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SPECIAL FEATURE: ORIGINAL ARTICLE

Blue Degrowth and the Politics of the Sea: Rethinking the Blue Economy

Designing sustainability in blues: the limits of technospatial growth imaginaries

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Abstract

In the midst of a global food crisis, the late 2000s saw tensions between rising food prices and demands for biofuels coalesce into a "food versus fuel" debate. In response to ensuing public outcries, governmental agencies, and researchers across the globe began mobilizing around alternative biofuel feedstock. Among these materials, algae emerged as the most "hopeful" sustainable alternative in producing biofuels. This article examines algal biofuel production systems designed offshore and integrated with wastewater treatment and carbon dioxide absorption processes to revitalize faith in biofuels in the blue economy. It discusses what makes algal biofuels sustainable by examining the ways practitioners talk about and design these integrated systems. Against the common refrain that algae's photosynthetic and reproductive capacity makes these systems sustainable, this article underlines that there is nothing natural, innate, about algae to add to sustainable blue economies. Rather, algae become naturalized as biofuel source and bioremediation technologies through technoscientific discourses and interventions, which embed and reproduce anthropocentric approach to sustainability that centers on the ideology of growth. By drawing particular attention to the ways that integrated algal biofuel production systems depend on the constant generation of industrial waste, this article problematizes anthropocentric sustainability imaginaries and claims for imagining sustainability otherwise through the lens of blue degrowth to create a radical socio-ecological change.

Keywords Sustainability · Imaginaries · Algae · Biofuels · Science and technology studies · Blue degrowth

Introduction

Algae are ubiquitous organisms.[1] They are present in almost all of our biosphere's ecologies. Algae can tolerate an impressive array of temperatures and milieus. Some species proliferate on the surfaces of moist rocks, stones, and tree trunks. Others inhabit dry soils. Some species are found in deserts, while others flourish in Arctic and Antarctic snows and ice. They mostly, however, thrive in aquatic environments—notably, oceans, rivers, lakes, ponds, and wetlands. They accumulate on the edges of glass aquariums, form pond scum, and drift along on oceanic currents. Algae are all around us. Yet, in many habitats, algae often go unnoticed unless they proliferate massively.[2] A notable example of this phenomenon materializes as "red tides"—where the overpopulation of a certain species of algae (e.g., *dinoflagellates*) produces potent and visible masses of toxins. Put differently, algae are mostly imperceptible to human eyes until they: (1) cause environmental or health problems, (2) contribute to the well-being of bodies and ecologies, or (3) create economic opportunities as they are processed into commodities, such as biofuels.

In this article, I critically examine the emergence of algae as a promising organism for sustainable biofuels and blue economies. The production of biofuels via the utilization of algae as biomass is not a new idea. In the wake of the early

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[1] By referring to algae as ubiquitous, I gesture towards anthropological studies that find trivial things important as an ethnographic object (Fortun 2012). For a slightly different take on the notion of "ubiquitous," which refers to the simultaneous universality and uniqueness of the microbial life, see Paxson and Helmreich 2013.

[2] For a further information on algal habitats, for example, see Graham et al. 2008; Hollar 2011.

1970s Middle East oil embargo, in the United States, algal biofuels projects attracted serious attention as key alternative fuel sources for decreasing dependence on foreign markets. Nevertheless, the extensive technoscientific work and policy interest in algal biofuels emerged in the late 2000s, in the midst of a global food crisis. The tensions between rising food prices and demands for biofuels coalesced into a food versus fuel debate (e.g., Gomiero et al. 2010; Biello 2011; Gamborg et al. 2012). This debate marked pushbacks against land-use practices that were meant to fuel cars instead of feeding people.[3] Many blamed biofuels, especially those produced from corn, for increasing food prices worldwide.[4] This tension peaked in the wake of *The Guardian*'s feature of a "secret report" prepared by the World Bank.[5] In response to ensuing public outcries, governmental agencies, and researchers across the globe began mobilizing around alternative biofuel feedstock, such as plant discards and algae. Among these materials, algae emerged as the most "hopeful" alternative in response to the food versus fuel debate—a sentiment most acutely felt in the United States (Gao et al. 2012). It seems that algae have the potential to transform the bad reputation of biofuels and to add more to the economy by providing other bioproducts, such as vitamins, and cosmetics.

This optimism for algal biofuels takes different forms, including the publicity of algae as a "fast-growing" productive species, and the quick proliferation of the knowledges and infrastructures that support algal biofuels' development. Nonetheless, algal stories promise a future of sustainable production through environmental remediation. Algae are positioned as biological materials that can absorb higher levels of polluting elements, such as carbon dioxide, nitrogen, and phosphorus. They become "good", industrious environmental workers in particular algal biofuel projects that are integrated with wastewater remediation and carbon dioxide mitigation processes. These projects mainly differ from other algal biofuel research that concentrates on algal strain development, e.g., through genetic engineering, and center on a system design to produce biofuels in a sustainable manner. These integrated algal biofuel production projects feature algae as a "win–win–win" opportunity (treating wastewater, mitigating climate change, and producing biofuels and bioproducts) not just in the register of hype or hope, but also as an expression of how specific environmental "threats" can be translated into "opportunities" through the utilization of the wastewater and flue gases for algal biomass cultivation required for biofuels.

In this article, I question the promise of these projects in contributing to sustainable futures through a case study of the US based algal biofuels project, the Offshore Membrane Enclosures for Growing Algae (OMEGA) Project (2009–2012). I show that the so-called sustainability of biofuels produced via algae in such a system is not about this organism's reproductive capacity but depends more on how the system is designed. Through examining the ways practitioners talk about and design this project, I discuss how sustainability gets constrained to technospatial growth imaginaries in integrated algal biofuel projects. Against limiting the sustainability question to such anthropocentric imaginaries, I suggest approaching sustainability, specifically in biofuel production, through the lens of (blue) degrowth.

The blue degrowth imaginaries help deconstructing "win–win–win" slogans while drawing attention to the illusions of blue growth discourses and practices in building and maintaining sustainable and just societal relations with the marine environments. Blue degrowth is thus an invitation for taking a critical and radical stance against reducing humans' relations with the seas and oceans as well as with different life forms thriving in marine spaces to economism (for further elaboration on the concept of "blue degrowth" see the editorial of this special issue; also see Hadjimichael 2018). As my study of the OMEGA project shows, limiting the relations between humans and more-than-humans to the growth imaginaries perpetuates present environmental problems rather than providing sustainable solutions. Given the dependence of the OMEGA project on the continuous production of waste, I argue that similar projects reproduce present waste regimes that are based on a technocratic mentality rather than providing meaningful ways out of toxic waste producing industrial systems. Instead, blue degrowth imaginaries help challenging the view of waste as a problem that can be solved through technoscientific interventions and zoom into the problem itself, that is, the inevitability of constant creation of waste in growth-based economies. Stated differently, through the lens of blue degrowth, it becomes possible to see that the problem is not waste per se, but the growth ideology.

[3] For an introduction to the literature on the "food versus fuel" debate, e.g., see: Chakravorty et al. 2009; Rosegrant and Msangi 2014. The "food versus fuel" discourse has its own politics as well. The critical scholars of agrarian change, for example, note that "the food-versus-fuel land-use discourse inadvertently risks serving the basic interest of nation-states by providing a 'moral' argument to engage in new food and biofuel production outside of already neatly demarcated private property on vaguely categorized 'public lands' generally assumed to be 'underutilized', 'marginal' and 'idle', despite contrary existing realities" (Borras and Franco 2011, p 48).

