**DSS5202 Sustainable Systems Analysis**

# Introduction to Systems Analysis & Thinking

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# 1. Review of Sustainable Systems Concepts

## 1.1 Sustainability and Sustainable Development

- The term sustainability is used very widely in many disciplinaries with different definition and meaning.

- The most common use of the word sustainability is in the context of Human Sustainability on planet Earth as a result of economic and social development.

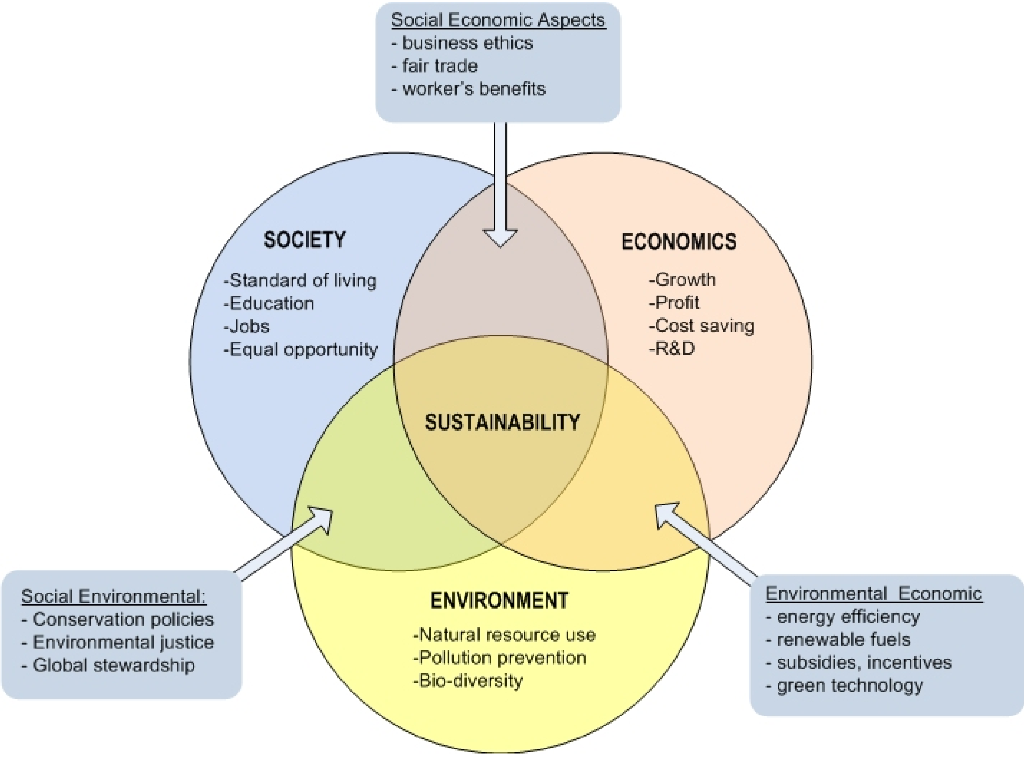
- The United Nations define Sustainable Development as “development that meets the needs of the present without compromising the ability of future generations to meet their own needs."

## 1.2 The Three Pillars of Sustainability

- Sustainable development is generally viewed as comprising three aspects:

    1. Environmental
    2. Economic
    3. Social aspects.

- For a particular process to be sustainable, it should not cause irreversible change to the environment, should be economically viable, and should benefit society.



### 1.3 United Nations' 17 Sustainable Development Goals (SDG)

- The 2030 Agenda for Sustainable Development, adopted by all United Nations Member States in 2015, provides a shared blueprint for peace and prosperity for people and the planet, now and into the future.

- 17 Sustainable Development Goals (SDGs) have been identified with urgent call for action by all developed and developing countries in a global partnership.

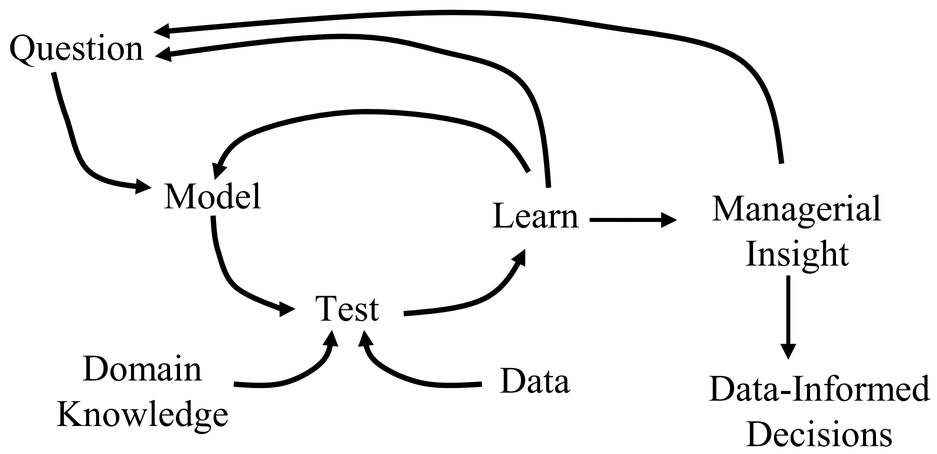
- It is recognized that ending poverty and other deprivations must go hand-in-hand with strategies that improve health and education, reduce inequality, and spur economic growth – all while tackling climate change and working to preserve our oceans and forests.


