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Article

Sustainable Capital? The Neoliberalization of Nature and Knowledge in the European "Knowledge-based Bio-economy"

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Abstract: As an EU policy agenda, the "knowledge-based bio-economy" (KBBE) emphasizes bio-technoscience as the means to reconcile environmental and economic sustainability. This frames the sustainability problem as an inefficiency to be overcome through a techno-knowledge fix. Here ecological sustainability means a benign eco-efficient productivity using resources which are renewable, reproducible and therefore sustainable. The KBBE narrative has been elaborated by European Technology Platforms in the agri-food-forestry-biofuels sectors, whose proposals shape research priorities. These inform policy agendas for the neoliberalization of both nature and knowledge, especially through intellectual property. In these ways, the KBBE can be understood as a new political-economic strategy for *sustainable capital*. This strategy invests great expectations for unlocking the productive potential of natural resources through a techno-knowledge fix. Although eco-efficiency is sometimes equated with biological productivity, commercial success will be dependent upon new combinations of "living" and "dead" labour.

Keywords: knowledge-based bio-economy; European Technology Platforms; innovation narratives; techno-knowledge fix; neoliberal nature; *sustainable capital*

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1. Introduction

European Union institutions continuously elaborate visions of imagined futures. As exemplified by the 2000 Lisbon Strategy [1], the Europe Union was meant to become the world's leading "knowledge-based economy" (KBE) by 2010, where knowledge is closely linked with technological innovation. Whether or not such imagined futures are achieved is less important than their role in shaping political-economic policies, institutional practices and wider societal changes. These changes are promoted through master narratives, such as the KBE, conflating technological advance with societal progress [2].

One increasingly important narrative is the "knowledge-based bio-economy" (KBBE). According to the European Commission, the KBBE is "the sustainable, eco-efficient transformation of renewable biological resources into health, food, energy and other industrial products" [3]. This has been elaborated through a partnership between EU institutions and European Technology Platforms (ETPs) in the agro-food-forestry-biofuels sectors. These ETPs produce vision documents and strategic research agendas that shape public research funding priorities through particular framings of natural resources, future markets and societal progress. This informs broad research and innovation policy, especially in relation to Framework Programme 7 (FP7).

This paper explores the following questions: How does the KBBE narrative favour a specific account of sustainability? Towards what wider aims? What alternative narratives contend for influence?

Although the KBBE concept could have imagined diverse futures, in practice it has favoured European policy frameworks around specific technological choices and neoliberal accounts of nature. The KBBE narrative discursively frames economic and environmental crises in ways that favour particular solutions, while demoting other potential solutions. In turn, the narrative promotes changes in wider policy frameworks constituting specific strategies as necessary and feasible.

Alongside supporting the extension of neoliberal market-like rule, the KBBE also elaborates an ecological vision reconciling environmental and economic sustainability. Here renewable is equated with sustainable, thus naturalizing a particular political-economic strategy. In this vision, technological innovation unlocks the renewable, biophysical characteristics of nature itself through genetic and bio-molecular knowledge, thus enabling the continuing expansion and accumulation of capital. This can be analyzed as a techno-knowledge fix, which provides a basis for creating *sustainable capital*, not just sustainable capitalism.

In order to carry out this analysis, we draw upon theoretical literature from geography on neoliberalization of nature [4,5]. We aim to show how the KBBE narrative reflects a specific techno-knowledge fix based on the harnessing and commodification of genetic and bio-molecular science in the intensification of natural productivity for commercial exploitation. This has been theorized as the *real subsumption of nature* by Boyd *et al.* [6]. We first outline the theoretical discussions around the neoliberalization of nature, before applying these insights to the KBBE narrative and its particular framing of sustainability. Then we apply these insights to the dominant KBBE narrative and its particular framing of sustainability—by contrast to some alternative, agro-ecological agendas. Finally we summarize those divergent agendas and comment on future prospects within the EU policy context.

2. Neoliberal Natures and *Sustainable Capital*

Over the last few years, geographers have built up a considerable body of work focusing on the neoliberalization of "nature" or, more precisely, the *neoliberalizations of natures*. Noel Castree [4,5], for example, has provided an extensive review of this material exploring the different logics, processes, effects and evaluations of neoliberalism in relation to different natural resources. In reviewing this material, Castree ([4], p. 137) draws attention to the "variants (or modalities) of nature's neoliberalisation"; he thereby highlights the need to think not only about the varied nature of neoliberalization as a process (*i.e.*, varieties of neoliberalism), but also "the biophysical influence of nature in the neoliberalisation process" (*i.e.*, varieties of nature) [4]. This latter point has also been made more generally by Gavin Bridge with regards to the emerging programme around environmental economic geography [7]; namely, that we need to consider how the biophysical characteristics of different natures, or natural resources, "make a difference to the functioning of economic processes" ([7], p. 79).

Although this is an important research agenda in its own right, we still have to consider how nature is made into (or 'becomes') a "resource"—an issue which Bridge has considered elsewhere [8]. In this other article, he argues that resources are political constructs. Although they may be unstable and heterogeneous constructs because of competing and contrasting interests, "resources "become" only through the triumph of one imaginary over others" ([8], p. 1221). Thus the construction of natural resources depends upon particular narratives, visions and knowledges that justify particular policies, whilst at the same time pre-empting other possibilities.

With regards to the neoliberalization of nature, this means that we need to consider the various processes that constitute nature's neoliberalization. This entails numerous different (and often contradictory) processes including privatization (e.g., of land), marketization (e.g., of air), deregulation (e.g., of environmental protection), reregulation (e.g., biodiversity), liberalization (e.g., of trade in resources), competitiveness (e.g., in resource markets) and so on. Some literature has analyzed how these diverse neoliberal processes are variously framed in policy narratives as problems (e.g., loss of global market competition in natural resources), opportunities (e.g., marketization of natural resources) and solutions (e.g., liberalization of natural resource trade) [9]. In turn, such policy narratives, discourses and visions help to constitute nature as a freely available "resource". Such narratives are based upon a neoliberal ethic underpinned by the idea that "free" markets, "free" market exchange and a "free" market logic should be the core organizing principles of economic, social, and political relations [10,11]. Furthermore these policy narratives inform the procedures and institutions that drive the neoliberalisation of nature through the production of new knowledge.

