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Article

Navigating the Biocosmos: Cornerstones of a Bioeconomic Utopia

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Abstract: One important insight from complexity science is that the future is open, and that this openness is an opportunity for us to participate in its shaping. The bioeconomy has been part of this process of "future-making". But instead of a fertile ecosystem of imagined futures, a dry monoculture of ideas seems to dominate the landscape, promising salvation through technology. With this article, we intend to contribute to regenerating the ecological foundations of the bioeconomy. What would it entail if we were to merge with the biosphere instead of machines? To lay the cornerstones of a bioeconomic utopia, we explore the basic principles of self-organization that underlie biological, ecological, social, and psychological processes alike. All these are self-assembling and self-regulating elastic structures that exist at the edge of chaos and order. We then revisit the Promethean problem that lies at the foundation of bioeconomic thought and discuss how, during industrialization, the principles of spontaneous self-organization were replaced by the linear processes of the assembly line. We ultimately propose a bioeconomy based on human needs with the household as the basic unit: the *biocosmos*. The biocosmos is an agroecological habitat system of irreducible complexity, a new human niche embedded into the local ecosystem.

Keywords: bioeconomy; bioeconomics; ecology; ecological economics; complexity; self-organization; utopia; imagined futures; biosphere; Georgescu-Roegen

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1. Introduction: The Necessity of a Genuine, Bioeconomic Utopia

It is a widespread notion that we as humanity find ourselves in a critical transition, a phase in our evolution that is expected to merge into "a new era that will ultimately replace the industrial society" [1] (p. 29). The bioeconomy, both as an academic discipline and policy agenda, is frequently promoted as an essential building block in this transition ([1]; see also [2–4] for a critical discussion). The term "bioeconomy" has its origin in the bioeconomics of Georgescu-Roegen, one of the key figures not only in the emergence of ecological economics but also in the sustainability and degrowth debates more broadly [5–7]. The original concept of bioeconomics was a fundamental critique of the modern industrial order and a call for a systemic transition (see also [8], on a related note). From Georgescu-Roegen's standpoint, the belief in technological innovation as a *panacea* is not the solution but the root cause of the very social, ecological, and psychological problems of the present industrial age. It perpetually increases our dependency on the technological complex that we are gradually merging with. As we engage in the invention of "tools to make tools, to make tools" [9] (p. 425), we weave an ever more complex web around ourselves and adapt to it. To paraphrase Georgescu-Roegen: We become *addicted* to technology and need more and more of it, thereby accelerating the spiral of entropy (see also [10]).

However, bioeconomics and bioeconomy have been defined and redefined many times over the last couple of decades. Therefore, multiple meanings of the concepts coexist in the literature (e.g., [11–14]). For example, Vivien et al. [11] have identified three distinct narratives or visions that shape the contemporary meaning of the bioeconomy and thus present us with different "imagined futures" [15,16]:

Type I Bioeconomy: An ecological or organic economy that operates within the ecological and planetary boundaries, in line with the bioeconomics of Georgescu-Roegen (important concepts: sufficiency, simplicity, bottom-up, counter-expertise);

Type II Bioeconomy: A (scientific) knowledge-based economy driven primarily by industrial biotechnology (important concepts: efficiency, productivity, technological innovation);

Type III Bioeconomy: A biomass-based economy focused on substitution of fossil fuels with bio-based resources (important concepts: carbon-neutral economy, top-down governmental policies and regulation).

Whereas the latter two narratives (II and III) harmonize well with each other, both being founded on the promise of technological salvation and "green economic growth", the original narrative of Georgescu-Roegen is incompatible with either of the two, as it rejects both the concept of limitless growth beyond ecological boundaries and the concept of sustainable development, arguing that the green growth paradigm is not contributing to a transition towards a post-industrial age but constitutes the very extension of the industrial order and its power structures [17].

Thus, according to Eversberg and Holz, there is an apparent "conflictual relation between 'technology-driven', highly growth-oriented visions based on promises of life science innovations on the one and 'socio-ecological' counter-concepts based on agro-ecology and inimical to such technological solutionism on the other hand" [18] (p. 9). However, Georgescu-Roegen's theoretical foundation is most often "not taken into account, not framed as part of a bioeconomy, or deemed unnecessary or undesirable" [18] (p. 3). In consequence, the technology-driven narrative has "hijacked" the original bioeconomy [11]. This has occurred despite the various reality checks concerning the tenability of the green growth promises [2,17] and the low ability of bioeconomy innovations to contribute to genuine socio-ecological transformations [19,20]. To resolve this conflictual situation in the bioeconomy, a thorough and "serious discussion of its theoretical foundations" has been called for by Giampietro [21] (p. 143). According to Veraart and colleagues, the growth critics, however, have "mostly focused, via negativa, on what should not be done, without offering itself a constructive, alternative paradigm" [22] (p. 18). Arguably, as a result, there appears to exist only one possible imagined future, namely, that of the total mechanization of human society. In fact, this dominance of type II and III over the social-ecological type I narrative of the bioeconomy could be understood as an outcome of what Almudi et al. [23] have called "utopia competition". The utopia of ever-increasing economic growth and the connected narratives of technological fixes and competition as a central organization principle has been more efficient in terms of its propagation compared to alternative utopias such as ecological economic ones. *With this paper, we thus aim to strengthen the evolutionary and ecological utopia of a type I bioeconomy in the sense mentioned above [11] by discussing and sketching selected cornerstones of this utopia and shedding light on some of the blind spots as a basis for further research and operationalization.* We thus revisit selected theoretical foundations of Georgescu-Roegen's bioeconomics with the intention of taking on the normative task of strengthening the bioeconomic utopia as a constructive vision for the bioeconomy from an ecological perspective. In other words, a bioeconomy needs to be sketched in which human activities are genuinely embedded into the local ecosystem and nature as a whole. The cornerstones of the utopia presented here are developed based on a narrative literature review (e.g., [24]) of the basic bio-physical principles and prior knowledge in order to better navigate the biocosmos in the sense of the interaction of biological processes, human needs, niche construction, and the continuous evolutionary re-assembling and synchronization with natural patterns, rhythms, and cycles. As we are dealing with the formulation of a viable utopia, the intention of this paper is to inspire in the reader a vivid and radiant imagination of the possible future presented on the basis of scientific concepts from various disciplines integrated into a consistent and organic thought structure. The lively writing style applied intends to support this inspirational quality without compromising scientific accuracy. The structure of this paper follows a logical evolutionary sequence, briefly describing the organization of the ecosystem and the biosphere (Section 2), the human sphere and its stagnant state of today (Section 3), and the proposed way out (Sections 4 and 5).

2. Bioeconomy at the Edge of Order and Chaos

2.1. A Brief Reminder on the Limits of Linear Thinking

The narrow focus of the Newtonian paradigm has led us to presuppose an isolated subject, separate from the world out there, investigating real-world phenomena by isolating the objects of investigation from their non-linear, complex context, dissecting them into parts and finding linear causal connection between them [25]. This ignorance of the dynamic interrelationships that inevitably results from this fragmenting method of investigation has become characteristic to the age of industrialization [25,26].

Over-exploitation of so-called natural and human resources, waste streams and pollution, the loss of biodiversity, etc., are but visible consequences of those isolating thought processes occurring in the 'hidden world' of the human mind and human culture (e.g., [27], and references therein). From the supposedly objective standpoint of positivist and reductionist scientific inquiry, the emergence of complexity and orderliness in the real world cannot be grasped nor explained; it slips, as it were, through our hands. For this reason, complexity and self-organization have been ignored for (too) long and we have been relying on linear thinking and "techno-economic" knowledge [28,29], even though we are confronted with complexity everywhere we look. We cannot deny, however, that many marvelous and useful inventions have been made on the basis of linear thinking. It is functional, but it has its limits in terms of capturing the interconnectedness and evolutionary dynamics of the world. Both points of view—the linear reductionist and the dynamic complex systems view—are valuable, depending on the context of their application; they depend on one another. But focusing only on isolated parts is like trying to look at a painting by analyzing its pigment particles, binders, etc. Only by taking a step back and looking at the whole at once may one reveal its meaning. In other words, one may not get the gist of the matter when investigating only the fragments as the Newtonian paradigm suggests. Nature is an evolutionary process rather than a static compilation of "things"; nature is in the process of becoming! It is like the painting in the process of being painted; the painting is yet to be completed, and the future is uncertain, open. This is where human creativity has its all-important role to play (see also [30–35]).

When individual components assemble into a complex evolving system, the system can spontaneously transition from one configuration to another. As the system jumps from one state to the other, it cannot be predicted without the knowledge of the previous states, the system's evolutionary history. This is known as path dependence [36,37]. However, even with perfect knowledge of the system's initial conditions, its future states cannot be determined (*non-deterministic*) due to the system's inherent sensitivity (e.g., [38–40]). As Prigogine puts it: "The more we know about our universe, the more difficult it becomes to believe in determinism" [41] (p. 155). Prigogine [41] describes these *dissipative structures* as open systems that exist outside of the thermodynamic equilibrium; they are in an excited state and are thus unstable, yet their instability is maintained by the perpetual absorption and dissipation of energy. Their instability is stabilized, as it were. These self-assembling and self-maintaining entities exist at the edge of chaos and order, making the system sensitive to slight changes that can amplify to produce a huge effect on the system (*butterfly effect*) [40,41].

Such phenomena are not at all exceptional in the real world—they are everywhere.

2.2. The Rhythmic Organization of Nature

Nature is such an *excited pattern* in rhythmic motion. Nature is rhythm and pattern through and through (see also [42], on a related discussion). What we call nature is a pulsating, self-assembling web of interactions, which emerges and persists in a state of sustained excitation, creating, organizing, and regulating itself as a whole; *natura naturans*, that is, nature in the process of becoming.