Source: https://sdgs.un.org/

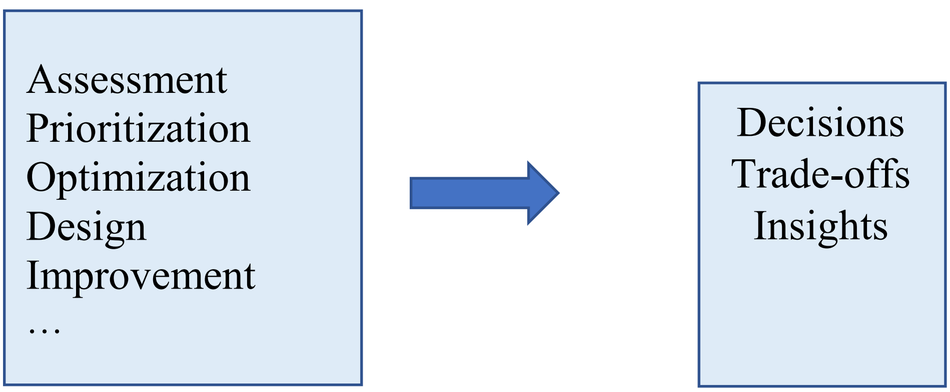
## 2. Sustainable System Science & Engineering

### 2.1 System Analysis

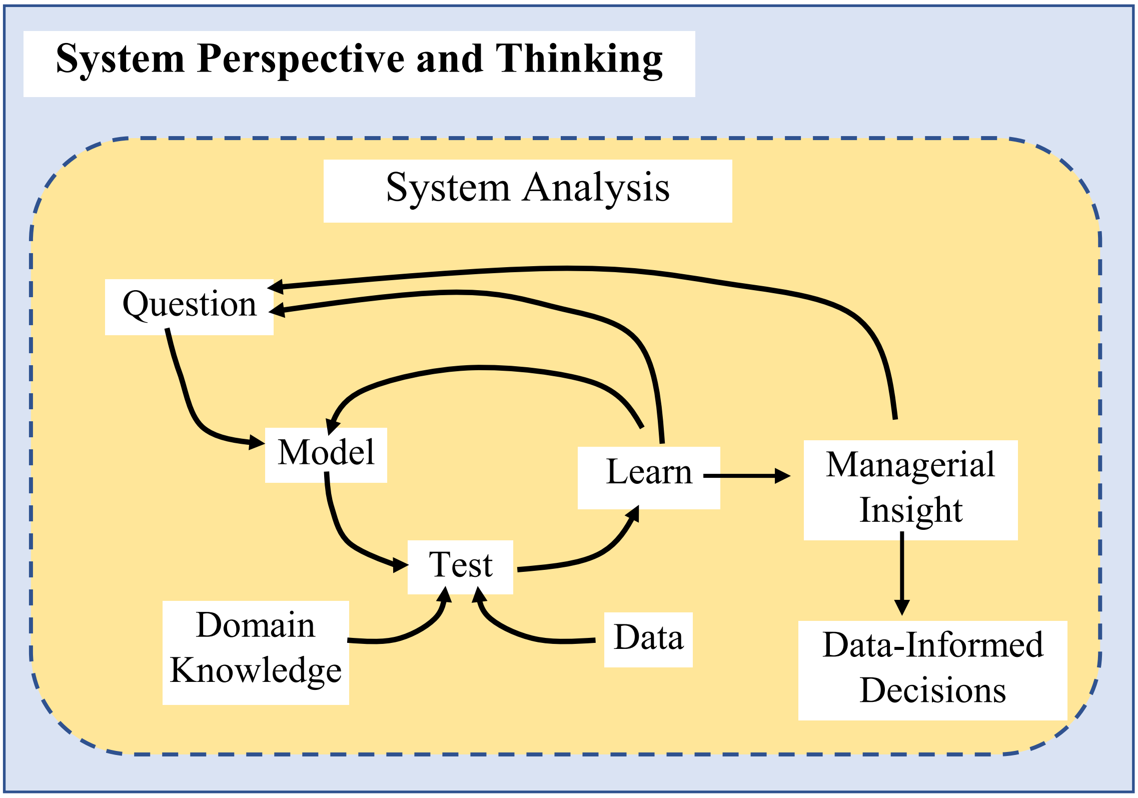
**Data-Informed Modeling, Analysis and Decision Making**




