An Integrated Framework for Life Cycle Engineering

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1 Motivation

2 Life Cycle Engineering Framework

3 Combining top-down and bottom-up

4 Outlook

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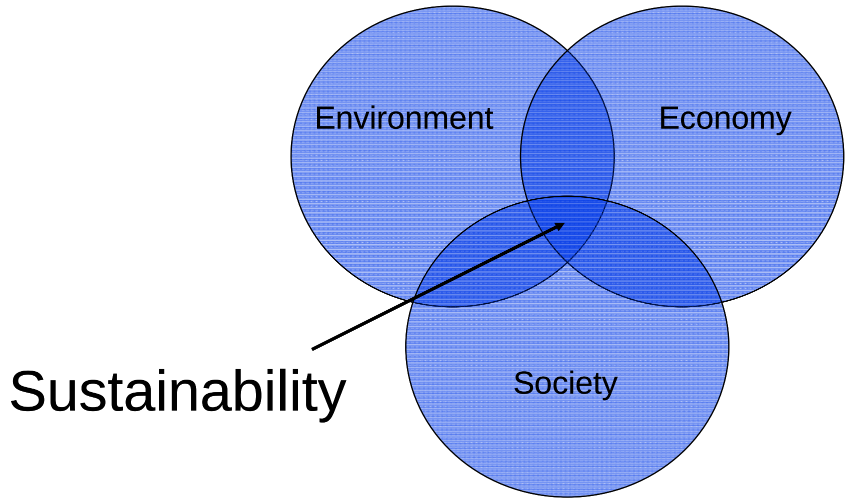
Sustainability?

<u>Brundtland Commission:</u>

A sustainable development *"...meets the needs of the present without compromising the ability of future generations to meet their own needs"*

Three dimensions interact in the creation of sustainable solutions

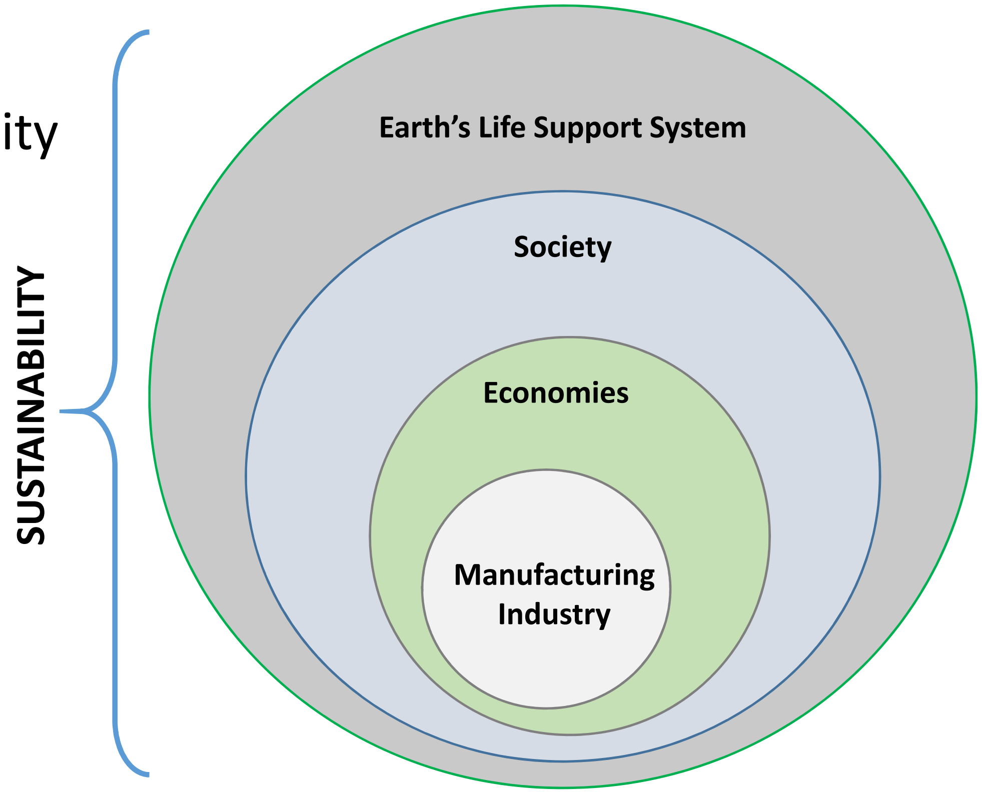
- Environment
- Society
- Economy



Weak and strong sustainability

<u>Triple bottom line:</u>

- Three dimensions or pillars of sustainability
- Optimization of Financial capital, Social capital and Natural capital
- Trade-offs between the dimensions?
- Can the three dimensions be traded off freely?

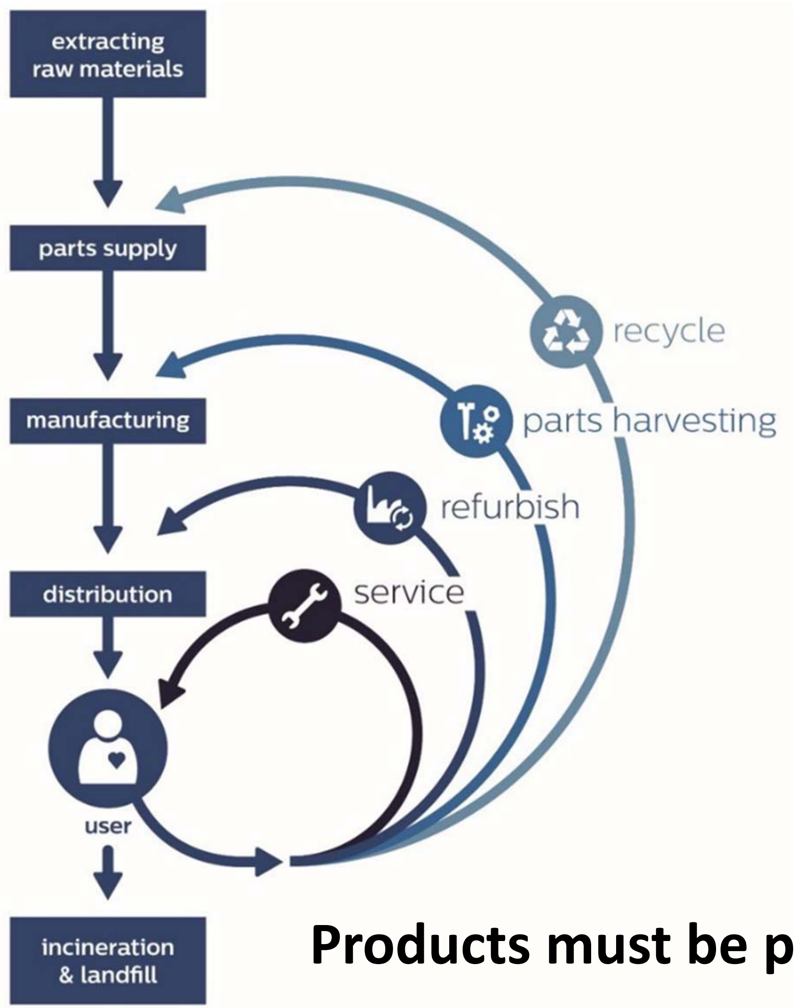


Based on Rockström, 2015

United Nation's Sustainable Development goals

17 goals to 'end poverty, protect the planet, and ensure prosperity for all as part of a new sustainable development agenda'

Circular economy



- **eco-design**
- increased **efficiency of manufacturing**
- **reduced use of chemicals** (accumulate through loops)
- **product-service systems, sharing economy**
- **use of recycled materials** and resources
- **industrial symbiosis**

Products must be planned and engineered in a life cycle perspective

Life Cycle Engineering (LCE)

Life cycle engineering (LCE) has a central role to play, but what is it?

- a systematic "**cradle to grave**" approach that "provides the most complete **environmental profile** of goods and services"[1]
- Focus on **design** and **manufacture** of **products**, optimizing the product life cycle and **minimizing pollution and waste**[2] while at the same time **encouraging economic progress**
- LCE tools are **life cycle-oriented**:
  - Analysis tools like LCA and LCC
  - Synthesis tools under the heading of Life cycle design
- … or life cycle **stage-oriented**:
  - Green Material Selection, Design for Disassembly (DfD), Design for Recycling (DfR), energy efficient manufacturing, …

[1] Keoleian and Menerey, 1993; Alting and Jørgensen, 1993

[2] Jeswiet, 2003, Hauschild et al., 2005

Life Cycle Engineering (LCE) framework – why and how?

Why?

- Position engineering activities relative to other efforts to achieve a sustainable development
- Guide LCE practitioners towards creating engineering solutions that are sustainable in absolute terms

How?

