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Entransy Concept and Controversies:

A Critical Perspective within Elusive Thermal Landscape

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Hello! *Thank you* *for the opportunity to present a holistic, phenomenological reasoning of some critical issues in Thermal-science*

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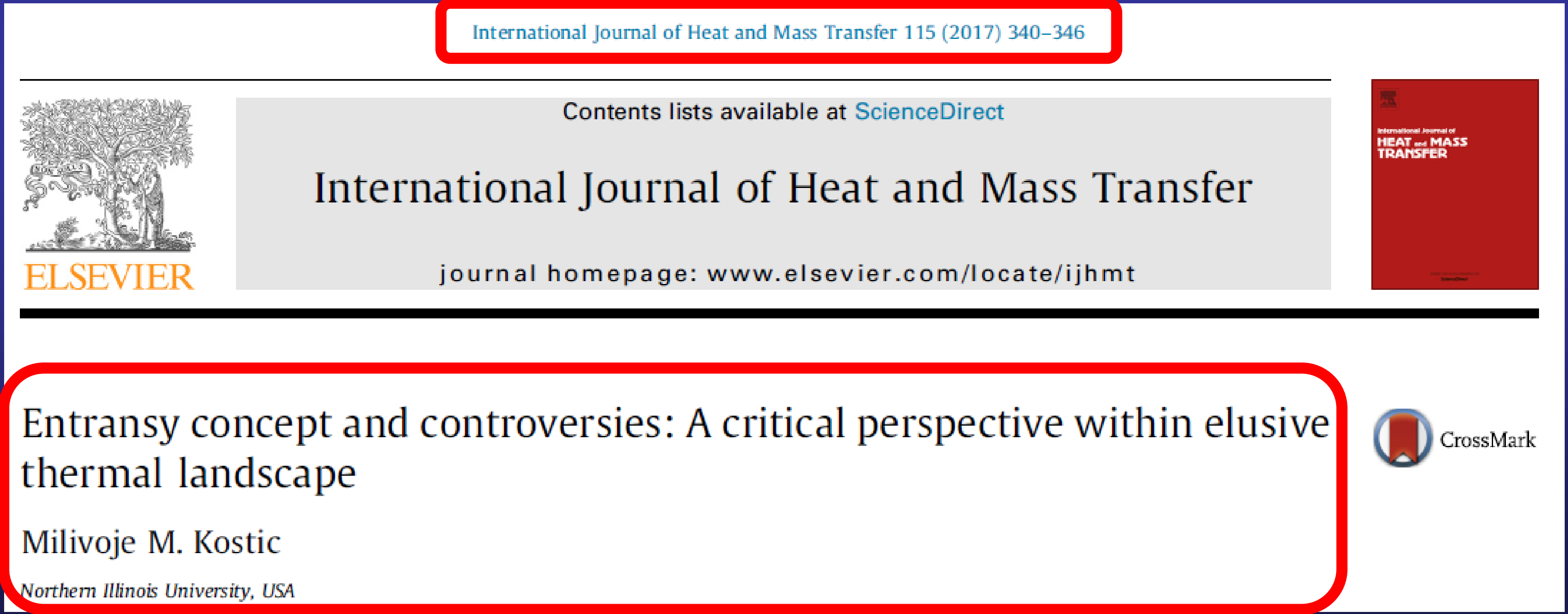
entropy



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Entransy concept and controversies: A critical perspective within elusive thermal landscape

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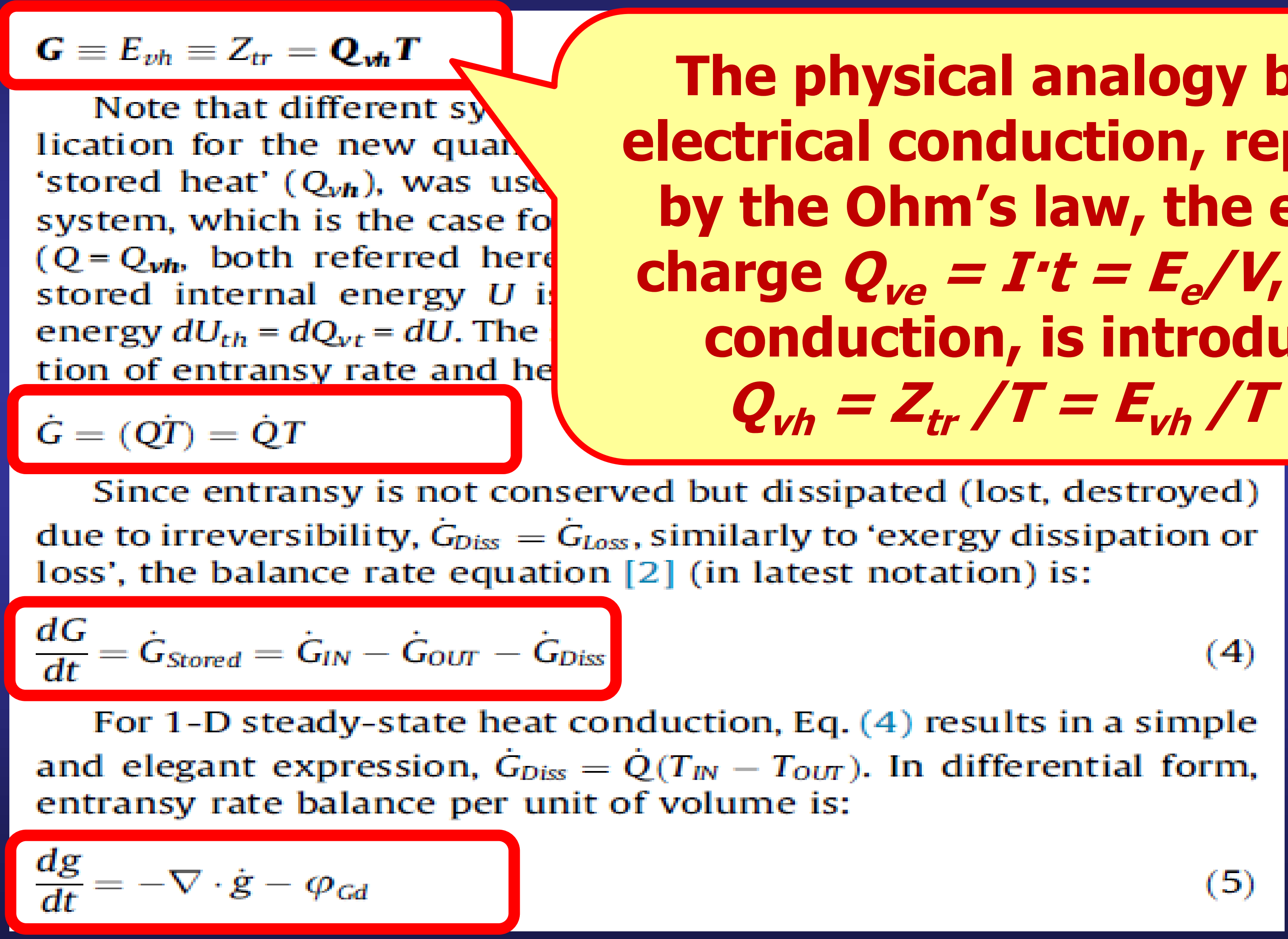
Entransy, $G=Q_{th}T$, is 'extended' thermal heat [JK]