Neoliberal processes operate in recursive rather than linear ways. Privatization of natural resources does not directly liberalize their trade, nor their discursive enrolment in the political construction of resources. Rather these neoliberal processes circulate through policy narratives in contradictory ways as they are enrolled to support particular policy positions, specific political interests and distinct institutional concerns. In this sense, the policy and natural world are closely entwined in the construction of natural resources. The policy world, in turn, is more than an array of different narratives, arrangements and mechanisms; it consists of broader *policy frameworks* which frame particular forms of policy-making and implementation as necessary, understandable and ultimately feasible [12]. These policy frameworks consist of the wider social, political and economic geographies in which decision-makers work. Such policy work consists of policy analysis, the construction of policy visions, the outlining of policy prescriptions, the modes of policy implementation, amongst other things.

In much of the world today, the dominant policy framework embeds neoliberal narratives that construct natural resources in particular ways. As Charles Thorpe argues, this construction entails the "decontextualisation, reification, and commodification of the productive and reproductive capacities of living things" in the pursuit of profit [13]. For a long time, this has meant transforming nature into resources through commodification following extraction; this can be seen as the "formal subsumption of nature", by analogy to labour exploitation. It also increasingly involves the "intensification of biological productivity (*i.e.*, yield, turnover time, metabolism, photosynthetic efficiency)"—or the "real subsumption of nature". Nature "is (re)made to work harder, faster and better", according to Boyd *et al.* ([6], pp. 563-564)

The latter imposes capitalist logics on nature in ways that transcend the processes of privatization and commodification [14]. It reorients the biophysical characteristics of nature by devising new knowledge and technologies in order to increase productivity and thereby the accumulation of capital. As Boyd *et al.* note [6], this analysis cannot assume the predictable compliance of nature to intensification efforts, thus leaving room for both pleasant and nasty surprises.

Policy frameworks embedding neoliberal narratives go beyond David Harvey's concept of "accumulation by dispossession" [15]. The latter primarily relates to the privatization of "common" (or shared) resources which concerns the "opening up of new arenas for investment and accumulation", according to Himley ([16], p. 443) Neoliberal policy frameworks also rework natural resources through new knowledge and technoscientific developments, which are themselves built upon the logics, strategies and expectations of capitalist accumulation through state-led (and -protected) market exchange. Thus the neoliberalisation of nature is tied to the neoliberalisation of knowledge, both of which can be seen in these wider policy frameworks that support and promulgate the real subsumption of nature through new knowledge to a capitalist logic.

These policy narratives, visions and expectations depend upon the reciprocal circulation of neoliberal concepts throughout policy frameworks; issues are variously identified as problems or threats, opportunities, and solutions. Moreover, there is a new discursive emphasis relating to natural resources that goes beyond the emphasis on commodification. It marks a distinction between the formal and real subsumption of nature highlighted above [6]. On the one hand, there is a continuing discursive emphasis on the idea of an "ecological fix", which Karen Bakker ([17], p. 1782) defines as "strategies of externalization and internalization of socioenvironmental conditions, in search of profit, both by states and by capitalists". The ecological fix relates to the externalizing of costs by firms (e.g., pollution), which can then provide opportunities for further capital accumulation by the same or other firms (e.g., emissions trading) [16,17]. On the other hand, there is increasing emphasis on a "technological fix" to ecological and economic crises, in which new knowledge and technoscientific developments (or imaginaries in many cases) are enrolled in the real subsumption of nature through its intensification by increasing the productivity of natural resources.

The real subsumption of nature necessitates new knowledge to create a technological fix or, more accurately, a "techno-knowledge fix". This latter concept adds to debates on the neoliberalization of nature, primarily because it illustrates processes broader than the privatization and commodification of natural resources. Although these processes remain relevant, it is the privatization and commodification of techno-knowledges that enable the real subsumption of nature, thus introducing the key novel feature of a new political economic strategy. For example, the introduction of new fertilizer technologies or genetically engineered crops, designed to increase crop yields, requires an "increase (in the) reliability, predictability, efficiency, and control" of nature, regardless of whether it commodifies "nature" [13]. To capture value from this control necessitates the privatization and commodification of new knowledge, rather than nature itself. Biophysical characteristics of nature may prove recalcitrant to more efficient use, so there is no way to ensure predictability or control of nature prior to implementing new technologies [4,7]. Thus the neoliberalization of nature depends upon privatizing knowledge of biophysical *function* rather than biophysical *form*; this marks an important distinction between the formal and real subsumption of nature.

This real subsumption of nature depends on an emerging political-economic strategy based on the idea of *sustainable capital* (and not just "sustainable capitalism"), as a shift from earlier regimes. Classically, capital accumulation has been "vampiric" in utilizing energy and natural resources, thus wasting them. Not merely negligent, such waste has resulted from the drive to increase labour productivity. This has been the "chosen metric of wealth in the capitalist era" ([18], p. 9). By contrast, in the KBBE narrative, resources become forever renewable through new technoscientific developments which improve the efficiency and intensity of resource usage. Economic growth can thereby avoid the "Jevons Paradox" whereby falling resource costs—as a consequence of increasing productivity—lead to increasing demand for resources and their potential depletion [8].

As an implicit concept, *sustainable capital* is built on potentially new forms of capital formation, energy and labour power. In some accounts, renewable resources even provide new forms of surplus value generated by nature itself [19]. By contrast, other analyses leave aside the question of whether or how the real subsumption of nature may depend on human labour. According to Boyd *et al.*:

> "In adapting these (subsumption) concepts to analyze nature-based industries, our aim is not to devalue the place of human labor in the production process, nor to engage the complex involutions of value theory. Rather, we use these concepts as a means to highlight some of the different ways in which biophysical systems are industrialized and, in some cases, made to operate as productive forces in and of themselves" ([6], p. 562).

