NPTEL ONLINE CERTIFICATION COURSES

# Introduction to Environmental Engineering and Science – Fundamentals and Sustainability Concepts


Dr. Brajesh Kumar Dubey
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IIT Kharagpur




## Sustainability Concepts – Innovations and Challenges

## CONCEPTS COVERED

# Week 1

- Sustainability Concepts and evolution
- Engineering for Sustainability
- Measuring Sustainability

# A bit about me…

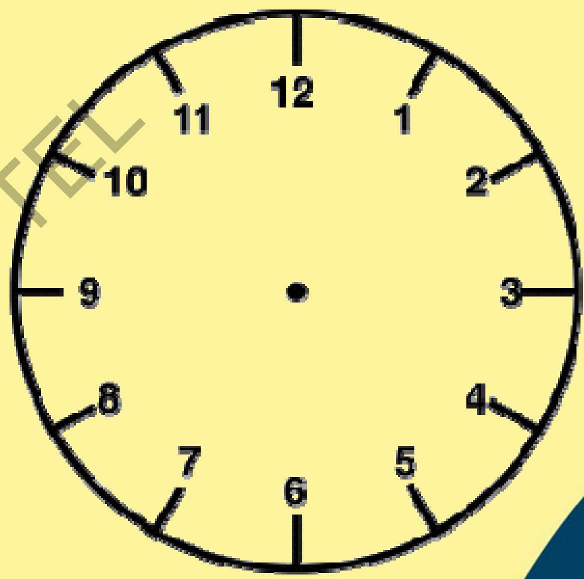
- Brajesh Kumar Dubey
  - B.Tech (Hons) in Civil Engg; IIT, Kharagpur, India
  - Worked as a consulting engineer at Engineers India Limited for 4 years, based in New Delhi
  - Graduate work leading to PhD from University of Florida in Environmental Engineering Sciences
  - Worked as Research Scientist in Florida for 2.5 years
  - Taught and did research in New Zealand (at UOA) for nearly 2 years
  - Worked as a Professor in USA and Canada for 6 years
  - Presently at IIT KGP since Mar 2015
  - http://scholar.google.ca/citations?user=gLXcah0AAAAJ
  - http://www.linkedin.com/pub/brajesh-dubey/0/883/716
  - https://twitter.com/wasteprof

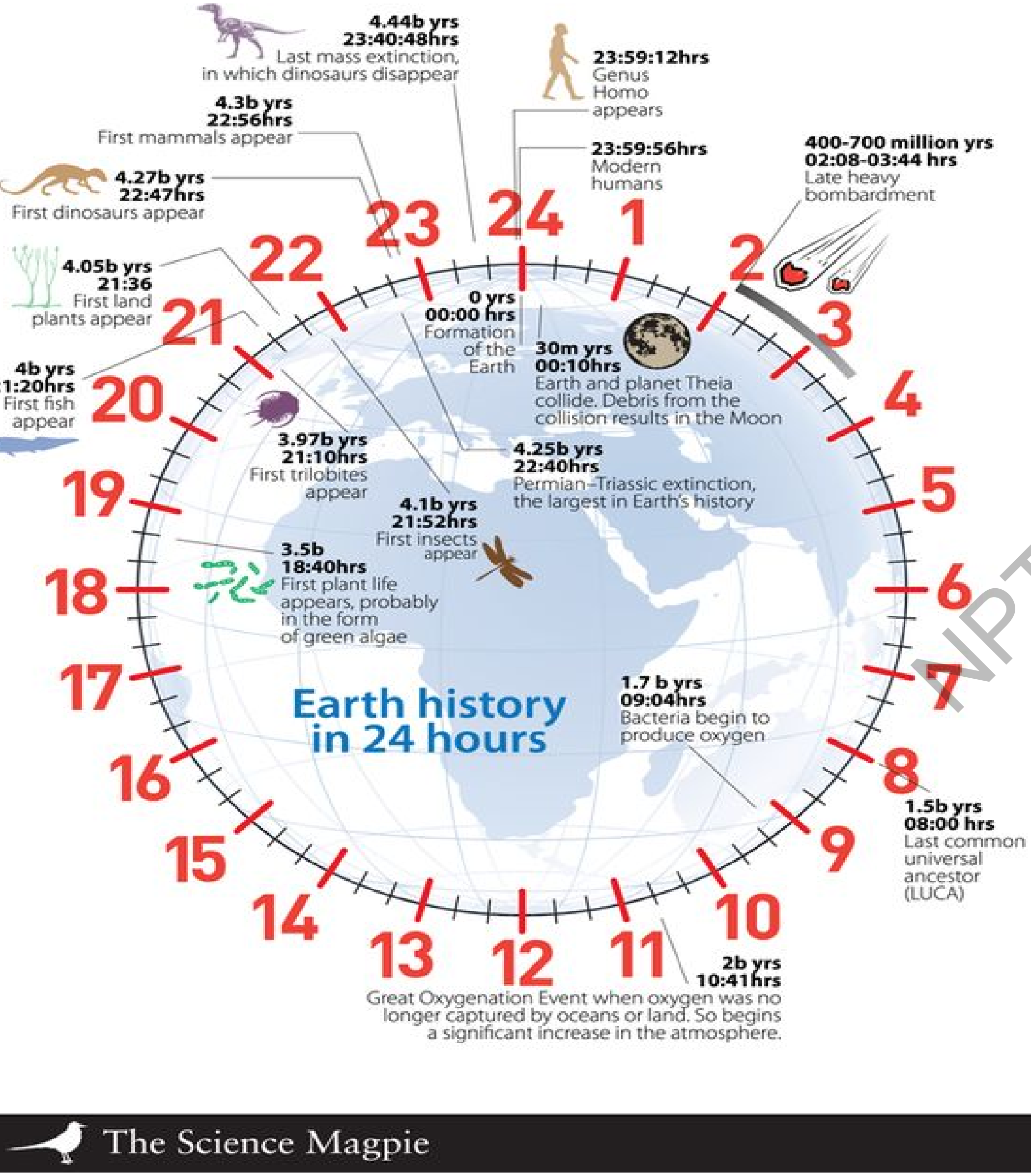
# Why Environmental Engineering and Science course?

- Supreme Court directive
- Sustainable Development
- India/Developing country
    - Demand of resources for development activity
    - Need to have a balanced approach with minimum impact on environment
- As a future engineer/professional in the country, you will have to make critical decisions related to development activities
- This course will provide you basic tools which will be helpful in making those decisions

