



Enzo Tiezzi, turning pioneering into modern ideas: tempos, Ecodynamics and sustainable economy

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ABSTRACT

Professor Enzo Tiezzi (1938-2010) was an eclectic Italian scientist who promoted the concept of sustainability in Italy and worked hard on the epistemological foundations of the concept mainly adopting systemic and trans-disciplinary approaches. Enzo emphasizes that ‘time’ is a fundamental concept supporting any sustainability discourse. Although there have been several conceptual, technological and/or managerial advancements towards a sustainable society, most of them entail a different understanding of, or simply ignore, ‘time’. This viewpoint article presents the most influential Enzo’s idea in which a sustainable society must be supported by its ‘biological time’ instead of the ‘historical time’.

1. Main text

“There is a piano on a floating platform in the ocean. A pianist plays and his note dies in the silence of the sea. Then the pianist presses the sustaining pedal and the note expands. The song of a whale, a megaptera, is heard in reply. The sustaining pedal maintains or sustains the sound in time. The megaptera’s song, different from that of other whales and other megapteras, is a metaphor for biodiversity. It is the voice of nature... the sustaining pedal is the metaphor for sustainability” (Pulselli et al., 2008). In this way, with the ecstatic words of a writer perceiving the hidden harmony of the biosphere, Enzo Tiezzi (1938 – 2010) liked to introduce the concept of sustainability.

Enzo was an eclectic mind, “a scientist with the approach of an artist”, as remembered by Sven E. Jørgensen in the Editorial of a Special Issue dedicated to his memory in the Ecological Modelling journal (Jørgensen, 2011). Enzo was a chemist and a humanist who succeeded in overtaking the boundaries across different scientific fields, establishing the transdisciplinary Ecodynamics Group at the University of Siena in the 1990s. The word “ecodynamics” is a neologism whose epistemological bases are derived from the mixing of environmental physical chemistry (mainly thermodynamics) and systems ecology (Tiezzi, 2003a; for the Italian version, see Tiezzi, 1996), with important implications in the wide field of sustainability as strictly connected with

biodiversity, the “voice of nature”, pillar of ecosystem stability (Tiezzi, 2003b); a long term view, recently confirmed by IPBES (2019). Enzo always highlighted the importance of diversity, biological and cultural, as wealth, and the necessity to understand different ways to perceive Nature. He loved telling us stories about new perspectives, visionary horizons, but also hidden and forgotten cultures, always neglected by western civilization, source of an ancient knowledge, of a different approach with Nature respectful of slow paces of ecological processes. Promoter of the scientific environmentalism in Italy, active in the political debate on sustainability and energy issues, his contribution was important in the process that phased out nuclear plants across the country. Herman Daly, in an essay written in his memory (Daly, 2011), was inspired by Enzo’s holistic vision to deep reflections on the “last things” and the end of time, while Robert Costanza emphasized his role, beside Daly and other scientists, of “major player in the development of Ecological Economics” (Pulselli et al., 2011).

Enzo published more than 30 scientific books, tales such as Rosaluna (WIT Press, 2009), poems such as “Di terra, di aria, di mare” (Marcos and Marcos, 2006) and photos from his travels across the world, collected in “Lo Sguardo sul Pianeta” (Laris Editrice, 2010). Arguably the most influential of Enzo’s works is the book “Tempi Storici, Tempi Biologici” (Tiezzi, 1984), an awardwinning best seller, published in English as “The End of Time” (Tiezzi, 2003b), and

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reviewed by Sven E. Jørgensen in *Ecological Modelling* (Jørgensen, 2004). This book represents a milestone for a deeper understanding of sustainability through the lenses of thermodynamics, quantum mechanics, information theory and chaos theory.

Over the last few decades, the environmental impacts of human activities have become a key issue. Global Warming, eutrophication, water and other resource depletion, environmental toxicity of synthetic compounds, are only some examples of how we are influencing the structure and functioning of the geo-biosphere. Since the 1960s, environmental issues, somehow neglected before, started gaining public attention. The book *Silent Spring* by Rachel Carson (Carson, 1962) revealed to a general public the impacts of environmental contaminants, pesticides in particular. Later, several American biologists, such as Barry Commoner and Lester Brown highlighted the environmental problems caused by the economy, focusing on the relations between human and natural systems, also considering the social aspects of environmental degradation (Tiezzi, 2003b). In 1966, Enzo met Barry Commoner for the first time, within a Fulbright post-doc program at the Washington University in St. Louis (USA). Since then, Enzo, with an academic background as a chemist, enlarged his interest to ecology, energy, social and political issues, focusing on understanding the links among these, and shaping his ideas and holistic vision of the world.

