

University of Stuttgart

Research group Resources Management and
Industrial Circular Economy at the ISWA

Application of Entropy-LCA to compare the environmental sustainability of industrial processes

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LCM
2021



Quantifying environmental impacts with entropy

What has irreversibility to do with sustainability?

Entropy S

quantifies the **difference** between “ideal” **reversible** processes and “real” **irreversible** processes:

$$S = S_{rev} + S_{irr}$$

- S_{rev} can increase or decrease.
- S_{irr} always grows: “entropy production”, e.g. unused heat

⇒ **The smaller S_{irr} of a process, the less irreversible, the less interaction with the environment.**

Quantifying environmental impacts with entropy

What has irreversibility to do with sustainability?

Thesis:

“The less impact a technical process has on its environment, the more environmentally friendly it is.”

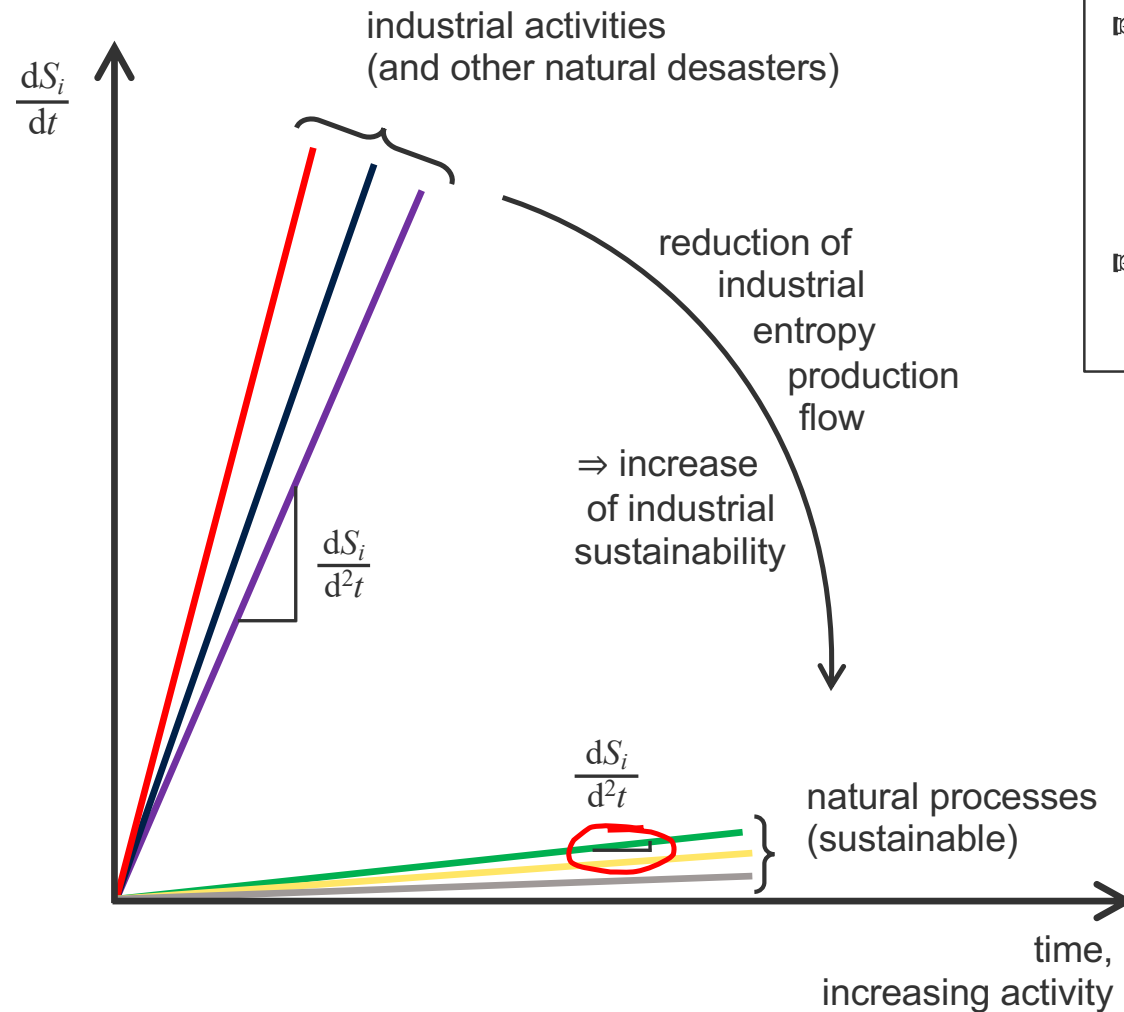
⇒ **To maximise the sustainability of human activities their entropy production must be minimised.**

(Entropy produced by *natural* processes maintains the dynamic *equilibrium* between earth and cosmos.)