# Humans on Earth

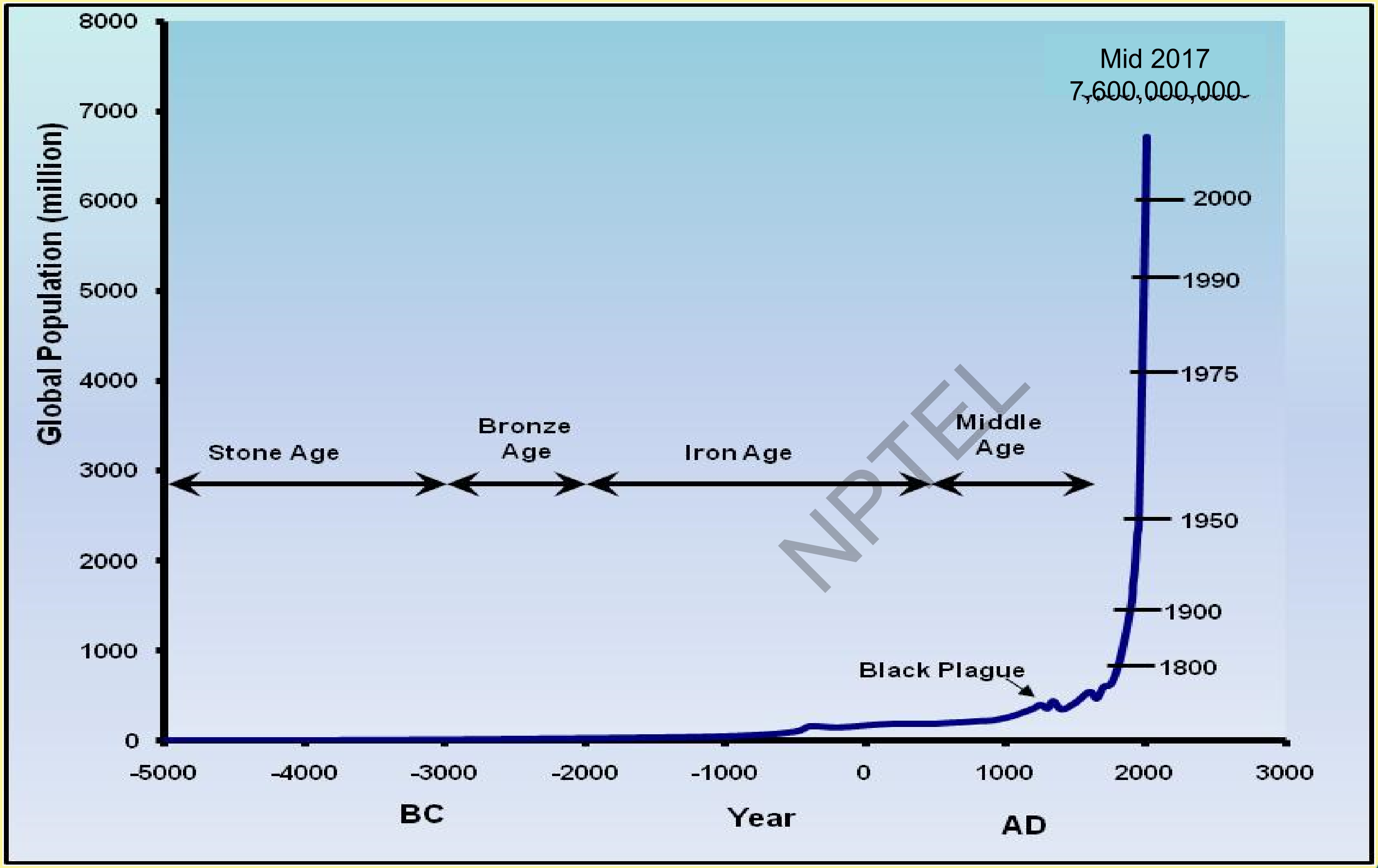
The Earth is 4.6 billion years old



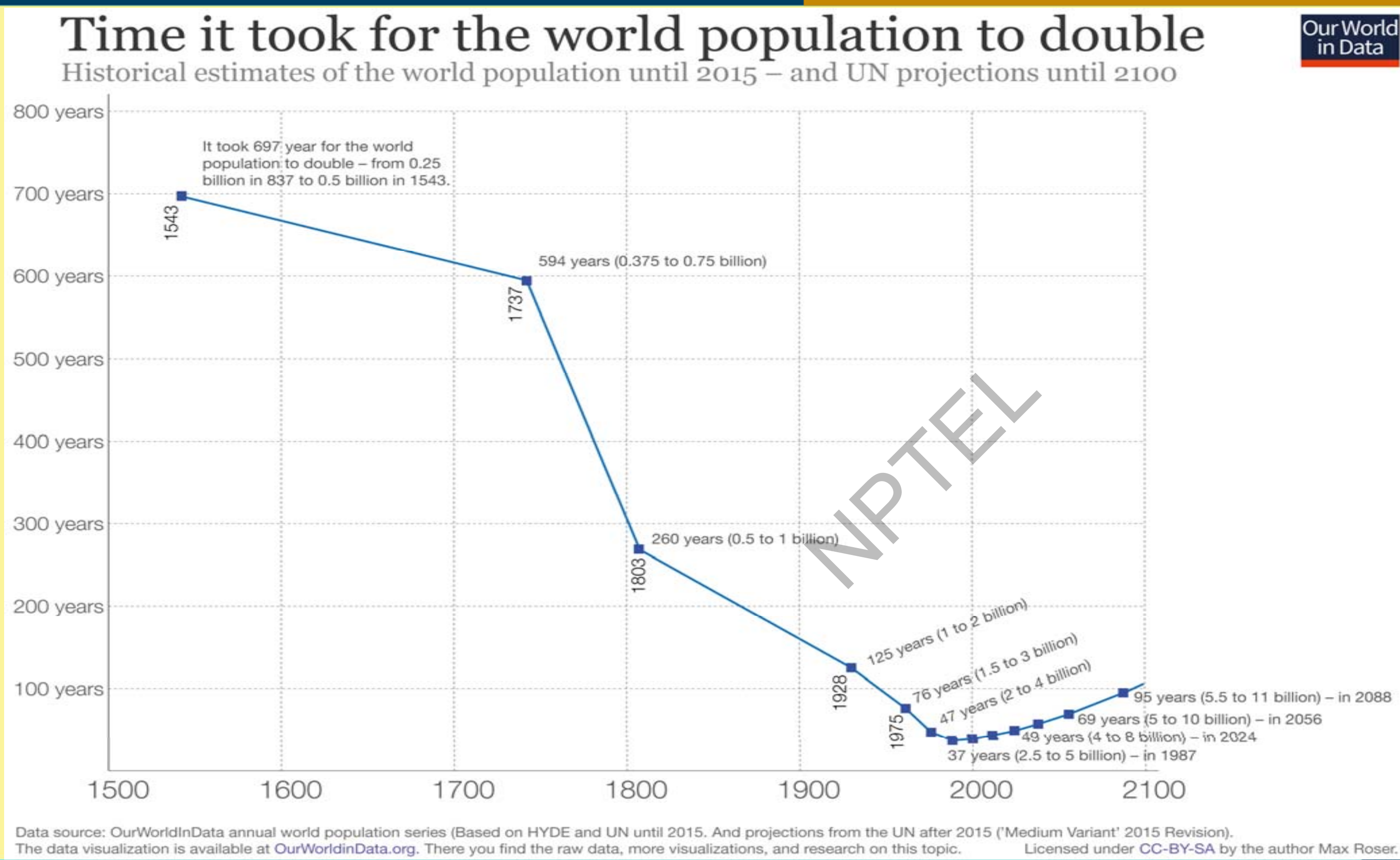


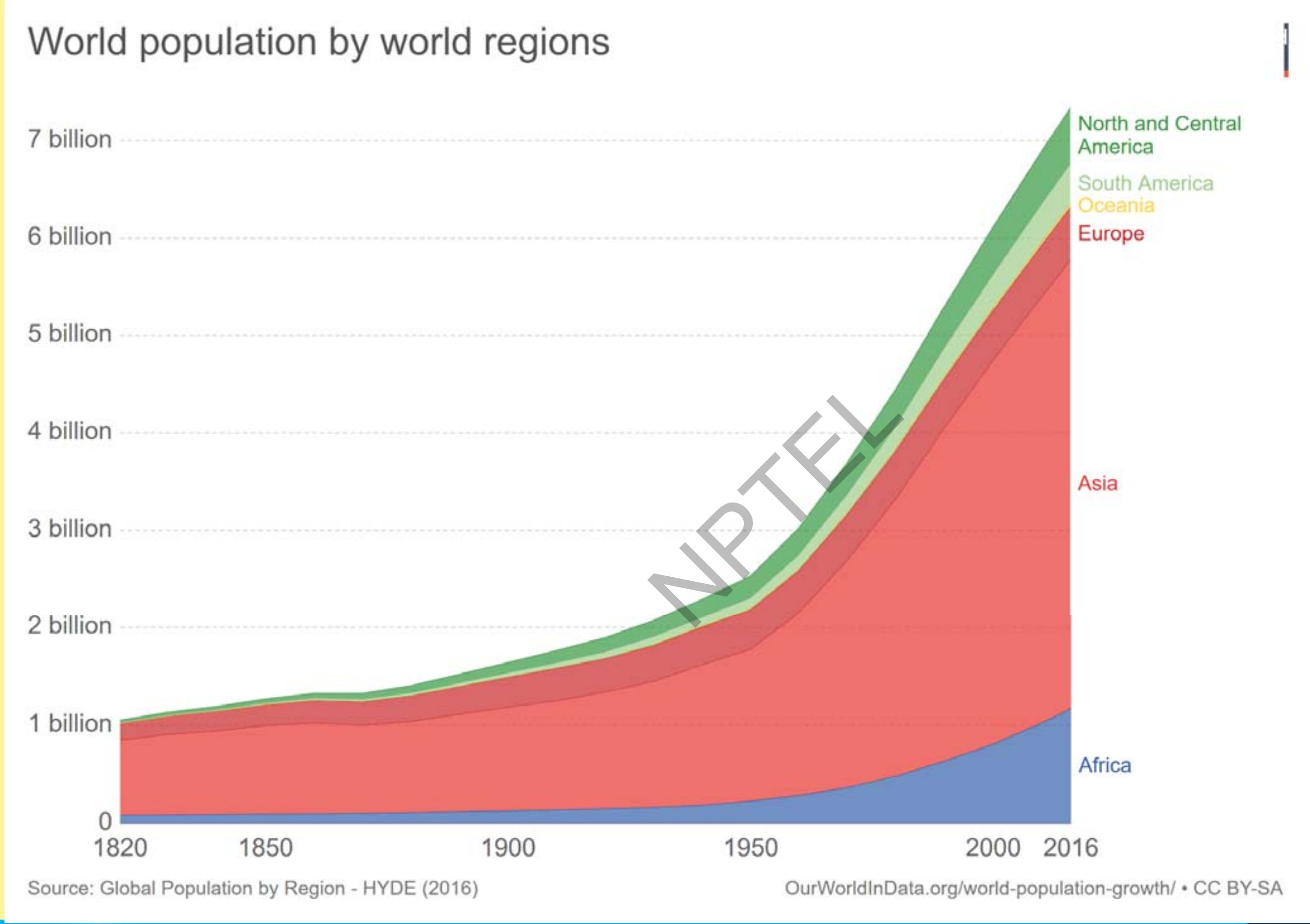

# Humans on Earth

1 second = 52,000 yr
1 minute = 3.125 Myr
1 hour = 187.5 Myr

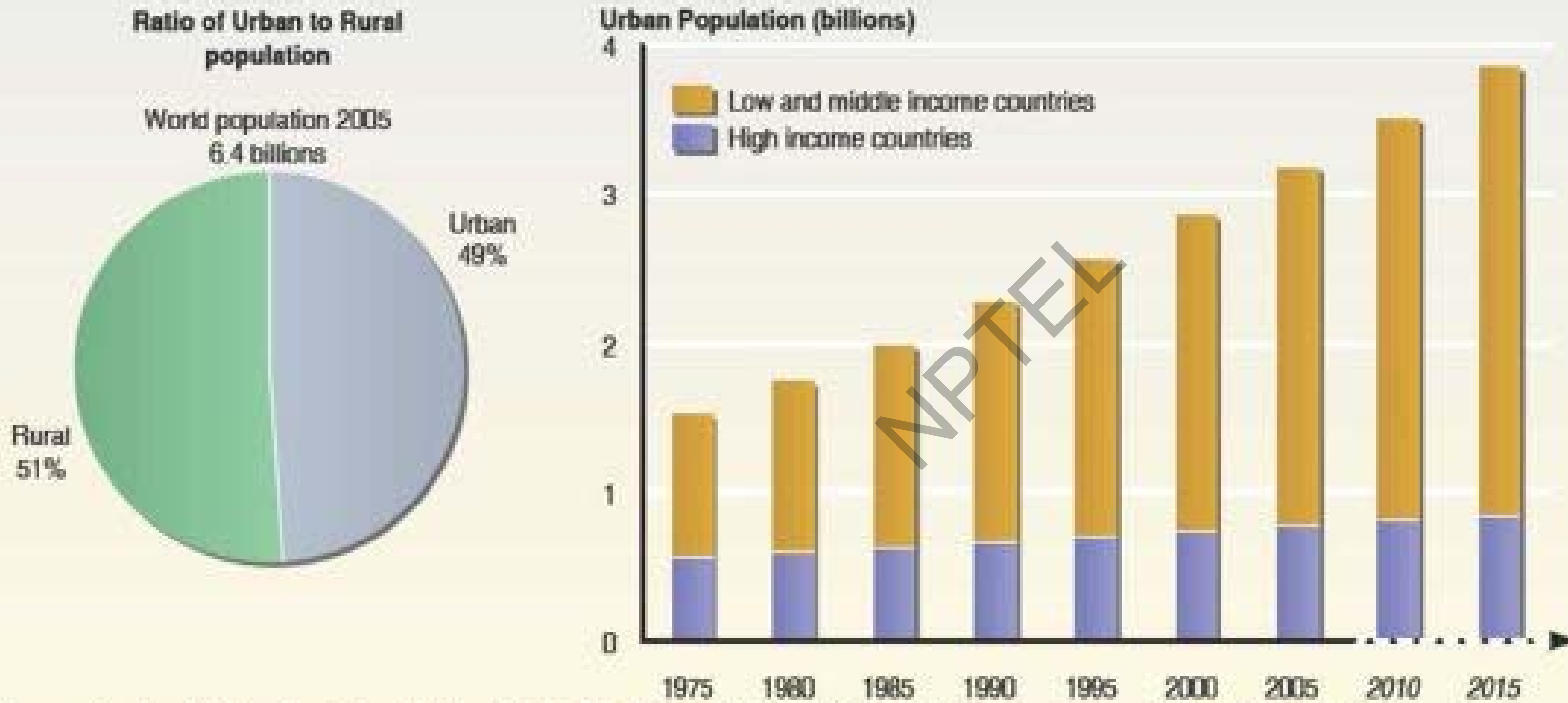


Mid 2017
7,600,000,000
Global Population (million)
8000
7000
6000
5000
4000
3000
2000
1000
0
Stone Age
Bronze Age
Iron Age
Middle Age
Black Plague
2000
1990
1975
1950
1900
1800
-5000
-4000
-3000
-2000
-1000
0
1000
2000
3000
BC
Year
AD


Time it took for the world population to double
Historical estimates of the world population until 2015 – and UN projections until 2100
Our World in Data
800 years
700 years
600 years
500 years
400 years
300 years
200 years
100 years
1500
1600
1700
1800
1900
2000
2100
It took 697 year for the world population to double – from 0.25 billion in 837 to 0.5 billion in 1543.
1543
594 years (0.375 to 0.75 billion)
1737
260 years (0.5 to 1 billion)
1803
125 years (1 to 2 billion)
1928
76 years (1.5 to 3 billion)
1975
47 years (2 to 4 billion)
37 years (2.5 to 5 billion) – in 1987
49 years (4 to 8 billion) – in 2024
69 years (5 to 10 billion) – in 2056
95 years (5.5 to 11 billion) – in 2088
Data source: OurWorldInData annual world population series (Based on HYDE and UN until 2015. And projections from the UN after 2015 ('Medium Variant' 2015 Revision).
The data visualization is available at OurWorldinData.org. There you find the raw data, more visualizations, and research on this topic.
Licensed under CC-BY-SA by the author Max Roser.
NPTEL


World population by world regions
7 billion
6 billion
5 billion
4 billion
3 billion
2 billion
1 billion
0
1820
1850
1900
1950
2000
2016
North and Central America
South America
Oceania
Europe
Asia
Africa
NPTEL
Source: Global Population by Region - HYDE (2016)
OurWorldInData.org/world-population-growth/ • CC BY-SA

# Urban population: status and trends




Sources: Food and Agriculture Organization statistical databases (FAOSTAT); Country income according to World Bank 2005.

# Urbanization

- ~1 % land surface BUT
- 60-70 % of anthropogenic greenhouse gas emissions
- Concentration of:
  - Population
  - Economic activities
  - Demand for food, energy, water, materials
- Urban areas drive global land use changes

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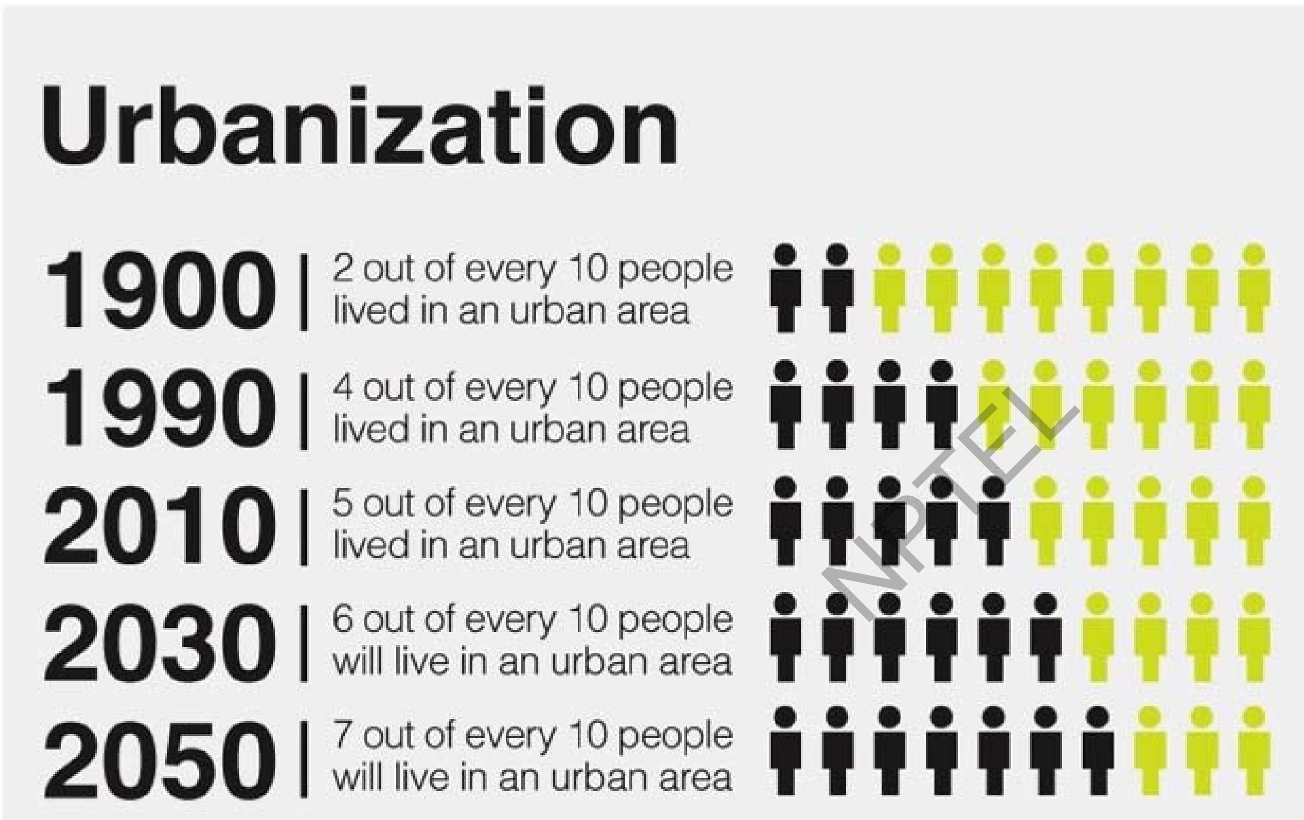
## Sustainability Concepts – Innovations and Challenges




Defined by UN HABITAT as a city with a population of more than 10 million

# Urbanization

Almost all population growth expected in cities & towns of developing countries. By 2050:

>70 % China's population urban

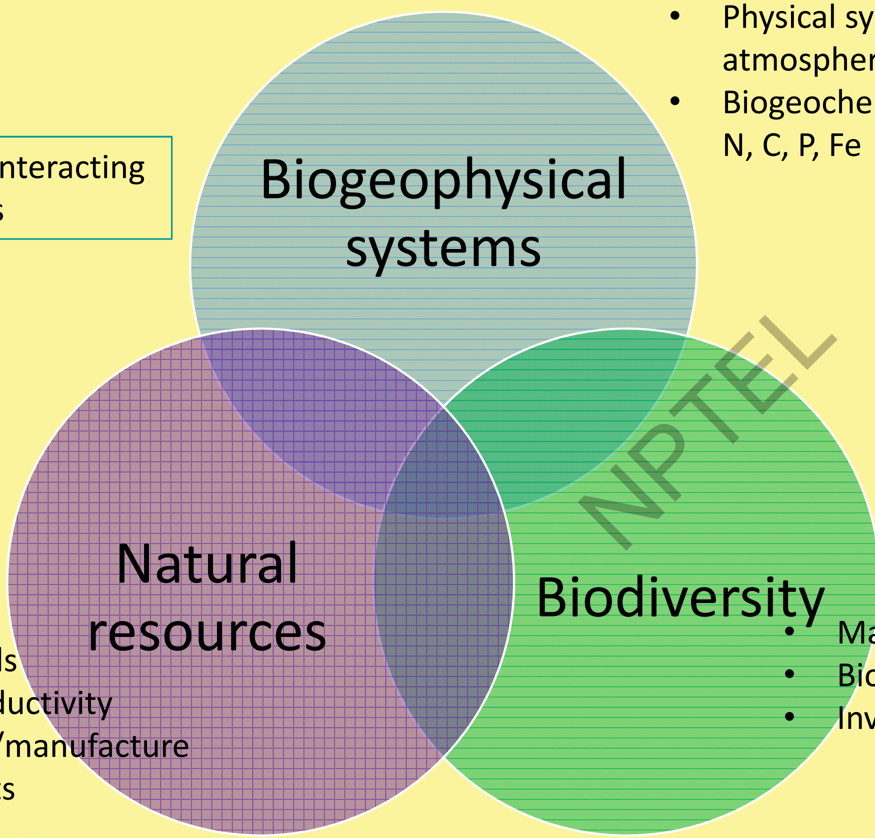
- China +30 cities >1 million people
- >50 % India's population urban
- India +26 cities >1 million people

Urban growth will require 100-200 million hectares (~equivalent to 2010 global urbanized area)

# Human Impacts on Environmental Systems

Complex & interacting components

- Physical systems – atmosphere/climate
- Biogeochemical cycles – N, C, P, Fe




- Water
- Minerals
- Fossil fuels
- Land productivity
- Pollution/manufactured products

