Sustainable development, from laws of Physics

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October 19, 2023 Frankfurt/M

Sustainability

- We do not want
  SUSTAINABLE STAGNATION, we want
  SUSTAINABLE DEVELOPMENT !
  The use of word “sustainability” frequently covers an opposition to science, technology & development.

- Political definition (loose): *Brundtland* report “*Our Common Future*” (1987). This definition states, “Sustainable development is a development that meets the needs of the present without compromising the ability of future generations to meet their own needs.”

- Is there a better SCIENTIFIC definition ?

Sustainability – Scientific Definition

- We have limited resources and territory on the Earth.
- About 3.8 billion years ago, life appeared first by single-celled prokaryotic cells, bacteria. Since then, the matter undergoes a continuous development with increasingly complex organization, both biologically, then in technology.
- *Erwin Schrödinger*, who invented the quantum mechanics, in his book, "*What is Life*" (1944), concluded that development is only possible in the direction of increasing **Complexity** (he used the term "**orderliness**"), that is with decreasing **Entropy.** (precise & quantitative!)
- Complex materials → develop → more complexity = decreasing Entropy. Is this possible and can continue?

In 1944

- **no DNA**

- **no neural networks**

- **no anatomy of nervous system**

- **many definitions of entropy**
  (e.g. Shannon entropy) >>

[**2017:**
L.P. Csernai, S.F. Spinnangr, S.Velle,:
Quantitative assessment of increasing complexity, *Physica A*]

Increasing Complexity → Entropy

The chemical and biological development:

Material or tissue	Entropy, S, for 1 kg [J/K°]
H_2 – ideal gas hydrogen	$58.3 \cdot 10^{3}$
H_2O – water vapor, ideal gas	$8.24 \cdot 10^{3}$
H_2O – liquid water, T = 100 C°	$4.43 \cdot 10^{3}$
H_2O – liquid water, T = 0 C°	$3.12 \cdot 10^{3}$
H_2O – water ice, T = 0 C°	1900.2
UF_6 – Uranium-hexa-fluoride, ideal gas	513.2
C_{60} – Fullerene, ideal gas	263.2
DNA molecule* of Candidatus Carsonella ruddii (CCr)	$1.79 \cdot 10^{-96105}$
Human DNA	$3.96 \cdot 10^{-1\,974\,000\,000}$
One state of the Human brain tissue	$\sim 10^{-301\,000\,000\,000\,000}$

*DNA molecule of the smallest bacteria, with only N = 159 662 base pairs.

[L.P. Csernai, S.F. Spinnangr, S. Velle, Quantitative assessment of increasing complexity, *Physica* A 473 (2017) 363–376, arXiv: 1609.04637.]

Second law of thermodynamics →

- in closed systems entropy increases

- e.g. humans / upto yr 16-18 - then \

- however the EARTH is not a closed system !

Energy, Heat & Entropy

- Most of the energy arriving from the **Sun** becomes ***Heat*** *(& some mechanical energy e.g. wind, flow)*