[4] Even, biofuels were objected as a "crime against humanity," in the words of former UN Special Rapporteur John Ziegler (FSC 2010, p 1). Further, the concept of "agrofuel"—instead of "biofuel"—was adopted by the oppositional groups to draw attention to the utilization of agrarian lands and crops for fuel production.

[5] The report was prepared by the economist Donald Mitchell suggested that biofuels from food crops is responsible for the 75% of the total increase in the world food process. For *The Guardian* article, see Chakrabortty (2008).

Methodologically speaking, my discussion of algal biofuels is based on a critical textual analysis that included closed readings of scientific articles, legal documents, reports on algae, algal biofuels, bioeconomies, the blue economy as well as web-based archival research on the OMEGA project that was conducted between 2013 and 2016.[6] In order to develop my analysis of the OMEGA project, I draw on a material-semiotic analysis of scientific articles, powerpoint presentations, project proposals, newspaper articles, and videos. Through this literature, I examine the ways practitioners talk about and design this project; the metaphors, concepts, knowledges, materials, techniques, technologies they use and build.

This article comprises three main parts. The first section introduces the main problem—that is, the economization of life—in conversation with the critical literature on bioeconomies in Science and Technology Studies (STS).[7] I note that algae's value in adding to sustainable blue economies is anticipated already as innate within this organism, and this anticipation becomes possible through the visions of algae as aggregate life in the container of the blue economy. While challenging such naturalization of algae as part of sustainable biofuel futures, I emphasize, in line with degrowth discussions, that sustainability imaginaries shaped by the growth ideology need to be decolonized so as to create radical socio-ecological change. The second section explores common refrains about algae that circulate largely in biofuels research as well as presenting the trajectory of changing scientific and commercial interest in algal biofuels. This analysis of scientific discourses demonstrates how algae become naturalized as a singular and ideal organism providing sustainable, enduring, energy resource in algal biofuels research advancing since the 1950s. In the third section, I do a close analysis of the OMEGA project. Here, I explore how this technoscientific project embeds and reproduces anthropocentric imaginaries of sustainability. By showing how this project's design centers on the constant generation of industrial waste, I problematize the economization of algal lives in this project under the guise of sustainability. This article concludes with attention drawn to the importance of re-thinking the relationships between humans and more-than humans, which is a key to create a radical socio-ecological change towards sustainable futures.

Imagining sustainability in the blue economy

Critical social science literature on biofuels mostly focuses on the uses of crops for fuel production.[8] Scholars have largely explored unequal socio-cultural and political economic relations that shape, and are shaped by, the uses of agricultural lands for fuel production (e.g., Dauvergne and Neville 2010; Biello 2011; Hunsberger 2014). This body of literature refers to the themes of land grabbing, colonialism, global North–South relations, and social movements among others (e.g., McMichael 2009, 2010; White and Dasgupta 2010; Borras et al. 2013). Other fields of study, such as political ecology, have explored the social and environmental impacts of biofuels, including concerns over deforestation and biodiversity loss (e.g., Baka 2014; Hunsberger and Ponte 2014; Balkema and Pols 2015), and marginalization of small farmers (e.g., Ariza-Montobbio et al. 2010). Although these discussions inform this article, I develop a perspective centered on Science and Technology Studies (STS) specific to critical biofuel studies. I do so by focusing on technoscientific discourses and practices that render algae into biomass for energy production.

While STS scholars have only begun to analyze biofuels (e.g., Mackenzie 2013; Birch and Calvert 2015; Birch 2016), there is an extensive literature on bioeconomies from which to start exploring the rendering of oceanic organism algae into biofuels. In 2005, the Organization for Economic Cooperation and Development (OECD) first coined the term, "bioeconomy". According to this definition, the bioeconomy makes up that part of economic activities that harness "the latent value in biological processes and renewable bioresources to produce improved health and sustainable growth and development" (Cooper 2008, p 45). While initial definitions of bioeconomy were equated with the production of "sustainable biofuels and bioproducts", it came to signify more than biofuels.[9] STS scholars have explored bioeconomies to demonstrate the intense traffic between the life sciences and capitalism (Cooper 2008). These scholars have traced the emergence of the bioeconomy as a practice that goes back to the 1980s—an era that witnessed the simultaneous rise of neoliberal economies, ecological modernity, and a biotechnology-based industry. From micro-level studies of scientific knowledge production to macro-level

[6] This research is part of my dissertation research, which was a multi-sited ethnography of the potentiation of algae as biofuel source in the United States and Turkey (Kasdogan 2017).

[7] As I will detail later in this part of the article, I use the concept "the economization of life" in reference to the historian and STS scholar Murphy's (2017) work.

[8] For an introduction to this line of discussions, for example, see, "The Special Issue 4—Biofuels, Land, and Agrarian Change," published by the *Journal of Peasant Studies* (vol 37, 2010).

[9] For example, for changing definitions of the bioeconomy in policy documents, see: Goven and Pavone (2015). STS scholarship has largely discussed bioeconomies with reference to health sciences and technologies; the case of biofuels has been marginal in these discussions.

analyses of financialization, capitalization, and assetization, they have examined a range of intersecting issues, including the instrumentalization of biomaterials, the creation of economic value out of biomaterials through manipulation, fragmentation, and extraction processes, and speculative nature of economies shaping life sciences (e.g., Rajan 2006; Waldby and Mitchell 2006; Franklin 2007; Landecker 2007; Helmreich 2009; Shukin 2009). In this regard, this literature helps me frame how technoscientific discourses and practices render organisms into biomaterials/biomass having economic value.

Anthropologist Helmreich (2009), in particular, has discussed the instrumentalization of biomaterials through laboratory practices. By following Marx's well-known formula M-C-M', "where M stands for money, C for commodity,' for the surplus value gained in a profitable exchange of a commodity for money, and M' for the total capital produced by that exchange," Helmreich writes an analogous formula: B-C-B' (Helmreich 2009, p 125). In this scenario, "B stands for biomaterial, C for its fashioning into a commodity through laboratory and legal instruments, and B' for the biotech product (or, perhaps, biocapital) produced at the end of this process, with' the value added through the instrumentalization of the initial biomaterial" (ibid). Helmreich underlines how economic value is already anticipated as innate within biomaterials before they are subject to laboratory experiments and legal practices—and before they come to circulate in markets. This is also relevant for algal biofuels research. Before algae are subject to experimental practices in laboratories and production sites, they are imagined having an innate value to add to economies. Such an anticipation of innate economic value centers on a particular take on algae, that is, algae as aggregate life.

To frame the rendering of algae into biomass, I also attune the work of historian Michelle Murphy. In *The Economization of Life* (2017), she explores the history of population and economy as two "aggregate forms of life." She describes how the economy has become our living environment as it is coupled with a naturalized population growth curve, one that is abstracted into a universalizing image of the balance between life and death.[10] From bacteria growing on a petri dish to *Drosophila* multiplying in a bottle, to humans reproducing in a class, city, nation, or on a planet, Murphy demonstrates how life everywhere gets "contained" to the container of economy (p 4). She studies economization as a "historically specific regime of valuation", one that governs life based on its ability to advance the macroeconomy of the nation-state. This is a regime of valuation that is historically specific—one that takes shape in and through technoscientific practices and social science methods rather than in markets (p 9). She draws attention to the emergence of a new era of experimentality in the 1970s that "contributed to building the infrastructures and epistemologies that made up the economization of life" (p 80). Experiments, for Murphy, are "technical-social assemblies that arrange and gather data about interventions into the world toward the possibility of making something different happen" (p 80). Further, she investigates how this particular form of experimentality emerged in the 1970s Bangladesh through state-governed family planning, and approaches it as a way to build infrastructures that posit "aggregate life as a recomposable conjectural domain open to and in need of repeated intervention" (p 80). Although Murphy's analytical scale is different from the one employed in this article, her work helps me frame algal biomass as aggregate life, which is subject to experimentation and contained in the container of economy. Such economization of algal life in the blue economy is the main problematic of this article.

