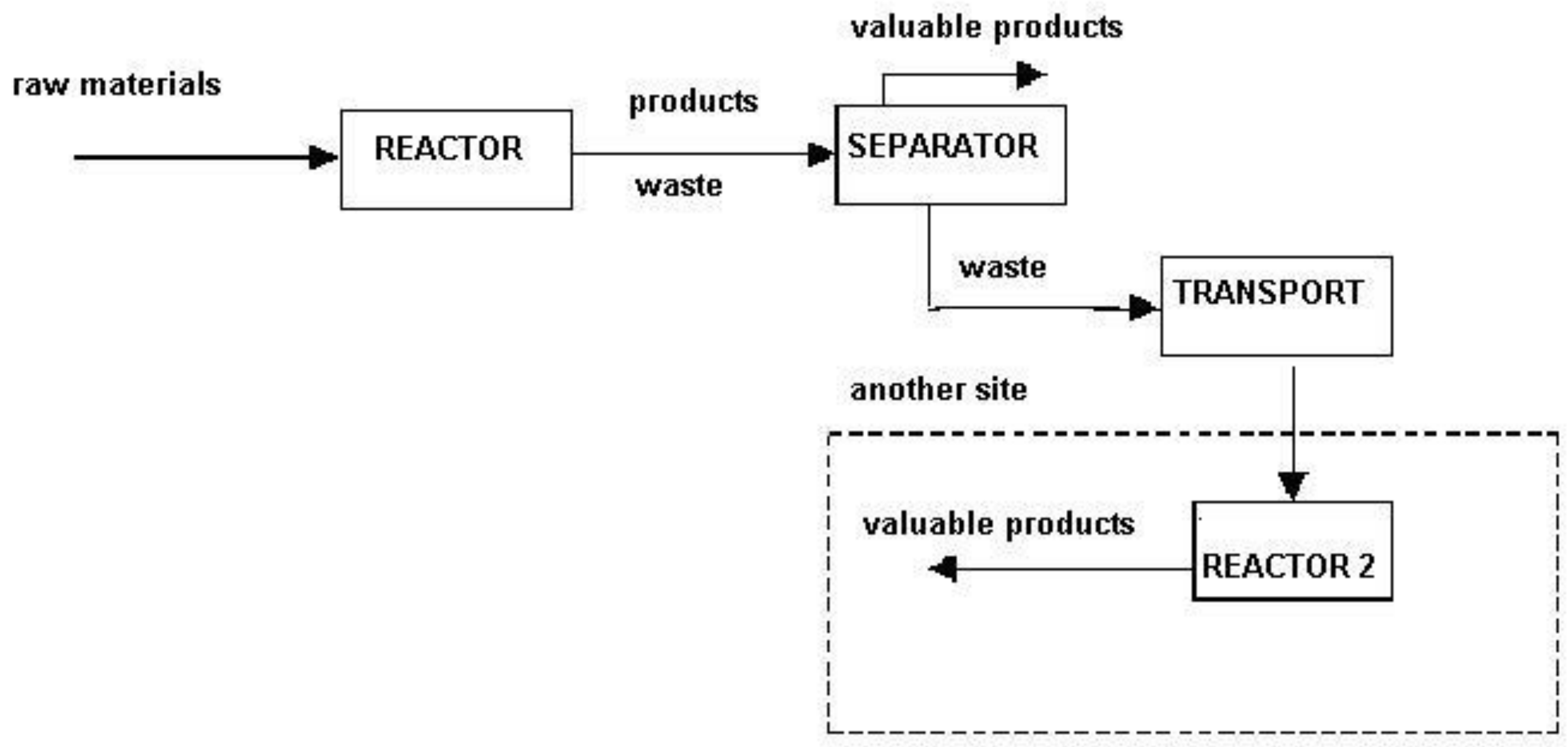


Fig. 5.6. Off-site recycling

•**waste treatment:** the output is sent to a separator, and the resulted waste are sent to a treatment stage, resulting less hazardous waste (Fig. 5.7):

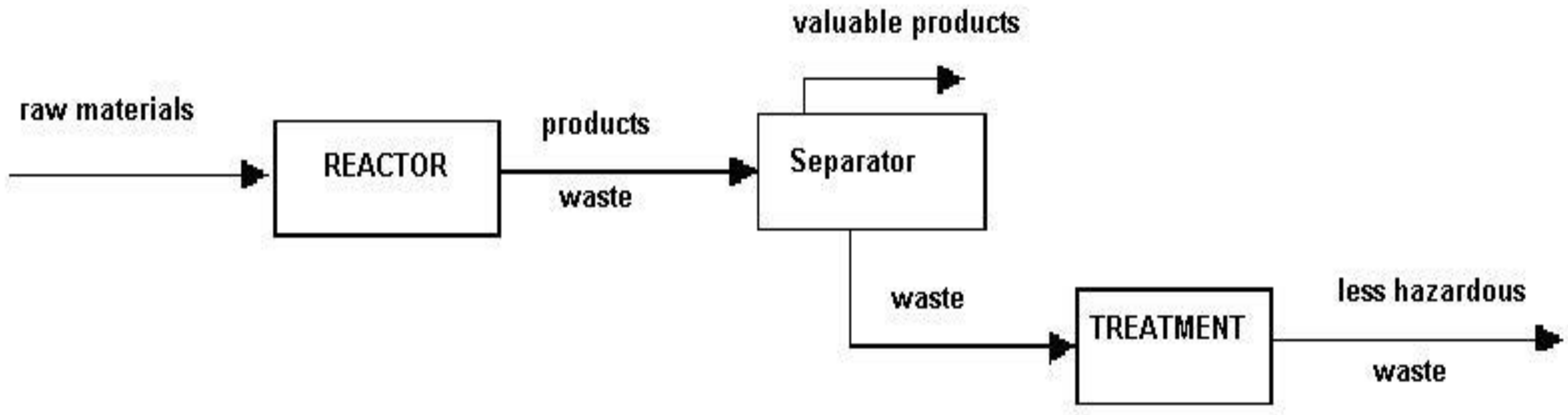


Fig. 5.7. Waste treatment

•**waste disposal:** the output is sent to a separator, and the resulted waste are sent to an ecological landfill (Fig. 5.8):

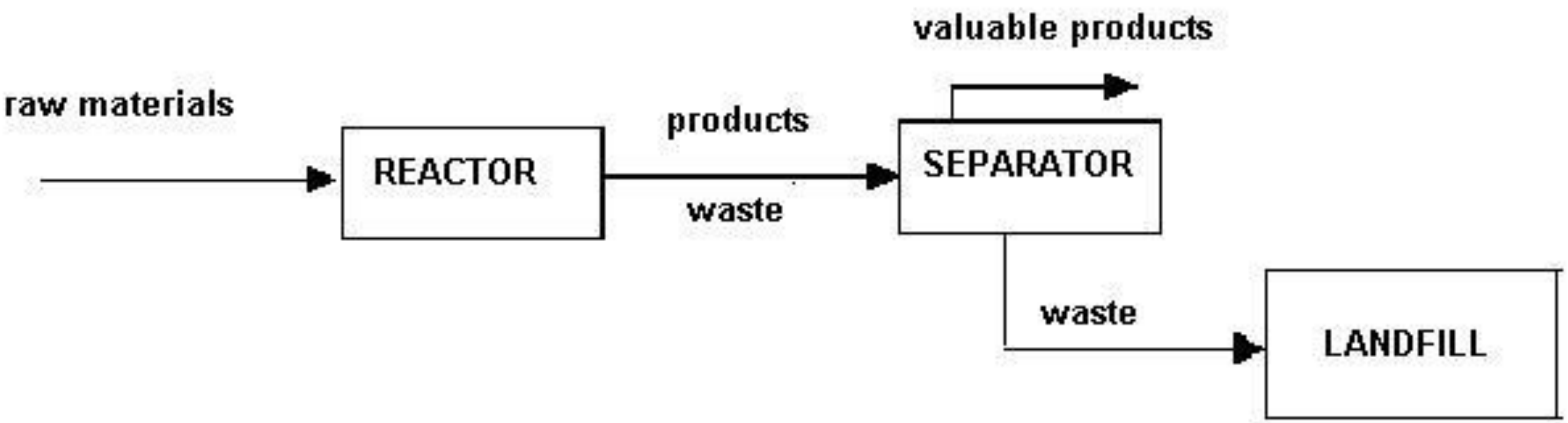


Fig. 5.8. Waste landfilling

•safe release of waste into the environment; the output is sent to a separator, and the resulted waste are discharged into the environment in safe conditions (Fig. 5.9):

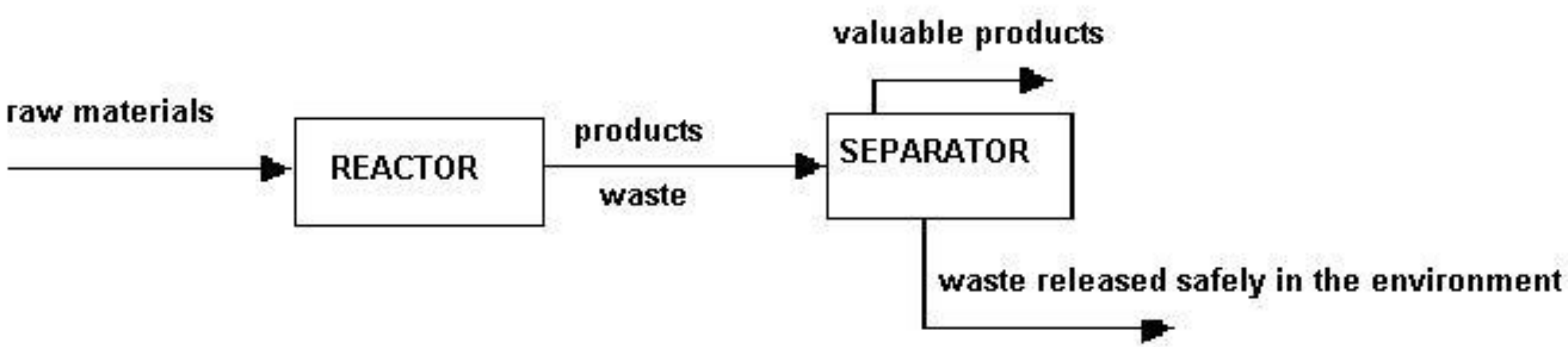
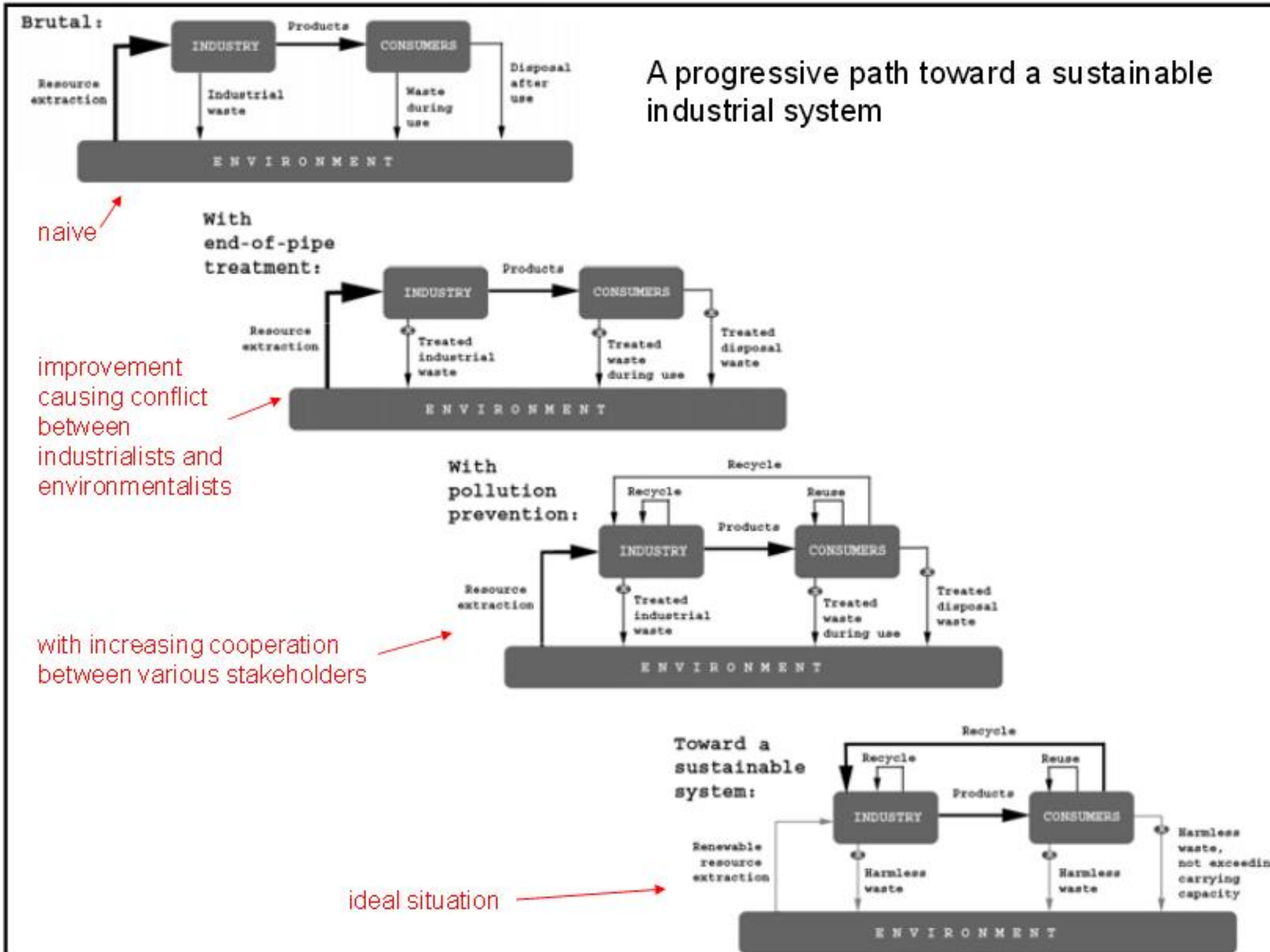


