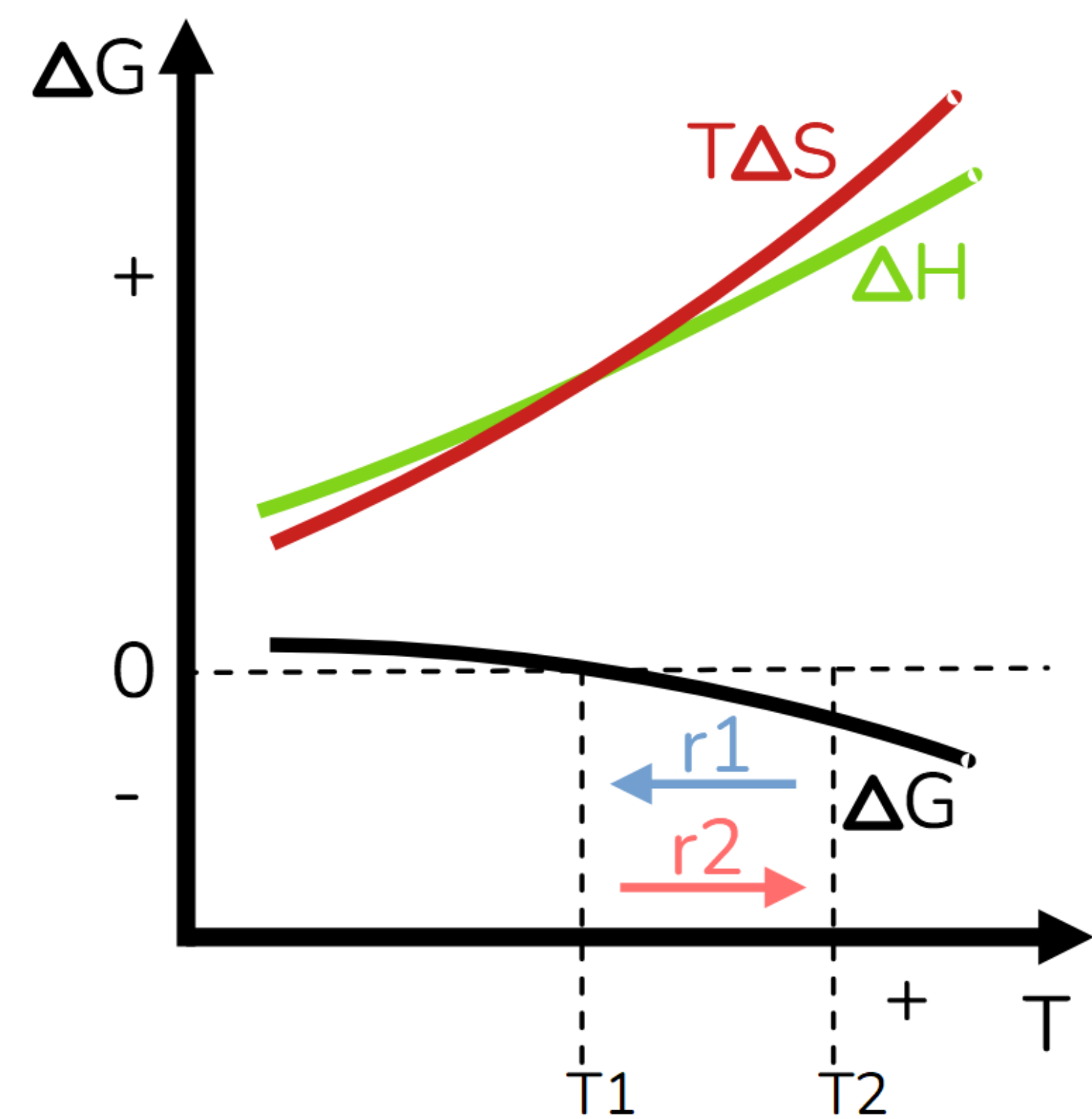


Thermo-Electro-Chemical Generation (TECG) of Power

a novel approach to harvest ultra-low-grade heat via complexing biomatter for autonomous IIoT systems

Dr. Frank Schneider, CSO, HEIONIT GmbH (dr.schneider@heiontec.com)
Waldemar Lewtschenko & Dipl.-Ing. Anton Ledwon, R&D, HEIONIT GmbH (forschung@heiontec.com)

MOTIVATION: Thermal harvesting technologies like thermoelectric generators (TEGs) require temperature gradients (01; 02). Similarly chemical equilibria can be used to harvest energy from temperature gradients (03) or fluctuations (04). However the requirement of sufficient temperature differences limits the applicability in near-isothermal environments. We suggest a TECG-approach based on entropy-driven complexation equilibria via humic, bio-derived materials (05a-c), wherein macromolecular organic structures provide kinetically imbalanced equilibrium states for harvesting ambient heat.



