Modeling the digital sectors production system: a timely and interdisciplinary endeavour

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Context

Copper mine in Gobi desert (Mongolia)

Context

Taihang mountain (China)

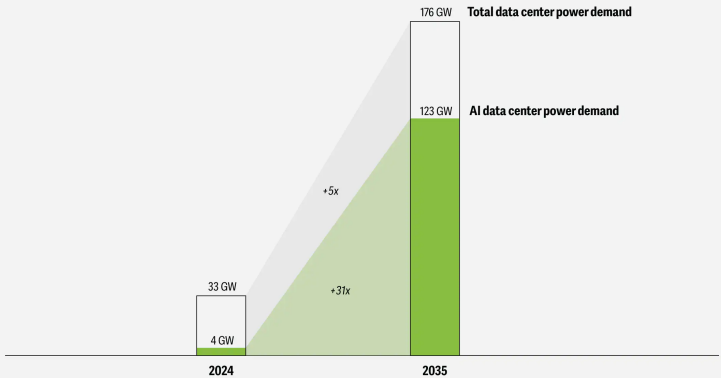
Context

Colossus xAI datacenter (Memphis, USA)

Context

Figure 1

US power demand from AI data centers is expected to boom



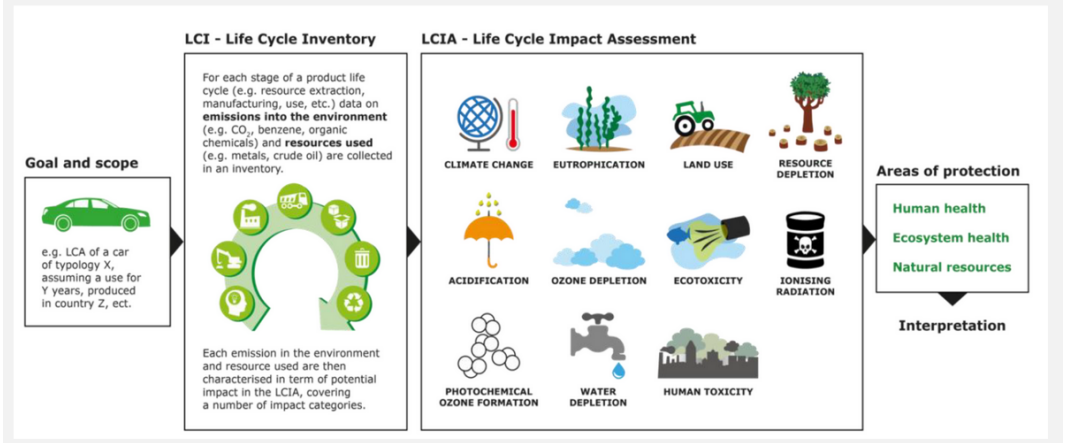
Source: Deloitte analysis of data from DC Byte, Wood Mackenzie, S&P Global, Lawrence Berkeley National Laboratory, Center for Strategic and International Studies, and Wells Fargo.

Deloitte. Insights | deloitteinsights.com

Wait.

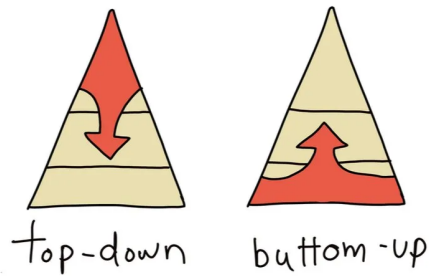
How much materials/fuel/real estate/labor... is that?

LCA solution

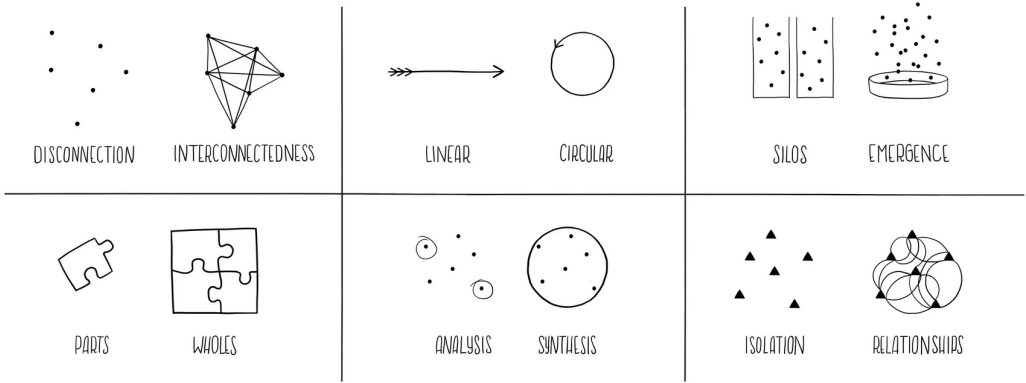


LCA limits

- Focused on the past
- Isolated studies
- Strong hypotheses (generalization)