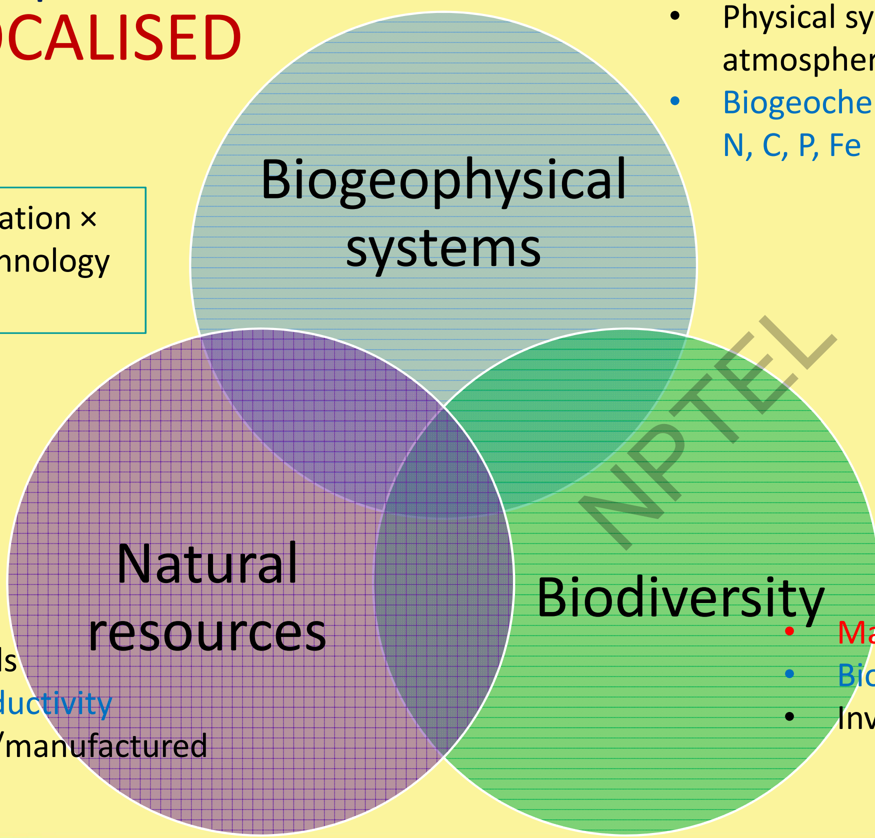
- Mass extinctions
- Biodiversity loss
- Invasive species

# Human Impacts Pre-Common ERA

## LOCALISED

- Physical systems – atmosphere/climate
- Biogeochemical cycles – N, C, P, Fe

impact = population × affluence × technology ($I = P \times A \times T$)






Global population steadily growing to ~200 million

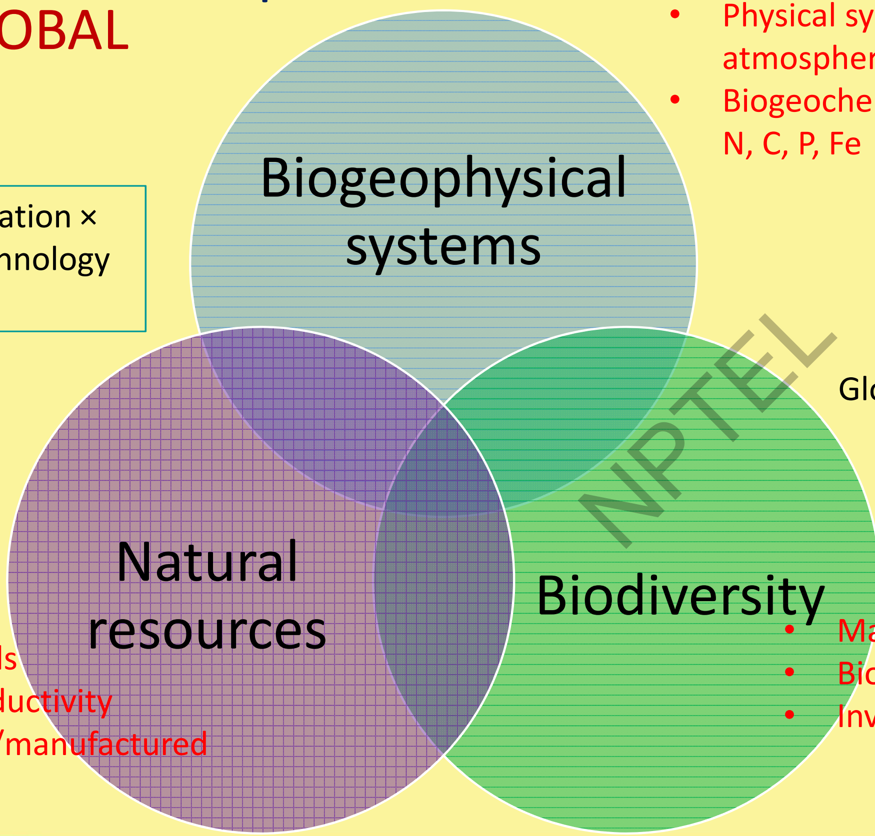
- Water
- Minerals
- Fossil fuels
- Land productivity
- Pollution/manufactured products

- Mass extinctions
- Biodiversity loss
- Invasive species

# Human Impacts Since 1800

## GLOBAL

impact = population × affluence × technology ($I = P \times A \times T$)

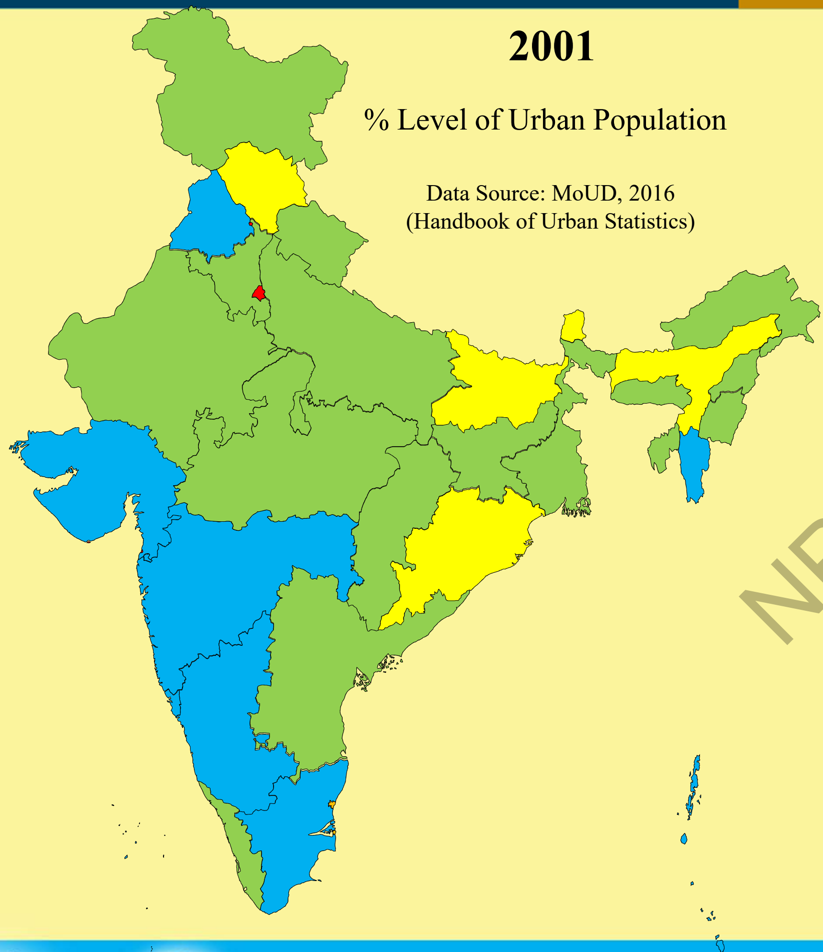



- Physical systems – atmosphere/climate
- Biogeochemical cycles – N, C, P, Fe

Global population growing exponentially to ~8 billion

- Water
- Minerals
- Fossil fuels
- Land productivity
- Pollution/manufactured products

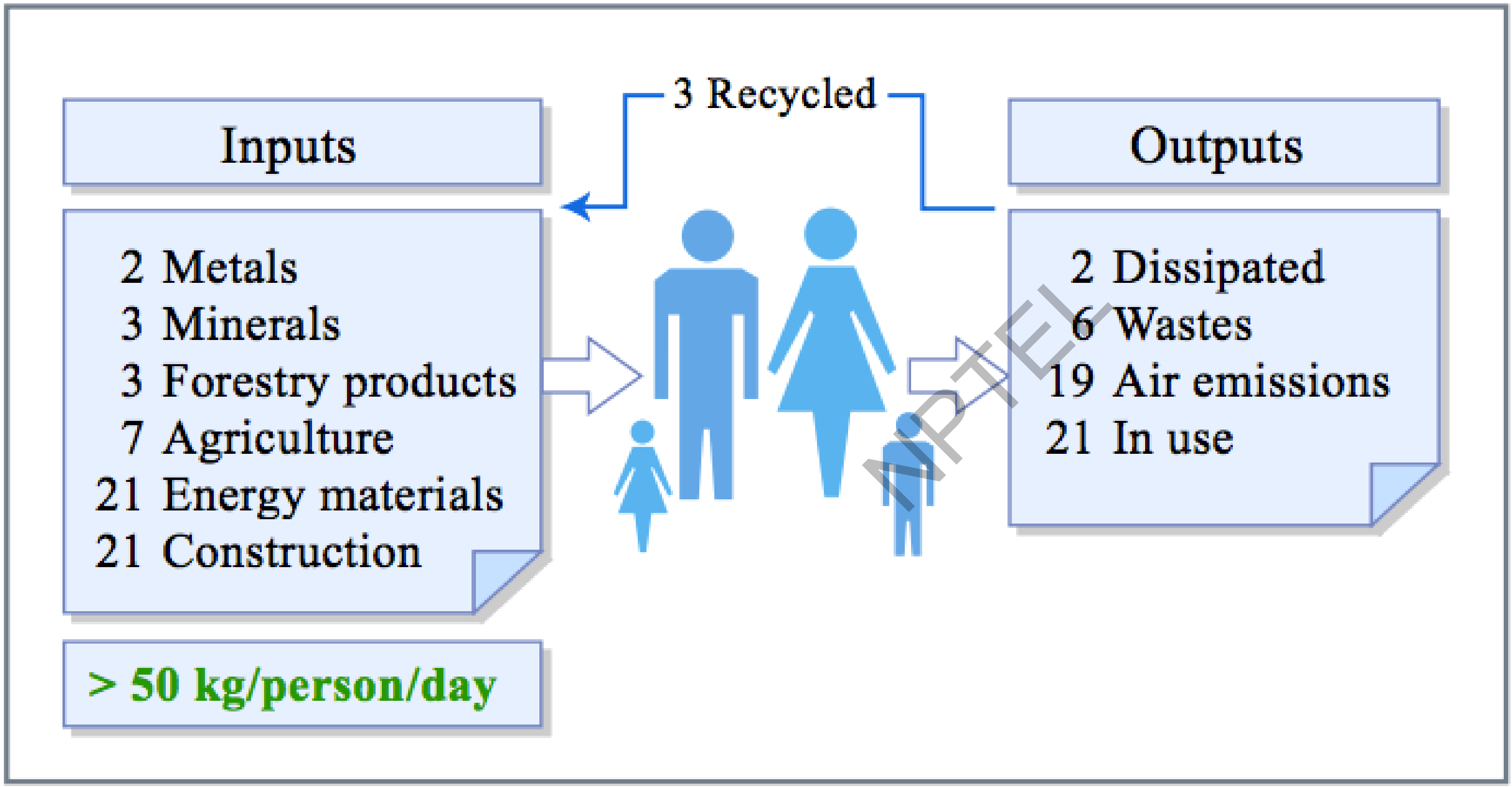
- Mass extinctions
- Biodiversity loss
- Invasive species





**MoUD:** *Ministry of Urban Development*

# How much do you use per day?



# Ecological Footprint

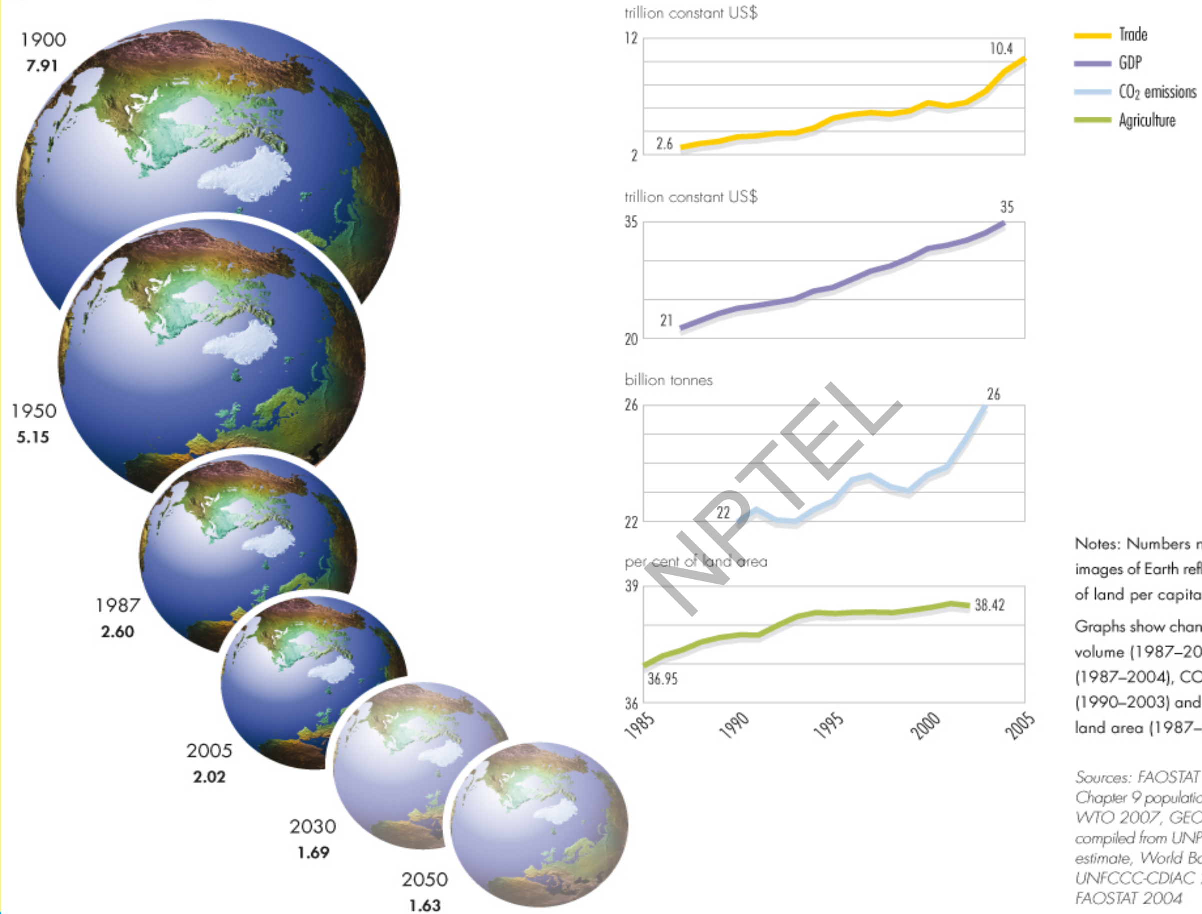
Ecological Footprint - the amount of land area and water required to produce sustainably the resources or ecological services needed to support a defined population at a set standard of living

- Vancouver - population 1.7 million

  ecological footprint - 19 times its area
- Netherland - 14 times its area
- Australia has one of the highest footprints at 6.25ha/person

http://www.wwf.org.au/our_work/people_and_the_environment/human_footprint/footprint_calculator/