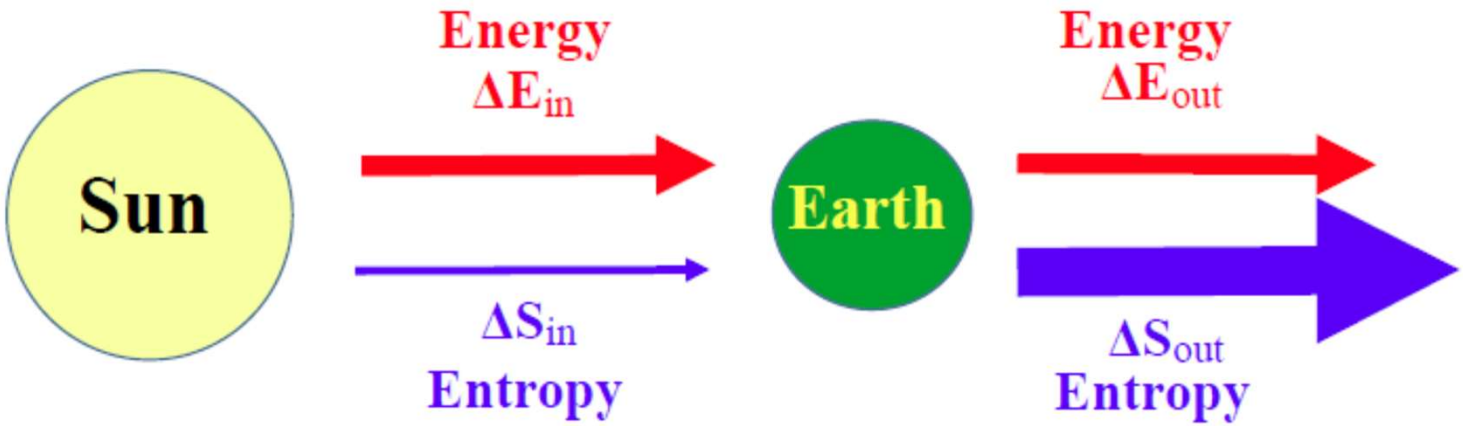
- For the present **Development** we need the present,
- relatively high temperature, **T ~ 300K**, for having
- chemical and biological reactions at reasonable **speed**.

  ← **Water in three phases !**

- The **Water on the Earth** is in 3 phases (ice, water, vapor) enables us to keep the temperature stable. → Large Entropy is radiated out from the Earth! The large latent heat of melting the ice keeps the temperature stable for 10000 – 30000 years, until all the ice melts.

[L.P. Csernai, I. Papp, S.F. Spinnangr and Yilong Xie, Physical Basis of Sustainable Development, *Journal of Central European Green Innovation*, 4, 39-50 (2016), arXiv: 1612.06439.]

Energy & Entropy balance of Earth



- (Entropy change: **$\Delta S = \Delta E / T$**.)
- The development on the Earth is governed by external conditions.
- The energy arriving from the Sun and the energy radiated out by the Earth are nearly equal, **ΔE.**
- The temperature of incoming solar radiation is high, **$T_{in} \approx 6000$ K**
- The Earth's radiation back to the cosmos is at **$T_{out} \approx 300$ K**.
- Thus, the Earth's entropy change is, **$\Delta S = \Delta E / T_{in} - \Delta E / T_{out} < 0$**, i.e. negative, the entropy is decreasing.
- This arises from the external conditions of our planet.
- Due to the fact that the Earth has an atmosphere, with water on its surface in three phases: ice, water and vapor.

Sustainable development - Energy & Entropy

- Sustainable development requires **Decreasing Entropy** by forming **more complex systems** from already **complex ones** ➔ **Sustainable Development**
- This formation **needs Energy**, mostly ordered, so called mechanical Energy.
- This Energy should be generated or made available with the possible **least Entropy production**, otherwise the resulting Entropy will not decrease.

Thank you for your attention.

Wind Power: Efficiency & Entropy generation

Turbulent flow behind the 1st row of turbines.

The turbulence leads to visible condensation and the “latent heat” goes into the atmosphere.

[See the cloud experiment at CERN]

Wind Power

Unødvendig: Vindindustrianlegg i norsk natur betyr store inngrep, mener Vidar Lindefjeld i La Naturen Leve. Foto: Blaaster Valseneset

- **Large size**
- Irregular not adjustable 0-25m/s → requires storage, & areal.
- Installed power is usually given, but
- Production is 20 – 25% of the installed power.
- Production and efficiency (almost never published !).

January 9, 2018

- **Intermittent** (!) ➔
- *Back up power* needed
- Cheapest: brown-coal
- German catholic church is demolished for surface brown-coal mine !
- Fire is kept on !!!

Wind Power: Efficiency

The wind is a form of mech kinetic energy, which is generated from the uneven Solar radiation. The wind-turbines at high wind-speed and low efficiency transform back this mech energy into heat in nearly 100% ! This is due to the fact that the wind turbines cannot adjust their production even to the available wind energy!

Sails adjust to the wind energy much better. The sails are permanently adjusted in their direction and shape, to gain most energy out of the wind with possibly minimal turbulence!

See the large, 45', America's Cup boats, which can reach 100 km/h in high winds.