The critical literature on blue economy has drawn attention to its multiple understandings, therefore, to the opportunity to "further adopt and subvert the term" (Silver et al. 2015, p 133; also, see: Winder and Le Heron 2017). Here, I take a critical stance towards such suggestions. I argue that the "blue economy" needs to be considered as a container in which organisms such as algae are imagined having an innate economic value in the form of aggregate life. For example, in such a container, algal lives matter until they refuse to grow in a manner that is meaningful to produce cost-effective biofuels to be bought and sold in the market. Stated differently, it seems that algal lives are not worth taking into account if they cannot be rendered into commodities in the container of the blue economy. This then provokes significant concerns regarding the so-called sustainability of blue economies: What makes blue economies sustainable? If it is, for example, algae's reproductive capacity and ecological value, why then would algae escape from attention at the moment they refuse to grow in cost-effective ways? It is clear that the blue economy depends on the constant economization of life, therefore, it centers on economic sustainability. At this point, I suggest that it is first required to get out of the container of the blue economy to begin building meaningful sustainable futures, at least (or, as it is possible for now) at the imaginary scale.

Imaginaries matter. They shape the articulation of the sustainability problem and the solutions offered to achieve and

[10] The degrowth literature has extensively discussed the way the "economic growth" paradigm became hegemonic by building upon historical and anthropological studies on the economy as well as the post-development studies (Kallis et al. 2018). While this literature puts emphasis on the institutionalization of growth paradigm as a worldview, Murphy's analysis draws attention to technoscientific practices—e.g., American biologist Raymond Pearl's experiments with fruit flies in bottles in the 1920 s, and the abstraction of the population growth curve (S-curve) that indicates the growth of fruit flies as a "universal tendency, repeatable for all life, everywhere" (Murphy 2017, p 2). .

maintain sustainable living. Scholars in the social sciences and humanities have long referred to "imaginary" as an analytic, object of study or effect in understanding modern societies. They have invited us to question the given nature of basic categories used in historical, social, cultural and political analyses. For example, Castoriadis (1998 [1975]) provided an understanding of society as a collectively imagined entity. Anderson (1983) opened an analytical space to conceive nations as imagined political collectives. Other works added specifications in understanding imaginaries: e.g., "the social imaginary" to explain different modernities (Taylor 2003); "spatial imaginaries" to explore how cognitive frameworks shape social movements (Wolford 2004); and, "climate imaginaries" as socio-semiotic systems that reflect particular environmental and cultural values (Levy and Spicer 2013). Recent works in STS further contribute to investigations of imaginaries at various theoretical and empirical levels (e.g., Marcus 1995; Fujimura 2003; Fortun and Fortun 2005; Jasanoff and Kim 2015; Tutton 2017).[11] From the imaginaries of scientists to the relation between imaginaries and knowledge production, STS scholars highlight that imaginaries are constitutive in scientific work as well as challenging the assumption that technoscience is only the realm of facts and artifacts. I suggest approaching the sustainability question within the framework of such imaginaries that shape, and are shaped by, technoscientific interventions.[12]

Until the nineteenth century, sustainable meant anything that is "bearable" (Oxford English Dictionary). Developed alongside ideas of economic growth and ecology, sustainability took on a new life in the 1960s as it began circulating in the field of economics and ecology—notably as an approach to the management of wild species and ecosystems.[13] With the Brundtland Commission's definition of "sustainable development" in 1987, sustainability has become a buzzword used across several domains of life and work, from engineering to architecture and design, to energy and ecology. Although both advocates and critics of sustainable development have widely debated the Commission's lack of specificity in defining exactly what sustainability is, it did pave the way for the emergence of a wide range of practices and ideologies about what sustainability could be. The concept further acquired undeniable prevalence by the 1990s, when it was championed at the 1992 United Nations Conference on Environment and Development in Rio de Janeiro. Since then, the notion of sustainability has spread in and through the earth in such a way that sustainability appears as if it is the collective desire of human beings across borders.

Governmental and non-governmental organizations, activists, artists, and scientists among other social actors work on sustainability at different scales from conceptual to scientific to policy one. Sustainability is treated, for example, as a specification of development, and critical studies of sustainability discourse have largely discussed the correlation between the rise of neoliberalism and the claim for sustainable development (e.g., McManus 1996; Escobar 1996). In line with these critiques, social scientists coined the term "green-washing" to draw attention to the capitalist embrace of sustainability—that is, the promotion of environmental and ecological branding to increase profit margins (e.g., Robinson 2004). Despite these critiques, many scholars suggest that sustainability narratives cannot be reduced to a capitalist logic, and instead claim that "the discourse of sustainability is part of the process of working towards sustainability" (Fricker 1998, p 374). These scholars suggest activating the concept of sustainability by refashioning its surrounding discourses and practices without reducing it into economic terms. In line with such a suggestion, some scholars began drawing attention to different dimensions of sustainability, including, economic, environmental and social (e.g., Adams 2006); and, they have explored sustainability as a political concern against the mainstream techno-managerial approach to sustainability by drawing attention to power relations and issues of distribution—for example, within the framework of environmental justice (e.g., Temper et al. 2018)—and/or as the normative goal (e.g., Patterson and Glavovic 2013).

Others have suggested embracing an understanding of "sustainability as a general, pluralistic, open principle that allows for many different solutions to be democratically discussed and acted upon" rather than technically or ideologically determining what sustainable solutions ought to be (Arias-Maldonado 2013, p 3). In the light of all these discussions, sustainability appears as if it is a boundary object: (1) it is "plastic enough" to be defined in particular

[11] For a genealogical approach to the plurality of STS approaches to imaginaries, see: McNeil et al (2017). In this piece, the authors extensively discuss key literatures that have been influential in the implementation of the imaginary concept in STS, namely, Western philosophy; psychoanalysis; late twentieth-century socio-political theory; and, science fiction. As such, this discussion also provides a review of different usages of the concept in social sciences and humanities.

[12] At this point, it should be clear that this article does not center on a critique of technological fixes while developing an analysis of the emergence of algal technologies to revitalize a faith in biofuels. Rather, I am interested in understanding the way technoscientific discourses and practices around algae and algal biofuels embed and constrain sustainability imaginaries.

[13] For example, see the definition of "sustainable growth," in The McGraw-Hill Dictionary of Modern Economy. Also, for ecological texts, see, Rachel Carson's *Silent Spring* (1962) and Meadows et al.'s *The Limits to Growth* (1972). Yet, these works do not by themselves "account for the emergence of the 'sustainable development' discourse associated with the Brundtland Commission" (McManus 1996, p 49).

ways according to local purposes,[14] and (2) it is "robust enough" to share a common identity across different contexts (Star and Griesemer 1989, p 393). What I am interested in is forming a common imaginary of sustainability, which should be bold enough—e.g., refusing the (blue) economy as a container for sustainable futures—to bring a radical socio-ecological change in the world. In a world witnessing the devastating effects of the constant economization of life through the growth ideology, (blue) degrowth discussions provide a significant point of departure to begin imagining sustainability otherwise.

