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For Rehumanizing Futures by Design

The Open Journal of ReFuturing

Centenary Special Issue

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Contents:

Notes from the Editors

What you hold in your hands is the Centenary Edition of The Open Journal of ReFuturing. To commemorate the hundred years since our first edition, the editorial team has chosen to pursue an experiment by reconstructing historical events accounting for a century of climate reparations. In the spring of 2131, a centenary lecture series was hosted by the Centre for ReFuturing Studies in Oslo to mark the occasion. The event hosted invited lectures forming a disciplinary coalition to study the past century of climate action and inaction; a look back to understand what lies ahead to remember the stakes involved. The rejuvenating lectures between the co-authors cultivated provocations and discussions that developed into this publication. To match the range of complexity that the authors bring up, we must veer away from tradition for this special centenary edition. While we usually publish articles, given the scholarship's peculiar nature, we were compelled to respond in kind to the scope of the generated outcome by rethinking our journal conventions. Therefore, we have decided to proceed with three long-form chapters for this edition. However, as is tradition, this issue is being published simultaneously in multiple regional languages. This is the English language edition.

While many who study the early 21st century tend to cast a sense of inevitability about the societal transformations, it was anything but. The following chapters reconstruct the scope of understanding the crises back then, what was known at the time, and having understood the challenges, what kinds of actions or inactions were pursued with this knowledge. As the authors conclude, to conceive of a radically different image of society in that time involved accomplishing the seemingly impossible to prevent the unthinkable. Established human life in these times relied on alienation from the natural world. Like a snake eating its tail, these regimes were constantly self-contradicting, destroying what they claimed to repair and care for. These contradictions were self-evident even in moments when they repeatedly tore these regimes apart and yet, bizarre as it may sound, were almost instantaneously remade as though societies could not imagine another way.
This so-called calcification of the social imagination inflicted a heavy price on the planetary biosphere as the climate thresholds were breached.

For this reason, this publication has been a daunting task of a historical reconstruction given how alien the rationalities that drove these tendencies seem today. We still find it difficult to imagine the kind of society that deliberately overlooked the possibilities of pursuing freedoms that lay dormant, barely concealed from view. One of the authors befittingly expressed this tendency as "a colossal stupidity of civilizational proportions." Despite unimaginable odds, those who struggled for fossil abolition and climate reparations continued to practice a creative audacity to imagine a different society. The chapters also attempt to illuminate some of the struggles our ancestors encountered and the brutal repression they endured.

Thus it is sometimes easy to forget that the Climate Reparations and the Blue Reparations projects were also civilizing movements. The rehumanization of everyday life in this period saw many fundamental freedoms maturing into lived cultures. Climate justice in everyday life was non-negotiable, and expanding institutions of care and social freedoms proved incomparably more symbiotic to the climate resilience movements than many acknowledged at the time. Perhaps we need to examine what may still be missing when we reimagine these forms of 'social freedoms' described by the authors. Freedoms that have made a tangible impact on the world: from the Climate Resilience Zones to the Pan-Indigenous old-growths; from the networked municipal microgrids to the indigenization of energy cultures emergent in radioactive landscapes; from the freedom to dream foolhardy rainmakers to the successes of symbiometallurgical practices; all to the colossal coral rehabilitation projects of the black coral reefs.

We hope those who read this publication care for the ideas within it as much as we did crafting it.

The Editorial Team
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A planetary sense-making

Illustration by Sephin Alexander

“There was never an energy crisis, only a crisis of civilization.”

– Noam Appiah (2106) in *First Letter of the Masisi Elders to the Old World*

1. Glocal Energy Cultures: Realising 22nd Century Radical Indigeneity and Beyond

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Introduction

The 22nd century continues to bear the long-term legacies of the fossil fuel infrastructures from the past centuries and their devastation of our planetary ecosystems. While a momentary industrial civilization emerged, it almost just as immediately became an existential threat to all of life and to itself. This chapter will explore the techno-historical legacies of this period leading up to the 22nd century that may help us understand the global energy cultures of our ancestors at the time—based on centuries of "cheap" fossil hydrocarbon fuel pumping carbon out of the Earth and ocean beds. Despite the near-collapse of civilization along the way, the 22nd century seems to have shown some promising signs of recovery, if one can call it so.

While one can explore this period's political, socio-economic, and ecological struggles within the open archival records, this chapter will explore some of these perspectives for a more coherent understanding of regenerative, community resilience practices through certain renewable energy artifacts. Other practices emerged over the past century, enabling the transformation of renewable energy infrastructures worldwide. While some artifacts, such as organic battery printers and 3D printed fiber-optic solar cells, were integrated within municipal microgrids, we will frame them in the contexts that realized them. These may have led to options for 'radical indigeneity' emerging in specific regions that have fundamentally reimagined more symbiotic notions of energy production and consumption for us. As plural socio-cultural and ecological pathways for climate reparations continue to develop, so does the radical indigenization of techno-social spheres of communal life. There is a newfound possibility that average global warming might start to fall below 2oC, as precarious as it may be.

1. Living on Stolen Time: The Paradoxes of a Climate Emergency

It would go without saying that the challenges of the 22nd century are different from the century that came before it, separated across continuums of space and time. However, why the near-collapse of civilization itself became possible remains unanswered, while much of the 22nd century continues to reel under the Hothouse Earth predicted over a century ago (Steffen et al., 2018; Ubumwe, 2114). However drastic the reduction in global energy footprints recently observed might be (Richardson et al., 2129), the shift has come about with much turmoil, ultimately creating the negative emissions loops needed for regenerative, renewable energy transitions. To attempt to grasp the emergence of these changes, one must understand them in the context of how they came about and perhaps ensure that there is a stable biosphere for humanity beyond the 'hothouse' state.

1.1 Climate Emergency over Space and Time

For decades, the intergovernmental committees investigating these concerns unanimously concluded that radical changes to organized human life were needed. They called for an end to fossil carbon emissions and a halt to the 'willful annihilation of whole ecosystems', urging governments to take drastic measures to restore and regenerate ecosystems (IPCC, 2018; IPBES, 2019). Socio-economic hegemonies systems ignored these proposals just as often as they were published. The nation-states and the ruling regimes pursued remarkably bizarre and irrational pursuits for infinite economic growth under the guise of human progress. Human civilization was crossing the non-negotiable thermodynamic thresholds of the planet while the very mechanisms and structures that caused the crises, to begin with, were proposed as the means to solve it (Figure 1 a).

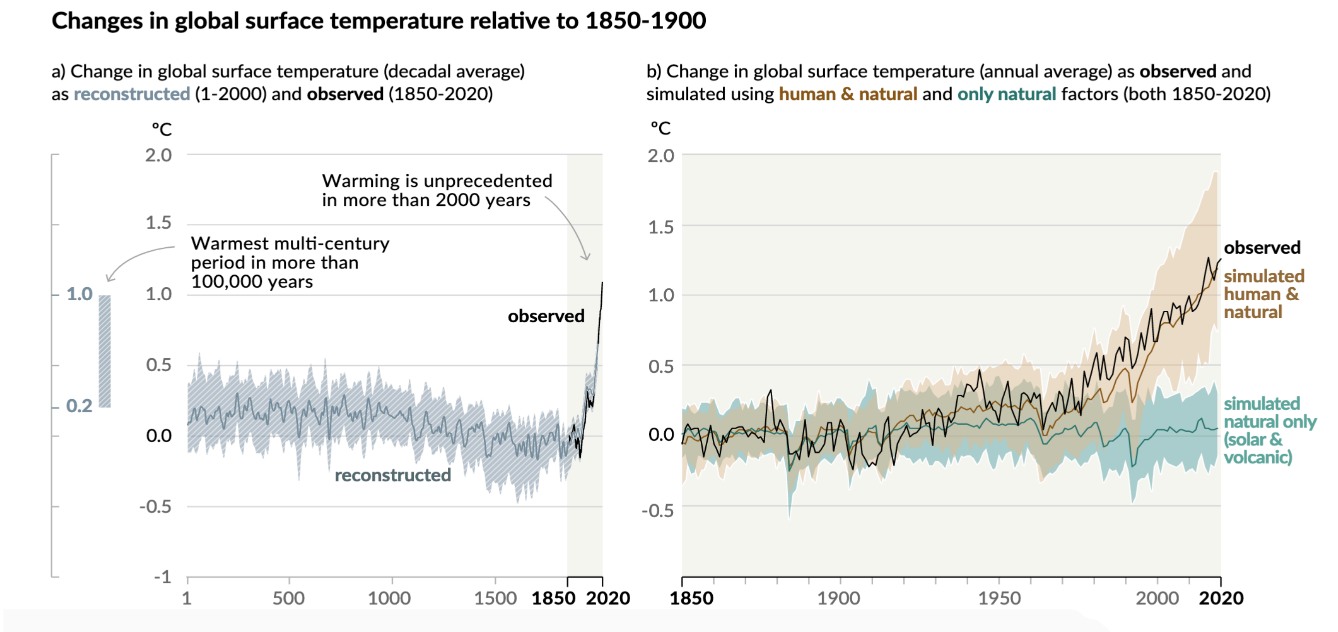

Figure 1 What was known of global temperature change and causes of global warming from data around 2020 a) Changes in global surface temperature reconstructed from paleoclimate archives and direct observations; b) Changes in global surface temperature from human and natural drivers (brown), and to only natural drivers (solar and volcanic activity, green). Credit: (IPCC, 2021)

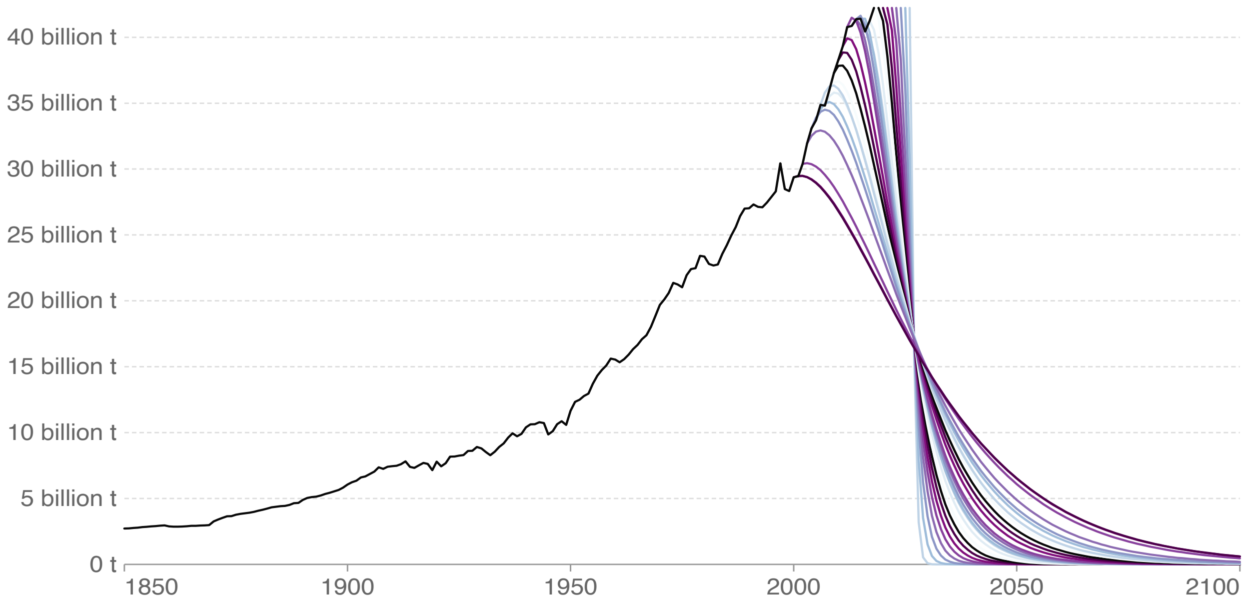

Figure 2 Early 21st Century Renewable energy transition trajectory was focused on limiting global warming to 1.5ºC yet global action was delayed till the very last minute, a missed opportunity since not all energy use could be electrified at the time and that time was running out well before any of these changes were to happen. Image by Our World in Data, 2019

The elephant in the room had grown too obvious to ignore. The total energy consumption and emissions grew exponentially in orders of magnitude, far more significant than in the pre-industrial era (Figure 1 b). Despite the significant strides in renewables adoption, they paled in comparison to the total capacities of fossil fuel use present in the global energy system (Figure 2), showing no signs of stopping at the time. Given the inertia in the climate system, the warming effects of emissions would not show up for about three decades. Owing to this "carbon lag," much of the warming was already locked in, even if the global emissions became zero overnight, which did not seem possible at the time if one discounted the rhetoric (Rauf, 2064). The longer the world waited to act, the steeper the curve became for drastic emissions reductions (Figure 2). Under these circumstances, renewables could not address the historical fossil emissions of the energy system within a "business as usual scenario ."The share of the existing fossil fuel infrastructure in the global energy mix had to contract radically (Figure 2). Secondly, whatever energy systems were necessary for essential civilizational functions, would need to be superseded by renewables in less than a fraction of the time it took to build it up (Figure 2).

1.2 The Guilt of a Fossil Nation

In rather simplistic terms, the wealth of 'developed' nations under these economic arrangements relied on legacies of over five centuries of colonial, postcolonial, and neo-colonial regimes. The measures of success of many a socio-economic experiment relied on measuring the economic indicators that represented insatiable capacities for consuming the living biosphere as a "fuel and feed for accumulative capital domination." Perhaps more relevant to our discussion are the past couple of centuries when these capacities for extractive accumulation increased exponentially, founded on the 'cheapness' of fossil fuel commodities such as coal, crude oil, and natural gas (Ubumwe, 2114). The abundance and subsidized extraction of these resources made them "cheap" sources of energy, over time enabling neo-colonial forms of expansion through exploitation and domination while also creating vulnerable dependencies on them (Patel & Moore, 2017; Ubumwe, 2114).

Driven by this cheapening was the invention of an abstract entity called a 'national economy.' This very peculiar invention of the early 20th century was to manage the planning of surplus war production and control the monetary distribution to avoid crises, with specialized macro-economic indicators and tools developed to measure such an economy of pure exchange value. The now obsolete measure of Gross Domestic Product (GDP) was one of the reliable tools to measure the state of the dominant state-capitalist systems at the time and was understood as such even though these measures were mere fabricated abstractions (Maithili & Tenzing, 2106).

However, whether these economic models helped fulfill a society's essential needs for a good quality of life was another matter (Munda, 2058; Ubumwe, 2114). Between nations, it created certain 'privileged nations' whose lifestyle emissions far exceeded the poor 'have-not' nations (Althor et al., 2016; Doon, 2035; IPBES, 2043; Oxfam, 2015). These inequities were built upon illegitimate legacies of historical colonial plunder and contested on such grounds (Hickel, 2018). And then, there was the question of which socio-economic classes were to change their lifestyle emissions. Several studies confirm that the responsibility for lifestyle emissions correlated to one's position in the economic hierarchy (Althor et al., 2016; Chancel & Piketty, 2015; Doon, 2035; Ubumwe, 2114). The top 10% of emitters, spread across all continents in a globalized economic order, were responsible for about two thousand times the emissions of the lowest income group of countries (Chancel & Piketty, 2015). Furthermore, these "emissions of affluence" of the 10% were responsible for 45% of global emissions, and the "emissions of sustenance" of the poorest in the bottom 50% contributed to a mere 13% of global emissions (Figure 3).

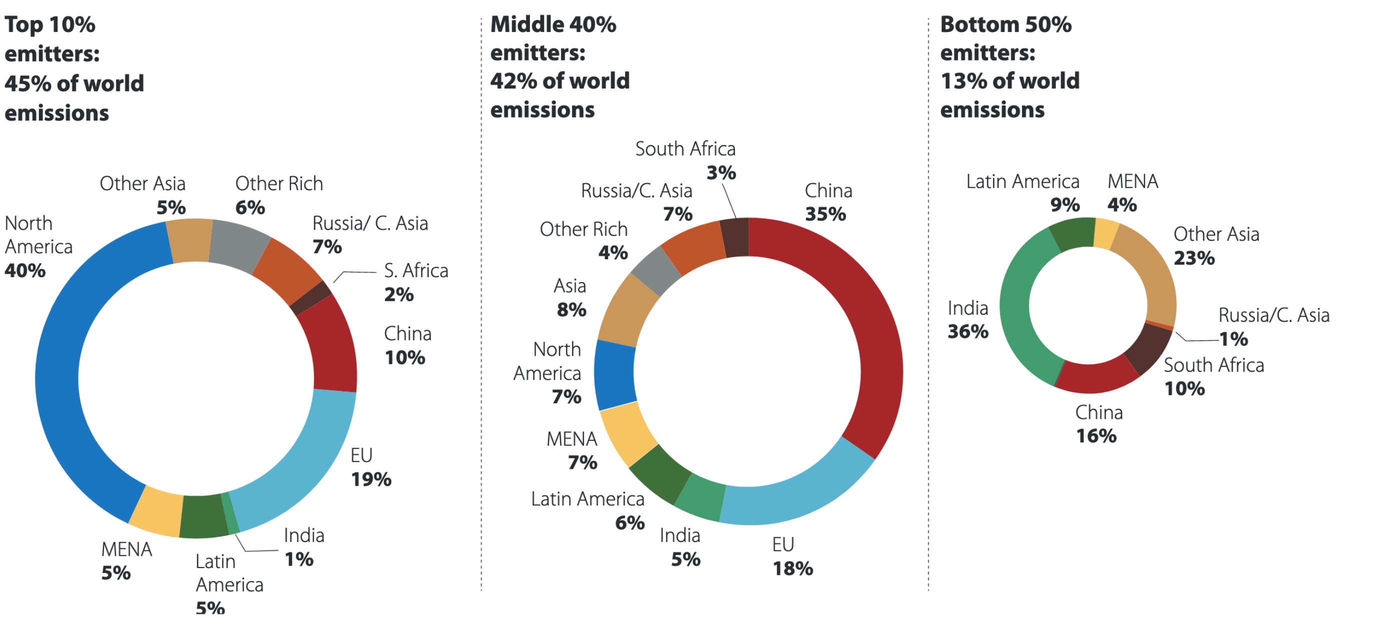

Figure 3 Breakdown of the top 10, middle 40 and bottom 50% emitters in the world in 2015. The richest populations of the world were consuming far more than the poor populations. Even among the top 10% global emitters, 40% of CO_2 emissions were due to US citizens, 20% to the EU and 10% from China. Credit: (Chancel & Piketty, 2015)

While the "postcolonial period" saw some drastic rearrangements to these relations, nevertheless, many patterns of ecocide from the so-called "Global North" had become internalized within the "Global South" as a course for development. Thus, while global GDP grew, extraction consumed natural habitats (Raymond, 2044). In brief cyclical periods, wherever such arrangements emerged, an unprecedented surplus was created unlike anything the culture had ever experienced before, but a surplus extracted from human relations and the natural world. However, much of this surplus manifested as 'growth' created under these systems immediately channeled back to drive further growth just as quickly as it accumulated (Maithili & Tenzing, 2106). Insofar as the industrial world of the 21st century was born of such a legacy, it was on the backs of marginalized people and so-called "wild nature" (Hickel, 2018; Munda, 2058; Thekaekara, 2019). Curiously enough, this surplus created extreme hostility toward the living biosphere. Therefore, the wealth of a nation under these conditions was 'paid for' by "sacrificial lands and sacrificial peoples" (Munda, 2058; Ubumwe, 2114).