**Figure 8.1 Our "shrinking" Earth**



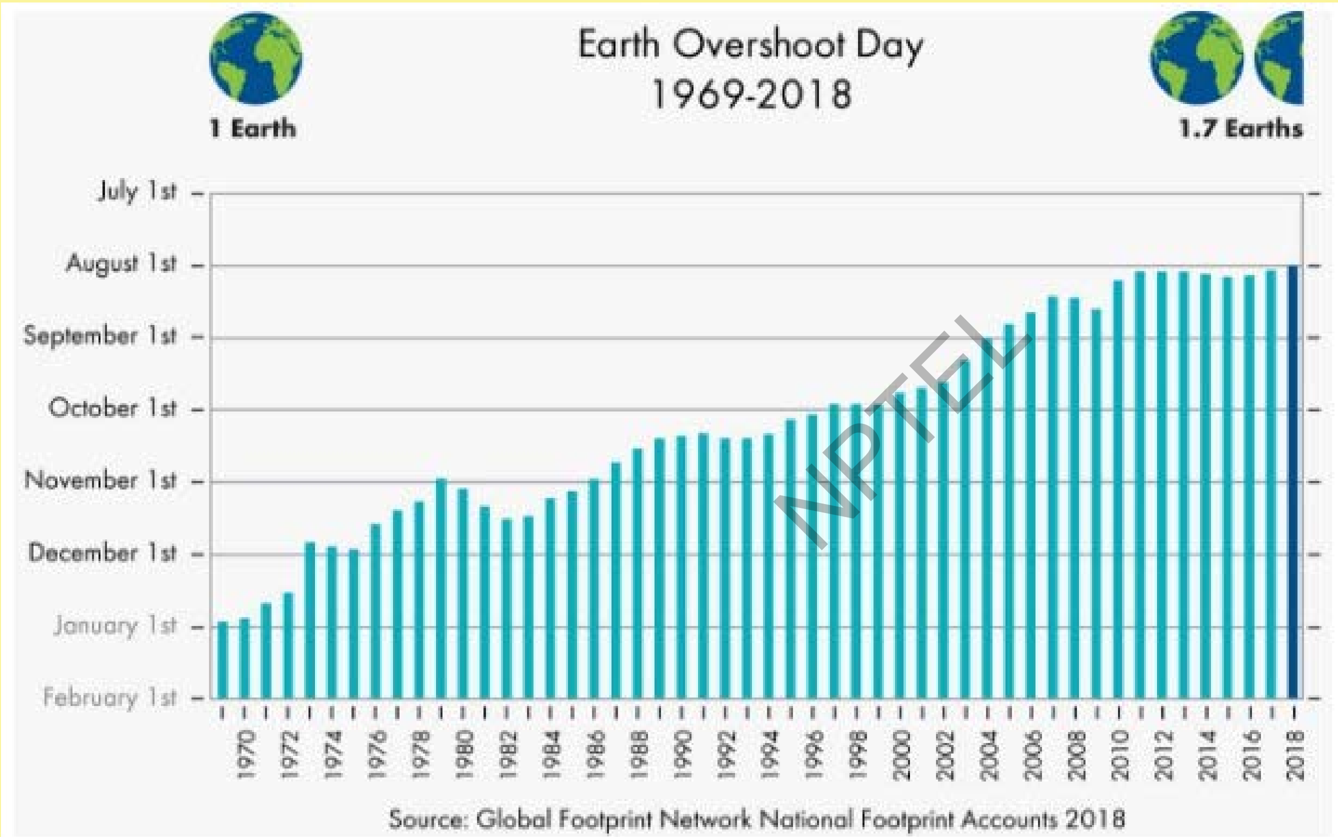



Notes: Numbers next to images of Earth reflect hectares of land per capita.

Graphs show changes in trade volume (1987–2005), GDP (1987–2004), $CO_2$ emissions (1990–2003) and agricultural land area (1987–2002).

*Sources: FAOSTAT 2006, Chapter 9 population projection, WTO 2007, GEO Data Portal compiled from UNPD 2007-low estimate, World Bank 2006a, UNFCCC-CDIAC 2006 and FAOSTAT 2004*

# Urbanization



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**Faculty Name: Dr. Brajesh Kumar Dubey**

**Department : Civil engineering**




## Sustainability Concepts – Innovations and Challenges

**Lecture 03:** Basics & Sustainability Concepts and evolution

CONCEPTS COVERED

# Week 1

- Sustainability Concepts and evolution
- Engineering for Sustainability
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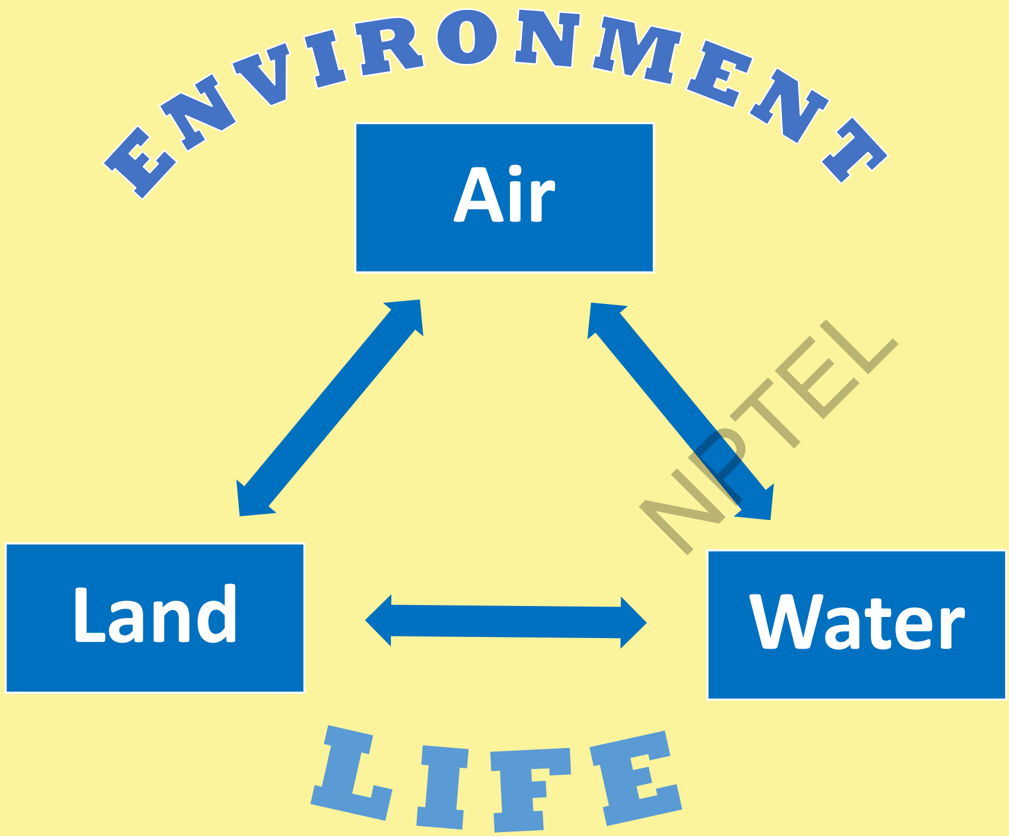
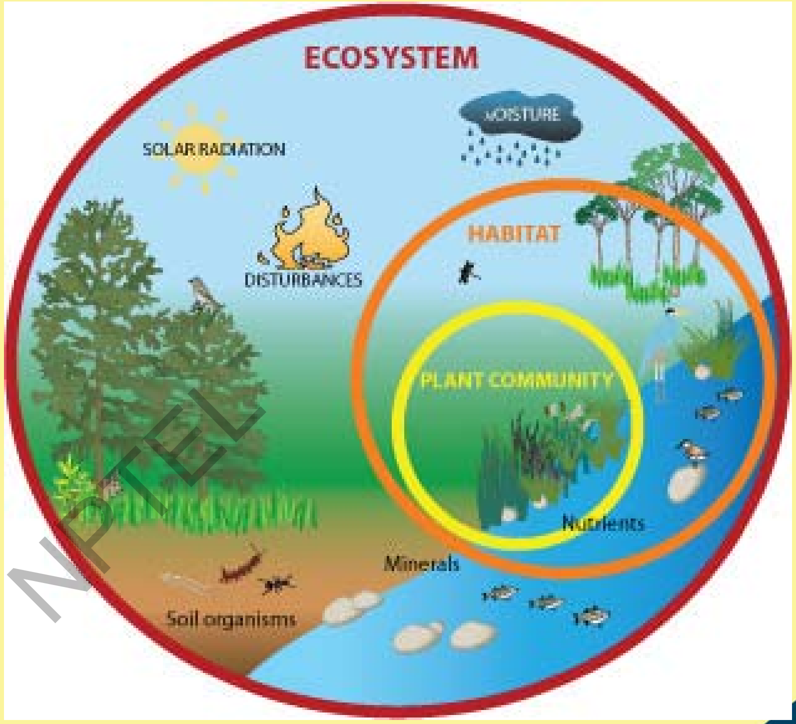


ENVIRONMENT
Air
Land
Water
LIFE

# Ecosystem

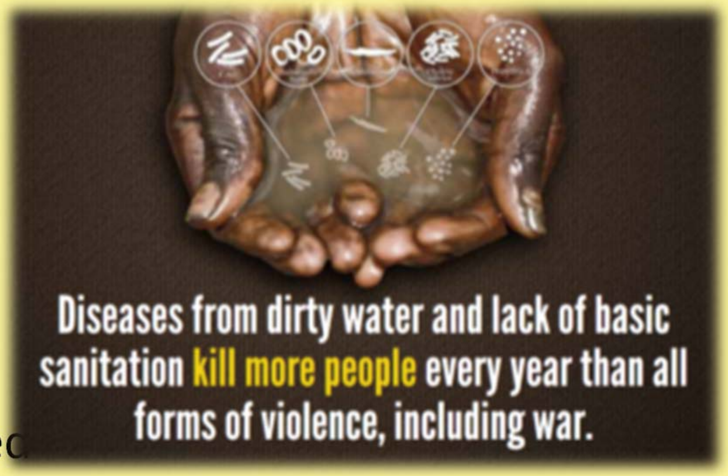
- Everything on earth is connected
  - Living and non-living things
  - Depend on each other
  - Affect each other
- Water, air, atmospheric conditions, plants, animals, soil are interlinked



# Water, Energy, Environment and Food Nexus

# Water and Health

- 80% of diseases in developing countries are due to the lack of access to clean potable water
- Pathogens transmitted through water
  - Kill 25 million people every year by amoeba linked diarrhea, cholera, and typhoid
  - ~3,900 children die EVERY DAY (WHO, 2004)
- 90% of 2.2 million deaths of children under 5
- The most effective management intervention
  - Providing safe drinking water and proper disposal of human waste




Picture is from charitywater.org

# Water and Health (contd.)

- Each year more than five million people die from water-related diseases.
  - A child dies from a water related disease *__every 15 seconds.__*
- 30 % of water-related deaths are due to diarrhea.
- 84 % of water-related deaths are in children age 0 – 14 years.
- 98 % of water-related deaths occur in the developing world.



www.water.org, Picture is from charitywater.org

•Copyright BAN (www.ban.org)


Copyright BAN
(www.ban.org)

# Why Study Environment ?

Fresh / Clean Resources

(Water, Air, Land, Minerals)

Resource Pollution

(Leads to severe impacts)



. or our survival, the maintenance of the environment is essential.

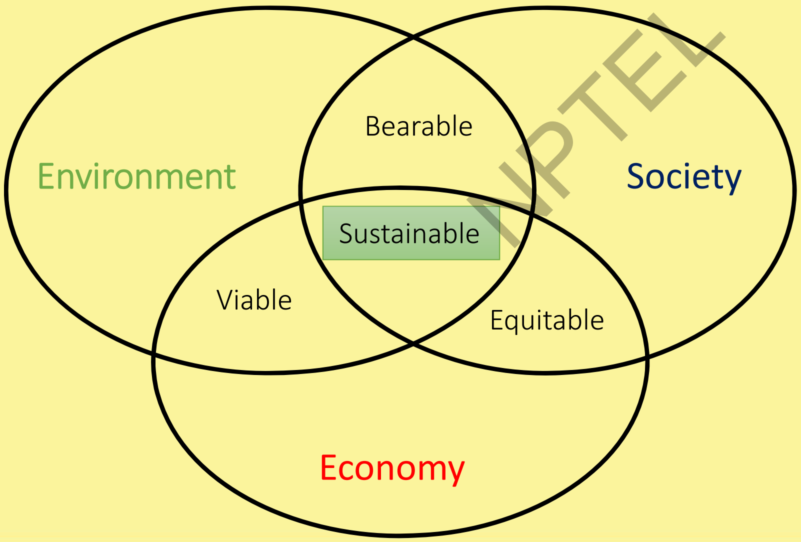
. or ealthy conomy, we need ealthy orkforce

# Defining Sustainability

- If you Google a word sustainability or sustainable development all of the definition refer to integrating the three elements of the triple bottom line (Environment , Economy and Society).

**Environment**
- Materials
- Biodiversity
- Energy
- Biophysical interactions

**Economy**
- Money and capital
- Employment
- Technological growth
- Investment
- Market forces




**Society**
- Human diversity (cultural, linguistic, ethnic)
- Equity (dependence / independence)
- Quality of life
- Institutional structures and organization
- Political structures

# Defining Sustainability

- **Sustainability**

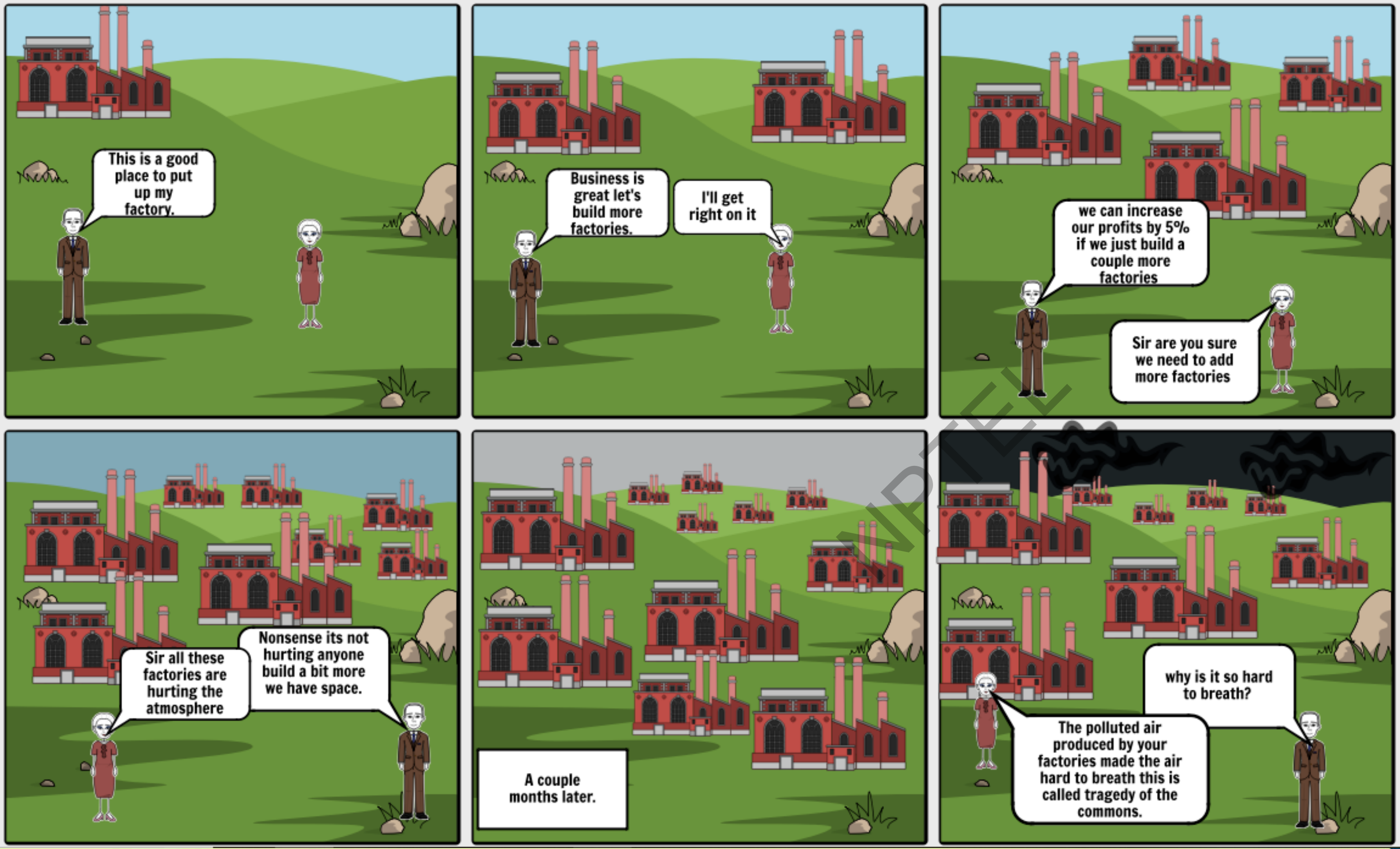
  Merriam –Webster definition: (1) of , relating to , or being a method of harvesting or using a resource so that the resource is not depleted or permanently damaged.

