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SCHOOL OF ENERGY AND ENVIRONMENT

CityU

SEE 1003
Introduction to Sustainable Energy and Environmental Engineering

Dr. Shauhrat Chopra
School of Energy and Environment

Module 2 – Human-Environment Impacts

Feb 14, 2022

SEE 1003 class overview

Week	Topics	Assignment issued	Key dates
Week 1	Course introduction; Climate Change and the Engineering approach		**Quiz 1**
Week 2	**MODULE I** Introduction to Sustainability Energy, Natural Resources and pollution, Electromagnetic energy; Electrical energy – Lighting, Light pollution, Policy	**Semester-long Project**	
Week 3		**Project deliverable 1.1**	
Week 4	**MODULE II** Energy and Environmental Implications– Transportation Human-Environment Impacts		
Week 5		**Project deliverable 1.2**	**Project deliverable 1.1**
Week 6	**MODULE III** Noise Pollution in Urban Environment	**Project deliverable 1.3**	**Quiz2**
Week 7	**MODULE IV** Urban Sustainability; Water and Energy Nexus		**Project deliverable 1.2**
Week 8	**MODULE V** Tools: Systems Analysis for Sustainability Cost-Benefit Analysis, Material Flow Analysis, Life Cycle Assessment		
Week 9			
Week 10	**MODULE VI** Advances in Environmental and Energy Engineering	**Project deliverable 1.4**	**Project deliverable 1.3; Quiz3**
Week 11	**MODULE VII** Waste management and Waste-to-Energy		
Week 12	**MODULE VIII** Economics and Policy of Energy and Environment	**Project deliverable 1.5**	**Quiz4** **Project deliverable 1.4**
Week 13	**Individual Presentations (5-mins)**		**Final Project Report**

Class Schedule

January 2022

	S	M	T	W	T	F	S
							1
	2	3	4	5	6	7	8
WK 1	9	10	11	12	13	14	15
WK 2	16	17	18	19	20	21	22
WK 3	23	24	25	26	27	28	29
	30	31					

February 2022

	S	M	T	W	T	F	S
			1	2	3	4	5
WK 4	6	7	8	9	10	11	12
WK 5	13	14	15	16	17	18	19
WK 6	20	21	22	23	24	25	26
WK 7	27	28					

March 2022

	S	M	T	W	T	F	S
			1	2	3	4	5
WK 8	6	7	8	9	10	11	12
WK 9	13	14	15	16	17	18	19
WK 10	20	21	22	23	24	25	26
WK 11	27	28	29	30	31		

April 2022

	S	M	T	W	T	F	S
						1	2
WK 12	3	4	5	6	7	8	9
WK 13	10	11	12	13	14	15	16
	17	18	19	20	21	22	23
	24	25	26	27	28	29	30

May 2022

	S	M	T	W	T	F	S
	1	2	3	4	5	6	7
	8	9	10	11	12	13	14
	15	16	17	18	19	20	21
	22	23	24	25	26	27	28
	29	30	31				

Final class on Apr 11th

Exam period

13 weeks of classes

Chinese New Year break
Holiday on 31st Jan, 2022

Semester-long Project

- Compare and contrast the finding for questions 1-5 with all four types of car technologies:

1) Biofuel-based cars, 2) Electric Cars, 3) Hybrid Cars and 4) Hydrogen Cars.

- Present your findings with respect to the questions below for each type of cars.

1) Research the underlying technology of all four types of car.
   - What is the underlying technology?
   - What is the performance of this technology?

2) Identify the major components and energy source of the technology.
   - What raw materials are needed to manufacture this technology?
   - Is there enough material available to meet the demand?
   - Will the car produced using this technology be cost-effective?

3) Is the infrastructure available to scale up this technology?
   - Can one easily store the energy source of this technology?
   - Is the infrastructure cost of the distribution network high?

4) What are the potential environmental impacts during the operation of this technology?

5) Are there any foreseeable challenges with the disposal of this technology?

- Compare and contrast the four types of car technologies in terms of environmental impacts based on your findings.

(Tip: you can find the best and worst technology for each of the questions; is there a technology that is clearly better?)

Semester-long Project: Example Table

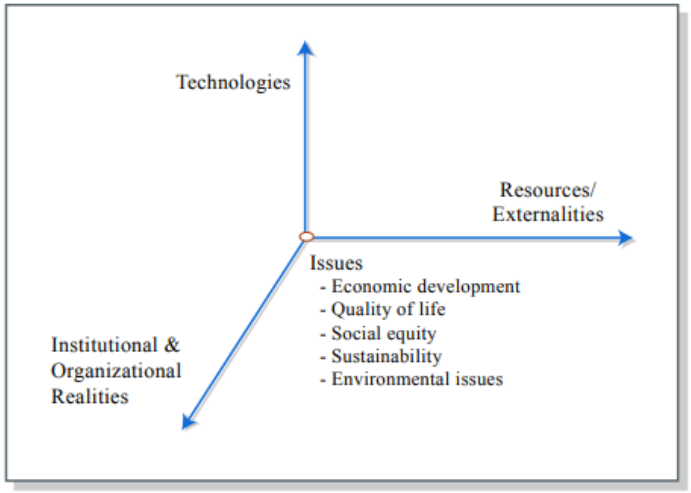
	Q1. Underlying Technology		Q2. Raw materials and energy source			Q3. Infrastructure		Q4. Environmental Challenges	Q5. Disposal Challenges
	Principle	Performance	Raw Materials	RM availability	Cost effective	Energy Storage	Energy Distribution		

Semester-long Project

Sub-assignment	Topics	Released	Due
Project Deliverable 1	Module 1: Sustainable Energy	Jan 24th	Feb 14th
Project Deliverable 2	Module 2: Environmental Impacts	Feb 14th	Feb 28th
Project Deliverable 3	Module 3: Noise Pollution	Feb 21st	Mar 21st
Project Deliverable 4	Module 4-6: Systems Analysis	Mar 21st	Apr 4th
Project Deliverable 5 + Presentation + Final Report	Module 7-8: Policy and Economics	Apr 4th	Apr 11th

- Individual Project: **Report** and **Presentation**
  - No group work allowed.
  - Plagiarism check mandatory: Turnitin or ithenticate
- Final Report is to be submitted in a PDF or WORD format to Canvas.
- Answer to each question to be no less than 500 words and no more than 1000 words, exclusive of the table and bibliography (double spaced, 1-inch margins, 11 or 12 point Times Roman or Arial fonts).
- References used are to be gathered in the bibliography at the end of the paper and cited at the appropriate place in the text of the paper as "(author, date)".

The Triple Bottom Line: Sustainability Paradigm



Sustainability has become increasingly important and has been

- driven by an **increasing human population**
- with **increasing per capita resource consumption**

on a planet which is after all finite.

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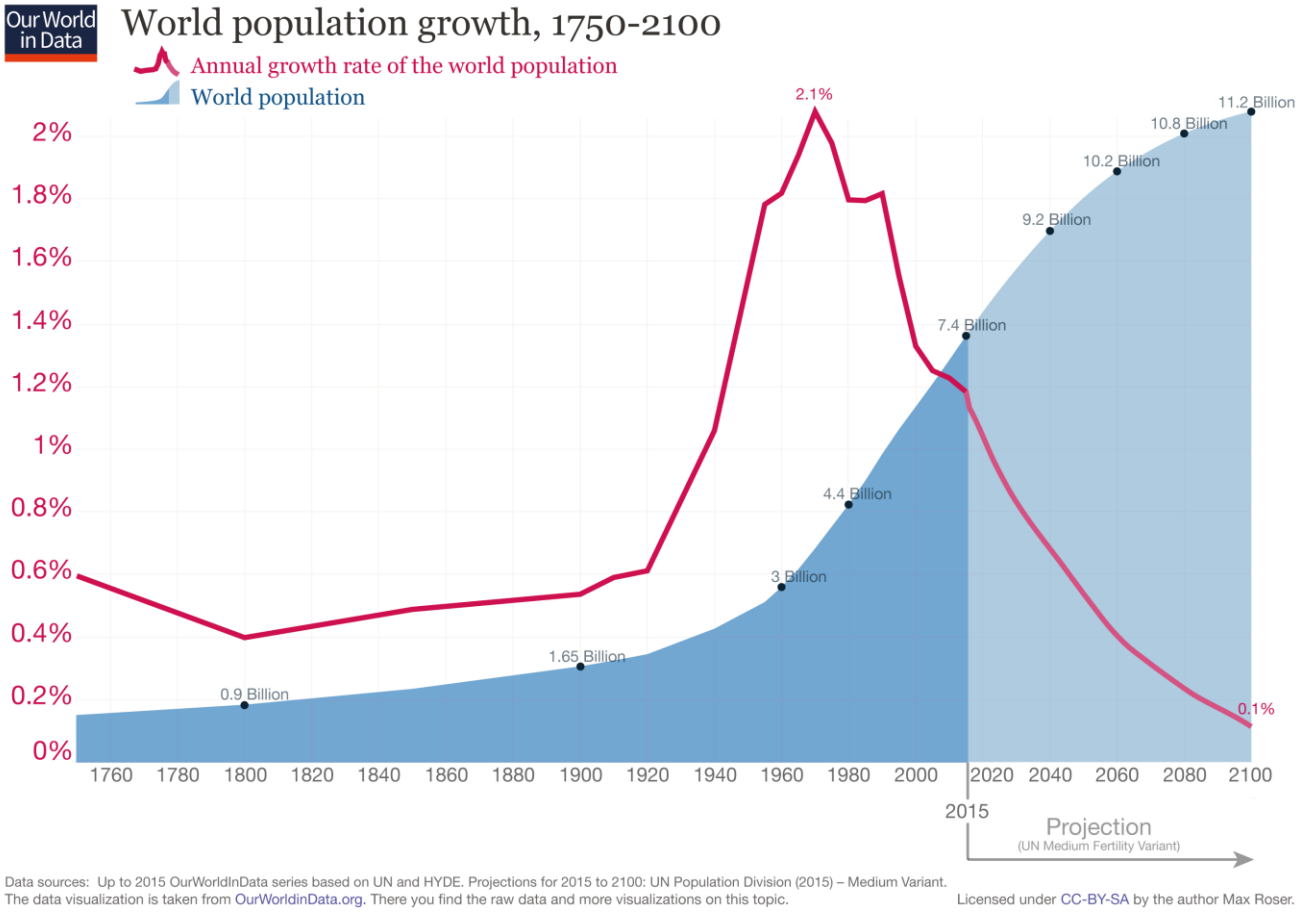
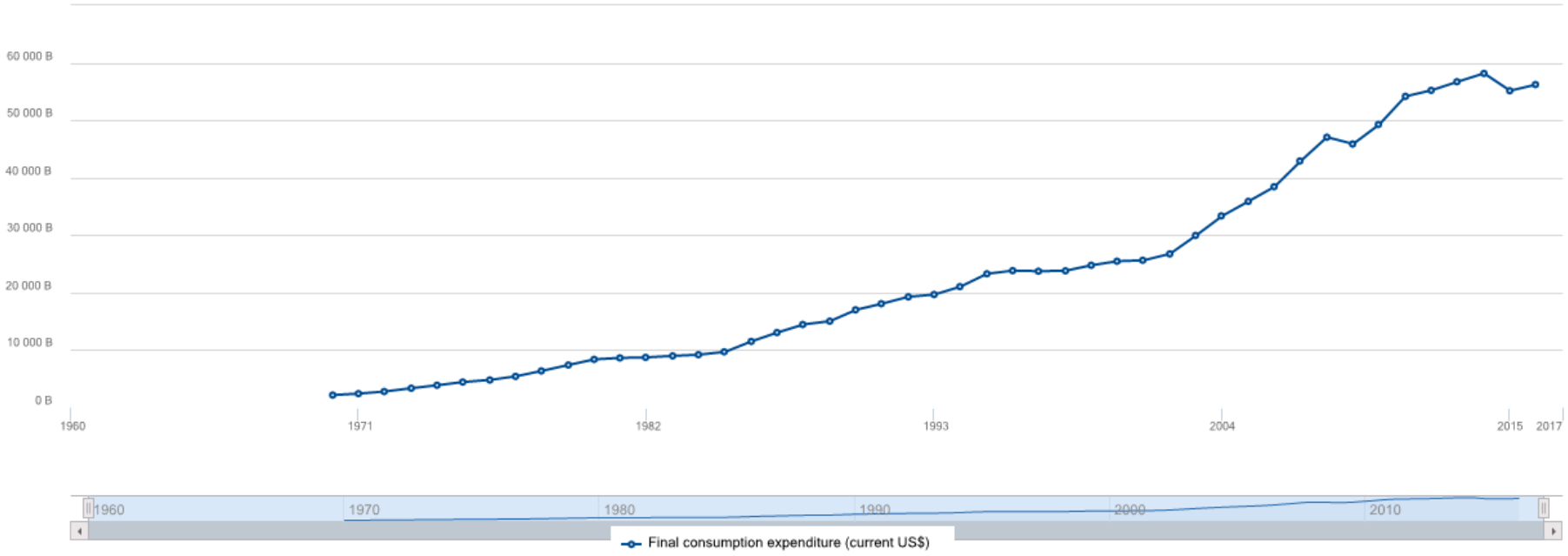
IPAT equation

