# What can economists and energy engineers learn from thermodynamics beyond the technical aspects?

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**Abstract**
For over half a century, progress in non-equilibrium thermodynamics, in particular with the emergence of the theory of dissipative structures, has inevitable implications for the self-organization of human societies and biodiversity whose losses affect directly subsistence and daily life. Seen from this angle, the thermodynamics of human societies resulting from that of living organisms, developed at the end of nineteenth century, suggests a likely collapse of societies that dissipate the most energy. In the unbalanced pursuit of economic growth, for the sake of competitiveness, economists and energy engineers must take into account this risk seriously before the situation becomes more critical. This awareness, resulting from the study of complex non-linear systems, can help build better energy solutions based on the energy efficiency and renewable energies, which must replace progressively fossil fuels to keep to a minimum their use.

**Key-words** economics, thermodynamics, energy engineering, efficiency, renewable energies

## Introduction

Thermodynamics as a science was born from the idea that "heat can be the cause of movement, it even has a great motive power, the conversion of heat to power: steam engines" (Carnot, 1824, p. 1). In this sense, the practice preceded, by more than a century, the theory since the first steam engine was built by the engineer Thomas Newcomen, in 1712, to pump water from the coal mine of Dudley in England. Thermodynamics is therefore a branch of physics whose fundamental object is the study of the properties of systems where the notion of heat intervenes.

The choice of the expression "heat can be the cause of movement", by the initiator of thermodynamics, is not insignificant since it is not limited to engines. This opens the field to all the structures involved in the dissipation of heat, including living beings and human societies, which constantly interact with their respective environments, and offers new perspectives for energy engineering in order to develop human-centered innovative solutions that benefit all without harming the environment, and without compromising the ability of future generations to innovate solutions that best respond to their needs and aspirations.

In this perspective, economic life is not a closed and autonomous universe governed by independent laws as stipulated by the mainstream theory. This leads to the following questions: How did the idea of thermodynamics of living organisms come to be? How did it open the way to the thermodynamics of human societies? What is the impact of this evolution on energy engineering, which concerns optimization of energy systems interacting with their respective environments?

After reviewing the literature and clarifying the epistemological posture, this paper deals with the thermodynamics of living organisms, then that of human societies to explore the impact of this evolution on energy engineering, before revealing some global guidelines that might interest economists and energy engineers who aspire, despite multiple constraints, to build a better world for all.

## Literature review and epistemological posture

Thermodynamics has aroused, since 1824, the interest of researchers in physics, chemistry, mathematics, medicine, sociology, anthropology, history, and more recently algorithmologists who perceive the second law of thermodynamics as a law of information (Béranger, 2018, p. 62). Energy is everywhere, to succeed in using it, organisms and devices need information.

One of the first scientists to use the law of entropy in economic analysis is the physician Sergei Podolinsky. In his work published in Ukrainian, at the end of the nineteenth century, under the title 'Труд человека и его отношение к распределению энергии' (Podolinsky, 1880), which means *'Human work and its relation to the distribution of energy*', he proposes a new definition of human work based on the second law of thermodynamics (Vozna, 2016, p. 2). After studying entropy in biological processes, he worked on economics as an open system of energy flows (Alier, 2008, p. 115).

Economists have ignored for a long time the laws of thermodynamics (Burley and Foster, 1994, p. 1). When they are interested, they often remain prisoners of their economocentrism, i.e. the tendency to use the contributions of other sciences to further refine their art of persuasion. As noted by Robert Gibrat (1936, p. 25), some economists have argued that economics needs principles at the height of those of thermodynamics. To this end, they imagine that humanity as a whole is a closed system, living on itself. This system includes, in reference to what is commonly known as the law of supply and demand, producers who are at the same time consumers. The problem is to establish the equilibrium equations of all the exchanges, starting from these two principles: conservation of the masses and conservation of values. In this perspective, Marc Lichnerowicz (1970, p. 159) proposed to develop a model of economic exchange whose principles are analogous to those of thermodynamics or inspired by them. For their part, Mark Glucina and Kozo Mayumi (2010) consider that thermodynamics seem more relevant for constructing a descriptive model, or pre-analytical vision of the economy, because they involve physical constraints on production and consumption. However, they do not seem to facilitate mathematical modeling in economics. As if the latter was an end in itself. The only usefulness of mathematics, as we learned during our engineering curricula, is to give greater clarity to a subject, which allows debate, because people can only listen to each other if they have a common way of posing problems, as Gilles Deleuze (1983) taught us during one of his fascinating conferences available today to the general public.