- **Sustainable Development**

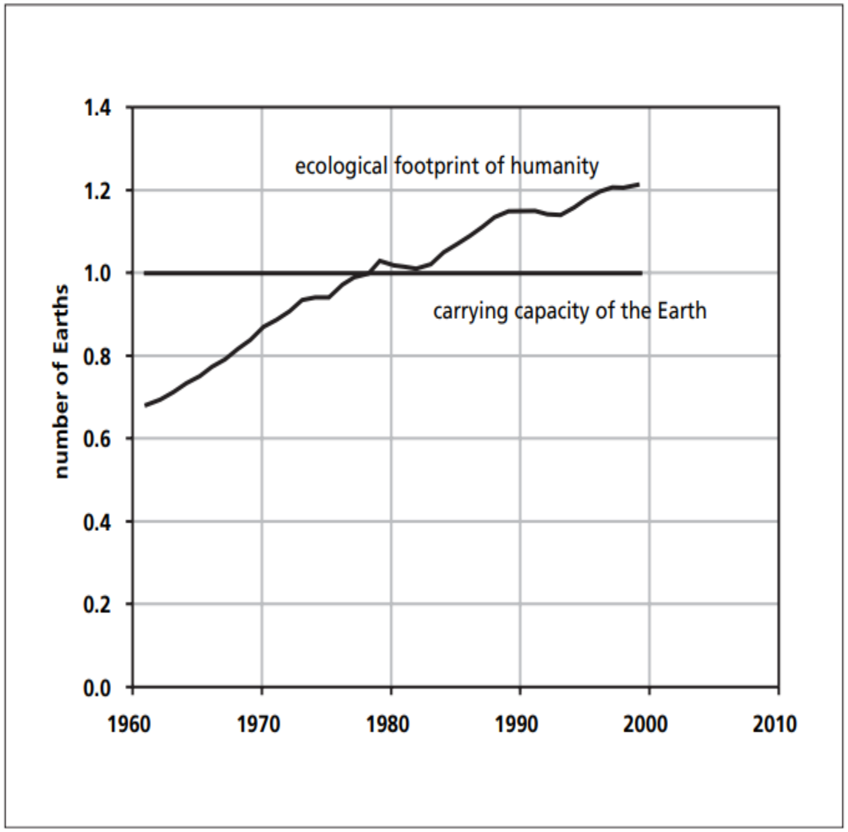
  Brundtland Commission: Development which meets the needs of the present without compromising the ability of the future to meets its needs.

- **Sustainable Engineering** : Design of human and industrial systems to ensure that human that humankind's use of natural resources and cycles do no lead to diminished quality of life due to either to losses in future economic opportunities or to adverse impacts on social condition, human health and the environment.

# Tragedy of common




https://www.storyboardthat.com/storyboards/tim-kelly/tragedy-of-the-commons

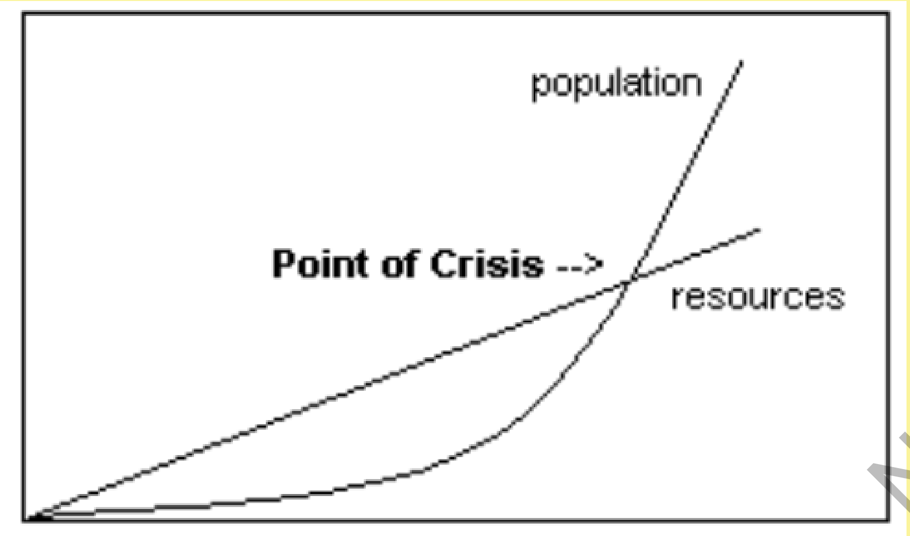


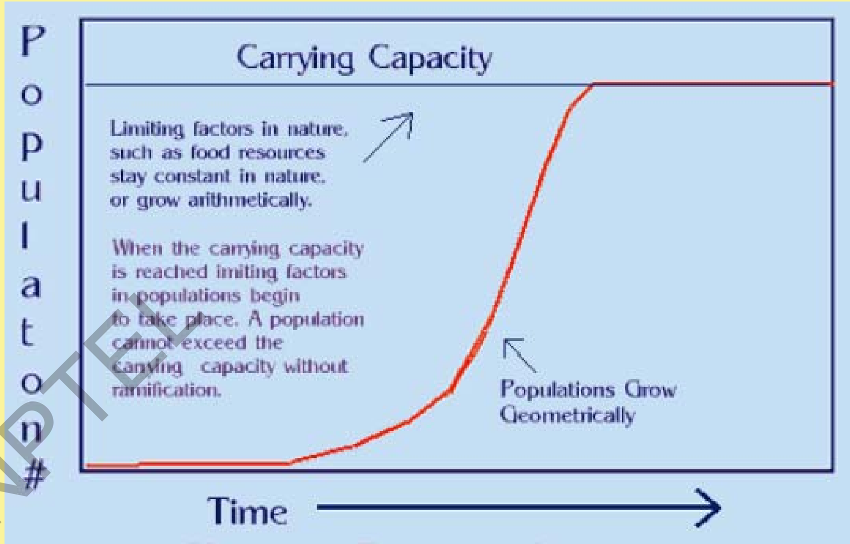

This graph shows the number of Earths required to provide the resources used by humanity and to absorb their emissions for each year since 1960. This human demand is compared with the available supply: our one planet Earth. Human demand exceeds nature's supply from the 1980s onward, over-shooting it by some 20 percent in 1999. (Source: M. Wackernagel et al.)

## Tragedy of common

- The tragedy of the commons is an economic theory by Garrett Hardin, which states that individuals acting independently and rationally according to each's self-interest behave contrary to the best interests of the whole group by depleting some common resource.
- It is this logic that has led to the current situation in ocean fisheries, the Amazon rain forest, and global climate change

# The Limit to Growth and Carrying Capacity

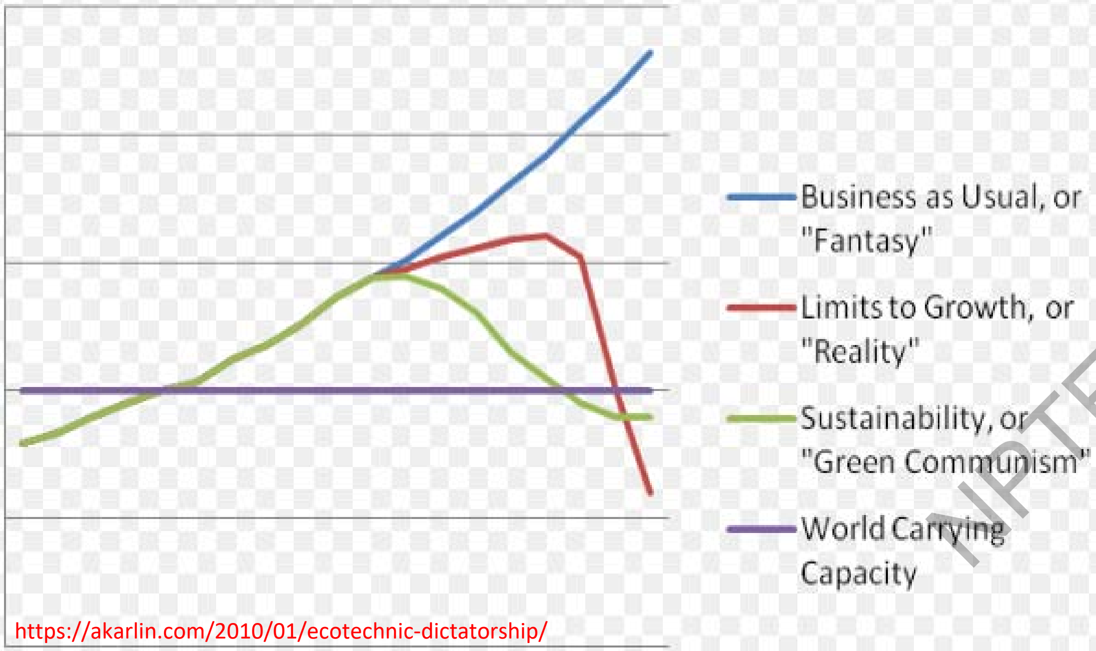



Graph source : https://environmentalethicsblogeisenhardt.wordpress.com/2014/10/17/earths-growing-problem-different-theories-on-resource-depletion/

It refers to the upper limit of population or community size ( e.g., biomass) imposed through environmental resistance . In nature, this resistance is related to the availability of renewable resources, such as food, and non renewable resources, such as space, as they affects biomass through reproduction, growth and survival .

# The Limit to Growth and Carrying Capacity




- **One solution** is to use technological advances to increase the amount of prosperity per unit of resource.
- However, there is risk that maintaining growth in a limited system by advances in technology can lead to overuse of the finite resource – efficiency alone is not an effective indicator of sustainability.

# Evolution of Sustainability Concept, how series of events ignited the Environmental Movement?

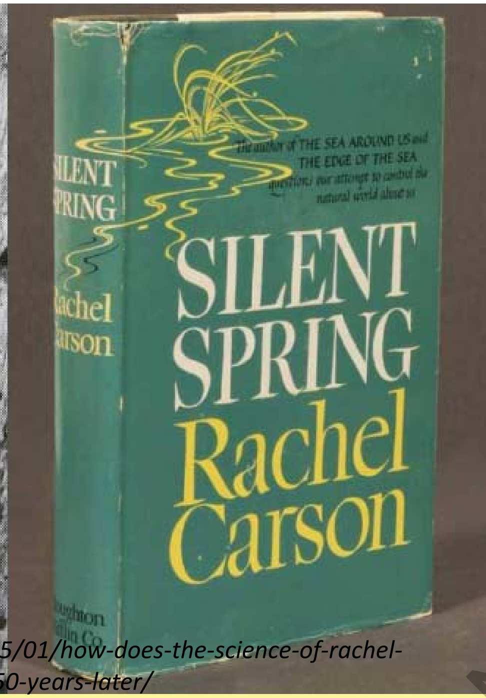
## (From Environmental protection to goal of Sustainability )

https://science.howstuffworks.com/environmental/conservation/issues/deadly-1948-donora-smog-launched-clean-air-movement.htm

- **1948 Donora smog**

The smog that blanketed the small town of Donora, Pennsylvania in October 1948 caused at least 21 deaths and ultimately resulted in the passage of the early version of Clean Air Act of 1963.

**Must read**
https://www.smithsonianmag.com/history/deadly-donora-smog-1948-spurred-environmental-protection-have-we-forgotten-lesson-180970533/




https://geneticliteracyproject.org/2018/05/01/how-does-the-science-of-rachel-carsons-silent-spring-stand-up-more-the-50-years-later/

- 1962 : Marine biologist Rachel Carson publishes ***Silent Spring***, calling attention to the threat of toxic chemicals (especially pesticides) to people and the environment.
- Carson is widely credited with banning DDT.



•How 'Silent Spring' Ignited the Environmental Movement (Must read)

Link

https://www.nytimes.com/2012/09/23/magazine/how-silent-spring-ignited-the-environmental-movement.html

# Cuyahoga River Fire

The 1969 Cuyahoga River fire helped spur an avalanche of water pollution control activities, resulting in the Clean water act and the creation of the federal Environmental Protection Agency (EPA)- 1970 -1972


How a burning river helped create the clean water act

Read https://www.alleghenyfront.org/how-a-burning-river-helped-create-the-clean-water-act/

# The Love Canal Tragedy

One of the most famous and important examples of groundwater pollution in the U.S. is the **Love Canal tragedy** in Niagara Falls, New York.

1980 :Congress passed the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), better known as the Superfund Act. Love Canal became the first entry on the list

https://blogs.roosevelt.edu/mbryson/2013/12/01/love-canal-a-still-unfolding-legacy-of-a-toxic-waste-community-disaster/

1976 : The Resource Conservation and Recovery Act (RCRA) is enacted by Congress


-with primary goals of protecting human health and the environment from the potential hazards of waste disposal, conserving energy and natural resources, reducing the amount of waste generated, and ensuring that wastes are managed in an environmentally sound manner.

- 1983

- The U.S. Environmental Protection Agency and the U.S. National Academy of Sciences release reports concluding that the build-up of carbon dioxide and other "greenhouse gases" in the Earth's atmosphere will likely lead to global warming.

- Reports spark conflict; greenhouse warming becomes a factor in mainstream politics for the fist time.

# Data on CO2 and Global warming will be talked about in later lectures

- 1984

- An estimated 10,000 people are killed and many more injured when Union Carbide's pesticide plant in Bhopal, India, leaks 40 tons of methyl isocyanate gas into the air and sends a cloud of poison into the surrounding city of 1 million.

https://www.livemint.com/Politics/sBzgTl9ogcYcRJPDLVuj1L/32-years-after-the-Bhopal-gas-tragedy-govt-apathy-intensifi.html

- 1987

- The Montreal Protocol

- The World Commission on Environment and Development publishes Our Common Future (The Brundtland Report) [the mission of the **Brundtland Commission** is to unite countries to pursue sustainable development together.]

- 1992:

- The Convention on Climate Change sets nonbinding carbon dioxide reduction goals for industrial countries (to 1990 levels by 2000).

- UN Conference on Environment and Development (Earth Summit), in Rio de Janeiro, Brazil.

- 1995 :

IPCC, releases a report concluding that “the balance of evidence suggests that there is a discernible human influence on global climate.

- 1997 :

- The Kyoto Protocol mandates that industrial countries cut their carbon dioxide emissions by 6 to 8 percent from 1990 levels by 2008–2012.


https://www.mdgmonitor.org/outline-of-the-mdgs-notable-challenges/



- 2000:

  Eight Millennium Development Goals (until 2015)

- 2002:

- World Summit on Sustainable Development in Johannesburg, South Africa, agree on a limited plan to reduce poverty and protect the environment.