Regardless of labour's role, some natural resources are seen as inherently sustainable and/or eco-efficient because they are renewable. As long as their productivity can be intensified, they will be able to replace existing (and wasteful) inputs in production (e.g., fossil fuels, capital derived from petroleum-dependent industries *etc.*). Their biophysical characteristics—*i.e.*, their function rather than form—are discursively conflated with capital. This conflation brings the promise of capital that is sustainable and/or efficient because it is renewable. In this cornucopian vision, certain forms of natural resources and their usage can reconcile economic with environmental sustainability. Life itself is characterized as capital, forever renewable and forever productive. Thus nature is meant to sustain capitalism through its own inherent renewability.

As a strategy, *sustainable capital* is based on certain assumptions about the biophysical characteristics of nature. It is based on the view that "living matter" (e.g., plants, animals, micro-organisms *etc.*) is an inherently sustainable resource because it is inherently renewable, in that new living matter can reproduce or be (re)produced. In some accounts, it is also supposed to be inherently efficient because it does not require new forms of capital, nor new energy-intensive production processes, nor greater labour productivity—because the living matter itself can be made more productive.

In this perspective, living matter is intensified through knowledge that promotes the real subsumption of life itself [6]. To achieve such intensification, however, necessitates a concurrent commodification of techno-knowledge to ensure the ascendance of *sustainable capital* as a political-economic reality in the future. So it is important to study the narratives that promote, legitimize and justify new technological developments leading to the intensification and privatization of life.

3. Extending the "Techno-knowledge Fix" through the Knowledge-based Bio-economy

Since the early 1990s, the European Commission has increasingly supported the idea that economic growth and development will be dependent upon new, often science-based sectors such as the life sciences. This view has been driven by a broader competitiveness agenda in which the threat of international competition from economic globalization has justified the ongoing reform of European institutions, strategies and policy frameworks. This wholesale reorientation is exemplified in various grand agendas such as the recent *Europe 2020 Strategy*, which extends the 2000 *Lisbon Strategy* by promoting "smart, sustainable and inclusive growth". Such agendas are also pursued alongside the political integration project, starting with the 1987 Single European Act through to the 2007 Lisbon Treaty.

These political-economic changes to the European Union are thoroughly entwined with neoliberal agendas. These generally involve, the "mobilization of state power in the contradictory extension and reproduction of market(-like) rule", argue Tickell and Peck ([20], p. 166). Through "market-friendly" regulations, neoliberal policies have extended various processes such as deregulation, privatization, commodification *etc.*, thereby creating new forms of market relations. [11]. The neoliberalization process also promotes a technological fix which "relies on the coercive powers of competition"; this "becomes so deeply embedded in entrepreneurial common sense, however, that it becomes a fetish belief: that there is a technological fix for each and every problem", according to David Harvey ([10], p. 68).

Imperatives for a "technological fix" have a long history in EU policy circles. In the 1980s, policy narratives presented biotechnology (and other new technologies) as a major driver of economic competitiveness [21]; this was later reiterated in the early 1990s with the European Commission's 1993 *Growth, Competitiveness, Employment White Paper*, which specifically highlighted the potential of high-tech sectors like biotechnology. This White Paper argued that "Comparable changes in productivity will be achieved by further progress in life sciences—biotechnology—through the creation of innovation in highly competitive areas of industry and agriculture" ([22], p. 92).

Such views of the potential for high-technology growth were later embedded in the 2000 *Lisbon Strategy*, which committed the European Union to become "the most competitive and dynamic, knowledge-based economy in the world, capable of sustainable growth with more and better jobs" by 2010. More explicitly, the strategy emphasized that "technology and research represents tomorrow's jobs" ([1], p. 18), an emphasis that was again repeated at the Barcelona European Council meeting two years later., Although the technological fix has a long history, it has taken new forms in recent years. It is increasingly aligned with the production of a knowledge-based economy and hence a "techno-knowledge fix', as we call it. More recently this techno-knowledge fix has come to promise both environmental sustainability and "sustainable" economic growth through greater productivity of natural resources. This underpins what we have conceptualized as *sustainable capital*.

In this broader policy narrative, the techno-knowledge fix necessitates new institutional, societal and policy frameworks in order to ensure the expected flow of potential products that new technologies promise. This expectation is then built into policy frameworks in order to achieve it, though not always successfully. For example, the 2006 *Aho Report* highlighted the need for Europe to "provide an innovation-friendly market for its businesses"; going beyond deregulation, this promoted "a cultural shift which celebrates innovation". Policy changes are necessary to facilitate "lead markets", such as for the Life Sciences. Consequently, the report tells us to rethink our current policy frameworks: "Europe and its citizens should realize that their way of life is under threat but also that the path to prosperity through research and innovation is open if large scale action is taken now by their leaders before it is too late" ([23], pp. 2, 6, 25).

The techno-knowledge fix presents opportunities highlighted by the European Commission's *Life Science Strategy*, which envisages modern biotechnology as the "next wave of the KBE [knowledge-based economy]" ([24], p. 3). As an "enabling technology", the life sciences are expected to be a significant contributor to the *Lisbon Strategy*. As the 2007 mid-term review of the *Life Science Strategy* argues, biotechnology is essential for solving the challenges of "health, energy supplies, global warming and an ageing population" ([25], p. 2). This expectation extends the ambitions of the "knowledge-based bio-economy" (KBBE) agenda, which was launched at a high-profile conference in 2005. This new concept combined the KBE narrative of the Lisbon Strategy with the OECD's proposal for a "bioeconomy policy agenda" [26]. Going beyond encouraging new biotechnological products, the KBBE agenda is directed towards promoting, linking and capturing new forms of market value. According to the EU Science and Research Commissioner, the bio-economy is a vitally important sector, "estimated to be worth more than €1.5 trillion per year" ([27], p. 1). In essence the KBBE exemplifies the *sustainable capital* strategy to develop the (re)productive powers of living matter in the pursuit of capital accumulation.