During the 1970s and 80s the concepts of “limits” and “renewability” were identified by scientists as the fundamental ones to understand and solve the global problems of food, pollution, energy and resource availability. These were the foundation bricks for sustainability. “The End of Time” (Tiezzi, 2003b), first published in Italy in 1984, showed that the issues of “limits” and “renewability” have “time” at their core. The idea is that “time”, something we probably not fully understand yet, is central to our relations with nature and the planet. Time is seen as a new dimension that connects human and natural dynamics. In particular, Enzo identified two kinds of time as relevant for sustainability: biological time and historical time. Biological time is what measures biological evolution and has a magnitude of billions of years, telling us the story of life on Earth. Historical time is what measures the history of humankind and has a magnitude of thousands of years. In terms of its extent, historical time is a small fraction of biological time, but today it seems our history interferes with processes occurring in 3 biological times. Historical time today runs too fast compared to biological time, and this is the source of many environmental issues.

According to Tiezzi (2003), sustainability is a problem of divergence between biological times and historical times. About these different ‘times’, he wrote at pages 27-28, “not only is economics ignorant of these concepts, but it introduces another which can be summed up as ‘time is money’. Progress is measured by speed of production and it has even been suggested that the faster we use up nature’s resources, the greater the advance of progress. In other words, the faster we transform nature, the more time we save. This technological or economic concept of time is exactly the opposite to ‘entropic time’. Nature obeys different laws to economics, it works in ‘entropic time’: the faster we consume natural resources and the energy available in the world, the less time is left for our survival. ‘Technological time’ is inversely proportional to ‘entropic time’, ‘economic time’ is inversely proportional to ‘biological time’. [...] Money time and clock time are not the scales on which a correct relationship with Nature can be established”.

This fundamental role of time for sustainability is recognized by Daly (1990): “For the management of renewable resources there are two obvious principles of sustainable development. First that harvest rates should equal regeneration rates (sustained yield). Second that waste emission rates should equal the natural assimilative capacities of the ecosystems into which the wastes are emitted”. Despite Daly focusing on time’s rate while Enzo on time’s scale, time becomes the key to comprehend sustainability. Time’s scale and rate are interconnected,

since when the former increases the latter slows down and vice versa. The history of life is the result of slow changes along millions of years while the human history, especially considering the last century, is the results of rapid changes along some decades, able to interfere, in a dramatically way, with the biosphere history.

Thermodynamics and its laws, especially applied to non-isolated systems like the biosphere or human systems, play a crucial role in the development of Enzo’s ideas. In this sense, his personal relationship with the Nobel laureate Ilya Prigogine, who wrote the preface of another Enzo’s book (Prigogine 2003, in Tiezzi 2003a), was of great importance. In 2004, to honor the memory of Professor Prigogine, Enzo encouraged the institution of the Prigogine Medal, awarded to scientists who gave a relevant contribution in the field of ecological systems and evolutionary thermodynamics (the latter being the core issue of another book: Tiezzi, 2005). Enzo was also part of a group of influential scientists who have been working on the advancement of “a new ecology” under a systems perspective for long time (Jørgensen et al., 2007; Nielsen et al., 2020).

When Enzo was writing his books in the early 2000s, it became increasingly evident that a new approach, a new way for human systems to produce and consume goods and services, and to manage natural resources according to biological times, was a requirement for achieving sustainable development. In the following years, and up until today, several potential solutions have been put forward for implementing sustainable systems of production and consumption. One of these solutions, proposed by the engineering community, was the Industrial Ecology. It aimed to understand how the industrial system works and interacts with the biosphere, on the basis on our knowledge of ecosystems, to determine how industrial processes could be made compatible with natural system functioning (Erkman, 1997).