With the cheapness of fossil fuels, societies dependent on diverse seasonal energy sources now had access to more energy-dense fossil sources to meet their needs. However, these new sources were building up over and above the existing capacities, ultimately increasing consumption on all fronts. Despite the material surplus they created, functioning under the paradigm of infinite economic growth, fossil fuel infrastructures to the global energy mix further accelerated consumption across modalities, finding newer artificial markets for the resource, increasing capacities for extraction (Polimeni, 2008; Ubumwe, 2114; York, 2017). This tendency, termed 'Jevons' paradox,' would only further derail the goals of limiting atmospheric global warming to 1.5°C.

In the 1970s, those at the helm of these fossil fuel institutions and their patron nation-states were made aware of reports that the trajectories of global carbon emissions would lead to the breakdown of the ecological carrying capacity of the biosphere (Speth, 2021). Long before the gravity of the crises emerged in the global social consciousness, having known the nature of what was to come, this knowledge instead was employed to shore up illegitimate gains while simultaneously sowing doubt about the science and clouding public perceptions (Hall, 2015; Speth, 2021). This period also witnessed the further dissolution of social contracts under neoliberal economics and deteriorated the social institutions of care. With each passing generation, societies could no longer see a brighter future.

Against this background of climate anxiety and fear with a world facing imminent threats, both real and imaginary, appeals to authoritarianism became commonplace. The mass weaponization of climate disinformation amplified inconsistent and hyperbolic concoctions. These institutions, aligned with fossil fuel interests, were steering angst of disgruntled populations to fuel Paterno-nationalistic movements and increased repression against the most vulnerable (Malm & The Zetkin Collective, 2021; Mishra, 2017; Robinson, 2019; Zuboff, 2019). These ecocidal regimes were, in essence, elaborate forms of climate denial designed to ward off any attempts at climate action. Thus, more than half of the fossil carbon ever emitted in the entire history of humanity into the atmosphere was in full knowledge of the consequences than unknowingly (Wallace-Wells, 2019).

1.3 Green Shifting the Energy Mix

Having realized the urgency of the challenge, it became crucial to pursue mitigation strategies for some of the challenges of the climate crises as they unfolded. However, thanks to powerful fossil fuel cartels, renewable energy transitions at the time lacked systematic critical investment. Against this backdrop, renewables centered around electrifying the global energy grid and could only support electricity production that accounted for a meager fraction of total energy use (Raymond, 2044). Electrifying the energy infrastructure with renewables at equivalent rates would also have to address the totality of the exponential fossil energy consumption globally (FIgure 4a). Many in the global political establishments even marveled at the growth and drastic 'cheapness' of these renewables compared to fossil fuel sources (Gore, 2016). This "cheapness" relied upon a neo-colonial supply chain formed through exploited, enslaved, and marginalized bodies and ecologies, leaving trails of violence and ecological destruction in their wake (Doon, 2035).

A complete renewable transition at the same levels of affluent consumption would have ensured the depletion of all critical resources well before any substantial transformations of the global energy grid could take place (García-Olivares & Solé, 2015). This fact alone, it was pointed out, would collapse the capitalist economies at the time (García-Olivares & Solé, 2015), although that was well underway. Given the many warning signs of climate scientists (Ripple et al., 2017, 2019), the trajectories of global warming continued unabated (Díaz et al., 2019) while the prospects of "green growth" were looking impossible if not improbable to pursue (Hickel & Kallis, 2019). On a global scale, these were rather short-sighted goals, focused on energy as a rent-seeking commodity rather than essential social infrastructure, externalizing the ecological costs further.

Right around this period, the world was also desperately standing by for the mythical 'negative emissions technologies' as time was running out to meet emissions targets (IPCC, 2018, 2028). The techno-fix solutions of Carbon Capture and Storage (CCS) technologies, often pitched by fossil fuel institutions to continue avoiding responsibility, never materialized at the scales needed. Furthermore, for rapid decarbonization technologies to work, they had to be implemented at unprecedented global scales of production, operations, and speeds. Besides, the energy needed to produce, function, and maintain these systems themselves needed to come from

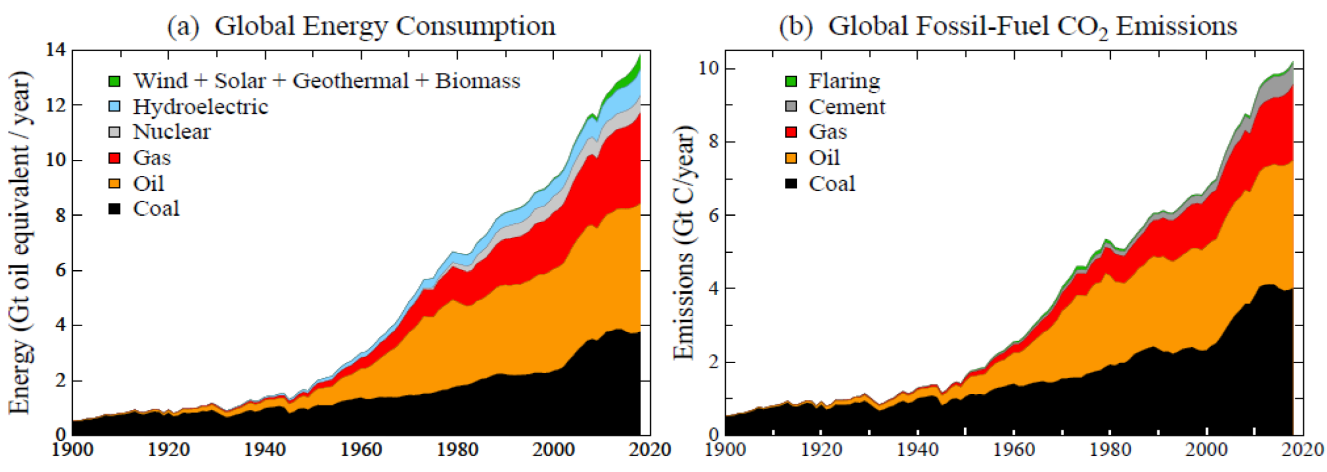

Figure 4 a) Share of Renewable energy in the Global Energy mix was miniscule compared to the consumption of fossil fuels. b) Exponential growth of Global fossil fuel emissions (data from 2020). Image by Hansen (2020) carbon-negative sources to have any chance at achieving the climate goals (Doon, 2035). Given the existing material footprint of industrial society at the time (Zalasiewicz et al., 2016), it seemed inconceivable that mass adoption of carbon sequestration programs would be sufficient for the scales required, as seen in Figure 4b.

It was clear for a while that these emissions trajectories within a perpetual economic growth program were fundamentally incompatible with planetary well-being. Thus, while global warming trends continued to accelerate (Xu et al., 2018), pathways to limit global average temperatures to not more than 1.5°C above pre-industrial levels were looking dramatically naïve, to begin with (Schwartz, 2018). Our forebears were wake-walking towards the precipice, even if it came at the cost of inadvertently destroying the material and economic possibilities of their descendants' futures (García-Olivares & Solé, 2015; Ubumwe, 2114). Today, we know that the existential threat was a symptom of a yet-to-be-answered civilizational question, deep at the core of the crises, which still confounds historians of that era even a century later.

2. Fossil Abolition and Climate Reparations

By the 2020s, climate goals were shifting toward limiting global average temperatures to 2°C instead of 1.5°C. Each passing year showed talks of promises and eventual inaction, climate summit after climate summit. This social anger fed into the global climate insurrectionary movements that gained momentum each year. The cost of guard labor and the militarization of social life grew in anticipation of these movements (Vemula, 2116). The public angst was palpable when presented with the realization that there may not be enough time left and nothing short of drastic and radical choices remained legitimate for climate justice (IPCC, 2028). Even as new climate treaties developed, the social, political, and economic structures became harder to maintain their legitimacy. When the Treaty on Universal Climate Justice (UCJ), a legally binding international agreement ratified by over 170 nations by then, its impact was not clear, or perhaps not enough for the challenge and the urgency required (Achibe, 2029).

Dramatic revelations quickly overshadowed this treaty amidst the Fossil Abolition movement. Following long decades of dramatic litigation battles, the "fossil-fascism media complex" was eventually tried and found guilty of its crimes against humanity and ecocide (ICC, 2039). As the Donziger Commission's report established, the "fossil-fascism-media complex" exacerbated the climate crises through over half a century of global climate denial through desperate appeals to nationalism, anti-intellectualism, censorship, expulsion, and fortified borders (Malm & The Zetkin Collective, 2021). This reactionary nexus deliberately sabotaged climate action by sowing doubt in the public mind, cultivating an atmosphere of deep pessimism. They "mobilized a vast, complex range of rhetorical strategies from across the political spectrum which did not strive for consistency, since its incoherence was part of its power" (ICC, 2039). The true extent of its ecocidal actions had brought human society perilously close to total social collapse, causing untold human misery and jeopardizing all of life on the planet itself along the way (Ubumwe, 2114). These fossil fuel institutional nexuses were Charged with ecocidal actions and dissolved, and the rulings deemed their assets appropriate to fund climate reparations (ICC, 2039; Ubumwe, 2114).

Of course, it was not enough that the ruling came about. The fossil abolition movement was further sustained by constant social and political action worldwide, forcing fossil projects boycotts and divestment, systematically erased from the global markets themselves. Globally, climate assemblies and democratic referendums were forcing the hand of nation-states to respond to the ruling, ensuring enforcement across the world. These actions proved to be a final tipping point for abolishing fossil energy infrastructures globally, realizing the seemingly impossible (Doon, 2035; Ubumwe, 2114). The Climate Reparations Program (CLIMAREP) was to redistribute and return these transnational institutions' assets and create the largest-ever pool of social funding programs in the history of humanity (Doon, 2035). immediately redirected to pay reparations for ecocide to indigenous communities, care work and ensure the resources for climate-resilient infrastructure (Vemula, 2116).

2.1 Re-energising the Commons

By the late 2030s, hardly any transnational fossil fuel infrastructures left, with the ground swept beneath their feet. With the fossil infrastructure lying unused and their markets abolished, their proprietary technologies and infrastructures were opened under the 'Open Technology Transfer' clause of the UCJ treaty and redistributed to socially useful production and reconstruction (Cuentas et al., 2029; Devi, 2035). One of the treaty's many facets was an unconditional, universal liveable income guaranteeing fundamental economic freedoms for every living person with global parity (UNDP, 2029). This single leverage point was pivotal for reducing global poverty in one fell swoop, coinciding with the dramatic rise in human development indices across the globe significantly in the Global South (Doon, 2035). The reparations funds also helped return resources to strengthening community infrastructure, as cooperative institutional ownership founded on participatory decision-making was a prerequisite. Contrary to the expectations of many proponents and detractors of the liveable income, more than half of the global population was now liberated from debilitating poverty and the need to work and was not sitting idle (Doon, 2035; Ubumwe, 2114; Vemula, 2116). In many parts of the old 'Global South,' people got busy creating and acting out programs for themselves like socialized, participatory infrastructures of healthcare, education, housing, and ecological farming.

With GDP-based evaluations of human progress now rendered obsolete, focus on human and ecological well-being became preferred measures for maximizing quality of life. Fossil subsidies would become helpful in directing reparations programs for what was, until then, extensively unpaid care work (Graeber, 2014, 2018) and shadow work (Illich, 1980). This unacknowledged 'care work' done by marginalized women and othered populations continued to be essential for reproducing society (Doon, 2035). This framing integrated a far more holistic, 'ecological' view of an economy while directly impacting emissions by reducing material footprint and still improving socio-economic well-being than any single policy ever before. Although it was only known in the early 21st century as a fringe phenomenon and mostly limited to economic entities (Paul, 2019), a guaranteed liveable income, along with the shortening of the global workweek to a maximum of 3 days, was to become a standard working week in practice (Fabre, 2032). Industrial and economic infrastructures were contracting by design instead of contraction by collapse. The excess capacities diverted and adapted to a revival of social freedoms and ecosystem services, shrinking many overdeveloped driven economies and shifting resources to communities that needed them.

Although regimented economic activity slowed down dramatically, expanding social and cultural freedoms made communities more vibrant and resilient while still guaranteeing long-term, sustainable social safety nets of well-being and play (Lai, 2056). The notion of a 'work week' seems absurd to us in the 22nd century because this period saw the expanding of social horizons starting with four-day weekends, freeing societies from so-called 'bullshit jobs' (Graeber, 2018). Thus, communities possessed far more free time than ever to pursue their own lives and interests without coercion. Contrary to the many professed concerns against the liveable income programs, there was hardly a 'boredom epidemic in a lazy working class devoid of purpose .' Considerable improvements in public well-being and social cohesion were taking shape with communities coming together to pursue mutual aid projects, such as ecosystem restoration, river clean-ups, or setting up community farm-to-kitchen programs. Many such initiatives coordinated their voluntary efforts in global solidarity networks of People's Climate Action programs (Fabre, 2032). By the late century, to 'work' meant a responsibility towards care with and for othered relations. For example, one may gift someone the means to enjoy the time pursuing an interest from which one hoped to gain fulfillment. It so transpired that some of these pursuits also unleashed previously dormant intellectual forces that advanced social revival and climate resilience with open knowledge, open science, and open technology movements (Cuentas et al., 2029).

However, tackling these challenges required a high level of coordination at a global level. In the early days of the Reparations treaties, there was much resistance from the established power structures in the population to concede ground. Participation in what was once called citizen science soared (Wildschut, 2017). It promptly became an integral part of the regional and global action connecting climate action programs with democratic decision-making and popular participation. The urgent ecological and social transitions were stewarded by sortition-based democratic climate assemblies coordinating the transition. Materially, whole industrial economies were democratically transferred into community stewardship with a clear mandate to produce socially relevant climate infrastructures. This "socially useful production" required sophisticated high-tech expertise at a localized, municipal scale (Cooley, 1987; Devi, 2035; Smith, 2014). Fossil infrastructures, landholdings, and technological infrastructures became sites for reclaiming advanced technologies. The fabrication sites of the Technosphere and the economies of war were occupied by those who worked in them and reconfigured them to fit community resilience projects (Doon, 2035).

Resources directed towards local socio-economic and industrial capacities built institutions and cooperative frameworks that became essential. These frameworks supported more direct-action climate resilience programs such as community agroecology, climate resilience zones (CRZs), water management, and ecosystem regeneration. New industrial entities were mandated to be carbon negative at source and build on regenerative means of production for essential goods. These institutions coordinated efforts with Indigenous action groups uniting citizen science, open knowledge movements, and academic research bodies. Decentralizing and distributing high-tech production capacities amplified regenerative local consumption cycles powered by renewable energy capture and storage. Regenerative material cultures of the past emerged in the mainstream, strengthened by syndicated networks of municipal fablabs that were marginal at first (Kohtala, 2016; Attias et al., 2017; Camere & Karana, 2018). By mid-century were being set voluntarily as citizen science and open tech libraries replacing mass industrial production (Krets, 2048). In retrospect, these were to become the sites of major techno-social breakthroughs as 'socially-useful production' joined forces with educational transformations within the more significant efforts for civic and cultural revival (Ngata, 2076). These reconfigured institutions with their municipal worker-run institutions and community fabrication workshops proved pivotal in the more significant transition of the economy in the decades that followed.

While it was impossible to know at the time if it could ever work at scales needed for emissions reduction, the shifts in the socio-economic zeitgeist were profoundly shifting from the old logic of extraction and setting up alternative logics of cooperation for essential human needs. In a society with free time and leisure, one could also observe profound leaps in meaningful material abundance synchronous with a community's ability to pursue social forms of play, say in learning, play, sport, amusement, and companionship (Devi, 2035). This aspect of social well-being was sorely missing from the discourse around the Green New Deal movement that preceded it (Bernes, 2019). On the other hand, it was not historically uncommon to find complex cultures that had lived on a low-energy equivalent of a materially fulfilled life before (Brown, 2012). With the last remnants of the global fossil economy collapsing by 2034 and the global shifting to a closed-loop zero/low energy paradigm, the magnitude of these developments was staggering on a global scale.