Fig. 5.9. Waste release in the environment

A progressive path toward a sustainable industrial system



Source reduction and **in-process recycling (or reuse)** are the first steps in the waste minimization hierarchy.

Source reduction prevents waste at the source, keeping unnecessary and excess materials out of your facility before they become waste.

Reuse is one of the most common source reduction strategies because purchasing reusable products, rather than single-use or disposable products, minimizes reoccurring waste streams.

They are the main components of **POLLUTION PREVENTION.**

P2 is a multi-media environmental management approach which emphasizes the elimination and/or reduction of waste at the source of generation.

P2 strives to eliminate and/or reduce waste at the source of generation.

Five different areas of P2 focus: water; air; solids; time; and energy

In certain aspects, CP is very similar to P2.

Most importantly, both P2 and CP emphasize environmental management through source reduction, rather than pollution control methods.

Similar to P2, CP should not be considered an absolute state, but rather a process which continually evolves with the introduction of improved technology and innovative ideas.

USEPA considered that there is one primary difference between P2 and CP.

While P2 is an environmental management concept which can be applied to all sectors, CP is a technique designed more specifically for sectors dealing with production processes, like the manufacturing sector (Fig. 5.10).

<--------------- Standard Industrial Classification Categories --->

Agriculture	Mining	Construction	Manufacturing	Transportation & Utilities

<---------------Standard Industrial Classification Categories (con.)----------------------------------->

Wholesale Trade	Retail Trade	Finance, Insurance, Real Estate	Services	Public Administration	Consumers

Fig. 5.10. Main sectors where P2 and CP can be applied

USEPA considered that **Pollution Prevention** applies to all of these categories.

Cleaner Production applies to the shaded areas, mostly to the manufacturing sectors.

Waste Minimization applies to the generation of hazardous waste, mostly in the manufacturing sectors.

Main components of CP

***Waste Reduction*:**

The term waste refers to all types of waste including both hazardous and solid waste, liquid and gaseous wastes, waste heat, etc.

The goal of CP is to achieve zero waste discharge.

Cleaner production requires applying know-how, improving technology, and changing attitudes.

Over 50% *of waste*

can be avoided by simple management measures and minor process changes

Over 65% of the *barriers*

to cleaner production involve human motivation and attitudes!

***Non-Polluting Production*:**

Ideal production processes, within the concept of CP, take place in a closed loop with zero contaminant release

***Production Energy Efficiency*:**

CP requires the highest levels of **energy efficiency** and conservation.

Energy efficiency is determined by the highest ration of energy consumption to product output.

Energy conservation, on the other hand, refers to the reduction of energy usage.

***Safe and Healthy Work Environments*:**

CP strives to minimize the risks of workers in order to make the workplace a cleaner, safer, and healthier environment.

***Environmentally Sound Products*:**

The final product and all marketable by-products should be as environmentally appropriate as possible.

Health and environmental factors must be addressed at the earliest point of product and process design and must be considered over the full product life-cycle, from production through use and disposal.

***Environmentally Sound Packaging*:**

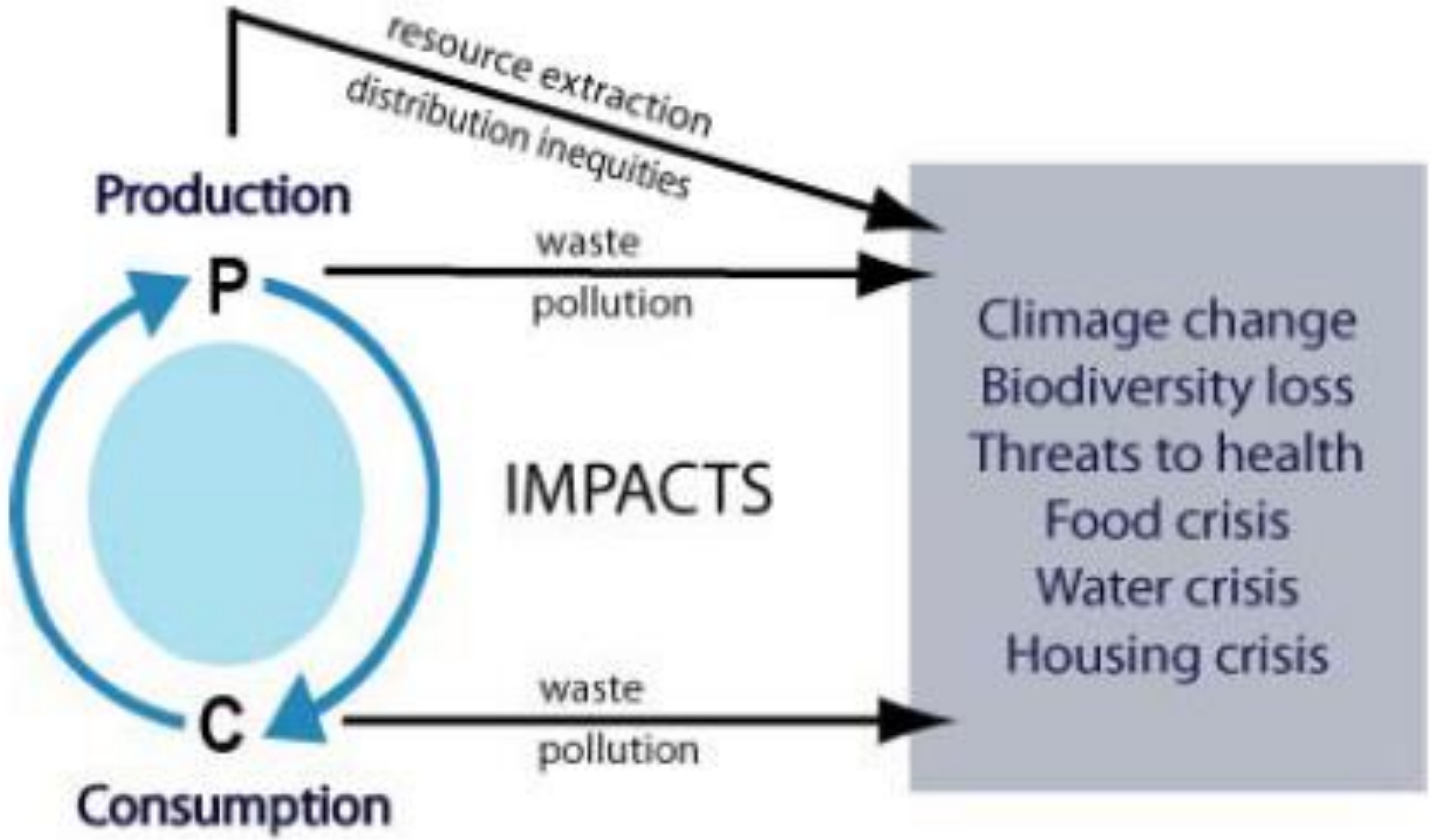
Product packaging should be minimized wherever possible.

Where packaging is necessary to protect the product, to market the product, or to facilitate ease of consumption, it should be as environmentally appropriate as possible.

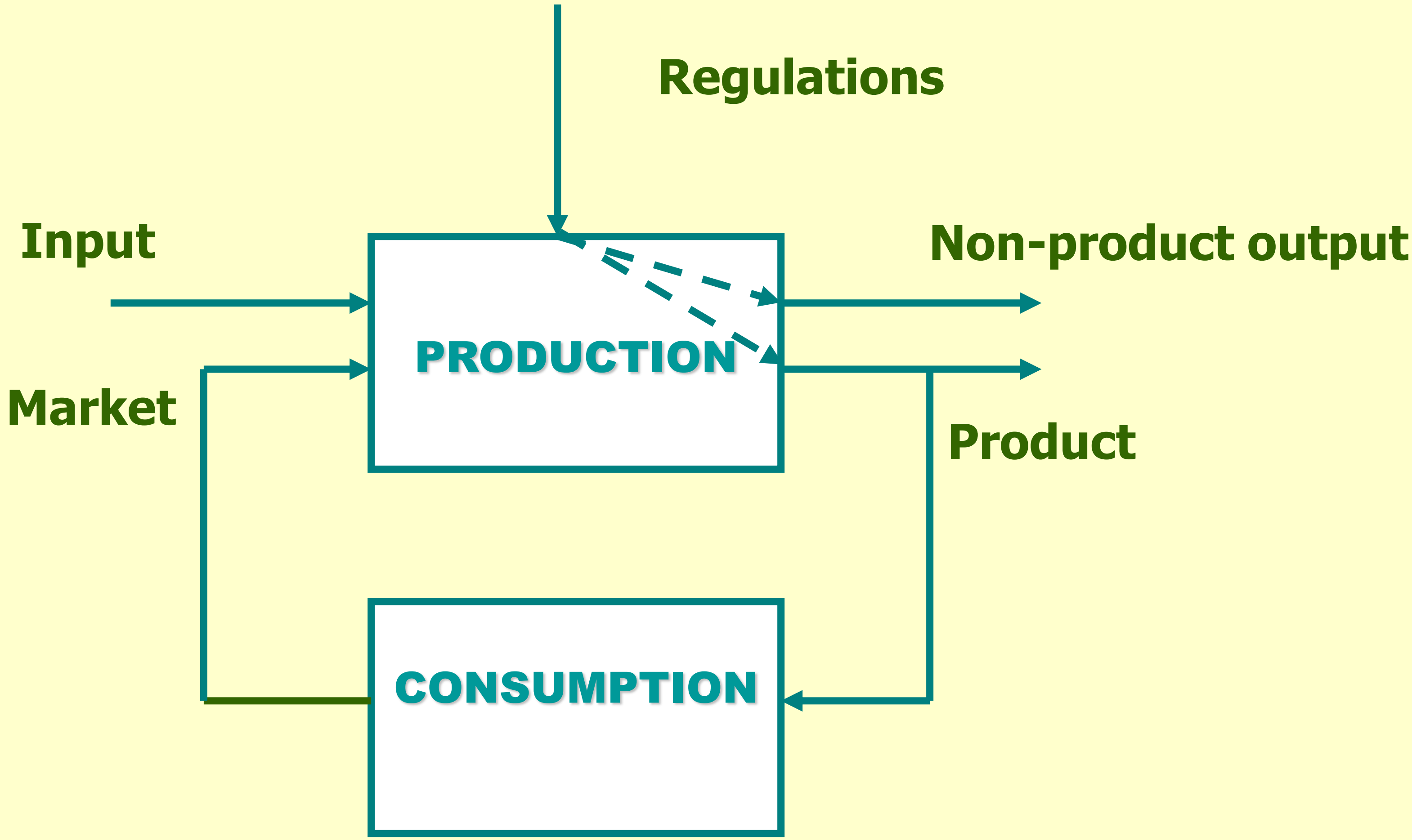
These initiatives address through a dynamic range of practices the major ecological and social crises of the planet:

- climate change and energy,
- species extinction,
- economic insecurity,
- the food and water crises

These initiatives and practices towards a sustainable industrial model are focusing on the root unsustainable production (P) and consumption (C) patterns, driving those problems.