### 2.2 Methods in System Science and Engineering



### 2.3 System Perspective and Thinking



# 3. An Overview of System Thinking

## 3.1 System Thinking

- System Thinking is an import skill for System Analysts and Decision Making.

- System thinking is a holistic approach to performing analyses that focuses on the way different parts of a system interact and how they influence one another within a whole.

- System thinking is about making sense of the complexity of the world by looking at it in terms of the wholes and the relationships rather than by looking at just its individual parts.

- Important concepts associated with system thinking:

    1. Boundaries
    2. Feedback loops
    3. Interdependence
    4. Open and closed system

## 3.2 What is a System?

- A system is a set of elements that are interconnected to influence or interact with each other and is organized in a way to achieve a certain purpose or goal.

- The three important components of a system are:

    1. The elements
    2. Their interconnections and relationships
    3. The overall purpose or goal

- The system components collectively determine the system's properties and behaviors such as:

    1. Development
    2. Resiliency
    3. Self-organization
    4. Self-repair
    5. Sustainability

- Hence a system is not just a random collection of its parts. Rather, the parts interact and impact each other resulting in some outcomes or behavior over time that are scientifically different from the outcomes or behavior of the individuals.

## 3.3 System Elements

- There are fundamentally three types of elements of a system:

  1. Stock
  2. Factor
  3. Decision

**Stocks**

- Stocks are used to represent elements that are cumulative and characterized by measurable amount.

- Stocks can accumulate (increase), deplete (decrease), or remain steady.

- **Examples of Stocks:**

  1. Money or savings in a bank account
  2. Number of trees in a well-defined area
  3. Number of people living in a city
  4. Amount of food stored for winter
  5. Amount of energy stored or generated at a power plant

- The stability or outcome of a system may depend on the maintenance of its stocks.

  1. If your bank account is stable or growing, then are doing well managing your finances.

  2. If there is no decline in tree population, then the forest is healthy.

**Factors**

- Factors are usually used to represent processes, flows, phenomena, actions, and even feelings that have influence within a system.

- Factors must be are measurable but they are not necessarily cumulative.

- Factors are typically characterized by rates or intensity of process rather than countable amounts.

- Rates are important as they affect the levels in stocks.

- Almost anything can be included as a factor in a system, as long as its variation influences the system state or other elements.

- **Examples of Factors:**

  1. Rate of tree falling in the forest.
  2. Electricity price at local market.
  3. Solar irradiance at a specific location.
  4. Number of cups of coffee you drink per day.

**Decision Points**

- Decision points are used to represent deliberate controls of a system by humans.

- Decisions made by human may not only be dictated by the system but also include other inputs such as knowledge, personal preferences, feelings, etc.

- **Examples of decision points:**

  1. Adopting a policy
  2. Decision to invest or not invest in a business
  3. Decision to restrict construction

## 3.4 Casual Loop Diagram

- A causal loop diagram is a graphical visualization tool that shows how the elements in a system are connected and how they influence each other through direct connections and feedback loops.

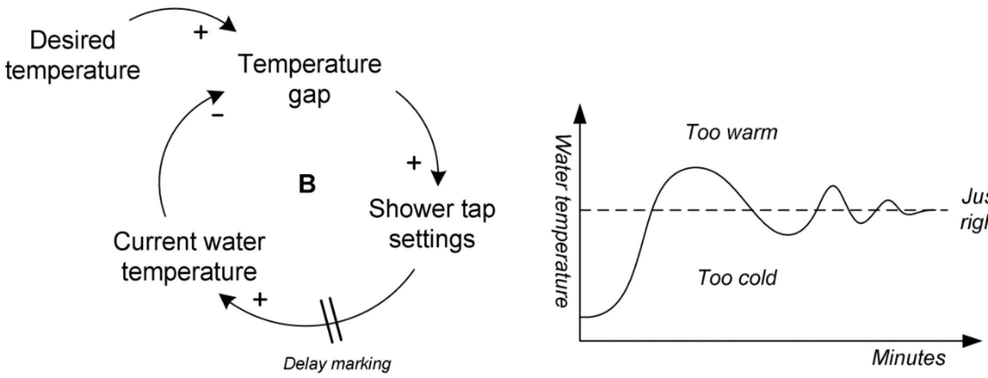
- A feedback loop is a circular chain of cause and effect that can either positively or negatively impact each other's.