Inspired by the second principle of thermodynamics, the economist Nicholas Georgescu-Roegen (1971) introduced in economics the notion of entropy: human production, which is only a transformation of matter, induces an irreversible upheaval in the state of the world. In the same way that energy is degraded during a transformation, the materials used inevitably degrade in economic growth: an important part of the resources is lost forever. He thus calls into question the possibility of recycling and provides for forced degrowth, in the long term, by the creation of entropy induced by human activity. Unfortunately, his approach is based entirely on the thermodynamics of the nineteenth century in terms of a closed system. Most of the work that proclaims, in one way or another, the importance of entropy in economics (McMahon & Mrozek, 1997; Ayres , 1998; Bryant, 2007; González, 2009; Kummel, 2011; Avery, 2012; Kovalev, 2016) are unaware of the advances in research in this area because they seem to be struggling to get out of their box, and realize that in the face of global perils, it is necessary to open up to other sciences in a serious and assiduous way to understand how the return effects, the permanent interactions, the chaotic accelerations, the unexpected bifurcations, the entropy, and the arrow of time affect the phenomena, both physicochemical and human. In the face of perils lying in wait for humanity, it is necessary to link the specialties to better understand the phenomena.

This epistemological posture, which is mine in this chapter, allows to explore new avenues of research so that the random, the irreversible, the unpredictable occupy an increasingly important place in economics and energy engineering, especially to better refine the decision-support, environmental impact assessment and modeling applied to climate change mitigation, the energy transition. In other words, the phasing out of energy sources based on the fossil carbon in favor of renewable energies, and the preservation of the biodiversity that is essential to ensure the future of humanity and a healthier way of life. The advances of research in thermodynamics can help to raise awareness on the relativity of economic thought, to better understand the economic evolution, and the risks of disaster that it incurs to the Earth. It is not a question of considering economics as a branch of thermodynamics (Roddier, 2015, p. 2), nor of substituting the laws of thermodynamics for the so-called law of economics, knowing that the word law does not have the same connotation in the literature on thermodynamics as in mainstream economics, as we will see later. In addition, energy engineering programs must place greater emphasis on the philosophy of science, sociology of knowledge, ethics and history of science and technology so that innovation does not become an end in itself in the competitiveness race.

**Thermodynamics of living organisms**

The idea of thermodynamics of living organisms had been debated at the end of the 19th century (Moret, 1884, p. 18; Hirn, 1887, p. 673; Gertsen, 1887, p. 3; Chauveau, 1888, p. 32). Generally speaking, a living organism, be it an animal or a plant, is a being who is born, grows up, eats, rejects waste, reproduces and dies. Certain unicellular organisms, i.e. living beings that are composed of a single cell such as bacteria, yeasts and plankton, can survive without fulfilling some of these conditions. If the laws of thermodynamics apply to living beings, we must have, according to Maignon (1907, p. 661), the following formula:

$$\text{Chemical Expense} = \text{Heat} \pm \text{Mechanical Work}$$

This idea of applying the laws of thermodynamics to living beings stems from a reasoning which joins to sources of heat of mechanical or chemical origin other sources which are peculiar to living beings. It is well known that the temperature of certain animals is kept several degrees higher than the ambient temperature and remains fairly constant despite variations of it. Some plants are in similar conditions. Hence the need to investigate how this vital heat in living beings is related to known sources, whether it obeys the same laws or if the exercise of life would not in any way change the essential conditions (Jamin & Bouty, 1906, pp. 118-119).

If some researchers have assimilated, under the prism of engineering, the living being to a living engine, and imagined that there could be applied to living beings a special thermodynamics where the principle of energy conservation would be preserved, but where the principle of Carnot would not be (Berthelot, 1917, p. 127), others say that living engines, more complex than common engines, have also their laws. These systems of rules are at the same time thermodynamic and physiological: thermodynamic because the animal engine is material and cannot escape the laws of matter, physiological, because this animal engine must present the laws proper to living beings, that the object of physiology is the study of the functions and properties of their organs and their tissues. It would be reductive to analyze living engines by extending the energetic rules of the material systems common to living beings, without taking into account the special conditions imposed by life (Lefèvre, 1912, p. 301). This refutes the idea that it is the interpretation of thermodynamics that was incompatible with experimental physiology and not thermodynamics in itself (Ameline, 1898, p. 17).