Social and environmental impacts from unsustainable production and consumption



Regulations
Input
Non-product output
PRODUCTION
Market
Product
CONSUMPTION

Continuous
Products
Processes
Humans
Preventive
STRATEGY for
Risk Reduction
Integrated
Services
Environment

The principles of implementing Cleaner Production are therefore to:

- **Improve housekeeping** by making changes to **procedures and management** in order to eliminate waste, e.g. spill prevention, improved worker education and training.

- **Effect source control** by **changing raw materials** (i.e. change to non-toxic or purer materials, use renewable raw materials or materials with a long service lifetime) or **using resources more efficiently** (i.e. water reuse, energy savings, optimum chemical use, etc.)

- **On site recycling**: i.e. useful application of waste material produced by the company, e.g. **reuse as raw material**, **recovery** etc. Only on-site recycling is considered to be a source reduction technique. ***Off-site recycling is seen as pollution control measure.***

- **Redesign or reformulate products** by **changing the product characteristics** such as shape or composition. The product life may be extended or it is made easier to repair. The manufacturing process may become less polluting. This also includes changes in packaging. Changes to product design often requires a life cycle assessment approach.

- **Change production technology and equipment**, e.g. **improved process automation, process optimization, equipment re-design and process substitution**. This can create less hazardous wastes and emissions.

Going to the source of pollution is the fundamental idea of cleaner production.

Good housekeeping is the simplest type of the cleaner production options.

Good housekeeping requires no investments and can be implemented as soon as the options are identified.

Good housekeeping is e.g. to repair all leaks and avoid losses by closing water taps and turning off equipment when not needed.

Even though good housekeeping is simple, it requires focus from the management and training of staff.

Better process control is to ensure that the process conditions are optimal with respect to resource consumption, production and waste generation.

Process parameters such as temperature, time, pressure, pH, processing speed, etc. have to be monitored and maintained as close to the optimum as possible.

As with good house keeping, better process control requires improved **monitoring and management focus**.

Material substitution is to purchase higher quality materials that give a higher efficiency.

Often there is a direct relation between the quality of the raw materials and the amount and quality of the products.

Material substitution is furthermore to replace existing materials with some that are environmentally better.

Equipment modification is to improve the existing equipment so less material is wasted.

Equipment modification can be to adjust the speed of an engine, to optimize the size of a storage tank, to insulate hot and cold surfaces, or to improve the design of a crucial part of the equipment.

New process technology is to install modern and more efficient equipment, e.g. a highly efficient boiler or a jet-dyeing machine with a low liquor ratio.

New process technology requires higher investments than the other cleaner production options and should therefore be considered carefully.

However, **the potential savings and quality improvements often pays back the investment in a very short time.**

Recycling

Waste streams that are unavoidable might be recycled within the company or might be sold as by-products.

On-site recovery and reuse is to collect "waste" and reuse it **in the same or a different part of the production**.

One simple example is to reuse rinse water from one process to another cleaning process.

Creation of by-products is to collect (and treat) "waste-streams" so they can be sold to consumers or to other companies.

Excess yeast from a brewery can for instance be used for pig fodder, fish farming or as a food additive.

Product modification

Improving the products so they pollute less is also a fundamental idea of cleaner production.

Changing the product is to re-think the product and the requirements to the product. For instance, if it is possible to replace a painted metal shield with a plastic shield for a certain product, then the environmental problems and costs related to paint finishing could be avoided.

Improved product design can result in large savings on material consumption and use of hazardous chemicals.

Changing packaging can be just as important.

The key word is to minimize the packaging and maintaining the protection of the product.

One example is to use recycled cardboard instead of plastic foam for protection of fragile items.

Source Reduction Technique	Description	Examples
1. Process efficiency improvements	A method of doing more with less by designing new systems or modifying existing ones; the most effective means of conserving materials and resources	High pressure, low volume (HPLV) spray guns for painting operations; centralized fluid distribution systems; water flow restrictors; energy-saving light fixtures
2. Material substitution	Replace hazardous chemicals with less toxic alternatives of equal performance	Using water-based paints instead of solvent-based paints; replacing solvent degreasers with aqueous cleaning systems
3. Inventory control	Reduce product losses due to product expiration and over-stocking	Restricting access to supply areas; maintaining accurate inventory records to prevent over-stocking
4. Preventive maintenance	Includes any activity that might prevent equipment malfunctions and environmental releases	Routinely inspecting equipment and storage containers; fixing problems immediately; following standard operating procedures
5. Improved housekeeping	Keeping a clean shop conserves resources and materials, prevents product losses, and prevents spills and leaks	keeping aisles clear; cleaning up spills and absorbents immediately; maintaining storage shelves in good order
6. In-process recycling	In-process recycling is considered source reduction if materials are not removed from the process (i.e., waste is not generated) or if materials are redirected back into the process	counter-current rinsing in the electroplating process

The most important steps necessary to be done in the view of PP/CP application refers to (Fig. 6.4):

- **Source inventory,** which identifies where waste and emissions are generated
- **Cause evaluation,** which identifies the main causes and roots which produce waste and emissions
- **Option choice,** which identifies the best alternative that can eliminate the sources and causes of waste and emissions

HOW TO DO CLEANER PRODUCTION

Three logical steps :

Source inventory

- Where are wastes and emissions generated?

✓ Cause evaluation

- Why are wastes and emissions generated?

✓ Option generation

- How can these causes be eliminated?

PP/CP implementation needs a large participation, starting with the management of the organization, till the workers involved in production, within pollution prevention/cleaner production programs, which means:

organized approach,

willingness,

commitment,

team work,

involvement

DESIGN FOR ENVIRONMENT (DfE):
STRATEGIES, PRACTICES, GUIDELINES, METHODS, AND TOOLS

Environmental impacts generated during the entire life cycle of a product/process:

(1) from extracting and processing raw materials;

(2) during manufacturing, assembly, and distribution;

(3) due to their packaging, use, and maintenance;

(4) at their end of their life.

Ways to minimize a product's environmental impacts:

- ***the greatest opportunity occurs during the product design phases***
- ***need to consider many factors related to the environmental impact of their products***
  - ✓ government regulations,
  - ✓ consumer preferences,
  - ✓ corporate environmental objectives

Design for Environment (DfE) (Eco-design):

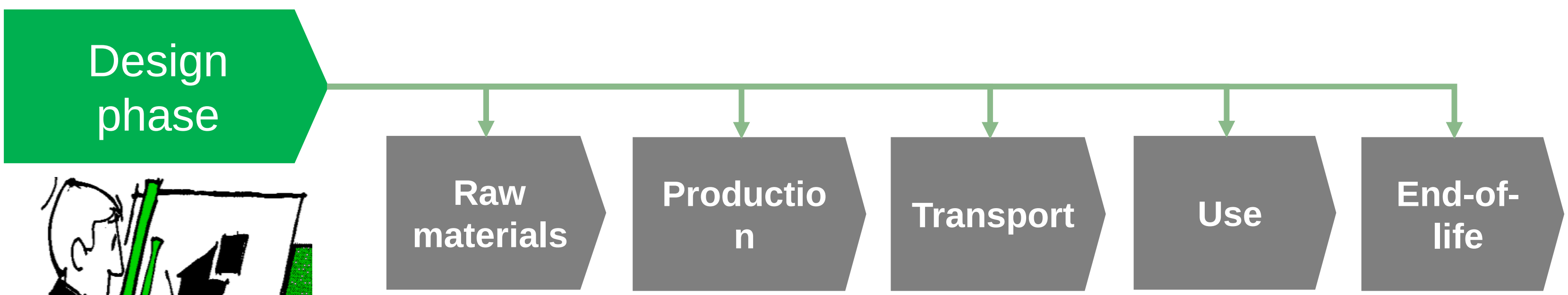
"the systematic consideration of design performance with respect to **environmental, health, and safety objectives** over **the full product and process life cycle**."

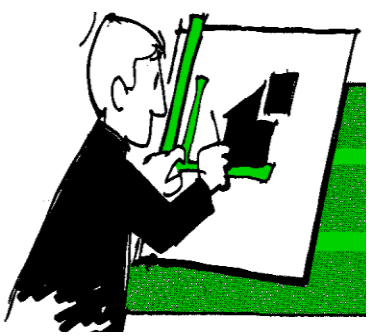
This is a more product-oriented tool.

Defined as:

Systematic integration of environmental considerations into product and process design, for the entire product life cycle.

Fiksel, Joseph, *Design for Environment: Creating Eco-efficient Products and Processes*, McGraw-Hill, New York, 1996





Design determines impacts throughout the life cycle of a product

✓**seeks to address product life-cycle concerns early in the design phase**

✓ **it is similar to:**

- design for manufacturing (DFM)
- design for assembly (DFA)
- design for production (DFP)

✓ **combines several design-related topics:**

- disassembly,
- recovery,
- recycling,
- disposal,
- regulatory compliance,
- Human health and safety impact,
- hazardous material minimization

Decision Making in New Product/Process Development

includes:

Design Decisions

address the question:

"What should the design be?"

Determine:
shape, size, material, process, components

Generate:
information about the product design itself and the requirements that it must satisfy

Management Decisions

address the issues of:
what should be done to make the design into a successful product

- control the progress of the design process
- affect the resources, time, and technologies available to perform development activities
- define which activities should happen, their sequence, and who should perform them
- determine what will be done, when will it be done, and who will do it

Environmental Objectives

Manufacturing system has identified six relevant goals:

1. Comply with legislation.

Products that do not comply with a nation's environmental regulations cannot be sold in that nation.

2. Avoid liability.

Environmental damage caused by a product represents a financial liability.

3. Satisfy customer demand

Some consumers demand environmentally responsible products. Retailers, in turn, pass along these requirements to manufacturers.

4. Participate in eco-labeling programs

Products that meet requirements for eco-labeling are more marketable.

5. Enhance profitability

Certain environmentally friendly choices such as remanufacturing, recycling, and reducing material use make good business sense and have financial benefits.

6. Behave ethically

Being a good steward of the planet's resources by considering the environment during the product development process is the right thing to do.

Environmental *objectives*

- for the most part, are driven by regulations and social responsibility
- reducing environmental impact doesn't clearly increase profit

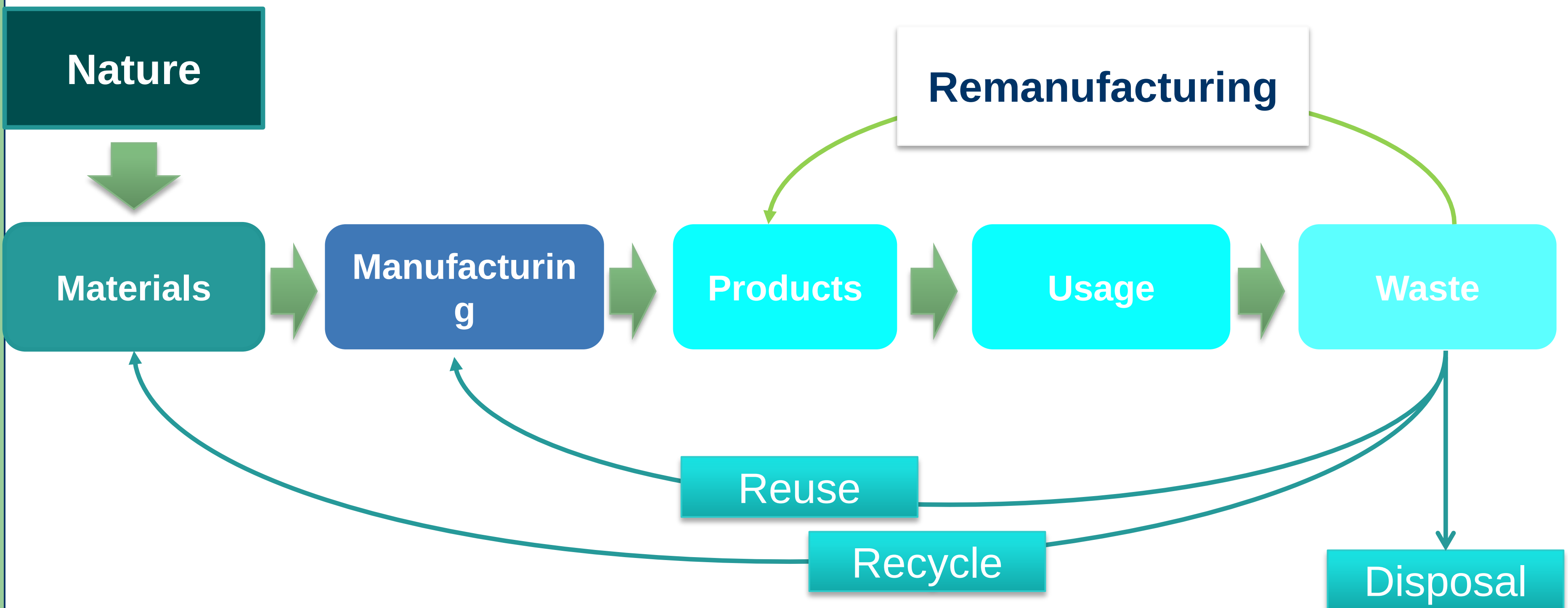
Product managers are not often willing to compromise profit, product quality, or time to market in order to create products that are more environmentally benign than required by regulations.