- Organize engineering activities throughout the life cycle of a product or a technology
- Position them according to their leverage in terms of promoting sustainable production systems and a sustainable society
- … considering the dimensions of scale and time
- … introducing absolute boundaries for sustainability

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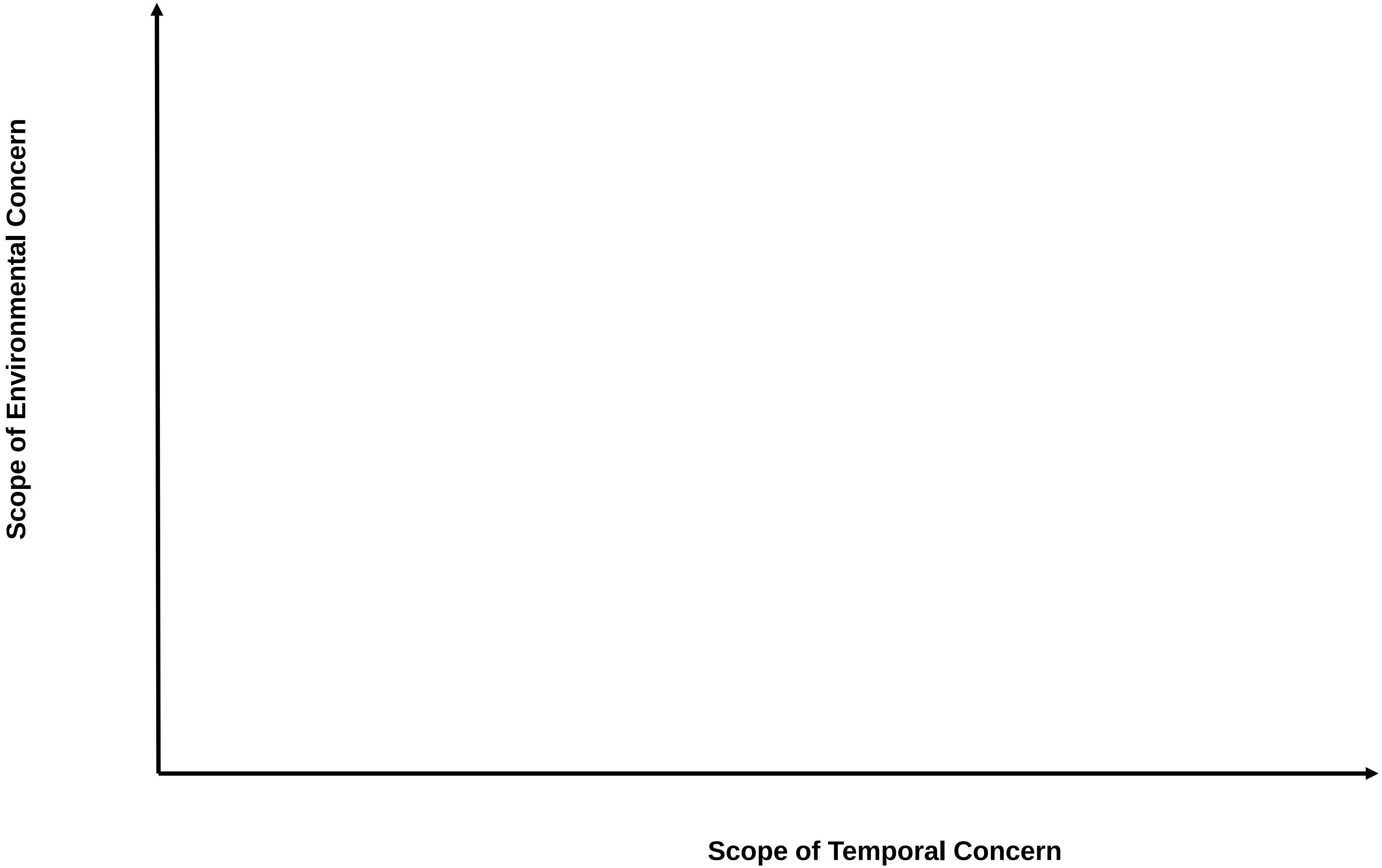
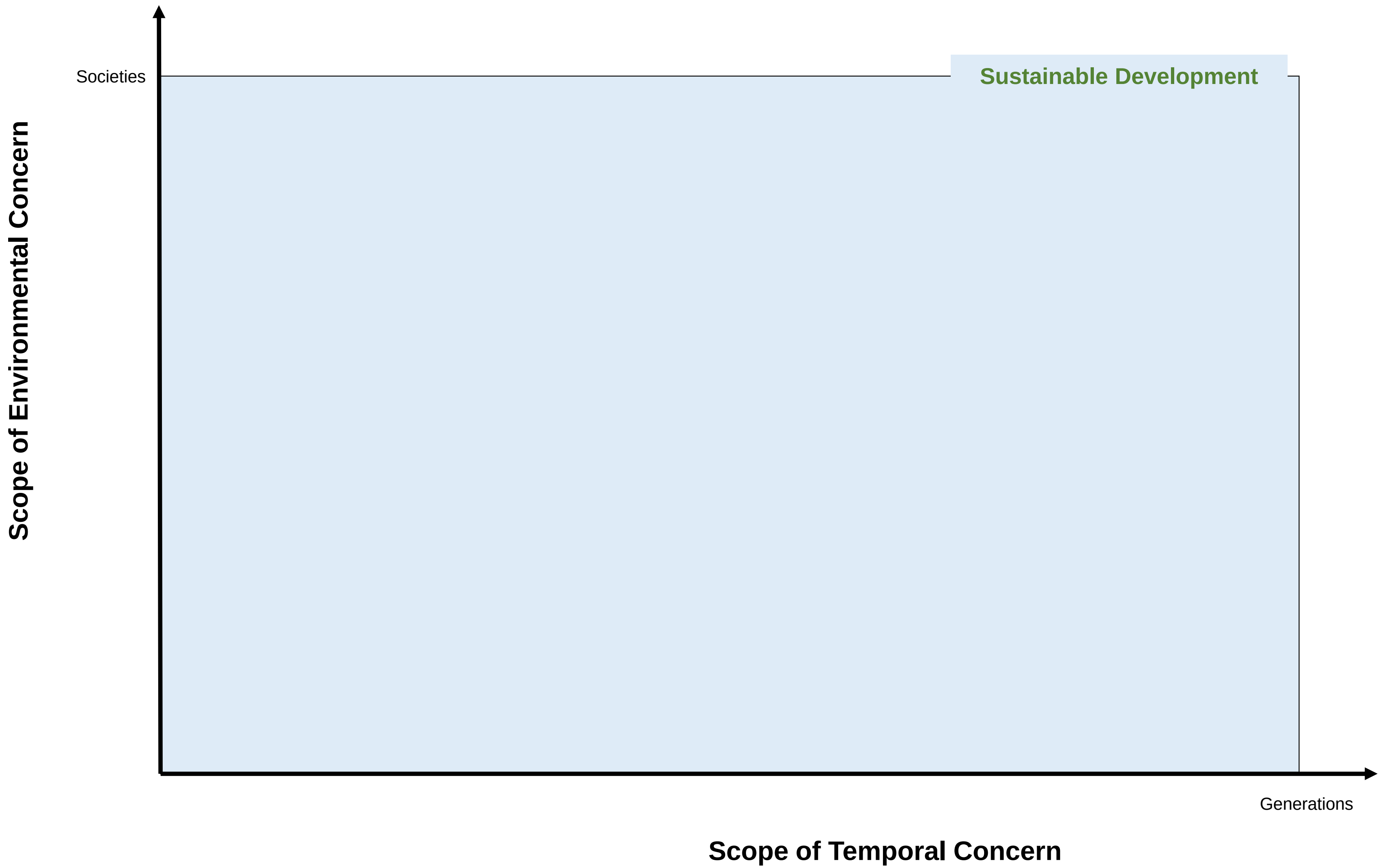
Life Cycle Engineering Framework



Life Cycle Engineering Framework



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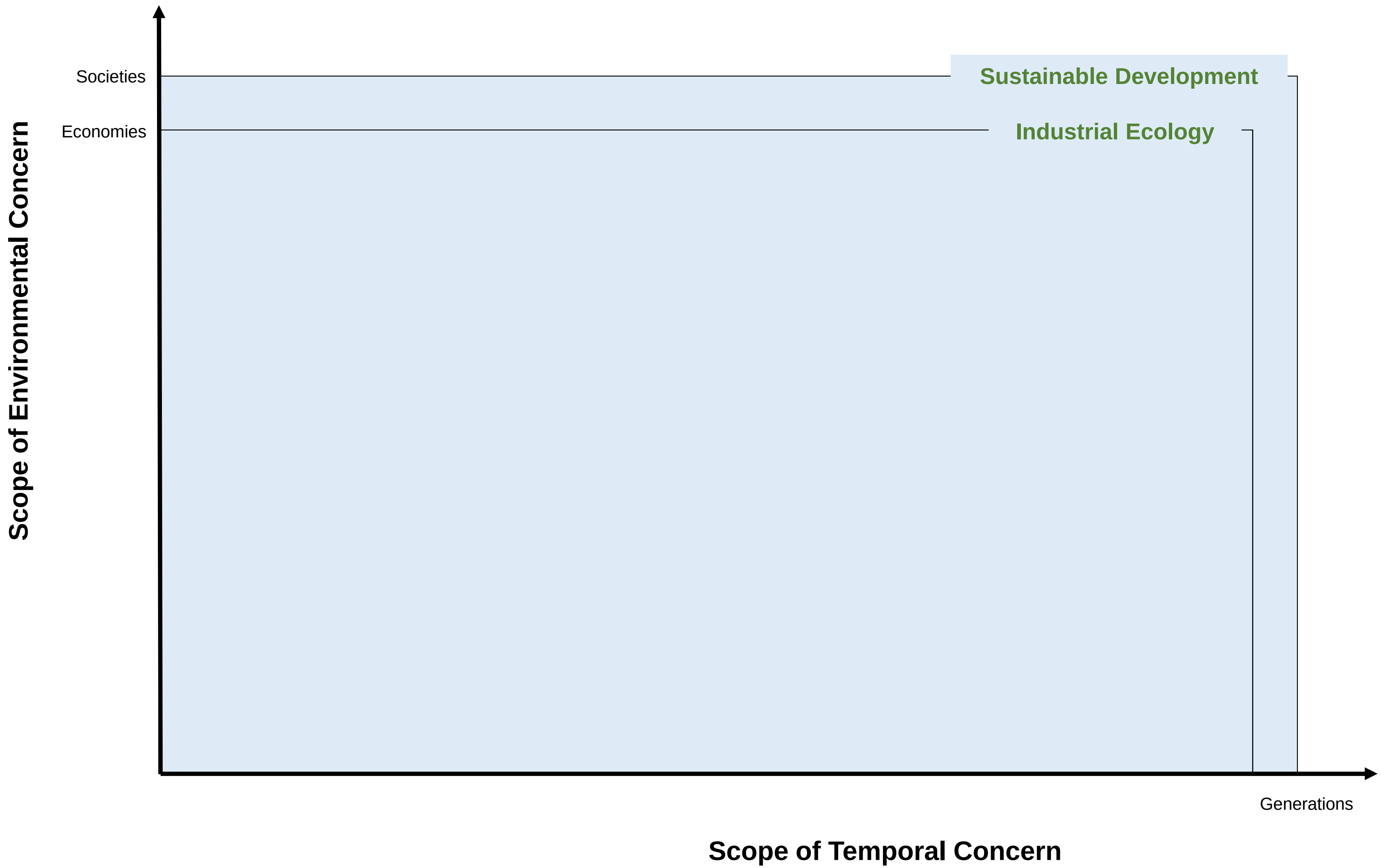