Advances in research have led to the idea that the second principle of thermodynamics is applicable to a living organism only in the very general form proposed by Ludwig Boltzmann in the context of the kinetic theory of gases. In this respect, Louis de Broglie (1953: 60) explains that according to the static interpretation of thermodynamics, the entropy S of a system appears as directly:

$$S = k \; log \, W$$

Where ‘k’ denotes the Boltzmann constant and ‘W’ the thermodynamic probability or statistical weight.

Soon after, Josiah Willard Gibbs generalizes this equation to the out-of-equilibrium case through the following equation:

$$S = k \sum p_i . log \; p_i$$

Where $p_i$ is the probability of the system being in a particular microscopic state. At equilibrium, all microscopic states are equiprobable so that $p_i = 1/W$ which restores the Boltzmann expression.

The second principle of thermodynamics or the increase of entropy, adds de Broglie, then receives an almost intuitive interpretation: “It expresses the tendency for any system to evolve towards states of greater probability”. In this approach, probability is not a non-knowledge, but a way of explaining chaotic and irreversible phenomena evolving out of equilibrium far from any determinism. This interpretation leads to the exploration of thermodynamics of human societies whose future is not written, but remains to be built day by day.

## Thermodynamics of human societies

In his lessons on thermodynamics professed during the first semester of 1888-1889, Henri Poincaré (1908a, pp. xii) notes that “the law of energy conservation can have only one meaning, it is that there has a property common to all possibilities; but, in the deterministic hypothesis, there is only one possible, and then the law makes no sense”. In this, the famous mathematician stands out from the determinism that finds its origin in the thought of Claude Bernard ([1865]1984, p. 109) as the basis of any experimental scientific method. The famous mathematician also writes in his '*Last Thoughts*':

> "But we are in the presence of a fact; science, rightly or wrongly, is deterministic; wherever it enters, it brings in determinism. As long as it is only physics or even biology it does not matter; the domain of consciousness remains inviolate; what will happen the day when morality becomes in turn object of science? It will necessarily become impregnated with determinism and it will undoubtedly be its ruin" (Poincaré, 1920, p. 245).

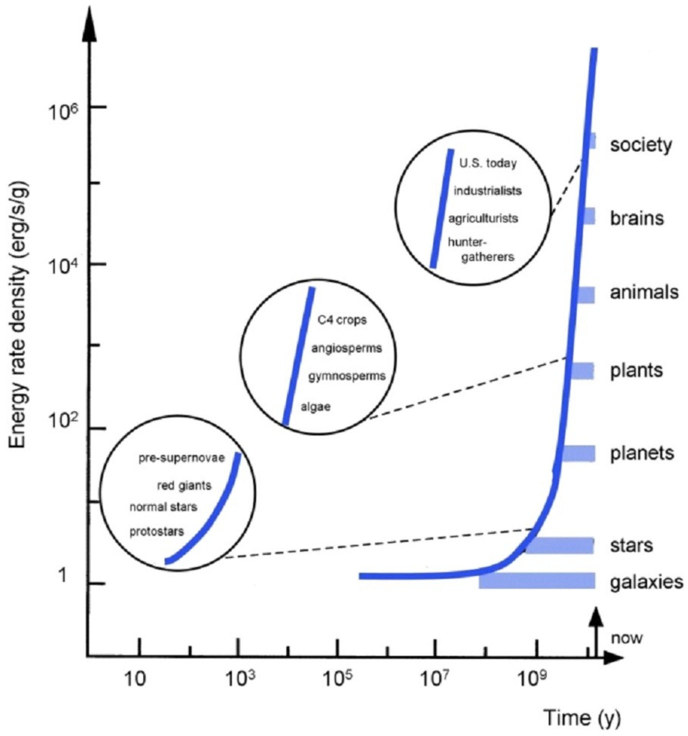
The existence of a law in thermodynamics, unlike economics, does not mean that it has only one way of acting. Does not the dominant discourse often repeat that we must adapt or disappear!