The use of concepts derived from the study of ecosystems into the definition and management of industrial systems is based on the idea that ecosystems are systems where mutual 4 interaction of living beings and their biotope takes place, without any influence from human activities (Commoner, 1997). However, since the industrial revolution this kind of pristine ecosystems became scarcer and due to the global scale of environmental impacts as global warming, dispersion of chemical pollutants, and biodiversity depletion we might argue that today very few ecosystems, if none, could be regarded as pristine (Gallagher and Carpenter, 1997; Lewis and Maslin, 2015). The essence of this is discussed by Enzo in “The End of Time”, as the main issue of “western culture” approach to Nature. He wrote at page 161, “Nature is an organism: it is everywhere. The westerners try to represent it by dividing it and laying it out in a line to look at it in pieces. They always seem like people outside who are trying to see what is inside”. For Enzo, industrial ecology, despite its importance, resembles a sort of mimicking exercise of something actually inexistent, instead of recognizing the broad overlap and integration of socio-ecological systems and the need for a trans-disciplinary approach to sustainability.

More recently, the idea of a Circular Economy was proposed for achieving sustainable development. It aims at overtaking the linear model of production and consumption in which goods are produced, sold, used and then discarded as a waste, with a new, circular model, inspired by the way in which nature works. According to Kirchner et al. (2017), who analyzed 114 different definitions, circular economy is “an (economy) that replaces the end of life concept, with reducing, alternative reusing, recycling and recovering materials in production/distribution and consumption processes... with the aim to accomplish sustainable development, thus simultaneously creating environmental quality, economic prosperity, and social equity, to benefit the current and the future generations. It is enabled by novel business models and responsible consumers.” Although circular economy could be a strategy or a tool to achieve sustainable development, through encompassing the three pillars of environmental, social and economic development (Fioramonti

et al., 2019), the relation between circular economy and sustainability is still unclear and deserves further insights (Millar, 2019).

We learned from Enzo the centrality of time for understanding sustainability, and the mismatch of historical and biological times. Some approaches to circular economy, such as the framework of the Ellen MacArthur Foundation, include a distinction between technical and biological cycles. In a circular economy, consumption should only happen in cycles, where for instance, food and biologically based materials are designed to feed back into the system through processes like composting and anaerobic digestion. “*These cycles regenerate living systems, such as soil, which provide renewable resources for the economy. Technical cycles recover and restore products, components, and materials through strategies like reuse, repair, remanufacture or (in the last resort) recycling*” (Ellen MacArthur, 2017). However, according to Sherwood (2020), the relation between circular economy and the speed of regeneration of natural resources is sometimes obscure and commonly based on economic or legal parameters. Notwithstanding, since current development are strongly based on fossil energy - historical ‘times’ -, even under the best technological and/or management alternatives in getting circular paths for the technical side of the circular economy framework, it has different ‘time’ than the biological side and goes beyond the Earth’s biocapacity.

Enzo stressed how the parameters to define sustainable production have to be scientific, and not solely economic. He wrote at page 46 (Tiezzi, 2003b): “*Economists continue to believe blindly in unlimited growth and technology, but nature has cycles which follow other rules and other times.*” Moreover, circular economy does not take into account other issues that Enzo deemed as crucial for sustainability, such as the economic and social gap between developed and developing countries, and the unequal distribution of wealth; as also pointed out by Moreau et al. (2017).

After industrial ecology and circular economy, the concept of Regenerative Economy has been proposed as another possible solution for sustainability. A regenerative economy is an economy that works to regenerate capital assets. It is based on self-feeding, self-renewal and adaptive learning processes that natural systems use to nourish their capacity to thrive for long periods (Fath et al., 2019). This is probably the solution that aligns the most with Enzo’s viewpoint, as it does consider the variable time, and then a long-term perspective, as crucial. Future developments on regenerative economy will tell us if it actually embodies the answers to those questions raised by Enzo in “The End of Time”.

In conclusion, Industrial Ecology and Circular Economy are very important breakthroughs for sustainable development but fall short of including the ‘time’ perspective. In this vein, one mayor contribution of Enzo Tiezzi’s work is that we do not only need to change the shape of the economy (from linear to circular), we also need to slow down consumption and production, aligning our cycles, in historical times, to nature’s cycles, in biological times.