- *Sunlight* illuminates the earth by day and—after doing structural work—is exported as heat into the cold blackness of space at night. This rhythm varies seasonally. Consequently, the different layers of our rotating atmosphere self-assemble and rhythmically organize and couple to the rhythmic excitation of the sun (atmospheric circulations), absorbing heat, organizing into rhythmic flow patterns of matter and energy (e.g., wind), thus regulating temperatures and weather (e.g., precipitation, storms), carrying particles and gases, microorganisms, spores, and even seeds along its winding pathways [43].
- *Water* plays a special role in the regulation of heat on the planet [44]. Its high specific heat capacity—much higher than that of air—allows it to absorb a substantial amount of heat as it transitions from liquid to gas phase, rises up into the atmosphere, and condenses into droplets, releasing the absorbed heat at high altitudes. Then it rains back down onto the earth, penetrating it and giving rise to various subterranean flows and reservoirs, which ultimately return to the surface, thus closing the cycle. The strong electric charges that build up inside the forming clouds, as ascending and descending frozen water droplets collide, give rise to extreme electric energies released in lightning and thunderstorms, which convert inert nitrogen in the air into a reactive form that ends up as nitrate raining down to fertilize the soil and the sea [43].
- *Ocean currents* form in response to the rhythmic excitation of the sun, and they carry along heat and matter from the equatorial regions of the planet towards the poles and back [44]. The ebb and flow sequences are caused by the gravitational pull of the moon in relation to the sun and the earth. This gigantic rising and falling of sea levels causes a variety of secondary currents, the so-called tidal currents. They periodically move in one direction, then stop and reverse direction, flowing back according to their own rhythms.
- By heating and cooling, wind, and rain, solid rock erodes and disintegrates into finer and finer particles. The water and wind carve out pathways into bedrock that over time mold the landscape into hills and valleys—increasing heterogeneity, creating more gradients that in turn allow for more currents to flow. The solid crust is merely a thin layer floating on a gigantic liquid soup of blazing molten rock (magma). Within this viscous boiling soup underneath our feet, tremendous forces are active [43].
- Underneath the molten mantle we find an electrically active outer core. Here, electrical currents spiral around the inner core, producing the earth's magnetic field that extends tens of thousands of kilometers into space. The magnetic field protects the earth by deflecting incoming solar plasma (solar wind) and cosmic rays that would immediately strip the earth of its protective atmosphere. At the poles, the fields spontaneously self-assemble into plasma cables that form circuits linking the earth to the sun [45].

This polyrhythmic dance of the four interwoven elements creates the heterogenous and dynamic scaffolding for the emergence of the diversity of organic life [44–46].

2.3. Life, Sentience, and Plasticity

Life evolves in a perpetual resonance with the elemental rhythms. A universal property of living beings is that they are sensitive or sentient. Its sentience allows an organism to both respond to its environment and its inhabitants, as well as its inner world of needs and preferences, allowing for purposeful behavior. Sentient beings can sense their needs, reach out, and find the objects of satisfaction—and feel different shades of pleasure. And so, each drive has a counterpart in the environment by which it can be satisfied. This external counterpart to an internal need is called a satisfier [47,48].

In order to stay alive, an organism has to remain sensitive and responsive to the dynamic environment. This sensitivity is higher at an early developmental phase than it is in later stages. Look at how fragile, sensitive, and soft a young seedling is, as it emerges from the seed soaked in water, or a baby, newly born; in this developmental stage—as the intrinsic form and structure begins to unfold—the being remains extremely plastic and is shaped by its environment. As it matures, the structure of an organism becomes more resistant to change, and more autonomous.

A mature living being remains plastic to long-term impressions in that its inner organization irreversibly deforms, thereby responding to the given impressions. This is known as phenotypic and developmental plasticity, which refers to the ability of organisms of the same genotype to vary in behavior, morphology, and physiology within their lifespans in response to a unique environment and its inhabitants—and those unique responses that are adapted best to the given conditions over long periods of time may be selected in the evolutionary process [49,50].

The concept of plasticity is important for our later discussion on the effects that our surroundings have on our constitution. We are shaped by the world we live in.

2.4. Life and Autonomy

On the one hand, the being develops and remains in intimate communion with the environment; on the other hand, the being strives for autonomy, wants to emancipate itself, resisting environmental influences in the pursuit of developing and maintaining its unique identity. This is when the organism resonates with its own needs and preferences and seeks to impose these on the world.

The living entity, in its developmental process, struggles to actualize and maintain its inner impulse, its ideal structure, form, and behavior. This ideal is a potential *gestalt* and inner organization specific to the species. But this ideal now encounters the reality of a changing environment and is challenged by it, stressed by its dynamics. The living being wants to maintain its unique identity, project it into its environment, and expand the boundaries between itself and *the other*, placing itself at the center. It strives to preserve itself, maintain its own point of view, and expand its sphere of influence to new domains and defend them.

It remains elastic in regard to short-term impressions, temporarily deforming the organizational structure and restoring its original structure once the impression is gone (*homeostasis*); autonomy is the refusal to adapt [51].

This stress that a developing being experiences when encountering the real world is necessary for the development of its autonomy. By being exposed to stress, the body learns new modes of response, learns to cope with it, and becomes more autonomous, stronger; its sphere of influence expands. This increases the elasticity of the being and sets new states of equilibria, allowing more stress to be buffered over time, thus providing an evolutionary advantage.

Elasticity, however, is a limited resource. Stretching an elastic piece of rubber too much or for too long eventually causes the material to fail. Likewise, continued exposure to stress comes with cumulative costs of adaptation (*allostatic load*), which deplete the body's adaptive potential, leading to exhaustion and disease, that is, the inability of the body to restore and preserve its original structural integrity. The constant wear and tear on the body thus erodes it over time, eventually leading to death (e.g., [51–55]).

The being's autonomy also entails agency. This means that the autonomous agent is endowed with the power to select between alternatives, that is, actualize potentiality: this, not that. Thereby, a living being can, to some degree, change existing routines in accord with its unique preferences and self-define rules it chooses to follow [56].

The plasticity just mentioned is not only a passive response to the environment and its inhabitants; it is also a feedback mechanism by means of which organisms can adapt to the conditions they themselves have created. In other words, an organism can reshape and then be reshaped by its environment during its lifetime because of its plasticity. This in turn may affect the long-term selection process of evolution. "The organism influences its own evolution, by being both the object of natural selection and the creator of the conditions of that selection" [57] (p. 106). Thus, an organism is properly seen as an autonomous agent that co-directs its process of evolution [57–60].

When looking at the evolution from early and simple to the later, more complex life-forms, one cannot fail to identify a trend towards greater autonomy [56,61,62]. Life strives to emancipate itself from the environment and widen its sphere of influence, extending the boundaries between self and other so as to protect itself from the stress of the environment. It can do so by internalizing *the other*, reorganizing its environment in reference to itself. But, more importantly, this enables the venturing into and the occupation of new domains and the acquisition of new capabilities. Autonomy is therefore the beginning and the end of evolution [56,63–69].

2.5. The Web of Life: On the Evolution of Ecosystems

The shared experience of time, which results from living beings sensing and influencing one another in response to the environmental rhythms, allows for the emergence of an intersubjective sphere of communication that unifies beings into networks by synchronizing their activities to one another and to the ecological cycles [44,70]. This perpetual dialogue between beings allows for synergistic networks to form, which in turn allow for the emergence of new sets of viable possibilities [8]. Therefore, ultimately, all life coevolves in a "single, expanding network" [71] (p. 340) integrated by the shared experience of time: the rhythmic sequence of light and darkness [72].

The process is path-dependent; it begins at a point of critical juncture or a point of highest sensitivity, a state of potentiality in which multiple possible interaction patterns co-exist. The interaction of all sentient participating agents with one another and their unique environment is at first undifferentiated, chaotic, but, over time, an interaction pattern emerges and stabilizes (lock-in). Developing increasingly sharp contours, this emergent viable pattern gradually stabilizes, gaining autonomy. In this coevolutionary process, the pattern begins to resist change to preserve its unique structural identity and does so by routinization of its participants, which goes hand in hand with a decrease in sensitivity. Having begun as fluid and plastic structure, it rigidifies over time into a stable definitive organizational structure in which the participants can meet their needs. This rigidification, however, is then prone to destruction in the face of radical or prolonged changes, as adaptive potential has been spent for increased efficiency [43].

Ecosystems pass through several stages of development, each stage preparing the conditions necessary for the emergence of the subsequent stage. The stages are marked by an increasing complexity as participants are replaced by others in a regular sequence until it reaches its climax, its stage of highest complexity. But even then, the ecosystem remains dynamic as disturbances constantly challenge the structure. But by this, the structure can adapt to better cope with these over evolutionary timespans, or a new pattern may be formed [43].

The needs of all living beings can be reduced to their essential function, which is to stay alive and healthy, and reproduce. This is only possible if the instability or excited state that forms the basis of its structural identity is maintained, and the influences of erosion that constantly act upon it are deterred. This is the universal problem that all organisms face and there is no way around it [8]. The organism has to feed and develop strategies that keep the erosive forces of wind, rain, temperature fluctuations, radiation, toxins, harmful organisms, predators, and so forth, at bay. In order to do so, an organism has two universal capabilities at hand, namely, its sensitivity to the outer world and its tendency to increase its degrees of freedom so as to have more possibilities at its disposal (*autonomy*). By means of these capabilities, an organism must devise strategies to solve the universal problem of making a living, of satisfying its own needs and those of its offspring within the framework of an evolving environment. The interplay of these two drives in their environmental context *is* evolution. The drive for autonomy constantly tends to disrupt the homeostasis (dynamic equilibrium) of ecosystems as species try to expand their boundaries and explore new domains—innovating. The drive for integration constantly buffers these perturbations or disturbances of the web of relationships in favor of collective stability. The drive for emancipation being directed towards the unknown impacts the trajectory of the evolutionary process, whereas the drive for integration holds all together in bonds that have proven viable. So, at first, there is an element of *creative destruction*, to use Joseph Schumpeter's words [73,74], producing new conditions, and then these conditions are stabilized into a new dynamic equilibrium. The former generates diversity; the latter integrates diversity into unity. Now there is growth and development; now there is evolution of the whole web of life.

2.6. Nature as Order and Chaos: Ecosystem Services and Erosion

This weaving of nature regenerates the air, purifies the waters, decomposes the waste, manages the weather and climate, keeps in check the growth of populations, facilitates pollination, cycles essential elements and nutrients, etc., in a reliable manner so that the web of life keeps existing [44]. The entire web of life and its trophic hierarchy can be seen as a marketplace, the bioeconomy, in which goods and services circulate and are potentially available to all beings [8]. This enables the satisfaction of a species' needs. The reliable supply of the natural goods and services is based on continuous re-organization through innovation and adaptation to the *rhythmic patterns* of nature to create viable, functional, and flexible ecosystems.