In a conference that opened the way to the thermodynamics of human societies, the sociologist Maurice Hauriou (1899, p. 5) took up this idea by considering that only the "thermodynamic laws shed some light on the possibilities of freedom". This presupposes a permanent interaction between the human and his environment and overlaps with the formulation of Douglas Hugh Everett, in his "Introduction to the Study of Chemical Thermodynamics" (1959), according to which "a particular proportion of the Universe is called the 'system' while the rest of the Universe is called 'the outside' or 'the environment" (Rybac, 1968, p. 137).

This conceptualization has allowed researchers to develop the thermodynamics of open systems, traversed by a flow of matter and energy, whereas the classical conception of thermodynamics considers closed systems, whose exchanges with the external environment are null or limited and tightly controlled. From this angle, the new thermodynamics gives a major importance to the phenomenon of irreversibility, where the old is placed in the vicinity of equilibrium, in the reversibility zone, which makes the human world appear to be subject to its potential momentum and not just the laws of thermodynamics in their traditional meaning. In this context, the appearance of the notion of dissipative structure (Prigogine, 1967, p. 371), which applies to phenomena as different as cyclones or living species, seems particularly interesting because it applies to human societies. Cyclones, living species, human societies, are famous for the unpredictability of their evolution.

Starting from the idea that to move, work, communicate, it is necessary to be constantly supplied with energy, that the natural selection favors the living organism which dissipates the energy most quickly (Lotka, 1922, p. 149), and that the basis of the national economy is the struggle for energy (Soddy, [1933]2014, p. 63), the astronomer Eric Chaisson (2001, p. 17) drew a curve that shows the energy dissipated per unit of mass (figure 1), and reveals the emergence of structures capable of dissipating more and more energy over the history of the universe. Human societies are at the top, since human beings are the only ones to have industries, services and all kinds of products that dissipate a lot of energy.

**Figure 1** Increase of energy dissipation



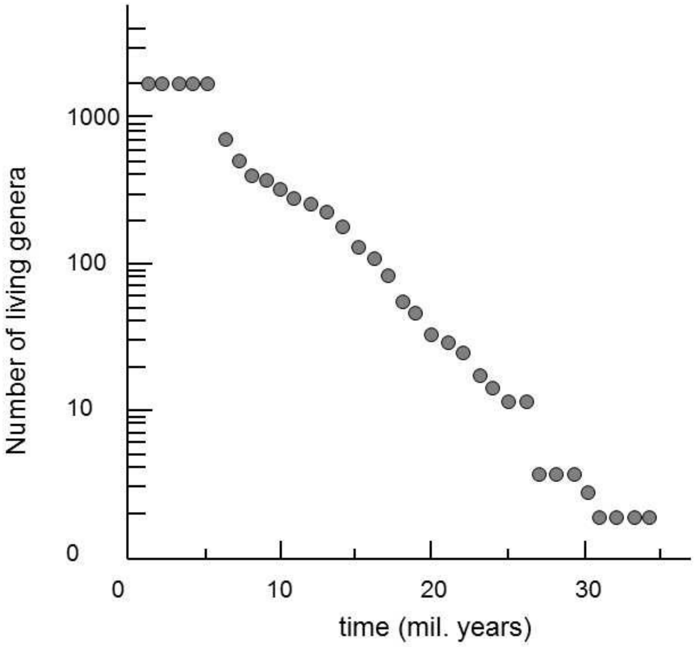

Source: Chaisson, Eric (2001) *Cosmic Evolution: The Rise of Complexity in Nature.* Cambridge: Harvard University Press, p. 17.

As astrophysicist François Roddier (2014, pp. 2-4) notes, dissipative structures memorize information about their environment. The more a dissipative structure memorizes information, the more it dissipates energy. But the faster it dissipates energy, the faster it changes its environment, so that the information it memorizes quickly becomes obsolete. The dissipative structure then has more and more difficulty dissipating energy. To be able to continue to do this, it must constantly restructure itself in order to finally reach a critical point. In this sense, the more a human society seeks to adapt itself to an evolving environment, the more it dissipates energy, therefore more it makes it evolve. Each structure will seek to adapt itself faster and faster until where the time of adaptation can no longer decreases. In this context, its vitality takes a hit and goes off gradually.

If the implications of out-of-equilibrium thermodynamics suggest a likely collapse of the most energy-dissipating human societies, the question then is if it is possible to avoid or at least delay collapse of such societies. To do this, the dynamics of the process needs to be understood in order to evolve slowly enough to continually have the time to adapt itself far from the obsession with competitiveness that feed a frantic race that have no other aim than to keep a market share.