Degrowth discussions underline that ecological and social sustainability require a radical political and economic reorganization of society (Kallis et al. 2018). Degrowth as a term "signifies a desired direction, one in which societies will use fewer natural resources and will organize and live differently than today" (Kallis et al. 2015, p 3). The emphasis on "different" encompasses almost all domains of life ranging from the energy use to the way humans establish relations with the more-than-human world to scientific practices. Rather than exploring the place of algal biofuel projects in a degrowth transition, I approach to (blue) degrowth as an imaginary, perhaps not within the terms of "utopia" (Kallis and March 2015), but more in the sense that inspiring new stories of algae that are not dominated by the tropes of economy. Algal lives outperform biofuel and/or blue economies; they are photosynthetic organisms and their ecological performance connects the sea to land, blue to green, humans to their environments. They are more-than-humans/oceans/blue economies/biofuels/biomass.

Blue degrowth is thus about "decolonizing the imaginary" (Latouche 2015): it is an invitation to imagine a society "in which economic values have ceased to be central (or unique), in which the economy is put back in its place as a mere means for human life and not as its ultimate end" (p 117). It can be considered as a call to drop using blue economy as "the container" of oceans, seas, and marine life forms, or as the dominant regime of valuation that specifies which lives worth living and which are not (Murphy 2017). In this regard, blue degrowth imaginaries provide a way out of the terms of economism to rethink the relations between humans and more-than-humans beyond utilitarian logic while developing technoscientific projects. Therefore, degrowth discussions simultaneously make an invitation to do science otherwise.

Political ecologists and degrowth scholars call for "the politicization of science and technology, against the increasing technocratization of politics" (Kallis et al. 2015; also see Asara et al. 2015). They, for example, call for a "post-normal science" to pluralize legitimate perspectives (against the rule of experts) and to increase capacity for problem-solving "when facts are uncertain" (D'Alisa and Kallis 2015). STS scholars further add to this discussion. There has never been a "normal science"—science has always been political; science gained its authority not through its fact making capacity or rigorous methods but through politics (e.g., see Shapin and Schaffer 1985). Thus, the way science is done becomes much more critical as it is shaped by, and shapes, the politics, which in turn, affect how sustainability gets imagined. In this article, I am particularly interested in the political effect of technoscientific projects centered on marine life, particularly of the integrated algal biofuel projects. I argue that these projects enforce particular sustainability imaginaries and exclude others. They constrain sustainability to technospatial growth imaginaries while rendering algae into biomass and bioremediation technologies. This limits the imaginaries of the relationship between humans and more-than-humans to economism. To me, this relationship stands at the very core of sustainability questions, and therefore, the ways humans build relations with more-than-humans matter.[15] Therefore, the overall aim of this article is to show the limits of anthropocentric sustainability imaginaries and emphasize the need to imagine sustainability otherwise through the lens of blue degrowth, out of the container of the blue economy. I now turn to a story of algal biofuels research to begin examining how these organisms get economized through technoscientific discourses and practices under the guise of sustainability.

Algal biofuels research

Algae are remarkably diverse organisms. Some scientists claim that 30,000 to one million species of algae exist on Earth (Guiry 2012), while others propose that a more accurate representation is closer to ten million species (Norton et al. 1996). Diversity comes not only in quantity but also in size. Researchers have also noted that algal species range from microscopic single-celled species "[smaller than] one micrometer in diameter to giant seaweeds over 50 meters long" (Graham et al. 2008, p 1). They present an array of colors ranging from green, brown, red, yellow, cyan, and golden—colors that alternate according to each organism's

[14] The emphasis on sustainability as a boundary object that is plastic enough also gestures towards the literature that acknowledges the strength of this malleable concept by noting that "it has the potential to create bridges among very different people" (Mansfield 2016, p 39).

[15] STS scholars have extensively contributed to the understandings of the relationships between "humans and nonhumans" with different analytics, concepts, theories, methods, and methodologies. A summary of this literature goes beyond the scope of this article; for works that focus on multispecies relationships, for example, see: Haraway (2008); Helmreich (2009); and, Tsing (2012).

production of chlorophylls and associated accessory pigments.[16] Some species, however, can also be transparent (ibid:11). Furthermore, algae take on different shapes. Several form filaments with cells joined from end to end, some clump together and form colonies, while others drift independently from each other. Algae also reproduce via diverse methods. Particular groups may multiply asexually, including fission or simple cell division; another species may undergo sexual reproduction—producing gametes that combine with the gametes of the opposite sex—while others perform different reproductive processes.

Despite their impressive variability, scientific discourses in biofuels research have often rendered these organisms into a singular form of life. In other words, distinctions between algal species may be overlooked in favor of searching for commonalities. During my research, I discovered that "algae," as an undifferentiated category, are often positioned as a singular, ideal, and sustainable source for biofuels. By this, I mean that a common term "algae" is employed to encapsulate diverse algal species into a singular grouping (e.g., DOE 2010). Further, it vernacularizes a distinction between algae and bacteria that are capable of photosynthesis from other photosynthetic organisms, namely plants such as corn, sugarcane, and wheat. Thus, although they are distinct organisms, microalgae, macroalgae, and cyanobacteria[17] all fall under the umbrella of "algal biofuels."[18] This lumping together of organisms largely lets any taxonomic differences or disputes disappear when discussing algae's potential and performance as a biofuel.

Another common refrain in scientific papers is that fossil fuels are the derivatives of ancient algae deposits.[19] This connection between fossil fuels and algae's "dead labor" illuminates one of the substantiated propositions in algal biofuel research: since the remnants of algae can form into fossil fuels over time, these organisms can be considered as energy sources in-the-making. The evolutionary timescale of algae is likely to solve problems on the industrial timescale of biofuels. In other words, these anachronistic narratives of algae envision this organism as providing sustainable, enduring, energy resource. Such stories naturalize algae's potential on the basis of its adaptation to various conditions throughout earth's history and make them readily available in the form of biomass for human use. Algae are no longer photosynthetic organisms playing a significant ecological role, but biomaterials that can be cultivated and accumulated in the form of biomass for energy consumption by humans. The naturalization of algae as an energy resource in scientific discourses is not neutral; these discourses make it possible to imagine algae having an innate economic value to add to the blue economy even before they become subject to laboratory experiments to be rendered into commodities.

However, algae are photosynthetic organisms. As algae photosynthesize, they participate in a process known as biogeochemical cycling; it is "the movement and exchange of both matter and energy between the four components of the Earth." These components are the atmosphere, the hydrosphere, the lithosphere, and the biosphere (Barsanti and Gualtieri 2005, p 159).[20] For example, in the eyes of scientists, oceanic single-celled algae become floating "invisible forests" that are responsible for almost half of the oxygen-carbon cycle on the Earth (Chisholm 2011). Further, studies of algae explore the flow of chemical elements in and through their bodies. This discourse of flows and cycles also emphasizes the major elements that largely compose algal bodies—namely, carbon (C), oxygen (O), hydrogen (H), nitrogen (N), sulfur (S), and phosphorus (P).[21] In this regard,

[16] Plants, algae, and cyanobacteria all contain chlorophyll molecules, which are identified in six different forms (*a, b, c, d, e,* and *f*) and differentiated according to the absorption of different wavelengths. Chlorophyll *a* exists in all photosynthetic cells and converts solar energy into chemical energy, while other forms of chlorophyll molecules work as accessories and transfer energy to chlorophyll *a*. Different chlorophyll molecules are called colour pigments, since they reflect different wavelengths to appear as different colours in sunlight (Campbell et al. 2009).