The exceptions are those organizations that court environmentally conscious consumers

Eco-design Directive (2009/125/EC)

- Framework Directive which sets eco-design requirements (or implementing measures/legislation) for Energy related Products.
- **Objectives:**
  - **To improve the overall environmental performance of these products using an eco-design approach**
  - **To ensure that disparities among national regulations do not become obstacles to intra EU trade)**
  - **To contribute to the security of energy supply and enhance the competitiveness of the EU economy**
  - **To preserve the interests of industry, consumers and other stakeholders**
- Compliance through CE marking, i.e. products not fulfilling requirements will not be able to carry the 'CE' label

Eco-Re-Design - Remanufacturing



Source : Advance Remanufacturing Technology Centre

5.3. Eco-efficiency

Involves minimizing waste, pollution and natural resource depletion (thus incorporating the concept of pollution prevention).

Eco-efficiency is reached by:

- the delivery of competitively priced goods and services that satisfy human needs and bring quality of life,
- while progressively reducing ecological impacts and resource intensity throughout the life cycle, to a level at least in line with the earth's estimated carrying capacity.

Eco-efficiency therefore combines economic improvements with the more efficient use of resources and the prevention of emissions.

It’s the pathway form constraints to awareness (from regulation driven to responsibility driven approaches) (Fig.5.11).

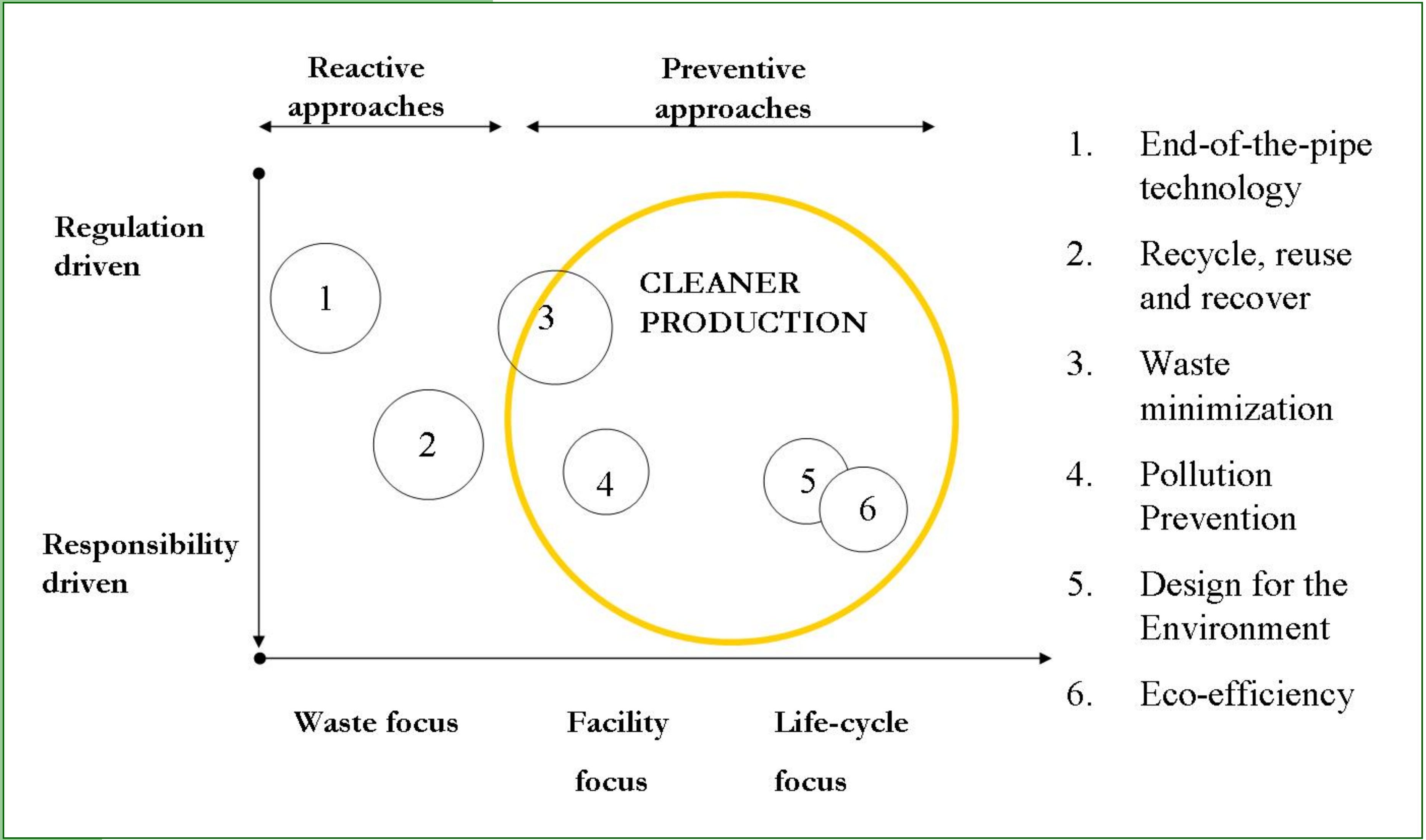


Fig. 5.11. Interconnections of the strategies for sustainable industrial production

Components of Eco-efficiency:

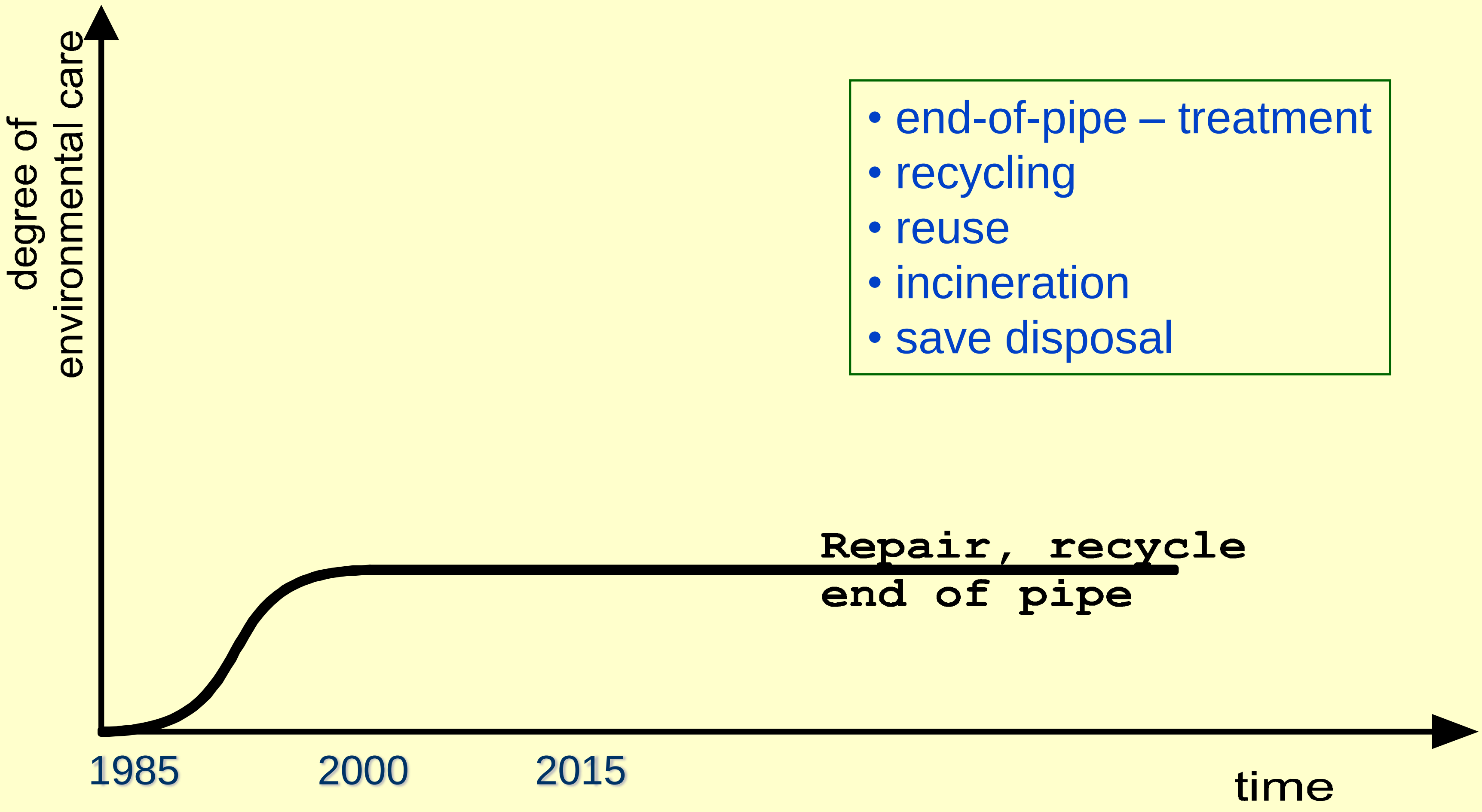
- reduce material intensity of goods and services
- reduce energy intensity of goods and services
- reduce toxic dispersion
- enhance material recyclability
- maximize sustainable use of renewable resources
- reduce material durability
- increase the service intensity of goods and services

To summarize:

Eco-efficiency is **a key driver for companies** because it helps them to understand that they can produce better goods and services while using fewer resources and generating less impact, thereby **improving both their environmental performance and their bottom line.**