⇒ **Entropy balances contain information about the (environmental) sustainability of processes.**

Natural and industrial entropy production (theory)

Entropy, entropy production and entropy production growth



☞ *It is not decisive, how much entropy a process produces, but how **quickly** the entropy grows.*

☞ *Nature can adapt to changing entropy flows, however, it needs **time**.*

with

dS_i / dt = entropy production flow

dS_i / d^2t = **growth** of entropy production flow

Natural and industrial entropy production (praxis)

Some simple real examples

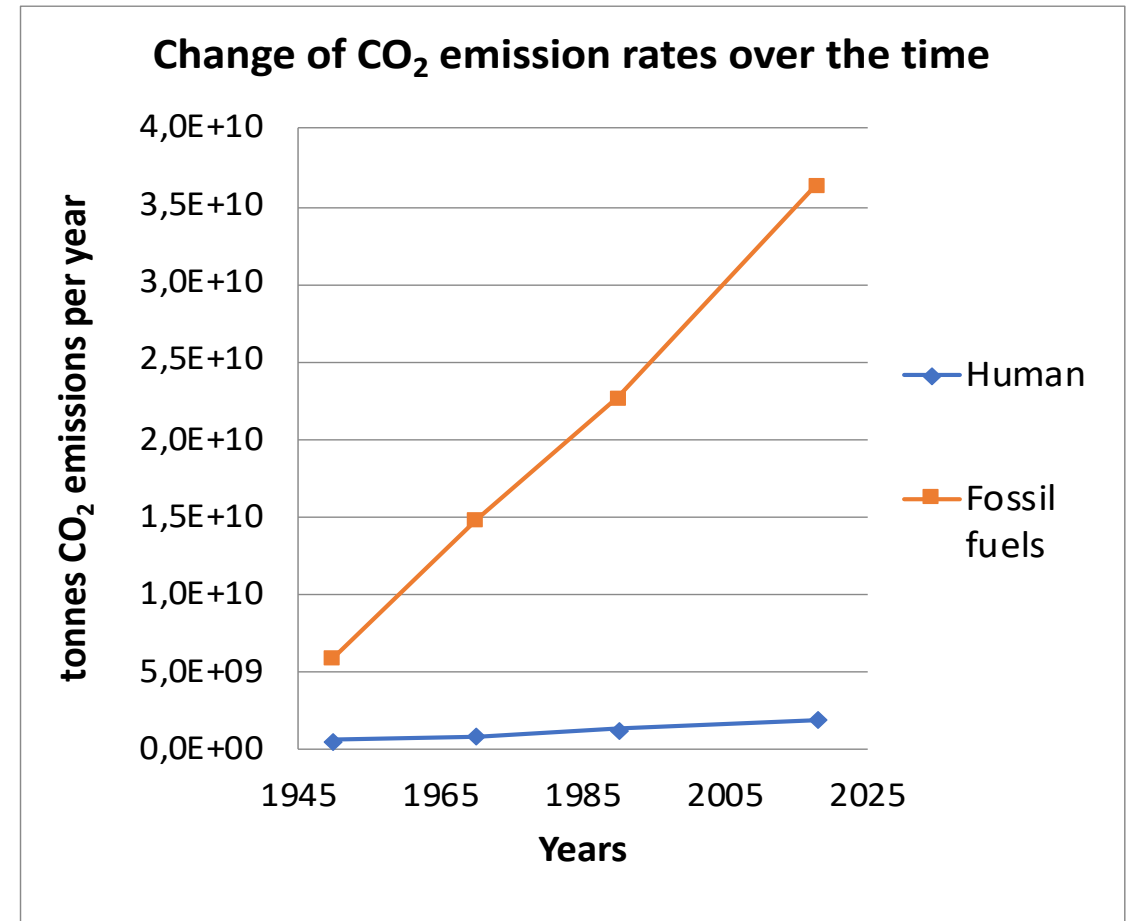
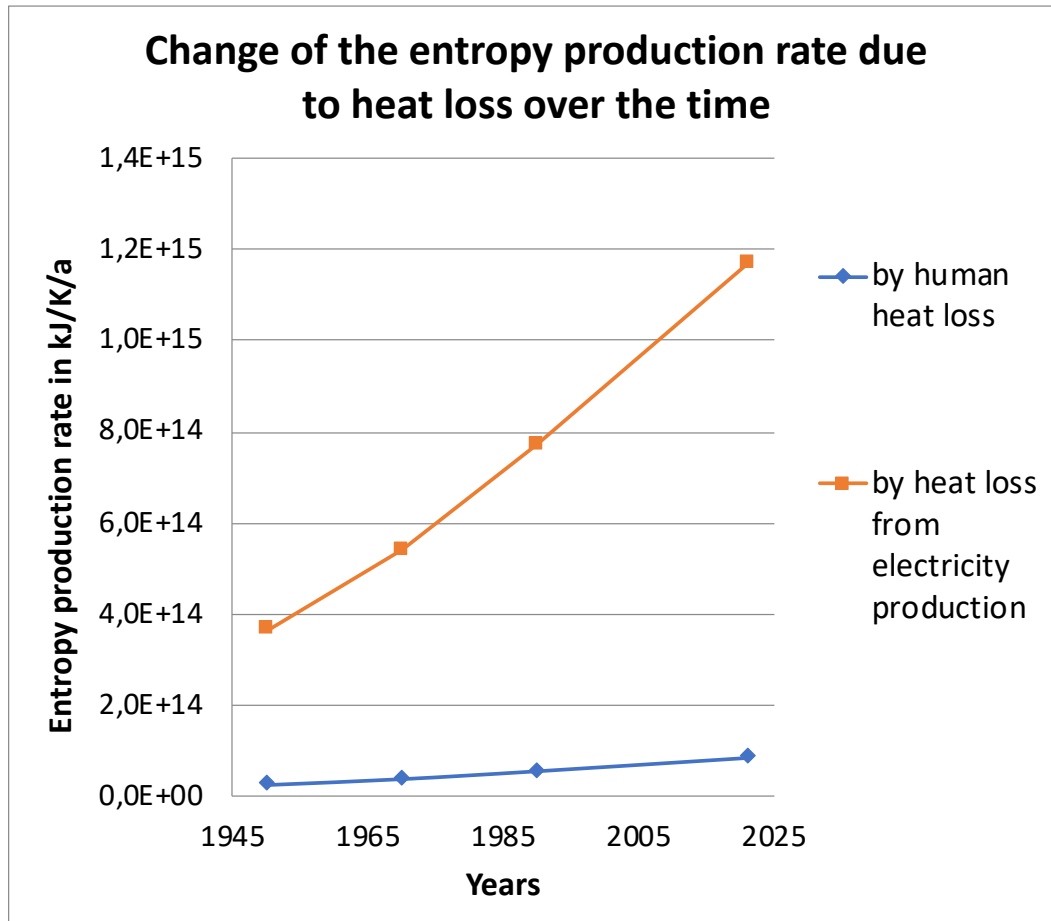