From an anthropocentric perspective, goods and services provided from an ecosystem to humans are called ecosystem services [75–78]. They are the practical result of the weaving of the elements and the fabric of life embedded into it. All this is freely available potential that is actualized differently by different species, and it exists so all can exist. And so, the satisfaction of needs is fundamentally tied to the health of the ecosystem, in many different ways [79–81].

In a very similar way that a mother sustains her infant both with nutrition and with affectionate attention, forming a resonant circuit through which their brain waves, heart rates, and endocrine systems synchronize [82–85], human beings are sensitive to their habitats, wittingly or unwittingly [86]. We perpetually communicate with the environment, whether deliberately or not. Evidence suggests that the mere exposure to a healthy ecosystem improves physical health (e.g., [80,87–93]), restores cognitive functions (see *attention restoration theory*) and improves perception [90,94], harmonizes the brain's neurochemistry and thus regulates mood and allows for an improved recovery from stress and addiction [79], increases our empathy and leads to crime reduction [95], "trigger[s] the sense that the world is enchanted, alive, whole and meaningful" [96] (p. 10), and facilitates experiences of transcendence [96–101]. This indicates that there are subtle but profound effects that happen below the threshold of our consciousness and shape our adaptive constitution. And this synchronization between humans and their habitat implies a direct link between human health and the health of the ecosystem [70].

However, nature is not only the source of order but also that of chaos. On the one hand, nature gives life; on the other hand, nature takes it. The fluctuations of temperature, rain, radiation, pathogens, predators, etc., are erosive forces that constantly challenge a being's integrity. There are cataclysms, volcanic eruptions, earthquakes, floods, epidemics, and wildfires. Beings must constantly shield themselves from these whimsy moods of nature so as to resist disintegration.

Consequently, all beings experience nature as both benevolent and hostile, life and death, order and chaos. Yet, the hostile side of nature is necessary for life to evolve, to grow stronger, to innovate, and to gain more autonomy. If an organism is not challenged and does not experience stress, then there is no development.

2.7. The Invisible Foundation of Nature

According to the (relatively) new paradigm of physics—which resulted from the attempts to dissect matter further and further to find its self-identical core—the physical world is not actually made up of matter. It emerges from a realm of potentiality, as Heisenberg coined it, a sea of undifferentiated possibility in which ripples of probability waves give rise to viable patterns that actualize [102,103]. This potentiality constitutes the hidden foundation of the cosmos (see also [33,104], on a related note). For example, Dürr [103] (p. 33) insists: "There are no particles that are indestructible, that remain self-identical, but there is a 'fiery boiling', a constant emergence and dissolution." It is matter at its critical juncture before it has become tangible. "At the bottom, the only thing remaining is something akin to spirit—holistic, open, alive, potentiality", whereas "matter is the slag of the spirit—divisible, closed, determined, reality" [103] (p. 33). What this paradigm implies is not only that we revise our notion of matter but, as Zeilinger demands, we need "a new deep analysis of space-time" itself [105] (no pagination). Kastner explains: "Quantum physics requires that we 'think outside the box', and that box turns out to be space-time itself. The message of quantum physics is that not only is there no absolute space or time, but that reality extends beyond space-time. Metaphorically speaking, space-time is just the 'tip of the iceberg': Below the surface is a vast, unseen world of possibility. And it is that vast, unseen world that is described by quantum physics" [106] (no pagination).

But what does the quantum world have to do with our macroscopic world of tangible matter? Here, we return to the phenomenon of self-organizing, complex systems and their inherent property of a sustained instability that allows for the amplification of minute perturbations. Dürr gives the following analogy [103] (p. 67): If you take a pendulum and raise it to its highest point, the very point where it stands upside down, exactly upside down, and you leave it there; at this point the pendulum is indeterminate—it is uncertain whether the pendulum will swing down to the left or to the right side. In this state of a critical juncture, the system is unstable, sensitive. Which side will it select, left or right? Here, all prediction fails as any slight disturbance determines the outcome. In Dürr's words: "At the point of highest sensitivity, the pendulum 'senses' what is going on in the world. ... Now it experiences this background field, the potentiality ... in which everything is connected to everything else. One can also say the pendulum at this point comes alive" [103] (p. 67). And this is where the vague and ambiguous quantum world becomes relevant even in the macroscopic world we perceive [103]. Since nature is a gigantic and interwoven fabric at the point of highest sensitivity, it is here that the potentiality can be witnessed in the process of actualizing, in the process of becoming. This creative process is ongoing and open, being plastic and indeterminate, vague. It is here that potential is actualizing into repetitive routines that make it appear self-identical and fixed, but it is still creatively weaving new possible patterns in space-time, playfully. It is here that future potential is available now. And it is the self-imposed duty of the bioeconomy to preserve this potential and participate in shaping it into a new possible world.

3. The Human Being and the Cultural Fabric

3.1. Needs, Drives, and Attention

We all experience needs as sensations of discomfort that stimulate us to reach out into the world and seek for their satisfaction. These sensations are sensed indicators of a present or anticipated disturbance of homeostasis or dynamic equilibrium of the web of interactions that hold the organism together [107–110]. Homeostasis is a state of sustained instability at the edge of order and chaos and allows the system to self-stabilize at this edge in the face of change. The dynamic equilibrium is maintained through constant change (*allostasis*). Allostasis also entails the anticipation of events, which is essential for survival and is present in all species [111,112]. Thus, the stabilizing interaction patterns underlying the human constitution are in constant motion in response to change or anticipated change.

The sensation of discomfort builds up gradually and provides a motive force that compels us to engage with the world in order to find that which is needed to restore the dynamic equilibrium of the body and the psyche. This sensation of discomfort springs from the personal unconscious and makes itself known to the conscious mind as, for example, appetite, which activates imaginative faculties to seek and select a discrete object of desire. Therefore, desire is always directed towards the future [113]. For instance, if a feeling of appetite arises, it is felt as a lack, which in turn stimulates our desire for an object of satisfaction: food. We then project our attention to an imagined future, simulating different possibilities; should I go for noodles, or hamburgers, etc. This variation or critical juncture of possible anticipated satisfiers (e.g., having certain types of food) adds agency to the process in that we can select among alternatives and go for it (lock-in). The process that had started out as an unconscious, instinctual drive is now a cooperative process between conscious and unconscious aspects of the mind. The unconscious provides vague but powerful motivational energy, while the conscious mind can direct this desire to a discrete anticipated future.

There are different means to satisfy our hunger, but if we fail to provide ourselves with food to satisfy this need, we experience dysfunction and ultimately death. According to Max-Neef and colleagues, fundamental human needs are, therefore, "the same in all cultures and all historical periods. What changes, both over time and through cultures, is the way or the means by which the needs are satisfied" [47] (p. 18).

Not all needs, however, lead to death if not satisfied, but those needs that do are, of course, more essential than those that do not. These are commonly referred to as physiological or biological needs. They include food, water, shelter, thermoregulation, etc. The second class of needs is about our health and well-being; we experience dissatisfaction or lack when they are not satisfied but we do not die immediately when they are not satisfied. Not satisfying these needs over longer periods of time can, however, result in anxiety and tension that can become chronic if the deficiency is not dealt with [114].

Those needs that are subordinate to the physiological needs have been classified differently by different researchers. The most widespread classification is probably Maslow's hierarchy of needs [114,115]. Doyal and Gough [116] tie the concept of needs to the concept of health and well-being. In general, if needs are not satisfied, there is harm; if they are, there is health and well-being [116]. According to the definition of health as "a state of complete physical, mental and social well-being and not merely the absence of disease and infirmity" [117] (p. 887), Doyal and Gough integrate physiological needs with psychological needs. Health thus refers to the dynamic equilibrium (homeostasis) of the body (physiology), the psyche (psychology), and society. Jung referred to the psyche as "a self-regulating system that maintains its equilibrium just as the body does" [118] (para 330). It therefore appears reasonable to integrate both physiological and psychological needs; they are both self-stabilizing systems at the edge of chaos and order. What is missing here, however, is the health of the ecosystem. The social system, the psyche, and the body are but subsystems of the ecosystem that influences them and on which all these ultimately depend [119]. Doyal and Gough [116] then reduce human needs to two universal ones: (*1*) *Health* and (*2*) *Autonomy.*

As Max-Neef and colleagues argue [47], the different needs are fundamentally interactive and interrelated and should thus be seen as a complex system, which also means that satisfiers, that is, the objects of desire, can satisfy more than one need at a time [47,48,120]. A popular example is bottle feeding in comparison to breast feeding. Bottle feeding satisfies the need for staying alive (subsistence), but breast feeding satisfies more than just the need to survive.

Without going into further detail, we can now integrate what has been pointed out previously. Elaborating on the biosphere, we identified two fundamental tendencies that are found in all living beings, namely *(i) the tendency to build relationships* within and among species, as well as with the environmental rhythms, and *(ii) the tendency to increase the autonomy* of the species in response to constraints.

Apparently, what has been described are those secondary needs just mentioned, namely, the need for relationship or psychological needs and the need for autonomy, the former being directed towards *the other*, the latter being self-referential. From that perspective, these needs are universal biological drives; they are not unique to human beings.

These tendencies also allow us to experience different domains of reality. The desire for relationships allows us to foster cooperation networks that allow for the reliable satisfaction of our primary need for survival and reproduction; the desire for autonomy or emancipation adds agency to the process of self-stabilization and allows us to compete with others and reshape our environments so as to create better conditions for the satisfaction of our primary needs. The desire for autonomy causes individuation, which creates diversity, whereas the desire for relationships integrates diversity into a unity—diversification and integration. The activities that are evoked from these intrinsic drives in each organism are the main drivers in the bioeconomy, which is essentially the combined effect of all needs-related activities in the biosphere that happen in the context of the polyrhythm of nature. In a broader context, this duality is also reflected in the interplay between *mutualistic/cooperative* and *antagonistic/competitive coevolution* (e.g., [121,122]).