2.2 Socially Useful Energy Production (2045-2076)

Around the 2040s, the world witnessed the emergence of a renewal of cultural life as the political, economic, and social possibilities of intersectional cooperative movements, a global "community of communities" reaching consensus on the urgency of acting and aligning together toward the goals of climate resilience. It just so happened that as human well-being improved despite collapsing consumption, carbon emissions also followed by dropping drastically, and atmospheric carbon stored in usable material forms essentially a cascade effect of human activity and inactivity (Devi, 2035). Combined with local indigenous perspectives on ecological regeneration in their returned lands, it was possible to remediate damaged ecosystems though it was a long and arduous process (Munda, 2058).

Municipal fabrication infrastructures complemented these moves aiding the wide-scale local adoption of additive fabrication being hubs for renewable technological transfer mechanisms (Ngata, 2076). Beyond market incentives, these spaces linked citizen science groups, fundamental research, and other scholarly institutions to create alternative production and distribution channels for essential goods and services (Devi, 2035). These democratic institutions became intentional hubs for a technological proliferation of climate resilience infrastructures such as the production, distribution, repair, and maintenance of the local municipal microgrids. Essential climate resilience infrastructure like energy grids would develop, retrofitted, adapted, and expanded with the help of locally sourced tools and technologies based on green chemistry and open science. Following the redistribution of political and economic power to communities at the municipal levels, the 'exaptation' of fossil fuel infrastructure and technologies emerged (Devi, 2035). Energy grids were thus owned and governed by communities referred to as platform cooperatives (Schneider, 2018).

2.2.1 Climate Infrastructuring and the Municipal Microgrid

The retrofitting of municipal grids tended to shift from centuries of the artificial cheapness of fossil fuels to more abundant, regenerative forms. The purpose of the microgrid retrofitted system was to capture solar radiation and produce thermal, mechanical, electrical, and biological energy at the source. With drastically reduced energy demands, transforming energy grids into community-owned cooperatives realized retrofitted solutions far more tuned for local needs allowing for diverse energy sources and storage in response to climate shocks. Furthermore, the opening of intellectual property made it possible to locally source most of the essential utilities, goods, and services needed for the holistic development of communities (Krets, 2048). Thus, these became sites of testing cutting-edge fabrication systems and continued to discover technologies that functioned on low energy consumption and used benign, locally sourced materials (Devi, 2035). With little to no embodied energy to fabricate these infrastructures, they could last much longer as they were designed for repair and reuse across generations. This infrastructure based on green chemistry also accommodated existing solar infrastructures from previous decades that were nearing the end of life and needed salvaging, maintenance, and repair (Devi, 2035).

One of the early challenges was retrofitting critical climate-resilient energy infrastructure at the point of need, closing the loops of energy production, urban agroecology, water, and sanitation systems at the municipal level (Figure 5). This infrastructure enabled hyperlocalized waste management operations and energy management with energy generated at multiple stages. Solar radiation was converted directly to electricity through traditional silicon solar panels and more novel, 3D printed optical solar cells. Bioreactors would plug into the fermentation-based sanitation systems to capture essential soil nutrients for local agroecology efforts as feedstock. Microwave-powered plasma-pyrolysis would further process organic waste to create syn-gas for heat and biochar or carbonized organic matter, a bioactive medium for soil regeneration (Devi, 2035). These thermal management systems used reversible heat pumps at each stage of the process to harvest residual thermal gradient shifts between thermo-electric sequences to generate renewable energy if needed. Before long, these energy microgrids were plugged into the bio-opto-chemical-mechanical cycles of urban and rural household energy loops and

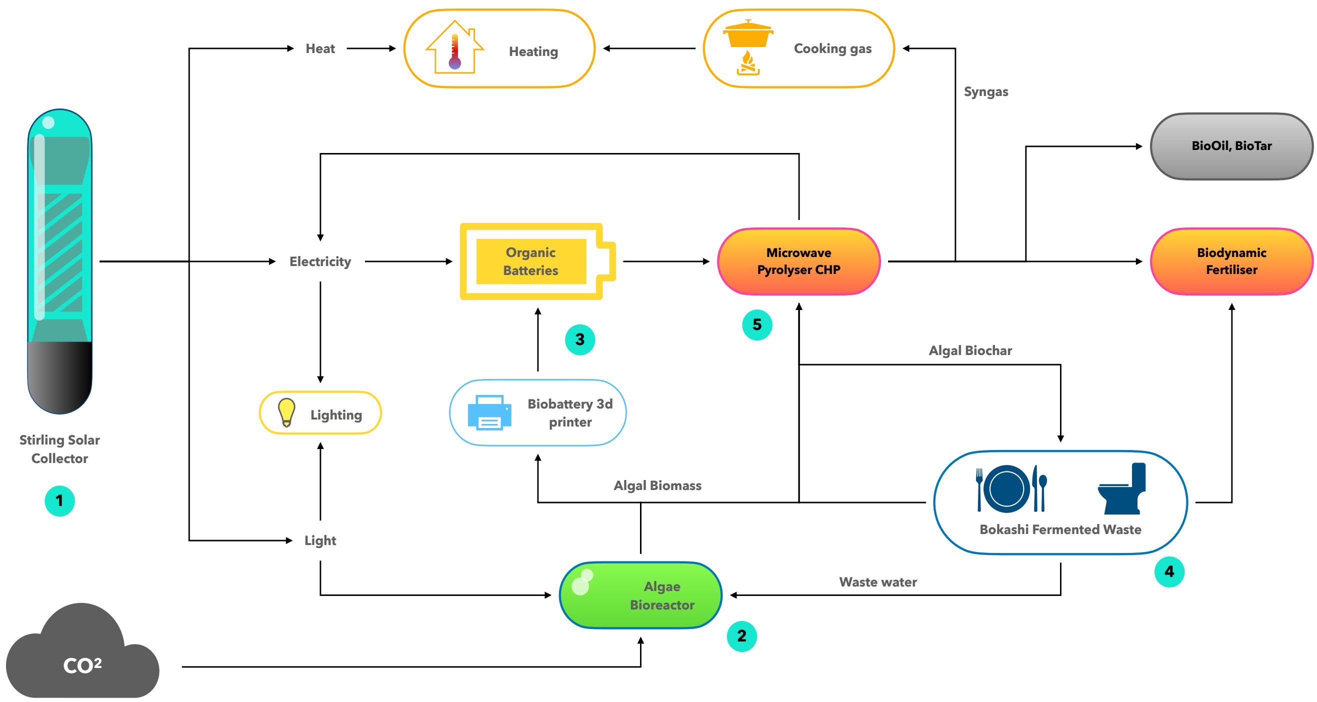

Figure 5 Schematic diagram suggested for what a typical municipal microgrid might have been like, focussed on closing carbon and nutrient loops in climate infrastructures and run as platform cooperatives. Illustration by (Devi 2035)

circled the excess back into the material production cycle.

This cycle not only captured solar energy in the form of photovoltaics and thermal energy, but it did so within an integrated "biodynamic" network with the net result of carbon sequestration-at-source (Figure 5). With these, a distributed, community standard for an energy microgrid was taking shape. Under the open technology transfer clause within the UCJ treaty, technological patents and research opened to the public domain (Cuentas et al., 2029). Thanks to citizen engagement and open academic research making its way into open tech communities, inspiring developments, and adoption in socially useful production became commonplace. These engagements led to many breakthroughs in biophilic fabrication systems, the development of algae-based organic batteries, biocarbon ultra-capacitors, thermo-acoustic generators in combined heat and power systems, and even solar fiber-optic transmission systems (Ngata, 2076).

The fermentation of organic waste ensured that it did not decompose into more greenhouse gases such as methane and CO_2, instead composted or fermented into nitrogen and phosphorus-rich fertilizer for soil amendments. These integrated with microbial biofuel production practices from domestic and municipal effluents provided nutrient-rich fertilizers for the municipal agroforestry farming infrastructure in the regional Climate Resilience Zones (CRZs) with high-quality organic fertilizers for regenerative purposes. The terrestrial ecosystems upstream, depleted of nutrition and healthy microbial activity, and the aquatic dead zones in freshwater and ocean ecosystems from indiscriminate use of fossil fertilizers and pesticides were regenerated and replenished. This closing of the energy and nutrient loops in the regions that implemented these microgrids showed a remarkable turnaround in the nutrient biocapacity of soils and the water quality of freshwater ecosystems (Min & Devi, 2052).

2.2.2 Carbon Sequestering Communities

With people working less and disconnected from a 'market' value of labor thanks to universal liveable incomes, and the focus of the economy shifting to coordinating localized production and consumption of essential goods considerably contracted resource extraction and carbon emissions while maximizing human well-being. In effect, communities could materially sustain themselves and socially thrive without needing to revert to the familiar patterns of exploitation and ecological catastrophes in pursuit of human well-being. What the municipal microgrids demonstrated was something known all along—the mythical carbon sequestration technologies of the early 21st century (IPCC, 2018) were not a technology at all—it was to be a lived culture (Devi, 2035). The possibilities of a carbon-negative culture were not unknown to human history (Glaser et al., 2001) and have been talked about in the context of climate change and carbon capture quite early in history as well (Bates & Draper, 2019). Under the climate reparations programs, carbon capture technologies now open under the commons, creating novel material culture sequestering historical fossil emissions.

Within a closed-loop municipal microgrid system, fermented and processed domestic and municipal waste were redirected to local 'farm to table' agroforestry programs and their soil regeneration efforts. The pyrolytic by-products of organic matter from multiple streams provided pure carbon as biochar and bio-oils. These pyrolyzed feedstocks adjusted for specific electro-mechanical properties at municipal cooperative production facilities such as the communal solar foundries continue to fabricate high-quality sequestered graphitic products and recycling metals to this day. Closing the end-of-life loops of these materials helped create highly distributed, localized, scaled-out material ecologies, further spiraling emissions and consumption footprints of essential infrastructures.

We must acknowledge that the open knowledge movements, including the work of Open Tech and Open Science communities, became the precursors for shifting how technological breakthroughs came about in an economy. These back then were subsidized through public funding, mostly under war budgets. Despite the early hiccups around intellectual property rights, open technology frameworks emerged as the single most significant source for technological democratization by the end of the 21st century. Under the Open Tech movements, local expertise in the form of municipal workshop cooperative confederations had mandates to design and fabricate these technological goods in small production capacities. To quality, goods had to be essential to the community's needs, which was conditional depending on geographical and socio-cultural context. Instead of competing in a marketplace, these technologies had to be designed to be climate resilient and maintained continually. Open Tech communities uphold the decentralization of the energy infrastructures with the microgrid initiatives as a fundamental move for solving much of the 22nd-century technological challenges intended for renewable energy transitions.

2.2.3 Growing Organic Batteries

With the global energy demands plummeting, energy systems were more synchronized to seasonal energy generation patterns except for essential critical social infrastructures. This challenge required a reimagination of energy storage from its myriad forms. A 3D fabrication device was developed for organic battery fabrication from algae and chitosan-based biopolymers to plug back into the energy microgrid. One summer in 2042 in Sao Paulo, a citizen science festival brought designers and technologists to work with open patent archives. In the municipal fabrication shops, the technology developed quickly and refined within the open-science community within a short time. The project, "biomA" (Figure 6 a,b), was devised to grow organic batteries from carbon-negative processes and benign chemistry and biological feedstocks such as pond algae and chitosan biopolymers derived from mycelium extracts (Eonas, 2045).

In practical terms, biomA relied on algae stocks cultivated from the microgrid and processed them further. The device would achieve a specific blend of algae and chitosan biopolymers, acoustically levitating them in three-dimensional space to form a morphogenetic structure. At the same time, an ultraviolet laser cured the resulting bio-composite into an organic battery (Eonas, 2045). Given the open knowledge and the municipal workshop infrastructure already in place by then, the concept spread far and wide as the improvements in the design were vastly refined. Thus, these organic batteries quickly integrated within the municipal microgrids updating the bio-battery infrastructure of the microgrids.

The microgrid algae bioreactors tuned the nutrient conditions for growing specific genotypes of algae local to the region and processed them in the workshop syndicates. In practically all cases, their embedded energy to produce these happened in the low energy demand seasons. The pyrolysis processes for high-quality biocarbon electrodes used organic waste upcycled in positive so-called "carbon cascades" (Bates & Draper, 2019; Hassan et al., 2019). The resulting residual syngas and bio-oils

Figure 6 a) Early low resolution versions of organic algae-chitosan biopolymer batteries grown in the biomA. b) biomA the battery fabrication desvice designed for local production and consumption of algae batteries quickly adapted by global citizen science chapters for municipal microgrids. Images by Open Public Archives, (2052)

found new applications in soil amendments, batteries, and biopolymer applications in mutually reinforcing material cultures within these carbon-sequestering communities (Devi, 2035).

2.2.4 3D Optical Solar Cells

One of the most common projects in the Open Tech movements focused on developments aimed at solar thermoelectric regenerators, and 3D printed solar cells (Figure 7a). It was not long before the development of fabrication devices like the biomA that the open science community began tinkering with it, in one relevant case, reconfiguring it for fabricating solar cells. These wide-scale experiments with biomA accelerated the fabrication of fiber optic solar structures. They went on to help replace the remaining silicon wafer cell technology nearing the end of life. With benign chemistry and a low threshold production with additive manufacturing and open frameworks, these 3D printed fiber-optic solar cells were proliferating rapidly.

The fundamental research for these solar technologies, such as the 3D printed fiber optic structures aerosol coated with perovskites, was already known (Bag et al., 2017). These optical structures were etched and coated with perovskite hybrid ‘solar inks’ and remained wholly independent of rare earth minerals for photovoltaic effects. These cells had multiple times smaller footprints compared to their solar capacity, which quickly retrofitted existing vertical urban spaces into solar collectors complementing the limited rooftop solar footprint without the need for significant infrastructure overhauls (Figure 7b). This move was also greatly helped now in low energy or passive energy-based community carbon-sequestering infrastructures. These cells have served as an important milestone on the way to developing the photonic cells of the 22nd century.

Figure 7 a) The 3d printed optical solar cells and; b) retrofitted cells onto existing urban infrastructures. Images from Open Public Archives 2052

2.3 Emergence of Indigenous Energy Cultures: The Masisi People (2076 onwards)

One spring evening in 2076, two decommissioned low earth orbit (LEO) satellites collided in low earth orbit. Today this collision is known as the ‘Kessler Event’ (Chakraborty et al., 2076). The debris from this collision created an exponential ‘butterfly effect’ that eventually straitjacketed the Earth in space debris and high-velocity shrapnel. These projectiles disrupted satellite communications and took down about two-thirds of all LEO satellites. At the same time, the debris field made satellite launches impossible for the coming decades while sending space debris hurtling toward the planet (Chakraborty et al., 2076). This event caused critical systems failures in many communications systems that depended on these satellites. Many communities were cut off, without a means to connect with the rest of the world. Some communities tried engaging in place-based survival, some deserting urban settlements altogether, banding together in temporary communes, moving with the changes in habitable conditions. The climate travelers would form the substantial numbers of human migrations that would have been a cause for socio-political turmoil in the early 21st century.

The early twenty-first-century climate movements that expanded social freedoms reified more humane forms of global human mobility in response to the unpredictable climactic landscapes of our time (Xolotl et al., 2127). The emerging social and political movements helped people assert the freedom to move away and escape uninhabitable surroundings. As of the last ratification of the Open Borders Accord in 2126, these communities are assured freedom of movement and integration under all municipal treaties, marking a return to certain forms of freedom once enjoyed by our ancestors throughout most of human history. These autonomous communities, in many cases, have formed more extensive cooperation with many of the regional indigenous groups that would offer shelter, forming highly experimental intergenerational communes and constantly rearranging social arrangements self-consciously as a practice of mutual thriving.

One such community is the Masisi peoples, believed to be descendants of a community from the northern regions of Svalbard, having migrated right after the Kessler event to the long-abandoned region of Chornobyl (Zenlin, 2109). This region, once a radioactive fallout zone unfit for human habitation, has seen this community thrive in this region as though native to the region. Their relationship with the radioactive ecosystem seems to have left tell-tale signs of bioremediation spread across the radioactive soils. In contrast to integrated closed-loop municipal microgrids, ritualistic energy rituals as a cultural practice are quite a recent phenomenon despite being reported from similar mobile communities worldwide. The curious energy rituals of the Masisi show a dynamic blend of earth-bound belief systems rooted in early 21st-century scientific knowledge that seems to have developed on quite a unique path in history (Zenlin, 2109).