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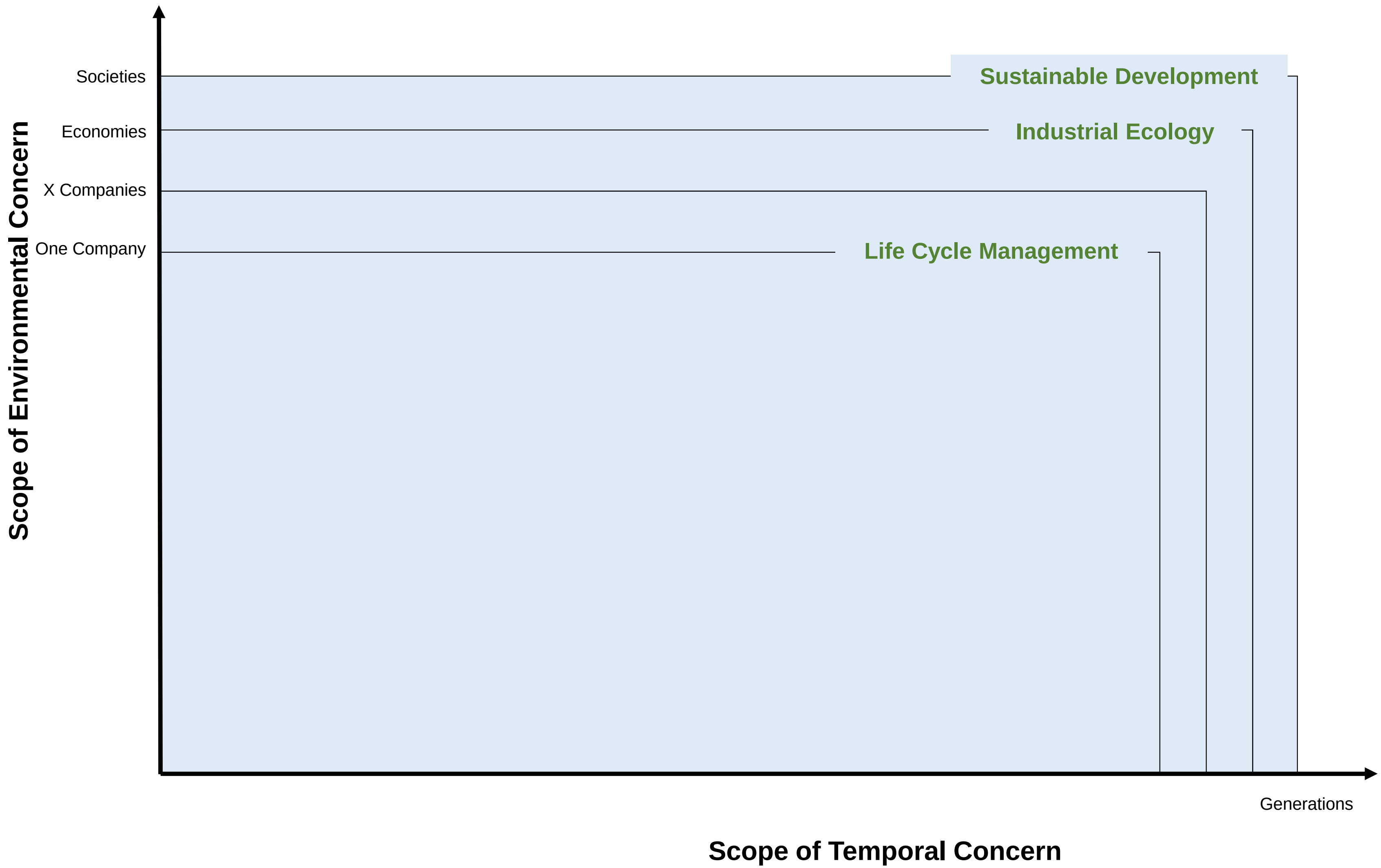

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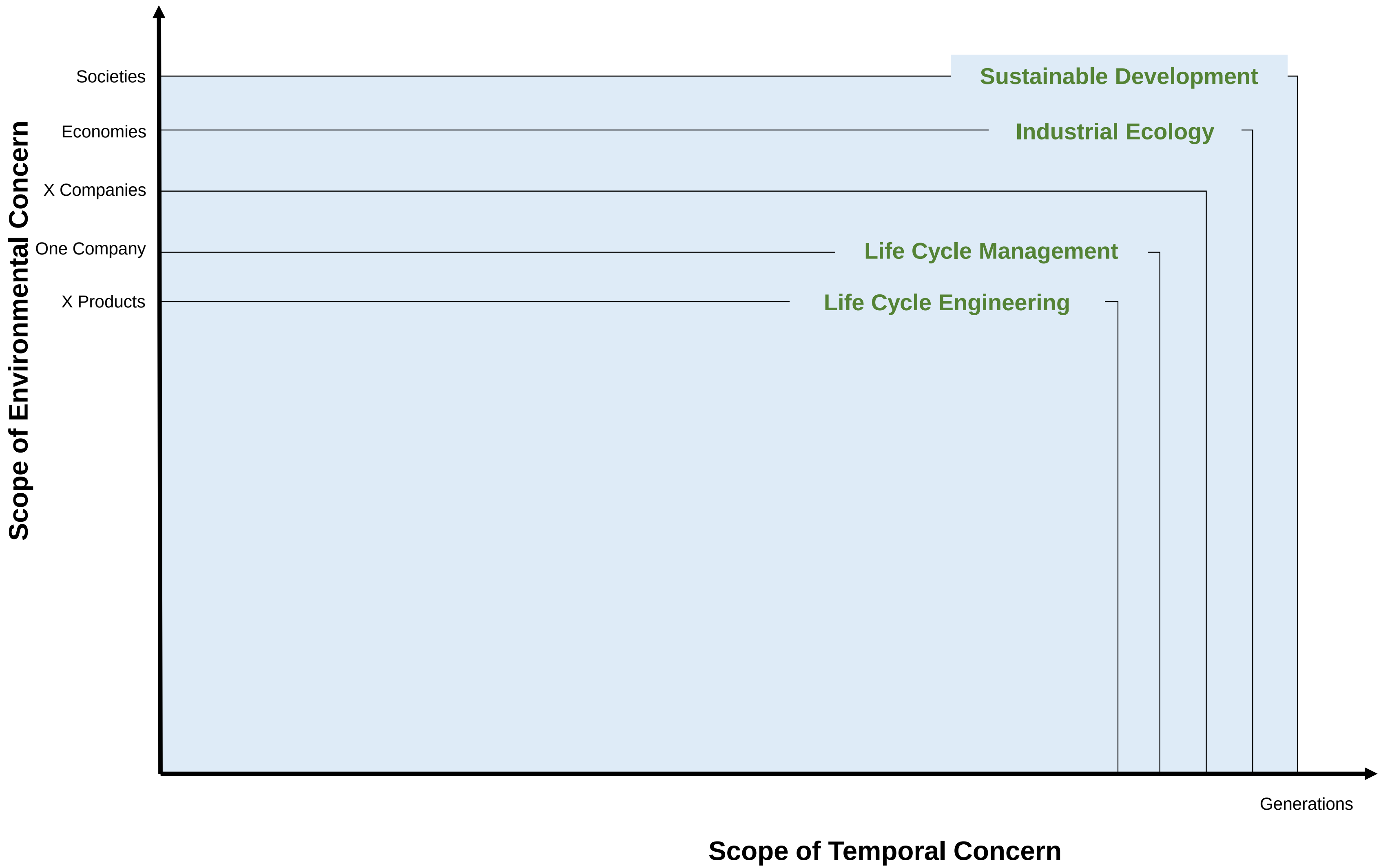

