NONEQUILIBRIUM THERMODYNAMICS AND CONSTRUCTAL LAW GUIDELINES FOR NATURE INSPIRED CHEMICAL ENGINEERING PROCESSES

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The chemical engineering specialty deals with the processing of matter and energy, with a special emphasis on designing and operating technological apparatus for the large-scale production of chemicals and the manufacture of products with desired properties through chemical processes. Matter and energy processing can be extended to information, especially at the chemical plant scale, covering areas similar to what Nature processes.

Within the sustainable growth challenges now everywhere, Nature is a realistic model of structures and processes, whose performance, efficiency and resilience can be envied by human-made activities.
However, nature-inspiration is far from being the norm in chemical engineering. Indeed, chemical engineering textbooks and handbooks show that chemical engineering processes are designed and operated on the basis of phase equilibrium hypotheses in reaction and separation engineering, that transport phenomena are usually described with linear phenomenological law and that process regulation is also mostly done with linear control theory. Most of these concepts are decades old.

Nature inspiration could help improve performance, efficiency and resilience of chemical engineering processes. To achieve this goal, the challenges have been clearly defined in the literature [1]: instead of merely copying natural structures or using biosourced material, one should understand mechanisms behind processes and materials in Nature, since human-made objects and processes do not operate in the same context as natural processes nor with the same goals.
In this contribution we shall revisit the classification of mechanisms underlying nature-inspired engineering proposed in [1], namely hierarchical transport network, force balancing and dynamic self-organization. In the light of nonequilibrium thermodynamics (NET) and of the constructal law (CL), we shall first consider any chemical system as an open system undergoing processes and evidence that the three above mechanisms refer to NET and CL concepts.
We shall also show that more NET and CL concepts could be exploited to design, build and operate nature-inspired chemical engineering processes. This could foster a great potential of innovation, in particular at the unit operation scale and at the chemical plant scale.

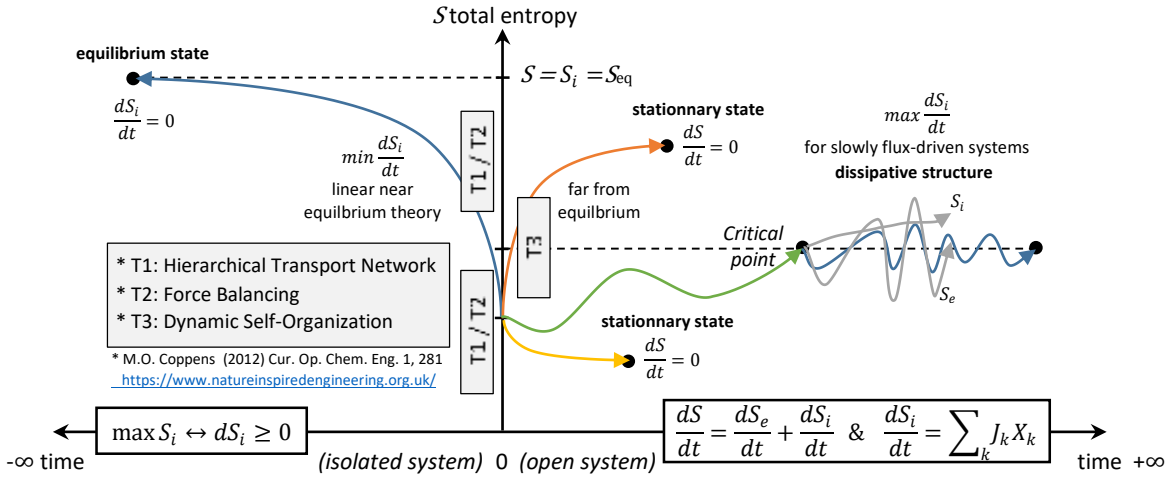

Figure 1 – Nonequilibrium perspective of nature inspired mechanisms

[1] M.O. Coppens. A nature-inspired approach to reactor and catalysis engineering. 2012. Current Opinion in Chemical Engineering, 1(3) 281-289.