$G \equiv E_{vh} \equiv Z_{tr} = \mathbf{Q_{vh}T}$

Note that different sy
lication for the new quan
'stored heat' (Q_{vh}), was us
system, which is the case fo
($Q = Q_{vh}$, both referred here
stored internal energy U i
energy $dU_{th} = dQ_{vt} = dU$. The
tion of entransy rate and he

$\dot{G} = (Q\dot{T}) = \dot{Q}T$

Since entransy is not conserved but dissipated (lost, destroyed) due to irreversibility, $\dot{G}_{Diss} = \dot{G}_{Loss}$, similarly to 'exergy dissipation or loss', the balance rate equation [2] (in latest notation) is:

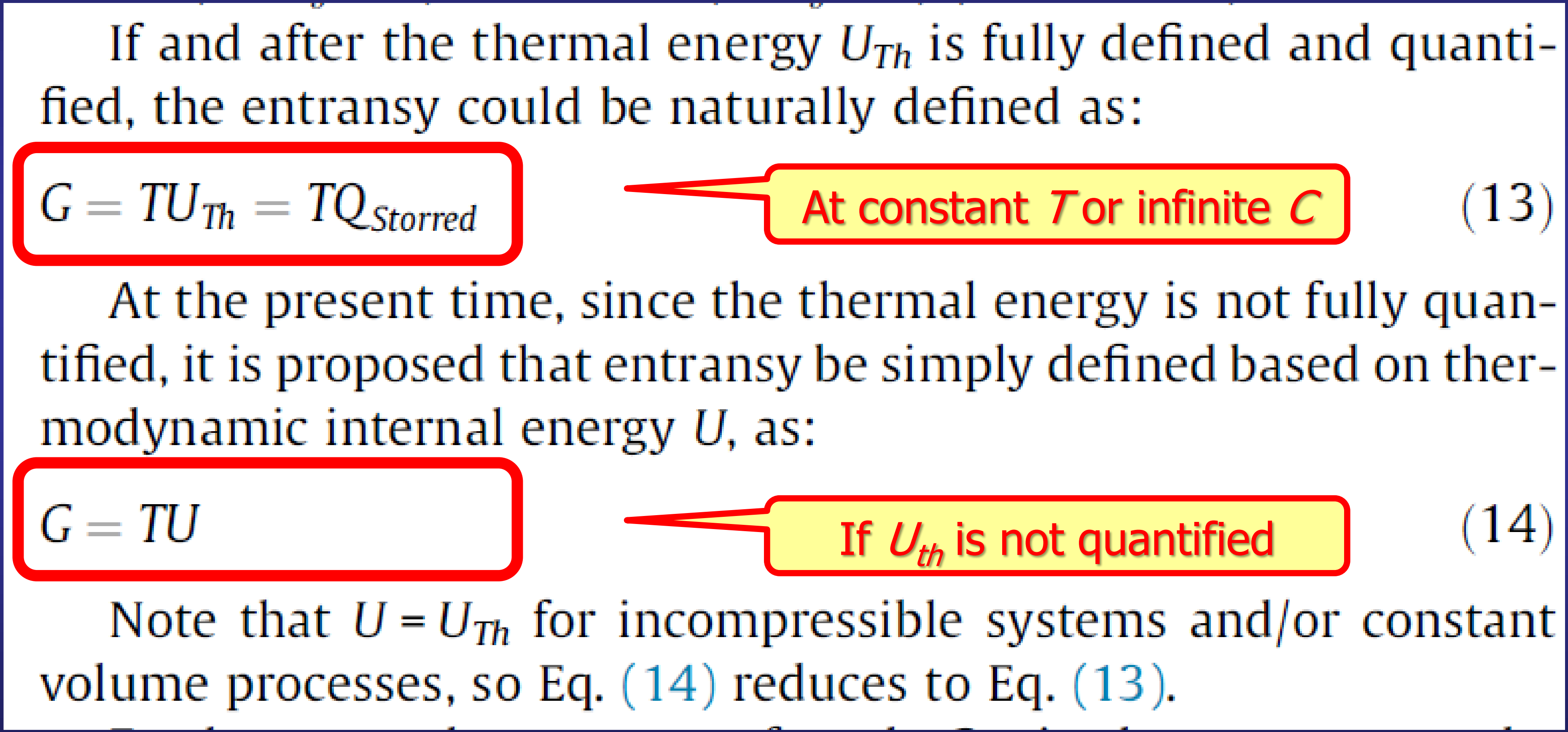
$$\frac{dG}{dt} = \dot{G}_{Stored} = \dot{G}_{IN} - \dot{G}_{OUT} - \dot{G}_{Diss} \qquad (4)$$

For 1-D steady-state heat conduction, Eq. (4) results in a simple and elegant expression, $\dot{G}_{Diss} = \dot{Q}(T_{IN} - T_{OUT})$. In differential form, entransy rate balance per unit of volume is:

$$\frac{dg}{dt} = -\nabla \cdot \dot{g} - \varphi_{Gd} \qquad (5)$$

The physical analogy between electrical conduction, represented by the Ohm's law, the electrical charge $Q_{ve} = I{\cdot}t = E_e/V$, and heat conduction, is introduced as $Q_{vh} = Z_{tr}/T = E_{vh}/T = G/T$

Entransy, $G=Q_{th}T \rightarrow G=U_{th}T$, is ‘extended’ thermal energy [JK]



If and after the thermal energy U_{Th} is fully defined and quantified, the entransy could be naturally defined as:

$$\boxed{G = TU_{Th} = TQ_{Storred}} \qquad (13)$$

At constant T or infinite C

At the present time, since the thermal energy is not fully quantified, it is proposed that entransy be simply defined based on thermodynamic internal energy U, as:

$$\boxed{G = TU} \qquad (14)$$

If U_{th} is not quantified

Note that $U = U_{Th}$ for incompressible systems and/or constant volume processes, so Eq. (14) reduces to Eq. (13).

Entransy Challenges and Controversies

- **Entransy concept**, while still in development and with certain deficiencies, has been lately **challenged** and **criticized** by several publications, as "**inconsistent and not needed, having lack of content in physics, redundant to entropy," among others**, thus creating **controversies**, that have been put here in broader, including historical and contemporary perspective, with regards to still-elusive nature and many open issues in thermal physics.