World population increased from approximately 2.5 billion in 1950 to about 7.0 billion in 2012



Animation of natural growth rates by country: https://ourworldindata.org/grapher/nat

Total World consumption expenditures rose from about 221 Billion in 1970 to approximately 56,000 billions in 2016 expressed in current U.S. dollars



Country : World
Source: World Development Indicators
Created on: 01/21/2019

https://databank.worldbank.org/data/source/world-development-indicators

Population Growth and Human Consumption are individually great indicators of humanity's abilities

But together they have resulted in so many people consuming so many resources…

IPAT Equation

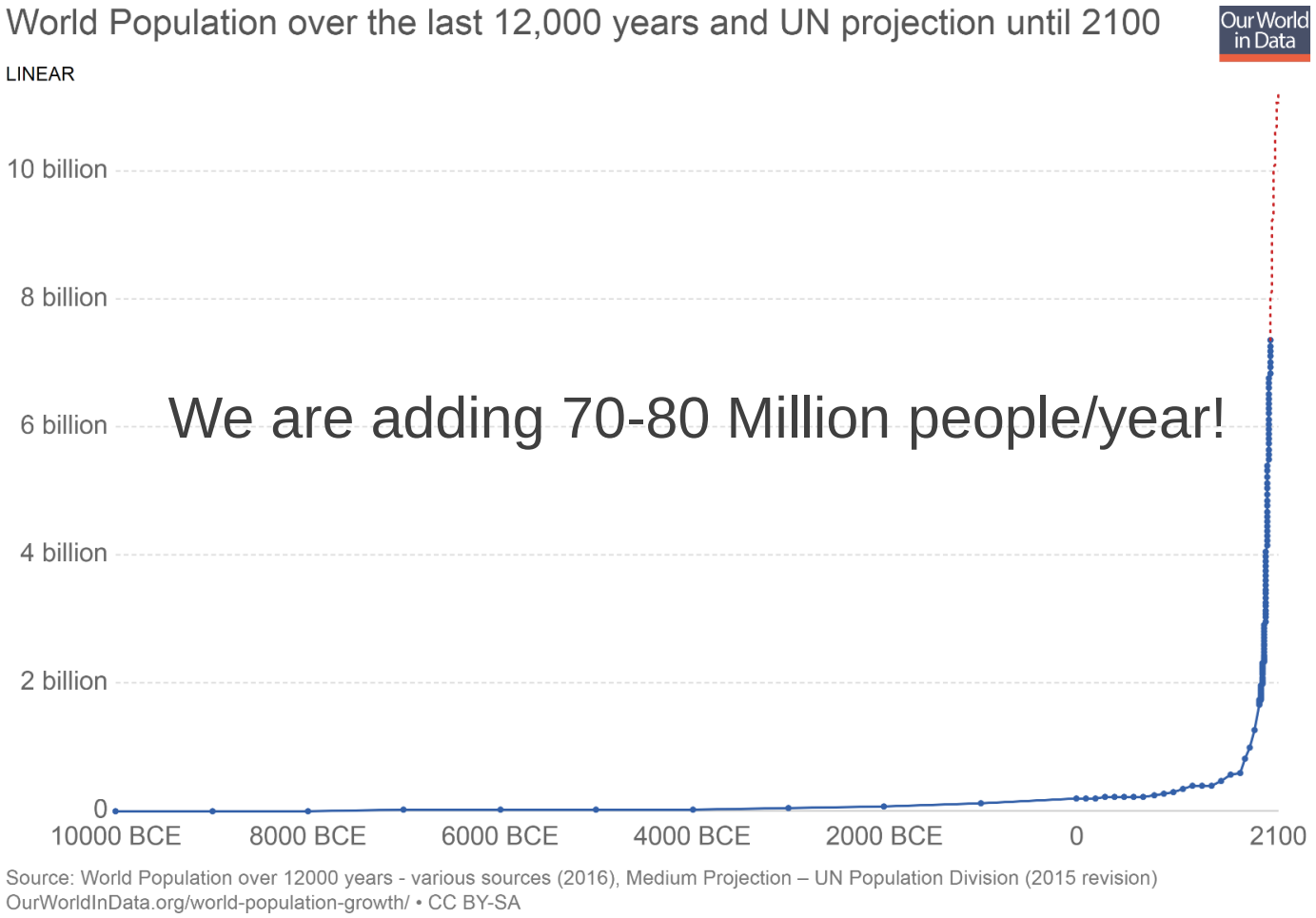
Disaggregating the Problem

$$\text{Impact} = \text{Population} \times \frac{\text{Goods \& Services}}{\text{Person}} \times \frac{\text{Impact}}{\text{Goods \& Services}}$$

$$I = P \times A \times T$$

The IPAT equation is a mathematical identity that shows that the underlying environmental problems are related to “scale”. Growth in Population and Affluence have exceeded improvements in Technology. Furthermore the terms in the equation are highly coupled!

World Population from 10,000 BCE to 2100 CE



Based on the IPAT, if we want negative impacts less than 0…

$$\frac{\Delta I}{I} = \frac{\Delta P}{P} + \frac{\Delta A}{A} + \frac{\Delta T}{T} < 0$$

"technology"

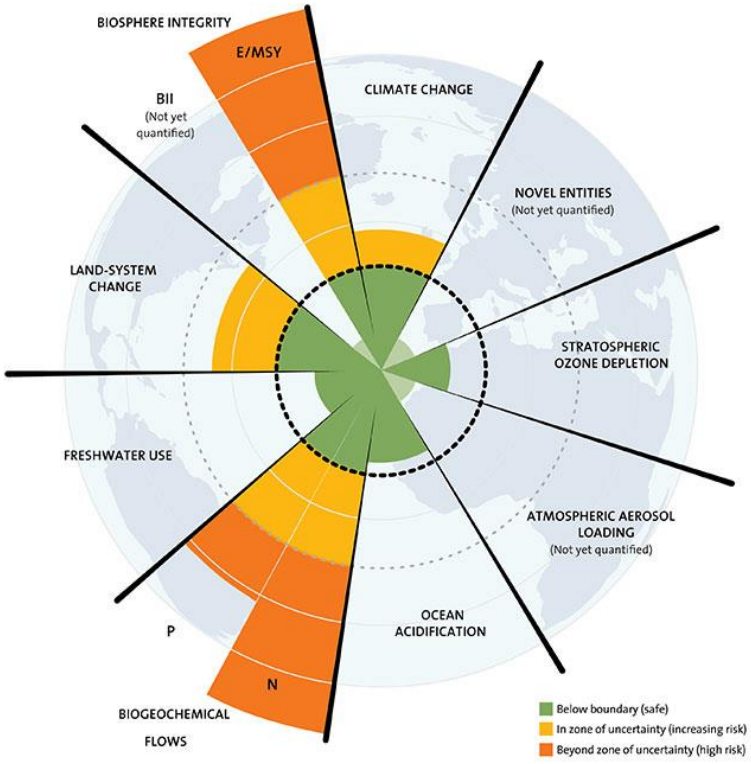
Based on global estimates…

$$1\% + 4\% - 5\% = 0$$

We must improve our environmental performance on goods and services by 5% a year just to stay even.

Planetary Boundaries

Planetary boundaries is a concept involving Earth system processes that contain environmental boundaries.



transgressing one or more planetary boundaries may be deleterious or even catastrophic due to the risk of crossing thresholds that will trigger non-linear, abrupt environmental change within continental-scale to planetary-scale systems.