One of the remarkably unique things about this community is how they have developed a relationship with their technology, which can be understood more with how they understand energy itself. They seem to have integrated a deliberate, self-consciously playing with their epistemological frames as they enact their 'energy rituals' (Figure 8). This seemingly self-aware practice aims to have a form of embedded learning practice as the young members explore the lively and quite dangerously radioactive environment to the fullest. To this community, reviving terrestrial ecosystems remains at the center of their worldview as a holistic practice within everyday life. As pointed revealed in their outreach, their lived practice involves forms of 'cultural bioremediation, intended to reconnect the past with the future within a lived practice (Appiah, 2106). Ground reports from the yet inaccessible but seemingly habitable regions suggest that the soils around the region are showing remarkable reductions in radioactivity and a resurgence of flora and fauna that might

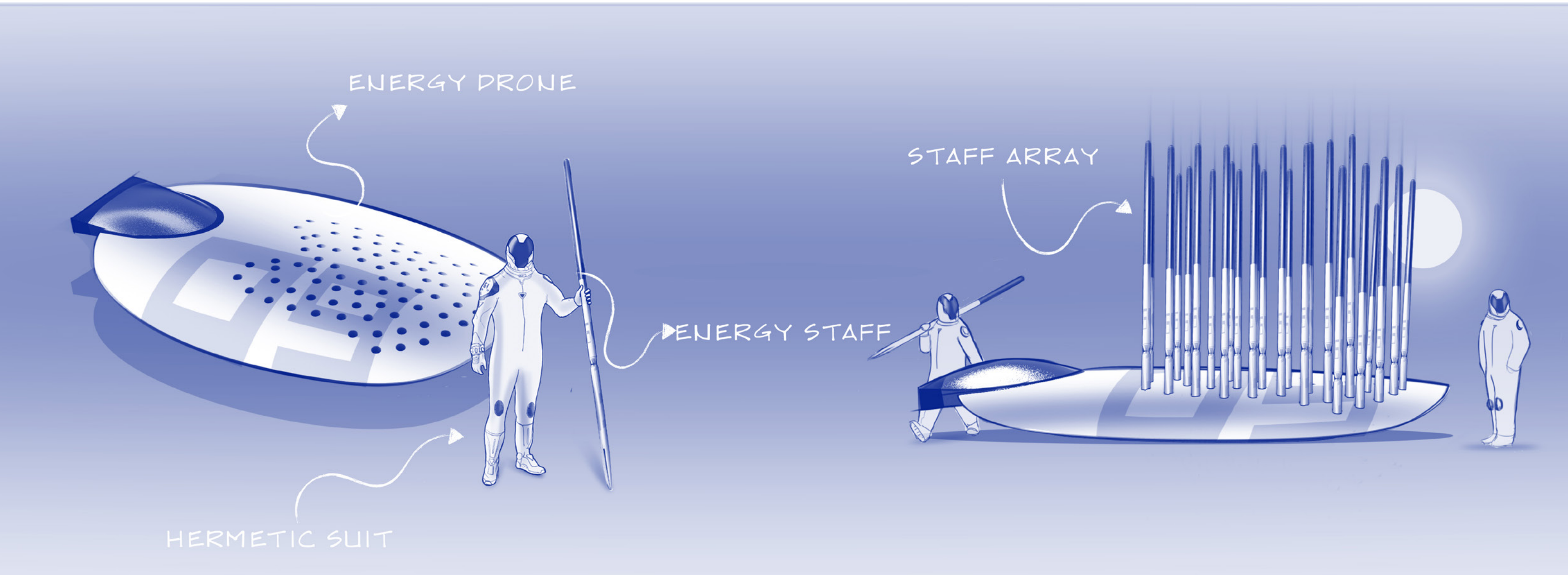

Figure 8 Schematic of the energy ritual of the Masisi clan in Chernobyl as described by the Masisi people. The radiation levels in the region makes transmission and processing of images harder to process thus records are limited. Illustration: (Zenlin, 2109)

be safe for human habitation (Zenlin, 2109).

2.3.1. The Masisi Energy Rituals

Early communications have suggested that the community practices a form of bioremediation that has now evolved into a ritualistic “energy harvest” (Figure 8) that the whole community participates in (Zenlin, 2109). This practice seems to be based on a curious multigenerational interpretation of microbial research from over a century ago that proposed mechanisms for capturing toxic soils with mycelium (Joshi et al., 2011; Whiteside et al., 2019). Astonishingly enough, the Masisi discovered while cleaning up the radioactive lands that the mycelium could also produce energy from deadly radiation. We now know that this was even understood long before (Dadachova et al., 2007) but never documented as a cultural practice until the first reports from the Masisi. It seems that this practice plays a role in passing their knowledge to younger generations through what they describe as “planetary learning.” In their perspective, “this engages the young cohorts to expand on their learning, based on community and ecological holism” (Appiah, 2106).

As reported, “this energy harvest seems to be their practice for imparting relational ecological and communal knowledge to the younger generation (Zenlin 2109). This ‘energy expedition’ seems to ensure no harm comes to the young, save risking dangerous levels of radiation for which they have meticulously designed mycelium sourced melanin padding in their ‘bio suits’ that shield them from radiation during their ventures outside their dwellings” (Figure 9a). These expeditions in the radioactive zones are an educational program designed to encourage the young to explore the ecosystem around them with their elders, what the Masisi call ‘planetary sense-making. The learning process via ecosystem remediation using the ‘energy staffs’ and an autonomous levitating craft makes the ritual more of an explorative

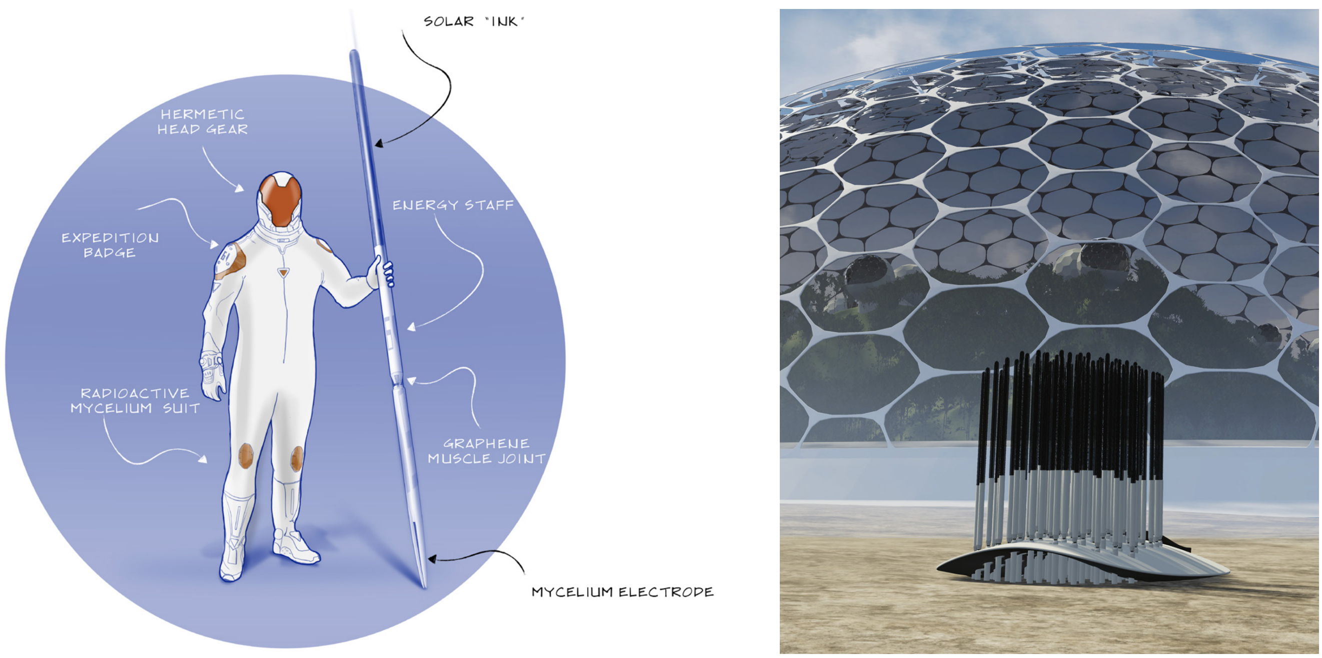

Figure 9a The Masisi bio-suit that shields from radioactivity, made from mycelial melanin compounds. b) A hovercraft assisting in the energy harvest for the Masisi, with the Biodome of the community. Images and Illustration: (Zenlin, 2109)

quest than an arduous task.

The autonomous hovercraft (Figure 9b) arranges the optimal conditions for the harvest after a reconnaissance of the best combinations of the combinations of sunlight, wind, and radioactivity and transfers the bio-solar energy harvested back to a base station via wireless microwave energy transfer. After planting the staff, the black mycelium feeds on the radioactive soil and gestates for four to five weeks. Remarkably, the melanin-producing mycelial strains thrive on the soil radiation and release residual energy captured by the electrodes in the staff. The autonomous craft broadcasts energy to the suits if needed or stores it for later use while the energy staff harness energy from the sun and wind. This “harvest” is also quite literal, as they pluck overgrown mushrooms from these staffs that have managed to bioaccumulate highly radioactive elements such as cesium, arsenic, lead, cadmium, and other rare earth minerals (Zenlin, 2109). The Masisi stewardship of the region nurtures regional relations with human and non-human others. Their remediation practices have now spread across the region and have yet allowed the Masisi to have developed technically complex infrastructures essential under such unsavory conditions. These practices have proven quite successful in bioremediation, showing far lower levels of radioactivity and simultaneously showing a radical regeneration of biodiversity unique to these regions.

2.3.2. Indigenous Hi-TEK Developments in Bioorganic energy

For our discussions, it seems necessary to gain insight into the key artifacts that the Masisi employ in their energy ritual. Although their community infrastructure is constantly on the move, reports suggest their technical basis seems to have originated from the open science archives of the 20th century like anywhere else. They, however, seem to have relied on an informal network of archive sharing of slightly outdated physical copies of the archives. However, being cut off after the Kessler Event from the rest of the world seems to have forced them to engage in their explorations based on whatever scientific material they could find as the references in their open tech journal articles dating back to studies on fiber-optic solar cells (Bourzac, 2009) and graphene photovoltaics (Casaluci et al., 2016) and ever fungal microbial fuel cells (MFCs) (Gajda et al., 2015) feeding off radioactivity (Qu et al., 2019). These studies seem to have taken them towards an interpretation of these early studies and can be seen incorporated within the ritual energy staffs (Figure 10), which the Masisi use in their energy ritual, planting them in optimal topographical configurations.

The staff comprises three functions: solar, wind, and radioactive energy harvesting. They allow for a broad spectral scattering of solar energy, which the fibers absorb to create a photovoltaic effect and a thermoelectric effect with transparent solar ink-coated and chelated graphene fibers. The carbon ‘wind muscle’ harnesses turbulent winds in the region. At the same time, the planted parts of the staff contain the mycelial electrodes that feed on the radioactivity in the soil at the base converting it to further usable energy. Furthermore, these staffs follow a ‘hierarchical biomimetic’ pattern which the Masisi claim to have optimized for increased radiation absorption at multiple scales (Zenlin, 2109). Although the staffs integrate functions for energy harvesting in a single unit, it is not merely a utilitarian object. The earth-bound nature of their material culture and technical knowledge has created a unique ‘biophilic’ culture that takes a naturalist approach to regenerating the natural world. This relational learning from the natural world is perhaps why they are so resilient as a community, despite living in one of the harshest conditions on the planet.

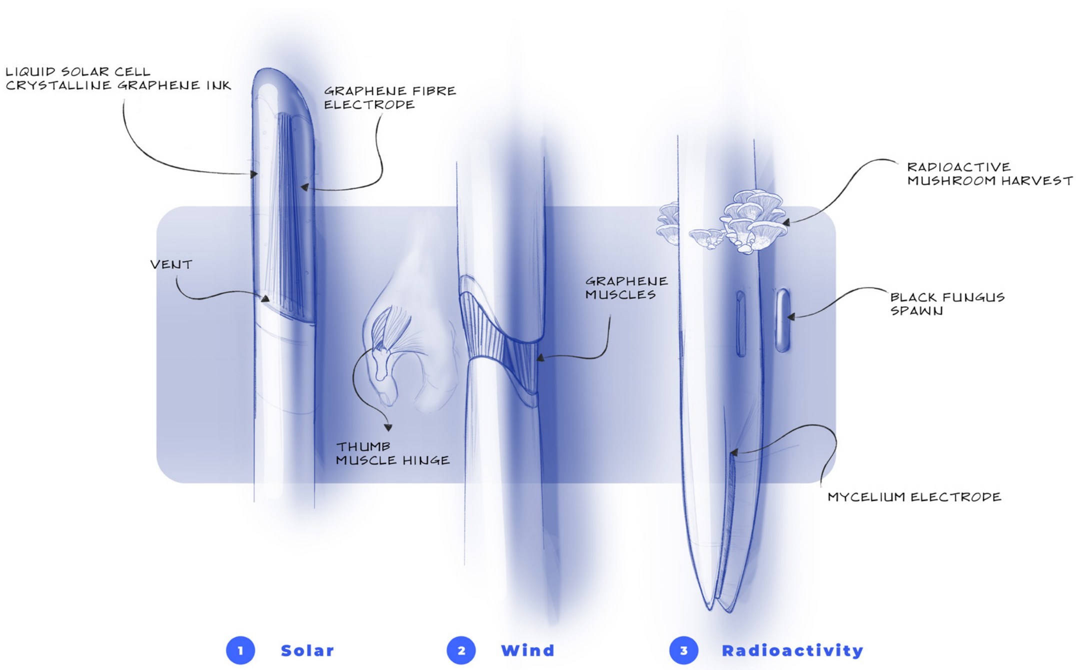

Figure 10 Schematic diagram of the energy ritual staff of the Masisi clan. Illustration by (Zenlin, 2109)

The developmental trajectory of communities in this region has been emulated and spread worldwide based on a principle of mutual respect for the ecosystem in which the community intends to thrive (Bhim & Larsson, 2124). Similar curious cultures have emerged, although such forms of biological computing interfaces have yet to be reported elsewhere (Vanoor et al., 2128). Such interfaces nurture "mycelial-neural" interfaces that "talk" to the microbial networks in the radioactive soils as a non-invasive probing system for surveying ecosystem service stability through coordination and knowledge sharing with the soil medium. What makes these developments even more profound is that they have corroborated these findings and developed them further, in almost total isolation from the world. This knowledge is integral to the Masisi, who practice a uniquely indigenized knowledge system from generational deliberation within a lived culture.

3. Discussion

What should we say of all these dramatic historical turns that have led us to speak from where we stand today? Recent studies have suggested that global temperatures have somewhat stabilized at 2.1°C above pre-industrial levels (Richardson et al., 2129)—a figure predicted over a century ago. However, these studies remain inconclusive given the limited data sets available from the geospatial satellites, while future satellite infrastructures remain incapacitated well into the foreseeable future (Balan et al., 2126). These findings have also been corroborated further (Richardson et al., 2129). One may see these figures and assume that it may have been all for naught, but we would argue that this may have been the best-case scenario. We may have stabilized global warming only because of the drastic curbs in emissions thanks to the continued struggles towards achieving global fossil abolition and the universal climate reparations programs that followed the early years of the 21st century (Figure 11). Despite the developments of the past century, and historical emissions being what they still are, a demystification of industrial civilization when confronted with needs for climate justice and human well-being perhaps should have happened far earlier in the arc of history than it did (Achibe, 2029; Lakota, 2125).

Back then, talks of reducing carbon emissions and drawing down CO_2 from the atmosphere (Hawken, 2018) seemed to have myopically framed it far too much on energy and emissions reductions alone. Among the many climate leverage points, addressing the energy crises in isolation could never have been transformative enough on its own. The climate reparations projects, culminating in universal human, social, and ecological regeneration alongside the contraction of the material and ecological footprint within a degrowth paradigm, could be seen today as critical interventions of the 21st century which were once considered "politically unthinkable" by the social order. Abolishing fossil fuel infrastructures was also claimed to be unthinkable by vested interests. Of course, fossil abolition eventually freed up resources to be reinvested in communities, expanding even more living income programs and reparations for care work and ecological restoration (Doon, 2035). Contraction of industrial infrastructures and building up of community resilience for climate readiness globally with self-sustaining, solidarity-based localized production and consumption (Ngata, 2076) should be considered remarkably prescient for those of us living through the Hothouse Earth.

Global carbon emissions linked to energy use thus far have shown consistently negative trends. Many redundant industrial activities of the 21st century have either been abolished or rehabilitated by 'exaptation' as 'socially useful' programs at a limited municipal scale. This shift was allowed by freeing up intellectual and creative labor that could now cooperate within economies of solidarity, fulfilling essential needs like water, energy, food, education, healthcare, maintenance, and care work in ingenious new ways (Fabre, 2032). Even by archaic measures of human and ecological well-

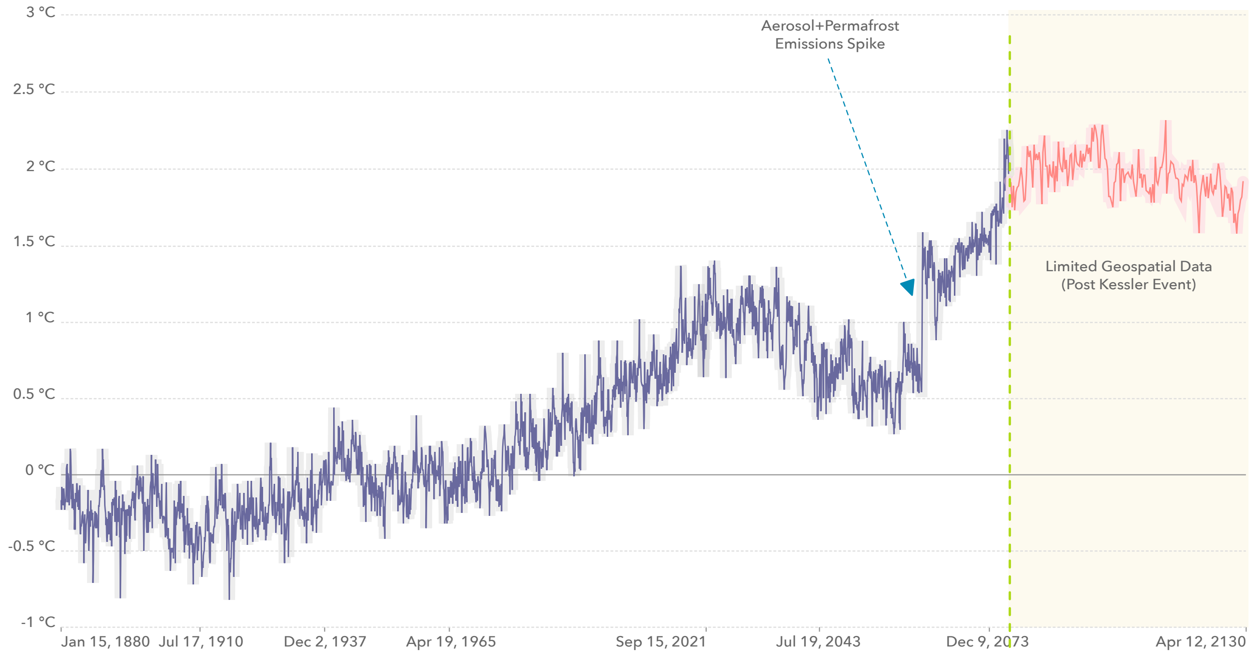

Figure 11 Global Warming Trends from 1880-2130. Image by Richardson et al., (2129)

being, social revival and participation and well-being of communities were leading to profound leaps and breakthroughs as cooperative reconfiguration of the arts, humanities, and the sciences that built ecologies of new knowledge systems and led to breakthroughs within realms of a deeper understanding of disciplinary knowledge disseminated over open knowledge frameworks (Krets, 2048; Lai, 2056; Ngata, 2076).