Systems thinking

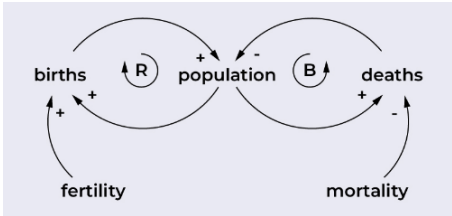


Different systemic approaches

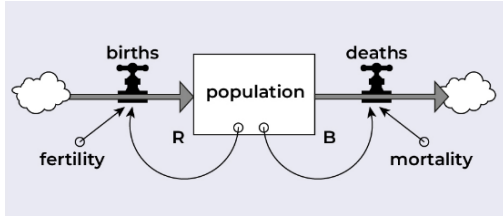
	Causal loop diagrams	Stocks and flows	Agent-based modeling
Expression	Graphical	Mathematical	Computational
Time	Non-temporal	Temporal	Temporal
Unit	System	System	Individuals
Approach	Top-down	Top-down	Bottom-up
Use	Represent the relationships between variables, identify feedback loops	Simulate the behavior of a system, identify critical points	Simulate the behavior of a system, identify emergent behaviors

Laetitia Bornes, Catherine Letondal, and Rob Vingerhoeds, "Systemic Sustainable HCI", in: *DIS Conference*, ACM, July 2024, DOI: 10.1145/3643834.3661618

Different systemic approaches



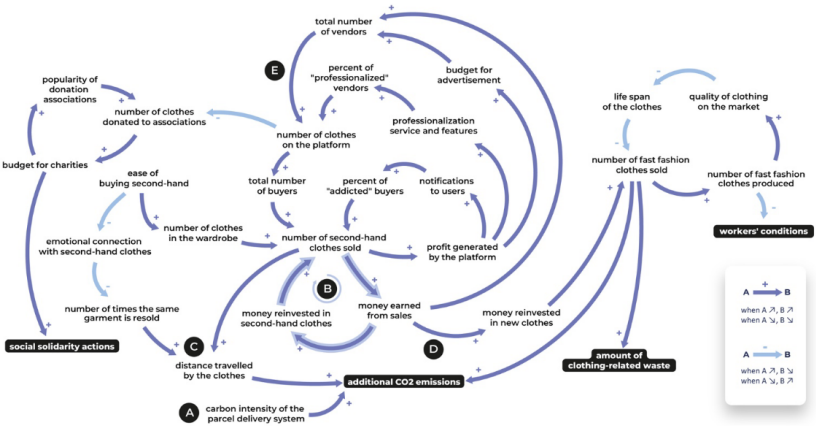
Causal loop



Stock & flow

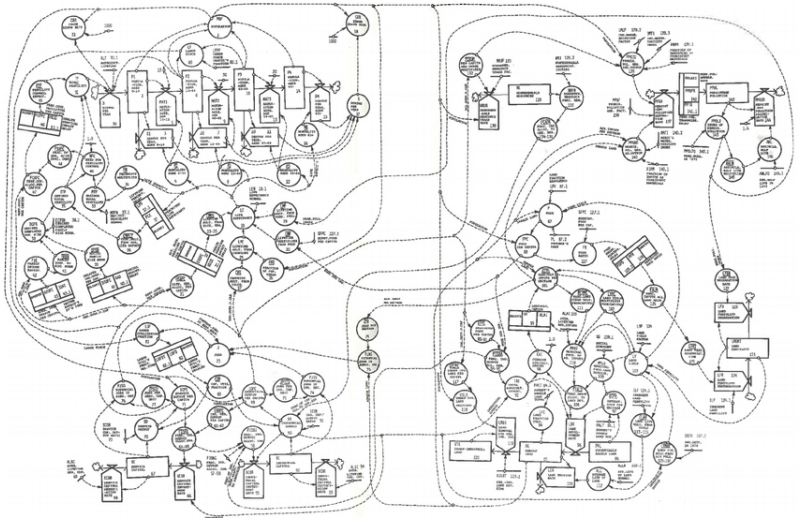
Understand the Present: Making the Invisible Visible