As an EU-wide policy narrative, the KBBE also promotes changes in policy frameworks towards the pursuit of "sustainable" capital accumulation. The KBBE diagnoses problems and identifies techno-knowledge fixes that require the removal of "barriers" to the exploitation of renewable resources through innovation and technoscientific developments. In turn, the KBBE naturalizes a techno-knowledge fix based on renewable innovation as the necessary prerequisite for economic competitiveness which underpins all of the European Union's prosperity, social gains and, in the end, political continuity; that is, the 'sustainability' of the EU itself. Thus, as in other master narratives [2], one specific technoscientific trajectory becomes the only path that will ensure societal progress—in this case, through the assumed sustainability of exploiting "renewable" resources and expanding their availability.

More specifically, the KBBE is an *elite master narrative* focusing on research and innovation policy. It is entrenched in EU-wide and national policy frameworks organized and configured by particular research and innovation policy elites and/or bureaucracies. Therefore its role does not depend on popular acceptance, acquiescence or even awareness.

Ostensibly a research policy, the KBBE appears in the overall agenda for the Framework Programme 7 (FP7) funding scheme, which was approved by the EU Council and Parliament. Furthermore, the KBBE influences national research budgets by setting agendas for the European Research Area (ERA), such as the ERA-Nets (e.g., KBBE-Net) and the UK's Technology Strategy Boards. As an elite master narrative, the KBBE circulates among policy elites in different places.

Such scale-jumping means that the KBBE narrative subsumes multi-scalar policy frameworks in an agenda and strategy that values a specific techno-knowledge fix over others. For example, the KBBE fits neatly into the longer history of innovation and research narratives that have sought to justify broader and easier access to patents for European firms. Here the narratives identify a trans-Atlantic gap in biotechnology patents as the rationale for facilitating access for European companies.

Patents have been turned into a key indicator of success or failure, and especially as a basis to blame Europe's fragmented patent regimes for lost competitiveness. Although the 1998 EC patent directive has a potentially broad scope [28], a biotechnological patent in one EU member state is not necessarily respected in all the others, especially given political and ethical disagreements. As a solution offered by the Commission and industrial stakeholders, a European Community Patent would guarantee EU-wide recognition. It would be designed "to increase the competitiveness of the European Companies in providing for an effective, affordable and legally sound protection and counter the present trend of biotechnology companies to prefer to patent in the US" ([29], p. 10).

This proposal was not enacted, so its absence can still be blamed for the lower level of innovation in Europe than the USA. Thus the KBBE narrative justifies the re-orientation of research and innovation policy frameworks towards patentable knowledge as a techno-knowledge fix for the societal problems and challenges facing Europe (e.g., energy security, ageing population *etc.*). It does so by promoting "European' (not national) competitiveness and growth, especially by refocusing research and innovation policy, "in order to foster market development for bio-based products and improve the uptake of new technologies", as in the revised *Action Plan for the Life Sciences* ([25], p. 8).

Inherent in the techno-knowledge fix underpinning *sustainable capital* is the need to prioritize specific technological sectors; this has been formulated by DG Enterprise as "lead market initiatives" (LMI). The techno-knowledge fix will not simply work with greater investment in research and knowledge about renewable natural resources and eco-efficient processes. According to the Commission ([30], p. 2), the competitiveness problem results from the slow and/or low uptake of new technologies, which in turn results from "uncertainty about product properties" (e.g., renewability, eco-efficiency *etc.*) as well as "weak market transparency" (e.g., consumer awareness, public acceptance *etc.*).

From this problem-diagnosis, the EU must provide "incentives for the emergence of the bio-based product market", including regulatory changes in order to encourage certain kinds of technological development, product uptake and thus new markets. This entails the embedding of private interests in policy frameworks, e.g., easier access to patents, as well as public procurement measures favouring "green" products. The European Association for Bioindustries (Europabio) supports these policy changes as a means to stimulate innovation: "By developing support policies and measures that will stimulate the demand for these products, this new policy [LMI] will encourage innovation in bio-based products by transforming knowledge in new bioproducts and bioprocesses" [31].

Overall, the KBBE narrative offers solutions that favour the development of technoscientific knowledge that can eventually be privatized and commodified, thereby framing that knowledge along lines that link societal relevance with the private interests of capital accumulation. In this sense, the KBBE attributes economic value to natural resources *and* molecular-biological science, thereby constituting *sustainable capital* as a political-economic strategy. In turn, research and innovation are represented as "natural" processes whose success is derived from the inherent and intrinsic qualities of the natural resources and biological-molecular knowledge that are amenable to privatization and commodification, rather than from the social relations that constitute economic practices and, especially, capital relations [32]. Inevitably, in justifying and naturalizing a specific techno-knowledge fix with reference to certain societal priorities and constructions of nature as resources, the KBBE narrative dis-empowers or demotes other possibilities [33].

4. *Sustainable Capital* and the KBBE: Framing "Sustainability" in the European Union Framework Programme 7

The KBBE narrative links together agriculture (food and crops), fisheries and biotechnology as a single work programme within Theme 2 of the European Commission's Framework Programme 7 (FP7). It explicitly aims "to build a knowledge-based bio-economy", which is discursively framed by the food, crops, forestry and biofuels Technology Platforms ([34], p. vii). These Technology Platforms were created in the European Council proposal to bring together "technological know-how, industry, regulators, and financial institutions to develop a strategic vision for leading technologies" ([35], p. 14). The Technology Platforms are meant "to involve all relevant stakeholders' in order to identify societal priorities, needs and future benefits. Technology Platforms formulate "common visions" that form the basis for Strategic Research Agendas, which are then incorporated into Framework Programme 7 research funding priorities. As future-oriented visions, the Technology Platforms identify specific models of research and innovation, as the basis for specific techno-knowledge fixes. Although these Technology Platforms emphasize "European" interests, priorities and competitiveness, their members or affiliates also include many trans-Atlantic multinationals.