[17] The term cyanobacteria itself emerged in the 1970 s when controversies over the classification of blue-green algae (now, cyanobacteria) ended up with the suggestion that this organisms "really resembles in overall features, the genetic map of *Escherichia coli* [a form of bacteria]" (Margulis 1977, p 83). I interpret the inclusion of cyanobacteria in the definition of algal biofuels —regardless of the debates over its place in bacteria or algae groups— as a strategy to popularize, and thus, potentiate a form of biofuels produced via organisms that are different than plant crops. .

[18] I draw attention to this distinction in order to highlight the problems of taxonomic orderings, while attempting to avoid the same trap of reproducing blanket categories. For the sake of writing convention, however, I speak of these categories in the shorthand of "algae.".

[19] "The oil we currently exploit comes from Cretaceous deposits of marine algae"—and, "[a]s we use up the oil deposits provided by ancient algae, we are turning the modern algae for help" (Chapman 2013, p 12).

[20] The atmosphere is "the air envelope that surrounds the Earth"; the hydrosphere "includes all the Earth's water that is found in streams, lakes, seas, soil, groundwater, and air); the lithosphere is the "solid inorganic portion of the Earth, including the soil, sediments, and rock that form the crust and upper mantle"; and, the biosphere refers to "all the living organisms, plants, and animals" (Barsanti and Gualtieri 2005, p 159).

[21] "In total, 99.9% of the biomass [algal bodies] is account for by [these] six major elements…The remaining elements [calcium (Ca), potassium (K), sodium (Na), chlorine (CI), magnesium (Mg), iron (Fe), and silicon (Si)] occur chiefly as trace elements, because they are needed only in catalytic quantities" (emphasis is mine, Barsanti and Gualtieri 2005, p 160).

algae can be considered “elemental rearrangers” (cf. Myers 2016). While algae become subject to biofuels research, their beings and doings are mostly reduced to the functional and instrumental roles (e.g., absorbing carbon dioxide, phosphorus and nitrogen) rather than being extolled as active organizers of elements having capacity in sustaining life on Earth. Instrumentalization of algae is also not a neutral act; rather, it domesticates organisms as use values for humans. In integrated algal biofuel projects, algae become domesticated not only as a resource for biofuels production, but also as bioremediation technologies by way of these organisms absorb carbon dioxide and phosphorus and nitrogen at the industrial scale. As I detail later in my discussion of the OMEGA project, the production of these elements at the industrial scale—in the form of waste—does not necessarily come to fore as a problem to be solved before it emerges, but appears more as an opportunity so as to cultivate algal biomass for large-scale biofuel production. Therefore, the promotion of these systems as sustainable based on algae’s capacity to absorb particular elements becomes questionable. Since, these systems foundationally depend on the sustained production of industrial waste.

At a practical level, algae-based biofuels were first conceived of in the 1950s through a study of small-scale algae-based methane production at the University of California, Berkeley in the United States (see Oswald and Golueke 1960). This project supported dominant scientific discourses at the time, which suggested that “photosynthetic processes such as algal systems may not be justifiable if used solely as large-scale energy plantations” (Goldman and Rhyter 1977, p 367). Further, the proposal was linked to a post-World War II paradigm where energy conservation programs, including wastewater treatment, were favored. Today’s algal biofuel projects that are centered on algal cultivation in wastewater—as in the case of the OMEGA project— should thus be taken into account as a scientific practice advancing since the 1950s.

The idea against the utilization of algae merely for large-scale energy plantations began to be challenged through the end of the 1970s. Biochemist John Benemann and his colleagues prepared a landmark report (1978)—entitled *Engineering Design and Cost Analysis of a Large-Scale Microalgae Biomass Systems*—for the US Department of Energy. This report proposed that large-scale algal systems could produce methane gas at prices competitive with projected fossil fuel costs. In the same year, President Jimmy Carter launched the Aquatics Species Program (ASP)—the first large-scale, government-supported algal biofuels research and development project in the United States.[22]

The main objective of the ASP was “the production of biodiesel from high lipid-content algae grown in ponds, utilizing waste CO_2 from coal fired power plants” (Sheehan et al. 1998, p i). Research activities were mostly carried out by National Renewable Energy Laboratory (NREL) researchers at the labs in Golden, CA, alongside “subcontracted research and development activities conducted by private companies and universities around the country” (ibid). This research projected algal biodiesel production costs twice as high as contemporaneous petroleum diesel fuel costs—even after accounting for aggressive developments in algal breeding programs (ibid:13).[23] Although some note that the program ended in 1996 over concerns of algal biodiesel pricing, I speculate that governmental support for corn-based bioethanol production played a major role in the closure of the ASP. I posit this assumption on the basis of insights garnered in the program’s closeout report. This speculation crystallizes when I return to the US government’s renewed interest in algal biofuels research and development in 2007, following the critiques of corn and other biofuel sources in the “food versus fuel” debate.

Established under the US Energy Independence and Security Act of 2007 (EISA), the Renewable Fuels Standard (RFS) mandate paved the way for the search of alternative source of biofuels that did not compete with agriculture.[24] Nevertheless, although the EISA revitalized scientific and commercial interests in algal biofuels, algae did not gain considerable popularity until May 2009 when US President Barack Obama and US Secretary of Energy Steven Chu announced the investment of $800 million in new biofuels research as part of the American Recovery and Renewable Act. The DOE largely revived its investment in algae-based

[22] The US Department of Energy’s Office of Fuels Development funded the ASP. The DOE funded the program through the Solar Energy Institute (SERI) in Golden, CO—which became the National Renewable Energy Laboratory (NREL) in 1991. SERI was a “first-

Footnote 22 (continued)

of-its kind federal laboratory dedicated to the development of solar energy. The formation of this lab came in response to the energy crises of the early and mid 1970 s…Among its various programs established to develop all forms of solar energy, DOE initiated research on the use of plant life as a source of transportation fuels.” (Sheehan et al. 1998, p 1). Today, the Office of Fuels Development is known as the Bioenergy Technologies Office under the Office of Energy Efficiency and Renewable Energy.

[23] In the first phase of the ASP, researchers collected algae from “sites in the west, the northwest, and the southeastern regions of the continental US, as well as Hawaii” (Sheehan et al. 1998, p 11). The second phase of the program focused on the biochemical and physiological studies of collected algae on the basis of their lipid production. Lastly, researchers employed techniques of molecular biology and genetic engineering to increase the productivity of algal lipid production.

[24] The RFS mandate limited the amount of corn-based bioethanol that could be blended with conventional transportation fuels to 15 billion gallons by the year 2022 out of a total of 36 billion gallons of renewable fuels (DOE 2016, p 1).

biofuel research, development, and deployment alongside the support of the Obama Administration.[25]

The pervasiveness and historical trajectory of algal biofuels research in the US has found its way into many other regions and countries in the world. For example, the European Parliament included algae as a renewable energy resource in the Renewable Energy Directive (2008); European Algae Biomass Organization was established to promote cooperation in the field; and, AlgaEurope conferences are organized each year, and these conferences work as a meeting point for academy and industry. Governmental agencies, civil society organizations, private investors, and scientists today continue working in tandem to make algal biofuels a viable and sustainable energy resource.