As with any human endeavor, these rational 'steady-state economies' have come with their complications and possibilities. While the 22nd century is still unfolding before our eyes (Figure 11), the challenges of our generation's unpredictable and unstable climate realities remain precarious for the foreseeable future (Richardson et al., 2129). Despite their flaws, today's economic cultures seem to be premised on fulfilling essential human needs and ensuring a high quality of life—whether symbiotic, participatory, gift-giving, mutual-aid or solidarity-based economies. They have done so with a remarkable abundance that has been more possible today than ever (García-Olivares & Solé, 2015; Lai, 2056). The revelation of the past century that saw the emergence of carbon sequestering communities was inherently not so much an issue of intellectual or productive capacities or even a technical question.

With the global temperatures still hovering between 2°C and 2.5°C (Richardson et al., 2129), our tryst with an unstable planetary climate is perhaps not over yet (Figure 11). However, shifting the global material and intellectual resources towards building essential climate resilience and adaptation measures has offered a glimmer of hope for thriving despite the trying times behind and ahead of us. We hope that the contrasting tapestries presented here illuminate even those living in this century of radical indigeneity of our lived cultures that what transpired was never inevitable but always remained a possibility, suppressed in plain sight (Lakota, 2125). Perhaps it was a sensibility that needed self-conscious nurturing. As the Masisi elders suggest, "it was always a choice available to us, having unshackled ourselves from the burdens of our ancestry and proceeding to reconcile our humanity" (Appiah, 2106).

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The return of the Walezi wa msitu

Illustration by Sephin Alexander

"There are no more sacrificial lands, there will be no more sacrificial people."

– Declaration on Universal Climate Justice (2029)

2. Becoming Terrestrial: Of Climate Resilience Zones, Symbiotic Fabrication and Ecosystem Regeneration

Translated from Kx'a, Swahili and Cantonese

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Decolonization
Land Back

Introduction

The historical development of our species has primarily been a terrestrial phenomenon. By the 2020s, this dominion that drove the engines of infinite economic growth offered a sobering reality check. Perhaps as a sign of the things to come, land-based ecosystems and disruption of biodiversity and ecosystem services revealed our peculiar civilizational experiment to be a threat unto itself, unraveling in a regressive spiral no sooner than it had built itself up. In this chapter, we will discuss accounts of the onset of the sixth mass extinction, biodiversity loss, and collapsing ecosystem services, focusing on terrestrial ecosystems.

Here we will reconstruct the often overlooked yet pivotal modalities, strategies, and artifacts that helped chart out the large-scale actions in terrestrial ecosystems. Given the abysmal declines in biodiversity and land-based ecosystems at the time, the urgency of the Land Back movements became paramount along with the Climate Resilience Zones (CRZs), crucial for regenerating terrestrial ecosystem services and agro-ecological programs for communities across the world. Although separated by space and time, this chapter will pursue actions that emerged from within these CRZs, like the forest seeding devices developed in the Mombasa CRZ based on indigenous collaboration and the culture of symbiotic mutualism and symbiotic fabrication in the sacred forests of Hong Kong CRZ.

Today, the CRZs have developed into Pan-Indigenous Autonomous Zones—a sanctuary for global indigenous stewardship and the development of symbiont material cultures. The legacy of socially useful fabrication practices in the CRZs has drastically eased ecological pressures on regional biodiversity and regenerated soil ecosystem services, creating an abundance of global food and material security and becoming hubs of habitat conservation and regeneration. The globalization of these symbiotic socio-technical cultures has mainly aided in realigning the material, social and ecological footprint directly to human well-being while mutually reinforcing the quality of life, social well-being, and climate resilience. These developments offer profound possibilities and challenges in the coming century, different from last, where both social and ecological regeneration are enmeshed, needing sustainment and care towards the long-term goals of flourishing in a Hothouse Earth.

1. Breaking Life

If we are to move towards a reconciliation of our shared ecological heritage in this hothouse earth, we must recognize the legacies handed to us, the choices we shape as much as they shape us in turn. This reconciliation requires that we acknowledge the legacy of the complex trajectories of planetary ecosystem services and biodiversity that we see today in the 22nd century were not inevitable but were rather deliberate choices. They were a path deliberately traveled brought on by the calamitous developments in affluent sections of humanity. Around this period, negotiating continued infinite economic growth seemed to overpower the more reasoned calls for climate action. By 2019, with the release of a landmark report on biodiversity and ecosystem services warned of an impending triggering of tipping points, it was clear that one was not compatible with the other (Díaz et al., 2019).

The report was explicitly clear in its conclusion—the unprecedented exploitation of nature had resulted in the rapid decline of ecosystems and biodiversity globally (Díaz et al., 2019). The alarming findings of such studies that were flooding in at the time forewarned that the 21st-century world was going headlong into triggering multiple tipping points where whole ecosystems collapse seemed highly likely. The planet was heading ever closer to the precipice, triggering feedback loops were in motion—the fires in the Amazon rainforests, the melting of the Greenland ice sheet, and permafrost were already happening faster than expected. As the last century progressed, the threat of climate tipping points (Figure 1) was threatening to plunge

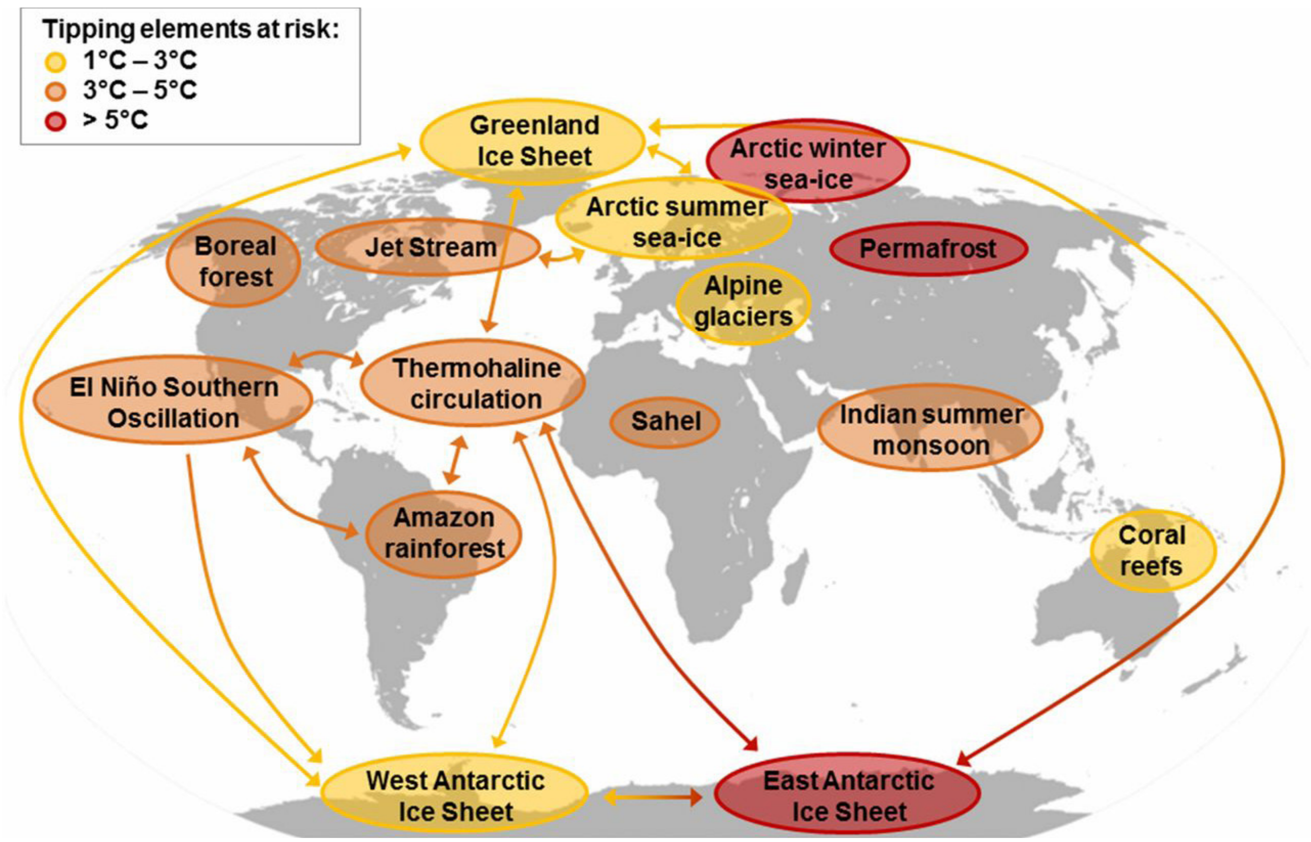

Figure 1 The various tipping points explored in the Hothouse Earth Scenario Image from (Steffen et al., 2018)

the planet ever closer toward a "Hothouse Earth" (Raabi et al., 2073; Steffen et al., 2018).

1.1. Biological Annihilation: Biodiversity and Ecosystem Services

With biodiversity drastically declining globally, the ecosystem services that the natural world ensured for human survival were drastically declining (Díaz et al., 2019). Simultaneously, the remarkable declines in biodiversity (Figure 2) signaled the onset of the sixth mass extinction (Ceballos et al., 2017). These declines were attributed to many factors: habitat loss, conversion to intensive agriculture and urbanization; pollution due to indiscriminate use of synthetic pesticides and fertilizers; pathogens and introduced species; and climate change (Díaz et al., 2019; Sánchez-Bayo & Wyckhuys, 2019). Organized human society faced catastrophic implications for food production. Ninety-five percent of the global food supply came from lands where industrial agriculture had ensured that 25 percent of the globe's greenhouse-gas emissions were emitted from land clearing, crop production, and fertilizers. Seventy-five percent of these emissions were from animal-based food production, with the rush towards modernization and industrialization of food systems requiring a constant supply of fossil fertilizers (Davis et al., 2004).

In later years, with the decimation of whole terrestrial ecosystems, including soil depletion, the decline in biodiversity and population collapse of pollinators were reducing the same yields for which the fossilized agricultural monocultures were established (Ray, 2019). Indiscriminate use of chemical pesticides decimated insect populations, including pollinators, and seeped into the complex food chains. On the other hand, intensive use of fossil fertilizers leached into soils, stripping their natural biocapacity for nutrition retention. The historical fertility of agricultural soil, once primarily endowed by the relational microbial ecosystems in the soil, was decimated after decades of intensive extraction. Large swathes of once productive soil ecosystems worldwide were being leached of their nutrient carrying capacity, rendering them infertile all for short-lived economic gains.

The fossil-driven anthropogenic emissions accelerated a pattern of ecological breakdown and destruction of terrestrial ecosystems that had been going on

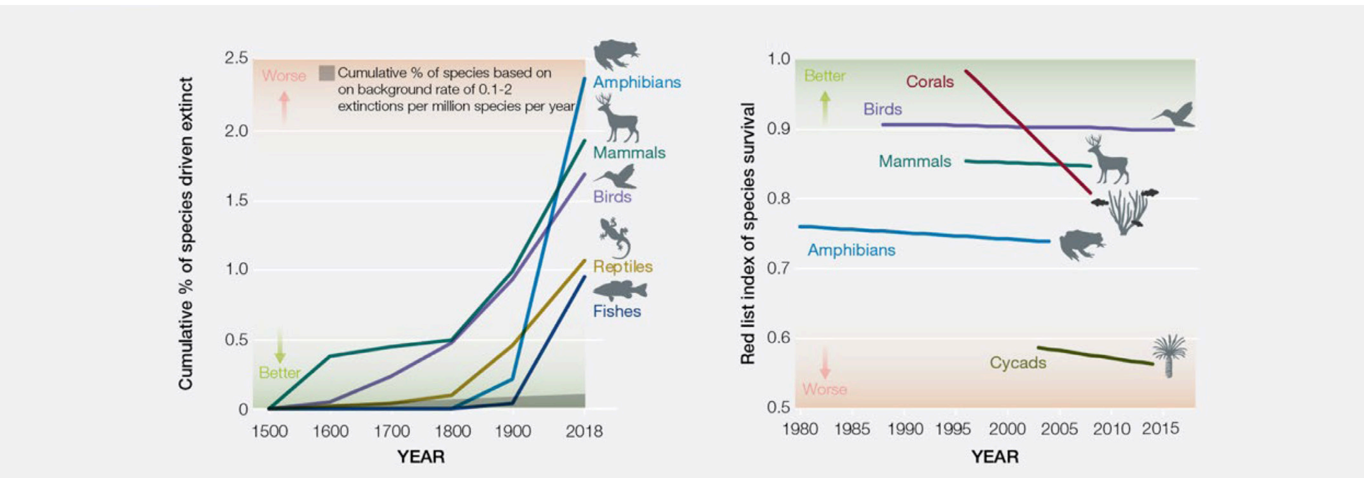

Figure 2. The sixth mass extinction event. (Left) exponential increase in species extinctions based on records from 1500-2018, (Right) Decline in species survival (Red List Index) between 1980-2018. Image from (Díaz et al., 2019)

for centuries. The gains from these activities disproportionately went to a narrow, economic elite section of the population (UNESCO, 2048). Despite this knowledge, global institutions seemed paralyzed by continuing mandates for maximizing accumulation as the window for climate action to safeguard human and ecological well-being continued to recede. Nevertheless, global economic agendas seemed unfazed by these existential threats. Within the frames of extraction and domination, it was pretty much confirmed many of the worst-case scenario predictions on biodiversity and ecosystem services (Maithili & Tenzing, 2106).

Under the global economic regimes, terrestrial ecosystems were stripped of vitality and reduced to a commodity. The ecosystems were treated as a one-dimensional input for producing "food, feed, fiber and bioenergy" in agricultural and industrial monocultures. These practices were breaching the planetary boundaries (Figure 3), eroding ecosystem resilience, and even endangering the prospects for quality-of-life scenarios just as the natural regulatory cycles of air and water, climate regulation, and habitat provisions of ecosystems were unraveling (Díaz et al., 2019). In the long run, under this pursuit of perpetual growth and control of resource and capital accumulation, biodiversity and ecosystem services were deteriorating rapidly (Díaz et al., 2019). Both historical and recent scholarship has appropriately pointed out that this was uniquely endemic to an economic system where cheapness and control of resources were integral to short-term growth although, for more long-term

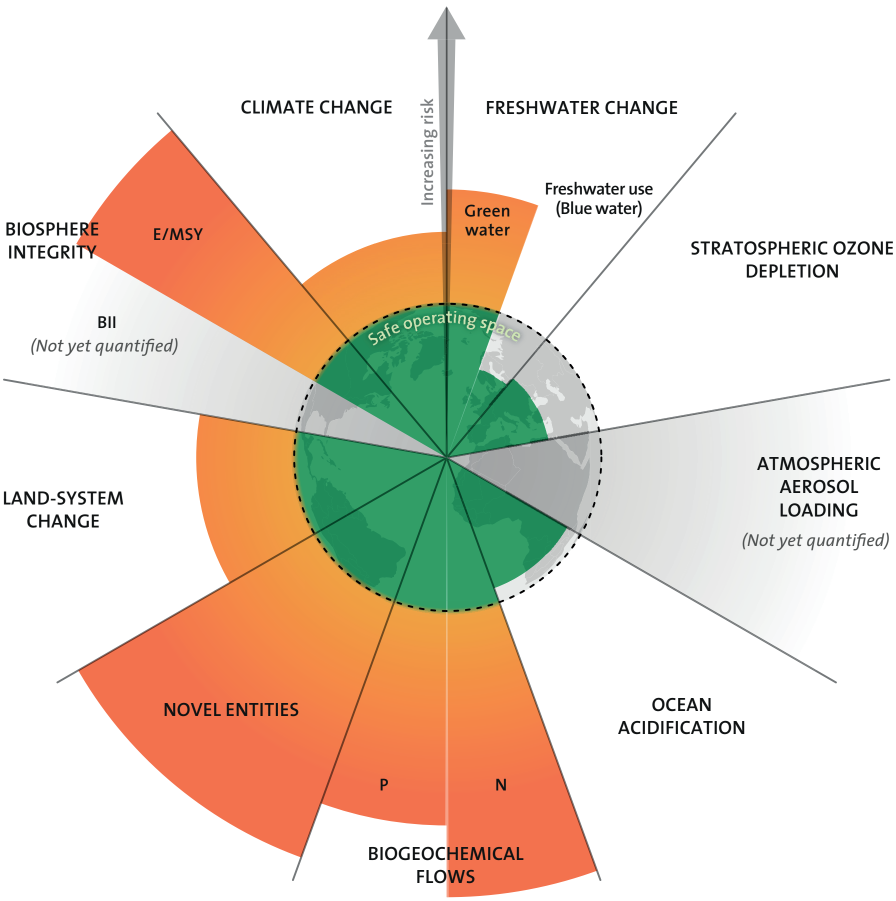

Figure 3. The overshoot of planetary boundaries with data from 2022. Image by: Azote for Stockholm Resilience Centre, based on analysis in Wang-Erlandsson et al 2022

challenges, reform alone would not suffice (Maithili & Tenzing, 2106; Patel & Moore, 2017).