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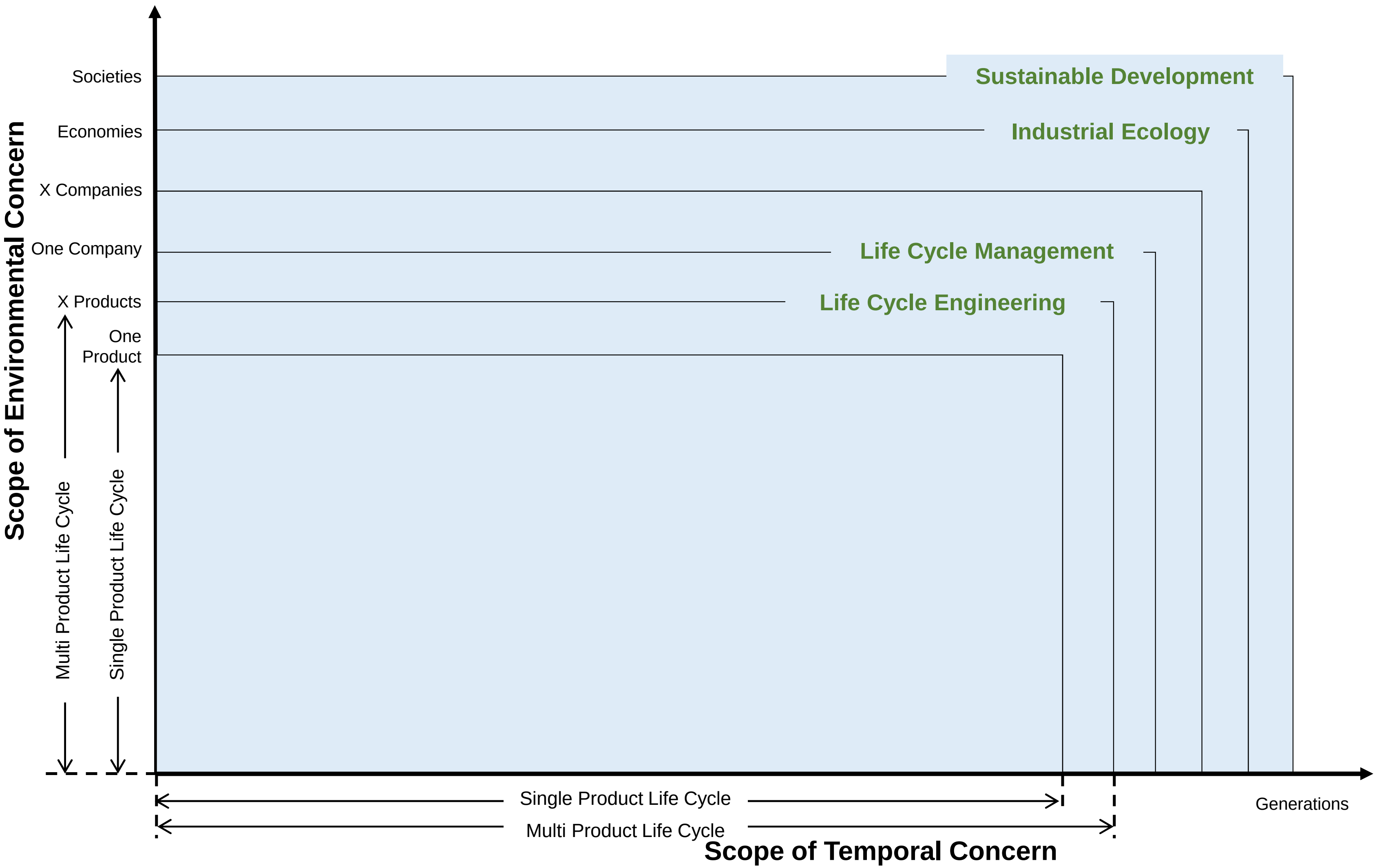

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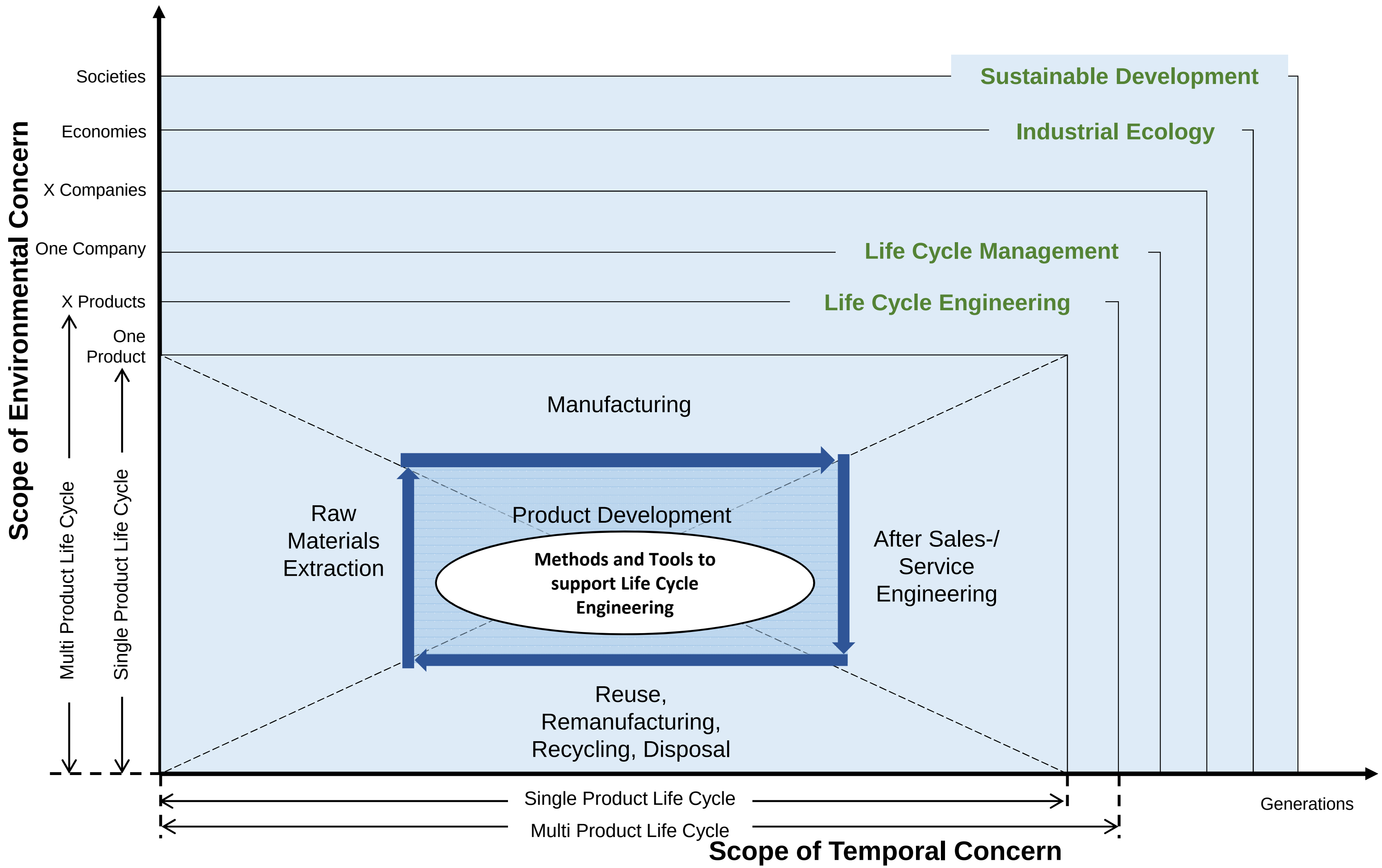
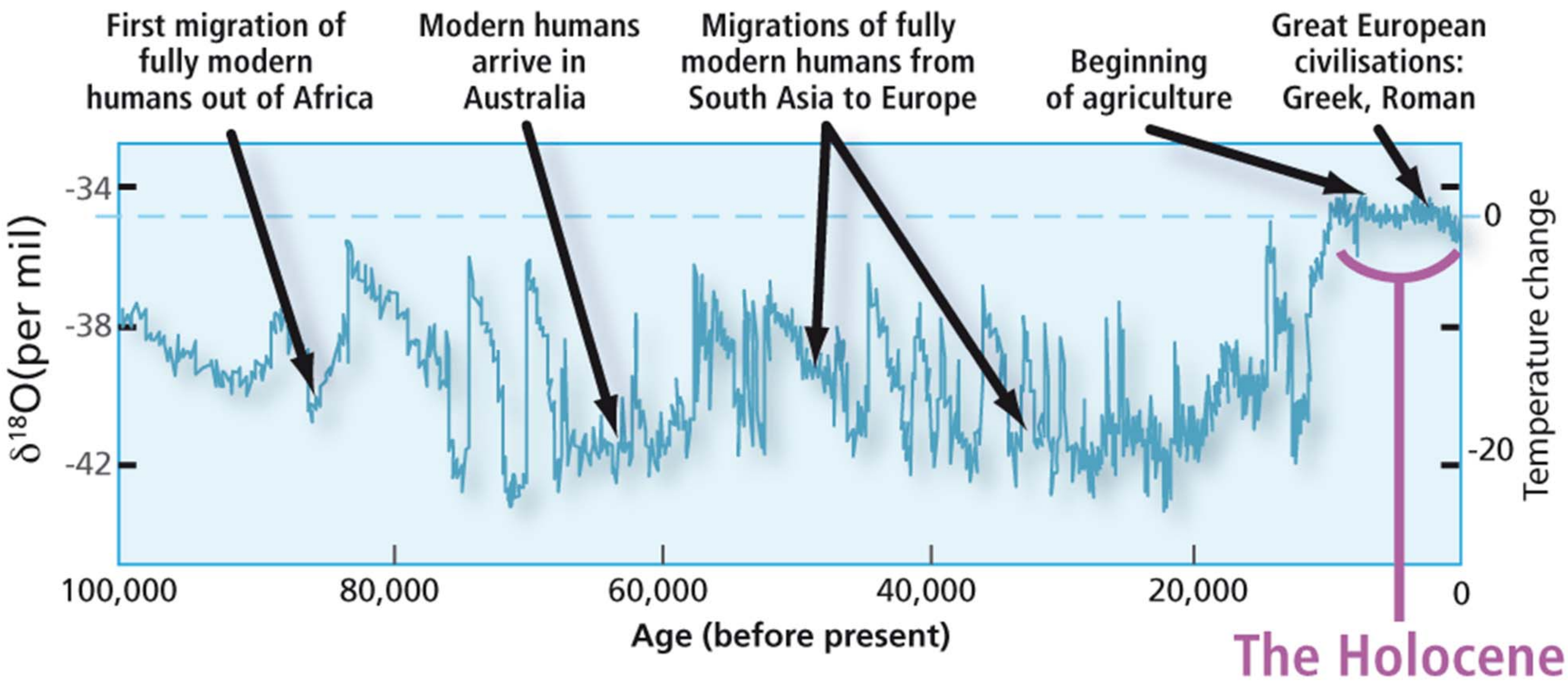
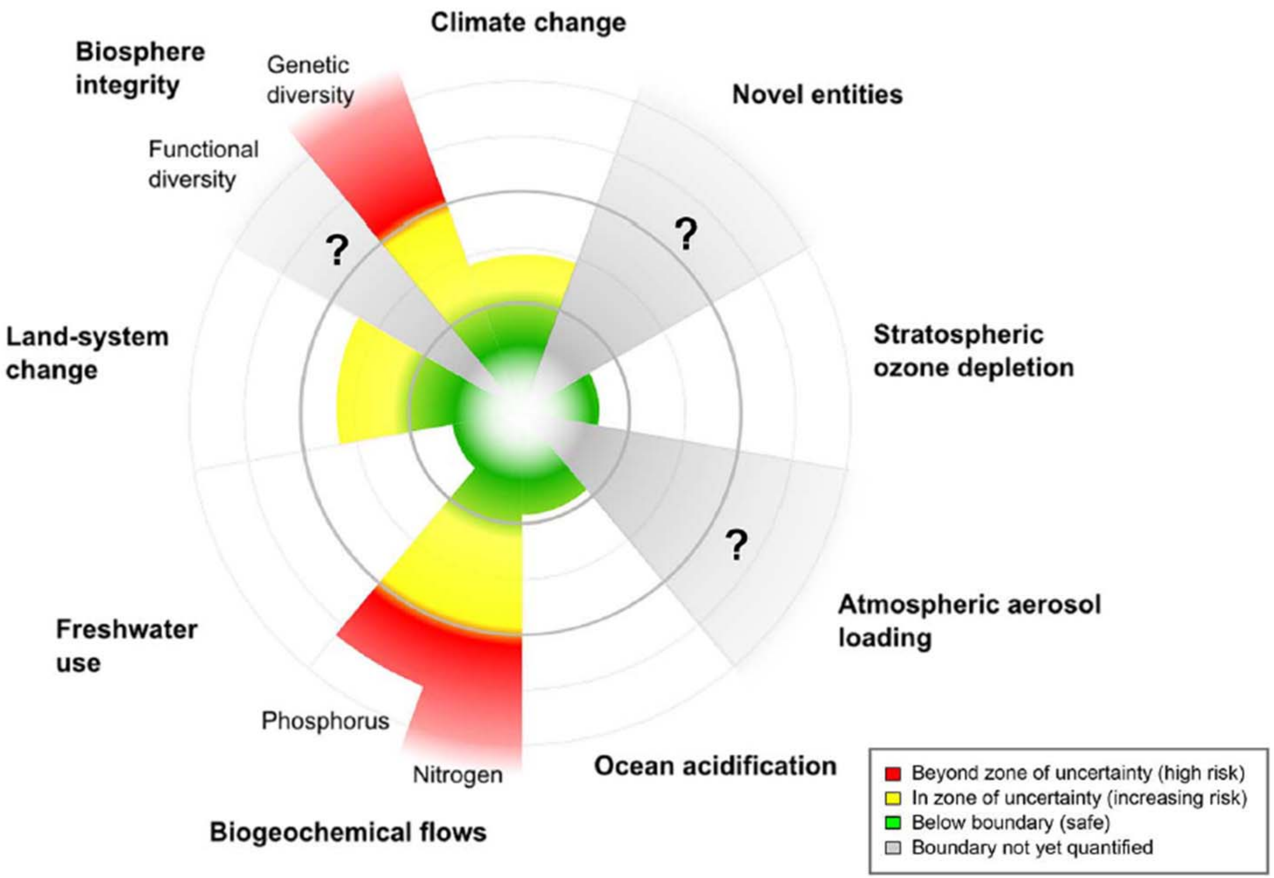