- For example, a causal loop diagram can help you understand how population growth, resource consumption, and environmental degradation affect each other in a vicious cycle.

- Causal loop diagrams can help you identify possible leverage points when intervention may be implemented to change the system behavior and outcomes.

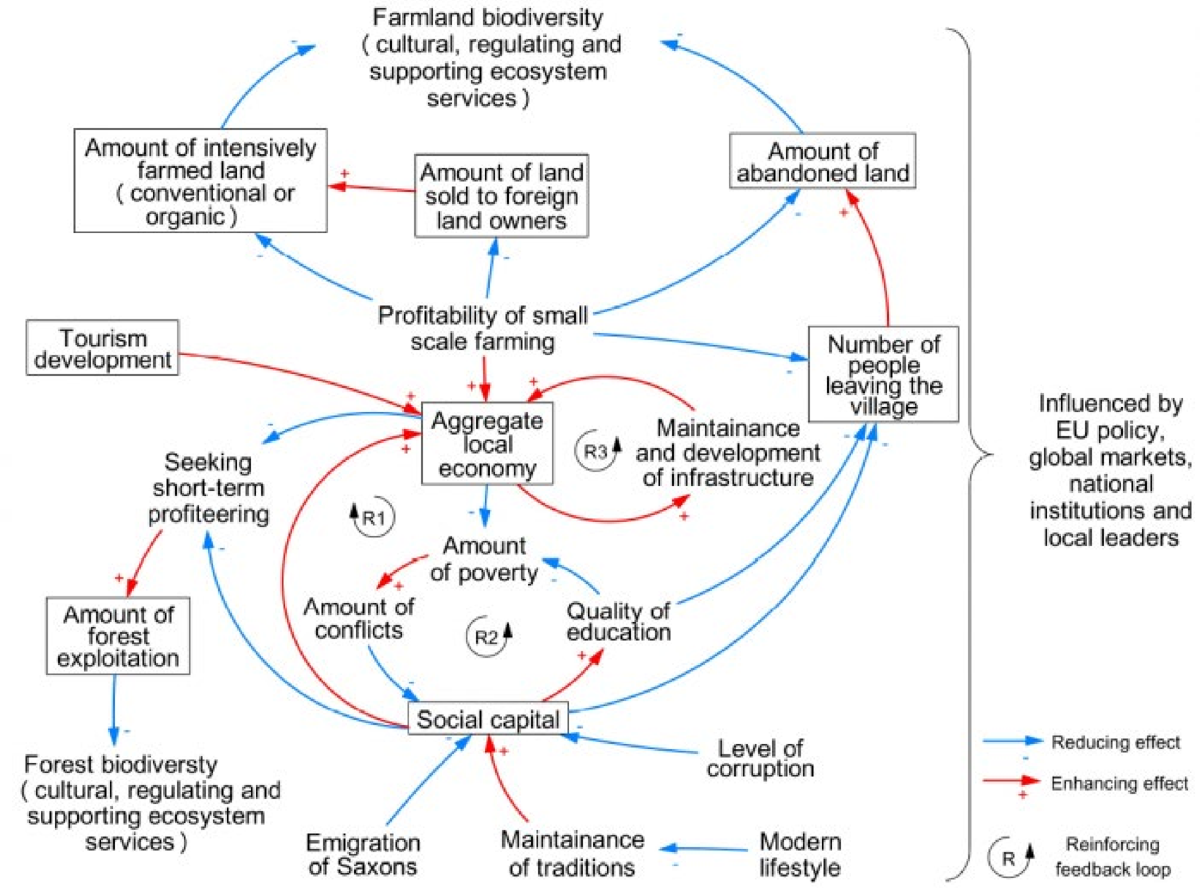
**Example**

- Shower Water System



**Example**

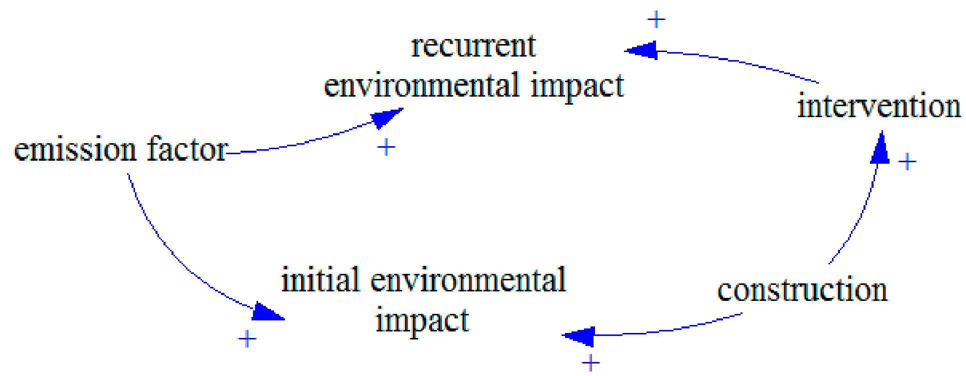
- Causal loop diagram depicting the dynamics in a regional social-ecological system (Hanspach et al. 2014).