Declaration of interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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References

- Carson, R., 1962. *Silent Spring*. Houghton Mifflin Company, Boston, MA.
- Commoner, B., 1997. The relation between industrial and economical system. *J. Clean. Prod.* 5 (1-2), 125–129.
- Daly, H.E., 2011. Escathology, ecology, economics in memory of Enzo Tiezzi. *Int. J. Des. Nat. Ecodynam.* 6 (4), 254–257.
- Ellen MacArthur Foundation, 2017. What is a circular economy? A framework for an economy that is restorative and regenerative by design. Available at: ellenmacarthurfoundation.org.
- Erkman, S., 1997. Industrial ecology: an historical view. *J. Clean. Prod.* 5 (1-2), 1–10.
- Fath, B.D., Fiscus, D.A., Goerner, S.J., Berea, A., Ulanowicz, R.E., 2019. Measuring regenerative economics: 10 principles and measures undergirding systemic economic health. *Glob. Transit.* 1, 15–27.
- Fioramonti, L., Coscieme, L., Mortensen, L.F., 2019. From gross domestic product to wellbeing: how alternative indicators can help connect the new economy with the sustainable development goals. *Anthr. Rev.* 6 (3), 207–222.
- Gallagher, R., Carpenter, B., 1997. Human-dominated ecosystems. *Science* 25, 485.
- IPBES, 2019. In: Brondizio, E.S., Settele, J., Díaz, S., Ngo, H.T. (Eds.), *Global assessment report on biodiversity and ecosystem services of the intergovernmental science-policy platform on biodiversity and ecosystem services*. IPBES secretariat, Bonn, Germany.
- Jørgensen, S.E., 2011. Editorial. *Ecol. Modell.* 222 (16), 2867–2868.
- Jørgensen, S.E., 2004. “The end of time” (199 pages) “The essence of time” (125 pages): Enzo Tiezzi, WIT Press, Southampton, UK, fall 2002”. *Ecol. Modell.* 172 (11), 95.
- Jørgensen, S.E., Fath, B.D., Bastianoni, S., Marques, J.C., Mueller, F., Nielsen, S.N., Patten, B.C., Tiezzi, E., Ulanowicz, R.E., 2007. *A new ecology - Systems perspective*. Elsevier, Amsterdam.
- Kirchherr, J., Reike, D., Hekkert, M., 2017. Conceptualizing the circular economy: Analysis of 114 definitions. *Reduce, Conserv. Recycl.* 127, 221–232.
- Lewis, S.L., Maslin, M.A., 2015. Defining the Anthropocene. *Nature* 519, 171–180.
- Millar, N., McLaughlin, E., Börger, T., 2019. The circular economy: Swings and roundabouts? *Ecol. Econ.* 158, 11–19.
- Moreau, V., Sahakian, M., Griethuysen, V.P., Vuille, F., 2017. Coming full circle: Why social and institutional dimensions matter for the circular economy. *J. Ind. Ecol.* 21 (3), 497–506.
- Nielsen, S.N., Fath, B.D., Bastianoni, S., Marques, J.C., Mueller, F., Patten, B.C., Ulanowicz, R.E., Jørgensen, S.E., Tiezzi, E., 2020. *A New Ecology - Systems Perspective*, Second ed. Elsevier, Amsterdam.
- Prigogine, I., 2003. From the culture of space to the culture of time. Preface of Tiezzi E., 2003a. *The Essence of Time*. Wit Press, Southampton (UK).
- Pulselli, F.M., Bastianoni, S., Marchettini, N., Tiezzi, E., 2008. “The Road to Sustainability: GDP and Future Generations”. WIT Press, Southampton, UK.
- Pulselli, F.M., Bastianoni, S., Marchettini, N., Tiezzi, E., 2011. “La Soglia della Sostenibilità - ovvero quello che il PIL non dice”. Edizione Ampliata, Donzelli, Roma.
- Sherwood, S., 2020. The significance of biomass in a circular economy. *Bioresource Technol.* 300, 122755.
- Tiezzi, E., 1984. *Tempi storici, tempi biologici*. Garzanti, Milano.
- Tiezzi, E., 1996. *Fermare il tempo. Un’interpretazione estetico-scientifica della natura*. Raffaello Cortina, Milano.
- Tiezzi, E., 2003a. *The Essence of Time*. Wit Press, Southampton (UK).
- Tiezzi, E., 2003b. *The End of Time*. Wit Press, Southampton (UK).
- Tiezzi, E., 2005. *Steps Towards an Evolutionary Physics*. WIT Press, Southampton (UK).

Further Reading

- Tiezzi, E., Pulselli, R.M., 2008. An entropic approach to living systems. *Ecol. Modell.* 216 (2), 229–231.