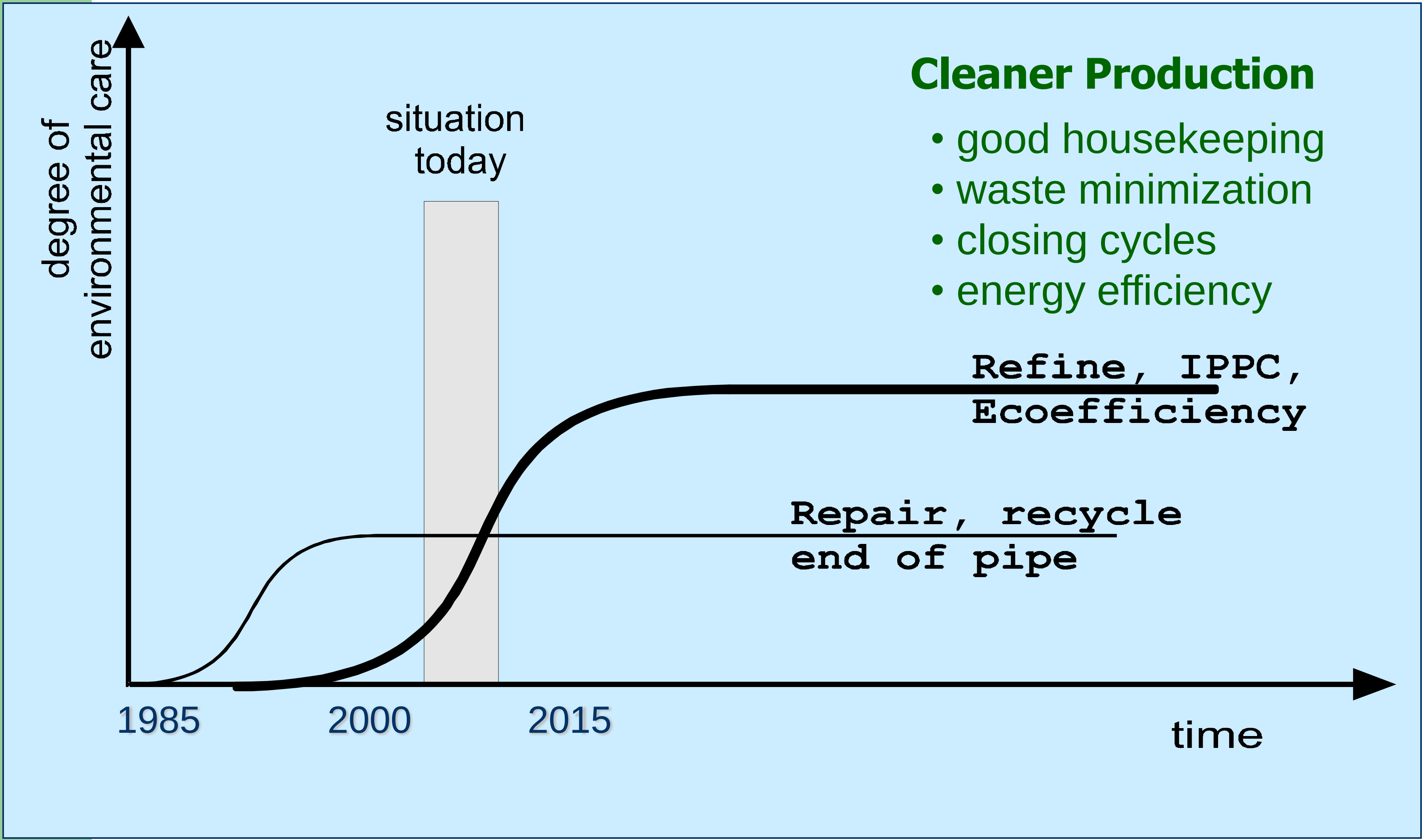
Eco-efficiency and Cleaner Production remain widely supported and successful strategies toward the achievement of sustainable development.

Environmental protection - reduced pollution

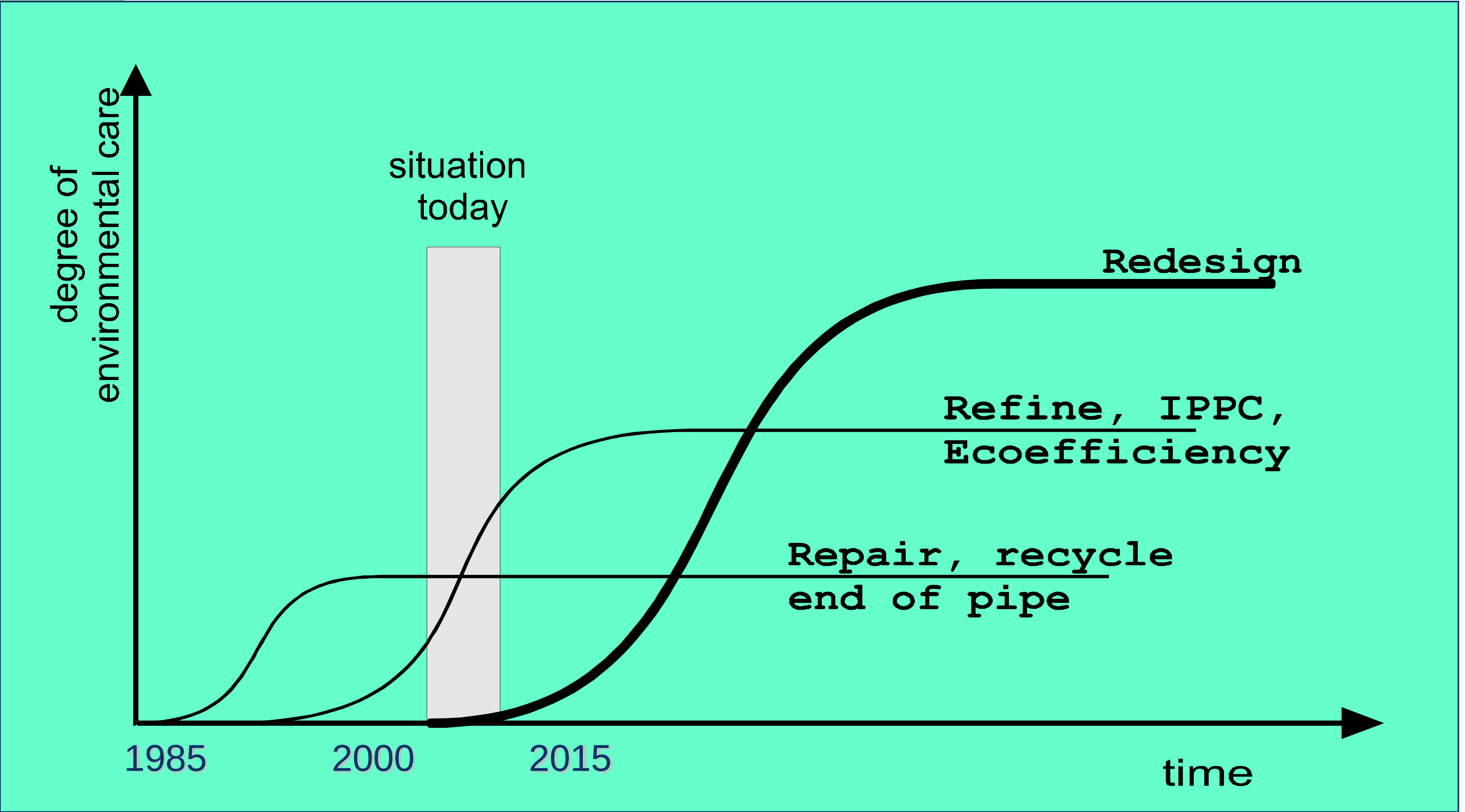


- end-of-pipe – treatment
- recycling
- reuse
- incineration
- save disposal

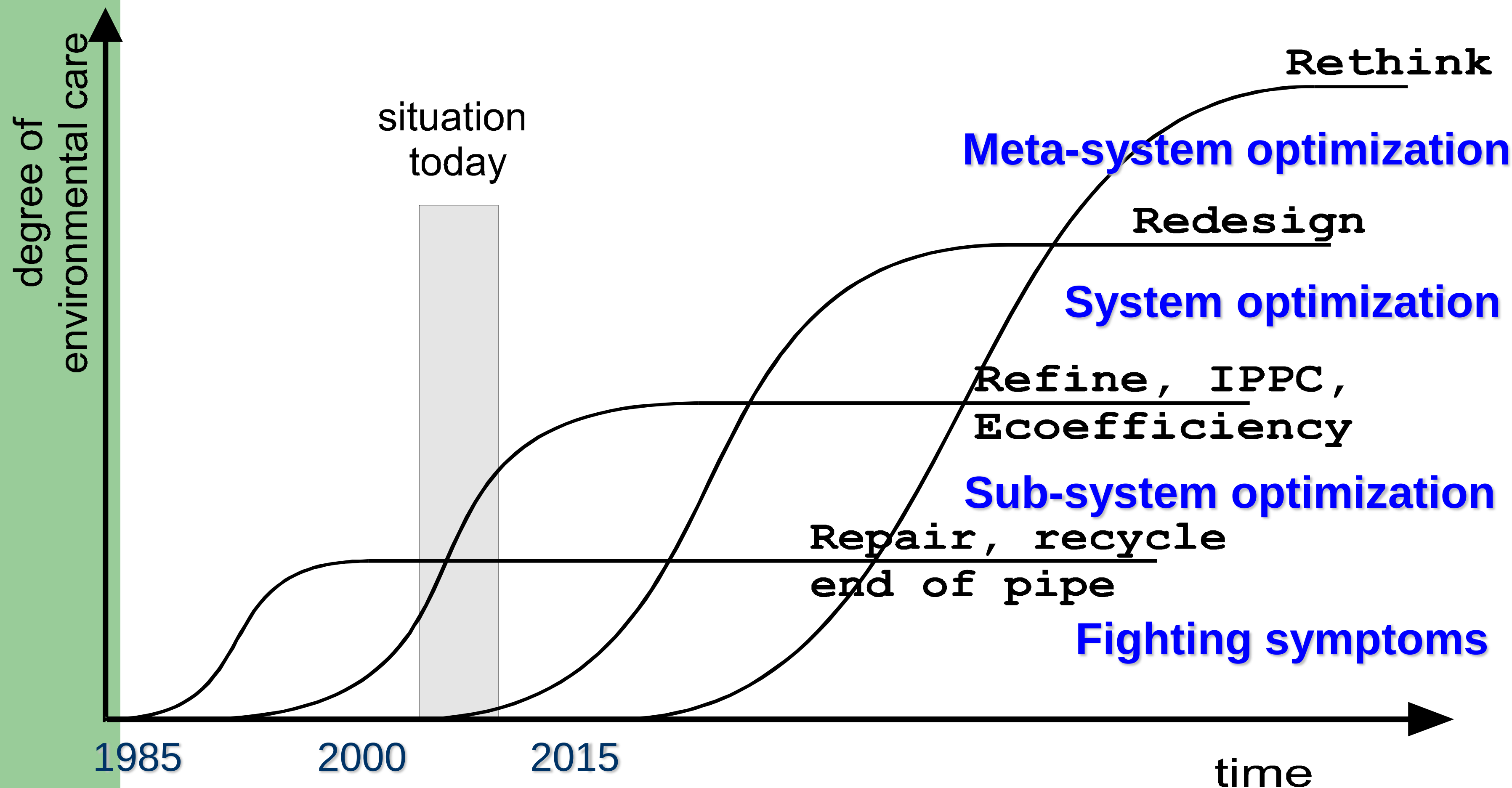
Eco-efficiency, IPPC, CP



The shift from continuous improvements to redesign



The paradigm shift in environmental protection



European sustainable consumption and production policies

The great challenge faced by economies today is **to integrate environmental sustainability with economic growth and welfare by decoupling environmental degradation from economic growth and doing more with less**

This is one of the **key objectives** of the European Union, but the ***consequences of climate change*** and the ***growing demand for energy and resources*** are challenging this objective

Action Plan on Sustainable Industrial Production and on Sustainable Consumption and Production

On 16 July 2008, the European Commission proposed a list of actions for improving the overall environmental performance of products and helping consumers to buy more eco-friendly products.

The Action Plan on Sustainable Consumption and Production and Sustainable Industrial Policy:

presents the strategy of the Commission to support an integrated approach in the EU, and internationally, to further sustainable consumption and production and promote its sustainable industrial policy

This strategy complements existing policies on energy use, notably the energy and climate package adopted by the Commission in January 2008.

The **Action Plan on Sustainable Consumption and Production and Sustainable Industrial Policy details the planned actions**:

- eco-design standards for a wider range of products
- improved energy and environmental labelling
- incentives rewarding eco-friendly products
- green public procurement
- work with retailers and consumers
- support to eco-innovation and environmental industries
- action to promote sustainable industry and production internationally.

Competitive and Sustainable Production Systems in Europe

The results of a 15-member independent expert group working in the frame of the **Growth** Programme show how **research, technology development and innovation (RTD&I) policies and actions** can contribute **to competitive and sustainable production systems in Europe in the period to 2020.**

De-coupling environmental impacts of products from functional performance and value-added

Today

• the European system of production is not sustainable
• current trends in modernization run the risk of not leading to sustainability
• present EU policies and actions for *Research, Technological Development and Innovation (RTD&I)* will have to be radically re-addressed in order to achieve sustainable production

Support and foster context-breaking approaches based on sufficiency

Institutional, organizational and managerial **deficiencies must be overcome through changes in culture and approach** based on **re-assessment of material consumption.**

This will require a broader and more flexible set of policy instruments.