Johan Rockström from the Stockholm Resilience Centre

https://youtu.be/8Sl28fkrozE

IPAT Example

- Gasoline used in Cars

Factors that influence the amount of gasoline consumed in a car

$$\text{gasoline} = \text{number of cars} \times \frac{\text{miles driven}}{\text{car}} \times \frac{\text{gasoline}}{\text{mile}}$$

Impact "I" = number of cars

population "P"

service provided / car "A" = miles driven / car

technology "T" = gasoline / mile

If we let *Q* be the quantity of goods and services delivered (within a given time period) to people, and *R* be the quantity of resources consumed in order to deliver those goods and services, then the IPAT equation can be rewritten in a slightly different way as:

$$I = P \times \left[\frac{GDP}{P}\right] \times \left[\frac{Q}{GDP}\right] \times \left[\frac{R}{Q}\right] \times \left[\frac{I}{R}\right]$$

$\left[\frac{R}{Q}\right]$ represents the "resource intensity,"

$\left[\frac{I}{R}\right]$ impact created per unit of resources consumed

$$R = Q \times \left[\frac{R}{Q}\right]$$

resources consumed are equal to the quantity of goods and services delivered times the resource intensity

$$\text{Impact} = \text{Production} \times \frac{\text{Impact}}{\text{Production}}$$

Energy Used Production (P) or Consumption 1/efficiency (e)

$$I = P \times \frac{1}{e}$$

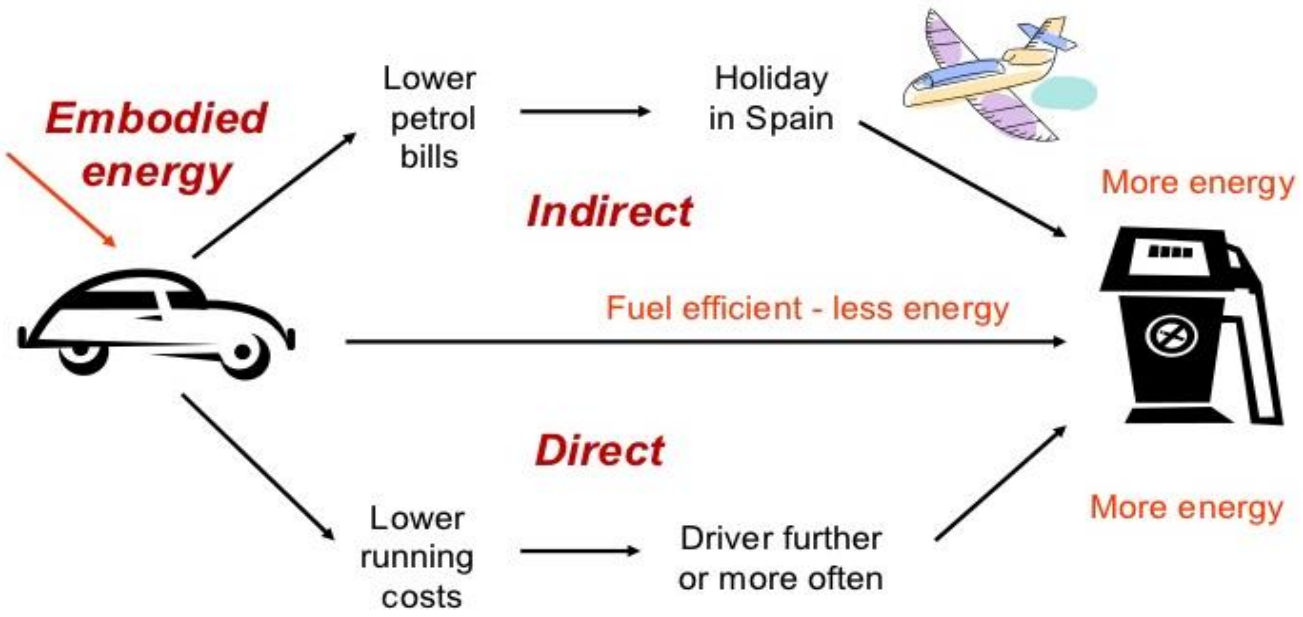
Coupled nature of e and P

- $e = f(P)$ *Increased production leads to increased efficiency through learning effects and economies of scale*

- $P = f(e)$ *Increased efficiency can lead to reduced prices and increased demand. The phenomenon is called the "rebound effect"*

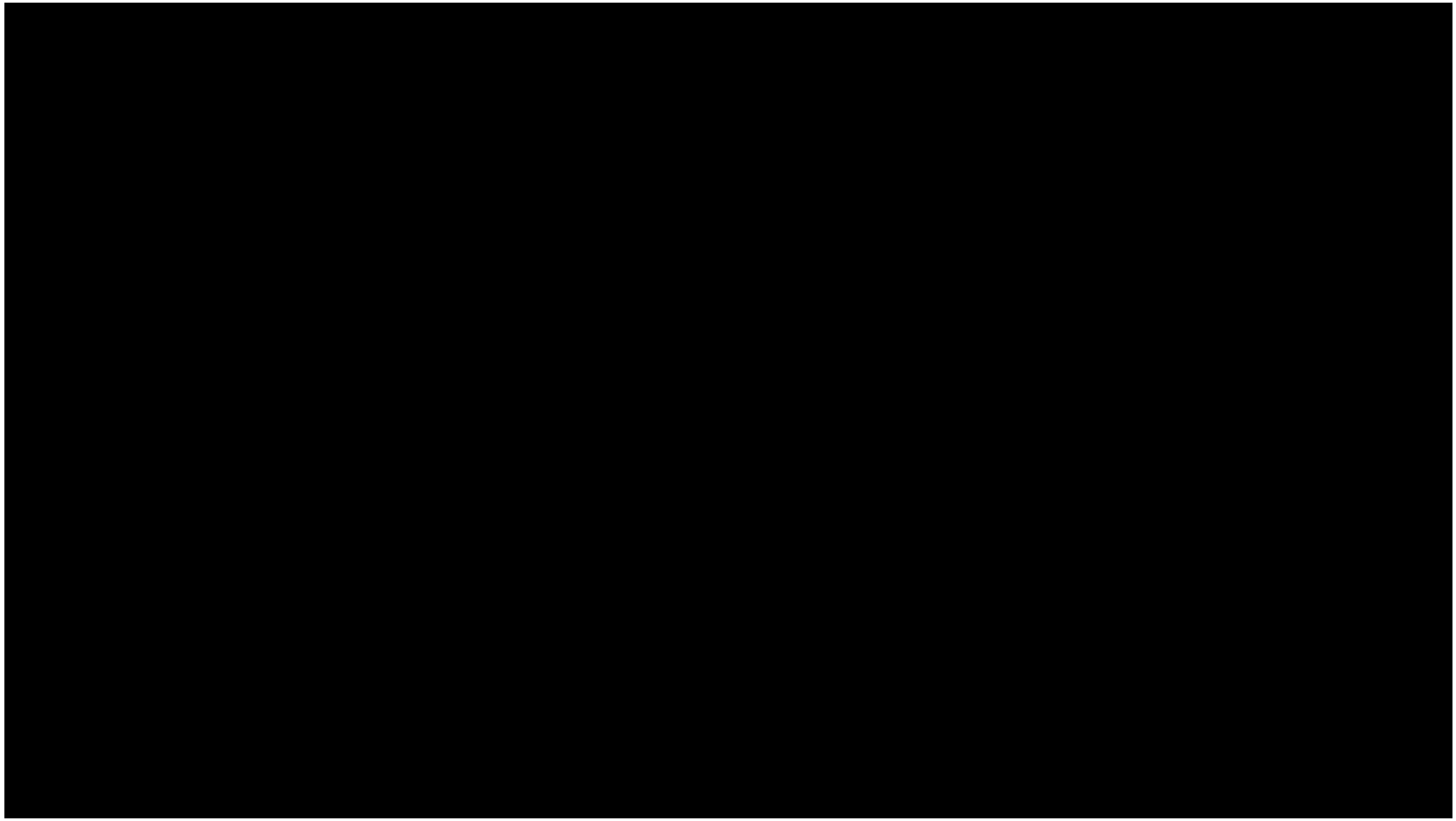
Rebound Effect

A gain in eco-efficiency does not necessarily translate in reduction in impacts.



Rebound Effect

- https://youtu.be/PXf4KVWyfjs

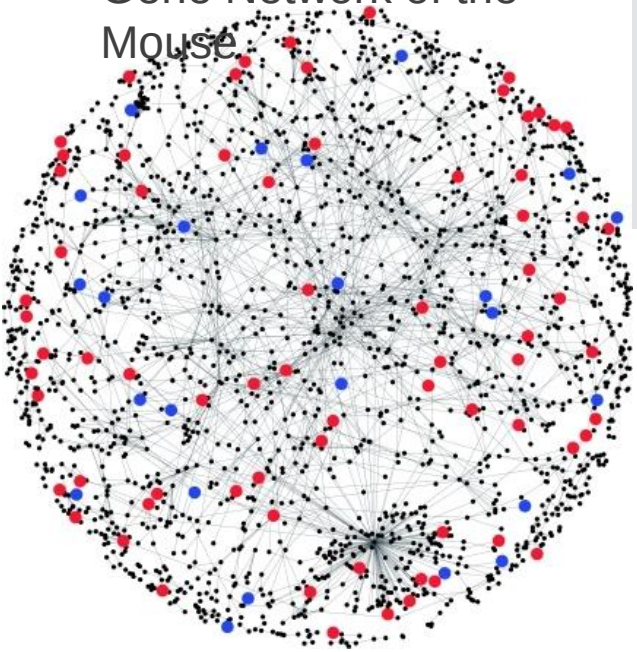


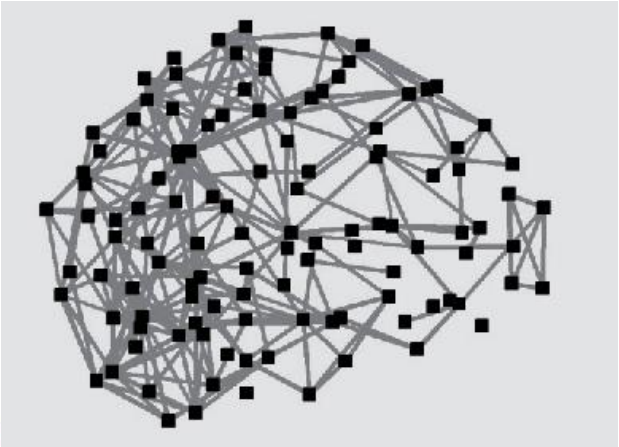
We need a systems approach!