Diagram from Pekgil, 2021

Diagram from Pekgil, 2021

Case study: Entropy production by 1 kWh electricity

Thermodynamic calculation of electricity from hard coal

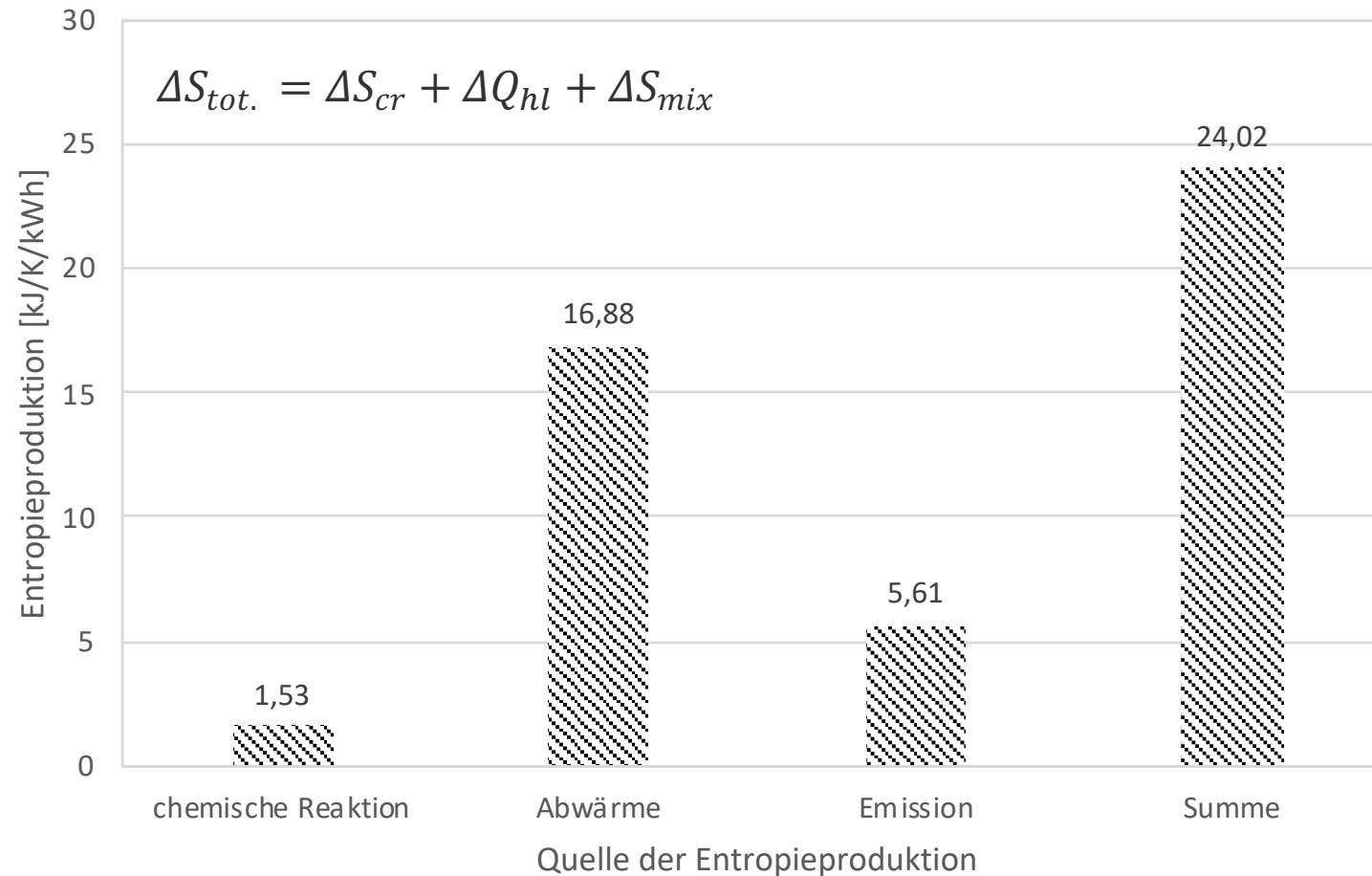


Diagram from Tang, 2021