3.2. The Invisible Foundation of Culture

Bioeconomic theory is based on the integration of economics, physics (thermodynamics), and evolutionary biology. Georgescu-Roegen integrated these different disciplines primarily by means of the concept of time. In doing so, he attempted to replace Newtonian physics (mechanics) based on reversible processes at the thermodynamic equilibrium with thermodynamics and its irreversible processes that occur away from thermodynamic equilibrium in economic theory. He distinguished between clock-time, that is, the measure of an interval or duration, from thermodynamic time or history. "Thermodynamic time is entropy time, characterised by change, irreversibility and irrevocability" [123] (para 14); in other words, time flows from past to future and cannot be reversed, and things that have happened cannot be undone. Each moment is part of an evolutionary process "connected with mankind's or with cosmological history . . . This time is not a cardinal variable" [124] (p. 42), as cited in [123].

At this point, it should be noted that like the synchronizing mechanism described in Section 2, when a child is born and the umbilical cord that has tied it to its mother is cut, the infant remains extremely plastic and sensitive and is now molded in accord with its environment and its mother. As the child grows, this sensitivity gradually ebbs away, giving way to a different phase of development, puberty, a phase which is marked by the urge for more autonomy [49]. The cutting of the bonds implies, however, a decreased sensitivity to the outer world as the inner drives rise to prominence, thus allowing for the separation of the individual from his or her context. Now the individuals seek to satisfy their needs on their own—only to foster new bonds (mating, cooperation) once autonomy has been established. In this process, it is essential to understand that adult human beings in the pursuit of the satisfaction of their needs in the web of life are not alone in their endeavors but are part of a collective, a culture. Like an intermediary, this cultural matrix stands in between the individual and the biosphere and shapes them. The culture they are embedded in comes with its own unique history that provides an individual with a set of beliefs, ideals, techniques, tools, habits, and so forth—and also with useless baggage—which, to a great extent, define how the individual meets his/her needs (see also [125,126]). These culturally evolved worldviews may constrain rational choice and add a historical component to bioeconomic activity ([5]; see also [27], on a related note). In Suzuki's words: "The way we see the world shapes the way we treat it" [44] (p. 1).

We should not fail to recognize that human social structures such as cultures, or any other organization, institutions, governments, and so forth, only exist on the basis of a shared belief that integrates individuals into a collective by providing a collective purpose [127–129]. So, basically, what holds together a social organism are cultural ideas and instructional habits of thought—or *memes*—and their communication [130,131]. But where do these come from?

What we generally consider conscious thinking is merely a thin solidified crust underneath which are found deeper strata of cognition, and it is there that, according to Graupe, "the vast majority of human cognition takes place" [132] (p. 244). These deeper layers of the human mind have been subject to scientific investigation ever since Freud opened the field of depth psychology. Freud's findings brought to light the layers of the mind that also house the personal drives just described [110]. Jung dove deeper and found much more obscure strata. These, he argued, are accessible to the human imaginative faculty, when thinking is temporarily suspended, and charged images from the depths are allowed to emerge, morph, and crystallize in the light of attention. These vague and ambiguous but energetic archetypal images are, Jung argued, the bridge between conscious and unconscious and are rooted in the evolutionary history of our species. From his considerations, Jung would derive the concept of the "collective unconscious", arguing that beyond the personal psyche, there are deeper strata, collective in nature but hidden, the content of which can only be approached indirectly through these images [133]. It is seen as an archaic preconsciousness in which latent possibilities take shape gradually and may crystallize into discrete thought structures. These mythical imaginations stemming from the collective unconscious, which Jung called "big dreams", are relevant not only for the individual but potentially for the entire cultural sphere. Since the bioeconomy holds the self-imposed task of defining *possible futures* and sketching out viable utopias, this topic seems worthwhile to discuss.

Putting this into context, it can be stated that that which organically weaves individuals together into a flexible cultural fabric emerges from the depths of the unconscious and provides meaning and purpose. These archaic and mythological imaginations are motivational potentials in the evolutionary process that are in the process of becoming. And this actualization includes the agency of the observer who has to define this potential and guides it towards purposeful action.

What Jung and others discovered in the human mind is surprisingly similar to what quantum physicists have discovered, and what Heisenberg had termed potentiality, the hidden foundation of the visible world in which all possibilities co-exist yet in a latent state at the edge of space-time, and which can spontaneously begin to actualize when the light of attention shines upon it [134,135].

In physics, actualizing potentiality was discovered in the outer world; in psychology, it was discovered in the inner world. In fact, Nobel laureate Wolfgang Pauli recognized the similarities between quantum physics and depth psychology. Pauli knew very well what Jung was trying to conceptualize as the "collective unconscious" and "archetypes", as he himself derived his scientific findings through preconscious imaginations [134]. The discussions between Pauli and Jung culminated in the suggestion of a "psychophysical reality", a unified yet hidden "*anima mundi*" in which not only the boundaries of space-time melt away but also those that separate inside and outside; their attempt to find a neutral language that applies to physics and psychology alike, however, remains unfinished [134,135].

Recapitulating what has been discussed and bringing it into context, just as the soft and fragile tip of a branch stretches forward, remaining in a state of highest sensitivity as long as it grows, actualizing potential, so the tip of the current of cultural evolution flowing through time remains sensitive to the potentiality as long as the tip progresses. The solidifying structures of the branch that form behind the tip are the memes, cultural norms, and routines that stabilize society into a discrete organizational structure. The transition towards a genuine bioeconomy is that tip carving its way into the future, actualizing potential.

Both the organic world and human imagination harbor latent potentials in the process of actualizing. These two domains are in the process of becoming, which implies that their future is uncertain, open. Because of this, these domains present themselves as the basis for the bioeconomy. Participating consciously in this creative process that takes place within and outside of us is the challenge we are facing, and the depths of the collective unconscious are the source of genuine utopian dreams.

"The future is uncertain . . . but this uncertainty is at the very heart of human creativity" (Ilya Prigogine, as quoted by [136] (p. 1)).

3.3. Prometheus and Pandora's Box: Godlike Power and Unintended Consequences

On examination of human evolution, Georgescu-Roegen identified incidents in human history which radically and irrevocably changed the trajectory of human evolution. These incidents were the introduction of what in bioeconomic theory has been called Promethean recipes, inventions that suddenly endowed humans with godlike power, yet came with unintended consequences [5]. Prometheus refers to the Greek mythological figure who stole fire from the gods and introduced it to humankind, thereby elevating humans to a state of godlike power. The cause for this theft was, in Plato's version of the myth, the helplessness of the human being, who was inadequately equipped for survival. The gift of fire, arts, and crafts was, from this perspective, a compensation for a fundamental lack, a need. But this gift was a breach of cosmic order and therefore did not pass without consequences. Both Prometheus and humans were punished for this by Zeus, father of the Olympian gods and keeper of order, who brought about his revenge through the hands of Pandora. She opened the jar (Pandora's box), releasing various evils (e.g., disease, old age, insanity, etc.) into the world, irreversibly.

Prometheus, whose name is translated as "foresight" or "thinking ahead" (*pro* = ahead; *metheus* = think), refers to that godlike power that changes the course of human evolution. Apparently, it refers to a function of the mind. Thinking ahead refers to what Husserl called protentions, which means a desire is projected into the future by means of attention [113,137,138]. Thinking ahead involves agency and so Prometheus might as well point to an increased sense of volition to direct the inner drive at will, which touches upon the problem of freedom. Freedom can either lead to self-mastery or the pursuit of pleasure, which will be discussed further on. It is intriguing that Goegescu-Roegen placed this myth at the foundation of bioeconomic thought.

Georgescu-Roegen argues that creatures have their capabilities embodied; birds have wings to fly, spiders weave their webs, extruding them from their bodies, etc. For the most part, they all have those capabilities they need to survive within their bodies, except the human being, whose major capabilities are exosomatic, that is, they exist outside (*exo*) of the body (*soma*). From this understanding, the bioeconomic concept of *exosomatic evolution* is derived, which is also drawn from the Promethean myth. It is different from biological evolution in that it is the created technology that begins to evolve on its own and human beings merely adapt to the changes happening outside of their immediate control but which they themselves have caused (see also the related notions of cumulative cultural evolution, e.g., [139], and "runaway" cultural niche construction [27,140,141]).

As previously mentioned, by constructing a niche and adapting to this modified environment, living beings influence the process of their own evolution [59,142,143]. By replacing the ecological rhythm of time by clock-time, the living landscape by lifeless and monotonous machines, fluid forms of the biosphere with heavy forms of concrete and steel, combined with rigid bureaucratic structures demanding formal, cold, and predictable behavior, the human need for communion with *the other* has been frustrated. *The other* became unresponsive, mute, hollow, as if one is looking and there is no one looking back. In consequence, the psyche has been seeking a substitute to compensate for the unfulfilling dialog with the environment.

The present phase of (exosomatic) evolution started out with the industrial revolution and was based on the capability of converting heat into motion to do work by means of the steam engine powered by fossil fuels. This energy technology was but the core building block of a technological complex powered by this novel exosomatic capability, which allowed for the mass production of commodities by a complex set of machines. It is this technological matrix that qualifies the emergence of the steam engine as a Promethean recipe as Georgescu-Roegen understands it.

The increasing specialization and advancements in the field of electronics and communication technologies were incremental in facilitating the functionality and expansion of the technological matrix. The gigantic, monotonous machinery required that individuals specialize and adapt to its dictates in order to survive, and so it restructured society on almost all levels. Human beings gradually embedded themselves in this matrix and became more and more dependent on it and were gradually being reshaped by it (e.g., [22]).

This new human niche emerged in the image of the world conception of a clockwork universe, a machine as introduced by Bacon, Descartes, and Newton. Nature gave way to the machine and spontaneous self-organization gave way to external bureaucratic control. (see also [25,26,30,31,104]). Without bureaucracy, the planning and management of mass production is impossible. In essence, a bureaucratic organization is a rational thought entity designed to organize humans into a hierarchy of authority, strict division of labor, and predictable standardized or routinized behavior [144]. In a bureaucracy, it is all about predictable results, which means that "the most rational means to attain a given end" [145] are applied. This results in the "rationalization of society" [145].

Modern cultural life is, as it were, molded around these techno-bureaucratic structures; they dominate modern life. These rigid social automata interconnect and form complex networks that constitute the memetic core of modern society. Harari [128] argues that, "in order to function, the people who operate such a system of drawers must be reprogrammed to stop thinking like humans and to start thinking like clerks and accountants. As everyone from ancient times till today knows, clerks and accountants think in a non-human fashion. They think like filing cabinets" [128] (p. 146).

