


Living technologies, a renewed perspective of Deeptech to foster climate and ecological transitions

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Introduction

Humanity has entered the Anthropocene, a geological era in which the effects of human actions on the Earth have been demonstrated (Crutzen & Stoermer, 2000), particularly on climate and natural settings. This overall context implies engaging in efforts to adapt our societies in order to respect planetary limits (Stephen et al, 2015) and hence attenuate climate change.

The institutionalisation of climate issues is taking place at all governance levels (Chateauraynaud and Debaz, 2017). The latest report of the IPCC (Intergovernmental Panel on Climate Change) points out the weaknesses of actions implemented so far (IPCC, 2021) but shows that solutions to attenuate climate change already exist.

The French Agency of Development (AFD) recognises that climate disruption represents an industrial challenge (2017) and identifies Deeptech innovation as a means to overcome it. Deeptech is defined as the production of innovations based on intensive R&D activities conducted over a long time. Therefore research and start-up companies engaged in it are capital and time intensive. Farming is targeted as one of the areas where efforts must be undertaken (Pachauri and Meyer 2014) to meet climate constraints. Based on a theoretical framework for characterising technologies according to their capacity to respect planetary limits, this paper aims to show that Deeptech projects for Agriculture are a good illustration that Deeptech offers the potential of developing within planetary limits at certain conditions.

1. Technologies and the Anthropocene: how can we remain within planetary limits?

As stated above, Deeptech projects and innovations have a true potential to provide solutions to address environmental and climate problems (Nedayvoda et al, 2020) however controversies have emerged relating to the sourcing of resources needed to develop, implement and market those innovations. Nedayvoda et al (2020) show that Deeptech is a way to solve complex environmental and climate challenges. It can foster productivity gains in a variety of resource-intensive industries lowering the damage to natural settings. The authors provide examples in high-tech sectors as well as in other sectors apparently less technological and yet vital such as agriculture.

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They refer to our daily technological uses (digital, energies, etc.) (Meadows et al., 1972, 1992, 2012; Murphy et al., 2021) but the same is true for basic consumption such as our daily food intake (Bowles et al., 2019). In this paper, we propose to delve into a theoretical framework that proposes a classification of technologies according to their long-term capacity to foster a sustainable future.

This emerging theoretical framework classifies technology properties according to their capacity to ensure the cohabitation on earth of human and other living entities. According to José Halloy et al. (2020, p 120), technologies must be analysed within the framework of the «Anthropocene». The question then is whether a technical system is sustainable from an ecological perspective over a long period, in opposition to technical systems that have detrimental effects due to their impact on non-renewable resources and/or on natural settings.

Within this perspective, sustainability is reframed as all the materials, processes (production, development, maintenance, etc.) and activities that can last in the long term without depleting non-renewable resources in particular those of carbon-based fossil origin (coal, oil and gas) or even using them (Halloy et al, 2020).

The framework proposed by Halloy et al (2020) was formalized by Monnin (2021a) as follows and differentiates Zombie from Living technologies.

	Resources	Sustainability	End of Life
Zombie technologies	Finite (long-term exhaustion)	Minimum durability in working order	Maximum life span as waste
Living Technologies	Renewable (strong sustainability)	Maximum durability in working order	Minimum life span as waste

Table 1

In this context, the author (Monnin, 2021) points out that zombie technologies are non-recyclable and in the rare cases where they are, it implies that they use an amount of fossil energy that makes it inefficient from a deep ecological perspective.

While most Deeptech solutions are high-tech technologies that will revolutionise the world (Nedayvoda, 2020), they are mostly digital technologies that use non-renewable materials (drones, satellites, AI, etc.), and according to the theoretical framework, they are considered "Zombie technologies" because they require a variety of resources such as minerals for their manufacture, energy for their use through digital networks and are barely recyclable due to

Table 1: *translated from Monnin (2021a, p.21)*

lack of knowledge in this area.
This view of innovation is however restrictive and other perspectives exist. The new "European Innovation Agenda" by the European Commission (2022a) has called for solutions targeting key societal challenges. As in the case of wind energy, bold policy choices, such as those dealing with climate change and environmental protection, require close cooperation between the public and private sectors. Policies are prompted to change due to both the covid crisis and the war in Ukraine. In this context, the European Union includes ideas such as a circular economy and a resource-efficient economy in addition to digital technologies and recognises the need for companies to build new capabilities both in terms of their production, trade and collaboration (European Commission

2. Using living technology for food: emergent technologies in agriculture

The weight of agriculture in the climate and environmental crisis is well identified and measured (IPCC 2021), in particular the use of pesticides that corresponds to a planetary 'negative common' (Monnin 2021b) in the sense that it has an impact on the long term and must be dealt with by communities. Public policy can act in different time frames both to eradicate pesticides and transform farming activities for the future. The European Union in its "Farm to Fork" strategy (European Commission 2019) aims to develop sustainable food production, however, it still specifies "that digital technology is key to success" (European Commission 2022b p. 6) through the optimization of pesticide use with the IoT. If those solutions need to be explored, they originate from non-renewable resources and have minimum durability in working order and a maximum life span as waste, as such they can be classified as a zombie technology (Monnin 2021a; Haloy et al 2021).

In the next section, we present living technologies developed within Université Côte d'Azur that have the potential to contribute to the agroecological transformation.
To achieve farming at a level that offers sufficient food resources, pesticides can be optimised through farming 4.0 solutions, but other biological biobased solutions are available that can lead to pesticide suppression. Université Côte d'Azur with INRAE has a long-standing history in biological control[1] (hereafter biocontrol) research and development for farming with its research centre Institut Sophia Agrobiotech (ISA). Biocontrol implies the use of different kinds of biological entities to help farmers in their growing activities. This can be microorganisms such as bacteria or microorganisms such as insects but also natural chemical compounds such as pheromones. Biocontrol involves four different strategies to fight against pests that range from the more usual practices which farmers are used to, to strategies that imply a natural equilibrium in the long run. The four strategies are conservation biocontrol, classical biocontrol, inoculation biocontrol and inundation (also augmentative) biocontrol.
Inundation biocontrol implies repeated use each year, and it corresponds to current practices. All the other strategies are far removed from current farming practices. The development of biocontrol techniques is a viable solution to achieve the agroecological transition and presents opportunities to develop Deeptech innovations. Boutet and Parmentier-Cajaiba (2022) showed that the very properties of each class of biocontrol call for adapted business models (Boutet &

1 'The use of living organisms to suppress the population density or impact of a specific pest organism, making it less abundant or less damaging than it would otherwise be' (Eilenberg, Hajek and Lomer, 2001)

Parmentier-Cajaiba, 2022). It means that to develop the full potential of the different forms of biocontrol, society needs to think outside the box of current farming practices and innovate to develop and disseminate these innovations that can, in the long run, be consistent with deep ecology requirements.

Conclusion

Université Côte d'Azur is already a stakeholder in this transformation. Thanks to the Initiative of Excellence Label, several programs have been created, such as Academy 4 "Complexity and diversity of living systems", which support innovative, original, and quality projects in life sciences that have an impact on national and international research. Université Côte d'Azur also supports Deeptech in biocontrol projects such as Mycophyto and entrepreneurship projects such as Evolutiv Agronomy and Agroinnov.

This example in farming shows that Deeptech has the potential to contribute to ecological transformation but must meet a threefold challenge: find ways to integrate living technologies both in production processes and uses, think about different time frames to achieve a transition within the planetary limits that remain socially acceptable, and accept that it is not only a question of product substitution but of changing our way of living.

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