## 3.5 Stock and Flow Diagrams

- A casual loop diagram provides the basic elements in a system, their connections and the signs of their influences.

**Example:** A casual loop diagram for the environmental impact of building usage.



- To capture the dynamic behavior of the system over time, it must be converted into a stock and flow diagram:

**Example:** Stock and Flow diagram for the economic impact of building usage.

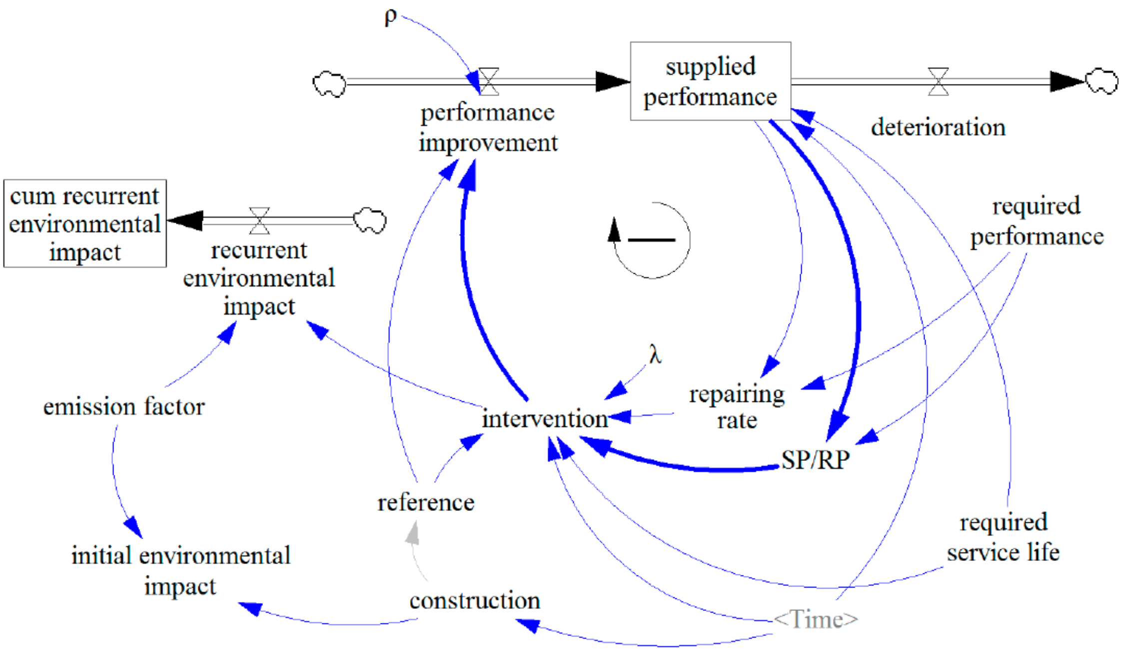



**Figure 3.** Stock and Flow Diagram of environmental impact in building usage stage.

- A time-step based simulation can be perform to observe and capture the behavior and key performance measures of the system.