The education system was also adapted to meet the needs of mass production, thus marginalizing creativity [146]. As Robinson argues, even today's educational systems favor linear thinking and mathematics over arts. Inflexible curricula paired with standardized teaching approaches aimed at training "human capital" are in line with the socio-economic processes of the wider industrial system (see also [29]). Those who deviate from the norm and think outside the proverbial box are selected out, resulting in an epidemic loss of mental plasticity, imaginative capacities, and aesthetics [146], thus essentially shutting the door to the unconscious. According to Harari, the merging of humans and machines has thus already begun with the Industrial Revolution, when "the timetable and the assembly line" became the "template for almost all human activities", and machines and bureaucracies gradually became the epicenter of human organization and substantially modified human behavior, but the merging was not yet physical [128] (p. 395).

3.4. The Human Being as Appendix of an Artificial Superorganism

Just as the steam engine externalized and automated manual workforce, human thinking was externalized and automated beginning with the programmable machine, the automaton, which evolved into electronic computers integrated into a world wide web, artificial intelligence (AI), and artificial neural networks. All these are exosomatic instruments; they are attempts to mimic organic biological processes. This growing technological complex or exosomatic superorganism has been weaving its web of wires around the wide world, expanding its tentacles even into space, weaving a web of satellites to integrate virtual, physical, and biological objects into one planetary infrastructure, the "internet of things". "It's like humanity acquiring a collective nervous system", says Elon Musk [147], one of the masterminds behind this venture.

By means of “wearables”, “implantables”, and brain–computer interfaces, the human being is merging physically with the technological matrix with the aim of accessing the inside of the human body because, as Harari puts it, “once an algorithm knows you better than you know yourself, institutions such as democratic elections and free markets become obsolete, and authority shifts from humans to algorithms” [148] (no pagination).

Hölldobler and Wilson [149], studying the social behavior of ants, have identified the ant colony as a superorganism, concluding that “one ant alone is a disappointment; it is really no ant at all” [149] (p. 107). In fact, the human individual in the modern technological matrix could be described in the same way: s/he is a disappointment; s/he is really no human at all. The human can no longer sustain him/herself but fully depends on the technological matrix. Embodied skill and knowledge are vanishing. This artificial superorganism seems to have already become the dominant species on the planet.

3.5. The Race towards Singularity Is a Waste of Time!

The promise of the technological narrative is salvation from ignorance, disease, and death through the omniscience and omnipotence of technology. These promises are based on the relatively steady increase in productivity growth in the semi-conductor industry that doubles computation power every two years. This forecast is based on Moore’s law, according to which, at some point in time, the increase in computing power—doubling every two years—will become so dramatic within a short period of time that it will result in an escalation of intelligence [150–152].

The law of accelerating returns as formulated by Kurzweil extends Moore’s law, predicting that technological development in general follows an exponential growth function, and its productivity increases both in quantity as well as in efficiency so that, as time progresses, the scope of innovation converges towards a point that exceeds human imagination. This escalation is believed to happen when different sectors, such as AI, biotechnology, cognitive science, and nanotechnology, cross-fertilize each other, leading to an explosion of innovation. This escalation is referred to as technological singularity. The concept of technological singularity was first formulated by von Neumann in 1958 as an “ever accelerating progress of technology and changes in the mode of human life, which gives the appearance of approaching some essential singularity in the history of the race beyond which human affairs, as we know them, could not continue” (John von Neumann, as quoted by [153] (p. 18)). Kurzweil claims: “I set the date for the Singularity . . . as 2045. The nonbiological intelligence created in that year will be one billion times more powerful than all human intelligence today” [152] (p. 136).

The role of the human being, that is, whether or not s/he will still exist after this intelligence explosion or not, is debated. Transhumanists assume humans will exist to enjoy the benefits of superintelligence, superpower, and immortality (at least some humans), whereas posthumanists assume that human evolution as such will end at this point [153].

However, the fact that the singularity cannot be fathomed by the human mind raises the question whether the promise of technological salvation is actually a promise. Singularity, being beyond the “event horizon”, by definition invalidates all predictions.

This race towards some imagined techno-paradise represents what Georgescu-Roegen termed “the circumdrome of the shaving machine”, which means “to shave oneself faster so as to have more time to work on a machine that shaves faster so as to have more time to work on a machine that shaves still faster, and so on *ad infinitum*.” [154] (p. 378). In other words, industrialization, with its perpetually improving mass production and its ever-accelerating computation power, has allowed us to produce commodities at increasingly faster rates, and we have assumed that, in consequence, we gain more time. However, this acceleration increases the pace of the entire socio-economic process within the technological matrix and its human appendix. Production accelerates; consumption accelerates.

Those who engage in production have to constantly come up with new technologies, goods, and services to stay in the race. They also have to come up with novel strategies to capture the attention of consumers and stimulate their desires at an increasingly faster rate. This increases the complexity of the exosomatic matrix further [22]. What is being lost, apparently, is time. In Georgescu-Roegen's words: "We must come to realize that an important prerequisite for a good life is a substantial amount of leisure spent in an intelligent manner" [154] (p. 378).

3.6. Consumerism, Producerism, and Compulsive Behavior

Infinite growth is impossible in the face of finite resources. Industrial–economic activity inevitably uses up low-entropy resources and converts them into high-entropy waste [5]. Even if all waste was recycled, this would not change the fact that all processes, including the recycling processes, degrade resources into waste, which implies that future potentials are irreversibly lost. Even though an increase in efficiency, in principle, could reduce resource pressure and lower prices, in reality, this might not actually happen. It has been shown that both consumption and production can still increase with an increase in efficiency (rebound effect) [22]. Furthermore, the race for innovation comes with the problem of planned obsolescence, meaning products are designed for short lifespans so as to tempt the consumer to keep consuming new versions of the product, thus wasting resources excessively [155].

From the original bioeconomic perspective, the belief in never-ending growth is a consequence of an insatiable desire for short-term desire gratification that is constantly being triggered so as to match mass production with mass consumption and keep the economy growing. Veraart et al. [22], based on the work of Stiegler [113], assert that "every economy of production and consumption as we generally understand it is always also a libidinal economy, i.e., an economy of desire, desire being the principal driving force of all human endeavours" [22] (p. 9). Based on this understanding, Veraart and colleagues "suggest the possibility that a 'corrupted' mode of collective human desire is at the heart of humanity's current failing to establish a new paradigm" within the bioeconomy [22] (p. 4).

Arguably, Edward Bernays played a decisive role in the emergence of modern consumer culture. In his book *Propaganda,* he argues: "The conscious and intelligent manipulation of the organized habits and opinions of the masses is an important element in democratic society. Those who manipulate this unseen mechanism of society constitute an invisible government which is the true ruling power of our country. We are governed, our minds are molded, our tastes formed, our ideas suggested, largely by men we have never heard of" [156] (p. 9). Today's economy is thus founded upon the illusion that the more we consume, the happier we become [128]. But consumerism only functions if there is also "producerism". From this point of view, the producers must "educate people thoroughly", to use Harari's [128] (p. 127) words. "From the moment they are born, you constantly remind them of the principles of the imagined order, which are incorporated into anything and everything . . . fairy tales, dramas, paintings, songs, etiquette, political propaganda, architecture, recipes and fashions" [128] (p. 127).

Neither desire gratification nor the pursuit of power and status can replace the satisfaction of true needs and so the human being consumes but does not nurture, and thus wants to consume more [157]. The result is a state of collective addiction. "It is because of this addiction that mankind's survival presents a problem entirely different from that of all other species", Georgescu-Roegen [154] (p. 369) argues. The main indicator for addiction is compulsive behavior that leads to a situation where the real needs—which are irreplaceable—are negatively impacted [157–161]. Frustrating these needs further increases the desire for a momentary relief from the resulting discomfort. But repeated and prolonged experiences of pleasure decrease our capacity to tolerate pain and increase our pleasure threshold. This means we need incrementally more to experience the same amount of pleasure, while our capacity to bear pain in turn decreases. And so, the more pleasure we pursue, the unhappier we become, and the unhappier we are, the more we tend to look for pleasure stimuli just to get a momentary relief from pain [161].

Recapitulating what has been laid out, it should be self-evident that the concept of a bioeconomy is incompatible with the present technological matrix and its associated fabricated myth of consumerism. Bio-based, CO_2-neutral, climate-friendly, sustainability labels are just new stimulants for consumption that perpetuate the entire economic system, which threatens the integrity of the ecosystem and systematically erodes life. This is why Georgescu-Roegen was uncompromising about his stance on the concept of sustainable development introduced by the Club of Rome in 1972. He called it "snake oil" and "one of the most toxic recipes" (Georgescu-Roegen, as quoted in [162]). He urged the public to be very critical of every endeavor by political or commercial interest groups that make use of the concept of sustainability to mask their real interests; after all, these power structures "have lured man into this empty infinite regress" in the first place [154] (p. 378). Apparently, his predictions were astonishingly accurate, given the inflationary use of the concept that remains vaguely defined almost five decades after its introduction. Yet, it is still the dominant concept in the bioeconomy, even though the idea of *green growth* "is simply inconsistent with basic thermodynamics principles", as Giampietro [163] (p. 750) asserts.

Consumerism (and producerism) and its associated collective addiction based on the hijacking of attention and the stimulation and exhaustion of libidinal energy corrupts the natural drives over time. Both of our fundamental drives (autonomy and relationship) fall victim to the technological matrix; it is a spiral of psychological entropy that mirrors the entropy spiral in the external world—resources are degraded into waste; potential is actualized excessively. Seen from that perspective, industrialization is literally a waste of time—not clock-time but lifetime.

Desires directed towards meaningful long-term goals or ideals, on the other hand, reverse the spiral of addiction because they entail the overcoming of obstacles and the endurance of pain along the path towards their achievement, which decreases the pleasure threshold and increases the capacity to bear pain. The pursuit of meaningful ideals requires that one is in charge of his/her attention and directs his/her desire towards an anticipated goal. The self-control of one's attention is the essence of the drive for autonomy, just as communion is the essence of the drive for relationship. As mentioned, a meaningful ideal or purpose and its actualization is a cooperative task between conscious and unconscious and should include the ecological context. We may argue that the invisible reservoir of the collective unconscious provides humankind with ideals that are connected to the greater whole of the cosmos.