How do we change an unsustainable system into a sustainable one…

Systems Thinking

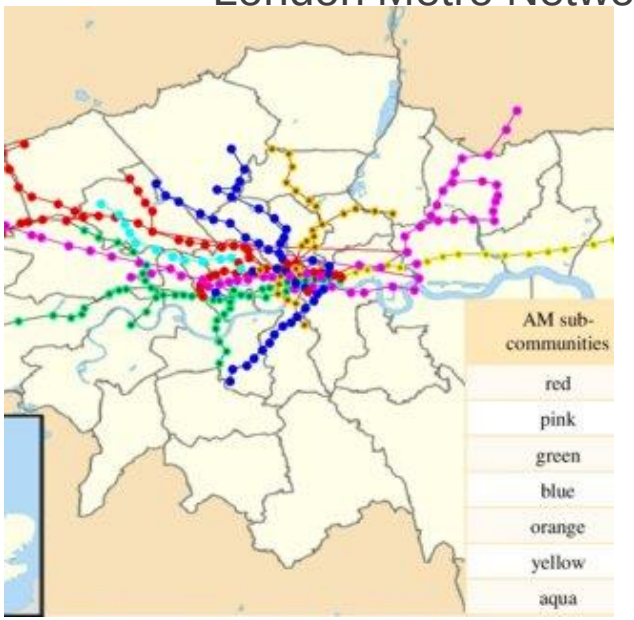
Gene Network of the Mouse





Brain Network of Schizophrenia

London Metro Network



What is a System?

- A collection of parts that function together

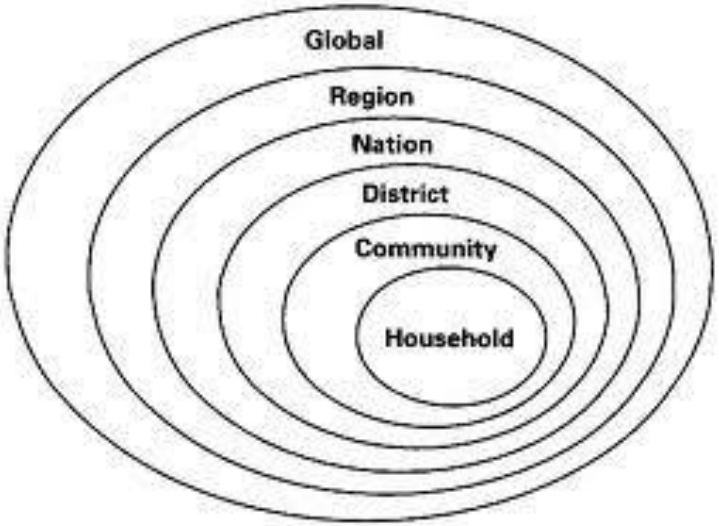
Nested systems

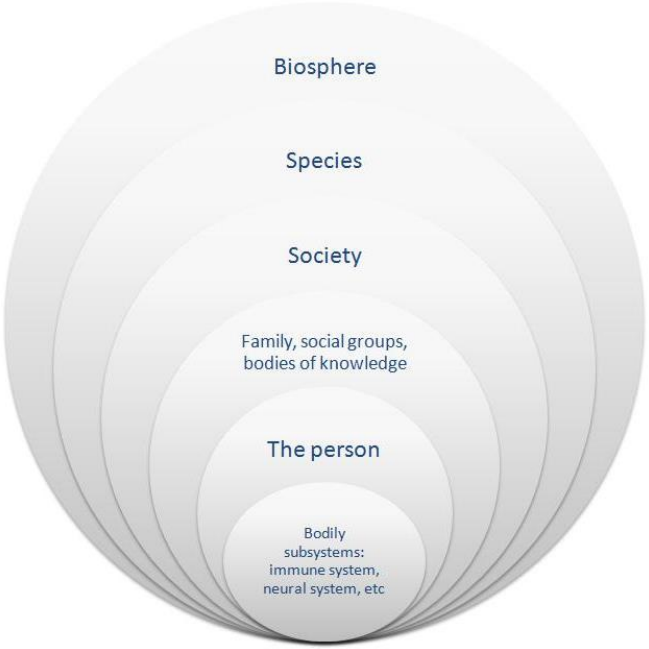
-city/neighborhoods/natural environment
-cell/colony
-human engineered facility/environment
-network (grid, internet, food, water)
-manufacturing facility

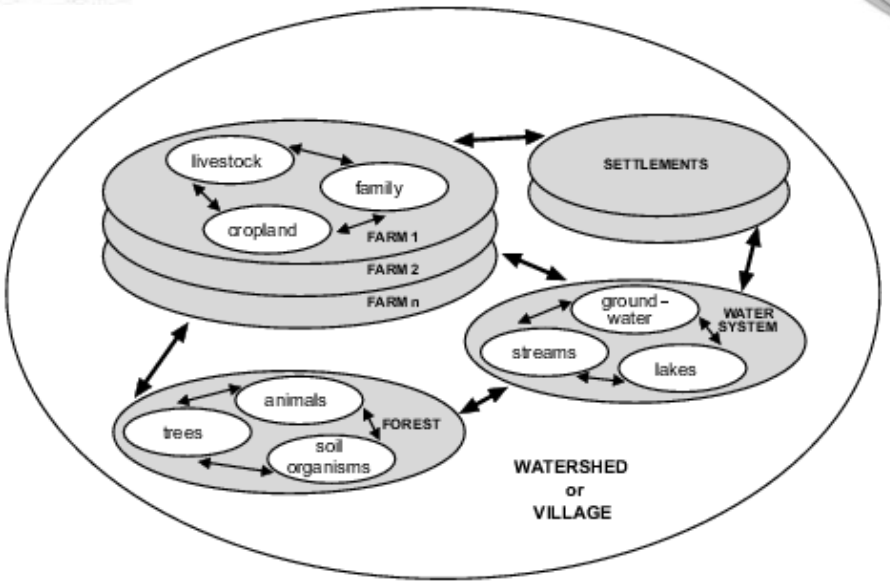
Can be physical or abstract

-legal system/system of justice
-cultural system
-organizational system

Nested Systems







"System of Systems"

Or

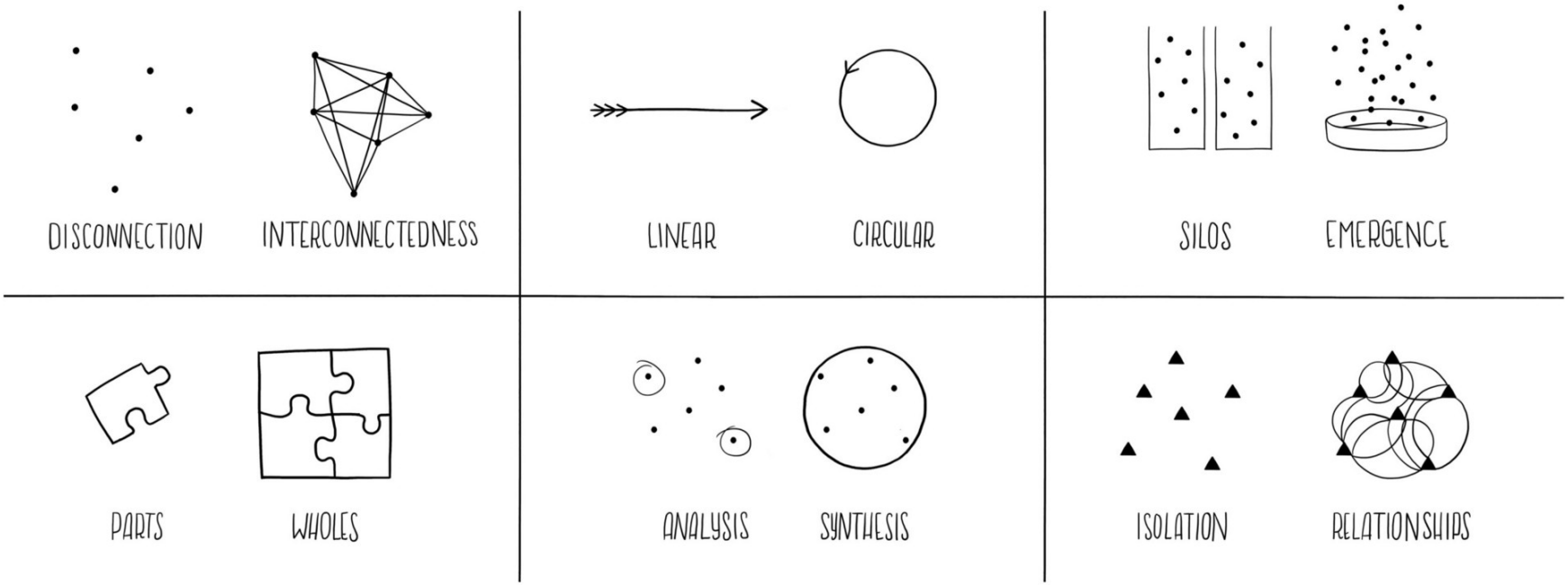
"Network of networks"

Attributes of Systems

- Structure and organization
- Behavior (e.g. transformation, translocation, linear, non-linear)
- Interconnectivity (usually)
- Boundaries (always)

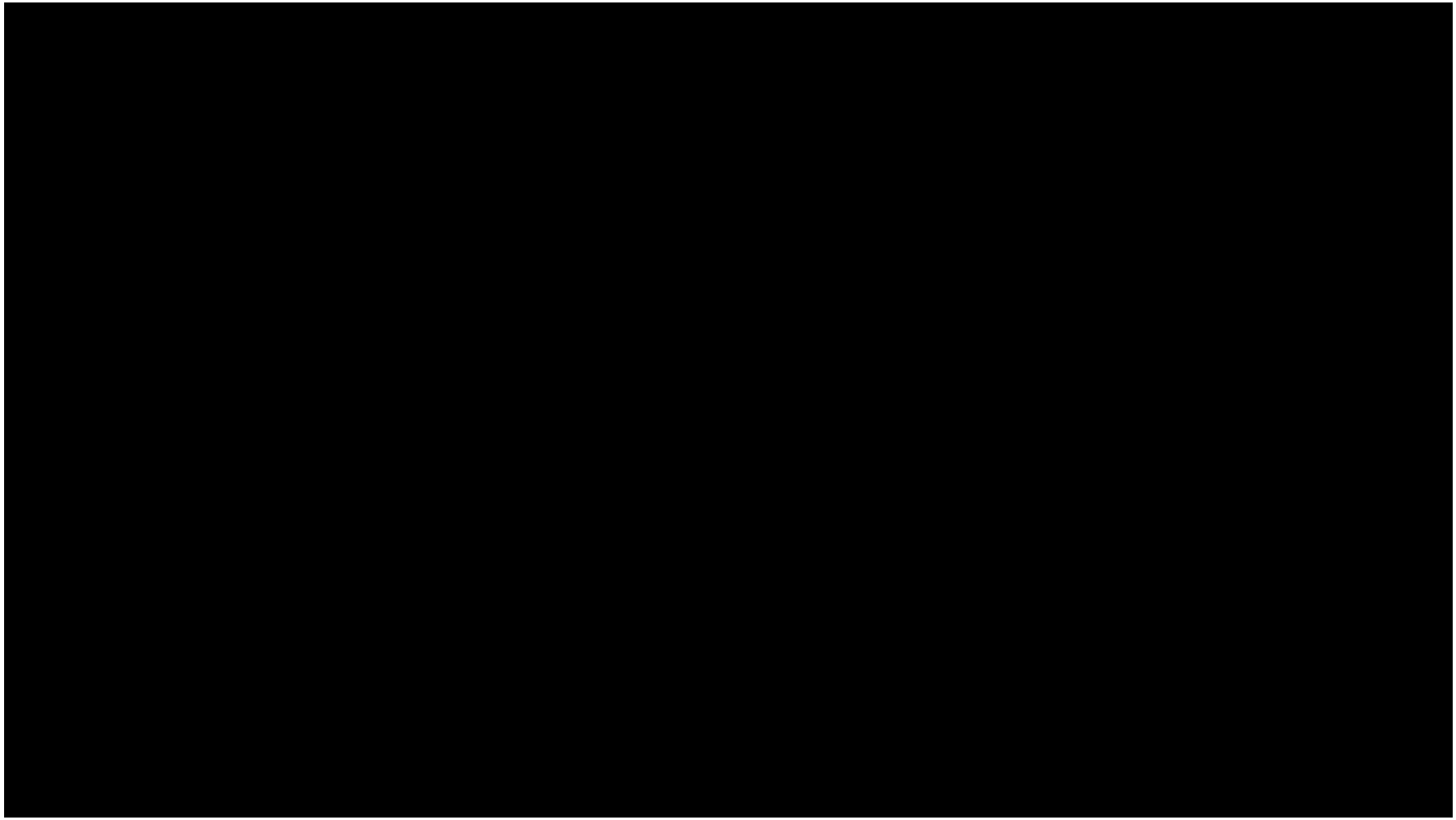
- Physical systems can be:
  - Open (exchange matter & energy w/environment)
  - Closed (exchange only energy)
  - Isolated (neither)