$\Delta G = \Delta H - T\Delta S$
G: Gibbs free energy [J/mol]
H: enthalpy [J/mol]
T: temperature [K]
S: entropy [J/(mol K)]

Figure 1 Illustration of a possible enthalpy-entropy compensation of the TECG-system

Gibbs free energy

From biophysics (06) it is known that macromolecular ligand binding and observable Gibbs free energy can show an unusual temperature-dependency as illustrated graphically:

Starting at T2 a reaction r1 will be spontaneous and cooling; at T1 G converges zero and reaction r1 ceases; regeneration reaction r2 is only possible via uptake of external, thermal energy, restoring the system to the initial state at T2.

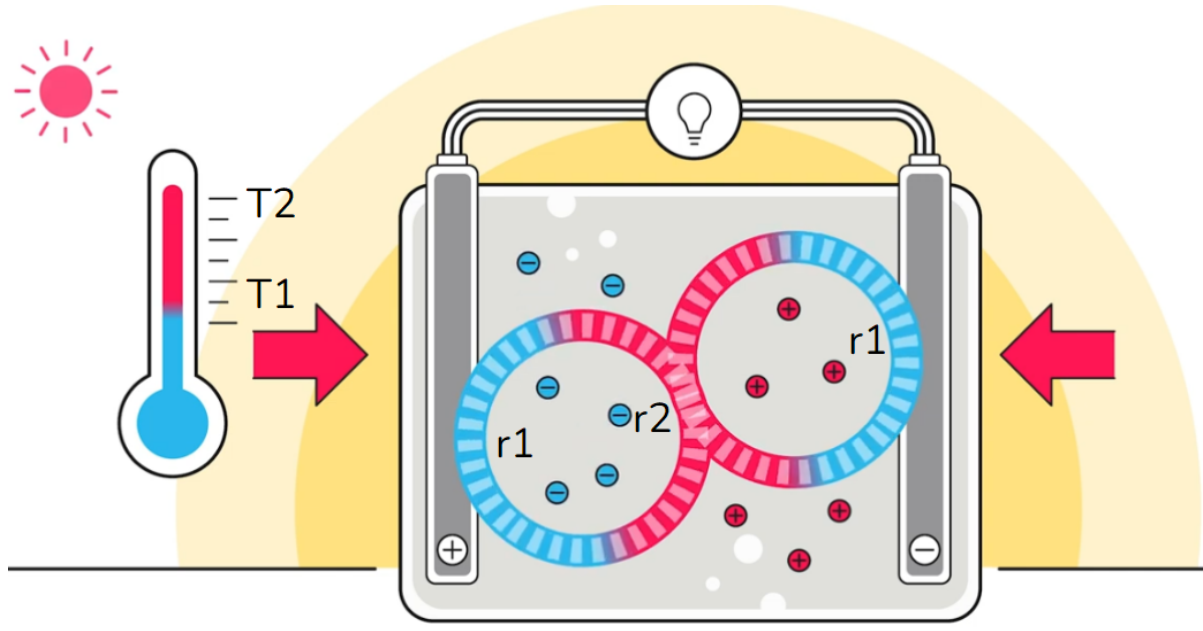


Figure 2 - schematic of the current TEC-G-cell

TEC-G Cell

,-': C-based electrode; catalytically interacting with complexed $\text{Fe}^{3+}/\text{Fe}^{2+}$
,+': metal-based electrode; interacting with a redox-buffer (e.g. H_2/H^+) within...
'grey liquid': aqueous, sulfuric acid, humic macromolecules, $\text{Fe}^{3+}/\text{Fe}^{2+}$ and organic additives (HEIONTEC formulation).

At T2 kinetically favored Fe^{3+} -complexes result in a positive potential on the ,-'-electrode. Reaction r1 becomes possible when circuit is closed (light bulb is on). Along the blue pathways T is lowered by r1 from T2 to T1 where usable current converges zero. Light bulb is switched off. By absorbing external thermal energy (arrows) system re-equilibrates via r2 (red pathways) to the initial state at U = 0,8V and T2.

U(OCV)= 0,8V; I(peak) = ~1mA; I(constant) = ~1μA; (I per gram electrolyte);
T: 10°C < T < 60°C; stable for years (current values, WIP).

Conclusion:

Results corroborate feasibility of harvesting ultra-low-grade heat under near-isothermal conditions. Such enables a new class of complementary solutions to existing thermal energy harvesting approaches, capable of operating without external temperature gradient. Potential applications comprise batteryless, ambient-heat powered IoT/IIoT systems, sensor-nodes, smart building infrastructure (09), self-discharge compensators and recovery of ultra-low-grade waste heat.

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