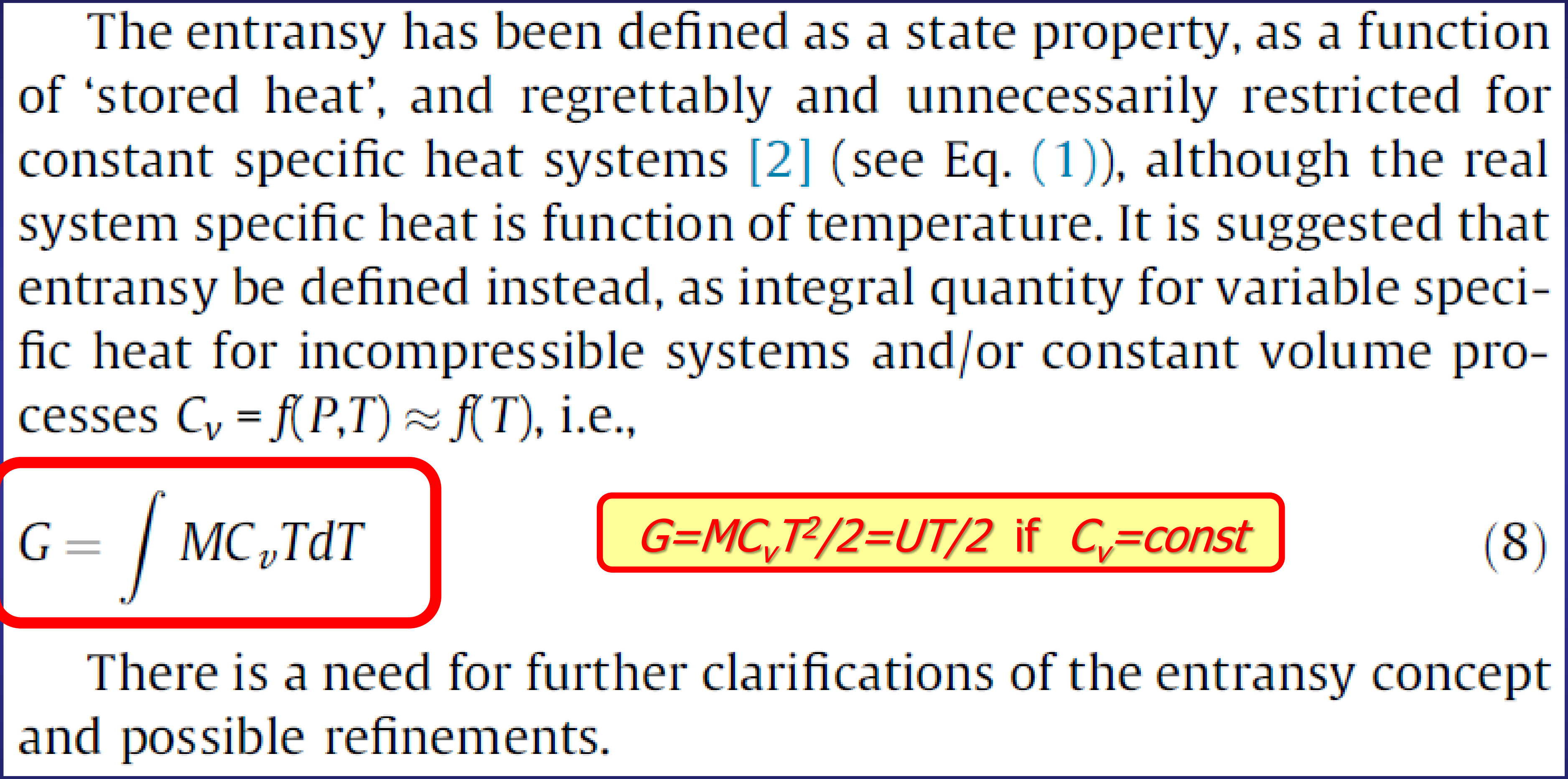
- It appears that some 'harsh' criticism, without due rigor of impartial and all-inclusive analysis of positives and negatives of a newly developing concept, is **not justified**.

- **Objectively judging** a new concept is challenging and requires comprehensive and critical analysis by many, over a long time.

Entransy Challenges and Controversies (2)

- Regardless of its redundancy, being derived from other physical quantities, as are also enthalpy, exergy and free energy, for example, it does not diminish **entransy uniqueness and usefulness** in thermal analysis and optimization.
- Despite the need for further clarifications and development of the new concept, it would be premature and unjust to discredit entransy, based on limited and subjective claims, as if the 'already established' concepts and methodologies are perfect, and do not need alternatives and innovations,
as if further progress is not needed.

Entransy ‘refinements’



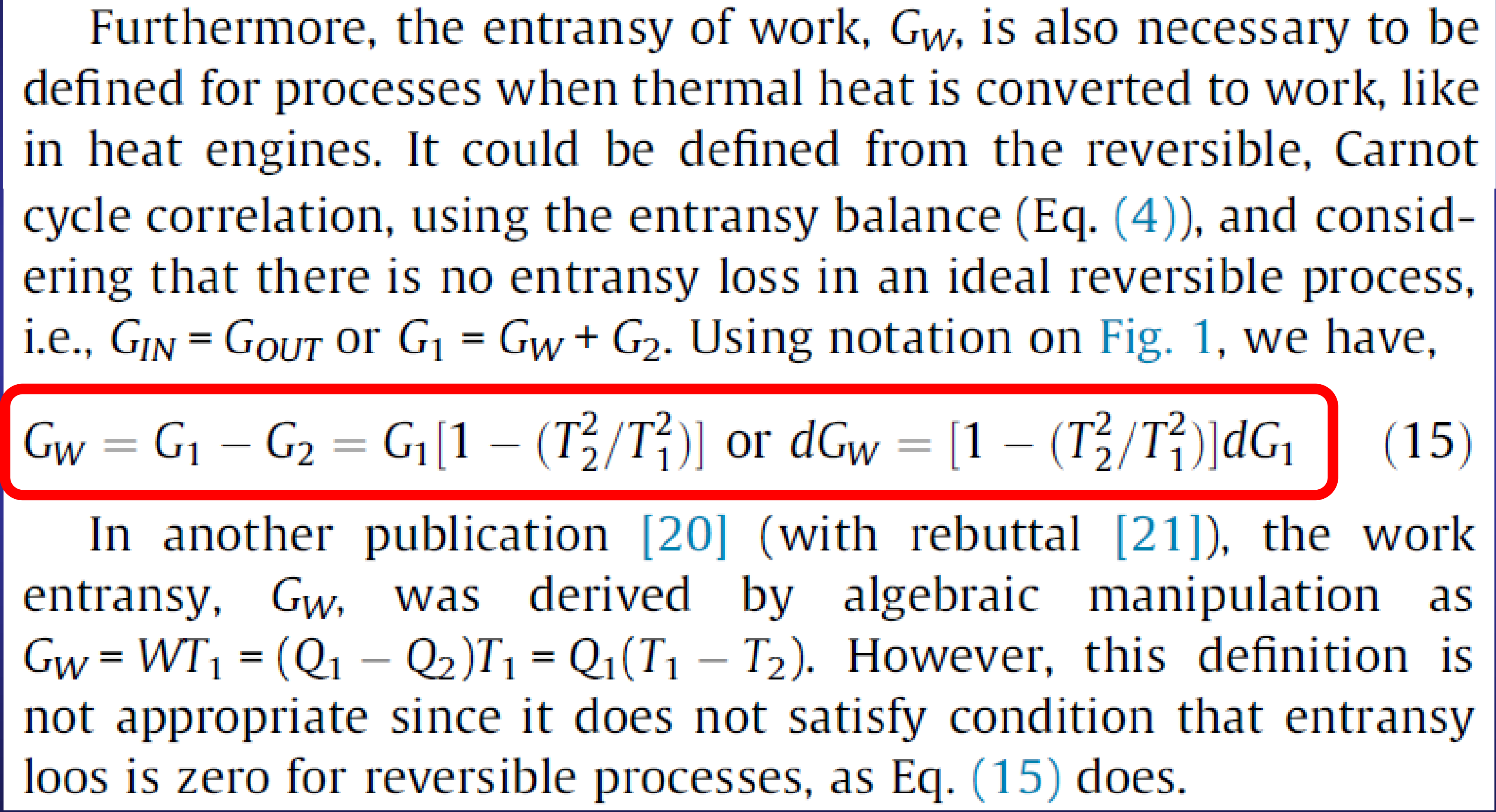
The entransy has been defined as a state property, as a function of ‘stored heat’, and regrettably and unnecessarily restricted for constant specific heat systems [2] (see Eq. (1)), although the real system specific heat is function of temperature. It is suggested that entransy be defined instead, as integral quantity for variable specific heat for incompressible systems and/or constant volume processes $C_v = f(P,T) \approx f(T)$, i.e.,