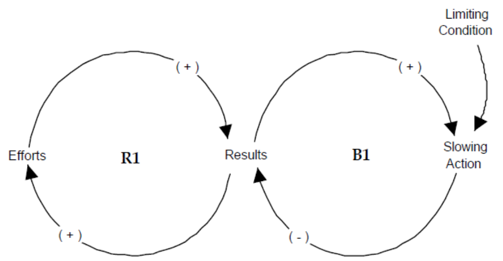
## 3.6 Systems Archetypes

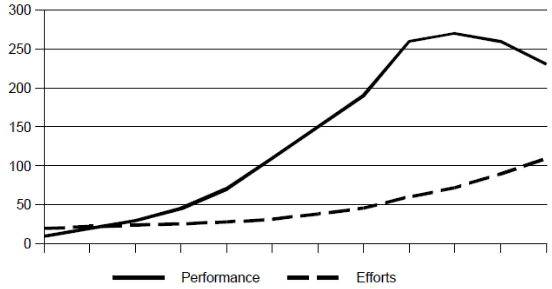
- The Systems Archetypes describe common patterns of behavior that emerge in various kinds of systems.
- Identifying a system under study as belonging to a certain archetype is useful in understanding the underlying structures and assumptions that shape the system behaviors and potential outcomes.
- Used as **diagnostic** tools to provide insight into the underlying system structures from which behavior over time and discreet events emerge.
  - Help to recognize patterns of behavior that are already present in the system.
  - Serve as the means for gaining insight into the underlying systems structures from which the archetypal behavior emerges.
- Used as **prognostic** tools to alert managers to future unintended consequences.
  - Can be applied to test whether policies and structures under consideration will produce the desired archetypal behavior.

- Ten archetypes are generally acknowledged as forming the set of tools that reveal patterns of behavior in systems (Braun 2002). https://www.albany.edu/faculty/gpr/PAD724/724WebArticles/sys_archetypes.pdf

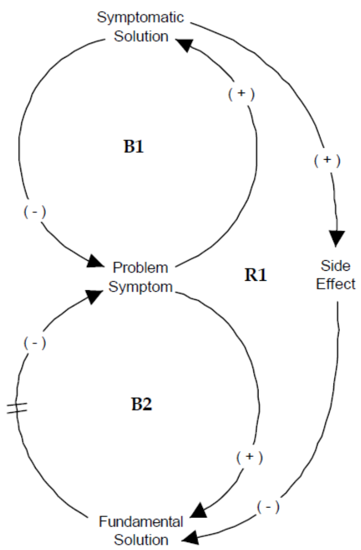
1. Limits to Growth (aka Limits to Success)
2. Shifting the Burden
3. Eroding Goals
4. Escalation
5. Success to the Successful
6. Tragedy of the Commons
7. Fixes that Fail
8. Growth and Underinvestment
9. Accidental Adversaries
10. Attractiveness Principle