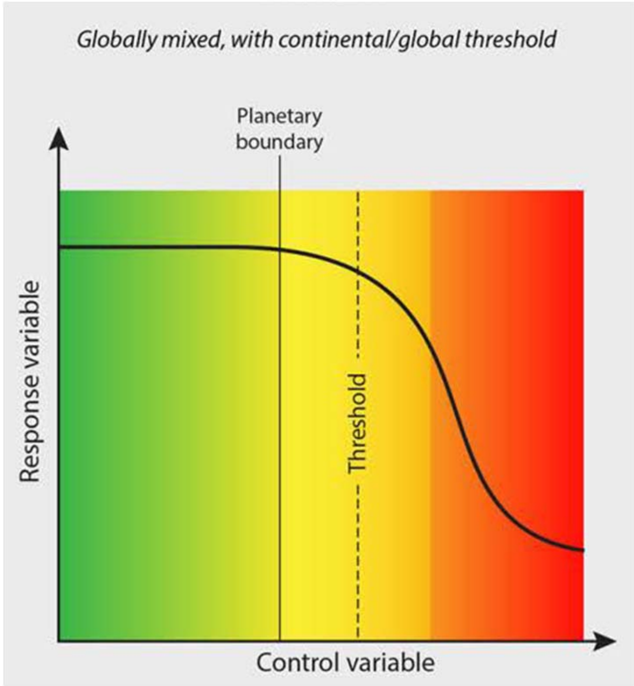
Keeping the planet in the holocene



International Geosphere Biosphere Programme (2015)

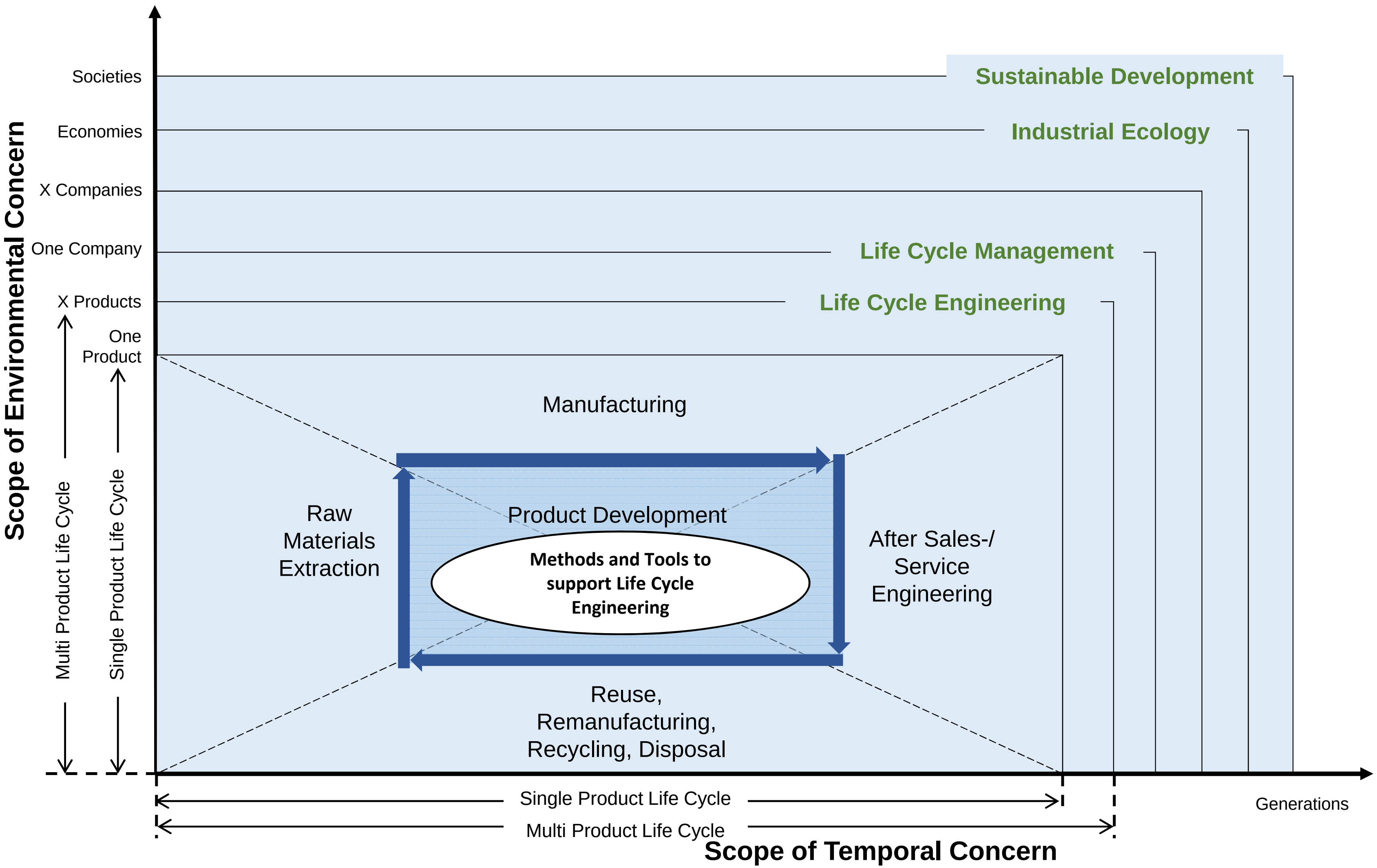
Planetary boundaries





Steffen et al. (2015)