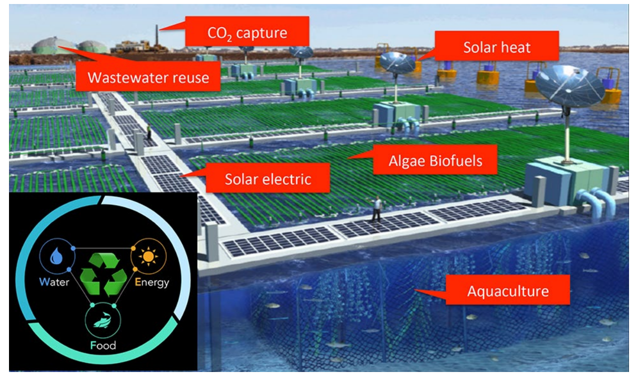

Fig. 1 The design of the OMEGA project The image retrieved on-line (Trent 2018)

Designing sustainability via algae

In a 2013 interview, NASA researcher Jonathan Trent exclaims, "[p]eople have lost faith in biofuels." He believes that algae could help with re-cultivating that "faith":

> Biofuels are my passion, but they have had rather a bad press [*sic*], from complaints about displacing food production to the inefficiency of soybeans and the carbon footprint of ethanol. Microalgae have a low profile but they deserve a much higher one, since the fossil oil we mine mostly comes from microalgae that lived in shallow seas millions of years ago—and they may be key to developing sustainable alternative fuels (Trent 2012) .

Trent signals the problems related to first-generation biofuels, lauding algae for providing solutions to these problems—problems that include the use of agricultural land for the cultivation of energy crops, and the inefficiency of crops such as soybeans on an industrial scale of production. For Trent, dead and sedimented microalgae in the oceans constitute fossil fuels over time, and therefore living algae "may be key to developing sustainable alternative fuels." In other words, Trent suggests that the evolutionary timescale of algae is likely to solve problems on the industrial timescale of biofuels. His passion for sustainable biofuels finds its way in a project that would become the hallmark of his career: the "Offshore Membrane of Enclosures for Growing Algae" (OMEGA).[26]

The OMEGA system is an offshore system that cultivates algae in floating plastic bags for manufacturing algal products such as biofuels, fertilizer, and food (Fig. 1). Algae are cultivated in a medium of wastewater fed by an additional carbon dioxide source. In addition to the waste treatment process, the system also integrates local energy resources (wave, solar, and wind), as well as aquaculture. Overall, the floating platforms make use of wave energy and are covered with water-cooled solar panels, which produce heat and electricity required to pump and circulate nitrogen and phosphorus-rich wastewater within the plastic bags used as photobioreactors for algal growth. Below the surface, the system supports aquaculture for local seafood production. Such an integrated design brings several blue economy sectors together, namely aquaculture and ocean energy (EC 2017). However, the promise of the OMEGA system while activating algal biofuels in/for the blue economy does not seem to be limited to sectorial development. Rather, the OMEGA project gets proposed as a sustainable solution to the problem of energy, food, and water.

In a TEDx Academy talk, entitled "Evolution in our environment from A to Ω (2015),[27] Trent presents the problem of energy, food, and water as interrelated.[28] In his talk, he

[25] The legislative environment that regulates and supports algal biofuels is not limited to the US DOE's jurisdiction. For a further information about the policy environment related to algal biofuels, for example, see Trentacoste et al. 2015.

[26] The project "Offshore Membrane of Enclosures for Growing Algae" (OMEGA) was led in between 2009–2012 as part of the NASA Ames Research Center. This project began as a biofuels project but later evolved into an algal biofuels projection integrated with

Footnote 26 (continued)

water recycling, solar energy production, and compatible aquaculture, among other components (https://www.bfi.org/ideaindex/projects/2015/omega-global-initiative). In 2015, the project leader Jonathan Trent launched the non-profit OMEGA Global Initiative to promote the OMEGA vision in coastal regions. Further, in recent years, the project also appears to have a new title while the abbreviation is kept—namely, "Operational Marinas for Economic Growth and Abundance." It is noticeable that growth (economic growth linked to algal growth) stands at the core of this project.

[27] Trent (2015, October). Jonathan Trent—Evolution in our environment from A to Ω [video file].

[28] The articulation of these problems as interrelated also speaks to what some are calling the "popularization of 'nexus thinking' in policy and academic discourses" (Williams et al. 2014, p 4).

locates algal biofuels among pictures of other infrastructures designed to cultivate resources, while also providing a reading of history through popular imaginaries about the co-evolution of humans and tools. He claims that humans developed tools to respond to problems related to energy, food, and water. These tools are both evolutionary and revolutionary, as humans have the capacity to respond and provide solutions to these enduring interrelated problems. As he states in one of his articles, today, these problems come together and constitute the "big unresolved problems at which governments should be throwing funds and brainpower as if we were involved in a Manhattan Project" (Trent 2012). Thus, according to Trent, a large-scale governmental program should tackle the present energy-water-food problem and algal biofuels should be a part of it.[29]

Trent's statement about the food-water-energy problem is neither naïve nor arbitrary. It is a political and strategic act to lobby for the OMEGA project. The figuration of these problems as enduring—as ahistorical and apolitical but evolutionary—creates the conditions for the anticipatory regime of the OMEGA project that "tack[s] back and forth between the past, present, and future" (Adams et al. 2009, p 256), which situate humans with capacity to solve these past and present problems for achieving sustainable futures. This talk also reminds me of feminist STS scholar Donna Haraway's (2016) discussion over telling so much earth history "in the thrall of the fantasy of the first beautiful words and weapons" (p 39). Haraway continues:

> Tool, weapon, word: that is the word made flesh in the image of the sky god; that is the Anthropos. In a tragic story with only one real actor, one real world-maker, the hero, this is the Man-making tale of the hunter on a quest to kill and bring back the terrible bounty (Haraway 2016, p 39) .

Haraway challenges anthropocentric storytelling and notes: "Man plus Tool does not make history. That is the story of History human exceptionalists tell" (p 49). Rather, she invites us changing the story to see "how a common world, how collectives, are built with each other, where all the builders are not human beings" (p 41). Trent does also change a story with the help of algae, that is, the story of biofuels that caused multiple socio-ecological problems ranging from deforestation to the marginalization of small farmers. However, the way Trent legitimizes the OMEGA project embeds, implants, and constrains the sustainability question within anthropocentric terms. As I discuss below, an anthropocentric approach to sustainability has political effects in the sense that this approach reproduces Malthusian visions of life, the ideology of growth, and even neocolonial visions of the future.

According to Trent, oceans, and specifically, protected bays, are the best opportunities to establish cost-effective algal farms. He explains why: "some 40–60% of Earth's population lives near a coast, most of the biggest cities are near a coast, and nearly all coastal cities discharge wastewater offshore." Thus, bays are potential sites for the establishment of OMEGA systems. Although there are no OMEGA systems yet in operation,[30] the selected research sites for this project are close to wastewater treatment plants and carbon dioxide-intensive industries, in specific American bays, such as San Francisco Bay.[31]

Trent sees opening the oceans to large-scale algal cultivation as an important step in avoiding competition with agriculture. Challenging algal biofuels projects that propose the use of "marginal lands" to build algal farms, Trent (2011) differentiates his offshore project by troubling the idea of marginal or non-arable lands:

> I don't buy the argument about using the so-called non-arable land for algae cultivation, because if we made all the effort of transporting water and fertilizer to non-arable land to grow algae, why would we not make it arable land and start growing food on it?