This questioning is based on the Red Queen's Hypothesis, proposed by the biologist Leigh Van Valen (1973, p. 17), inspired by an episode of the famous novel Lewis Carroll's Alice's Adventures in Wonderland published in 1865: the young Alice meets a queen dressed in red, and is soon thrown into a frantic race. Alice runs a moment with her, then, surprised, tells her: “Well, in our country, you'd generally get to somewhere else – if you run very fast for a long time, as we've been doing?" And the Queen answers: "Now, here, you see, it takes all the running you can do, to keep in the same place. If you want to get somewhere else, you must run at least twice as fast as that!" (Carroll, 2015, p. 206.) When the environment evolves faster than a living species can adapt to it, this species is doomed to stand still. However, nothing is moving forward, and this inevitably leads to the near extinction of the species as shown in figure 2 which represents the gradual decrease in the number of mammalian genera over approximately thirty-six million years.

**Figure 2** Survival of the individual genera of mammals.



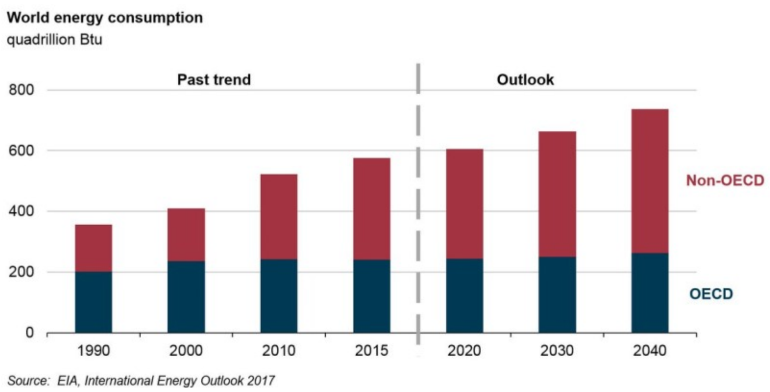

Source: *Evoluční biologie*, 2. vydání (*Evolutionary biology*, 2nd edition), J. Flegr, Academia Prague 2009, According to Van Valen, Leigh (1973). A New Evolutionary Law, *Evolutionary Theory*, 1, July, p. 5.

In this context, a restriction of energy dissipation is needed to oscillate around critical instabilities that are not static critical points but dynamic critical points. It is necessary to cooperate in this collective awareness in a multidisciplinary perspective (thermodynamics, energy engineering, environmental science, economics) in order to take action in time to escape from the principle of energy dissipation of Dewar Law (2003): A structure decreases its entropy (organizes itself) to maximize the entropy flow (the rate of energy dissipation). This principle, has up to now, took the Humanity of renewable energies to fossil fuels and to a globalization focused on an unrestrained race for competitiveness (Groupe de Lisbonne, 1995). This reflection which deals with the field of energy (conversion and use) in relation to environmental and economic issues, also deals with the current fundamental aspects related to the evolution of our world (earth, sky, water, human life), to rebuild it on a new basis. It stands at the antipodes of competitivism, the ideology of competitiveness, whose success never ceases to surprise, every day, despite the lack of standard definition, robust indicators and a rigorous theory (Belabes, 2001). The impact of advances in thermodynamics research on energy engineering should be explored.

**Impact on energy engineering**

Energy engineering is a diverse field that deals with energy efficiency and services, facility management, environmental friendliness and alternative energy technologies. Global energy consumption is steadily increasing across the globe and the sector will be affected by an increasingly complex set of economic, geopolitical, and environmental challenges. In its latest *'Global Energy Transformation report*: *A Roadmap to 2050'*, the International Renewable Energy Agency (IRENA, 2018, p. 16) believes that the global energy system needs to be transformed according to the two pillars of energy transition that are energy efficiency and renewable energy. As shown in Figure 3, global energy consumption could increase by 28% between 2015 and 2040 according to the latest EIA (2017, p. 6) report "International Energy Outlook 2017".

**Figure 3** World energy consumption




Under the pressure of environmental activists and the growing resistance of consumers, especially via social networks, manufacturers are called to invest in cleaner energy sources, optimize their assets and customer interaction, and capture the value of data from the digital world using recent advances in algorithms and artificial intelligence. They must design energy systems and processes by anticipating the strategic stakes of the development of new energies, understanding the prospects of economic and managerial change raised by industrial ecology in the product life cycle project, from its conception to its recycling.