Life Cycle Engineering Framework



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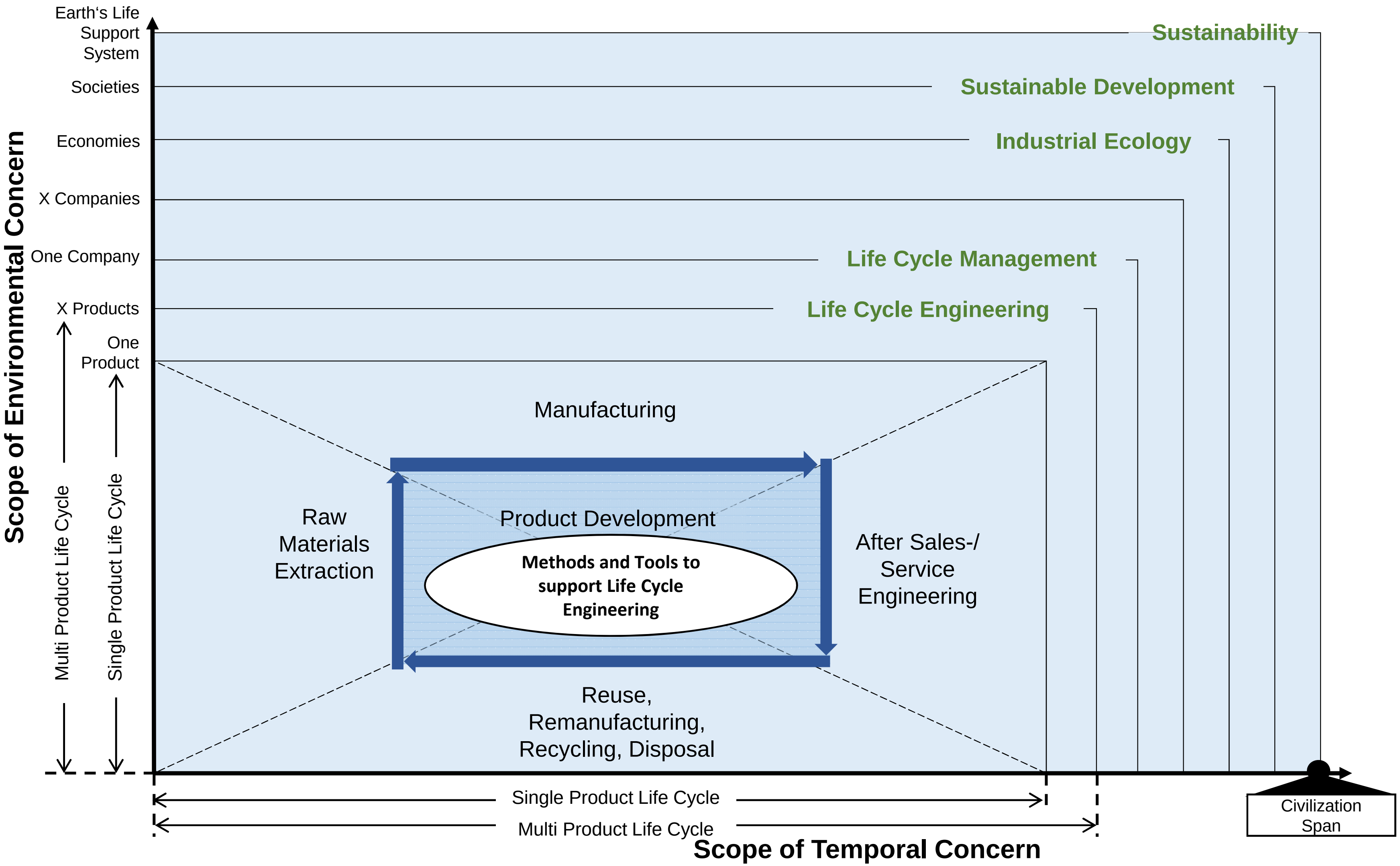


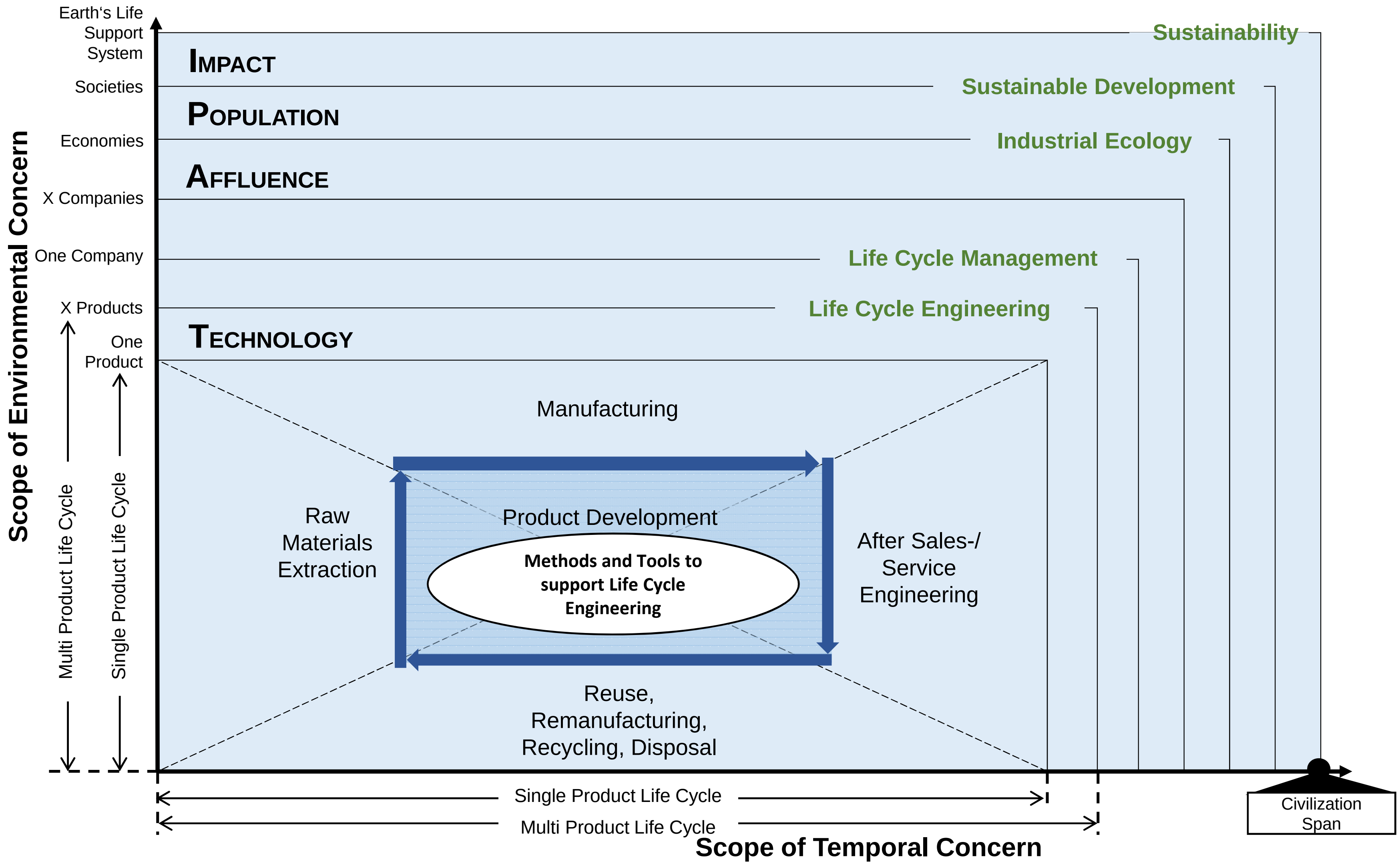
The sustainability challenge

$$I = P \cdot A \cdot T = Pop \cdot \frac{GDP}{person} \cdot \frac{I}{GDP}$$

Ehrlich and Holdren (1971)
Commoner (1972)
Graedel and Allenby (1995)

- *I* is the environmental impact
- *Pop* is the **global population**
- $\frac{GDP}{person}$ is the **Affluence**, the material standard of living
- $\frac{I}{GDP}$ is the **Technology factor** – environmental impact per created value