Case study: Entropy production by 1 kWh electricity

Thermodynamic calculation of different power plants

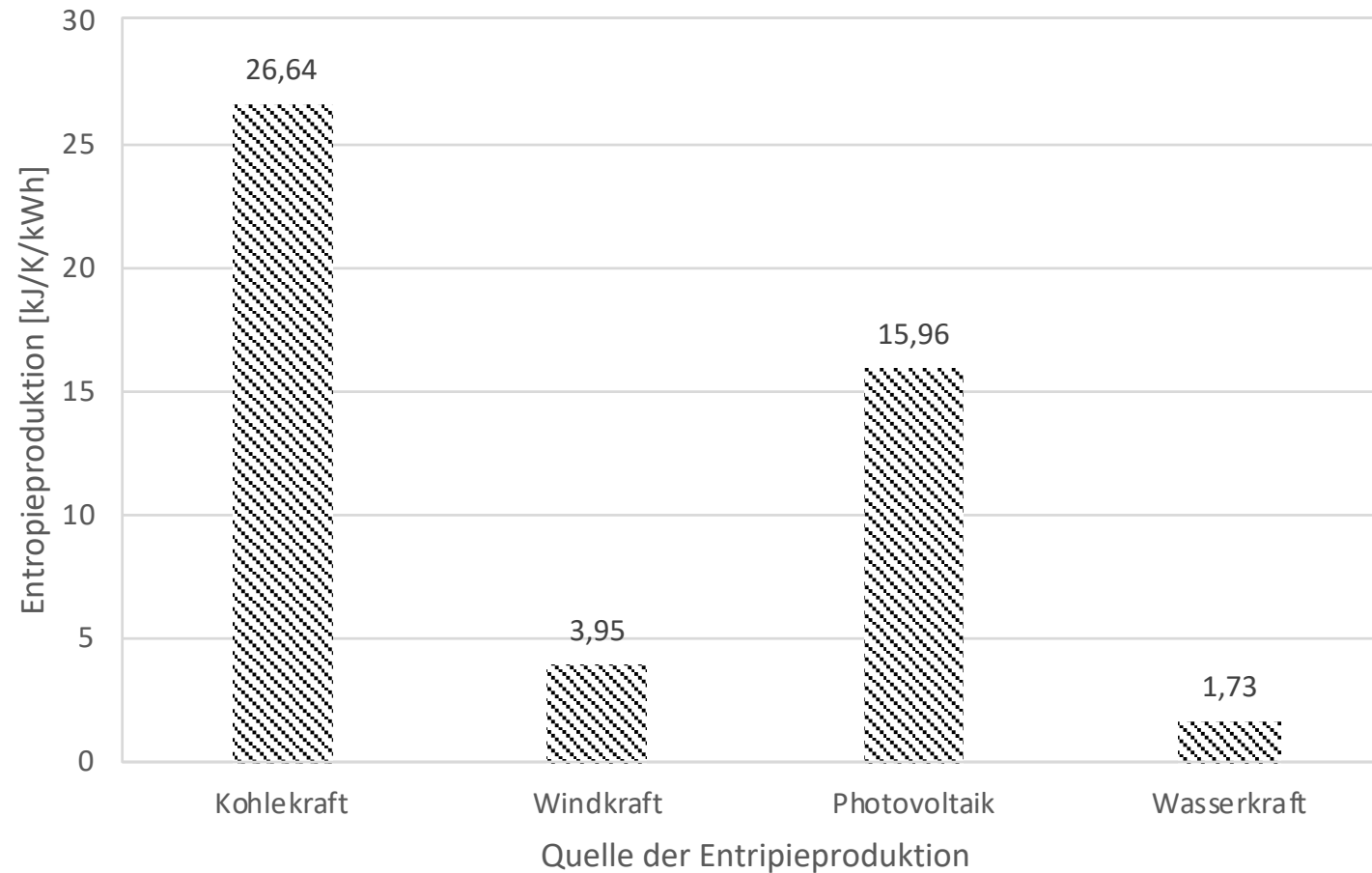


Diagram from Tang, 2021

Case study: Entropy production by 1 kWh electricity

Does the thermodynamic calculation fit to classical LCA?