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## Sustainability Concepts – Innovations and Challenges

**Lecture 04:** Engineering for Sustainability

CONCEPTS COVERED

## Week 1

- Sustainability Concepts and evolution
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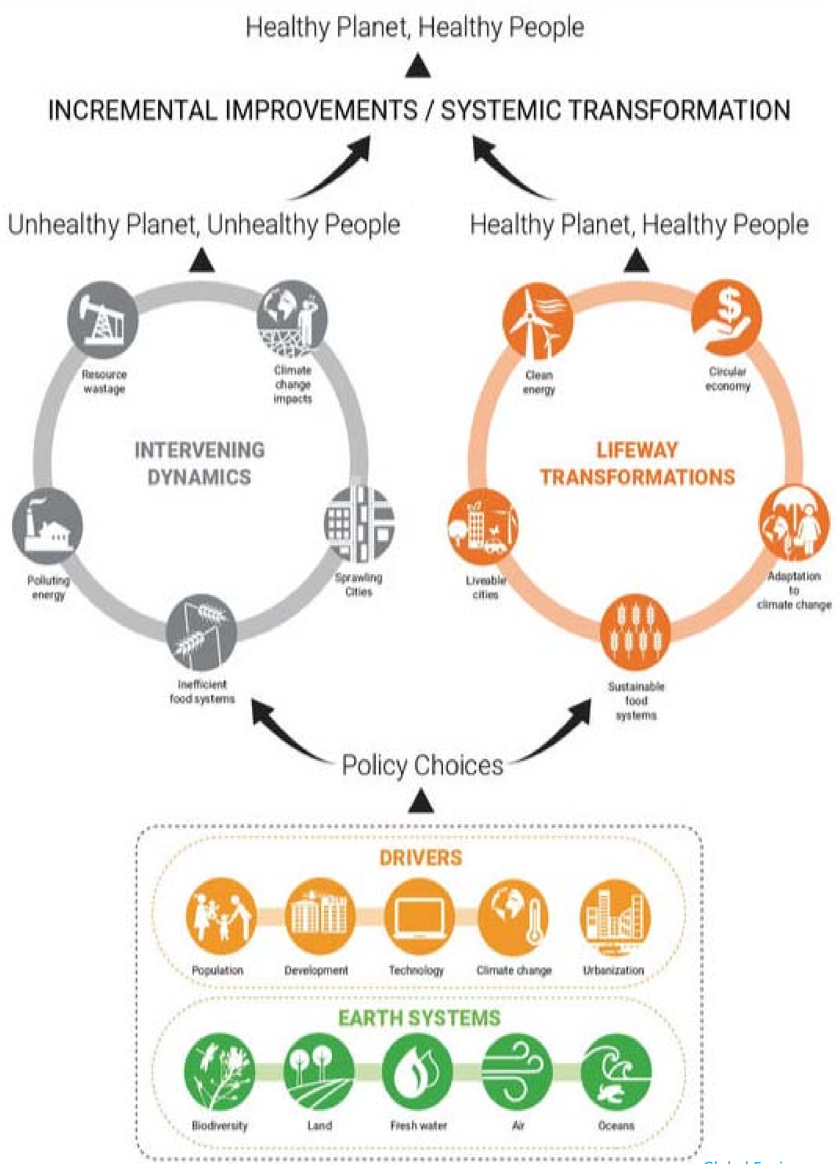
https://en.wikipedia.org/wiki/Sustainable_Development_Goals



2016:

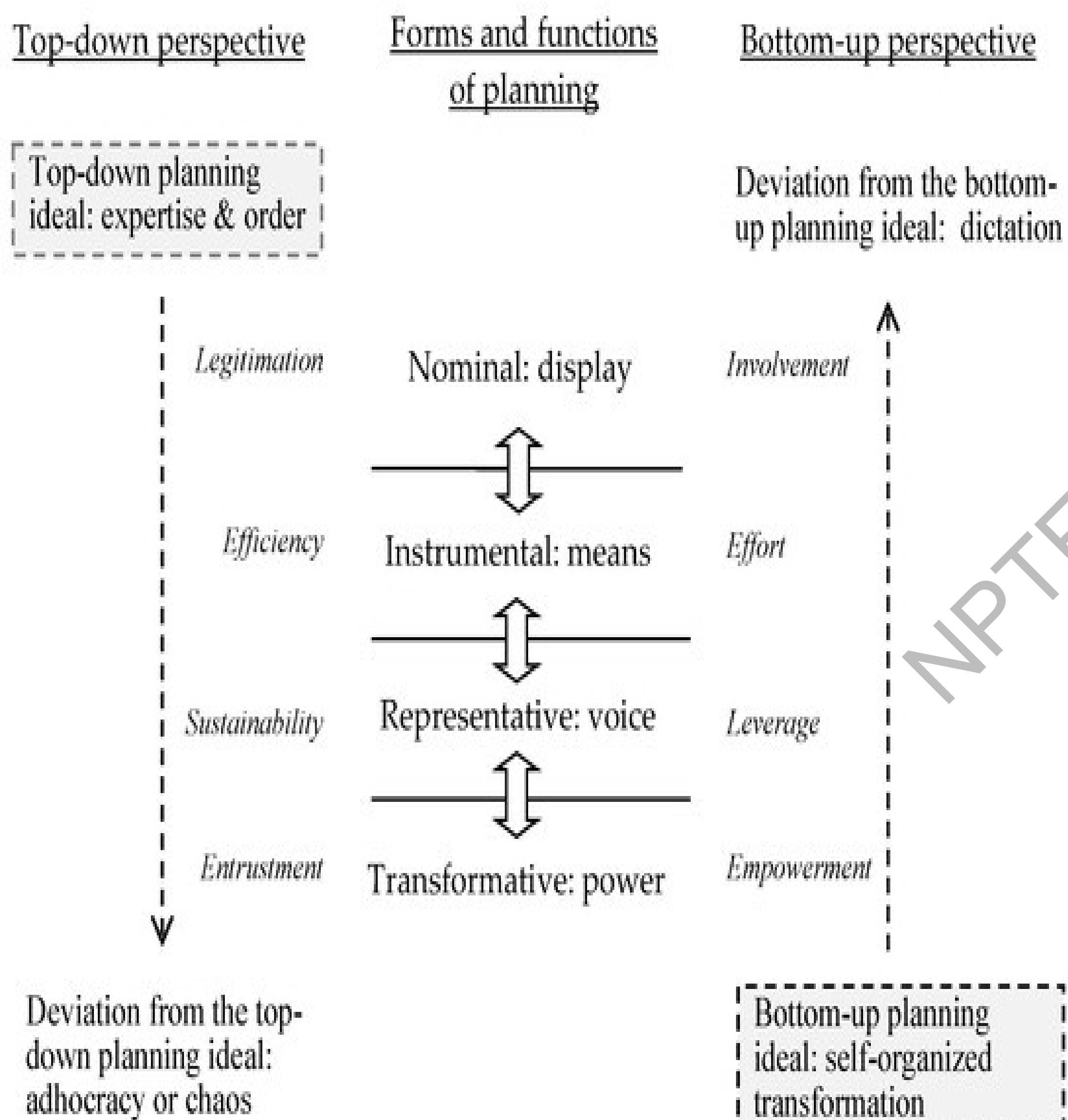
- Paris Agreement
- The Sustainable Development Goals (SDGs) replaced the MDGs in 2016.




Global Environment Outlook 6

# Path forward

- Once there is an intention to pursue sustainability , there is a clear need to identify an approach to problem solving that is evolved from previous approaches which had not systematically incorporated triple bottom line consideration.




Anttiroiko, (2016)

# How to move from discussion to operation?

Operationalizing Sustainability

Two broad classes

I. Top down
II. Bottom up

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Faculty Name: Dr. Brajesh Kumar Dubey

Department : Civil engineering




## Sustainability Concepts – Innovations and Challenges

**Lecture 05:** Life Cycle Thinking and Circular Economy

CONCEPTS COVERED

# Week 1

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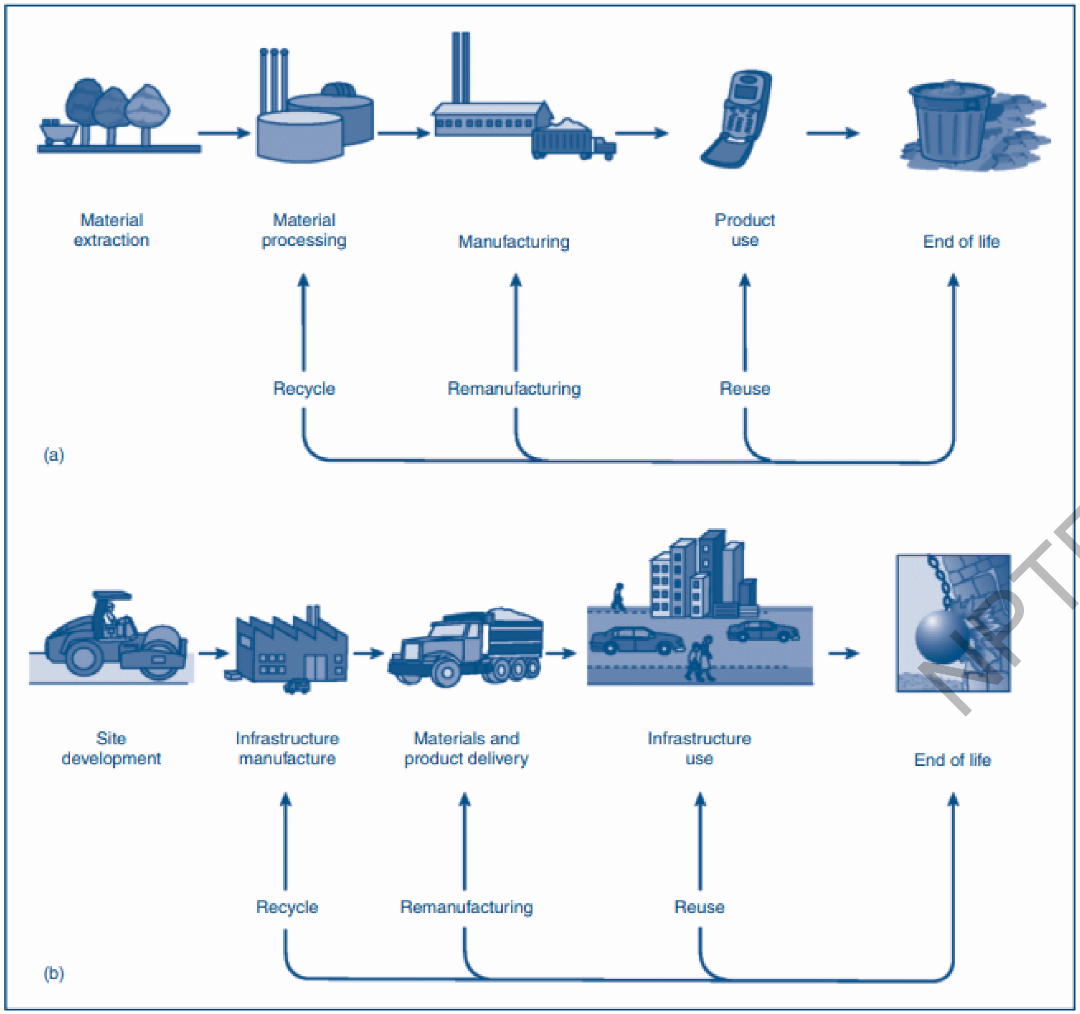
# Towards sustainability goal

## Two frameworks

1. Life cycle thinking
2. System Thinking

--life cycle thinking is focused on material and energy flows and the subsequent impacts

--while systems thinking can also capture the relationship of political, cultural, social, and economic considerations, and potential feedbacks between these considerations and material and energy flows.




## Life Cycle Thinking

- Systemic framework that takes a holistic view of the production and consumption of a product or service and assesses its impacts on the environment through the entire life cycle.
- It goes beyond focusing on a specific site or product.

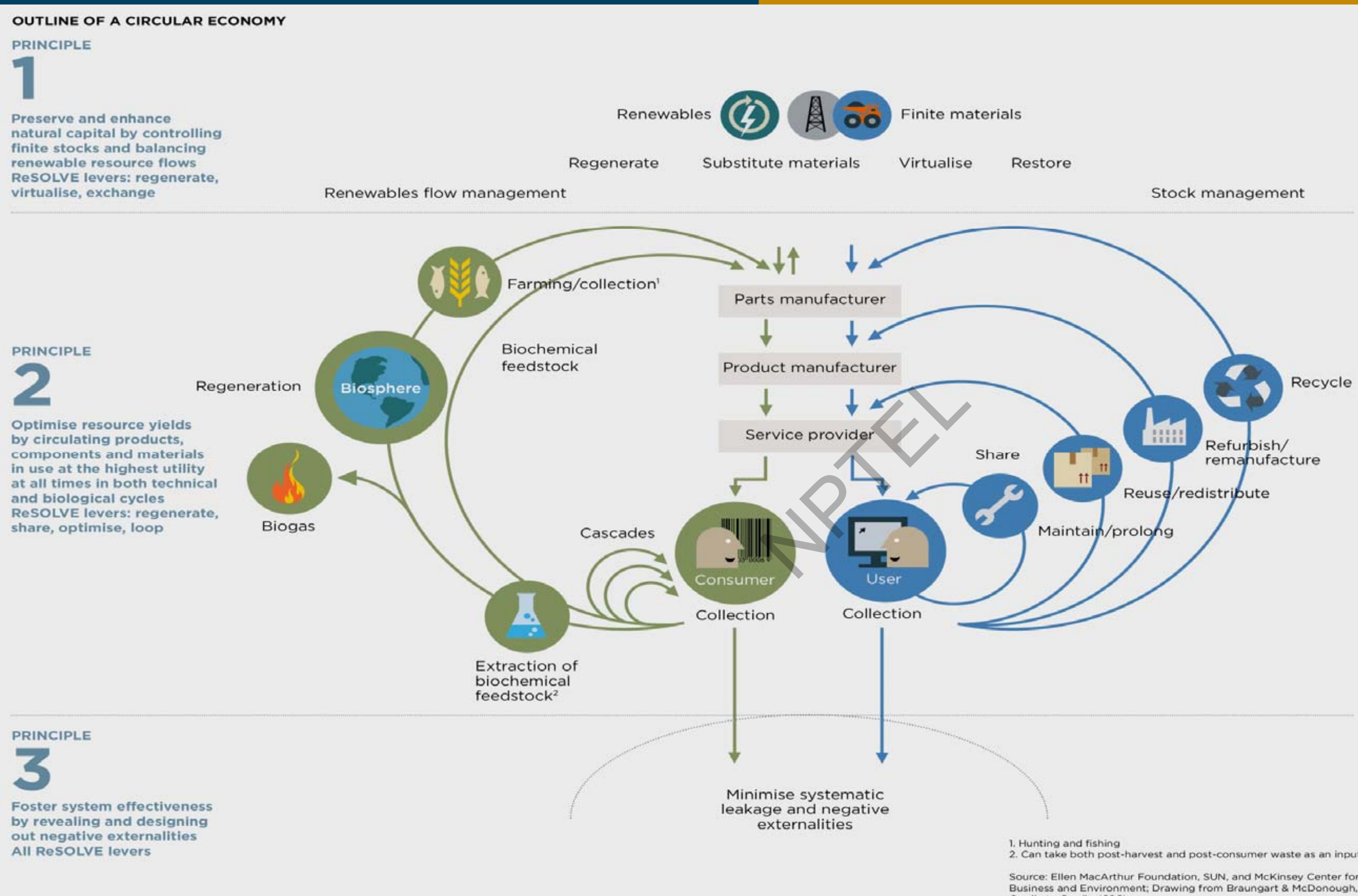
# What is a circular economy

- A circular economy is an alternative to a traditional linear economy (make, use, dispose) in which we keep resources in use for as long as possible, extract the maximum value from them whilst in use, then recover and regenerate products and materials at the end of each service life.
- A circular economy is restorative and regenerative by design. This means that materials constantly flow around a 'closed loop' system, rather than being used once and then discarded. As a result, the value of materials is not lost by being thrown away.
- In the case of plastic, this means simultaneously keeping the value of plastics in the economy, without leakage into the natural environment.