TOOLS OF A SYSTEM THINKER



DISRUPT DESIGN

Systems Thinking for Innovation



https://youtu.be/qvng4b00OdA

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Systems Approaches

Systems show several defining properties

- A systems approach assesses questions holistically

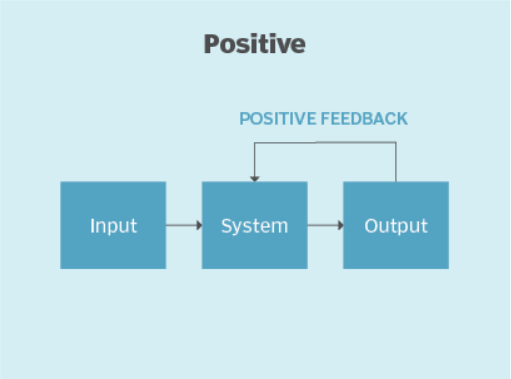
System = a network of relationships among parts, elements, or components

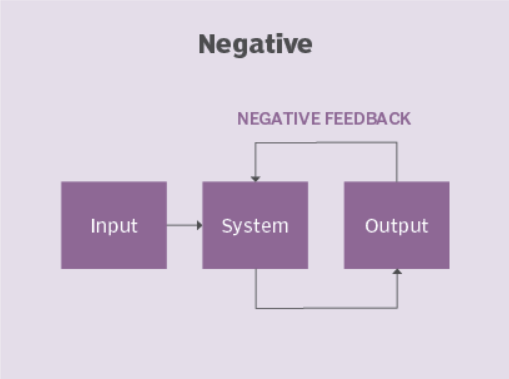
  - They interact with and influence one another
  - They exchange energy, matter, or information
  - Systems receive inputs of energy, matter, or information
  - They process these inputs and produce outputs

- **Systems can highlight behavior that is hard to understand and predict**

Reading systems

- Recognizing common patterns in specific situations
  - Resource flows and cycles
  - Feedback loops





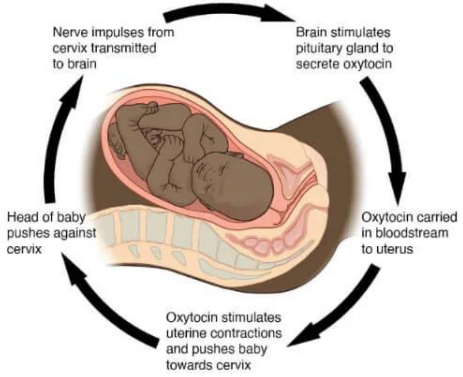


Fig: **Positive Feedback** (Childbirth)

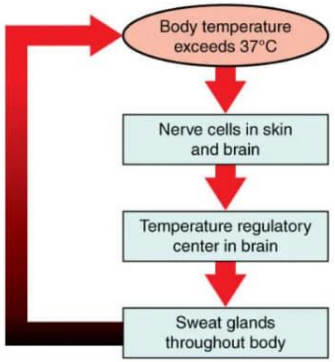
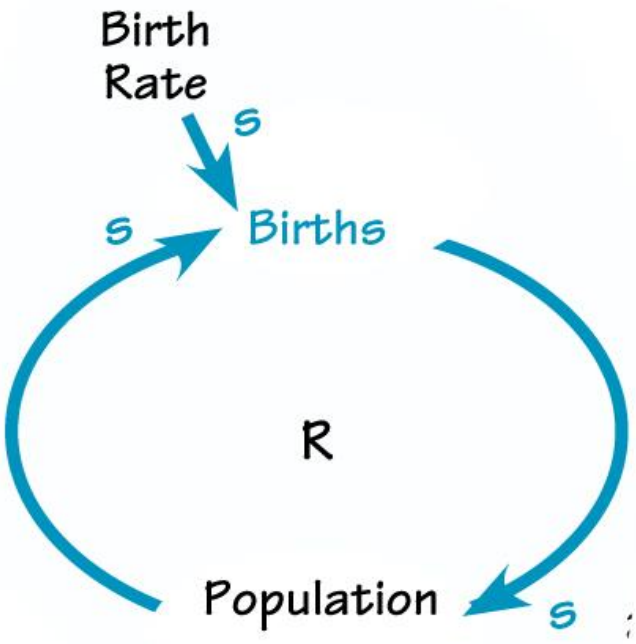
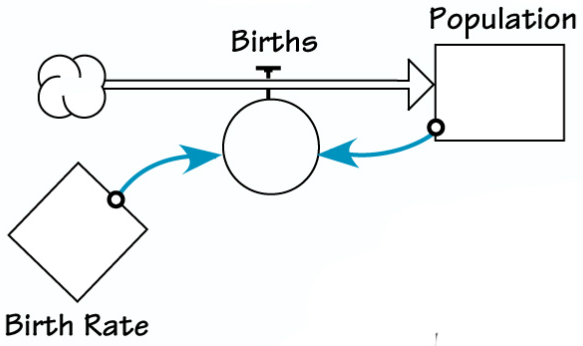


Fig: **Negative Feedback** (Temperature Regulation)

Stocks and flows

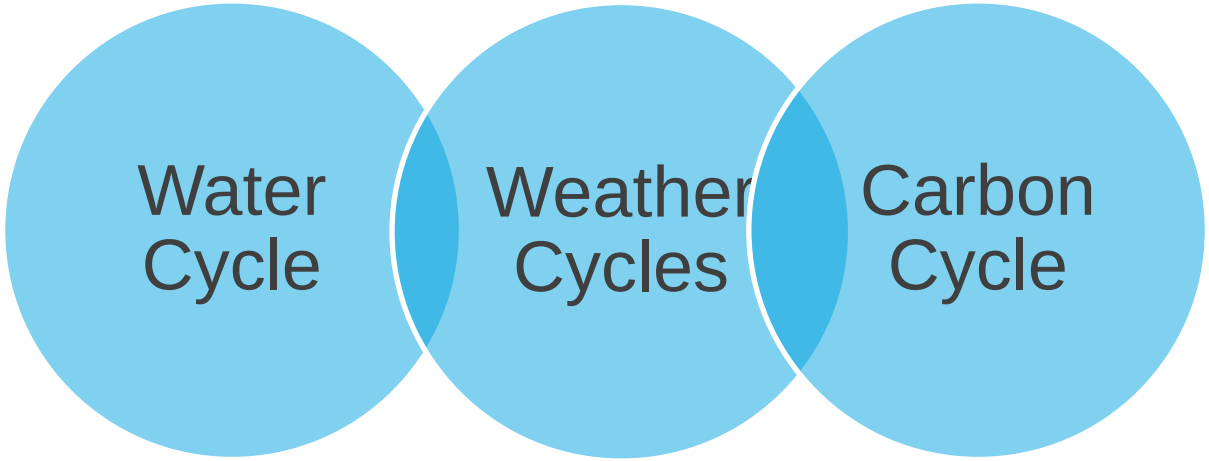
- Stocks are entities that can accumulate or be depleted
  - Foundation of any system
  - Elements that can be seen, counted, measured
  - An accumulation built up over time
    - Bathtub
    - Population
- Flows, on the other hand, are entities that make stocks increase or decrease
  - Stocks change over time through the actions of flows
    - A faucet or drain affects the level of water in a bathtub
    - Births and deaths





Changes in Stock levels can have a Big Impact

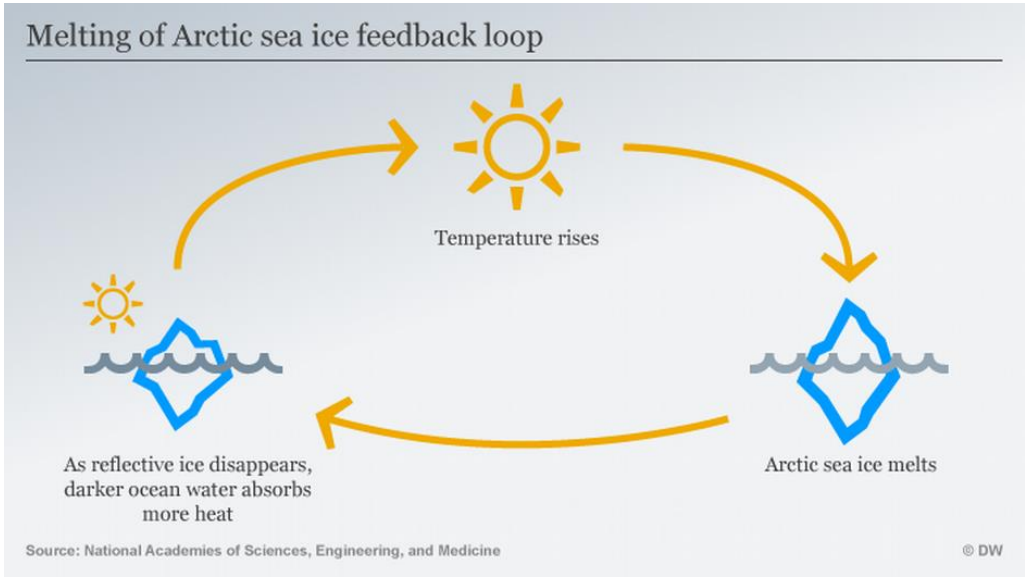
- Sometimes large quantities of flows can be sequestered, so they are not traveling through the cycle
- Changing stock levels
  - sequestering or releasing water or carbon affects the climate as ice or carbon dioxides interacts with planet's weather system