In this context, energy engineers must receive training that is based on a multidisciplinary and transversal approach, allowing to match the different stages of the energy chain, from its production process, to the optimization of the procedures of rational use, considered in the perspective of environmental respect, devoting a large part to the phenomenon of irreversibility and to the notion of entropy, by developing analysis methods to deal more effectively with the very current issues of management and economics related to energy engineering, energy mastery, and intelligent use of thermal / electrical renewable energies: calorimeters, evaporators, condensers, flow meters, pumps, turbines, compressors, combustion chambers, boilers, cooling towers, heat engines, turbojets, thermal power chimneys, fuel cells, heat pumps, air conditioners, refrigerators, thermoelectric generators. The knowledge and skills of engineers must be up to date to meet the challenges of this new millennium and they must cultivate a commitment and a passion for lifelong learning, which will generate new useful solutions that make life easier and more durable (Riley, 2011).

The energy strategy of some countries, with an environmentally friendly culture and a consciousness of the risks related to the maximum energy dissipation, tends to accentuate the role of local communities to build a more viable future. The Energy productions are moving towards decentralization, and promoting renewable energies often anchored in territories that mobilize local resources. This orientation complicates the management and operation of energy systems, spatially and temporally, particularly at level of production and consumption.

This orientation, that comes under the local governance in virtue of the principle of subsidiarity, leads to the development of territorial energy systems consisting of an integrated and simultaneous analysis of all energy aspects of a territory (needs, resources, conversion and storage technologies), considering a range of different solutions at the level of production, distribution, consumption, conversion and storage of energy, that requires the collection of a large amount of data and complex analysis tools (Cherix *et al.*, 2015).

The emergence of Big Data and the multiplication of increasingly powerful data processing techniques, notably machine learning and deep learning, open the door to a multitude of applications in the energy sector. The growth of the Internet of Things can, moreover, become a key lever for adapting production to consumption, optimizing the performance of energy equipment and their maintenance and providing, with the help of sensors, valuable information and in real time on the operating status.

Beyond the deontology of engineers, historically related to the practice of consulting engineering, and the reflection on the social, environmental and cultural impact of technological development, and the risks inherent to a technical society, the ethics of energy engineering must pay particular attention to the performative nature of the technique that requires human control, and the participation of all segments of society in the technical choices and their governance, to initiate a process with the ability to regulate its internal environment, and to maintain a constant equilibrium in the face of an ever-changing external world (self-regulating process of homeostasis), driving a struggle against the maximal dissipation of energy and the process of self-organized criticality that initiates enormous transformations on very short time scales (Bak *et al.*, 1987).

Faced with this major challenge that must mobilize collective intelligence and wisdom, a better conceptualization of energy engineering innovation is proving more necessary than ever beyond the slogan that innovation is an idea that creates market. Does not higher education institutions, specialized in the field of science and technology (Aulet, 2013), teach the equation:

$$\text{Innovation} = \text{Invention} \times \text{commercialization?}$$

In the broad sense, an innovation is a change that responds to a need for improvement (Conseil de la Science et de la Technologie, 2000, p. 5). Innovation is a varied and complex object. Hence the need to distinguish between incremental innovation, radical innovation, disruptive innovation and frugal innovation (Barnu, 2012), just to mention a few of the most used in the specialized literature. Future research will undoubtedly bring forth other varieties.

The substitution of the notion of "market-agencement" to the that of market, to address products as processes (Callon, 2013), is in line with such approach, following on from earlier work (Polanyi, [1944]2001), although there is still much to do. This will provide a better understanding of the energy market-agencement so that it can be changed to a way of life that is more respectful of human beings, nature and all forms of life. As noted by Jean-Pierre Dupuy (2011), “the greatest threats today come less from the bad guys than from the industrialists of the good”.