$$G = \int M C_v T dT \tag{8}$$

$G=MC_vT^2/2=UT/2$ if C_v=const

There is a need for further clarifications of the entransy concept and possible refinements.

Work Entransy, G_W

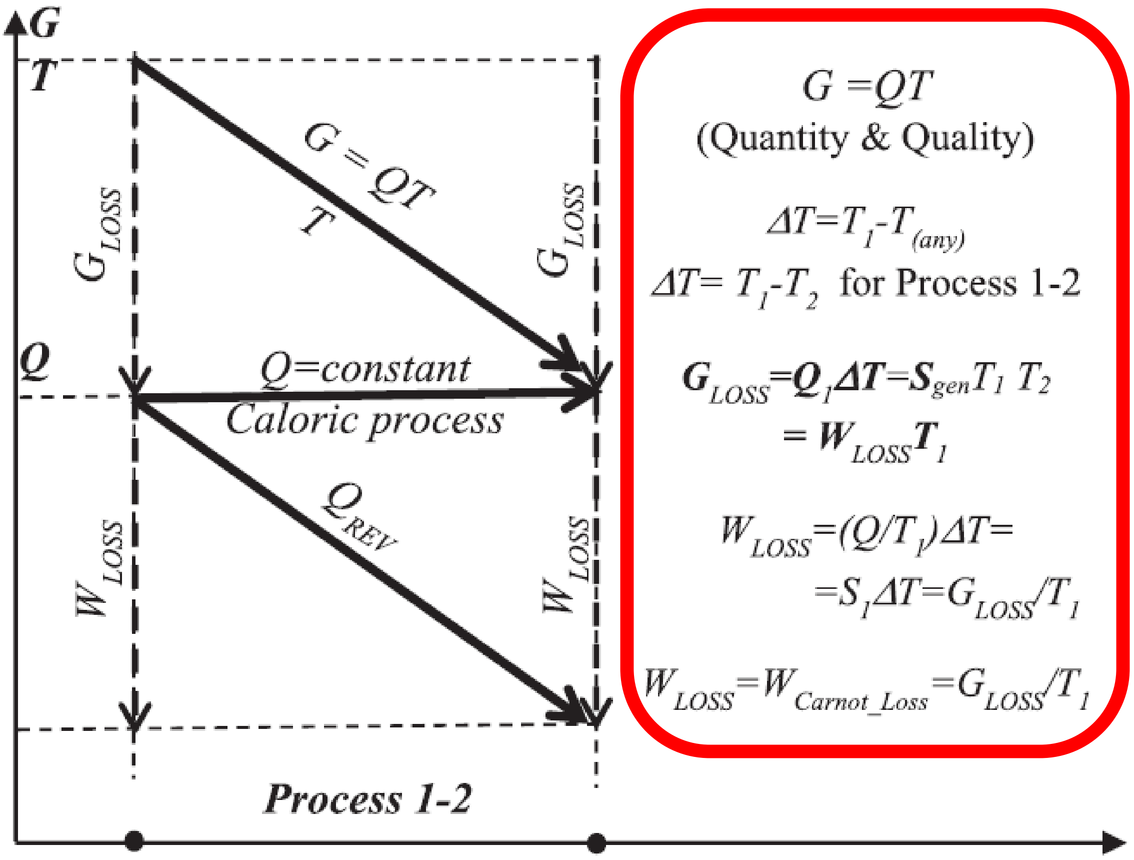


Furthermore, the entransy of work, G_W, is also necessary to be defined for processes when thermal heat is converted to work, like in heat engines. It could be defined from the reversible, Carnot cycle correlation, using the entransy balance (Eq. (4)), and considering that there is no entransy loss in an ideal reversible process, i.e., $G_{IN} = G_{OUT}$ or $G_1 = G_W + G_2$. Using notation on Fig. 1, we have,

$$\boxed{G_W = G_1 - G_2 = G_1[1 - (T_2^2/T_1^2)] \text{ or } dG_W = [1 - (T_2^2/T_1^2)]dG_1} \qquad (15)$$

In another publication [20] (with rebuttal [21]), the work entransy, G_W, was derived by algebraic manipulation as $G_W = WT_1 = (Q_1 - Q_2)T_1 = Q_1(T_1 - T_2)$. However, this definition is not appropriate since it does not satisfy condition that entransy loos is zero for reversible processes, as Eq. (15) does.

Entransy dissipation
(irreversible loss, similar to Exergy loss)



$$G = QT$$
(Quantity & Quality)

$$\Delta T = T_1 - T_{(any)}$$
$$\Delta T = T_1 - T_2 \text{ for Process 1-2}$$

$$\boldsymbol{G_{LOSS} = Q_1 \Delta T = S_{gen}T_1\, T_2}$$
$$\boldsymbol{= W_{LOSS} T_1}$$