Life Cycle Engineering Framework



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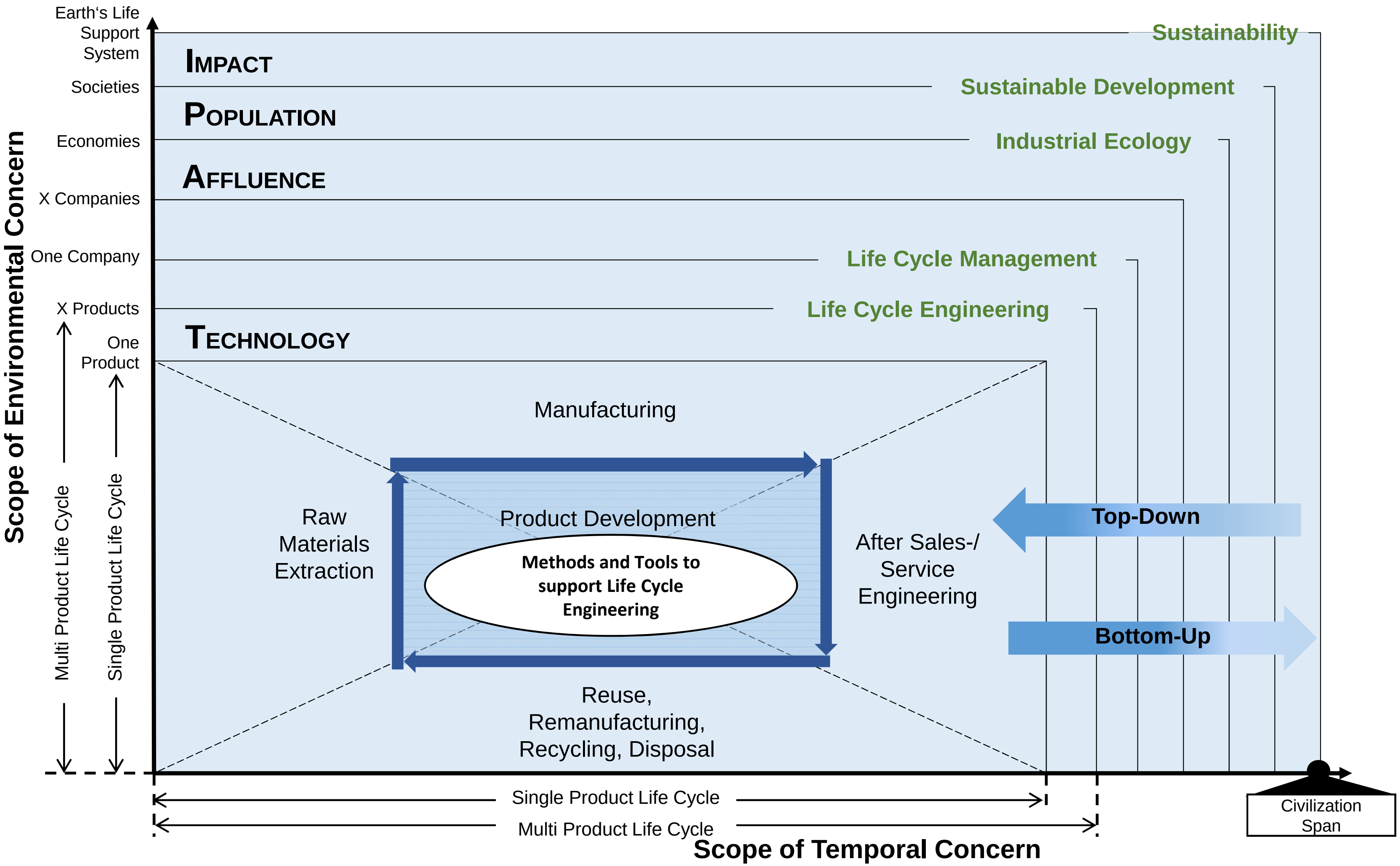

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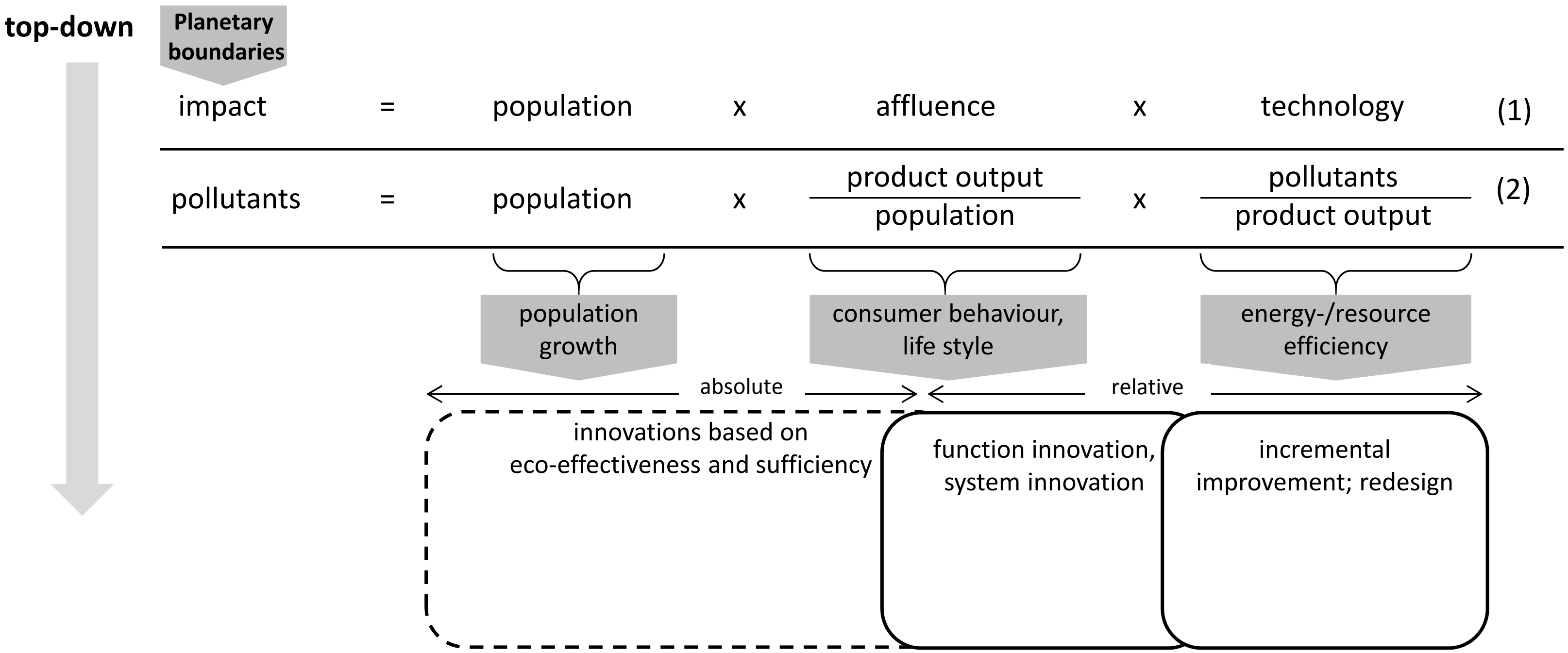


The sustainability challenge

$$impact = population \cdot \frac{products}{person} \cdot \frac{impact}{products}$$

- The global population may level off around 10 billion
- Material standard of living will grow strongly in newly industrialised countries (Asia, South America)
- The environmental impact already exceeds sustainable levels in many areas
- So what is the challenge?

Factor 4, 10 or 20

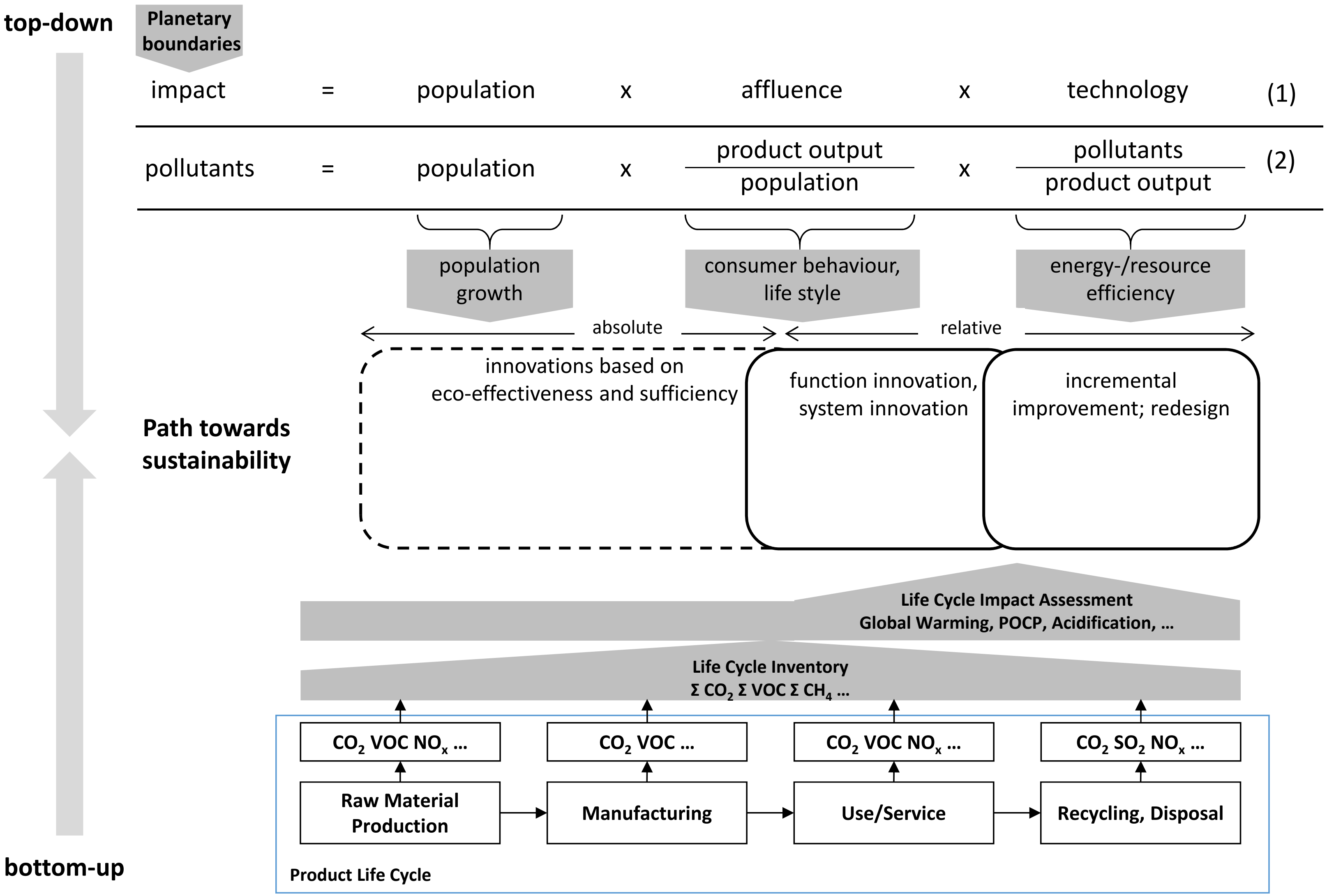
The technology factor $\frac{impact}{products}$ $impact = population \cdot \frac{products}{person} \cdot \frac{impact}{products}$

must decrease 4-20 times in order to

- counterbalance the expected growth in population and material consumption
- achieve the needed reduction in the environmental impact