4. The Normative Task of the Bioeconomy: Merging with the Biocosmos

4.1. Back to Basics? The Oikos

In order to foster the theoretical foundation of bioeconomics, it seems useful to revisit the original concept of the economy as the ancient Greeks developed and understood it. The origin of the concept of the (bio)economy is the *oikos* (*οἶκος*), the household. The oikos was actually an estate, whose function it was to produce, process, and satisfy the basic needs of the household members and generate surplus [164]. Production power remained fully in the hands of the private household and served as the foundation of the Greek city-state, the birthplace of democracy. According to Gallego, this had significant consequences on the social, political, and economic organization of the polis, as "the agriculturalists did not have to produce a regular surplus for the social and/or political elites" [165] (p. 13). According to archaeological findings, "the distribution of the land in regular and relatively equal plots has been verified throughout the Greek world", indicating that the distribution of wealth was rather equal [165] (p. 10).

The oikos was, as Gallego explains, "an intensive cultivation system combining crops of cereals, olive trees, vines, pulses, vegetables and fruit trees, with less time devoted to fallow and more attention to soil improvement (manure, weeding, terraces building and maintenance), with a few animals, a high input of hand labour, and good water supply" [165] (p. 10). The social status of the smallholder was positive. He was a free citizen with full rights to participate in civic life with no obligations towards an elite, forging his own destiny. The state had almost no influence on the production of goods and services and received neither taxes nor rent from the citizens.

The ancient Greeks saw nature as a source of abundance that, if economized well, would sustain the needs of the household members and produce surplus. "Natural and necessary desires [needs] are easy to satisfy, and their fulfilment is all that the philosopher needs in order to pursue his way of life" (Epicurus as quoted in [166] (p. 182)).

They knew two ways to generate the surplus: increase production or decrease consumption. Managing production and consumption autonomously and intelligently according to one's own free choice and considering psychological aspects was a very interesting way of conceptualizing the economy. Psychological health was maintained through an economy of desire so that "by moderating his needs [desires], the philosopher can spend most of his time philosophizing" (Xenophon as quoted in [164] (p. 229)).

From the experience of the ancient Greeks, the oikos would naturally produce abundance, resulting in luxury if traded on the market. Within the Greek philosophical culture, however, luxury was considered immoral, as it ensnared the human mind in the endless pursuit of insatiable desire—it makes one lose time. Moderate surplus, by contrast, was considered optimal because it enabled the head of the household to free himself from being caught up in business and engage in philosophy instead, that is, have free time to delve into the world of ideas and pursue ideals. The original economy was thus primarily an economy of time: time management in the context of needs and environmental constraints [164].

As Pungas [17] points out, the smallholder household and its associated house- and farmwork are major blind spots in today's bioeconomy agenda. These blind spots are the invisible foundations that have ever since supported and sustained the economy but have not been recognized as such, have been devalued, and have been deemed undesirable [167]. Ever since humans have reverted to a sedentary lifestyle, households were most often surrounded by small pieces of land from which the household members drew basic resources needed for making a living [168]. Today, around 2 billion people live in smallholder households [169]. People are classified as smallholders when the size of their farm is less than 2 hectares in size. [170]. In the current (bio)economy, these are not considered worth mentioning and thus remain invisible, even though they constitute a substantial part of the economy. What is visible in the (bio)economy is only formal wage labor [17]. Estimates suggest that smallholders produce 30–34% of the global food supply using 24% of the agricultural land, implying that the surplus is rather significant [171]. Smallholders are marginalized even though these invisible spaces have since time immemorial served as basis for the satisfaction of the needs of the human population. Without them the economy would collapse [17]. We suggest that these invisible spaces can be seen as opportunities, as pockets of freedom, that exist outside of the current economic system and that these in principle could serve as nuclei for a transition towards a post-industrial age, leapfrogging the fossil resource age.

4.2. Bioeconomy as the Merging of Nature and Culture

A transition towards a more desirable state can only be successful if the concept of a bioeconomic utopia is not in conflict with the culture and belief system of a given place. A bioeconomy can only take root if the idea is culturally acceptable and compatible (cf. [172]). As mentioned above, culturally evolved worldviews provide a basic framework for human orientation [27]. These shared beliefs, or memes, play a decisive role in how we act and whether a society descends along the vicious spiral of entropy (or ascends along the spiral of virtue; cf. [173]). The Promethean problem, the problem of human creative power, is discussed in most organizing myths, as it presents a universal human challenge. Spiritual traditions, both religious and indigenous, show an astonishingly high level of discourse on the philosophical question of human freedom and the issue of ecological responsibility; for example, the concept of a sacred nature or landscape seems to be held in all indigenous cultures in some form [44,174–177]. The ecological knowledge that so-called indigenous people have developed in intimate relationship to the land is an immense resource that bioeconomics can and should recognize as a basis for cooperation.

Even though religious concepts have been widely used to justify environmental disruption and colonialism on a global scale over the past centuries, all major religions also, in one way or another, emphasize human accountability in regard to ecological issues [178,179]. We may thus argue that the idea of a bioeconomic utopia is "endemic" to the human mind and can provide a universally acceptable vision compatible to local cultures around the world. Beliefs, however, do not necessarily translate into actual practice; so, as Berkes writes, "there is invariably a gap between 'the ideal' and 'the actual' in making sense of how societies deal with biodiversity" [178] (p. 110). How such conceptions can indeed translate into actual practice is demonstrated in the example of the church forests of Ethiopia, oases of biocultural diversity [180–182]: Church forests are biocultural diversity hotspots found around community churches and monasteries in rural Ethiopia. A view on the northern and central highlands of Ethiopia from above reveals a landscape dotted with small green patches spread all over barren land. The small fertility oases, each symbolizing the forest garden of Eden [183], are the only remnants of the biodiversity that was once prevalent in this mountainous region. Today, these church forests make up 100% of the regional forests [184]. The church forests are the last pillars of ecological stability in the region and serve as a refuge for many endemic and endangered species [180]. The forest is composed mainly of endemic species but is augmented with plants that are used in relation to the satisfaction of human needs. As Alem and colleagues highlight, the "local people rely on these church forests for the provisioning of livestock feed, tree seedlings, fuelwood, honey, clean water and other essential ecosystem services including shade, climate regulation, habitat for pollinators and spiritual values" [185] (p. 2). Being under human stewardship, church forests integrate nature and culture into one unified system. Festivities and meetings perpetually attract the community members to these oases of biocultural diversity. They do not only serve as sanctuaries for the endemic flora and fauna but also for humans. If, for example, people from the local communities find themselves in need, they can find shelter in the church forests and are allowed to stay and use some of its produce to meet their needs. Furthermore, those people who have chosen a spiritual path seek out these spaces to advance on their path without distraction.

The phenomenon of the church forests demonstrates the critical role cultural ideas and memes play in determining how people treat their respective environments and thus influence the functionality of ecosystems. Nature and culture can indeed merge and this should be an essential objective in the bioeconomic transition. In general, as this example has aimed to stress, a common understanding on matters of ecological health between science and local culture on the basis of local myth in relation to bioeconomics allows local people to embrace the transition intuitively when the underlying concepts have correspondences in the given local knowledge system and facilitates participation at eye level and mutual exchange in a transdisciplinary manner [177,186]. The bioeconomy should, therefore, serve as a reviving force for local culture.

4.3. Niche Construction of Agroecological Habitat Systems in Human History

As an expression of autonomy, niche construction is a universal survival strategy in the biosphere [58–60,139,142,187]. By transforming different landscapes of the planetary ecosystem into fertile habitats, humans in the past have been able to colonize a broad range of ecosystems and came up with very different answers to the universal question on how to guarantee long-term survival. This resulted in all kinds of successful and unsuccessful attempts to create and occupy different habitats. When the Amazonian region was colonized by humans at the end of the last ice age, for example, these humans encountered a savannah ecosystem that was seasonally flooded, making it difficult to cultivate crops. So, they constructed a new niche, rearranging the landscape with the intention to increase its fertility. They constructed mounds that remained above the water level in times of flood. On these mounds, they cultivated trees and food crops and, as Lombardo et al. explain, already more than 10,000 years ago, "began to create a landscape that ultimately comprised approximately 4700 artificial forest islands within a treeless, seasonally flooded savannah" [188] (p. 190). These human-made forest islands thus became major hotspots of biodiversity and crop domestication in the region, in which wild crops were transformed into food crops [188]. One of the greatest wonders of habitat engineering in the ancient world was the kingdom of Saba (or Sheba); situated on the spice route in present day Yemen, Saba was renowned for its magnificent irrigation technology that was used, as Weiss and Gerlach write, to create the "largest oasis landscape that was artificially created in ancient times and was in continual operation for thousands of years." [189] (p. 1). The Great Marib dam and its associated canals, basins, and sluices, which could be opened and closed, were the heart and lifelines of the Kingdom of Saba. At its peak, the dam turned around 9600 hectares of dry land into a rich and fertile oasis by collecting, storing, and distributing the monsoon rains of the Yemeni highlands [189].

These are all successful examples of human niche construction, where the constructed habitat exhibits a positive overall effect on the surrounding ecosystem, enhancing biodiversity and ecosystem services over time, thus allowing humans to meet their needs reliably. Apparently, there is a vast potential in the creation of novel ecological habitats. As human beings, we certainly have the power to destroy ecosystems, but we also have—and have always had—the capacity to create viable agroecological habitat systems and enjoy their long-term benefits for survival without compromising the survival of other species and the stability of the ecosystem. Given the knowledge available today, the invention of new agroecological habitats is not only a matter of long-term survival but it might also pose one of the most fascinating creative activities available to the human experience. Human interference into ecosystems can and should result in a virtuous spiral of self-organization.

4.4. Biocosmonauts and Their Organic, Coevolving Entourage

The challenge that presents itself is a normative one; it is sketching the bioeconomy not as it is but as it should be. The bioeconomy should be concerned with the challenge of merging the human economy with an ecological matrix instead of a technological one. That is its self-imposed obligation. What is explored, therefore, is the possibility of a new human niche, which is fully embedded into the biosphere. This new habitat system is designed for the maintenance and even enhancement of the functionality of the ecosystem services that provide humans with material and immaterial nourishment and serve as a solid basis for a state of human health and well-being—and restore the connection to the vast sea of potentiality.