4.1. Renewable = Sustainable

In seeking to combine different stakeholders and research agendas, the KBBE narrative specifies particular research and innovation priorities centred on "renewable" and "eco-efficient" natural resources. According to the Commission:

> "Renewable biological resources are the basis of a European knowledge based bio-economy (food, feed, agriculture, forest based, fisheries, aquaculture, biochemistry, *etc.*) that today has an estimated annual turn-over of more than €1,500 million. The increasing demand for biological resources, both in quantity and quality, can only be met through innovation and advancement of knowledge in the sustainable management, production and use of these biological resources (micro-organism, plants and animals). This programme (FP7) brings together all relevant actors (appropriate research disciplines and industrial sectors, farmers, forest owners, consumers, *etc.*) to develop the basis for new, sustainable, safer, affordable, eco-efficient and competitive products … Eco-efficient products are less polluting and less resource-intensive in production, and allow a more effective management of biological resources" ([36], p. 3).

The narrative conflates "renewable" and "eco-efficient" with "sustainable"; *i.e.*, less polluting, less wasteful and less "resource-intensive in production". This conflation assumes that biological resources will replace synthetic products such as chemicals, whilst organic waste will itself become a new resource (*i.e.*, raw material) for further productive processes. Consequently, as Gavin Bridge argues more generally [8], these "raw materials" are constructed as specifically *sustainable resources* through the assumption that living nature is abundant because it is inherently renewable (*i.e.*, it reproduces) and that using waste matter is eco-efficient because it would otherwise be thrown away.

In projecting abundance onto nature, the KBBE narrative creates an imperative for investment in new knowledge and technologies—for identifying natural characteristics, for extracting specific components, for recomposing their elements, for using the novel combinations, and ultimately for running "biorefineries" (see below). Knowledge provides the means to develop the new resources that will then provide the basis for new products and processes, thus linking Europe's global competitiveness with its environmental responsibilities. This framing of sustainability provides the rationale for promoting and supporting research funding (and the later re-regulation of markets) on non-food uses of living material (e.g., plants) at the genetic and molecular level. According to the vision document of the Plants for the Future Technology Platform, for example, "Europe cannot afford to miss out on the benefits offered by plant genomics and biotechnology" ([37], p. 17).

The need for such technology to provide "sustainable" resources assumes that consumer demand stimulates global markets and global pressures on natural resources, e.g., land and fossil fuels; such pressures generate greater competition over resource use (e.g., food *vs.* energy), deplete them and create more waste. As the later Strategic Research Agenda of the same Technology Platform states:

> "This implies that the worldwide demand for feed will increase dramatically as a result of the growing demand for high-value animal protein … In addition, it is now well established that feed and food are increasingly competing with non-food products (bio-energy and industrial products, such as bio-plastics for packaging) for acreage systems … *All the above facts mean that more arable land will have to be farmed for feed and food or crop productivity will have to be boosted significantly*" ([38], p. 3).

From that problem-diagnosis, the KBBE narrative promotes a techno-knowledge fix: more efficient technoscientific techniques and knowledge can ensure the "sustainable" replenishment of capital. The real subsumption of nature can intensify the productivity of those natural resources [6].

This intensification strategy has a circular reasoning which casts resource shortages as deficiencies in resource productivity, rather than in inherent limits of natural resources. From that diagnosis, such deficiencies can only be overcome through further intensification rather than further extraction. Therefore we must develop new knowledge and technologies which will improve agricultural productivity and efficiency in response to external market pressures. For example:

> "Faced with the conflict between rising demand, environmental concerns and increased land competition, the application of new agricultural technologies can help provide a more sustainable solution. Advances in plant breeding methods could help boost crop yields and quality (palatability and digestibility), while reducing costs. These new technologies will enable European farmers to be competitive in the global feed market" ([38], p. 15).

Alongside greater commodification and privatization, intensification will also encourage further monocultural agricultural practices with attendant high-input resource usages (e.g., fertilizers) and vulnerabilities (e.g., pests). In the KBBE narrative, hazards of intensification are attributed instead to threats from an external nature, which thereby warrant techno-fixes. For example:

> "Adverse environmental conditions are major factors directly reducing yield or, at least, impairing plant performance … Reduced rainfall and increased water requirements will affect crop yields and tree growth. Plants able to withstand drought, cold and salt stress would not only stabilise yield potentials but also contribute to reducing the impact of agriculture on the environment … These adverse environmental conditions also increase susceptibility to pests and pathogens, resulting in higher consumption of agri-chemicals and further yield and quality losses" ([38], p. 46).

In this way, global competition and resource vulnerabilities are naturalized as exogenous, objective forces which must be addressed to ensure that Europe does not fall further behind its rivals. In this framing, technoscientific developments are presented as the means to address this concern. When launching the KBBE agenda in 2005, the Science and Research Commissioner Janez Potočnik declared: "Research in agriculture… can be a perfect example of how science can unlock potential for human well being" ([27], p. 12). The overall construction of sustainable resources is premised on the need to compete more effectively in a global market where natural resources are both "abundant" (because they are renewable) and "scarce" because they are threatened by depletion, wastage and vulnerabilities to exogenous hazards (e.g., pests). Ecological damage endemic to industrial production systems is instead attributed to inefficient use of resources [18]. Thus these environmental problems are not simply obstacles from a recalcitrant nature; they also represent opportunities for societal progress, if only the barriers to technoscientific development were removed.