Feedback

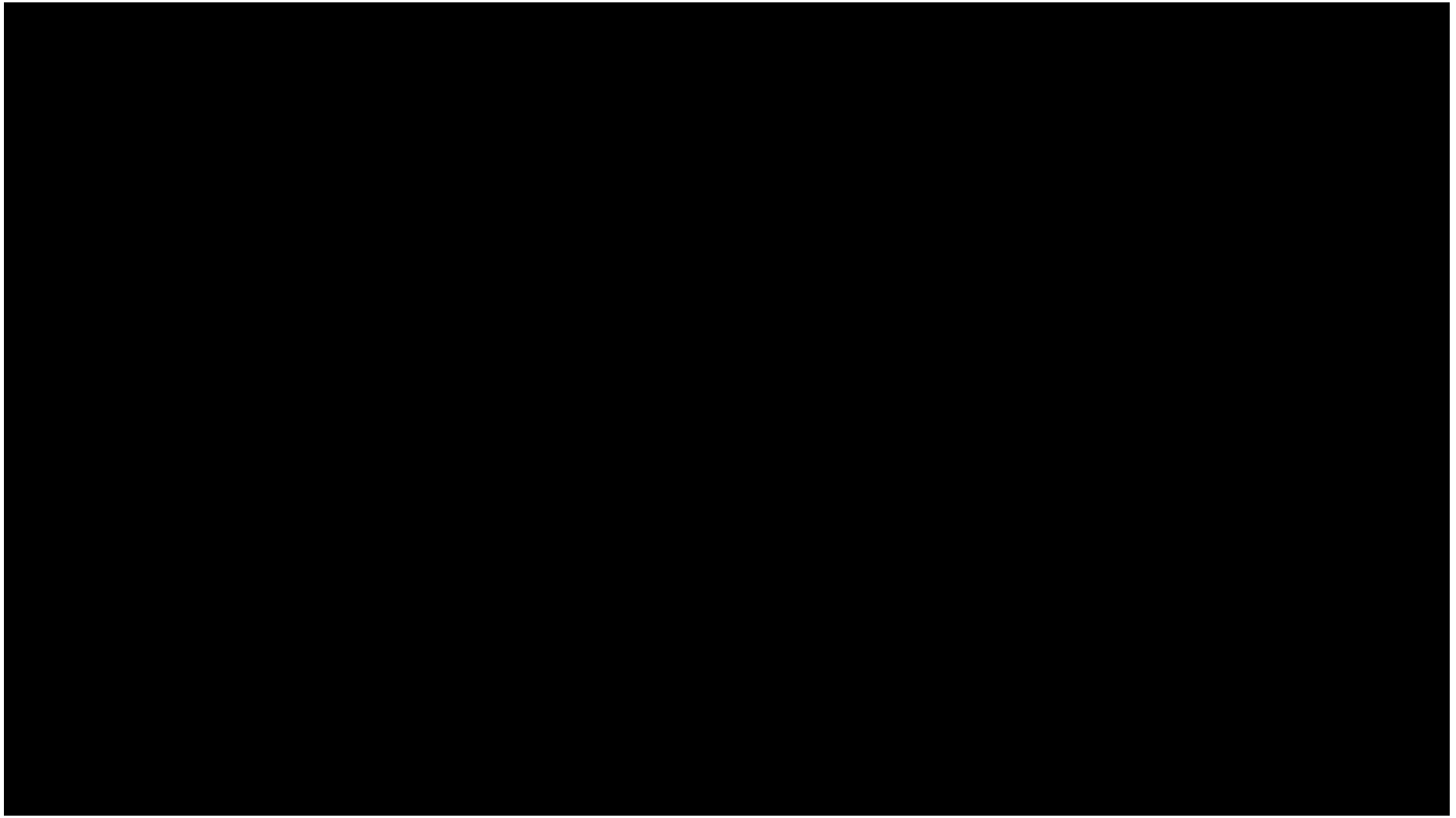
- If there is a behavior in system that persists over time – stock grows or declines swiftly or is held in a certain range there is a control mechanism at work
- Operates through a feedback loop
  - E.g. increase in temperatures due to climate change will increase evaporation, in turn increasing greenhouse gases in the atmosphere.

Another example, disappearance of Arctic Sea ice.

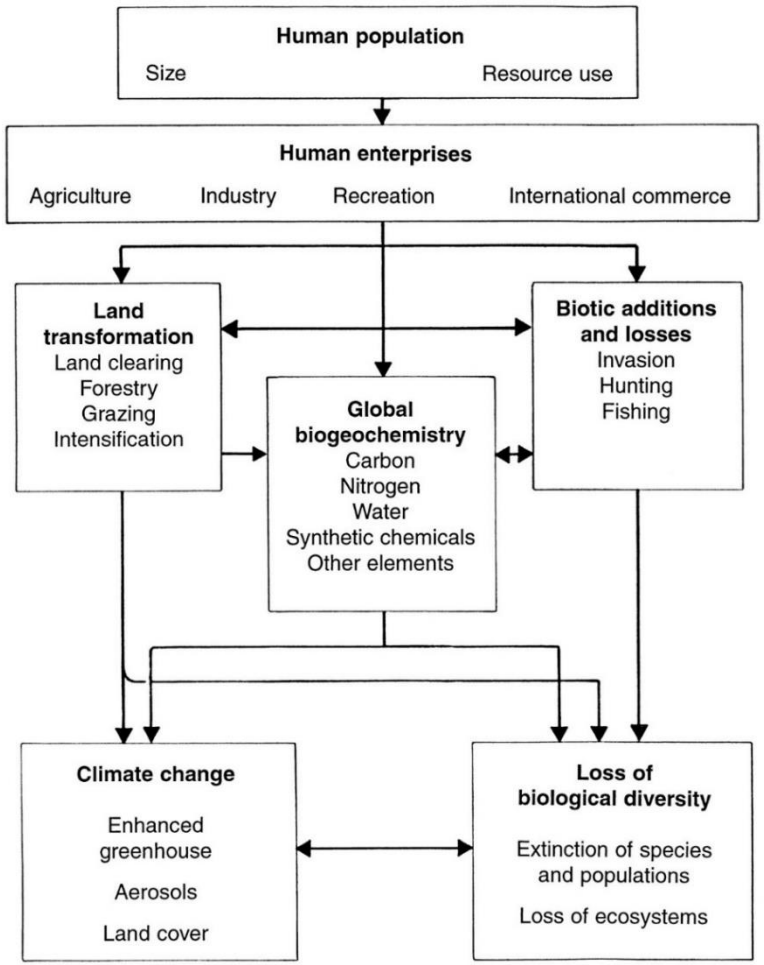


Feedback loops

- https://www.youtube.com/watch?v=inVZoI1AkC8



A conceptual model illustrating humanity's direct and indirect effects on the Earth system

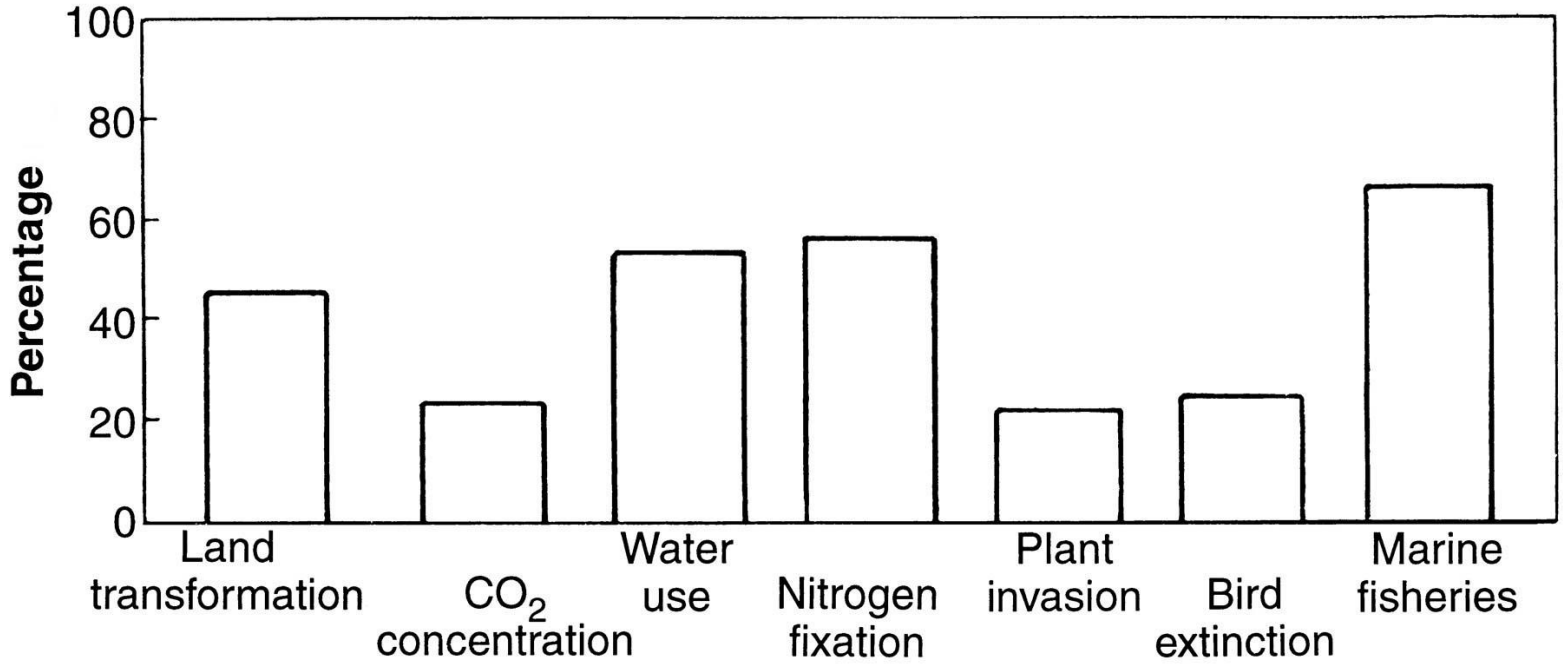


- The growth of the human population, and growth in the resource base used by humanity, is maintained by a suite of human enterprises such as agriculture, industry, fishing, and international commerce.
- These enterprises transform the land surface (through cropping, forestry, and urbanization), alter the major biogeochemical cycles, and add or remove species and genetically distinct populations in most of Earth's ecosystems.
- These changes in turn entrain further alterations to the functioning of the Earth system, most notably by driving global climatic change and causing irreversible losses of biological diversity.