**Conclusion**

Among the main lessons of thermodynamics useful to economists and energy engineers, it should be remembered that:

- The interest of thermodynamics laws, under the prism of the philosophy of science, lies fundamentally in the fact that they open the field to the possibilities of freedom in the broadest sense of the word that is not centered on the market and non-intervention of the state in business. Free market ideology does not lead to the freedom it promises, but reduces it to a consumerist freedom basically framed by the market.
- The existence of a law in thermodynamics does not mean that there is only one way to act and develop solutions. This opens the field, at least, to three strategies: to adapt to an environment, to co-construct an environment, to influence an environment.
- Complexity and chaos incite awareness essential to building a better world. The ethics of energy engineering, previously developed, can play a constructive role in this process to improve the quality of life and bring happiness to people far from the frenzied race for competitiveness that has proven to be a dangerous obsession pulling down and inducing, in the end, a dynamic zero-sum game.

Thus, the conception of laws in thermodynamics is different from that commonly accepted in economics where, ultimately, there is no choice but to adapt or disappear; it is synonymous with common property and, more generally, with trend or regularity empirically observable. In other words, it is not performative. Most economists forget or are unaware that the answers provided by models are valid only in a given context: there are no universal economic laws valid at all times and in all places.

Moreover, the non-equilibrium thermodynamics, which postulates the existence of a local thermodynamic equilibrium for each of the elementary subsystems associated with an element of space-time, opens the field to diversity and sensitivity to initial conditions. As Henri Poincaré (1908b, p. 72), points out, “if it may happen that small differences in the initial conditions generate very large differences in the final phenomena; a small mistake on the first would produce a huge mistake on the last ones. Prediction becomes impossible”.

The facts of everyday life in the field of alternative and renewable energy, which are generally ignored in economics, become worthy objects of study that need to be carefully studied by energy engineers, which undermines any fixed point, any formula that is ready, any step that starts with some certainty or leads to certainty. In the world of certainty, there is no room for questioning, nor for substantive debate. There are only answers, ready-made solutions, denying time, space, and local cultural heritage. However, as Ilya Prigogine (1998) pointed out in an interview, thirty years ago, “complexity is when the truth is no longer certain, and uncertainty is not more ignorance”. Moreover, the enemy of complexity, noted Edgar Morin (1990, p. 254), “*is not the simplicity, it is the mutilation. Mutilation can take the form of one-dimensional conceptions or reductive conceptions*”. The preliminary study of social structures and their attributes, both material and immaterial, becomes crucial.

The notion of *wujūh ma'āsh al-'umrān al-basharī* of Ibn Khaldun ([1376]2004, 2, p. 68), literally livelihood opportunities in cities, that explores the way in which human societies that have entered a state of decadence are trying to survive, seems very timely, even if the energy of that time was essentially firewood, charcoal, oil, and dried cow dung that our grandmothers used to care for in the rural areas, about forty years ago, although electricity and gas were available to them. They had a sense of respect for the environment by giving priority to natural solutions in their wisdom putting each thing in the right place. This opened the way for an approach of history "from below" turning away from the chronicle of institutions and great men to focus on reporting micro-resistances (Thompson, [1963]1988).

From this perspective, the progress of research in thermodynamics may, moreover, incite to rediscover those who had been relegated to the pantheon of ignored or misunderstood authors despite the quotations that fail to exceed "the semantic level" (what is he talking about?, i.e. the form) for the benefit of the "critical level" (how did he work?, i.e. the structure not just the form), to quote a distinction dear to Umberto Eco (2013) who opened our minds, while we were students in engineering, in reference to semiology after reading *In the Name of the Rose*, on the need to take an interest in the relationship between technology and progress. A bit like "too much tax kills the tax", too much technology would kill technology. The practical applications of scientific knowledge, especially in industry, have no meaning except from the persons whom they should serve.

This led us, subsequently, to the writings of Ivan Illich ([1973] 2005, p. 19), who drew up a critique of the industrial society by showing that its service structures go beyond a certain threshold, against the objectives assigned to them. In this sense, technology could create more problems than it solves. But the most serious risk is that these institutionalized services make the use of expert knowledge unavoidable, which leads to freezing the imagination and to depriving individuals of simple means and their scope, to manage their lives or solve their problems as our grandmothers used cow dung to bake bread whose flavor is invaluable. This leads to the following major methodological issue: We cannot study a phenomenon with fixed images like our grandmothers used only cow dung or only electricity. The reality is much more complex and infinitely more interesting.

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SUGGESTED CITATION:
Belabes, Abderrazak (2019) “What can economists and energy engineers learn from thermodynamics beyond the technical aspects?” *real-world economics review*, issue no. 88, 10 July, pp. 130-143, http://www.paecon.net/PAEReview/issue87/Belabes88.pdf