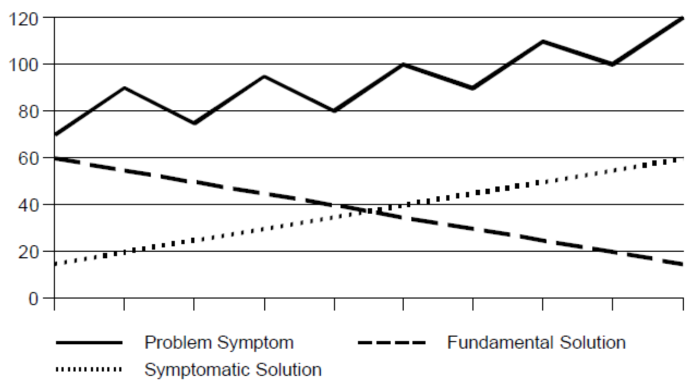
**Limits to Growth**



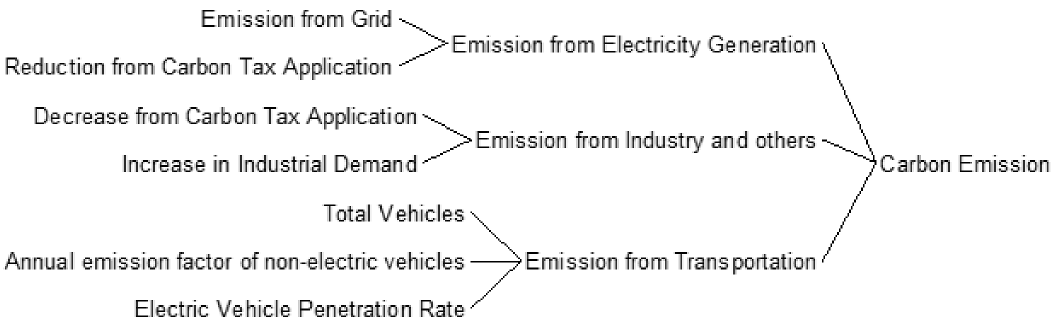

**Shifting the Burden**



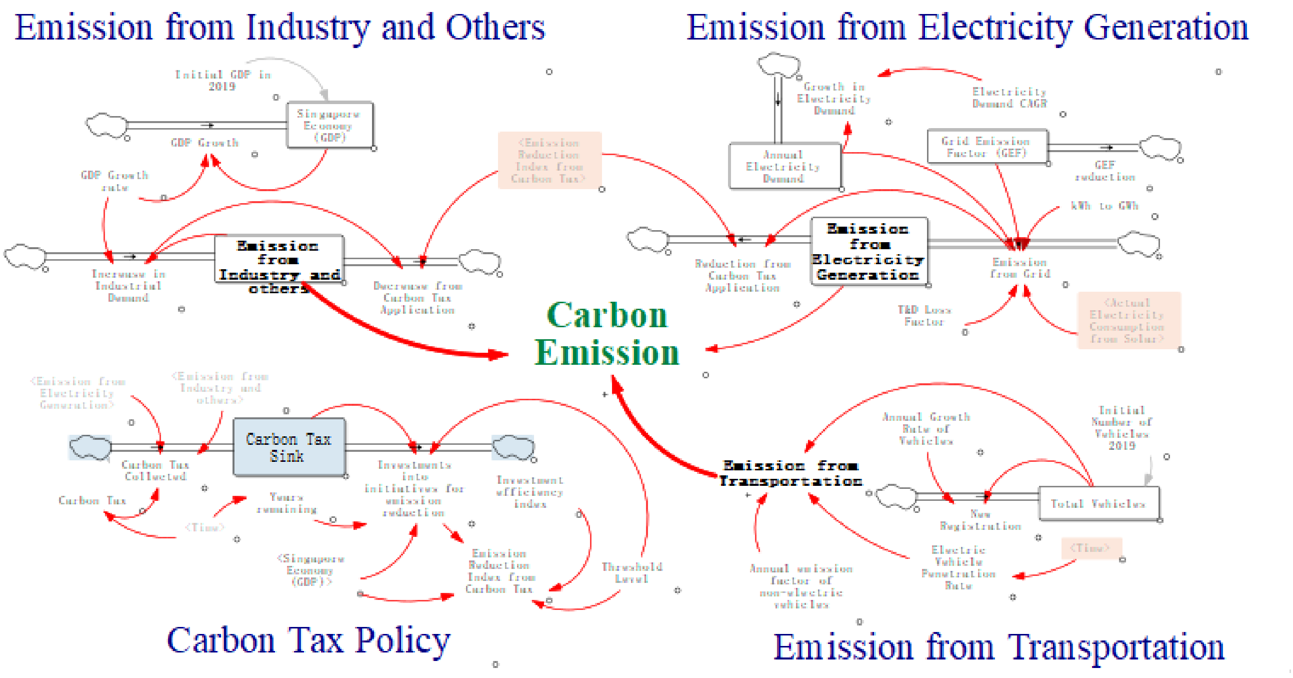



### 3.7 Example: Using System Dynamic to model and analyse decarbonization strategies

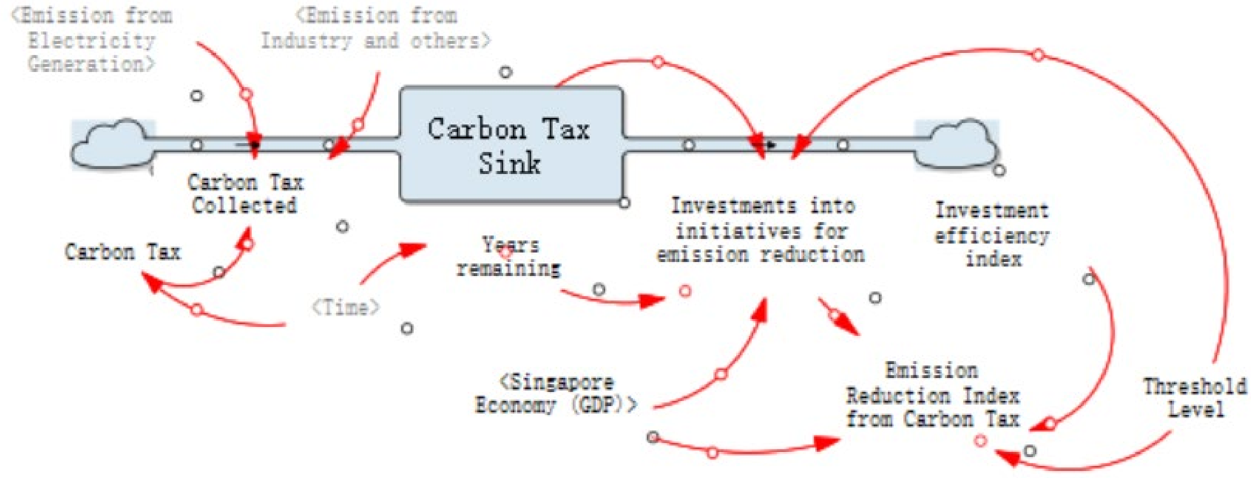