4.2. Nature = Fixed Capital

In the imagined techno-knowledge fix, all biological resources become potential raw material for producing and circulating *sustainable capital*. Natural recourses are also characterized as machines through industrial metaphors. For example: "In addition to the countryside's role as a "food factory", it could be used to grow renewable bio-resources as sustainable raw materials for our energy needs and for industry" ([27], p. 5). So rather than extend the ecological fix through the externalization of costs and their subsequent internalization [17], such metaphorical framings extend agri-technological innovation systems beyond food production. In so doing, they incorporate a more diverse set of stakeholders and potential beneficiaries (e.g., farmers, industrialists, energy companies, consumers, environmentalists *etc.*). Framing nature as a literal "oil well" or "food factory" facilitates this enrolment of diverse groups in the over-arching vision of the KBBE as a techno-knowledge fix. It can even include environmental NGOs advocating sustainable resources derived from nature.

The narrative presents both an opportunity and an imperative that links several diverse industrial sectors along a newly imagined value chain which encompasses food, animal feed, energy, industrial products, *etc.* The supposed inherent properties of living matter ("biocrude"), especially plants, become a universal sustainable resource; for example, the predecessor to the Biofuels Technology Platform claims that "New developments are ongoing for transforming the biomass into a liquid "biocrude", which can be further refined, used for energy production or sent to a gasifier" ([39], p. 21). As a renewable resource, living matter can be utilized in new, more efficient ways that will ensure environmental *and* economic sustainability.

The vision of the techno-knowledge fix is exemplified by the "integrated biorefinery", here defined by the Biofuels TP predecessor:

> "All alternative possibilities of integration will have to be explored. Conversion of intermediates and residues into valuable products is a central objective of the integrated biorefinery. The co-production of fuels and co-products, *i.e.*, basic chemicals for synthesis purposes or high valuable minor components, can meet the challenges of economy and sustainability." ([39], p. 22).

To benefit from the renewable and eco-efficient properties of nature, implicit in the reworking of capital as *sustainable capital*, necessitates the reorientation of social and institutional frameworks in response to the imperative of horizontal integration of numerous industries denoted by the "biorefinery" concept. According to the Technology Platform Plants for the Future, for example:

> "… the production of green energy will also face the exceptional challenge of global industrial restructuring in which the very different value chains of agricultural production and the biorefining industries must be merged with the value chains of the energy providers" ([38], p. 33).

Such integration requires flexibility amongst industrial sectors, individual firms and state agencies in order to link diverse technoscientific developments and applications, e.g., crops, animal feed, energy, environmental remediation, and industrial and medical products [40]. This integration is celebrated as an environmental boon that will lead to the sustainable economies of the future.

Other mechanical and informatic metaphors reinforce the restructuring imperative by fetishizing human powers as the properties of natural (and especially molecular-biological) resources; plants become "cell factories", "cell micro-computers", "biotech pistons" *etc.* For example:

> "… biotech employs micro-organisms, such as yeasts, moulds and bacteria as so-called "cell factories" and enzymes to produce goods and services. This implies developing and producing chemicals at the cellular level by exploiting and adjusting natural processes in living organisms to generate the substances and enzymes needed by industry" ([27], p. 9).

Extraordinary powers are attributed to natural resources, especially at the molecular level in reference to (bio-)technoscientific developments and applications [41]. These metaphors thereby raise expectations about the economic, societal and ecological benefits that certain knowledge will provide; in particular, laboratory knowledge concerned with genetics, genomics, proteomics *etc.*, which contrast to the possibilities offered by other approaches such as agro-ecology. Long before the KBBE agenda, molecular biology and genetic engineering were seen as “breakthrough” technologies, which not only offer “total” but also “universal” solutions to societal problems. Consequently, laboratory knowledge is valorized over other forms, which means that there is an “underestimation or neglect of the indirect, global or systemic and long-term impacts of agricultural systems and innovations”, argue Vanloqueren and Baret ([33], p. 979).

Extending that legacy, the KBBE narrative likewise emphasizes biotechnological knowledge, e.g., for the redesign of crops to increase their productivity, the use of biological processes in industrial production, the extraction of energy from biomass, *etc.* The EU’s expert advisors have elaborated imaginaries for bio-based products, which aim to “Improve agricultural land productivity in a sustainable way in the EU and in third countries, e.g., through yield increase, reuse of degraded land, use of unused land, better land management, cropping system, *etc.*” As they also note, “The fact that a product is bio-based is not alone a proof of its sustainability; a range of other factors need to be considered (e.g., health, safety, environmental effects, waste).” This uncertain link becomes a rationale to set European standards which can facilitate sustainable “green” products ([42], pp. 16, 10).

4.3. Capitalization = Societal Progress

The techno-knowledge fix of new (bio-)technoscientific developments and applications, designed to intensify the productivity of (living) nature, is embedded in a contradictory and circular neoliberal logic. Global market demand is represented as inevitably increasing, thereby intensifying the existing pressures on land use alongside creating new pressures (e.g., non-food uses), which will necessitate the intensification of land productivity. Through this reductionist framing, private interests are presented as societal needs; such societal needs, in turn, can only be satisfied through (bio-)techoscientific innovation (e.g., increasing agricultural productivity through genetic engineering) and private property regimes to incentivize this innovation, e.g., intellectual property (IP). This is similar to Kathleen McAfee’s argument that such reductionism discursively legitimates genetic research as “unique” and “inventive”, which justifies commodification, whilst characterizing other efforts and activities (e.g., breeding) as “non-scientific”, not inventive and not legitimate property [41].

Through such a reductionist separation of knowledge from nature, technoscientific attributes become intrinsic to a particular technology or artefact itself, rather than to the social relations of its production [32]. Technofixes for saving nature help to justify its commodification [43]. This enables the enclosure of (bio-)technoscientific knowledge through private property regimes, by extending on the classical liberal concept that only human labour can confer value upon nature [44]. In the KBBE narrative, for example, the integrated biorefinery mentioned above is meant to turn plant matter into a diverse array of products:

> "In the long term, the increased demand for agricultural land will require increased productivity and extraction efficiency. For this demand to be met, it will be necessary to develop multifunctional crops that can be processed in integrated biorefineries in which the utilisation of feedstock is maximised. For example, in the case of biomass crops, in addition to serving as a source of lignocellulose, feedstock could also be used as a platform for the production of specific biochemicals that represent in their own right, high-value industrial feedstocks" ([38], p. 37).