1.2. Biting the Hand that Feeds

The global food systems at the time, whether it be grain trade or commercial seed transactions, were consolidated and dominated by a small handful of powerful private institutions (Hossain, 2017; Min & Devi, 2052). Such concentrations of power and influence over policy decisions made the discussions around industrialized agriculture and organic permaculture highly contested. However, what was undeniably clear was biodiversity loss and disruption of the biosphere's capacity to sustain the balance in the biogeochemical flows of the nutrient cycles necessary for the global food systems to function (Figure 3). Decades of pumping artificial fossil fuel fertilizers had leached the soils of their natural capacities of nutrient retention of nitrogen (D. Chen et al., 2016) and phosphorous (Cordell et al., 2009) were deemed essential nutrients for soil fertility and food production.

Moreover, the increase of carbon dioxide (CO_2), methane (CH_4), and nitrogen dioxide (NO_2) in the atmosphere from anthropogenic emissions was overwhelmingly from the use of fossil fuels, both as a source of energy and from land use and land-use changes, particularly agriculture. Emissions growth disrupted the dynamic balance of natural processes while rapidly overwhelming carbon sequestration capacities from the atmosphere (Ciais et al., 2013). Even by 2015, the deterioration of soil ecosystem services was causing alarming levels of instability in the fertility of soils globally. Major food belts worldwide faced diminishing agricultural yields as decades of fossil fuel-based agricultural practices were beginning to drastically affect soil quality (FAO and ITPS, 2015). The remarkable collapse of many terrestrial ecosystems and the onset of tipping points forced an unprecedented overshoot of consumption of resources far beyond the planetary boundaries.

Nevertheless, one must ask, despite these evident misgivings of the last century's increasingly industrialized, global food production system, did it fulfill the nutritional requirements of the global population? If so, perhaps one may understand its shortcomings in a better light. Studies at the time found that approximately 11 percent of the world's population was undernourished, and 20 percent were dying prematurely due to diet-related diseases, including undernourishment and obesity (Díaz et al., 2019). Furthermore, these arrangements were even shockingly inept at ensuring seed biodiversity and pest resilience. Despite being dosed with a copious amount of fossil fertilizers and toxic pesticides for maximizing yields, ecosystem resilience was eroding (Díaz et al., 2019; Shiva, 2008). Thus, even while the world could produce enough food to feed the human population, these practices were destroying the very productive capacities of soils and further reducing crop yields (Cordell et al., 2009; Min & Devi, 2052; Ray, 2019).

Despite global food production producing more food than ever to satisfy the world population, much of the food was mostly wasted. Even basing human development on calorific intake as opposed to the more relevant nutritional indicators of health, globally, more than half of the global population remained food insecure (Hickel, 2016). These contradictions laid bare the stark dissonance in narratives of growth and development as extreme inequality in human society at the time reached new heights (Oxfam, 2015). The climate and ecological breakdown also exacted a horrific toll on human life, shedding light on the structural failures in the prevailing socio-economic structures at the time. The global food supply chains relied heavily on small farmers, the majority of whom struggled to stay afloat on the market regimes tuned for maximizing profits per yield rather than nutritional needs, either human or ecological (Shiva, 2001; Hossain, 2017; Min & Devi, 2052).

Furthermore, climate breakdown induced heatwaves, droughts and floods consistently diminished annual harvest yields (Min & Devi, 2052; Ray, 2019). Before global debt jubilees, farmers with small landholdings were victims of predatory debt regimes. Farmers were coerced into purchasing proprietary seeds, fertilizers, and pesticides for monoculture cash crops. When seasonal rainfalls failed, harvest yields suffered, and farmers were forced into forms of indentured slavery to service such debts (Carleton, 2017; Shiva, 2001). Under the threat of destitution from extreme debt and poverty, these debt spirals culminated in widespread farmer deaths-by-suicides in poor agrarian societies and even in seemingly advanced industrialized economies (Carleton, 2017).

Farming became one of the most dangerous professions on the planet at the time (Carleton, 2017; Ubumwe, 2114), a bizarre concept for some of us to grasp today. Centralized, fossil-fed food systems had also forced whole generations of farmers into destitution. The largest demographic of those experiencing hunger back then were involved in agriculture (about 70 percent). With the devaluing of labor and care work in agriculture, people cultivating the global food production could not afford to purchase the fruits of their labor. Thus, cheap food was only so because of farm labor and land exploitation. We must point out that despite these unimaginable odds, the peasant food web-fed most of the global population, using roughly a quarter of the natural resources while still preserving biodiversity, making the food systems resilient.

1.3. Land Back: Broken Treaties and Indigenous Erasure

It was about this time of a near-religious push for economic development and growth coincided with the rapidly declining agricultural productivity, soil fertility, and biodiversity around the world; as the last remaining fertile soils on the planet, the indigenously managed lands were being auctioned for industrial extraction (Phillips, 2019). Indigenous managed lands across the globe were oases of biodiversity and sites of sequestering anthropogenic carbon (Figure 4). As a commodity in such an arrangement, complex interconnected, intergeneration ecologies became cleaved of their relations as forests, marshes, or bogs, atomized entities, being brought under the purview of industrial productive capacity (Periyar, 2043). The indigenous regenerative stewardship of the land was either infantilized or pejoratively considered archaic.

However, as the arc of history suggests, the truth may have been quite the opposite. The illusory “invention” of nature outside the human—was the more infantile position to take, even though it offered some usefulness, creating value for the commodities it could produce, such as food, real estate, minerals, or timber(Min & Devi, 2052). When the lands became industrial farms, it was for their productive capacities, a commodity within that framework, so their purpose was to be profitable (Min & Devi, 2052). We now know that there was no way for such arrangements to survive long enough to avoid hitting the thermodynamic limits of the climate system. It seemed to have been a temporary end unto itself to make use of an “unproductive” nature and force it into “productive” service that often leaned towards fast, cheap commodities shipped to all corners of the world, then just as quickly consumed, and wasted (Maithili &

Tenzing, 2106). Pair that with the rise of neoliberal financialization, and at each stage of this process, "derivative markets" played havoc with the planetary and social well-being in a series of boom-and-bust cycles (Chang, 2012; Hera, 2010). However, even as ecological breakdown accelerated at unprecedented rates (Ellis-Petersen, 2020; Phillips, 2019), nation-states continued to demarcate protected indigenous lands for industrial and economic exploitation (Ellis-Petersen, 2020; Phillips, 2019; Thekaekara, 2019). Ironically, given the declining rates of profit globally, these policies could not offer tremendous returns on investment (García-Olivares & Solé, 2015; Hickel & Kallis, 2020; Maithili & Tenzing, 2106).

These protected forest lands became targets for future expansion for industrial resources and agricultural conglomerates even though these were perhaps the last tracts of the planet that still had pristine biodiversity managed by indigenous ancestors. These acts of brutalization began and ended with indigenous ancestors and the ancestral lands. Their displacement and genocide formed the foundation of a so-called civilized world, cast as the harbinger of progress, revered in the ability to consume its life-giving ecosystem. Furthermore, with the so-called neoliberal

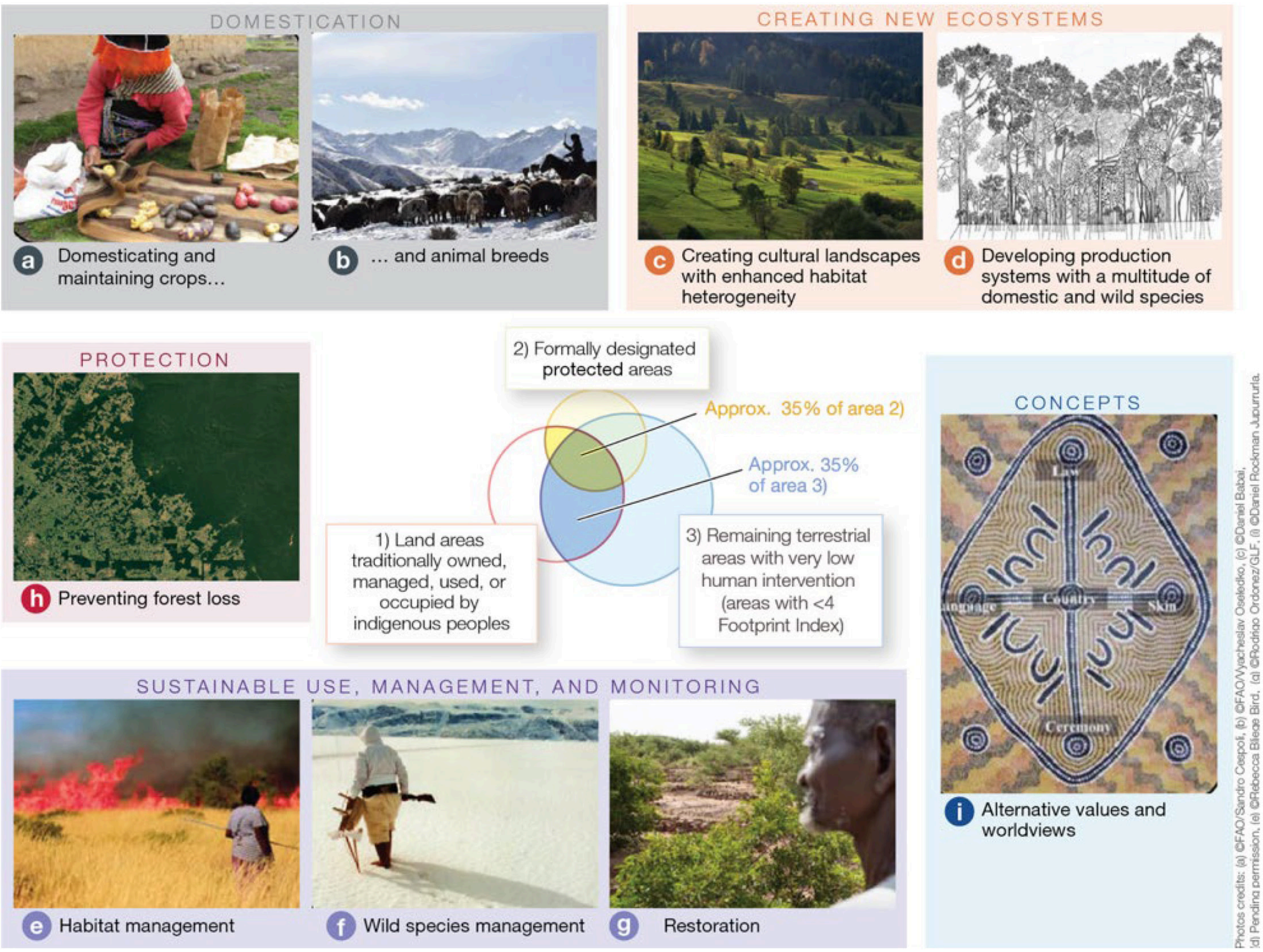

Figure 4. Contributions of Indigenous knowledge as described by IPBES report 2019 as a crucial strategy for climate action. Image by (Díaz et al., 2019)

era, the logic of domination and extraction turned onto human society and saw the commodification and militarization of social life, the consequences of which were profound. These patterns are all too familiar for those who study the centuries of forced relocation and land dispossession that had resulted in the genocide and mass displacement of Native Nations and peoples from their original and ancestral homelands. Such experiences also followed the destruction and violation of nonhuman relatives wrought by violent militarization, toxic dumping and contamination, and resource extraction (Thapa, 2047). Given these hardships, indigenous lands were the bastions of ecological stewardship, building ecosystem resilience, and preserving global biodiversity (Munda, 2058; Nenquimo, 2020). Despite the unimaginable odds, indigeneity had endured.

1.4. The Crises of Legitimacy

Many of these destructive tendencies found common ground with the political alliances of dark fossil money funneling resources to quell progressive movements practicing democratic dissent. These tendencies were considered a reaction to safeguard “business as usual” (BAU), given the declining rates of profit and the onset of climate breakdown that threatened to undo (Robinson, 2019). The consequences of unprecedented inequality and social unrest were not limited to the social sphere alone; the unrelenting extraction of fragile ecosystems was partly due to such disparity. The coronavirus (COVID19) pandemic of 2020-2023 forewarned, in no subtle ways, the significance of sustaining these ecosystem services beyond the extractive hegemony of the time and confronting the real threat of total social collapse that could undo all human progress in a relatively short amount of time (Milanovic, 2020). Further loss of ecosystem services threatened to unleash more novel and unprecedented pandemic-level diseases as the sustained destruction of forests and terrestrial ecosystems for short-lived economic gains (Díaz et al., 2019). For example, the Amazon rainforests were heading towards a point of no return (Lovejoy & Nobre, 2019), poised to become a source of carbon emissions (Covey et al., 2021).

Given the repression and a consistently abysmal record of global climate action until the early 21st century, it was legitimate to be skeptical of nurturing any hope in a substantive directive from public institutions to match up to the challenge. The climate justice movements faced relentless repression, often by the same institutional forces pushing the world closer to the ecological precipice (Maithili & Tenzing, 2106). As communities faced imminent existential threats along with a collapsing quality of life, there seemed to be inertia setting in. The global order could find no other recourse except to continue BAU (Maithili & Tenzing, 2106). These crises emerged specifically because the old hegemonic systems of extraction and domination refused to yield under the climate realities of the time and let alternative views and perspectives take root, simultaneously eroding the social contract (Robinson, 2019; Torres, 2027).

In the face of such concerns, institutions attempted to regain their legitimacy by illegitimate actions, approaching dissenting voices with authoritarian responses, fortifying the delegitimization further. It was not long before communities across the world came to terms with the erasure of the social contract, the disillusionment of the grand promises, and ultimately, climate betrayal and inaction. Shortly, faced with ever-increasing climate catastrophes, global pandemics, and authoritarian coups, public trust in institutions was at an all-time low (Torres, 2027). Civilization seemed to be at war with itself for a long time, willfully cannibalizing itself, even its imagination. The socio-cultural imaginaries of the time stand out in their normalization and idealization of climate fatalism. However, these climate apocalypses were lived realities for our ancestors, the poor, indigenous, and marginalized people of the world. What were perhaps cautionary tales were becoming reactionary forces. It is pertinent to point out that the early reactionary authoritarianism movements tended to capture democratic institutions to resurrect a neo-colonial, nationalistic global order. However, these movements tended to collapse under their weight just as swiftly as they rose to power.

2. Regenerating Life: Renewing Social Freedoms for Global Climate Action

What could one say of this "crisis of civilization," and where would human society find forms of conviviality to avoid its demise? To survive the unthinkable, our ancestors had to do precisely the impossible—by becoming an earth-bound terrestrial organism native to the planet. It necessitated discovering synergies, old and new, with the planetary ecology humanity had alienated itself from, exploring alternative rational pursuits of radical indigeneity, bidding farewell to a "childhood of mankind" (Graeber & Wengrow, 2021). The shedding of certain stunted and debilitating myths of 'civilization' as was understood until then certainly helped, collectively reconnecting with a natural, relational world that had begun to undergo rapid, sometimes incomprehensible transformations.

Around the early 21st century, far more transformative coalitions of a progressive kind were also taking root. Despite the relentless repression, many resistance movements were creating new pathways of resilience, and possibilities of social tipping points continued emerging. The many movements dedicated to social and economic justice, labor mobilization, indigenous sovereignty, and land back, global justice and climate reparations, sustainable agriculture, animal rights, food sovereignty, farmer struggles, public healthcare, prison abolition, debt cancellation, citizen science, open knowledge movements, and technology transfers, began to strengthen around interlinked struggles for a new climate just world (Hampton & Kuruvila, 2092). These movements steadily built consensual coalitions and alternative infrastructures that intersected in myriad ways of being and acting, deliberating a move away from the expectations of incrementalist change, and insisted on pursuing their own transformative, structural projects as alternatives based on climate justice (Hampton & Kuruvila, 2092). This implied restorative justice, an end to settler-colonial institutions, and ensuring reparations integrated restoration of biodiversity and food security for the most vulnerable globally. It proved essential in addressing the sixth mass extinction for regenerating ecosystems and habitats under severe stress due to climate system collapse. Under the circumstances, these intersecting movements were creating new, place-based alternatives even while counteracting authoritarian repression with multiple alternative formations of mutual-aid programs for climate resilience (Vemula, 2116). What was taking shape in these emerging coalitions was the articulation of universal social contracts to reclaim the ecologies of freedoms that a civilized life promised to come at the expense of others, which became more crucial for realizing the goals of climate action needed.