$$W_{LOSS} = (Q/T_1)\Delta T =$$
$$= S_1 \Delta T = G_{LOSS}/T_1$$

$$W_{LOSS} = W_{Carnot\_Loss} = G_{LOSS}/T_1$$

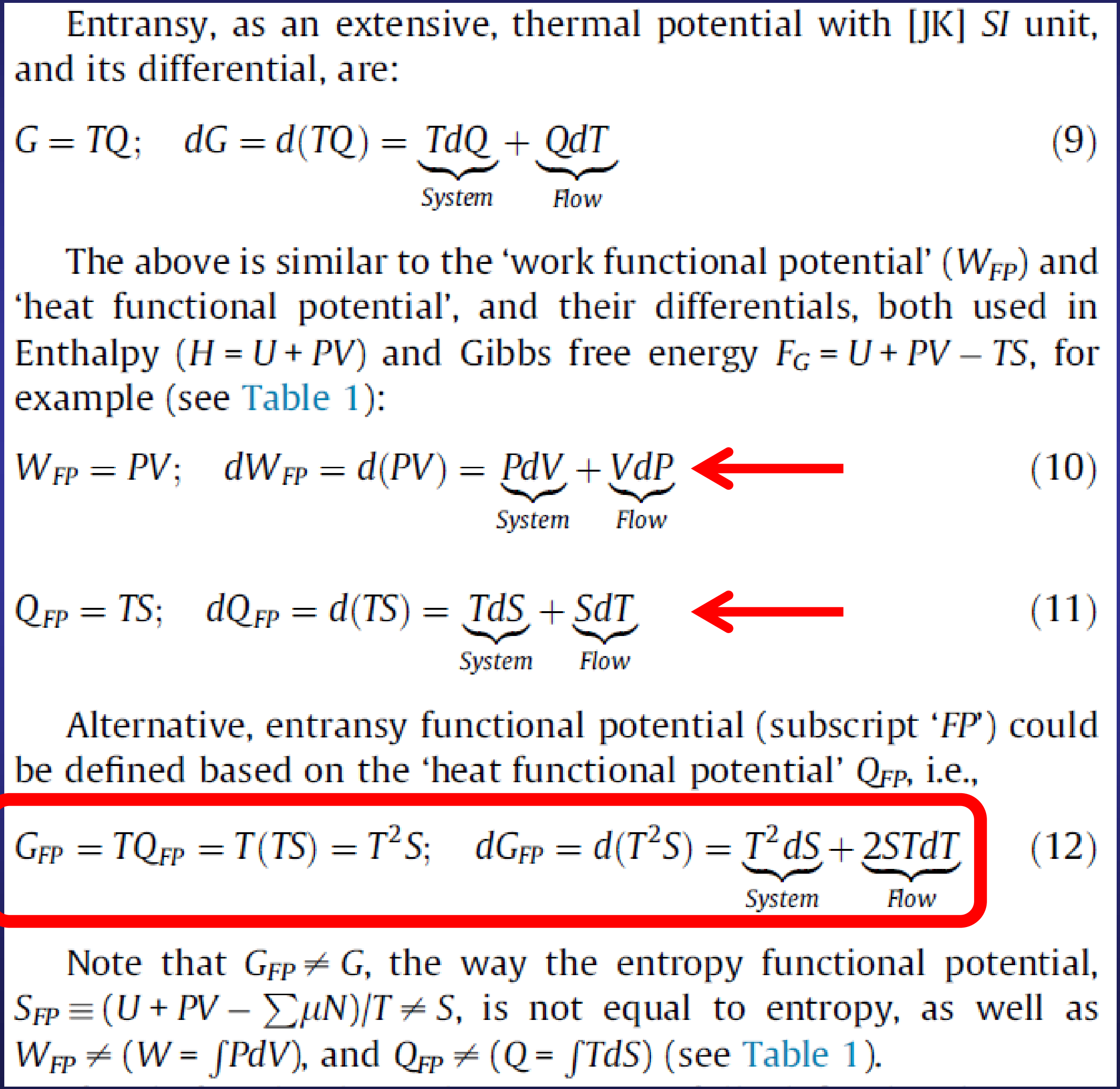
Fig. 3. Correlation between entransy G, reversible heat Q_{REV}, entransy dissipation or loss G_{LOSS}, and Carnot work-potential loss W_{LOSS}, during 1-D steady-state heat conduction caloric process 1–2 with conserved heat transfer Q.

Entransy and Exergy losses are similar and directly correlated to Entropy generation.

Entransy and Exergy are similar as integral properties and both represent quantity and quality of heat and energy, while Entropy is thermal space, similar to Volume space.

Entransy ‘functional potential’ property

$G_{FP}=Q_{FP}T=(TS)T=T^2S$



Entransy, as an extensive, thermal potential with [JK] *SI* unit, and its differential, are:

$$G = TQ; \quad dG = d(TQ) = \underbrace{TdQ}_{System} + \underbrace{QdT}_{Flow} \tag{9}$$

The above is similar to the ‘work functional potential’ (W_{FP}) and ‘heat functional potential’, and their differentials, both used in Enthalpy ($H = U + PV$) and Gibbs free energy $F_G = U + PV - TS$, for example (see Table 1):

$$W_{FP} = PV; \quad dW_{FP} = d(PV) = \underbrace{PdV}_{System} + \underbrace{VdP}_{Flow} \tag{10}$$

$$Q_{FP} = TS; \quad dQ_{FP} = d(TS) = \underbrace{TdS}_{System} + \underbrace{SdT}_{Flow} \tag{11}$$

Alternative, entransy functional potential (subscript ‘*FP*’) could be defined based on the ‘heat functional potential’ Q_{FP}, i.e.,

$$G_{FP} = TQ_{FP} = T(TS) = T^2S; \quad dG_{FP} = d(T^2S) = \underbrace{T^2dS}_{System} + \underbrace{2STdT}_{Flow} \tag{12}$$

Note that $G_{FP} \neq G$, the way the entropy functional potential, $S_{FP} \equiv (U + PV - \sum \mu N)/T \neq S$, is not equal to entropy, as well as $W_{FP} \neq (W = \int PdV)$, and $Q_{FP} \neq (Q = \int TdS)$ (see Table 1).

Thermodynamic ‘functional potential’ properties: PV, TS, $(\mathbf{TS})\mathbf{T} \rightarrow H$, A, F, $\mathbf{G}_{FP}$