Primarily, bioeconomics is concerned with the acquisition and utilization of resources needed to make a living [8]. We all have needs, and so we need to access those resources that can be turned into those things that satisfy our needs (food, shelter, medicine, materials, etc.). In order to safeguard individual freedom and increase creative potential, the ecological matrix is designed "around" individual humans and their household to directly provide for the needs of the household members without intensifying external dependencies and obligations. As time is irreversible, the utopia presented in this article is not about going "back to nature", it is about going "forward *as* nature". The possibilities are limited only by the degree of fluidity of our minds and our competence to actualize an imagined world.

What is imagined, therefore, is the transformation of the private household (and its associated smallholder farm) into a complex agroecological habitat system, the *biocosmos*. The biocomos is a productive ecological and socio-economic unit that is self-sufficient and generates surplus. The biocosmos is best understood as a life support system composed of a synergistically combined community of lifeforms necessary for making a living. The community of beings form a functional bioeconomic pattern—an interaction pattern of irreducible complexity that is syntropically embedded into its local ecological context.

This pattern of irreducible complexity must be designed in such a way that the degrees of freedom of the household members, the *biocosmonauts*, are maximized and dependencies are reduced to a minimum. In this way, we can make use of one of the main advantages of biological over mineral and fossil resources in that biological resources can be brought into close proximity of the individual household—as they are available and accessible to anyone.

What is looked for is the smallest community of beings necessary to provide the household members with the spectrum of resources required for restoring and maintaining their health and the health of the ecosystem without compromising their autonomy. Thus, the individual creates the world s/he wants to live in. His/her personal preferences and the natural constraints narrow down the spectrum of possibilities. The biocosmos is based on the fostering of mutualistic coevolutionary relationships between floral and faunal species and the household members. The bioeconomic demand is based on the needs; the bioeconomic supply is based on the possibilities the local biosphere harbors. And vice versa, each species has its own specific set of needs that are to be known and satisfied. These needs-based interactions are the "market" in the bioeconomy. The currency is time, and so the bioeconomy is about managing one's time in the context of needs and environmental constraints. As previously mentioned, needs are universal and relatively constant; what varies is the way or means by which these needs are satisfied [47]. In other words, how we satisfy our needs is relatively open. Which variation one selects is a question of personal preference and natural constraint. This dialog between the point-of-view and its circumference results in a unique style. The biocosmos is a new style of nature, a new evolutionary pathway.

The navigator of the biocosmos, who manages this living household, is the biocosmonaut, whose terrain is the fluid ocean of possibilities that he/she discovers and explores within the realm of creativity and imagination. In this fluid state, the biocosmonaut exists on the edge of order and chaos, at the liminal frontier where the unknown becomes known, where fluid possibilities coalesce into discrete space-time patterns of new possible worlds. The mind of the biocosmonaut stabilizes at the critical juncture, where the evolutionary paths of all companion species come together, thus co-authoring the "Book of Nature" by inscribing into it new patterns of life.

Nature provides us with potential to satisfy both our physiological as well as our psychological needs. We receive those gifts by coupling, bonding with *the other*. It is our natural drive for relationships that allows us to be sensitive and commune with other species, the place, and the rhythms and patterns of nature, as well as other people [44]. These bonds allow us to form an ecological pattern, a web, which guarantees the reliable provision of goods and services needed for a decent life. This tendency is therefore our main strategy in the process of evolution. From this perspective, the boundaries of the self dissolve [70], allowing the individual to gradually merge with the biocosmos.

However, nature is also the source of chaos and erosion (pathogens, radiation, toxins, temperature fluctuations, and so forth). They comprise the hostile side of nature, which is something we need to protect ourselves from, something we have to resist. In order to shield ourselves from the erosive action of nature, we build houses and equip them with furniture, acquire food and medicine, make clothes; we remove waste in all its forms and keep things clean, etc. We do so in order to reduce fluctuations in temperature, radiation, rain, wind, etc., acting upon us. All these activities are responses to the destructive side of nature, which constantly challenges our homeostatic balance and triggers responses lest we perish. We respond to these from the standpoint of our autonomy, which allows us to resist stress and push back the boundaries of constraint. Doing so makes us stronger and more powerful (as explained in Section 2). Autonomy is self-referential and makes us internalize our environment and restructure it in reference to ourselves. The biocosmos, seen from this perspective, is like an ecological fabric, a dress around the human being who has extended his/her boundaries to the periphery of the biocosmos. And so, with one hand, nature provides for us, and with the other hand nature challenges us, which is necessary for our growth. Correspondingly, with one hand we receive the gifts of providence, and with the other we ward off erosion, entropy. The result is a balanced relationship between humans and nature, as schematically depicted in Figure 1, which summarizes this balanced relationship based on the concepts outlined in this article. These principles form the basis of what could be called *biocosmology*.

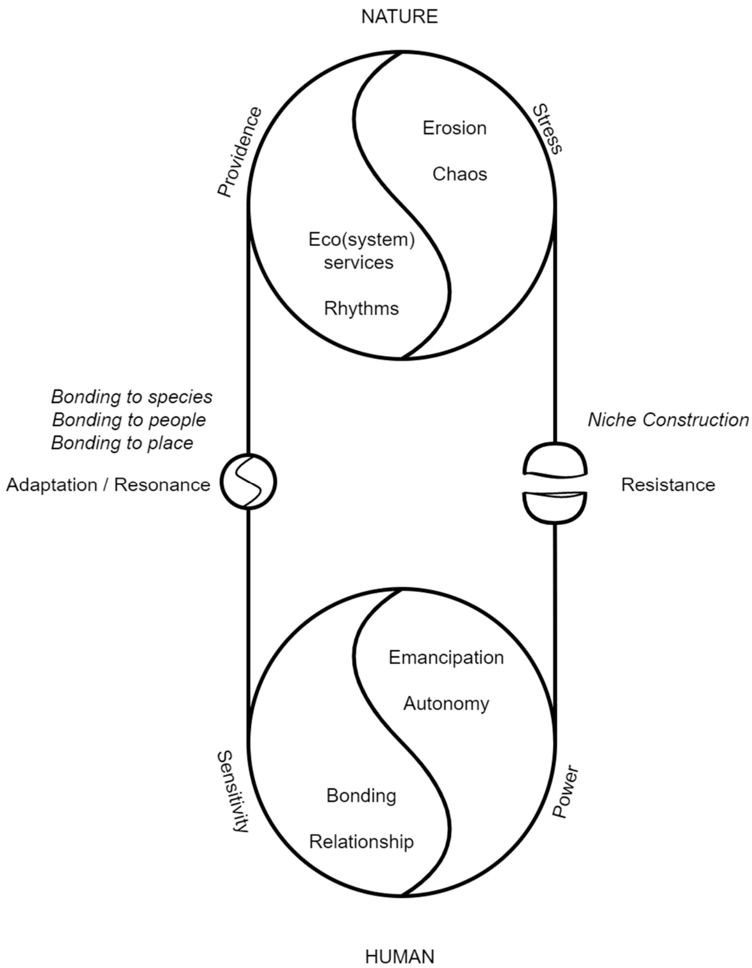

Figure 1. Harmonized human–nature relationship in the biocosmos.

Instead of relying on exosomatic instruments (technology), the bioeconomy as sketched in this utopia is to be based on the "human instrument", its faculty of imagination, its motivational drive, its sensitivity, its workforce, and creative skill. These capabilities can and should be developed. "Insofar as he makes use of his healthy senses, man himself is the best and most exact scientific instrument possible" (in Goethe's terms [190], p. 311). The operation of a biocosmos thus involves three different sets of key tasks:

(i) cultivation of crops and microorganisms (bacteria, algae, yeast, fungi);
(ii) processing of the produce to obtain a broad spectrum of substance possibilities;
(iii) the creative and synergistic combination of the building blocks to produce the complex set of satisfiers and thus create the world one wants to live in.

The community of beings is grouped into a network of five small biomes that mimic the evolution of the local ecosystem and create an ecosystem of high complexity and high density that is meant to power the ecosystem services. These biomes include but are not limited to:

- a microbiocosmos (bacteria, algae, yeasts, fungi);
- a wetland biome;
- an annual grassland biome;
- a perennial grassland/heathland biome;
- a forest biome.

These are the organ systems of the biocosmos.

4.5. The Creation of a Biocosmic Superorganism

Constructing a niche begins with the reorganization of the prevailing order of a particular place yet with the intention to better bring out its potential. Here, the biocosmonaut is the agent of "creative destruction" in the Schumpeterian sense, breaking the existing pattern that keeps the essence below its potential so as to allow a new pattern with a higher density of life to form. Then s/he populates the place with life, regenerates the place. The backbone of the biocosmos is based on locally endemic species which are augmented by a community of species necessary for human survival. By designing a new ecological pattern, the biocosmonaut acts as agent of creation. S/he bonds to the community of beings s/he has selected and woven together, thus acting as a "systems entrepreneur" co-creating a dedicated innovation system [191]. Here, her/his sensitivity to *the other* is the dominant mode as s/he tries to sense the needs of her/his species and manage the household so that all species in her/his estate get what they need. But then again, s/he destroys the web s/he has woven as s/he responsibly and "honorably" harvests (cf. [177]) the produce and dismembers the species in order to convert them into useful parts.

But s/he does so only because s/he will regenerate the parts again and bring them back to life. Thus, the biocosmonaut transforms nature into culture. This is the realm of arts and crafts. There, s/he brings the parts together to inhale new life into them, resurrecting the dismembered parts into meaningful "wholes", which together form what Koestler calls "holon" [192]. Multiple products and/or satisfiers (including water, food, shelter, clothes, medicine, etc.) are formed, possessing advanced, aesthetic, and even high-performance properties using just a few tools. The human being is the creator and the keeper of his/her household and coevolves with his/her companion species, adapting to their needs as they adapt to his/her needs. They all share the fundamental experience of the cosmic polyrhythm to which they all are aligned and synchronized in complex ways [44]. Together they form an elastic structure that self-regulates. The different biomes are the evolutionary history of the biocosmonaut; they remind him/her of his/her past as s/he carries them into the future. Gradually, they merge into a single unit. This unit is, by definition, a superorganism, a biocosmic superorganism—the first of its kind.