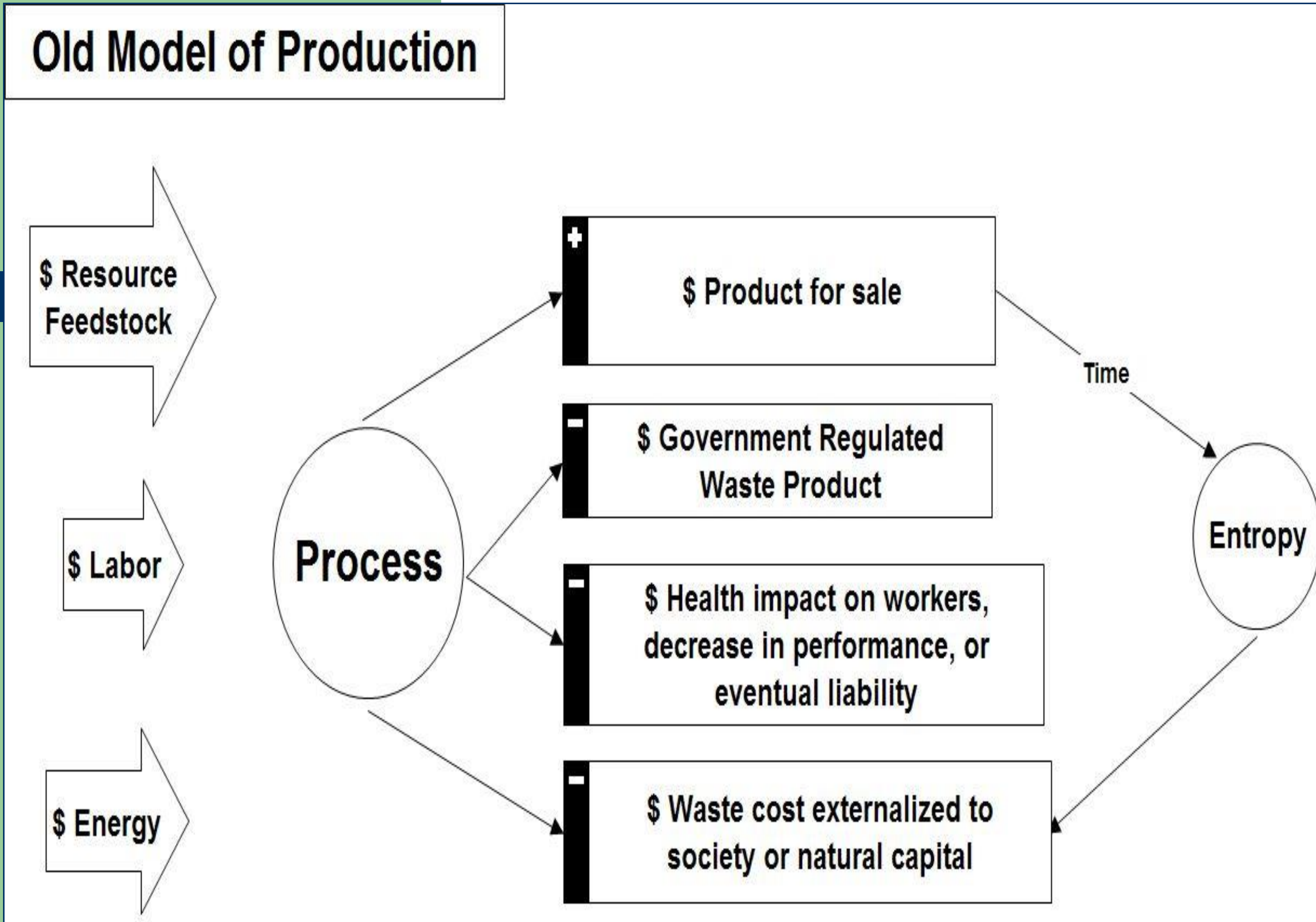
A framework based on concurrent processes in response to the present system RTD&I system

- generating ideas for innovative approaches in selected socio-technical systems
- understanding socio-technical systems
- resolving the barriers to change
- supporting enabling technologies
- engaging a variety of actors
- demonstrating and disseminating the processes and their outcomes.

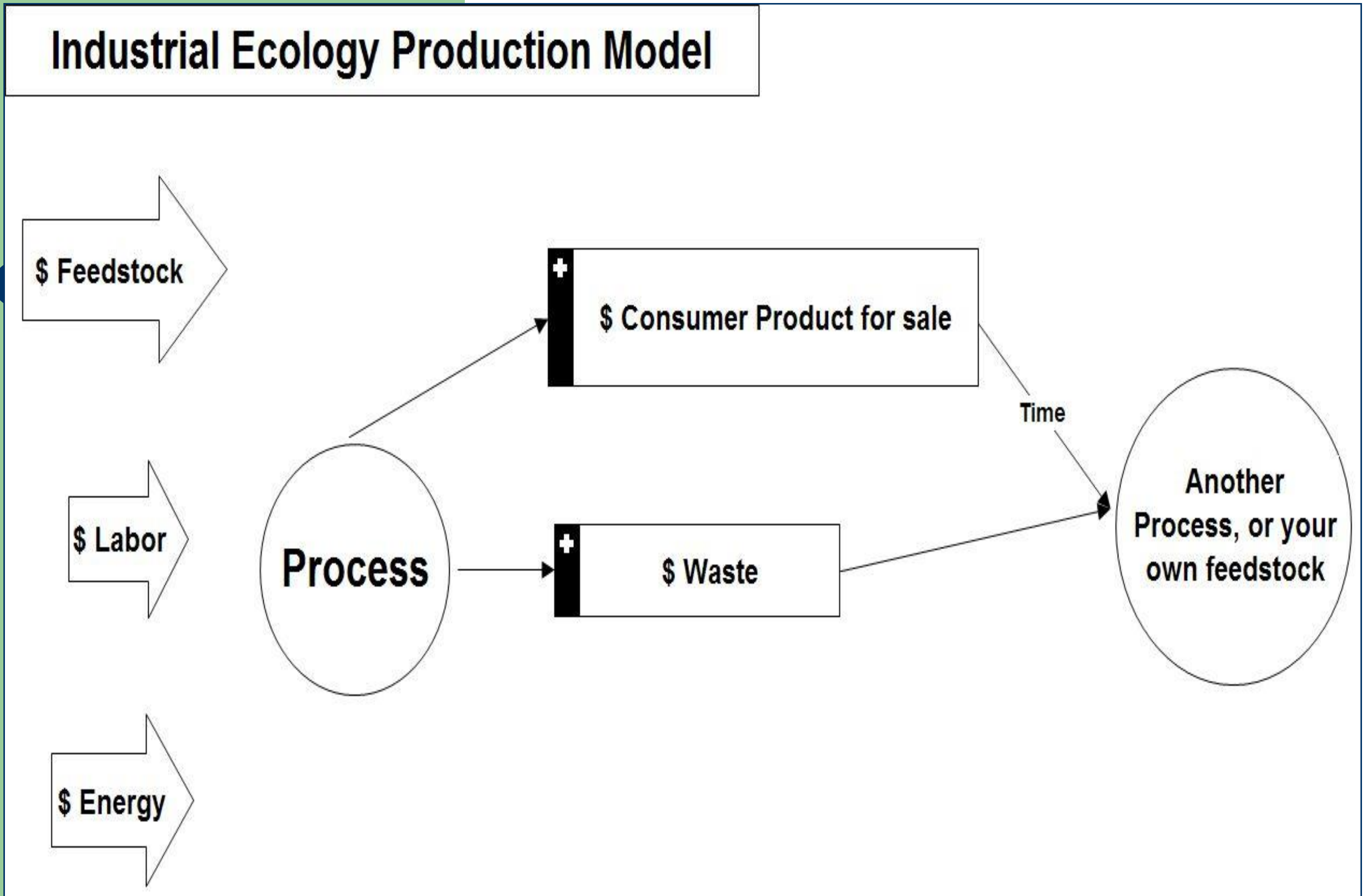
Clear opportunity for international collaboration through co-operation

… with other developed industrial economies as well as with developing economies and economies in transition, involving support and commitments to capacity building towards sufficiency strategies and context-*breaking pathways.*

All these measures should change the actual industrial system structure to a sustainable one .



Unsustainable model of production

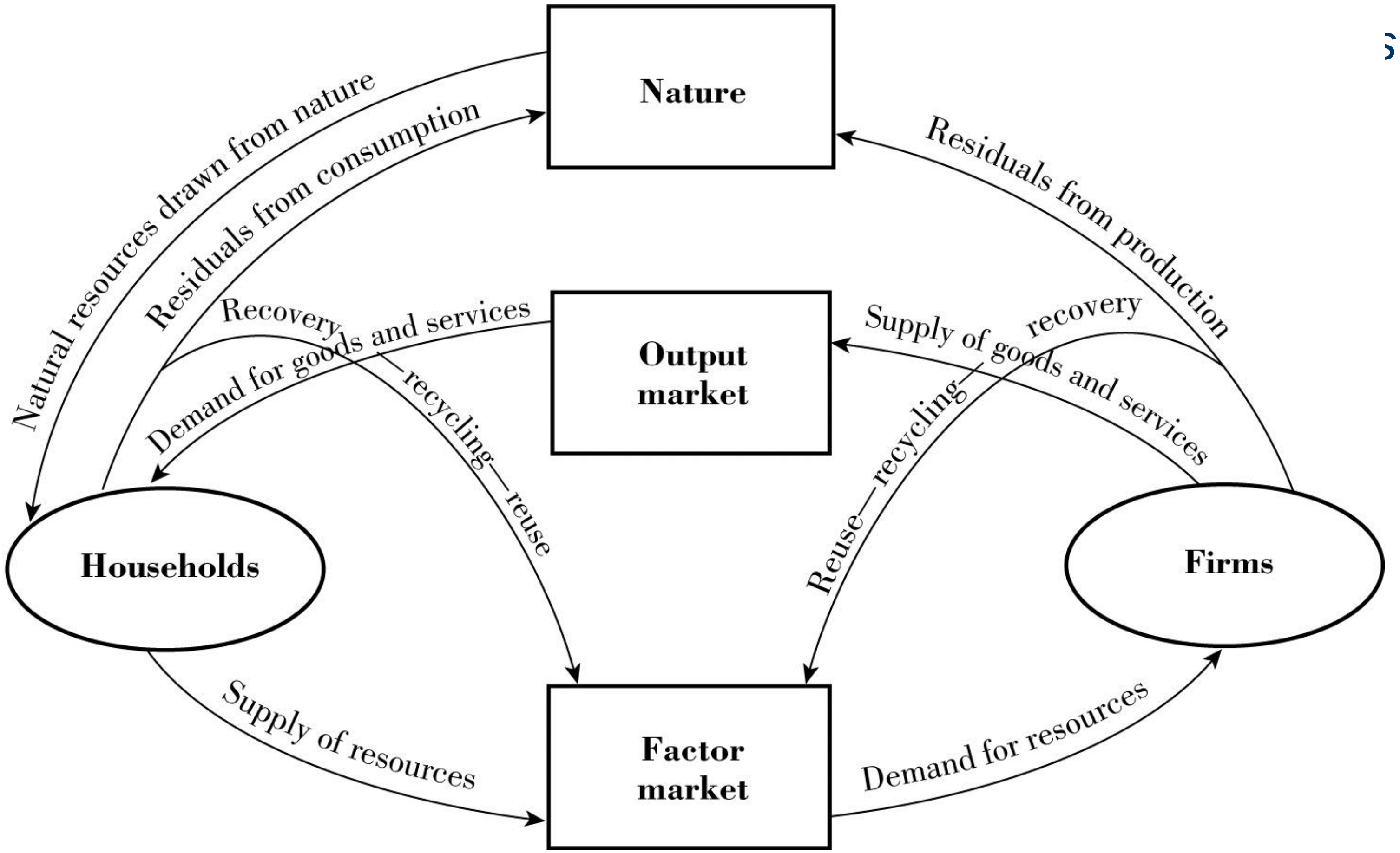


Sustainable production model, according to Industrial ecology principles

Industrial Ecology: A Systems Approach to Sustainable Development

- What Is Industrial Ecology?
  - **Industrial Ecology** – a multidisciplinary systems approach to the flow of materials and energy between industrial processes and the environment

Industrial Ecology: A Systems Approach to Sustainable Development



Two definitions

Biological ecology ”The study of the distribution and abundance of organisms and their interactions with the physical world”.

Industrial ecology ”The study of technological organisms, their use of resources, their potenial environmental impacts, and the ways in which their interactions with the natural world could be restructed to enable global sustainability”.