### Casual Tree for Carbon Emissions



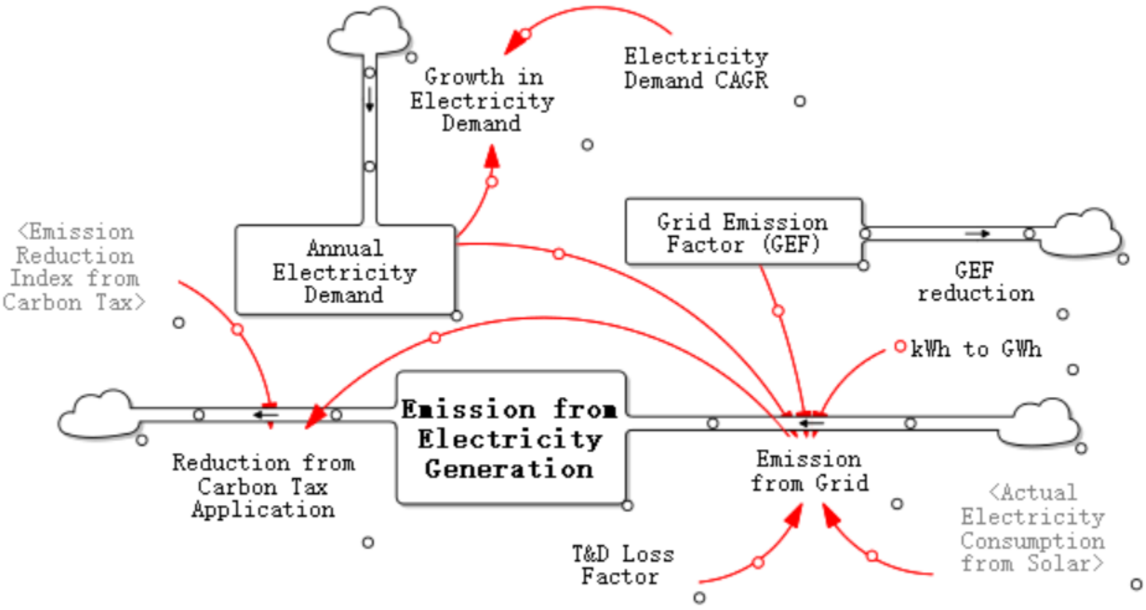

### Overview of Base Model on Carbon Emissions and Carbon Tax Policy



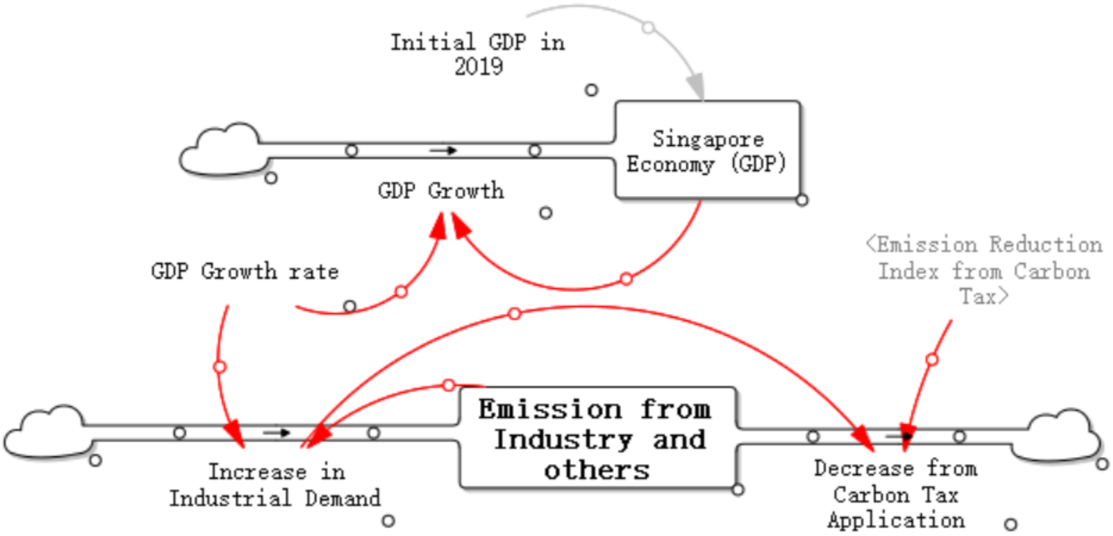
**Singapore's Carbon Tax Policy**




**Carbon Emissions from Electricity Generation**



**Emissions from Industry and Others**




**Carbon Emissions from Transportation**