…i.e. to be environmentally sustainable

Combining top-down and bottom-up



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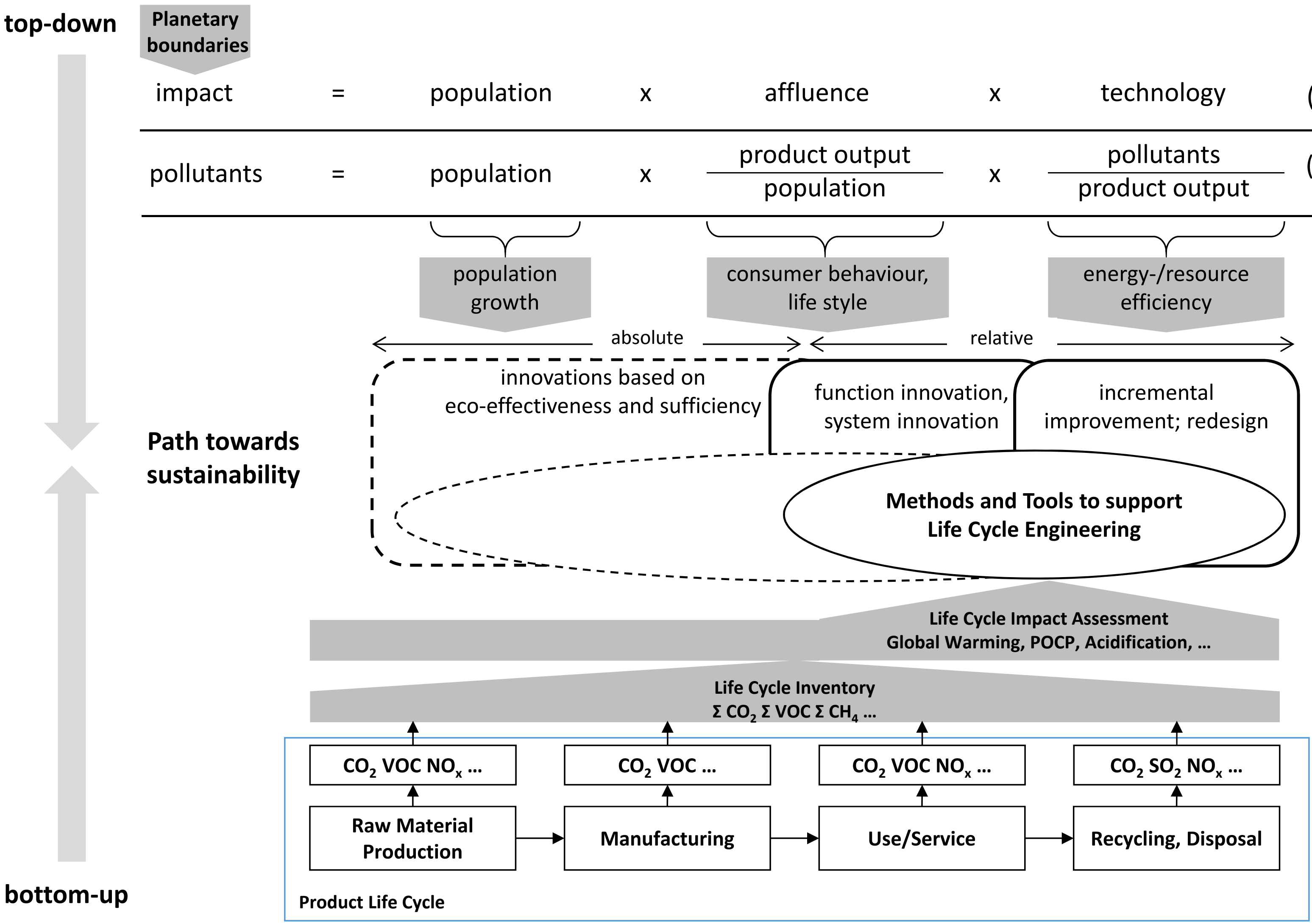

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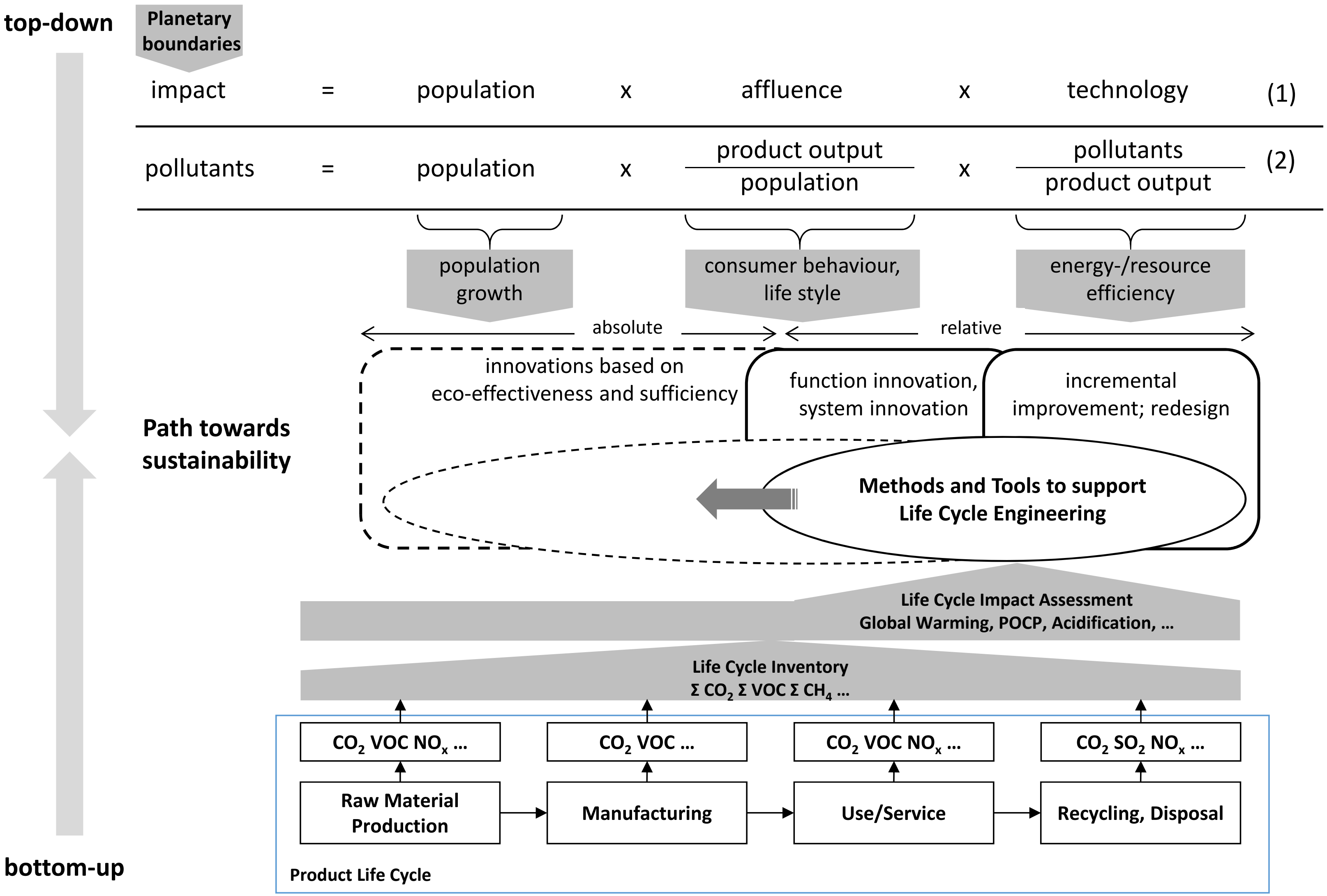

LCE in absolute terms

LCE is thus redefined as

- sustainability-oriented product development activities within the scope of one to several product life cycles
- aiming to achieve sustainable manufacturing that allows fulfilling needs of both present and future generations without exceeding the boundaries of Earth’s life support systems

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Sustainability pushed into national and corporate agendas by UN's World goals for 2030 and quest for circular economy

Emphasis on importance of life cycle engineering

Focus of LCE must shift from triple-bottom line thinking towards

- environmental sustainability dimension (Earth's life support function)
- absolute sustainbility targets rather than relative improvements
- developing tools that target eco-effectiveness rather than eco-efficiency improvements
- operationalizing large scale sustainability targets at the level of companies

The presented LCE framework aims to support this development

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