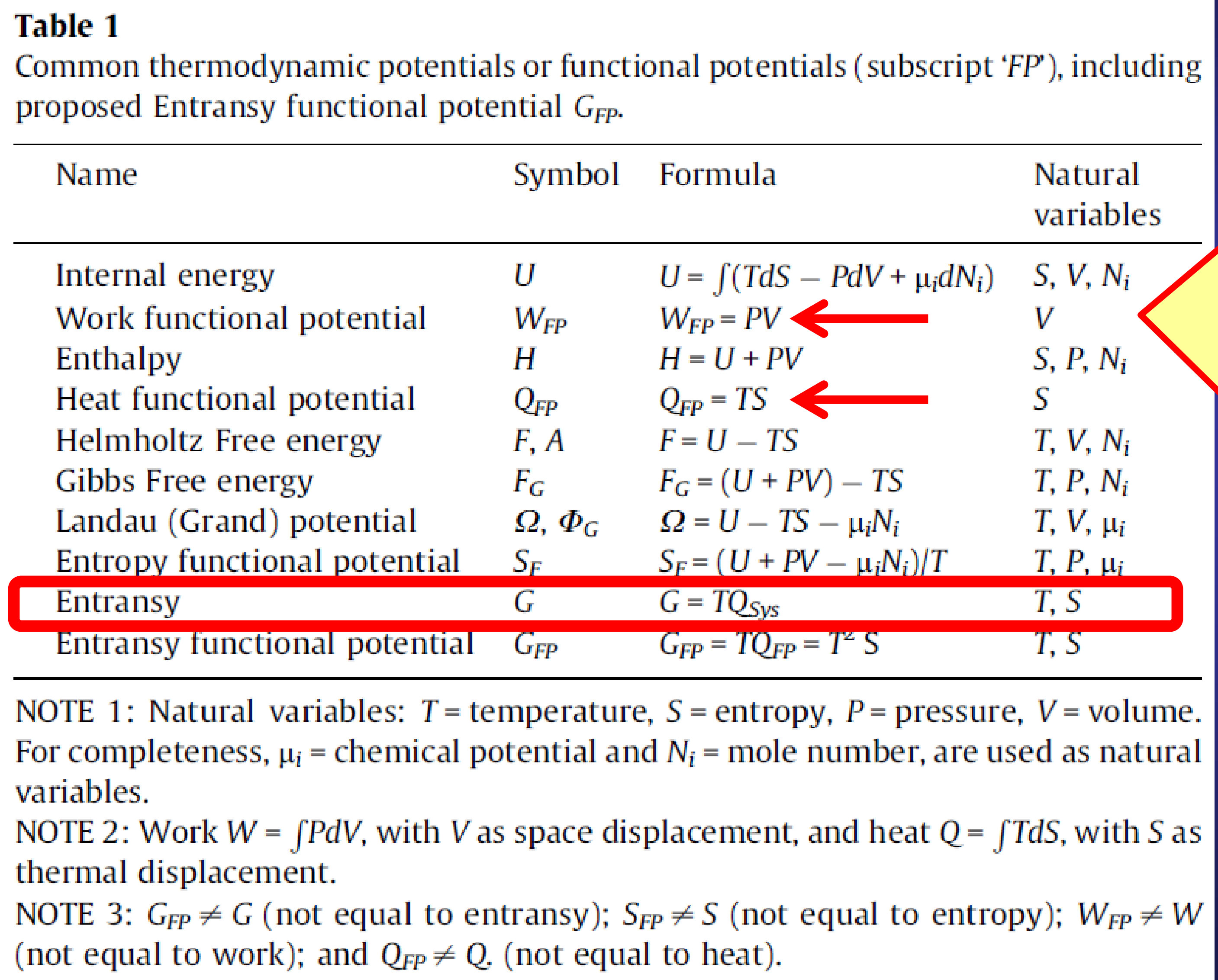


Table 1

Common thermodynamic potentials or functional potentials (subscript ‘*FP*’), including proposed Entransy functional potential G_{FP}.

Name	Symbol	Formula	Natural variables
Internal energy	U	$U = \int(TdS - PdV + \mu_i dN_i)$	S, V, N_i
Work functional potential	W_{FP}	$W_{FP} = PV$	V
Enthalpy	H	$H = U + PV$	S, P, N_i
Heat functional potential	Q_{FP}	$Q_{FP} = TS$	S
Helmholtz Free energy	F, A	$F = U - TS$	T, V, N_i
Gibbs Free energy	F_G	$F_G = (U + PV) - TS$	T, P, N_i
Landau (Grand) potential	Ω, Φ_G	$\Omega = U - TS - \mu_i N_i$	T, V, μ_i
Entropy functional potential	S_F	$S_F = (U + PV - \mu_i N_i)/T$	T, P, μ_i
Entransy	G	$G = TQ_{Sys}$	T, S
Entransy functional potential	G_{FP}	$G_{FP} = TQ_{FP} = T^2 S$	T, S

NOTE 1: Natural variables: T = temperature, S = entropy, P = pressure, V = volume. For completeness, μ_i = chemical potential and N_i = mole number, are used as natural variables.

NOTE 2: Work $W = \int PdV$, with V as space displacement, and heat $Q = \int TdS$, with S as thermal displacement.

NOTE 3: $G_{FP} \neq G$ (not equal to entransy); $S_{FP} \neq S$ (not equal to entropy); $W_{FP} \neq W$ (not equal to work); and $Q_{FP} \neq Q$. (not equal to heat).

NOTE that W_{FP} and Q_{FP} are properties and are not equal to W and Q, respectively. The W and Q are energy transfer quantities, not properties.

2nd Law can be challenged but **cannot** be violated !

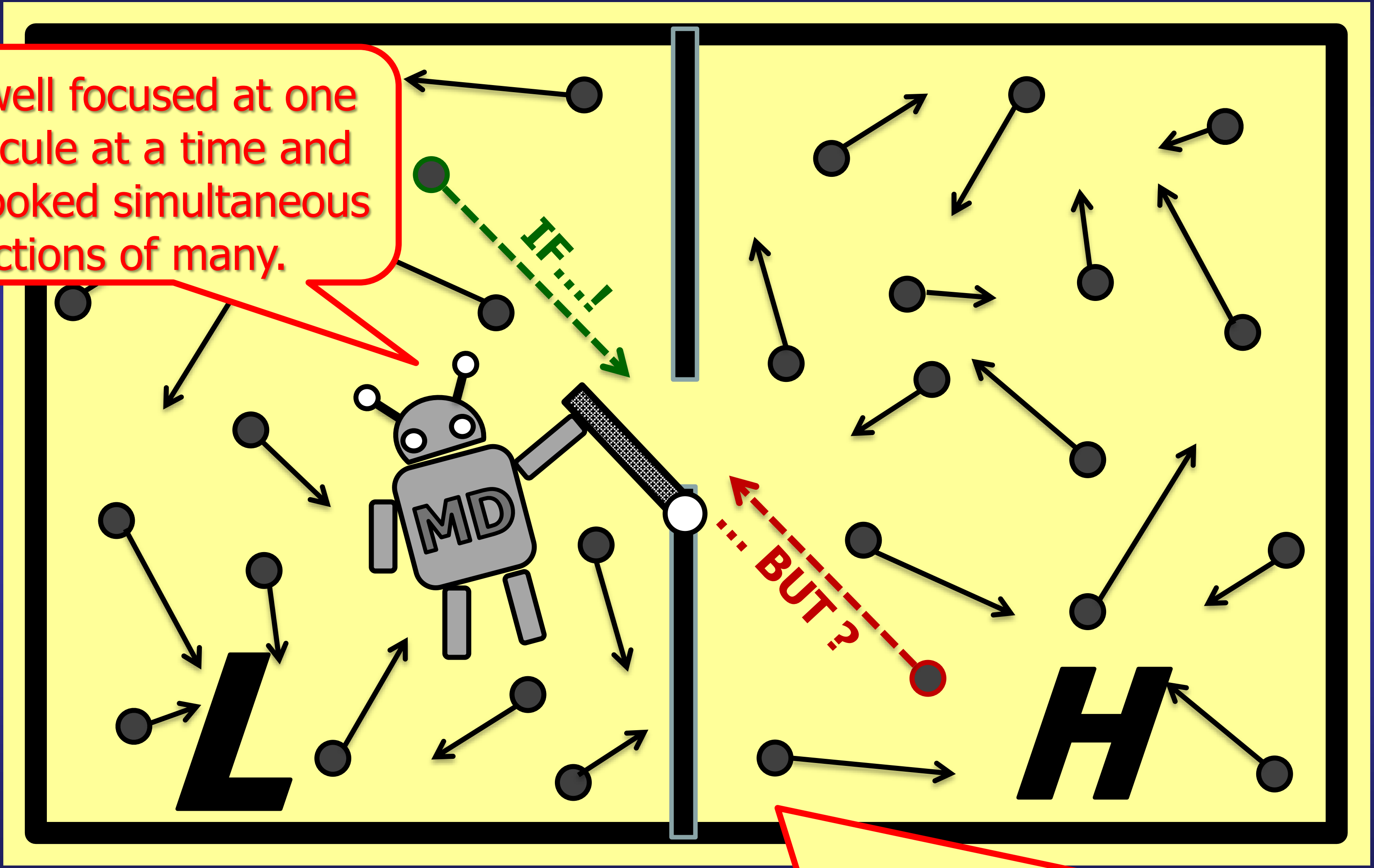
2nd Law can be challenged but cannot be violated !