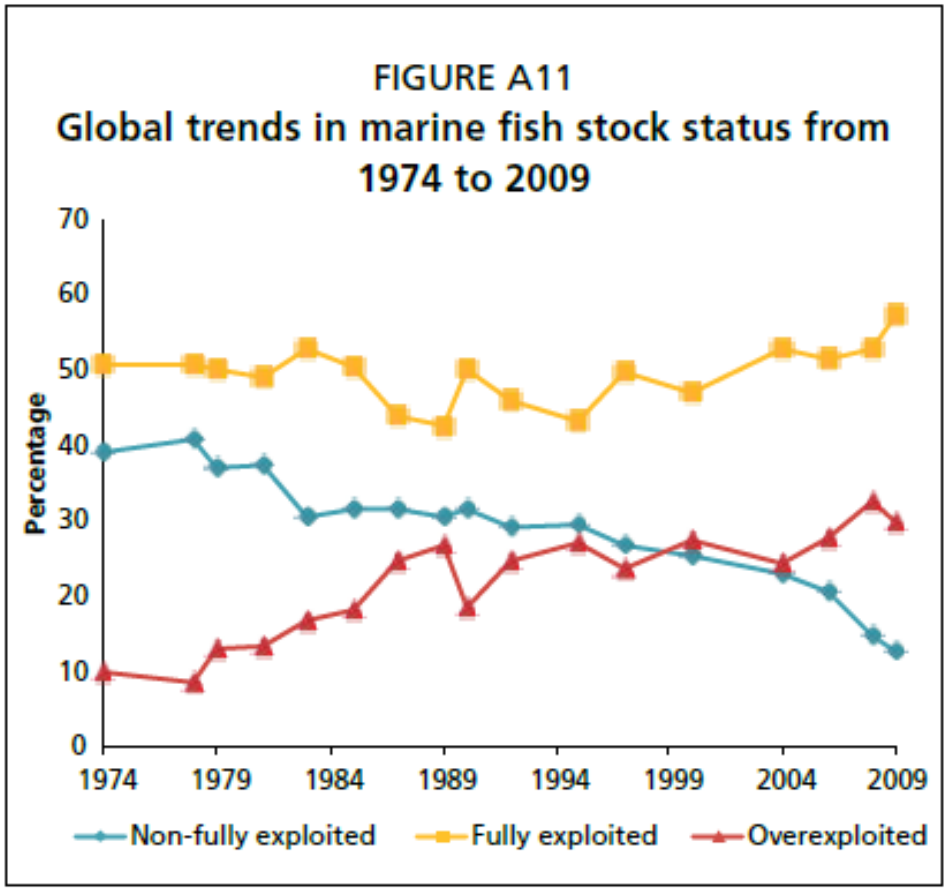
Peter M. Vitousek et al. Science 1997;277:494-499

Published by AAAS

Human dominance or alteration of several major components of the Earth system, expressed as (from left to right) % of the land surface transformed; % of the current atmospheric CO2 concentration that results from human action% of accessible surface fresh water used; % of terrestrial N fixation that is human-caused; % of plant species in Canada that humanity has introduced from elsewhere; % of bird species on Earth that have become extinct in the past two millennia, almost all of them as a consequence of human activity; and % of major marine fisheries that are fully exploited, overexploited, or depleted



Peter M. Vitousek et al. Science 1997;277:494-499



Review of the state of world marine fishery resources, FAO Fisheries and Aquaculture Technical Paper, 569, Rome 2011.

Human-Environment Systems Diagram

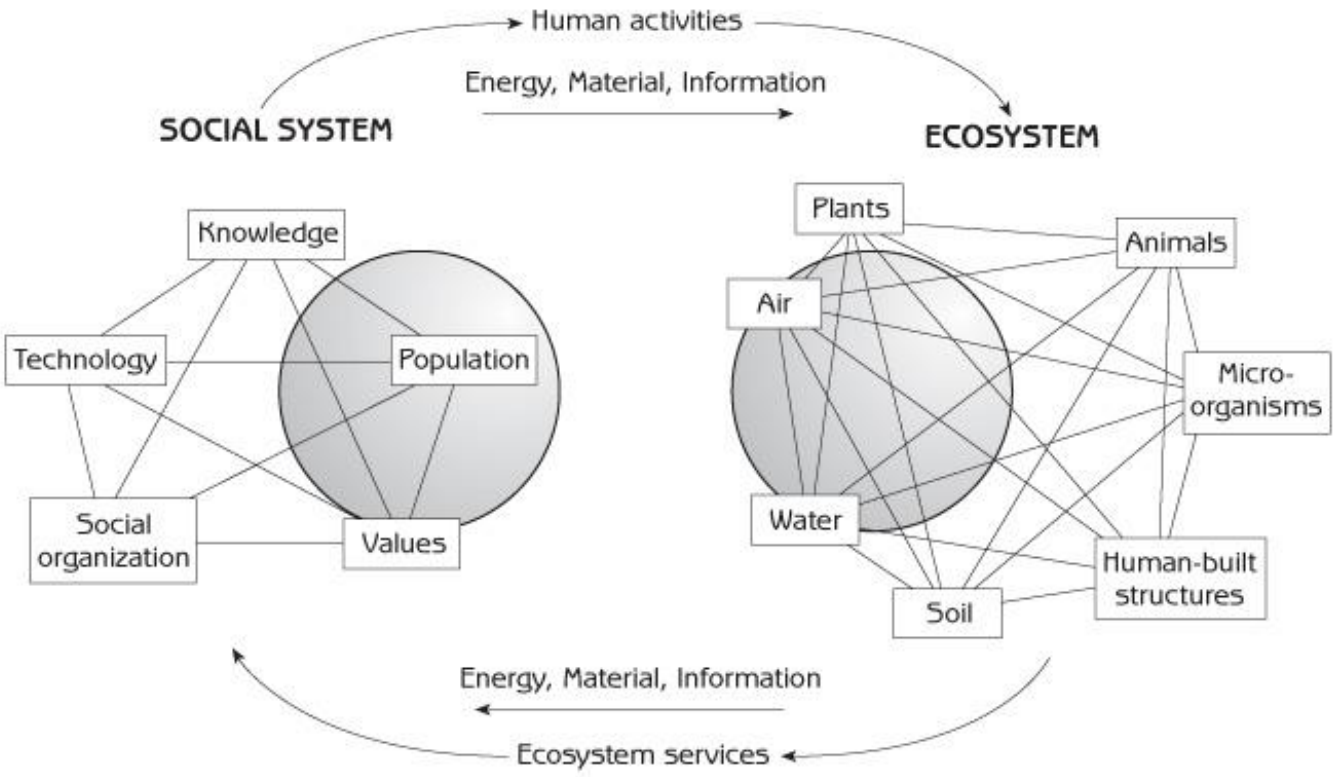
Both humans and the environment impact each other.

Note the arrow from the Environment box to the Humanity box - and the arrow from the Humanity box to the Environment box with the word affects next to each arrow.

Source: https://www.e-education.psu.edu/geog030/node/325

Human Ecology

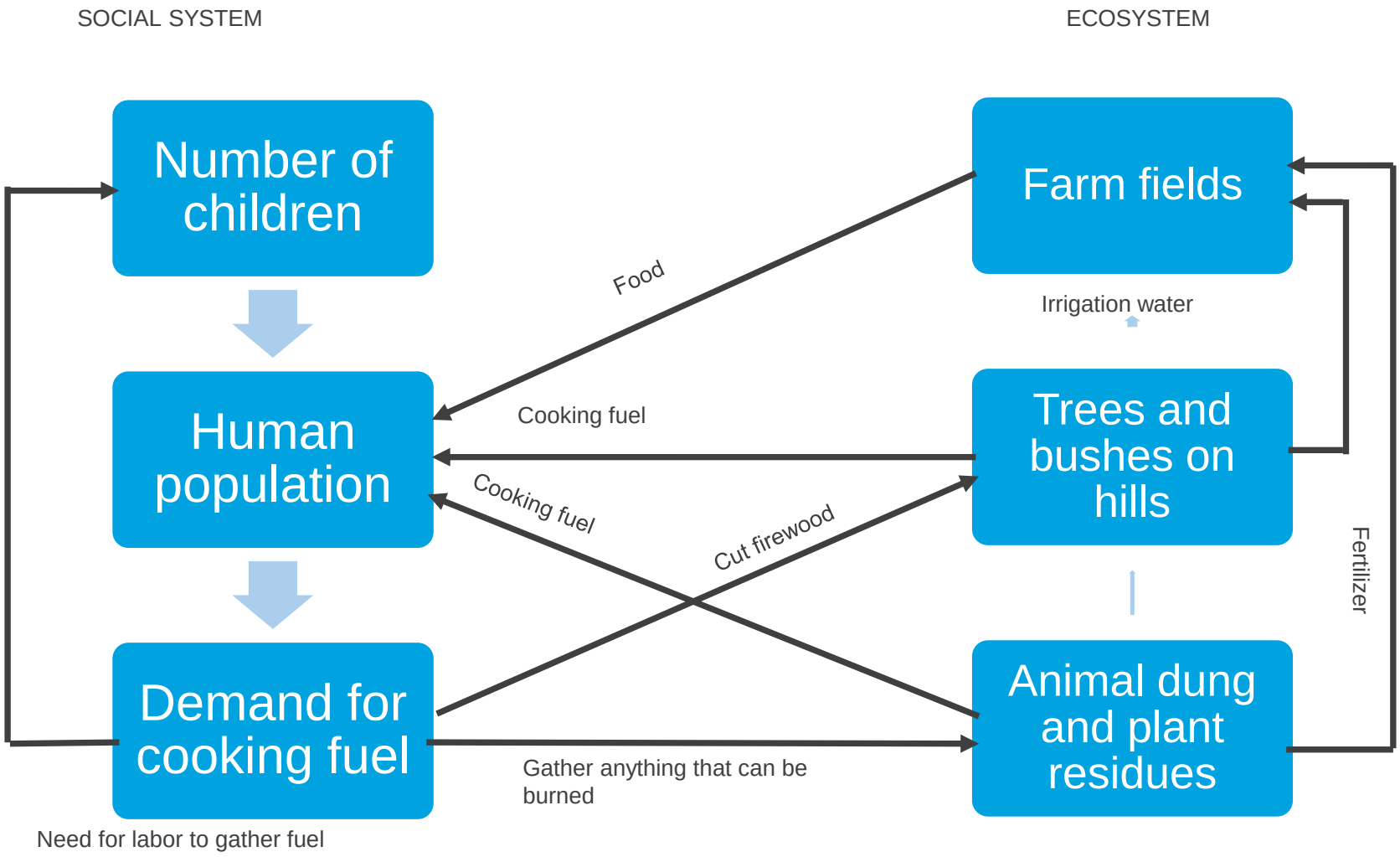
relationships between people and their environment