Trent challenges the claim that non-arable lands are only suitable for energy projects. Yet, Trent's critique is different from discussions about how the concept of "marginal land" works as an economic-technical legitimizing tool for land-grabbing, an issue that has been widely discussed in

[29] Trent, while claiming that the OMEGA system provides solutions to all these problems in an environmentally friendly and sustainable way, underlined how this system contributes to "green economies," what he sees as the "revolutionary tool" of present times. The concept of a "green economy," institutionalized in/through the United Nations Conference on Sustainable Development (Rio+20, 2012), has been subject to wide critical scrutiny for how it valorizes and monetizes nature conceived as "natural capital"; as if nature were a service-provider for human well-being (e.g., Jessop 2006; Shear 2010; Escobar 2011; Kenis and Lievens 2015). What I want to underline here is how ideas and practices around green economies are spreading in a way that legitimizes projects such as the OMEGA system.

[30] STS perspective especially becomes important for studying projects that have yet to be realized at least to an extent that let social scientists to assess their socio-environmental impacts. The analyses of not-yet-realized projects are not a speculative endeavour to assess any potential impacts. Instead, the focus on thought experiments or technoscientific practices at the laboratory and pilot scales is informative in understanding what these projects do to the world. Stated differently, experiments are not mere scientific processes but are world making practices. .

[31] As the full name of OMEGA (Offshore Membrane of Enclosures for Growing Algae) already connotes, the political economics of this project constitutes a new form of enclosure extended from land to the oceans. Such an imaginary of enclosure not only limits the use value of oceans to specific power groups, but also establishes a (new) instrumental relation with nature (cf. Heidegger 1977). .

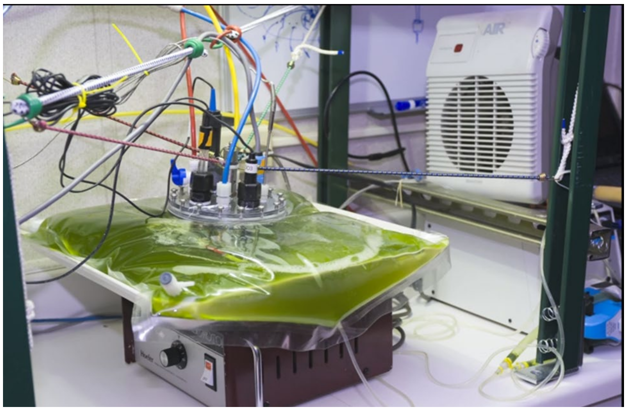

Fig. 2 Developing OMEGA photobioreactors The image is from the on-line news page of NASA, from the article entitled "NASA envisions 'clean energy' from algae grown in waste water" (April 22, 2009)

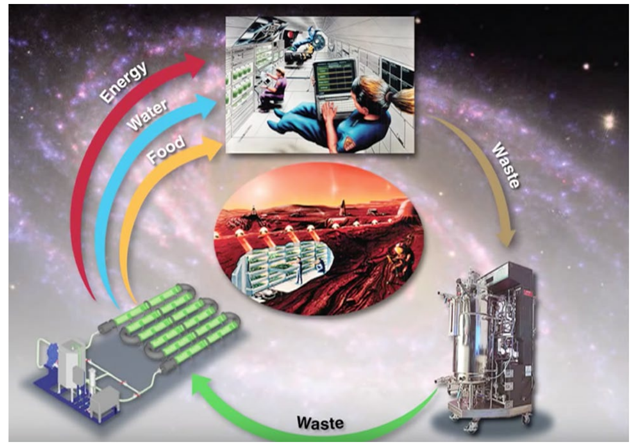

Fig. 3 Recycling waste The image is retrieved from the on-line public source and represents how the OMEGA system is based on NASA's "life support system"

critiques of biofuels (e.g., see Nalepa and Bauer 2012). In Trent's critique, economics override social and political concerns about marginalizing lands for re-appropriation, for example, for energy projects or construction. Trent's insistence on offshore systems instead of land-based ones is in line with what the blue economy suggests: that oceans are economically productive ecologies.[32] For Trent, oceans become productive when they allow large-scale algal biofuels production systems to endure. He is interested in the "economic sustainability" of these systems. At this point, it is required to unpack how the economic sustainability of the system gets translated into its ecological sustainability. One possible analytic could be to zoom into the design of this system by exploring its material semiotics.

OMEGA system centers on a particular technology—the floating photobioreactors (PBRs)—that is developed by the project team to cultivate algae offshore (Fig. 2). The operation and management costs of PBRs are high in comparison to open ponds, as they require artificial light sources if built indoors, or additional systems such as cooling or heating, if built on land.[33] Trent et al. (2011) note: "To produce biofuels, thousands of acres of raceways and tens of thousands of PBRs [located in deserts and unusable fallow land] will be required… The Devil is in the details" (p 19–20). The details include how the PBRs are designed and installed offshore—how they benefit from being located in the oceans: they clean waste, ideally without any added energy use, through osmosis.[34]

The design of the OMEGA PBRs was inspired by NASA's "life support systems" (Fig. 3). The basic idea behind these systems is to re-use waste for "efficient" and "parsimonious" uses of resources during space travel. As Trent et al. (2011) note: "The challenges and rigor of space travelled NASA to design and develop equipment and life-support systems that optimize the use of resources, minimize the use of energy, and recycle, refurbish, and reuse everything" (p 22). Trent (2013) then suggests that the management of "limited resources" during long space exploration travel should also be a concern for life on planet earth, especially at this time of depleting fossil fuels, warming atmosphere, and increasing human population. In other words, for Trent, the OMEGA system provides a solution to the problems associated with urbanization as well as population growth. The solution includes recycling waste at the same time meeting the new energy demands of an ever-increasing human population, demands that can no longer be met by fossil fuels. The way he sets the problem, which centers on the question of "resource scarcity" amidst unchecked population growth, reproduces Malthusian visions of life.

However, the production of waste at the industrial level—the wastewater and flue gases—that constitutes one of the challenging environmental problems does not seem to be directly addressed. Rather, these environmental problems

[32] For example, see the report on the blue economy, published by the World Bank and United Nations Department of Economic and Social Affairs (2017).

[33] Open ponds are inexpensive infrastructures to produce algal biomass. Yet, the problems of contamination and evaporation, as well as the lower yield associated with these ponds encourage algal researchers to work with PBRs.

[34] By balancing osmotic pressures against hydrostatic pressure, the OMEGA PBRs benefit from the salinity difference between wastewater and seawater with the help of a selective semi-permeable membrane. For further technical details, see OMEGA-So (2015) .

emerge as opportunities for large-scale algal cultivation in PBRs Trent (2013) notes:

> In these life-support [systems], *waste is a verb* and everything we consider a waste product here on Earth is carefully scrutinized for its potential contribution to making food, clean water or energy (my emphasis) .

In Trent's words, waste is not a "matter out of place," as the Douglasian analysis would suggest.[35] Rather, he talks about waste as an agent or catalyst, one that contributes to the making of food, energy, and clean water. This idea of waste as a verb is made possible through the design of PBRs—which I call, *built ecologies*. These PBRs fundamentally depend on algae's photosynthetic capacity and the flow of elements in the waste streams (e.g., nitrogen, phosphorus, and carbon dioxide). Algae are no longer photosynthetic organisms but rendered into a bioremediation technology that cleans waste. Furthermore, the waste streams activate algal growth and reproduction within the limits of these built ecologies. In other words, algal cultivation in the OMEGA system depends on the industrial waste streams, and for this system working, it seems that waste needs to be generated again and again. As such, the OMEGA project provides a solution to industrial waste problems without necessarily problematizing its generation. What the OMEGA project promotes seems to me like this: *More growth more waste more algae more growth.* This makes me question the emergence of the OMEGA system as a sustainable solution that centers on the valorization of waste while managing it through built ecologies.