Increase of ENTROPY in an isolated system is a necessary but not sufficient condition of the Second Law of thermodynamics.

Entropy can be transferred and reduced, but **cannot be destroyed** locally or at a time **and compensated** by generation **elsewhere** or later.

ENTROPY is irreversibly GENERATED everywhere and always, at any scale WITHOUT EXCEPTION, and cannot be destroyed by any means (no 'thermal order'), the latter implying increase of non-equilibrium and more efficient than 100% reversible process with mass-energy flux displacement against natural cause-and-effect, natural forces.

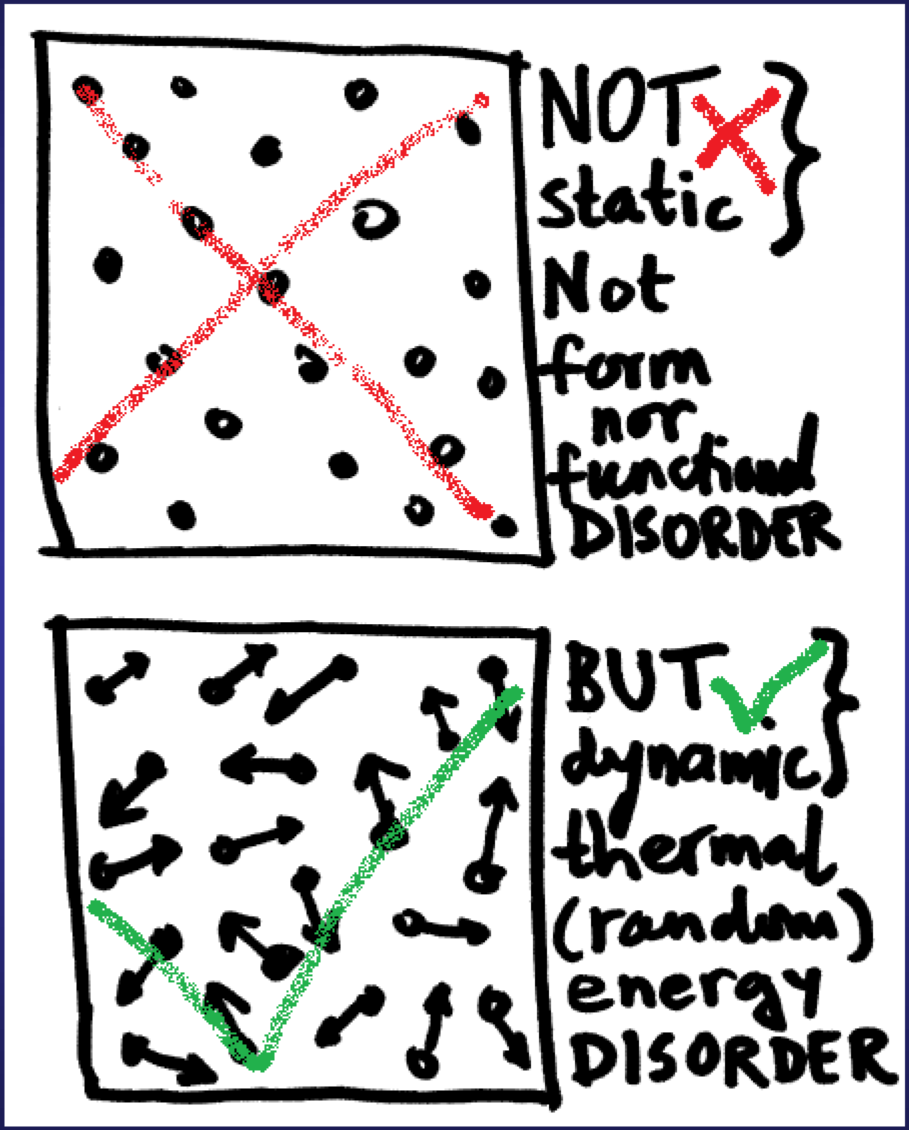
Maxwell’s Demon (MD) in 1867



Maxwell focused at one molecule at a time and overlooked simultaneous actions of many.

Fluctuations of micro properties ‘make’ macro-equilibrium, do not violate SL and cannot be ‘demonized’ into macro nonequilibrium.

Entropy Is …



Entropy is the most used and often abused concept in science, but also in philosophy and society.