Industrial Ecology is a dynamic systems-based framework
that enables management of human activity on a sustainable basis by:

•Minimizing energy and materials usage

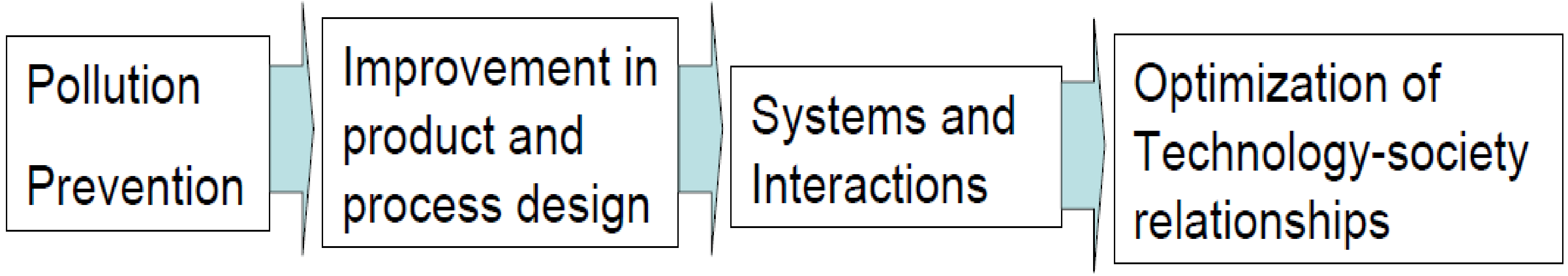
•Ensuring acceptable quality of life for people !

•Minimizing the ecological impact of human activity to levels natural systems can sustain

•Conserving and restoring ecosystem health and maintaining biodiversity

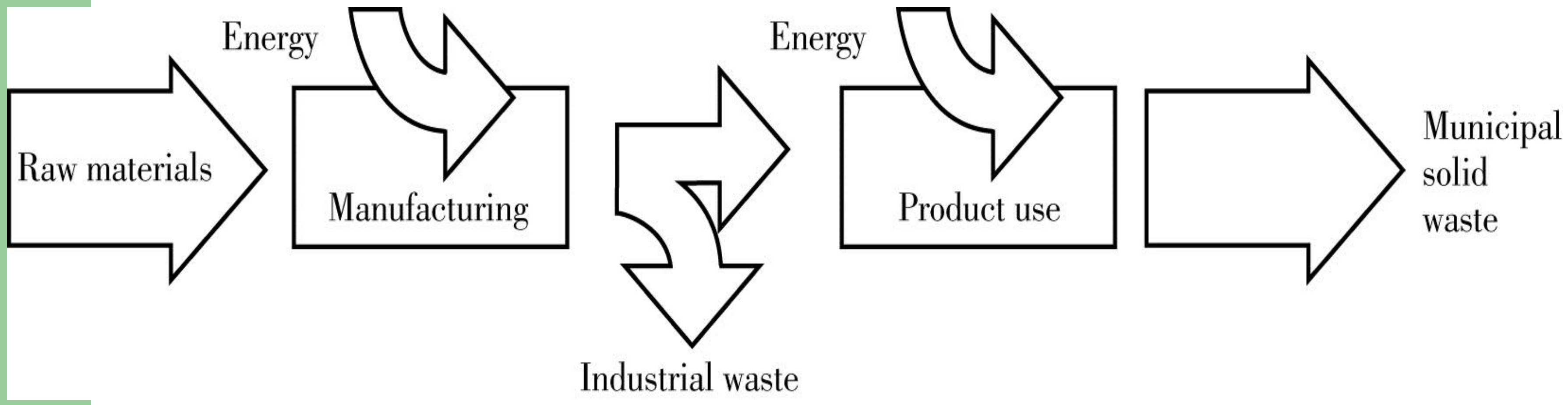
•Maintaining the economic viability of systems for industry, trade and commerce.

Industrial ecology evolution



Industrial Ecology: A Systems Approach to Sustainable Development

Conventional Linear Perspective of Materials Flow

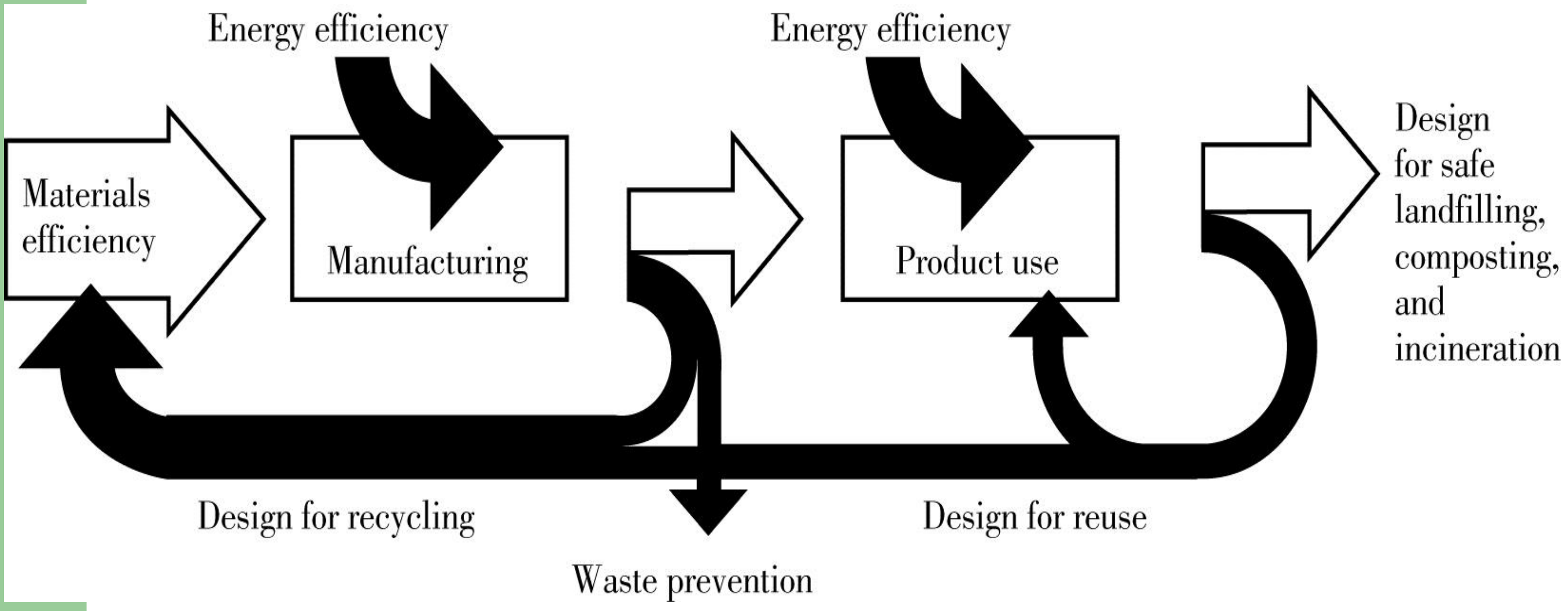


Industrial Ecology: A Systems Approach to Sustainable Development

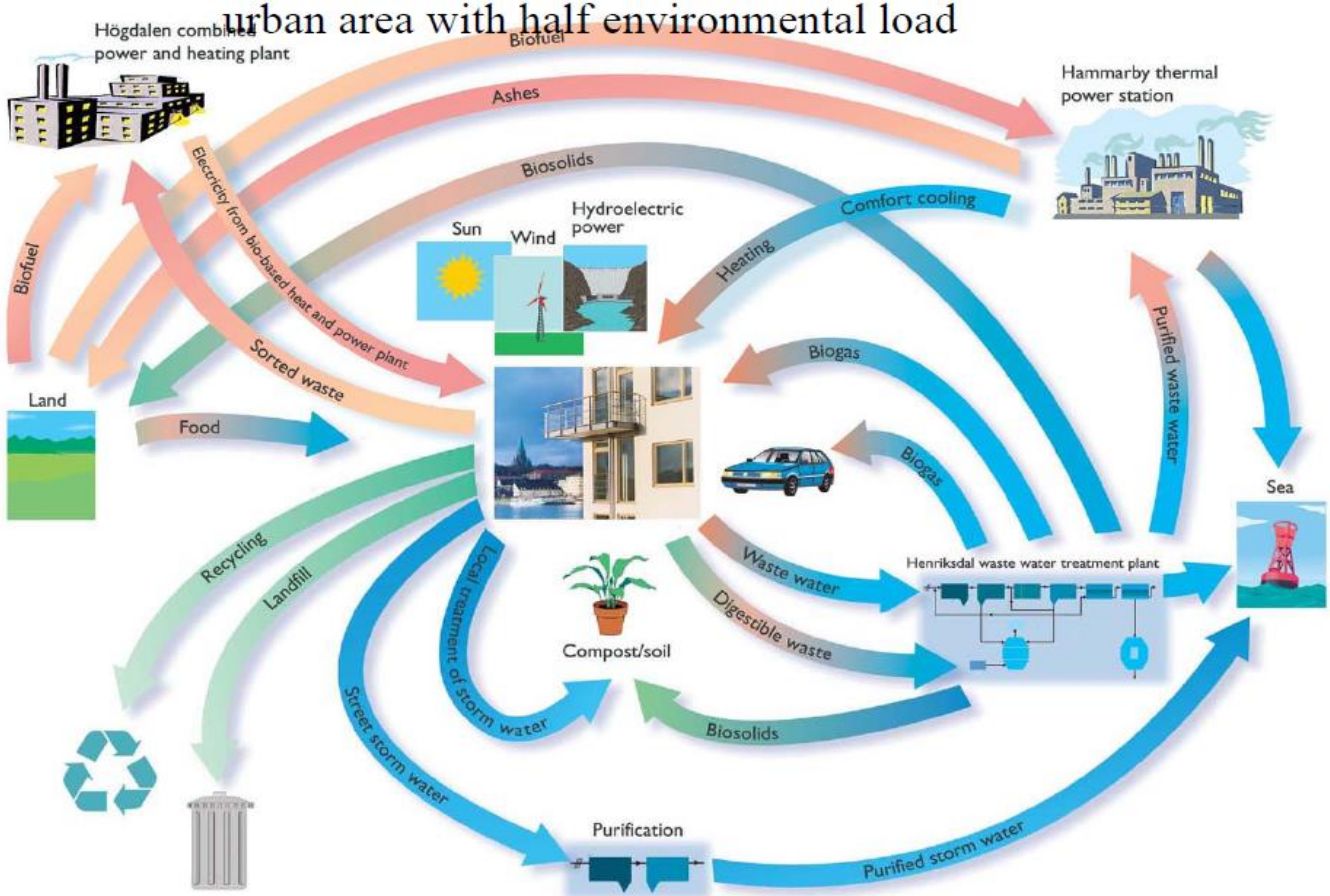
- **Cyclical or Closed Materials Flow: Cradle to Cradle**
  - Cyclical flow of materials – assumes that materials run in a circular pattern in a closed system, allowing residuals to be returned to the production process