Being situated in a unique environment and housing people and other beings with unique preferences, each of these entities is different. Since each biocosmos also produces surplus, these superorganisms are destined to interact with one another to engage in concerted creative processes, for example, in a polycentric network [193]. These constellations are flexible and elastic; the individual superorganisms do not depend on one another for their survival, but maintain their sovereignty at all times, which allows them to freely engage and disengage in relationships with other biocosmic entities.

Since the biocosmos consists of a diversity of microhabitats, they attract life forms from the different trophic levels and a trophic hierarchy naturally forms over time. The biocosmos thus acts like a magnet attracting life; the plants attract insects, which attract birds, and so forth. Like the church forests of Ethiopia mentioned in Section 4.2, the biocosmos serves as a refuge for life, so that the biocosmos gradually evolves into a local biocultural diversity hotspot. The details of the process and its accompanying transition pathways and exnovations go beyond the scope of this article and shall be the subject of further research.

5. Discussion and Conclusions

5.1. Recapitulation

The bioeconomic utopia presented in this article illuminates some blind spots of current bioeconomy developments against the backdrop of how Georgescu-Roegen understood the term 'bioeconomics'. With our article, we thus contribute the following seven key take-away points to the bioeconomy discourse. First, a genuine realization of a (type I) bioeconomy is impossible within the framework of the present economic system and its underlying thought routines or memes. Second, the conceptual boundaries between the human world and the rest of the biosphere are to be dissolved. The bioeconomy should be defined as the combined effect of all needs-related activities in the biosphere [8]. Third, ecosystem services and goods are the "supply side" of the bioeconomy, while needs constitute its "demand side". Fourth, according to the principle of reciprocity, these roles also have to swap, that is, the ecosystem also has needs, which the human being has to satisfy in order to maintain the reliable long-term provision of ecosystem services. Fifth, the phenomenological basis of human needs is found in the unconscious motivational drives that form the basis of human activity and are directed by the conscious mind, that is, attention. Human bioeconomic activity is, therefore, a concerted operation of drive and attention that produces purposeful behavior in anticipation of the satisfaction of needs. Sixth, the collective unconscious has the unique and natural function to serve as a reservoir of latent creative potential. Seventh, the household—the invisible foundation of the (bio)economy—can be seen as an opportunity for a transition towards a bioeconomic utopia.

5.2. Outlook: A Glimpse Ahead

Both the rhythmic elemental framework discussed in Section 2 as well as the entire web of life that forms within it and evolves through diversification and integration are sensitive to the potentiality that comprises the invisible yet ever-present background of the cosmos. By means of amplification, potential from that sea of possibilities can spontaneously be actualized macroscopically by rhythmic systems, which exist at the edge of chaos and order. This means we live in a cosmos that is profoundly creative [194,195]. This natural creativity is also present within the deeper strata of the human mind, where fluid patterns and vague images emerge and may, over time, crystallize into discrete ideas to produce novelty. Creativity however, is a double-edged sword [195]; it entails a necessary disruptive element—a "Faustian aspect" [196] that can have vicious effects if not responsibly directed by genuine purpose. This is the Promethean problem, our own creative power, which allows us to give directionality and purpose to the evolutionary process.

One key challenge of transitioning towards the bioeconomic utopia sketched here is to overcome the self-reinforcing mechanisms, the rigidified thought patterns and routinized patterns of behavior, and the associated structures that keep us trapped in the "technobureaucratic matrix". This rigidity has been conceptualized using different terminology such as "lock-in" [197], "path dependence" [37], "undesirable resilience" [81], "wicked resilience" [198], "unhelpful resilience" [199], or "traps" [200], depending on the specific discipline (cf. [81]). Whichever terminology we might favor, as Oliver et al. highlight, "unless we can tackle the strong feedback mechanisms that maintain a given system in its current undesirable state", endeavors towards a more desirable system state remain abstract and theoretical [81] (p. 3). We suggest that these self-reinforcing mechanisms may be bypassed. There are blind spots within the dominant system that exist as if outside of the existing order and its self-reinforcing mechanisms. Using Graupe's geological metaphor [132], one could say that the dominant system is but the solidified crust, underneath of which there is an invisible foundation that constitutes the fluid potential capable of initiating a transition. Since self-provisioning of commodities in private households and transactions among private households may involve neither money nor the formal market routes, this informal sector has been mostly ignored in the present economic system. Yet, without these informal activities, the economy would arguably collapse [17]. However, even in the current bioeconomy debates, the domain of the private household and self-provisioning activities are not considered worth mentioning and thus remain invisible. Hence, these invisible spaces can be seen as opportunities, as pockets of freedom that exist "outside" of the dominant system. Therefore, the private household can serve as nucleus for a transition towards the bioeconomic utopia outlined in this article. While the dominant bioeconomy narratives are based on top-down approaches through policy, legislation, and technological innovation, the original concept as defined by Georgescu-Roegen—on which our utopia is founded—is a counter-expertise approach that intends a transition in accordance with the principles of self-organization.

What does this imply for support structures and scaffolds aimed at creating the conditions for this self-organization? The transition towards a biocosmic future can be assisted by the creation of biocosmic community centers that serve as epicenters of diffusion. These centers are the "motherships" that contain and provide the basic elements needed to launch the creation of the biocosmos at the household level in the given community. These centers are meant as biocultural hotspots mushrooming from the invisible underground to facilitate the multiplication of these superorganisms. Here, new cadres of biocosmonauts are trained to responsibly navigate the biocosmos and thus actively and consciously participate in the process of evolution. These centers are meant as platforms, where knowledge, skills, and practices are developed, compiled, and shared. In more advanced stages of the transition, these spaces can be used to coordinate collective action. These nuclei of diffusion can be set up by local "systems entrepreneurs" [191], to activate a chain of commitments and serve as models for the concept of the biocosmos. These centers may also serve as seed banks and breeding spaces for relevant plant and fungal species and microbial cultures. This provides the local people with the resources they need to begin and advance in the transition. It can also serve as a meeting place where local tradition and bioeconomics are brought into contact with each other so as to find a common conceptual basis for a transition that is in line with and sheds new light on the given local philosophy and memetic belief system. In line with this eye-level contact, local artists and craftsmen are included in the process of reviving their local traditions in light of bioeconomics.

A substantial number of human beings live in rural areas and every fourth human being is a smallholder, that is, they are already in the possession of land. Those who are not may gain access to land. Primarily countries in the Global South—where the potential for agroecological production is high—are particularly suitable for a bioeconomic transition. Ironically enough, it is there that poverty is most prevalent. The biocosmos may thus be an effective means to eradicate poverty and restore human dignity to those who have been excluded from the present industrial order, which they have been carrying on their backs.

The biocosmos is, however, not limited to a particular geographic location; it can be embedded into almost any landscape. If implemented in cities, where land availability is limited, emphasis can be put on the community of selected microorganisms; these can be cultivated indoors [201]. Cities also pose a great opportunity to tap into existing waste streams and turn these into value by means of microbiology.

The biocosmos may also be a means to regenerate contaminated sites or to counter desertification. Abandoned mines and other polluted or desertified areas can be remediated through the biocosmos and turned into habitat systems that restore ecosystem functionality. In cases of pollution, emphasis is put on bioremediation by means of bacteria and plants that can mobilize and extract the given pollutants from the soil, which can then be transformed into value.

Finally, the biocosmos can also be a way to populate new territory. This habitat system can be constructed as a floating platform in lakes or on sea in what is known as seasteading. Given that 71% of the earth's surface is water, the possibility of venturing into the blue is not as far-fetched as it might first appear. Moreover, the sea is, in principle, neutral territory, which would allow for the creation of a diversity of floating households that could be integrated into autonomous floating cities, communities, or (polycentric) nations. Seasteading is a reasonable way to escape the rigid structures that occupy the landmass of the planet and prevent the emergence of new forms of living. However, the existing approaches on seasteading are based on high technology instead of ecology.

To navigate further towards the realization of the bioeconomic utopia, the following six important avenues for further research are suggested, though they are, however, far from exhaustive. First, the bioeconomy needs a knowledge base! Part of the normative task for the bioeconomy is to compile and make accessible knowledge that provides capabilities relevant for the satisfaction of real needs. Knowledge becomes meaningful only if applied for meaningful purposes. The challenge, therefore, is to gather, compile, and make accessible knowledge from various sources (academic, traditional) to transform it into embodied knowledge or capabilities relevant for the creation and operation of the biocosmos. We therefore call for the creation of an organic body of knowledge that can be embodied and distributed by biocosmic community centers as mentioned in the previous subsection. Second, given the complexity and scope of the topic, which requires that concepts from a broad diversity of academic disciplines and non-academic sources of knowledge are integrated, there are certainly concepts that—even though relevant—have not been addressed in this article. Hence, further knowledge synthesis is needed in this regard. Third, although we have been critical of top-down approaches and bureaucracy, it is certainly an achievement of modernity to have produced a "social ontology" [129,202] that differs from the "natural ontology", namely functionally differentiated social subsystems [127,203]. What has been forgotten in modernity, however, is the fact that the entire "social ontology" is only viable if it is compatible and in resonance with the "natural ontology". The ecological crisis we face confronts us with the contingency of the "social ontology" of our modern social existence. Hence, future research is needed on the specifics of a naturally compatible social ontology that is in line with emergent phenomena and complex systems (instead of rigid, bureaucratic/technocratic, and mechanistic ontologies). Fourth, in this connection, having focused on a bottom-up approach, the roles of formal institutions remain to be defined in regard to possible transition pathways, phase-out and exnovation processes, and transformative policies. Fifth, for biocosmonauts to plant "seeds of change", the complex task of transforming existing policies, legislations, contractual relations, standards, and codes of conduct has to be addressed, and a chain of commitments for these actors in their (potential) role as "systems entrepreneurs" as discussed in [191] needs to be defined and specified. Sixth, one of the most immediate tasks is to develop a comprehensive modeling process that can be applied to designing the biocosmos. A complete biocosmos will have to be modeled to demonstrate what is possible. This will have to include the selection of a specific site, species, conversion processes, and crafts.

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