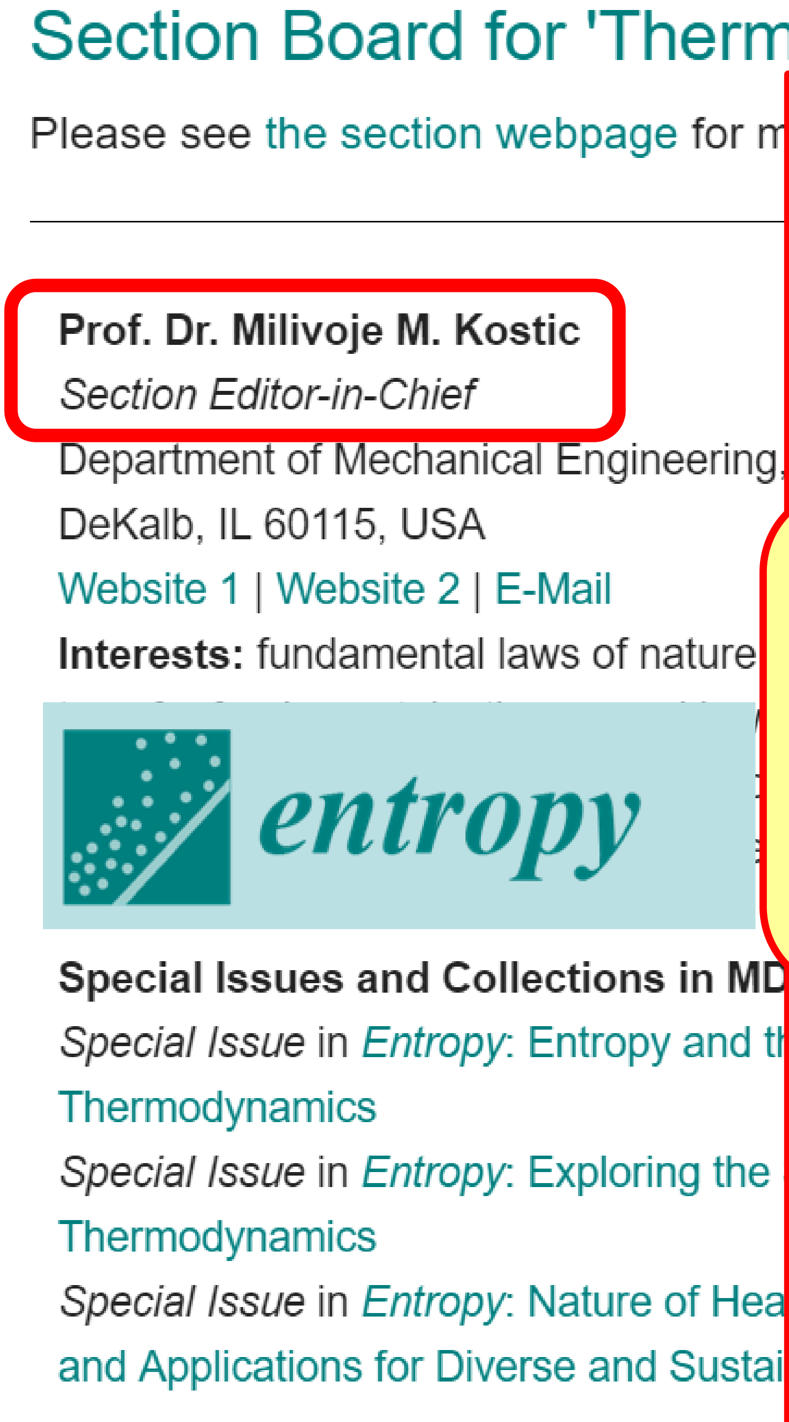
Entropy is a thermal displacement (**dynamic thermal-volume**) of heat or thermal energy due to absolute temperature as a thermal potential:

$$dS = dQ_{Sys}/T = dU_{Th}/T$$

$$= (dQ_{Tr} + \underline{dQ_{Gen}})/T$$

$\underline{d}Q = TdS$ similar to $\underline{d}W = PdV$

Kostic, M.M. The Elusive Nature of Entropy and Its Physical Meaning. *Entropy* **2014**, *16*, 953-967.



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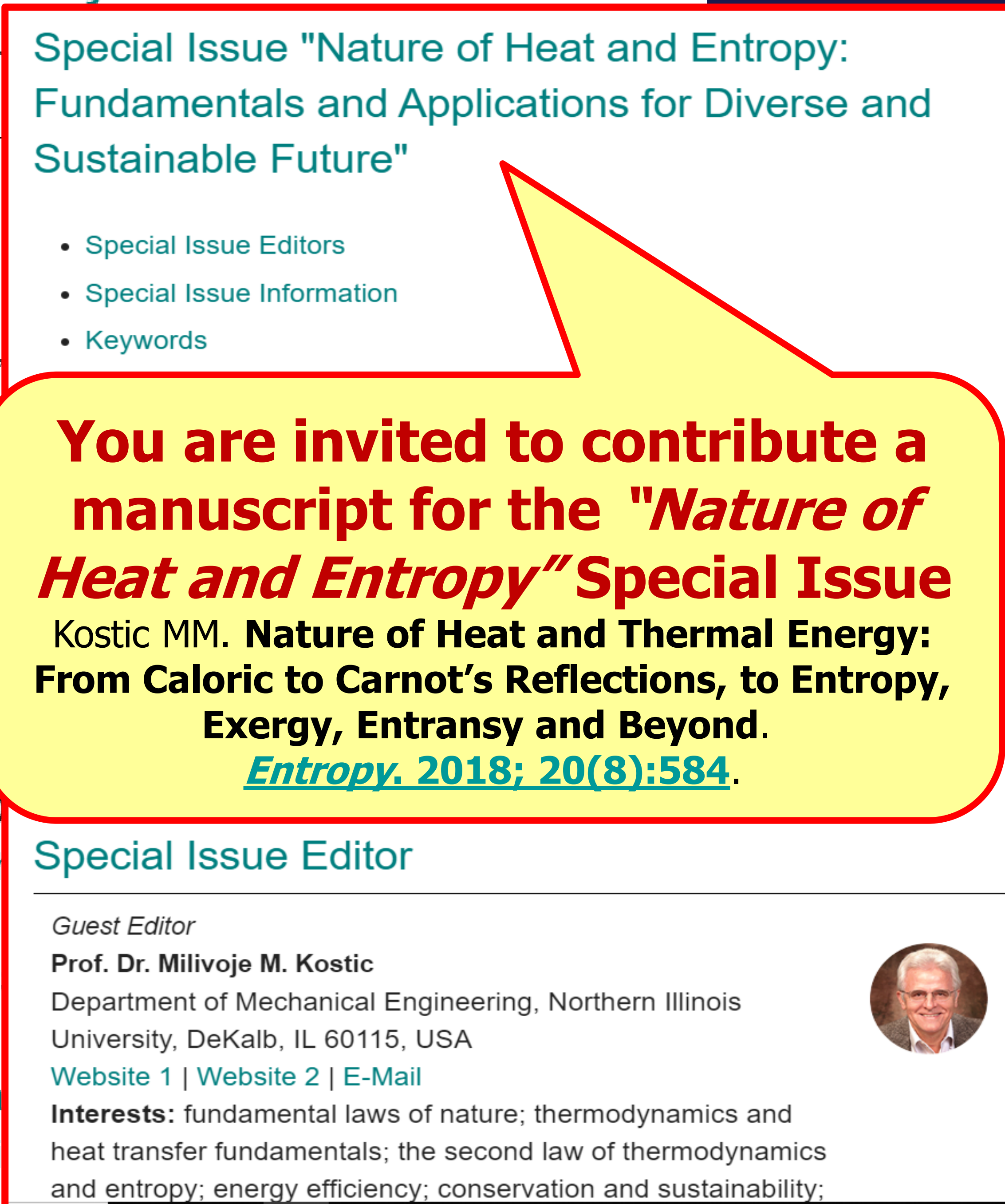

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Kostic MM. **Nature of Heat and Thermal Energy: From Caloric to Carnot's Reflections, to Entropy, Exergy, Entransy and Beyond**. ***Entropy*. 2018; 20(8):584**.

Special Issue Editor

Guest Editor

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Interests: fundamental laws of nature; thermodynamics and heat transfer fundamentals; the second law of thermodynamics and entropy; energy efficiency; conservation and sustainability;

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