2.1. Rethinking Planetary Economics

With public trust in institutions in ruins, communities were mobilizing and constructing alternative institutions for addressing unfulfilled needs, exercising their right to self-determination and community building through alternative economic models. When the UN Emergency Assembly approved the Mutually Assured Thriving (MAT) treaty on Climate Action (IPBES, 2028), it was out of fear of being challenged by the alternatives created in grassroots organizations. This crisis of legitimacy showed made itself known when even after the binding clauses and commitments from public institutions, they hardly registered in the public discourse, given how so many of these treaties had failed in the past to offer lasting transformative change. The MAT treaty even proposed alternative governance models such as Global Climate Assemblies to regain public trust in institutions (Dirik & Chen, 2029). The MAT treaty was complimentary to the treaty on Universal Climate Justice (UCJ). While both focused on climate justice and ecological reparations, the MAT treaty focused more on land-use changes for regenerating the commons, biodiversity, and ecosystem services, even though many thought it was already too late (Achibe, 2029).

Thus, even as the treaty was fleshed out, multiple green economic deals were already being implemented by Global Climate Assemblies (GCAs) directed through the policy platforms of national actors. The traditional resistance to the policies came from the predominantly affluent states or those that intended to pursue similar trajectories to these states. This path to affluence, extracted from the biosphere, was a logistical dead end as many rich nations suffered through an under-developing stage where the social and ecological indicators were showing severe declines despite stellar economic performance (Anh, 2028; García-Olivares & Solé, 2015). These nations facing a crisis of overdevelopment were to implement a 'degrowth' model for contracting their ecological footprint (Hickel, 2020), focusing on remedial social programs for human well-being to avoid social collapse (Anh, 2028). At first, it was performatively accepted and half-heartedly implemented. With adequate social pressures, the move was sweeping enough to tip the scales toward climate justice, as had become popular in the discourse at the time.

Decoupling economic growth from material well-being meant that production and consumption of essential goods and services were taken off the market and fundamentally shifted towards possibilities of exploring "socially useful production" for fulfilling fundamental human needs (Ngata, 2076). Beyond this, it identified that in this new framework, formally acknowledging infrastructures of care and social reproduction as fundamental to ensuring human well-being, work that until then had been exclusively done by the most marginalized demographics throughout history (Graeber, 2014; Stanley et al., 2021). Until then, an economy was only considered successful in the globalized sense if it found ways to maintain ways to cheapen social reproduction to sustain such a socio-economic order. Nevertheless, it was the quintessential bedrock for regenerating all human societies. Following this, the Universal Declaration of Climate Justice under the UCJ ensured the implementation of a universal liveable income (UNDP, 2029) instead of the more conservative proposals of a universal basic income (Bregman, 2017). The initial proposals were heavily condemned as they designated a massive diversion of funds to bail out redundant industries and economic institutions responsible for the crisis in the first place (Lee & Cooper, 2028).

Moreover, the distribution channels were less than optimal as many groups of people were not accounted for in the bureaucratic apparatus. At the same time, some communities and nations refused to participate in the process entirely. While the policy itself was implemented in a rush, which would mean that in some places, it would take years before its impact could be felt in full. In some other instances, some distribution channels were being sabotaged.

2.2. Reclaiming Community: Renewing Social Life

Remarkably enough, even as whole industries disappeared with people leaving unacceptable working conditions, the social indicators of health and well-being improved drastically. However, it was not surprising in hindsight. Those who preferred to work their three-day working weeks despite the guaranteed liveable wages were pursuing socialized activities in their free time (Zerrano, 2036). People in their "unproductive" time were volunteering and arranging community projects such as langars and other open food kitchens sourcing locally cultivated produce, repairing technological artifacts, building social dwellings, and 'rewilding' and reviving dense urban forestry. Despite the harsh climate unpredictabilities the world was experiencing, these voluntary communities showed great therapeutic value for the social body, increasingly addressing the mental health crisis and mass climate anxiety, lingering vestiges of the previous order. The slowness in matters of global economic activity instead sped up social engagements as people redirected their energies in their communities. Universal social programs radically expanded in places where liveable incomes were inadequate to tackle systemic impoverishment (Doon, 2035).

Communities were attempting more spontaneous actions in their free time. Volunteering programs and regeneration festivals took up community causes. Resources were being pooled together by those who aimed to regenerate soils, develop agroecological food cooperatives, and rewild ecosystems. Community farming projects became widely reported as it looked dramatically possible to create carbon sequestration frameworks that returned atmospheric carbon into the soils. Coincidentally, many of these actions were supported by provisions in the MAT treaty (IPBES, 2028), which communities instinctively pursued. Impoverished farming communities were freed from debt traps through their universal liveable incomes, becoming stalwarts for rural life's cultural, intellectual, and ecological revival. Urban life, on the other hand, transformed into different variations of transition town programs as more local circular economies revived urban life worldwide and made cities more liveable again. Markets contracted globally, while local economies flourished as weekly bazaars became hubs of local exchange economies for locally produced artifacts forming the means for socialized exchange. Urban and rural social life found other forms of expression as festivals, art, music, recreational sports, and other cultural pursuits occurred in exponentially expanded capacities.

Many of these changes were made possible with the help of spontaneous community volunteering activities, where people took charge of their communal spaces and pursuit of interests. Open science movements such as "Citizen Science" (Wildschut, 2017) showed remarkable promise during crises (Hussein, 2018). Before long, they became crucial platforms supporting scientific dissemination and validation within communities (Cuentas et al., 2029). Freed from the coercion of work, individuals spontaneously organized around common interests that focused overwhelmingly on socially essential work, often volunteering for ecological restoration and social justice (Ngata, 2076). The Open Tech and Open Science movements have emerged from this specific period, spreading out from these previously "subaltern" communities (Ngata, 2076). These rainbow coalitions of citizen science groups, war abolitionists, and indigenous groups also spelled an end to the 'economies of war' (Vemula, 2116).

2.3. Decolonising the Land: Realising Indigenous Sovereignty

In the early 2030s, the pivotal ruling on ecocide indicted the vast global networks of climate-denying fossil fuel institutions. They were held accountable for their crimes against humanity and the planet by delaying climate action for decades and triggering a mass extinction event (ICC, 2034). The wealth of many nation-states that depended on these networks back then was founded upon these arrangements—upon the displacement, erasure, and genocide of indigenous peoples of the world for fossil and mineral exploitation to develop their regimes (Munda, 2058). Behind the rhetoric of so-called development, one could find a system designed to benefit a few privileged sections of a fossil-fuelled society at the cost of the many. Codified in its actions was a trail scattered with egregious ecocidal acts to enrich a few. Henceforth, under the climate reparations act, such a model of neo-colonial development was to be abolished. The GCAs issued calls for climate reparations paid for the displacement and genocide of native peoples by supporting the land back movements, returning indigenous lands, and acknowledging them as sovereign geological entities (UNCAC, 2043).

The abolition of fossil infrastructures radically contracted the fossil emissions footprint and put the proverbial 'brakes on the system.' In hindsight, this became the foundation for resilience efforts to succeed of their own accord, transforming both industrial and agricultural engines of civilization. In the years that followed, fossil fuel infrastructures were abolished in their totality while paying for reparations. For multinational fossil agricultural institutions, agricultural soil was only as valuable as the profit margins that the commodities could get in return. In the aftermath of the abolition of fossil industries, these margins were negligible as the subsidies for fossil fuel-derived fertilizers and pesticides were dismantled or abandoned, making industrialized farm holdings less productive and financially unsustainable. Large tracts of industrial farming land lay abandoned, occupied by local agroecologists in later years, and returned to indigenous stewardship in most cases. The urban and rural communities took stewardship of these lands. With an agroecological farming approach, local farms emerged as alternative ecological sites for food cultivation. Over time, these sites became sanctuary sites for a resurgence of natural habitats. Some participatory economic arrangements even found ways to integrate universal benefits within the practice of local, ecological farming to replenish and renew the soil while achieving carbon-negative loops in a just climate transition.

While carbon drawdown proposals depending on ecological soil and land management and the contraction of global industrial land management were tipping the scales of global emissions as the growth of new emissions plummeted. This problem had come up most noticeably in the IPCC reports and had just been hand waved away by citing the now-infamous Carbon Capture and Storage (CCS) technologies that claimed to solve this quandary (IPCC, 2018). Under degrowth, however, the global carbon drawdown programs proved far more reasonable, as the emissions reductions from slowed economic activity and consumption massively boosted their possibilities. As the redistribution of climate-resilient essential infrastructure spread, global coalitions formed to answer the call for intentional, community-first climate action. Communities were now slowly rediscovering and reviving local indigenous knowledge and combining it with the scientific discourse at the time, offering a silver lining in perhaps achieving the impossible drawdown targets. The indigenous know-how and practices applied to such a large-scale endeavor. Despite some conflicts along the way, it proved to be very effective for working towards ecosystem conservation, restoration, and regeneration goals, coordinating the transformative changes across economic, social, political, and technological factors that were so desperately needed (Díaz et al., 2019).

With the return of these lands, the sovereign indigenous communities carried out the long and arduous task of reviving and restoring their ancestral connection to the damaged terrestrial ecosystems and the habitats mutilated by a so-called civilized society. Complementary to this move, governance modes shifted towards internal policies for local resilience and global equity, based on human-scale development to safeguard climate reparations and ecosystem regeneration integrated with human and social well-being. These regions were ecosystems managed with deliberations on indigenous knowledge frameworks in collaboration with the science of the time. Open technology transfers made this knowledge possible with climate reparations as global efforts dismantled fossil agrotech intellectual property rights built on privatizing the commons and indigenous knowledge (Cuentas et al., 2029; Shiva, 2001). More than ever, the collaborations between indigenous knowledge systems and open science movements strengthened as technology transfers made intellectual property obsolete.

2.4 The Long Carbon Drawdown: Rewilding, Biodiversity and Agroecology (2028-2054)

By mid 21st century, global climate strategies were finding synergies, aiming toward regional and globally integrated approaches towards biodiversity and agroecology in response to the climate crises. Although many infused the latest technological know-how, the ones that worked best were those that developed founded on traditional wisdom and local indigenous knowledge. Together with networked communities pursuing citizen science, these practices reimagined for a new technological culture relying on regenerative ecosystems through permaculture practices, local conservation, and sustainable food production practices at localized scales.

Thus began the truly colossal task of regenerating ecosystem services allowing for healthy soils already known to have far more potential and capacity for carbon capture than the atmosphere or even vegetation (Ciais et al., 2013). Furthermore, reconnecting the sovereign old-growth forests of the world had already shown potential for bringing back terrestrial biodiversity (Damschen et al., 2019). Once regenerated, healthy soils could subsequently offer even better ecosystem services, including biomass production from agriculture and forestry, storage, filtration, and transformation of nutrients and water; biodiversity habitats; raw material sources; and carbon sinks (FAO and ITPS, 2035).

Industrial food systems, which once relied on cheap fossil fuels, could no longer be cheap and were repurposed for community-managed agroforestry. This transition intensified the material production and consumption cultures, which began to integrate into ecologically regenerative permaculture practices. The ecological restoration was realized through sustainable agricultural, aquacultural, and livestock systems, safeguarding native species, varieties, breeds, and habitats. Liveable incomes and local production and consumption were fulfilling essential human needs and ensuring that distribution networks were reducing hunger and nutritional deficiencies of roughly half of the world's undernourished population to an all-time low. The victories of the Indigenous Land Back movements, and the land redistributions thanks to the climate reparations programs, helped rejuvenate rural life and drastically reduced death-by-suicides in these vulnerable communities (Thapa, 2047). Under this arrangement, the localization of food systems and the setting up of People's Seed Archives (PSAs) initiatives strengthened seed biodiversity and food security while substantially aiding the recovery of ecosystem services once thought lost (Naipanoi & Kelmer, 2031). With farming communities worldwide learning and exchanging farming techniques and sharing seed resources and know-how, the indigenous autonomous belts became sites for other crucial efforts. Rewilding ecosystems played a massive role in rehabilitating millions of recently liberated livestock from industrial slaughterhouses. The drastically changed nutritional patterns also influenced pastoralist movements that supported the ecological supervision of the domesticated animals on protected lands naturally proved transformative for livestock management and regional biodiversity restoration (Wu & Young, 2035).

2.4.1 Rewilding Networks of Climate Resilience Zones (CRZs)

Over the past century, large-scale studies established the relationship between the profound ways climate reparations and indigenous action transformed the renewal of knowledge systems and fulfilled the much-needed climate goals. In the post-reparations world, this was to build on tacit knowledge frameworks of indigenous ecosystem management and reinforced with citizen science to focus on the regeneration of ecosystem resilience. These collaborations of mutual thriving materialized with establishing the first Climate Resilience Zones or CRZs that were emerging around then, founded on indigenous perspectives for climate resilience practice (Goldman, 2028). These CRZs, named as a reference to the "Special Economic Zones" (SEZs) that had driven much of the latter part of 20th-century economic development based on unregulated industrial expansion and growth that was a tool for neo-colonial extraction (Neveling, 2015). These CRZs thus were a unique move in history that transformed these once sacrificial dead zones of urban envelopes into today's dense, pan-indigenous old-growth mega-forests (Figure 5).

It is important to note that the first CRZs came about around the urban fabric of Mombasa at a time climate breakdown was ravaging the East African region with unprecedented hurricanes yearly. It is here that many of the guerrilla forestry coalitions applied unique fusions of local indigenous knowledge resurrected in the sovereign indigenous lands in collaboration with the restoration and citizen science movements taking shape in the region. These collaborations tried to figure out a solution to the ecological crisis while the annual hurricane seasons grew calamitous with each passing year. While mass climate migrations forced the urban population to decline in some regions, some communities in and around the city still choose to persevere. Even though such holistic land management practices have been familiar to the indigenous cultures through their lived practice for thousands of years, the rapid changes caused by climate and ecological breakdown drastically threatened this knowledge. These CRZs realized alternatives to the long-known and proven possibilities of regenerative urban development that worked together to revive ecosystem services in cooperation with the ecological processes. The technicalities challenges needed complementary domains of knowledge to situate and act symbiotically with other ways of knowing to ensure the longevity of actions. Perhaps it was from these frames that the Mombasa CRZ developed as it did, being the first documented case of a CRZ that brought together this deep connection between indigenous knowledge and citizen science groups that got together to regenerate forest ecosystems around them.

Many of these efforts were hidden from the world, carried out by everyday people living in the greater Mombasa region. These CRZs forests were recovering dramatically over a couple of decades, in dense patches that were sometimes even difficult for humans to walk through. The randomized, intentional patterns seemed designed to help protect the urban and rural infrastructures that faced extreme hurricanes. These

Figure 5 Reconnecting Disconnected habitats Accelerated Regeneration of biodiverse regions aiding in revival of old growth forests. Image by (Cech & Tarkovsky, 2108)

enmeshed agroecological patches of dense, old-growth forests confirmed what previous studies had only hinted at (Thom et al., 2019). During hurricane seasons, the crisscrossing of patches of extremely dense old growths dissipated the energy of storms extremely well and advanced climate resilience to drought and heatwaves through seasons. The CRZs and the communities that sustained them were far more resilient, integrated with regions of local ecological agriculture, medicinal flora, and engineering fibers for local fabrication use. To further safeguard food security, many cities in the Global South also followed this practice in the coming years integrating ways to include human and forest habitations within the urban tapestry, mutually reinforcing each other. The coming together of local and indigenous knowledge as a pragmatic climate mitigation strategy better suited Mombasa further developed—to grow dense forest belts enmeshed within and spread across the city, becoming windbreakers and as a storm surge prevention strategy at strategic locations across the city.

Perhaps in the early half of the 2030s, community experiments of planting dense patches of old-growth forests cutting across the city were being carried out (Goldman, 2064). Many thriving old-growth forests nestling human settlements today are thanks to such afforestation and rewilding efforts. As CRZs ecosystems expanded, antiquated urban and industrial infrastructures were 'depaved' and reclaimed from built urban environments and infrastructures that were not needed anymore (Ceranos, 2031). These CRZs were to be established as protected regions and adopted worldwide soon enough as indigenous and allied coalitions reclaimed once pure concrete and asphalt areas. These areas transformed into spaces for expanding urban social life, climate resilience, biodiversity, ecosystem regeneration, and local food production (Ceranos, 2031).

To establish CRZs, communities had to revive the degraded nutrient capacity of soils from about a century of intensive fossil agriculture. This revival was based on well-established indigenous practices, amending soils with carbonized matter known as 'biochar' biologically activated with healthy microbes. Historically, this biochar or biocarbon was known to have facilitated the fertility of the Amazon rainforest soils known as 'Terra Preta' and could also sequester carbon for thousands of years (Glaser et al., 2001). It was also well studied that this carbon-amended soil could help provide sites for rich microbial ecosystems that needed it (Hammer et al., 2014; Lehmann & Joseph, 2009; Ngatia et al., 2019). This stable soil amendment made from carbonized organic matter was even proposed as an effective means of carbon sequestration while integrating into local industrial production of high-quality products too (Bates & Draper, 2019). Thus, even socialized farming was being framed within a larger ecological context premised on 'indigenous knowledge systems together with open science and open technology as the means. The CRZs were now home to livestock animals recently liberated from industrial meat factories and helped establish further rewilding of these sites, ensuring pastoral contribution to ecosystem regeneration (Wu & Young, 2035). This symbiotic nurturing of these CRZs with local permaculture farms created favorable climate feedback loops. It proved key to regenerating old-growth microbial ecosystems in these soils assisted by human activity. As early interventions demonstrated, rewilding and reconnecting the old-growth forests of the world led to practical breakthroughs in bringing back biodiversity (Figure 5) and showed that the older an old-growth, the more carbon it could accumulate than previously understood (Tollefson, 2014; Cech & Tarkovsky, 2108).