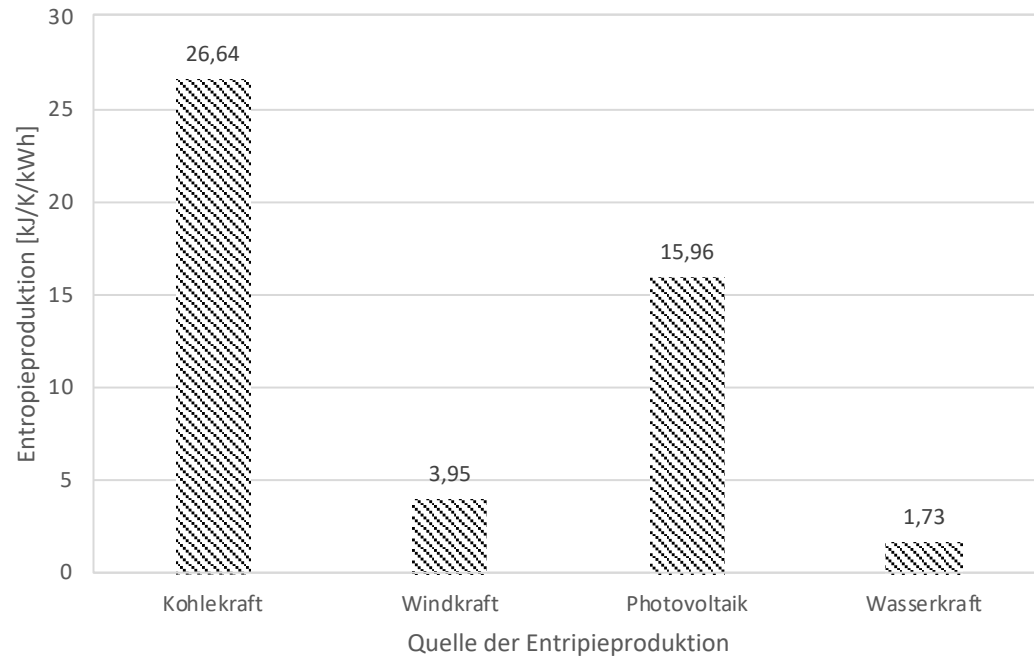


Diagram from Tang, 2021

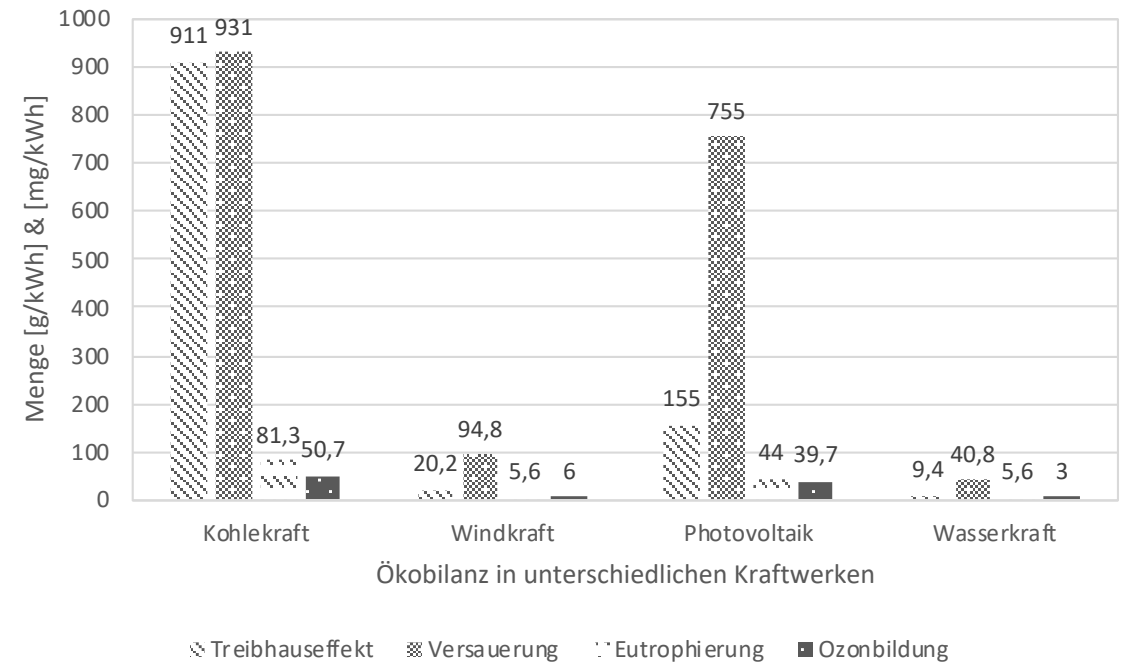


Diagram from Tang, 2021, values from Hennings et al., 2006

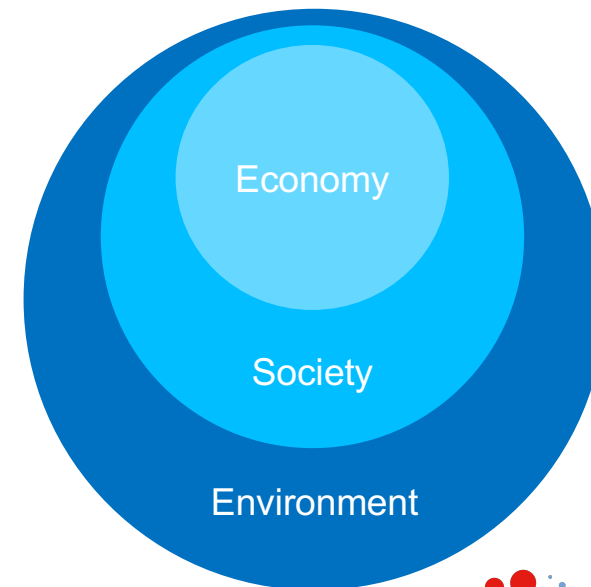
Outlook

Entropy-LCA: Work in Progress – suggestions for cooperations

- Entropy production as process variable
 - ⇒ **no process, no entropy production**
 - state of being contaminated
 - state of health hazard
 - state of land use ...
 - ⇒ **substitution processes?**

- **Entropy and sustainability**
 - Entropy and economy (Georgescu-Roegen)
 - Entropy and ecology (Shannon)
 - Entropy and society (Bailey)
 - ⇒ **Entropy balancing for LCSA?**

- **Entropy-LCA and balance limits**
 - process-related (side processes)
 - space-related (global vs. local)
 - time-related (future events)
 - ethical: human illness and death

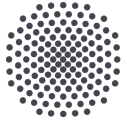


Acknowledgement

The project in relation to this presentation is generously funded by

Vector Stiftung Stuttgart.





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