In the OMEGA system, waste as an environmental problem gets transformed into resources that support algal growth and economic growth. This transformation requires technoscientific knowledge as well as the development of particular technologies, such as photobioreactors. Designing an integrated algal biofuel system offshore with the help of scientific knowledges and technologies constrains solutions to sustainability problems to techno-spatial growth imaginaries. These imaginaries are limited in the sense that they reproduce the growth ideology and the Malthusian visions of life. However, sustainability is a problematic: it indicates the devastating effects of growth ideology, colonial relations, the capitalist mode of production, and human hubris in controlling nature. Such indicators are rendered invisible in the OMEGA system without questioning the constant waste generation by industrial activities.

Following anthropologist Fortun (2014), I suggest that rendering algae both as a bioremediation technology to clean waste in the OMEGA system is in line with the familiar story that she calls a "modernist mess" in "late industrialism." For Fortun, "late industrialism" is the timescale of "[d]eteriorating industrial infrastructure, landscapes dotted with toxic waste ponds, climate instability, incredible imbrication of commercial interest in knowledge production, in legal decisions, in governance at all scales" (Fortun 2014, p 310). In a conversation with Latour (1993), Fortun notes:

> Industrial order… in some of its dimensions, has indeed never been modern, mastered, subjected to law. Yet it is also modern with a concreteness that has had devastating environmental effects. It is these discontinuities that we must attend to… [E]ven if we have never been modern, we still have a modernist mess on our hands, a concrete mess, produced (in part) by what could be called an industrial theory of meaning and value, an industrial language ideology (Fortun 2014, pp 310, 312) .

In the OMEGA system, wastewater and flue gases are a "modernist mess" that is subject to remediation. Fortun draws attention to particular forms of "remediation" that move such messes to other "more marginal places, out of sight and mind," such is the case of environmental racism in the story she tells about Perry, Alabama, which is home mostly to African-Americans living below the poverty line (Fortun 2014, p 310). In the OMEGA system, however, pollution is not externalized in this way. Rather, the practitioners of the OMEGA system try to integrate, if not internalize, waste into "late industrialism." This approach differs slightly from the efforts of environmental economists who treat "negative externalities," like pollution, as commodities to be included in the market (Scoones 1999, p 486). This line of capitalist thinking suggests the "cure" for pollution lies "within the market functioning of the system itself" (Swyngedouw 2010, p 223).[36] Although the story of OMEGA appears to unfold along similar lines, I see this approach as more nuanced. The OMEGA project is not merely reiterating another story of commodification—for example, as in the case of carbon trade. In that approach, externalities remain

[35] Social scientists, including anthropologists, sociologists, and geographers, have discussed not only what waste is, but also what multiple discourses and practices around waste in different societies teach us about people, cultures, economies, politics, and environments. I discern two main schools of thought in the literature on waste within the scope of my research. The first can be traced to anthropologist Mary Douglas's *Purity and Danger* ([1966] 2002). Douglas examined cross-cultural and temporal meanings of "pollution." Studies following Douglas's structural and symbolic account have explored waste as a "matter out of place," as well as a "mirror of culture" (Reno 2014). By the 2000 s, similar social constructivist approaches had been challenged extensively, and waste has become the topic of materiality studies (e.g., Gille 2010; Reno 2015).

[36] As many discard studies scholars remind us, the pollution question is not only about capitalism but is also largely linked to colonialism. For a discussion on "pollution as colonialism," see: Liboiron (2017).

external, only to be integrated into the industrial order to create new markets and economic values. Said differently, the design of the OMEGA project suggests that if there were no externalities—such as excessive sources of carbon dioxide—it would not be possible to cultivate algae as biomass to drive the blue economy. Therefore, the blue economy is not merely about creating a new commodity frontier at the scale of marine environments. Instead, as my study of the OMEGA project depicts, the blue economy works as a container for the "modernist mess," and calls in algae to clean up this mess. At this point, it is required to activate blue degrowth imaginaries to prevent the recreation of the same problem, that is, the industrial waste constantly produced through growth imperatives. Sustainable blue futures would thus become imaginable only out of such containers that have nothing to do more than economizing life and preventing radical socio-ecological changes.

Conclusion

In a panel held at Stanford University in 2014, the OMEGA project leader Jonathan Trent began his presentation entitled "Sustainable Energy for Spaceship Earth" after showing a video clip prepared for Rio + 20.[37] In the clip, I hear a woman's voice, while seeing several segments from an image of planet Earth. The voice tells a story of how humans, as a species, have changed the planet, and ends with the slogan, "Welcome to the Anthropocene." And Trent, as if he had accepted the voice's invitation, began his talk. He raised the question: "Can we shape our future? I mean we're shaping our present, but can we shape our future?" By "we," he directly referred to the American people, not the wider "we as humanity" in the video presentation. Trent continued: "The US can now export another lifestyle to the world through the OMEGA." Such a neocolonial vision of the future made me wonder more about the OMEGA project while developing an ethnographic research on the emergence and spread of algal biofuel projects.

In this article, I have examined the algal biofuel projects that seek to revitalize faith in biofuels in the blue economy. I have questioned what makes these projects sustainable. Against the common refrain that the utilization of algae as renewable energy resource makes biofuel projects sustainable, I underlined there is nothing natural, innate, about algae to add to the blue economy. Rather, algae are rendered into the so-called sustainable energy resource through technoscientific discourses and practices. To understand how such a rendering happens, and with what effects related to the sustainability question, I first discussed the mainstream scientific discourses and practices in biofuels research that naturalize algae as sustainable energy resource through reducing these oceanic organisms into a form of aggregate life (biomass) as well as instrumentalizing their photosynthetic capacity in cleaning waste. I noted that algae had already been rendered into a resource and bioremediation technology before they become subject to the OMEGA project. I then analyzed the OMEGA project from a material-semiotics perspective to explore the politics embedded in this technoscientific project. While exploring how the economic sustainability of an algal biofuel production system gets translated into its ecological sustainability through its very design, I showed that waste as an environmental problem—pollution—emerge as an opportunity for biofuel production. Given that the OMEGA system depends on the constant generation of industrial waste, I questioned the promotion of this system within the terms of sustainability.

My analysis of the OMEGA system shows that the "sustainability" imaginaries around algal biofuel projects are anthropocentric, and largely shaped by the Malthusian visions of life and the ideology of growth. These anthropocentric imaginaries are neither naïve nor arbitrary. These are the imaginaries that create the sustainability problematic, which then again get addressed through technoscientific projects that reproduce these imaginaries—that looks similar to what the OMEGA project promotes: *more growth more waste more algae more growth.* Instead of getting stuck in such a world, I strongly believe that the sustainability question needs to be addressed from a very different perspective than the blue economy towards radical socio-ecological change. To do so, first, a change needs to be created at the imaginary level; neither technoscience, nor algae, or the blue economy would solve today's urgent environmental problems such as climate change. That is why, as degrowth scholars suggest, "we" need to begin with decolonizing our imaginaries. And, yes, a radical change in lifestyle is required; but this change would not happen through reproducing colonial desires of importing US lifestyle to the rest of the world, but through changing how people establish relationships with the so-called non-human world in/through various domains of life. Given that these relationships have largely been shaped, specified, determined by the ideology of growth, blue degrowth is the point of departure to begin activating meaningful sustainability imaginaries around marine life, which are not contained, constrained into economism. How to do so, for example, in terms of human–algae relations, perhaps, require creative practices and stories that draw attention to algae's photosynthetic capacity more than its reduction into resources and technologies in/through biofuel projects.

[37] Trent (2014, February). Franchise for humanity: Jonathan Trent on sustainable energy for spaceship earth [video file].

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