Nature here is to be intensified and mined for interchangeable raw materials that can then be extracted, processed and commodified through new private property regimes; thus nature, and particularly, living matter, becomes new and exploitable "oil wells", as articulated at an international conference on the biorefinery:

> "Participants included members of the forestry, automotive, pulp and paper, petroleum, chemicals, agriculture, financial, and research communities … It was noted by DOE [US Dept of Energy] and EU that both the U.S. and EU have a common goal: Agriculture in the 21st century will become the oil wells of the future—providing fuels, chemicals and products for a global community"[45].

In this sense, living matter is constructed as an economic asset that can be renewably cultivated. However, its market value depends upon the intensification of nature's productivity—which must be enhanced through the "the use of biotechnology for the conversion of biomass and waste into value-added products", according to an EPOBIO report ([46], pp. 17, 18). In this way, market value depends upon new molecular and genetic research which has "the potential to produce both chemicals and biofuels in an integrated biorefinery" ([47], p. 10).

As mentioned already, the integrated biorefinery links together diverse private interests such as major agriculture industry sectors (e.g., seed, fertilizer, pesticide, genetically modified crops *etc.*) with energy sectors (e.g., transport fuels, electricity generation, automotive industries *etc.*). These sectors treat nature as an economic asset whose productivity must be intensified in order to appropriate market value. Through industry-wide trade associations and the European Technology Platforms, these private interests have influenced EU policy with regards to biofuels policy; as well as research subsidy, state support includes market incentives for "eco-efficient" technoscientific innovation. One ETP forerunner argued that:

> "Legislation promoting biofuels could be based on tax incentives, mandates to use biofuels or via emission standards. Creating a market advantage for biofuels will also speed up RTD [research and technological development] and make it more target-oriented" ([39], p. 26).

Subsequently, the research agenda for biorefineries has helped to implement the *Action Plan for Bio-based Products*, which forms part of the state-led Lead Market Initiative [30,42,48]. Here the KBBE agenda helps to reorient policy frameworks in order to reposition European companies higher up the value chain, especially by acquiring patents on (bio-)technoscientific and engineering knowledge for biorefineries. For applying biotechnology through a bio-economy, a trans-Atlantic research network emphasized patents as a key driver:

> "A significant challenge and opportunity that impacts scientists across the industrial and academic sectors with relevance to both fundamental research and scientific collaboration is Intellectual Property (IP). While not specifically a scientific challenge, it certainly is driven by and has a strong influence on science. Successful resolution of IP issues in any given research area can and will dramatically affect scientific progress" ([49], p. 17).

The agenda emphasizes the commodification of knowledge within new patent regimes that are meant to promote product development from natural resources—in the name of sustainable energy, bio-based products and societal progress.

5. Alternative Imaginaries and Research Agendas

The Commission's agricultural research priorities have been criticized by some NGOs. To evaluate the Commission biotech strategy, an environmental NGO compared the societal benefits of organic agriculture and agri-environmental schemes, on the one hand, with agri-food biotech, on the other. Benefits were quantitatively analyzed in terms of industrial competitiveness, market diversity, resource impacts and job creation. On all those criteria, agbiotech failed to achieve the strategic objectives of the Commission's Lisbon agenda. By contrast, organic farming within a rural development policy provides a competitive alternative, argues the report [50]. Other NGOs too have criticized the dominant KBBE agenda and have counterposed alternatives [51].

Since at least the 1990s, small-scale and organic farmers' organizations too have been promoting alternatives to the dominant agri-industrial model. Advocating "sustainable rural communities", they have emphasized farmers' knowledge of local biological resources for quality agriculture, in turn as a basis for consumer support through short food-supply chains.

The Commission has financed some research on organic farming, e.g., genomics tools for identifying pest-resistant crop varieties [52]. Since 2006 organic farming researchers and industry organizations have attempted to gain Commission funding for a Technology Platform Organics, on grounds that organic systems "are an important and fast-growing part of the European knowledge-based bio-economy". Although that attempt did not succeed, they built broad stakeholder support, including relevant commercial actors and environmental NGOs. Eventually they published a *Vision for an Organic Food and Farming Research Agenda to 2025*, recasting key terms from the KBBE narrative: "the innovations generated by the organic sector have played an important role in pushing agriculture and food production generally towards sustainability, quality and low risk technologies" ([53], p. 9).

They also recast farmers' competitiveness in terms of appropriating agro-ecological knowledge for higher productivity:

> "Organic farming is a highly knowledge-based form of agriculture involving both high tech and indigenous knowledges and is based on the farmer's aptitude for autonomous decision making. The weakness of organic agriculture so far remains its insufficient productivity and the stability of yields. This could be solved by means of appropriate " eco-functional intensification", *i.e.*, more efficient use of natural resources, improved nutrient recycling techniques and agro-ecological methods for enhancing diversity and the health of soils, crops and livestock" ([53], p. 34).

Their *Vision* report was followed by a *Strategic Research Agenda*, which emphasised the need for knowledge networks among farmers and researchers:

> "New approaches of participatory research, knowledge exchange networks, development of decision-making tools (including internet based tools) as well as coaching and mentoring are frequently advocated… At the same time, organic farmers and growers contribute actively to the development of new knowledge and techniques" ([53], p. 39).

Some research proposals from TP Organics have been incorporated into FP7, as well as into CORE Organic, a programme which links funds from national research budgets. Some calls for research proposals mention organic production methods, while others emphasise other key terms such as enhancing soil management, recycling organic waste, replacing chemical pesticides, *etc.* In these ways, an alternative has gained modest place in EU-level research agendas, thus countering the general lock-out of agro-ecological methods [33]. As a basis for these gains, proponents recast key terms from dominant KBBE narratives and presented alternative agendas as broadly relevant to agriculture beyond organic farming.