Interaction of the human social system with the ecosystem. Source: **Human Ecology - Basic Concepts for Sustainable Development**, Gerald G. Marten

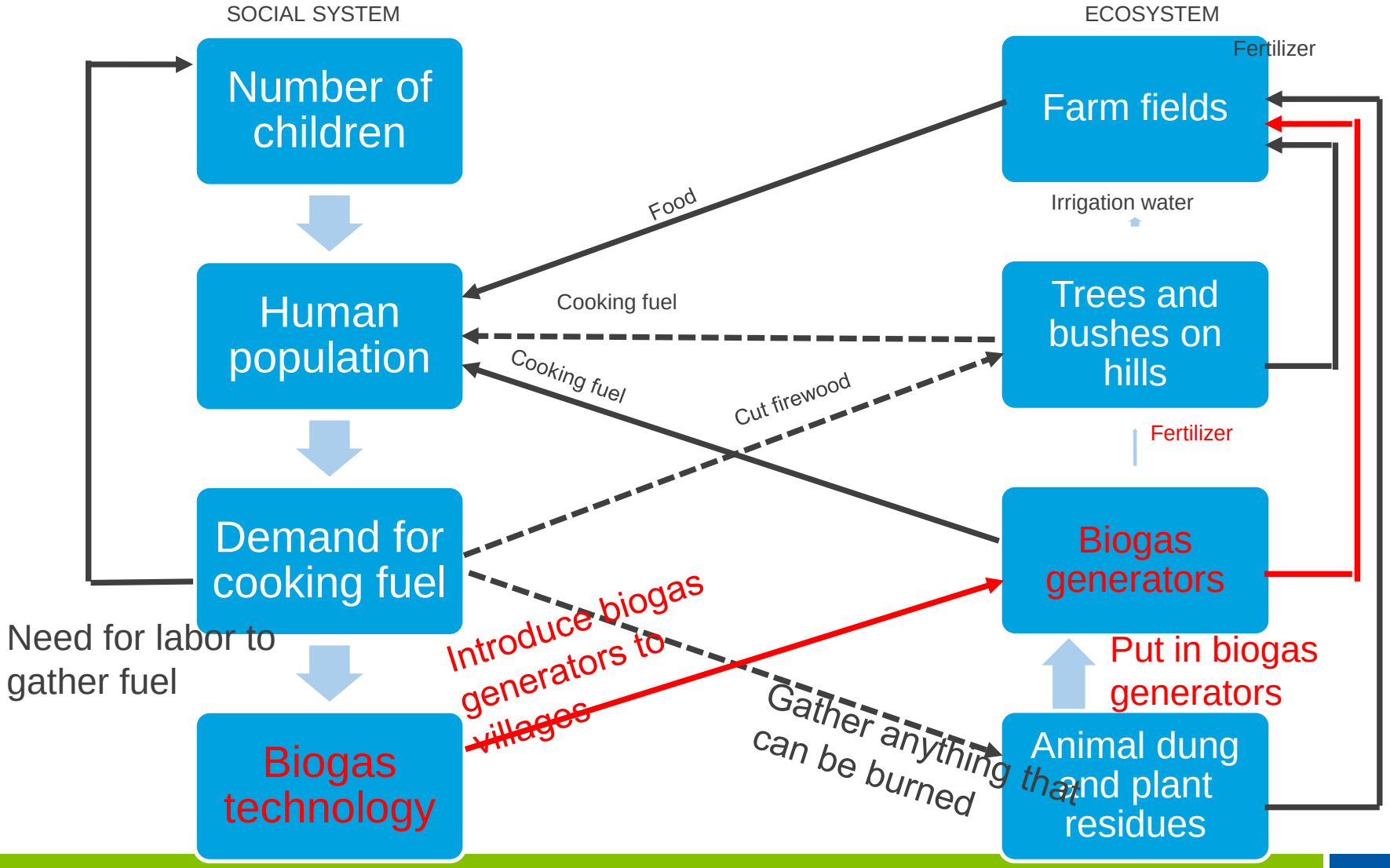
Cooking fuel and deforestation in India

Source: Human Ecology - Basic Concepts for Sustainable Development, Gerald G. Marten



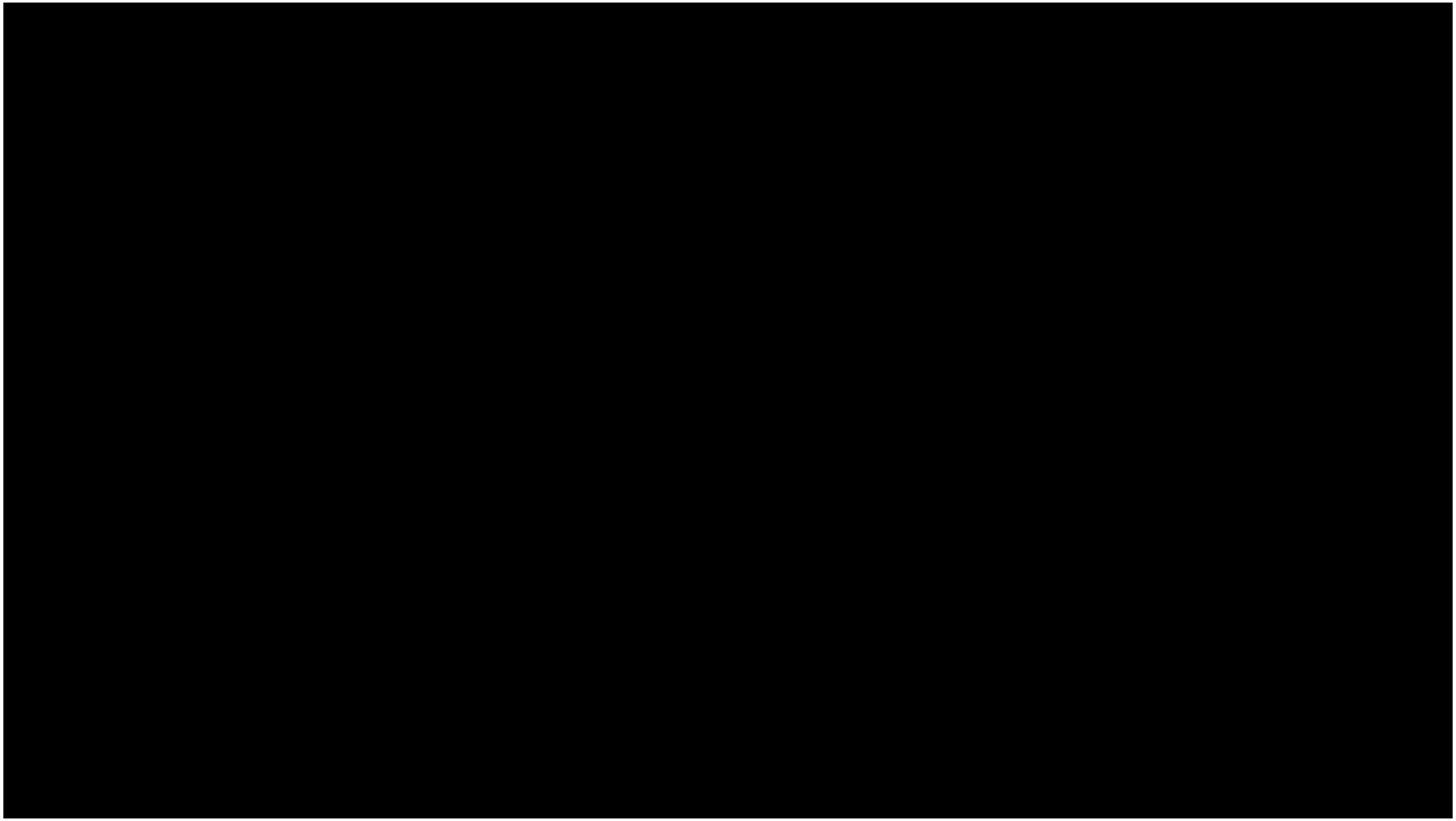
Cooking fuel and deforestation in India

Source: Human Ecology - Basic Concepts for Sustainable Development, Gerald G. Marten



Tragedy of the Commons

- CONCEPT: a shared resource in which any given user reaps the full benefit of his/her personal use, while the losses are distributed amongst all users.
- RESULT? Tragedy all around.



https://www.youtube.com/watch?v=CxC161GvMPc

How to avoid the Tragedy?

- Elinor Ostrom: Only woman to have received the Nobel Prize in Economics
- Challenged Hardin's approach to the "Tragedy of the Commons"

Argued that common resources are well managed when those who benefit from them the most are in close proximity to that resource

Identified eight *design principles for Common Pool Resource (CPR)* institution

https://youtu.be/Qr5Q3VvpI7w

Identified eight *design principles for Common Pool Resource (CPR)* institution

1. **Clearly defined contents of the common pool resource** and effective exclusion of external un-entitled parties;
2. The appropriation and provision of common resources that are **adapted to local conditions**;
3. **Collective-choice arrangements** that allow most resource appropriators to participate in the decision-making process;
4. **Effective monitoring** by monitors who are part of or accountable to the appropriators;
5. A scale of **graduated sanctions for resource appropriators** who violate community rules;
6. **Mechanisms of conflict resolution** that are cheap and of easy access;
7. **Self-determination of the community** recognized by higher-level authorities; and
8. In the case of larger common-pool resources, organization in the form of **multiple layers of nested enterprises**, with small local CPRs at the base level.

Summary

- Energy Consumption in Hong Kong
- Transportation sector and its Energy Dependence
- Environmental Impacts associated with Transportation
- Impact Assessment for Sustainable Development
  - IPAT equation
  - Rebound Effect
- System Thinking is key for Understanding the Overall Impacts
  - Feedback loops

Assignment 2 has been released, due 28th Feb!

Don't Forget:

Quiz next week (21st Feb) over Canvas

- Duration: 10 mins
- Format: MCQ and short questions