Industrial Ecology: A Systems Approach to Sustainable Development

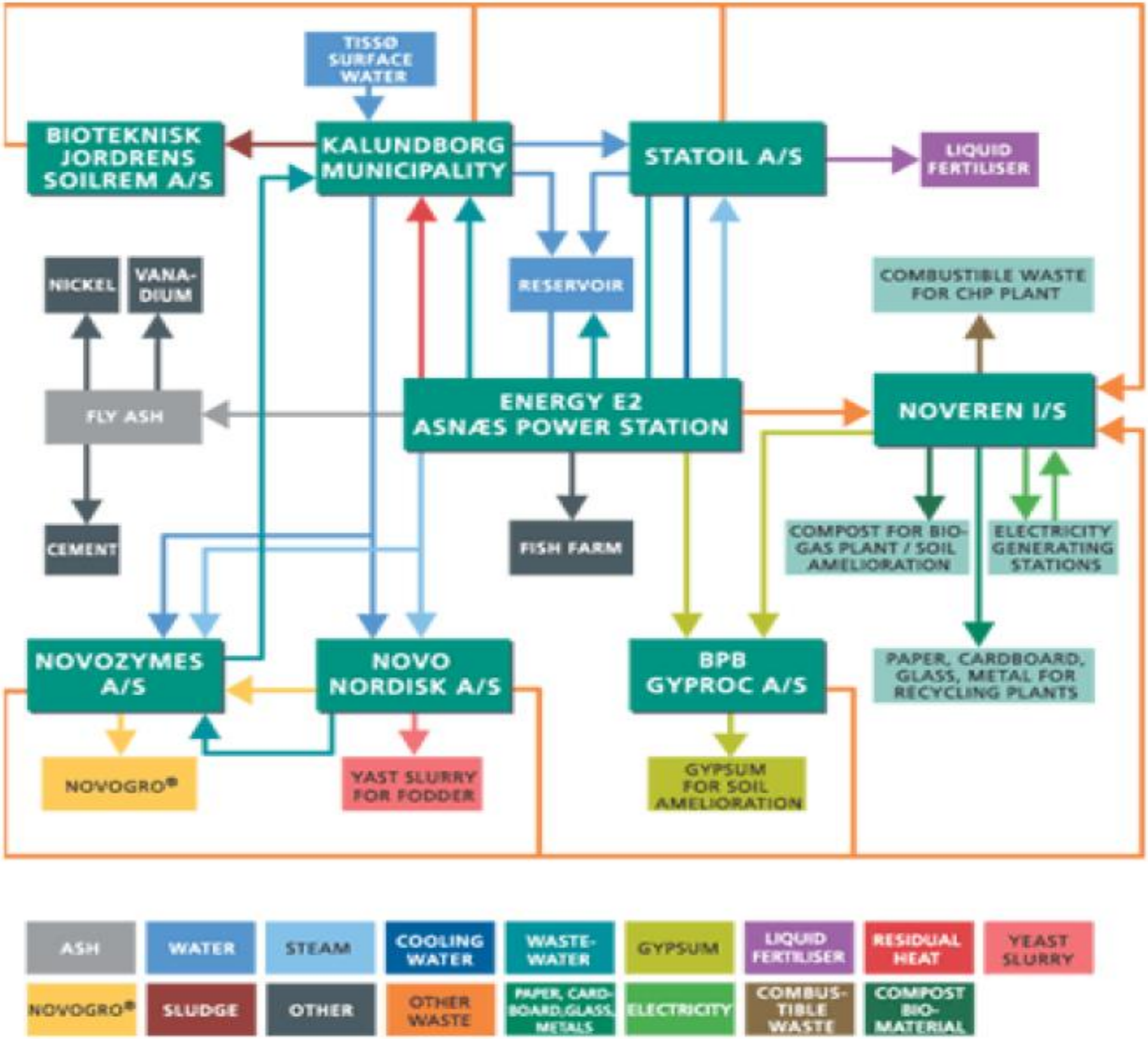
Moving Toward a Closed System of Materials Flow



An Industrial Ecology Model of a residential urban area with half environmental load



The Hammarby Model



Kalundborg industrial park

- **Comparing Pollution Prevention to Industrial Ecology**

  - P2 promotes risk reduction through minimizing or eliminating wastes while Industrial ecology argues in favor of using wastes as inputs in other production processes
  - P2 solutions are aimed at the single firm while industrial ecology is aimed at a network of businesses
  - P2 proposals considers efficiency a tool while industrial ecology views efficiency as an end itself

- **Objectives and Techniques in Pollution Prevention**

  - Source reduction – preventive strategies to reduce the quantity of any hazardous substance, pollutant, or contaminant released to the environment at the point of generation
  - Toxic chemical use substitution – the use of less harmful chemicals in place of more hazardous substances
  - Raw materials substitution – the use of productive inputs that generate little or no hazardous waste

- Changes in manufacturing processes – the use of alternative production methods to generate less hazardous by-products
- Product substitution – the selection of environmentally safe commodities in place of potentially polluting products

- Corporate Experience with Pollution Prevention
  - **3M** Corporation launched Pollution Prevention Pays Program in 1975
  - **McDonald’s and Environmental Defense** collaboration – developed Waste Reduction Action Plan (WRAP) completed in 1991

Examples of tools in Industrial Ecology

LCA – Life Cycle Analysis
MIPS – Material Input per Unit Srvice
ERA – Environmnetal Risk Assessment
MFA – Material Flow Acounting
CERA – Cumulative Ebergy Requirement Analysis
IOA – Input-Output Analysis
LCC – Life Cycle Costing
TCA – Total Cost accounting
CBA – Cost-Benefit Analysis

- Using Economic Analysis To Implement Pollution Prevention
  - Cost-Effectiveness Criterion
  - Efficiency Criterion

Strategic Initiatives and Programs

- **Extended Product Responsibility** (EPR) – a commitment by all participants in the product cycle to reduce any life-cycle environmental impacts of products
  - More extensive approach than extended *producer* responsibility
  - All players in a product cycle are expected to participate

Strategic Initiatives and Programs

- **Design for the Environment** (DfE) – an initiative that promotes the use of environmental considerations along with cost and performance in product design and development

Strategic Initiatives and Programs

- **Green Chemistry Program** – an initiative that promotes the development and application of innovative chemical technologies to achieve pollution prevention

Strategic Initiatives and Programs

- Disseminating Information and Technology on a Global Scale
  - Technology Transfer – the advancement and application of technologies and strategies on a global scale
  - Environmental Literacy – awareness of the risks of pollution and natural resource depletion

The Dimensions of Industrial Ecology

- Science – Values - Policy process
  Justice-Equity, Cleaner-Production-Consumers choice
  The role of technology
  Democracy

- Time
  Present –Future

- Space
  Local – Regional – Global
  What should be sustainable?

- Sector
  Economy – Social – Environment (What is most important)
  Consumer – NGO – Company – Public sector

- Development

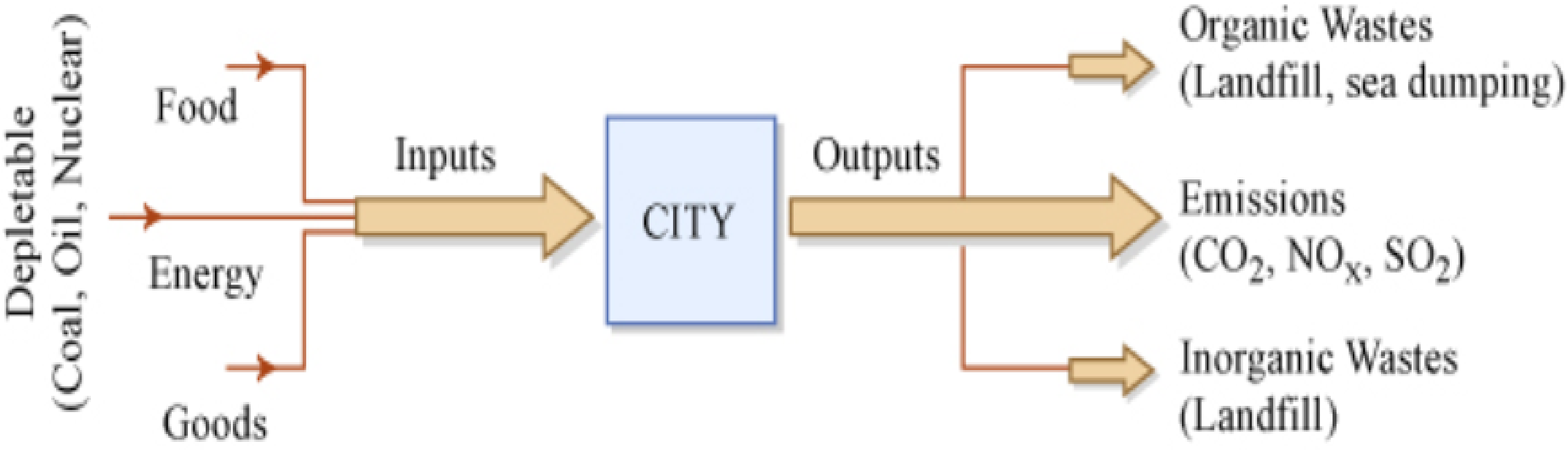
Implications of Sustainability for Industrial Ecology

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

"The fundamental task of Industrial Ecology is to … match the inputs and outputs of the man-made world to the constraints of the biosphere."
(Ernest Lowe, "Industrial Ecology – An organizing framework for environmental management, *Total Quality Environmental Management*, 73-85, Autumn 1993)

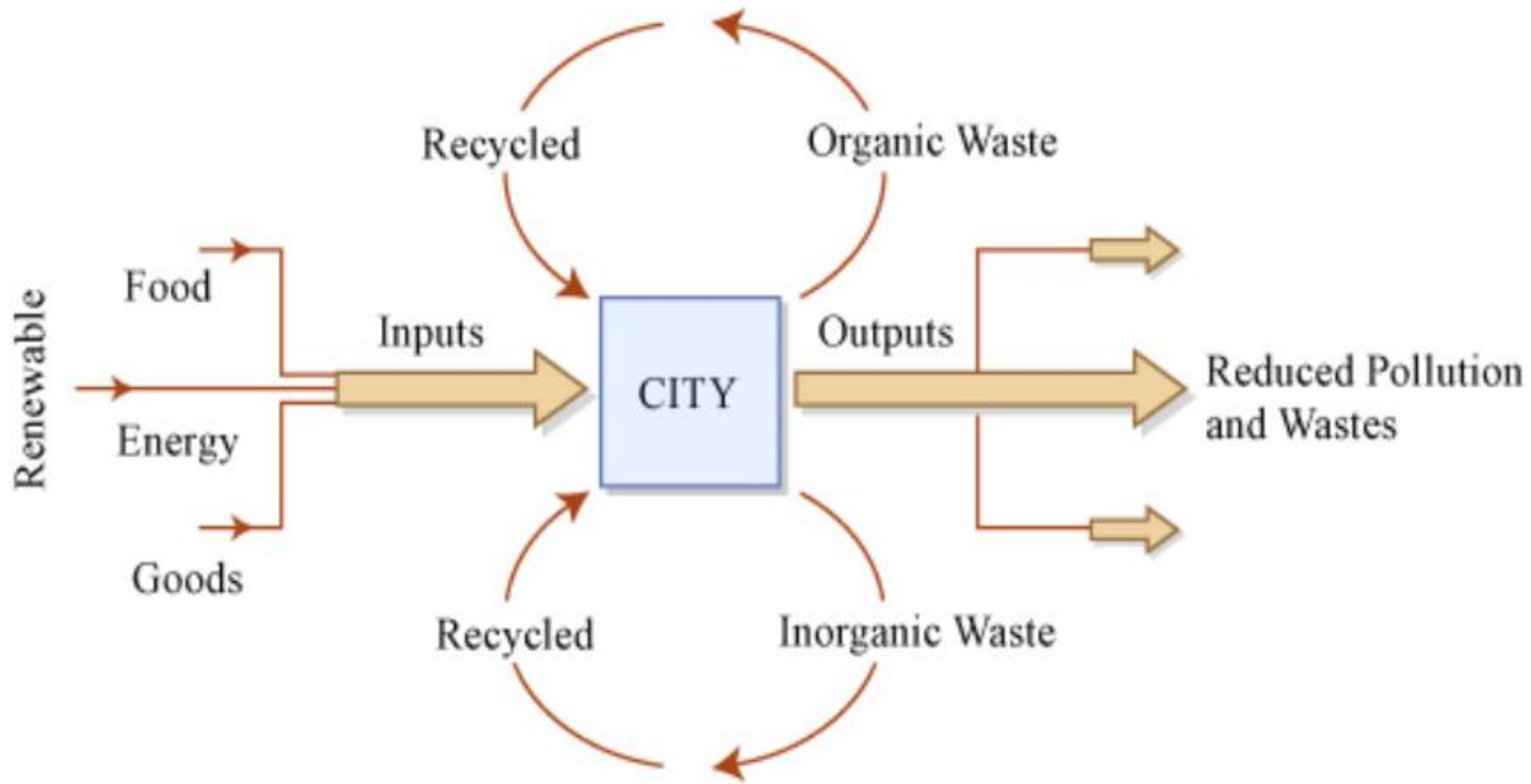
"The economy is a subsystem of the biosphere, not the other way around."
(David W. Orr, "Shelf Life", *Conservation Biology*, Volume 23, No. 2, 2009, quoting Herman Daly)

Unsustainable Linear Urban Metabolism



A) 'Linear metabolism' cities (consume and pollute at a high rate)

Sustainable Circular Urban Metabolism



B) 'Circular metabolism' cities (minimise new inputs and maximise recycling)


The Road To Sustainability
Impact Assessment
Risk Assessment
Risk Management
Benign by Design
WASTE MINIMIZATION
INTERSTATE
P2
Computer Modeling
Green Chemistry
CLEAN CATALYSTS
SEPARATION
CHNOLOGIES
Clean Products
CLEAN ENERGY
Renewable Sources
Electrochemistry
Solar, Wind, Biomass
SLOW
Roadwork Ahead
Systems Analysis
Life Cycle Assessment (LCA)
NRMRL/EPA