6. Conclusions

As the preceding analysis has shown, the "knowledge-based bio-economy" (KBBE) has divergent narratives, whose dominant one is a new strategy for *sustainable capital*. This promotes bio-technoscience as the means to reconcile environmental and economic sustainability. It frames the sustainability problem as an inefficiency to be overcome through a techno-knowledge fix, especially through molecular-level changes. Here ecological sustainability means a benign eco-efficient productivity through resources which are renewable, reproducible and therefore sustainable—by contrast to inanimate nature (e.g., minerals), which lacks those characteristics. This imaginary of cornucopian living resources encourages political and financial investment in a techno-knowledge fix.

Within this imaginary, mechanical-informatic metaphors (e.g., cell factories) are invested in Nature—which thus represents human qualities usually ascribed to industrial activities, entities and products [27]. These metaphors narrowly define the social, economic and ecological potential of natural resources—as intensified productivity seeking commercial products suitable for global markets. The techno-knowledge fix fetishizes specific social forms of natural resources (and of knowledges) as inherent characteristics, thus naturalizing their potential privatization and commodification.

This technoscientific imperative is embedded in global market demands that extend the continuing (over-)consumption of natural resources. As a response, techno-knowledge fixes are meant to expand resource availability, while also competing globally in "bio-based" sectors. This solution requires changes in policy goals, agendas and frameworks so that they can be adapted to commercial imperatives of *sustainable capital*.

All this forms the basis for *sustainable capital* as a politico-economic strategy to sustain capital accumulation through proprietary knowledge of nature's productivity. Sustainability is framed as knowledge that enables the intensification of natural resource productivity, to be unlocked with new knowledge embedded in technoscientific innovation. European Technology Platforms establish vision statements and set priorities that extend commercial imperatives into the research process; they emphasize research which could eventually facilitate commercial products and proprietary knowledge.

Intrinsic to this drive for global competitiveness, proprietary knowledge can protect any capital return on innovation expenditure necessary to increase the productivity of nature in the first place. Many natural resources otherwise would be freely reproducible for re-use and exchange, e.g., seeds and enzymes. As a valuable resource, nature has to be protected from competitors. Or, more precisely, knowledge of natural resources has to be protected, since the capture of market value from knowledge depends upon intellectual property rights (IPRs). These play multiple narrative roles—as an indicator of Europe lagging behind its competitors, as an imperative for a European patent procedure to overcome obstacles, and as a flexible explanation blaming market-unfriendly policies for technological failure.

As a political-economic strategy, *sustainable capital* combines the formal and real subsumption of nature in new ways, while also going beyond them [6]. Real subsumption redesigns nature for intensified production, while formal subsumption identifies and extracts components for recomposing them in new products with higher market value. As a distinctive feature, this dual subsumption emphasizes natural resource functions, rather than specific forms which could fulfill those functions. The intensification of "natural" processes through new knowledge reorients policy frameworks to the demands of capital accumulation.

Sustainable capital has novel features in recasting the resource problem. Earlier regimes sought to increase labour productivity through mechanical energy from fossil fuels, thus causing enormous ecological damage. As a novel diagnosis, the KBBE agenda frames the problem as energy and other resource shortages, resulting from their inefficient use and consequently wasting resources. This waste is framed as both a problem and opportunity—not simply as a "negative side-effect" to be managed.

As a remedy, research seeks ways to make capital itself renewable through a techno-knowledge fix that goes beyond the current dependence upon inanimate natural resources such as oil and gas, metals, minerals *etc.* Research agendas promise sustainable resource usage through intensified, more efficient biological activity of renewable resources. This promises a dual benefit—ensuring the renewable replacement of natural resources for the foreseeable future, as well as shortening the timescale that is currently necessary for the geological formation of "non-renewable" resources.

Renewable replacements need to be found not only throughout the value chain (e.g., to replace resource inputs, machinery, energy *etc.*), but also within a broader shift in "ecological regime" [18,54]. This regime shift invests great expectations for unlocking the productive potential of natural resources. In this cornucopian resource imaginary, technoscientific innovation will develop new forms of "fixed" bio-capital (e.g., plants or plant cells as bio-factories), new forms of non-human "labour" (e.g., micro-organisms as bio-catalysts), new forms of energy supply (e.g., biomass and biofuels) and new forms of "life" with greater biological productivity, as the basis for new forms of surplus value.

Defined as "the eco-efficient transformation of renewable biological resources", the KBBE is sometimes equated with biological productivity, implicitly distinct from labour productivity. For those cornucopian resource imaginaries to gain commercial success, however, a techno-knowledge fix also depends upon exploiting new combinations of "living" and "dead" labour. These include the following: expertise in lab research, fixed capital in bio-refineries and conventional agri-industrial labour for providing large-scale biomass, especially in the global South.

As a divergent imaginary of a bio-economy, agro-ecological approaches have been promoted for enhancing farmers' knowledge of natural resources. Recently this has been elaborated as a means to increase on-farm biological productivity, e.g., through eco-functional intensification, dependent upon expanding a knowledge commons. Dominant biotechnological agendas have generally locked out agro-ecological approaches [33]. Nevertheless such alternatives can achieve gains through well-organized stakeholder networks, as this case study illustrates.

The stakes have been raised by the *Europe 2020* strategy, which promotes "smart, sustainable and inclusive growth", especially through "resource efficient technologies". The European Commission plans to launch European Innovation Partnerships to speed up the development of the technologies needed to meet societal challenges, especially for "building the bio-economy by 2020' ([55], p. 10). In this new policy context of the KBBE, alternative versions could either be marginalized or else become counter-hegemonic. Here lies a strategic question: "how do counter-hegemonic forces challenge routinized categories and naturalized institutions, generate new subject positions and social forces, and struggle for new projects and strategies?" ([56], p. 163). As a related question: Can alternatives be more effectively promoted by representing them as complementary to the dominant agenda—or else as contradictory?

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