Source: http://www.wrap.org.uk/about-us/about/wrap-and-circular-economy

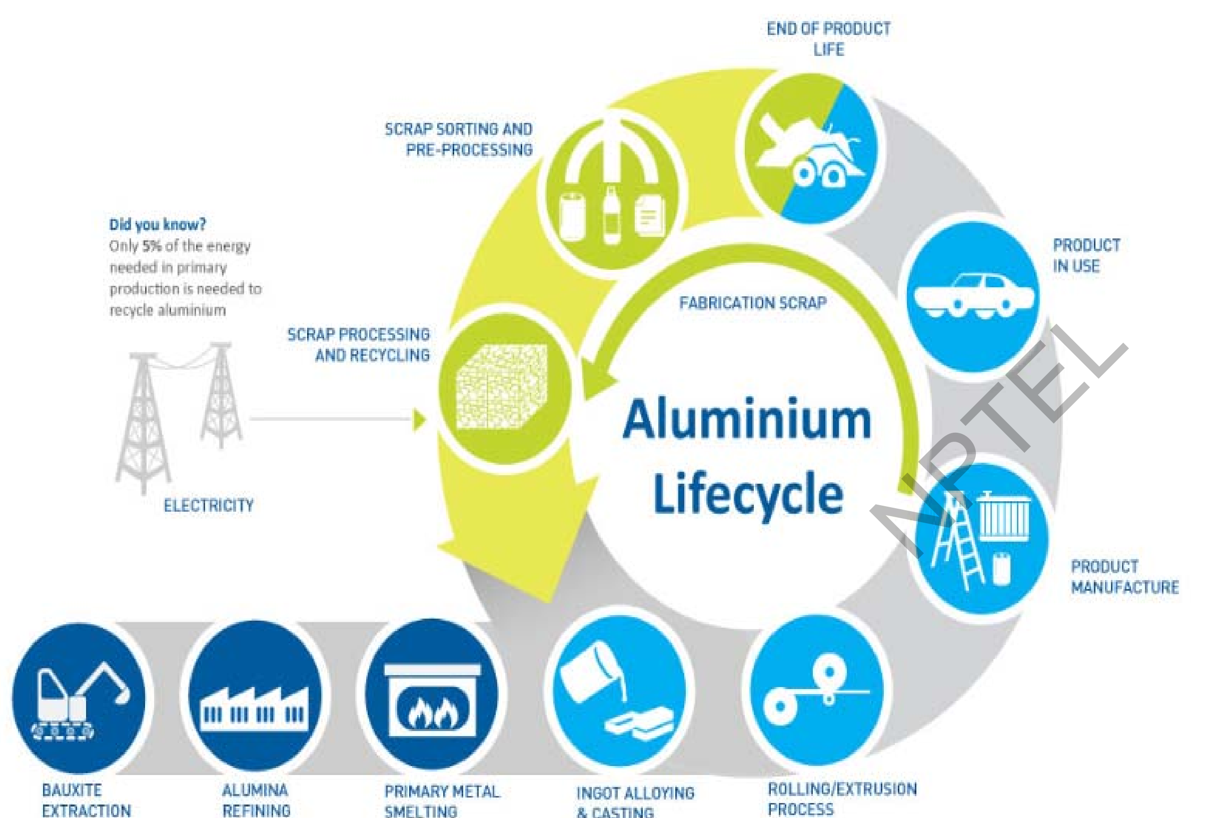
# Circular Economy


Source: https://erp-recycling.org/wp-content/uploads/2017/11/ERP-Circular-Economy-Roles-and-Responsibilities.pdf




(Source: ellenmacarthurfoundation.org/circular-economy)

# Why is Life Cycle Thinking important ?



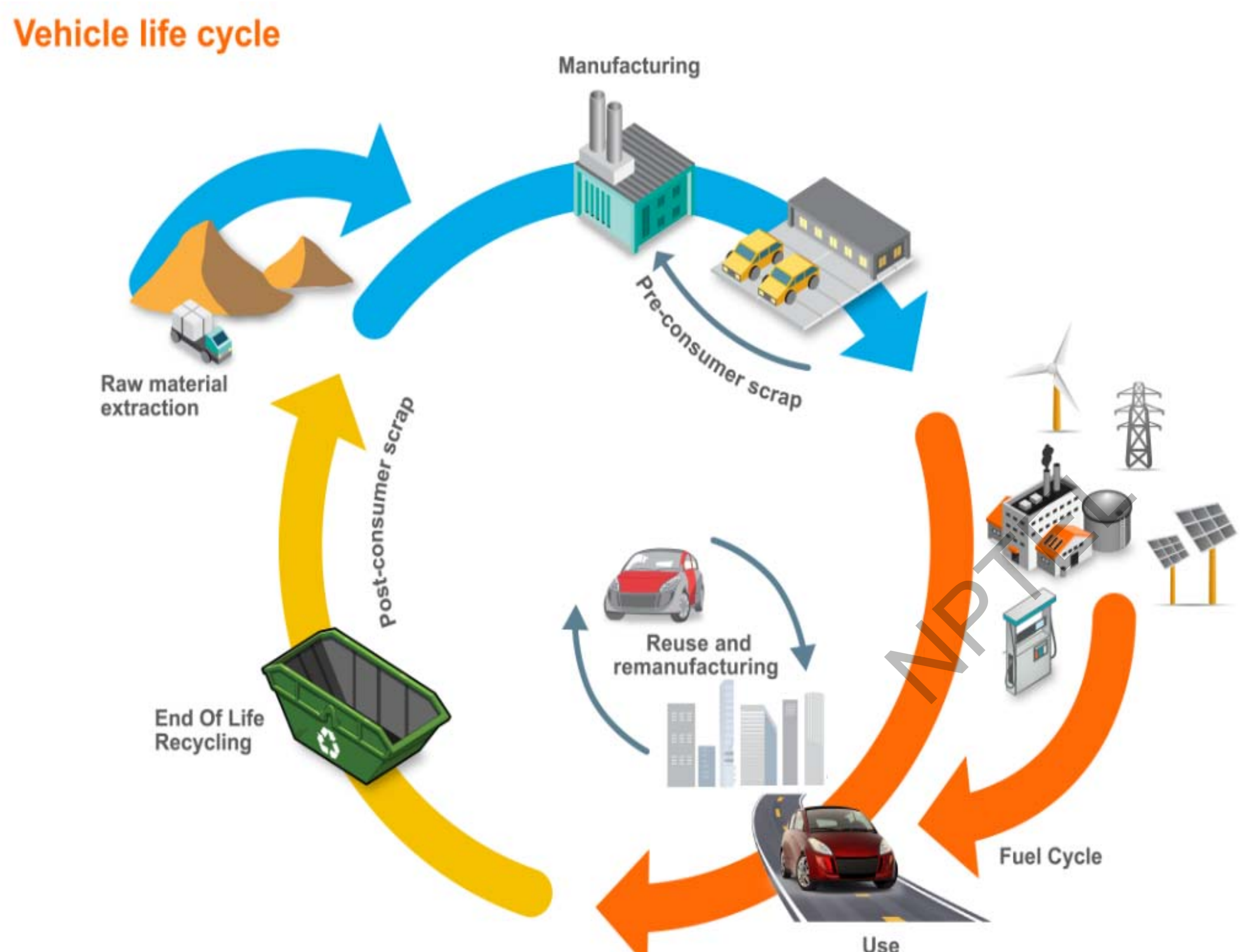

https://www.hulamin.com/about/aluminiums-lifecycle

--*Because different environmental impacts can occur during different stages.*

**Example1:**

--*Some materials may have an adverse environmental consequence when extracted or processed, but may be relatively benign in use and easy to recycle.*

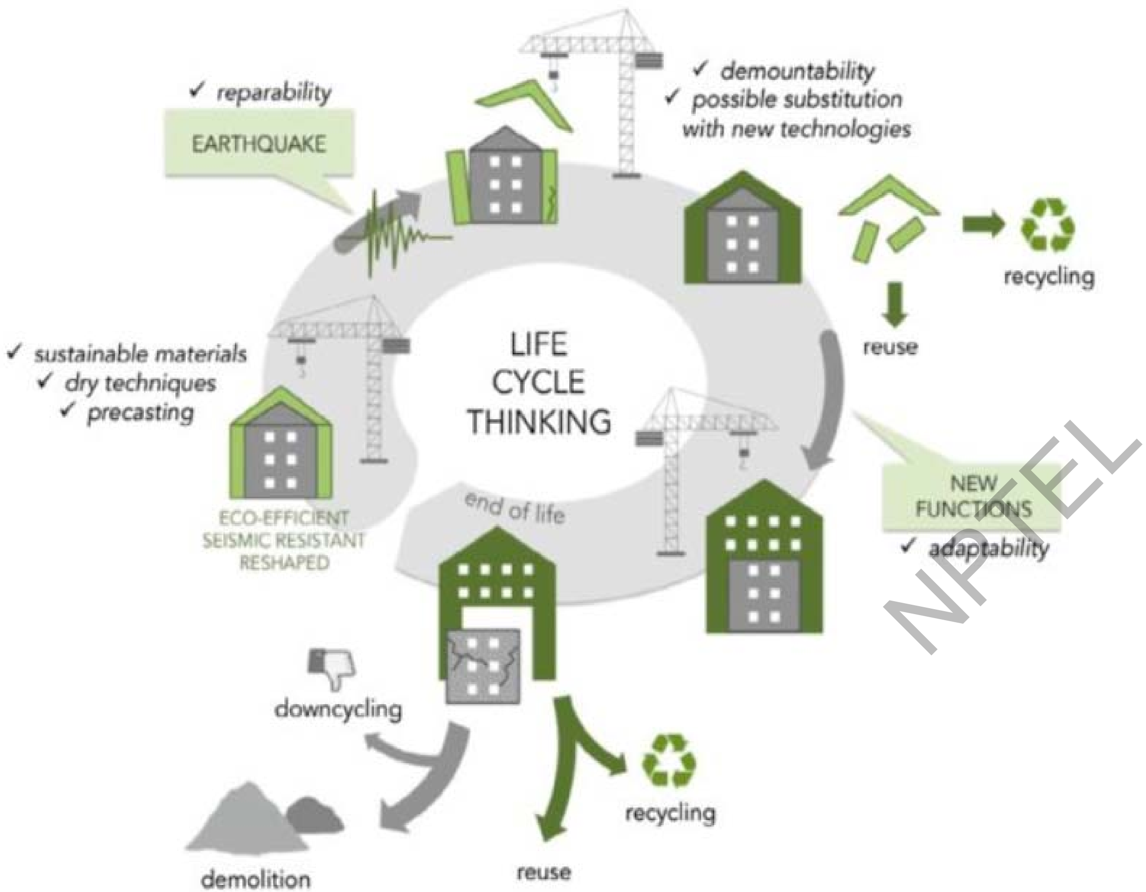
-- Aluminum is such a material. On one hand, smelting of aluminum ore is very energy intensive. This is one reason aluminum is a favored recycled metal




https://www.worldautosteel.org/life-cycle-thinking/case-studies/battery-electric-vehicle-life-cycle-energy-aluminium-vs-ahss/

## Example 2:

--An **automobile** will create the bulk of its environmental impact during the use life stage, not only because of combustion of fossil fuels, but also because of runoff from roads and the use of many fluids during operation

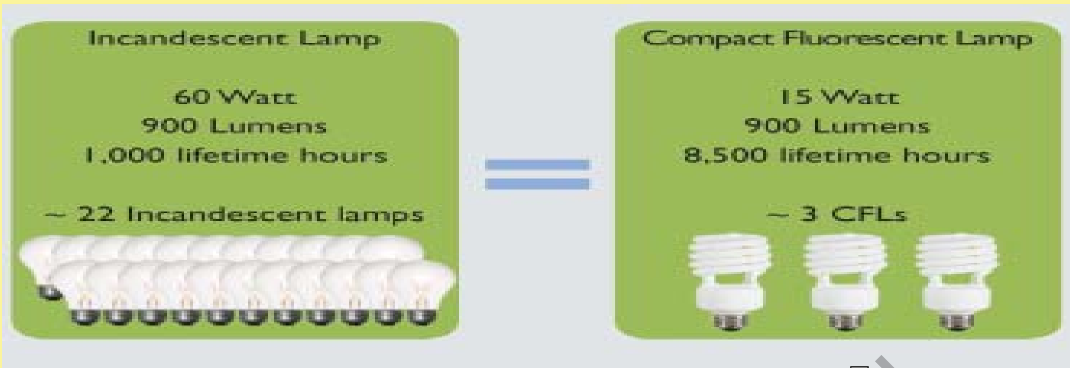



http://www.absolutecarrecycling.com.au/what-exactly-happens-to-the-older-vehicles-in-the-end/life-cycle-of-vehicle-car-wreckers-melbourne/

## Example 3:

--Buildings, though a vast amount of water, aggregate, chemicals, and energy goes into the production of construction materials, transport of these items to the job site, and construction of a building, the vast amount of water and energy occurs after occupancy, during the operation life stage of the building.