Understand the present: Causal loop diagrams



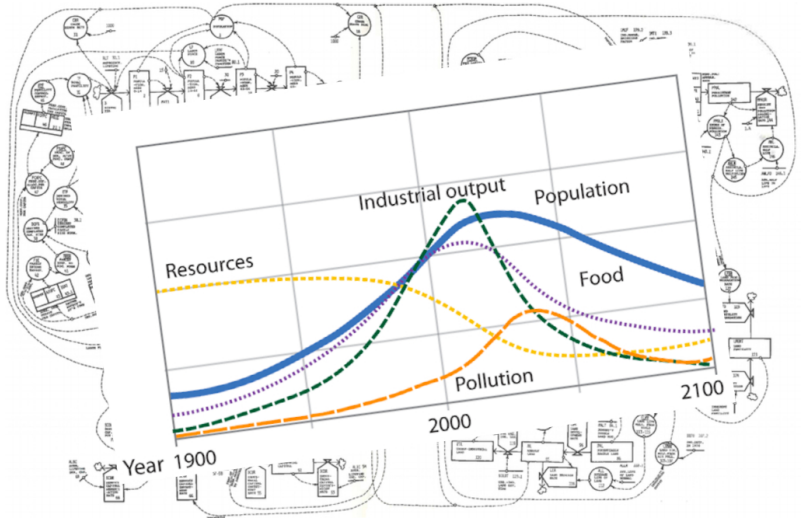
David Ekchajzer et al., "Decision-Making under Environmental Complexity: The Need for Moving from Avoided Impacts of ICT Solutions to Systems Thinking Approaches", in: *ICT4S* (2024)

Anticipate the Future: World 3



Donella H. Meadows et al., *The Limits to Growth*, New York: Universe Books, 1972

Anticipate the Future: World 3



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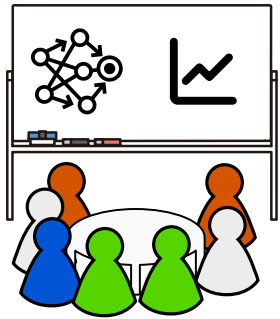
Anticipate the future: Back to our introduction case

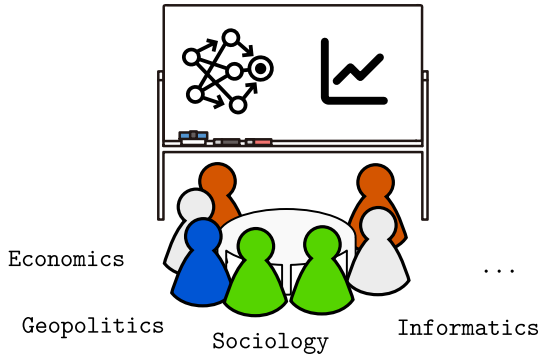
By 2055, our societies will need to mine as much material as since the dawn of humanity.

-- Olivier Vidal et al.

A collective work



A collective work



How can we model the role and interactions of the digital sector in order to visualize and predict its holistic environmental and social impacts?

References

[Mea+72] Donella H. Meadows et al., *The Limits to Growth*, New York: Universe Books, 1972.

[MW08] Donella H. Meadows and Diana Wright, *Thinking in Systems: A Primer*, White River Junction, Vt: Chelsea Green Pub., 2008, ISBN: 978-1-60358-055-7.

[Fre+21] Charlotte Freitag et al., "The Real Climate and Transformative Impact of ICT: A Critique of Estimates, Trends, and Regulations", in: *Patterns* 2.9 (2021), DOI: 10.1016/j.patter.2021.100340.

[Vid+21] Olivier Vidal et al., "Modelling the Demand and Access of Mineral Resources in a Changing World", in: *MDPI Sustainability* (Dec. 2021), DOI: 10.3390/su14010011.

[Aca24] Leyla Acaroglu, *Tools for Systems Thinkers: The 6 Fundamental Concepts of Systems Thinking*, Disruptive Design, Mar. 28, 2024, URL: https://medium.com/disruptive-design/tools-for-systems-thinkers-the-6-fundamental-concepts-of-systems-thinking-379cdac3dc6a (visited on 12/03/2025).

[BLV24] Laetitia Bornes, Catherine Letondal, and Rob Vingerhoeds, "Systemic Sustainable HCI", in: *DIS Conference*, ACM, July 2024, DOI: 10.1145/3643834.3661618.

[Ekc+24] David Ekchajzer et al., "Decision-Making under Environmental Complexity: The Need for Moving from Avoided Impacts of ICT Solutions to Systems Thinking Approaches", in: *ICT4S* (2024).

[Jeg24] Maya Jegen, "Life Cycle Assessment: From Industry to Policy to Politics", in: *The International Journal of Life Cycle Assessment* (Apr. 2024), DOI: 10.1007/s11367-023-02273-8.

[Rou+25] Gauthier Roussilhe et al., *Purer than Pure: How Purity Reshapes the Upstream Materiality of the Semiconductor Industry*, Sept. 2025, DOI: 10.48550/arXiv.2509.18768.

[] *The Systems Thinker*, The Systems Thinker, URL: https://thesystemsthinker.com/ (visited on 12/03/2025).