# CFL




**Without Life Cycle Thinking.**

- If reducing the amount of energy, and subsequently carbon emissions, associated with lighting is only considered

Trade off



4 mg Hg per bulb

Environmental and human concern

https://www1.eere.energy.gov/buildings/publications/pdfs/ssl/lca_factsheet_apr2013.pdf

## With Life Cycle Thinking


Energy efficient and no "Hg"

Trade off

Disposal

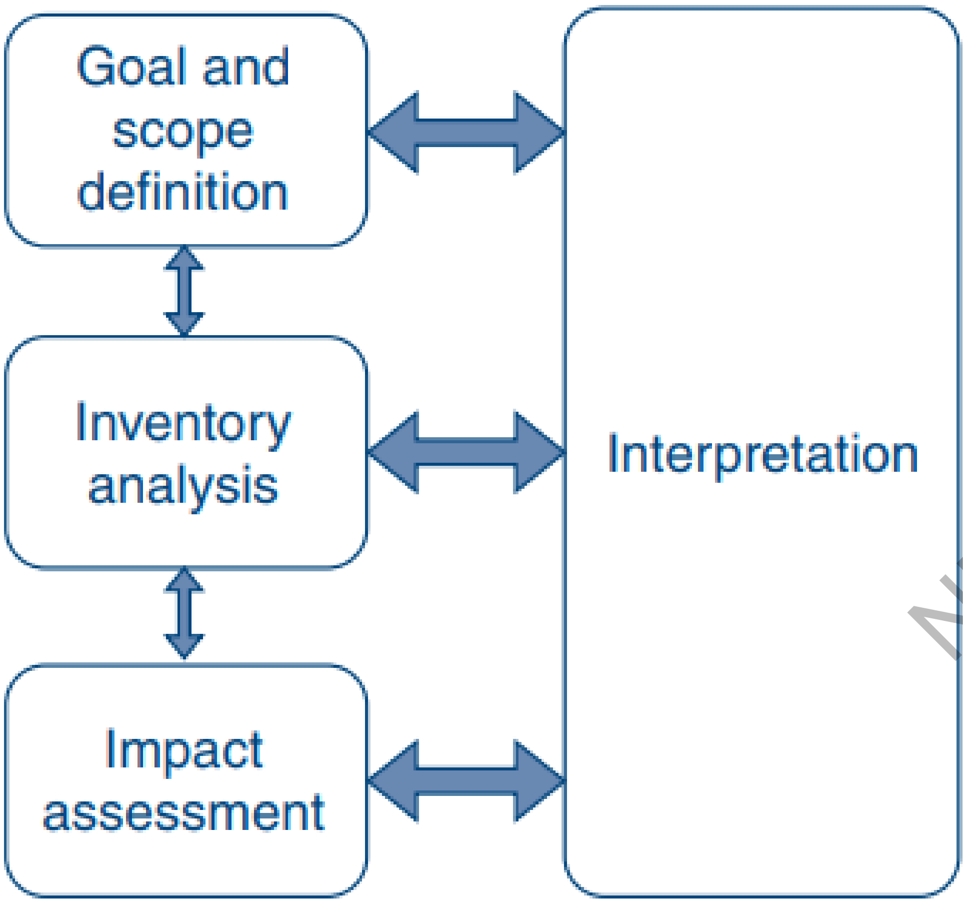
* Extra cost of LED is repaid in long term (Longer operation time)

More innovation is needed

# How to solve such trade off?

- Life cycle thinking supports the goal of improving the overall environmental performance of an engineering design and not simply improving a single stage or endpoint while shifting burdens elsewhere in the life cycle

- To effectively capture these impacts across the entire life cycle of the product, process, or system, one must consider the environmental impacts for the entire life cycle through an LCA.



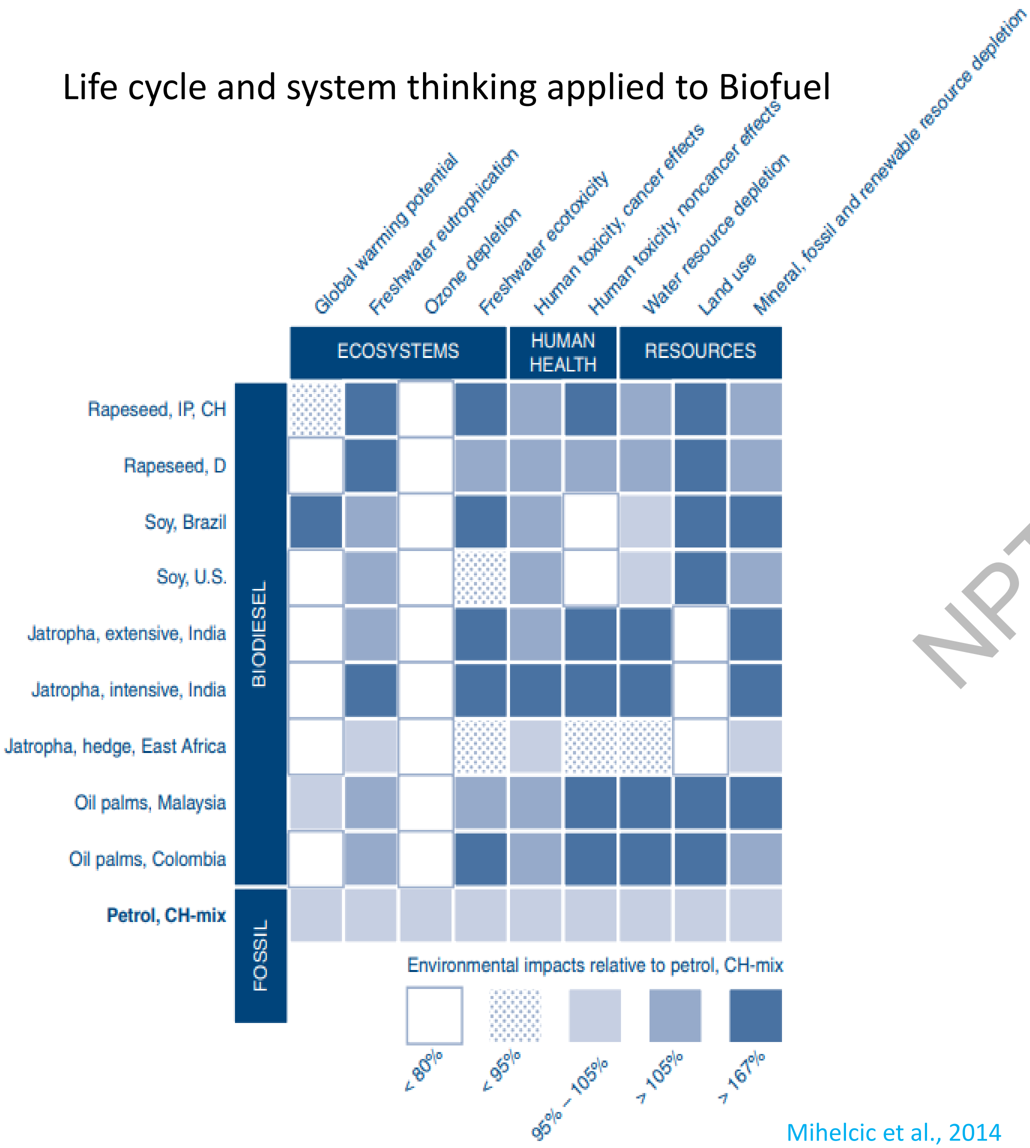

# Life Cycle Assessment (LCA).

•An LCA is a sophisticated way of examining the total environmental impact through every life cycle stage.

Brief in week 6.

Detail in previous NPTEL online course , titled: **Sustainable Engineering Concepts And Life Cycle Analysis**

Life cycle and system thinking applied to Biofuel




Mihelcic et al., 2014

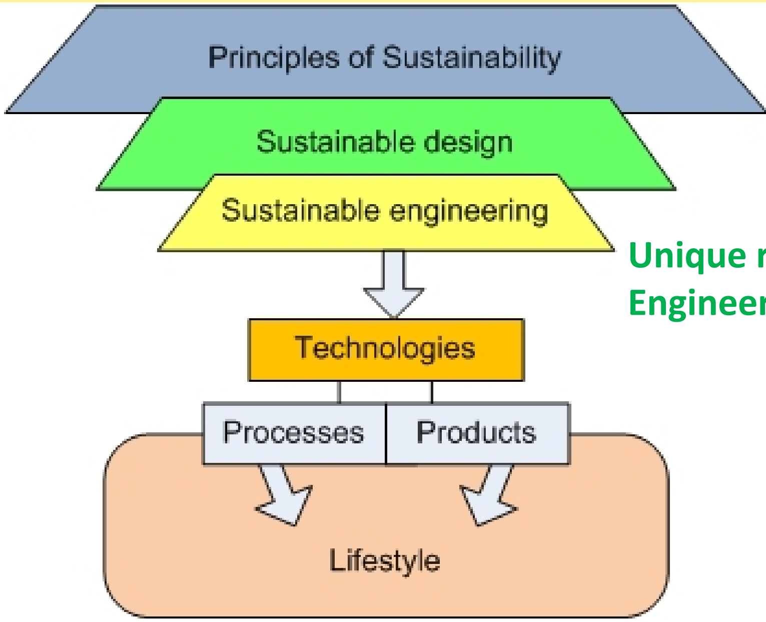
# System Thinking

- **Systems thinking** is the process of understanding how things influence one another within a whole.

•Without LC and system thinking frameworks, significant and varied environmental impacts across the life cycle cannot be understood

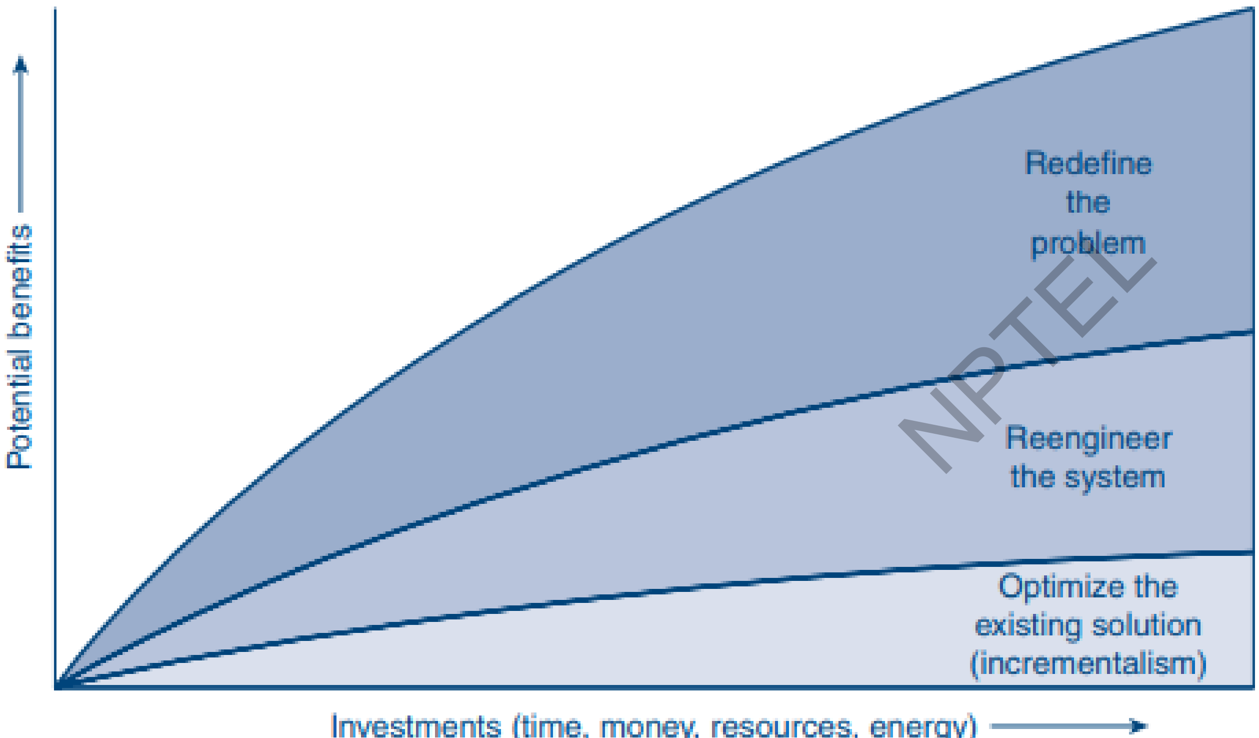
*Example : "greener" fuel can have significant and varied environmental impacts across the life cycle.*

# Engineering for sustainability




**Unique role of Engineers**

# Importance of design and innovation in advance sustainability




Mihelcic et al., 2014

- Design is the engineering stage where the greatest influence can be achieved in terms of sustainable outcomes.

# Degrees of Freedom and Sustainable Design

In 2004, the average miles per gallon for a car on the road in the United States was 22. In response to concerns about global climate change, policy makers and engineers are working toward a more innovative technical and management strategies to improve gas mileage and lower carbon dioxide emissions. What are the design opportunities for improvement scaled with increasing degrees of freedom and what are the potential benefits?

Three design solution

Increasing degrees of freedom →

| | Incremental Improvement | Reengineer the System | Redefine the System Boundary |
|---|---|---|---|
| Design solution | Improve the efficiency of the Carnot engine; use lighter-weight materials (composites instead of metals) | Use a hybrid electric or fuel cell system for energy; change the shape of the car for improved aerodynamics; capture waste, heat, and energy for reuse | Meet mobility needs without individual car; implement a public transit system; design communities so commercial districts and employment are within walking and cycling distance; provide access to desired goods and services without vehicular transportation |
| Potential realized benefits | Moderate fuel savings; moderate reductions in $CO_2$ emissions | Improved fuel savings; improved reductions in $CO_2$ emissions; improved material and energy efficiency | Elimination of the environmental impacts associated with the entire automobile life cycle; maximized fuel savings and $CO_2$ reductions; improved infrastructure; denser development (smart growth); improved health of society from walking and less air pollution |

Mihelcic et al., 2014

# Measuring Sustainability

Indicator :

--Something that points to an issue or condition. Its purpose is to show you how well a system is working.

--A sustainability indicator measures the progress toward achieving a goal of sustainability.

| | | |
|---|---|---|
| Economic indicators | Traditional | Median income<br>Per capita income relative to the U.S. average size of the economy as measured by gross national product (GNP) and GDP |
| | Sustainable | Number of hours of paid employment at the average wage required to support basic needs<br>Wages paid in the local economy that are spent in the local economy<br>Dollars spent in the local economy that pay for local labor and local natural resources<br>Percent of local economy based on renewable local resources |
| | Emphasis of sustainability indicator | What wage can buy<br>Defines basic needs in terms of sustainable consumption<br>Local financial resilience |
| Environmental indicators | Traditional | Ambient levels of pollution in air and water<br>Tons of solid waste generated<br>Cost of fuel |
| | Sustainable | Use and generation of toxic materials (both in production and by end user)<br>Vehicle miles traveled<br>Percent of products produced that are durable, repairable, or readily recyclable or compostable<br>Total energy used from all sources<br>Ratio of renewable energy used at renewable rate to nonrenewable energy |
| | Emphasis of sustainability indicator | Measuring activities causing pollution<br>Conservative and cyclical use of materials<br>Use of resources at sustainable rate |
| Social indicators | Traditional | Number of registered voters<br>SAT and other standardized-test scores |
| | Sustainable | Number of voters who vote in elections<br>Number of voters who attend town meetings<br>Number of students trained for jobs that are available in the local economy<br>Number of students who go to college and come back to the community |
| | Emphasis of sustainability indicator | Participation in democratic process<br>Ability to participate in the democratic process<br>Matching job skills and training to needs of the local economy |

Mihelcic et al., 2014

## Efficiency factor

- Several quantitative sustainability metrics are heavily utilized by engineers. One of these metrics is the efficiency factor (or E factor), which is a measure of material efficiencies, that is the waste generation for materials.

$$\text{E factor} = \frac{\sum \text{kg inputs}}{\sum \text{kg product}}$$

- Calculate the E factor for the desired product, given the following chemical production process:

$$CH_3CH_2CH_2CH_2OH + NaBr + H_2SO_4 \rightarrow CH_3CH_2CH_2CH_2Br + NaHSO_4 + H_2O$$

| Type | Molecular Formula | Molecular Weight | Weight (g) | Moles |
|---|---|---|---|---|
| Reactant | $CH_3CH_2CH_2CH_2OH$ | 74.12 | 0.8 (added) | 0.80 (added) |
| Reactant | $NaBr$ | 102.91 | 1.33 (added) | 1.33 (added) |
| Reactant | $H_2SO_4$ | 98.08 | 2.0 (added) | 2.0 (added) |
| Desired product | $CH_3CH_2CH_2CH_2Br$ | 137.03 | 1.48 | 0.011 |
| Auxiliary | $NaHSO_4$ | | | |
| Auxiliary | $H_2O$ | | | |

# Policies Driving Sustainability

1. Regulations ( Example: EPR, Banning)
2. Voluntary Programs ( Eco labeling and Preferential purchasing).

# Conclusion

By considering the fundamental concepts of sustainability, engineers can contribute to addressing the challenges traditionally associated with economic growth and development.

**NPTEL ONLINE CERTIFICATION COURSES**

# Thank you