Many studies confirmed that the microbial mycorrhizal pathways in the land enabled healthy agroforestry practices. These healthy microbial beds could regenerate ecosystem services at a holistic scale and were far more effective mediums of nutritional exchange of nitrogen and phosphorus and carbon sequestration (Whiteside et al., 2019). Furthermore, their carbon sequestration potential was exponential as these ecosystems became more "old growth" ecosystems implying that the soils of these forests had the immense potential for carbon sequestration on a much more profound level than ever before (Thom et al., 2019; Tollefson, 2014). At the time, studies confirming the influence of these forest ecosystems were at the geological scale, altering precipitation patterns at geological scales (Kooperman et al., 2018; Popkin, 2018; Steidinger et al., 2019). It was not until much later that this simple intervention for the revival of soil microbial health in the CRZs created the global cascade effects influencing whole geological scales of precipitation and carbon cycles (Cech & Tarkovsky, 2108; Goldman, 2064). Even though these CRZ communities were only pursuing them for seemingly narrow nutrient allocation and carbon sequestration goals, their development and revival of ecosystem services influenced multiple climate feedbacks more profoundly than ever thought possible.

2.4.2 Guerrilla Seeders of the New Mombasa CRZs

The regeneration of the Mombasa CRZs and their new, old-growth forests was an important demonstration of collaborations between indigenous knowledge systems and contemporary ecosystem resilience programs. This application of holistic cultural knowledge to study and revive these native ecosystems with native climate-resilient species became a foundation for CRZ practices worldwide. The New Mombasa Climate Resilient Zone overgrew with dense native forests within a decade of seeding efforts which naturally would have taken hundreds of years. With open knowledge frameworks in place, the experience and knowledge had created a successful strategy built upon the well-known regenerative practices. Thus, the CRZ experiment's success in Mombasa transferred quickly to other parts of the world. This practice accelerated exponentially and quite rapidly spread out as CRZs and duplicated extensively across the globe (Thapa, 2047).

Aiding with re-establishing the old growths required the means to germinate their symbiotic microbial pathways in leached agricultural soils rapidly. While traditional industrial farming practices regularly disturbed microbial fauna crucial for regenerating forest ecosystems and establishing agroforestry regions. Cultivation practices adopted more ecological practices with the contraction of heavy fossil fuel-based machinery and exploitative farm labor. Agroecological, no-tillage farming could apply seed ball techniques in a “zero” farming framework (Fukuoka, 1978). Seed balling enriched the soil’s nutrient biocapacity and allowed for an agroecological practice. They simultaneously revived and regenerated old-growth forests with pockets of organic food cultivation. Each of these seed balls contained a specific combination of native seeds chosen for a specific type of ecology required (Figure 6a).

The balling of native seeds began with making a dough of biocarbon compost provided the nutrient-rich medium for seeds to germinate, even in the harshest conditions. Many studies at the time had already suggested that this biocarbon could be further “supercharged” with essential nutritional elements such as nitrogen and phosphorous from non-fossil sources (Ngatia et al., 2019; Zhou et al., 2019; Zhu et al., 2019). As was understood then, this biocarbon further enhanced nutritional access to the seeds by establishing new underground soil mycorrhizal pathways (Figure 6b) (Whiteside et al., 2019). Certain varieties of mycelium spores were masters of supercharging forest growth (Tsing, 2015). Native seeds were selected based on mapping archival records and indigenous knowledge to encourage symbiotic relations specific to the local ecosystem. In places where habitats were disconnected, they planted seed ball combinations of lost species belonging to the same ecosystem. For this purpose, the seed archives helped source and recover native species once considered lost from historical records (Naipanoi & Kelmer, 2031). In some other cases, new intentional species found their way to balance the ecosystem enmeshed with those relevant to human needs (Goldman, 2028). Planting in more randomized patterns mimicked the natural patterns of these seeds. Known as the Miyawaki method, this creative way of dispersing seed balls made forests grow resilient and introduced some randomness inherent in ecological regeneration patterns (Miyawaki, 1999, 2004). This method was a less pragmatic choice for industrial machinery, but ‘seed balls’ helped cover remote areas that could be accessed by the volunteer groups, given the ambitious scale of the regeneration programs.

Figure 6(a) Seed ball made from biocarbon, soil and compost inoculated with mycelium, Image by: Seedballs Kenya (2014) (b) mycorrhizal network in biocarbon particles that over time are fully integrated into the soil system with no signs of decomposition, and act as a reservoir for nutrients and water through mycorrhizal hyphae (orange structures). Image by (Bruckman & Klinglmüller, 2014)

Urban communities witnessed collective actions for regenerating local ecosystems. These CRZs were transformative sites for rehabilitating biodiversity, establishing agroforestry practices, and addressing the community's nutritional needs. Direct yet informed community actions such as 'depaving' made former concrete and steel infrastructures revealing soil from the revived urban land (Ceranos, 2031). In Mombasa, much of this work was done in secret by a guerrilla direct action group of indigenous peoples, volunteer arborists, and the citizen science community went about preparing the old-growth soils with specialized seeding devices (Figure 7). These groups called the "walezi wa msitu" (guardians of the forest in Swahili), took long routes traversing the region, surveying and documenting local forest species, and then later started cultivating the CRZs in the Mombasa region. This guerrilla group understood at the time that bringing back native forests was the best way to make the city self-reliant in food products and provide a natural barrier to the increasingly devastating hurricane seasons. The seeding instruments (Figure 7) they developed were a curious blend designed by the local citizen science and Open Tech communities from locally available technologies and resources in the region.

In the latter half of the century, these guerilla actions had become more mainstream and spread widely, taking on culturally situated characteristics. The early success with the CRZs in Mombasa influenced similar restoration efforts with the seed archives, allowing communities to automate the work of reforesting old growths faster, shaped by indigenous coalitions and local academic and research institutions. In Hong Kong, these actions took the form of airborne seeders (Figure 8), combined

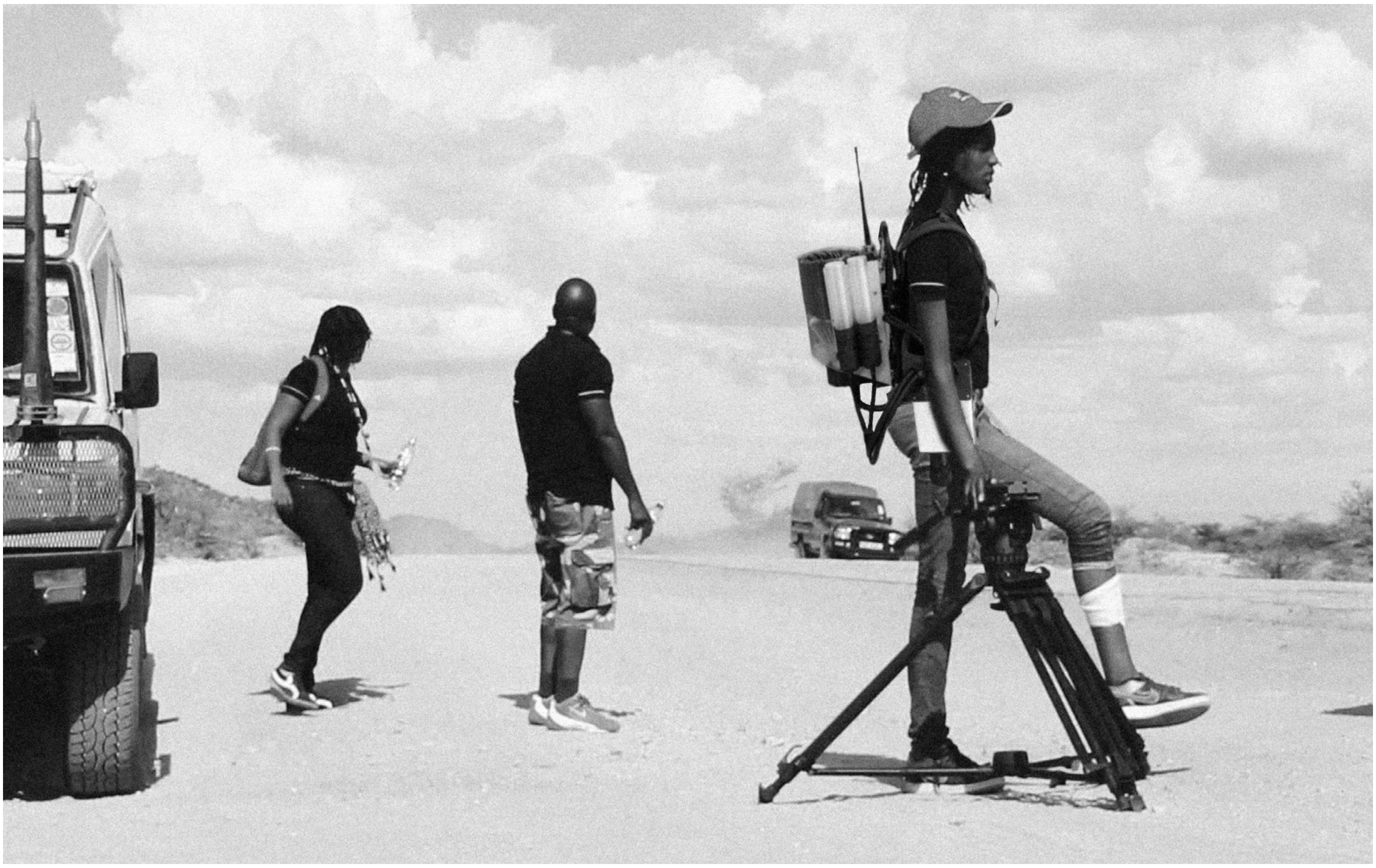

Figure 7 One of the rare documented images of the forest seeding practises of the volunteers of the secretive 'walezi wa msitu' about to traverse far and wide planting the CRZs for food and biodiversity restoration. Image by: Open Archives, Mombasa (2064)

Figure 8 Autonomous "firefly" seeders at one of the regular old growth regeneration festivals in California, Image by Open Archives , (2108)

with abandoned autonomous technologies opened from the coffers of a defunct military-industrial apparatus (Ngata, 2076). The citizen science groups in the region took the concept of the CRZ seeders and automated processes to carry out more effective regeneration processes. They were ironically referred to as 'fireflies' (螢火蟲) in a period when insect declines with the sixth mass extinction were still a serious cause for concern. Today, the original forest seeders survive the test of time and are employed even almost a century later. Under the hothouse conditions and the unpredictable climate cycles, these assisted seeders have offered possibilities for migrating vulnerable forest ecosystems to suitable climates zones, assisted by civilized cultures. However, this is only done under desperate attempts to preserve biodiversity and relieve these ecosystems of climate stressors as disruptive climate patterns play havoc with ecosystems worldwide. Even today, one can see these 'fireflies' busy planting new ecosystems in regions where the heat death of forest ecosystems has occurred (Cech & Tarkovsky, 2108).

2.5 Transformative Resilience: Pan-Indigenous Autonomous Zones (2054 onwards)

The links between the Land Back movements and the CRZs were taking shape in more ways than one. The legal right to personhood for the CRZs was already in full effect under the climate reparations program (UNCAC, 2056). The practice spread far and wide through the open knowledge frameworks that helped communities build their versions of it. While the colossal task of regenerating rich forest ecosystems was underway, the material cultures were also simultaneously evolving, responding to this shift towards a regenerative practice. These tendencies arose from seemingly pragmatic decisions about the need to sustain, maintain and regenerate the CRZs as climate resilience insurance (Goldman, 2028, 2064). The old extractive industrialization paradigm was shifting simultaneously to localizing production and consumption. The focus for production had shifted from consumer markets of fast, mass-manufactured, cheap products and technology to high-quality, locally produced, and manufactured goods for community consumption that were only fabricated once and maintained for decades at a stretch (L. Chen, 2031; Ngata, 2076).

While market-based production drastically contracted to cater to very niche needs, solidarity and mutual aid economies created alternative models for socialized allocation of universal, essential needs at a community level. Within the latter, the material and technological resources were to be fulfilled by open knowledge frameworks and syndicated fabrication facilities (Alex & Mehrawi, 2080). This 'short circuited' the systemic vestiges of an industrial past and addressed the ecological and social externalities. These were incompatible with a historically polluting mass manufacturing system that created planned obsolescence following market growth and held captive intellectual patents; this gave way to a more scaled-out, distributed, community-run fabrication framework. These comparatively slower production processes centered around reducing the energy and ecological footprint by designing high-quality, reusable, and repairable production methods, 'exapting' old industrial practices towards new socially valuable fabrication systems (Krets, 2048; Ngata, 2076). Even so, these emergent practices proved capable and equipped to provide for the material abundance of the societies dependent on the CRZs (Goldman, 2064).

2.5.1 Emergence of Symbiotic Mutualism: A Self-Conscious Practise

With the regeneration efforts in full swing, connecting previously urbanized landscapes with sovereign indigenous belts along terrestrial regions proved quite successful. The encroachment of the rising seas over lands was being managed well in some cases with mangrove and coral sea walls to preserve infrastructures at the intersection of terrestrial and ocean ecosystems. The cooperative volunteer networks combined the important restoration works of the CRZs by expanding the ancient sacred forests in the region, achieving unmitigated success, and creating unprecedented resource abundance in these regions. However, this path to this abundance was not without friction. Hong Kong CRZ encountered certain sections of the population attempting to gain exclusive monopoly rights over the commons. Perhaps yearning for a mythical past, there was a regression to some forms of primitive capital accumulation, a tendency that was more common than we would like to believe. There were elaborate and reasonable justifications for these actions—fulfilling the community's material needs. The popular discourse around the time saw these as attempts to revive the archaic patterns of indiscriminate extractivism that had only recently shown a reversal. These trajectories were signaling yet another race to the precipice. Unfortunately, many of the traditional fabrication syndicates in the regions were also beginning to see these CRZ ecosystems as a resource bank, which they reasoned should be open to exploitation if only they had to be quickly restored (Goldman, 2064).

Consequently, the struggles for the future of the Hong Kong CRZ took a curious turn. Frustrated with these early signs of a return to a pattern recently shed, rainbow coalitions of agroforestry cooperatives started occupying these delicate ecosystems to protect them from resource poachers. In these occupation sites, one could see impressive advancements attempting to create alternatives to the syndicated fabrication workshops. These initiatives, supported by the citizen science and open knowledge communities, investigated alternative syndicated fabrication methods. The aim was to regenerate resources from these new old-growth ecosystems beyond the need to dominate or exploit them solely for human consumption.

These collectives proposed developing 'SymFab' Units (Figure 9 a,b) to address these tensions by integrating principles of symbiotic manufacturing they had been practicing over the years in the CRZs with the syndicated fabrication processes in the region (Wong, 2081). The symbiotic fabrication processes they were engaging with were still based on the principles of symbiotic mutualism but fundamentally reimagined and integrated with the CRZs to create hyper-localized fabrication and address essential social needs. The symfabs or "symbiotic fabrication units" came about as discussions about how to fabricate the materials resources needed in the region without damaging the delicate CRZ ecosystems in the process. Thus, the limits of the resource capacities of the CRZs led to new research into exploring material science developments and ecological management of the natural fibers and tree resins available from within the CRZs. Over the years, numerous recipes for these fiber and plant resin composites were developed, leading to breakthroughs in biopolymer batteries, semiconductors and resin-based supercapacitors, and composite construction technologies. The symfabs functioned as interstitial sites between human society and the old growths for reciprocal regeneration between the CRZ ecosystems. The interfacing coordinated the fabrication needs by 'growing' a techno-material culture to ensure mutually assured thriving for the social and ecological assemblages.

Symbiotic mutualism refers to the reciprocal regeneration and flourishing of an organism or ecosystem entangled in a human-non-human assemblage. The phenomenon recognizes the autonomy of an organism to flourish and regenerate

Figure 9 a) Sym-Fab unit undergoing maintainance by the people of the forest. b) Fabrication pods grafted onto an old growth ecosystems that epitomise symbiotic mutualism. Images by (Qiao & Sakharov, 2093) itself through its entangled relations to the other organism in these ecological assemblages. The regeneration can be something that others can consent to and accommodate. Under symbiotic arrangements, if an ecosystem was to fulfill the material needs of human society, it had to be first done by understanding whether the actions were appropriate for the large ecosystem as a whole. That the ecosystem was aware or cognizant of these entangled relations and had agency in the process of flourishing through human affectation was only recently confirmed (Vanoor et al., 2128). Symbiotic mutualism has been observed by monitoring interstitial mycorrhizal interface networks leading to the living “symbitronic computation” systems (Vanoor et al., 2128).

It may be worthwhile to bear in mind that the aim was to build a mutual symbiosis established on responsibility for mutual thriving and respect. The non-human organisms in question would not be subject to debasement merely for human gains. The system was premised on symbiotic mutualism as the excess organic carbonized material would be processed into feed material for further processing of carbon-resin composite products by a caretaker. Some pyrolyzed matter would be ground up and inoculated with microbes by the caretaker, which would then be used to expand the forest’s ecosystems further and regenerate the ecosystem with the help of autonomous ‘firefly’ seeders. Thus, every act of local production and consumption was prefiguratively a mutually regenerating ecosystem. These units were limited to being beneficial only for small-scale high-tech fabrication. The processes employed were type-dependent to safeguard the health of the organism it interacted with, to ensure that the relationship was mutually symbiotic to the organism and not a parasitic one, which would endanger both organism and ecosystem (Qiao & Sakharov, 2093).

2.5.2 Symbiotic Fabrication within CRZs

Symbiotic fabrication is a seemingly disparate set of processes that describe fabrication methods that are both derived from and have led to a better understanding of the phenomenon of symbiotic mutualism. The resurgence of these old-growth ecosystems through deliberate human mediation opened divergent possibilities from the CRZs (Qiao & Sakharov, 2093). Some of the methods that made these material cultures possible were already touched upon in the early 21st century (Haneef et al., 2017) and only started to reach substantial maturity in later years under more open tech frameworks (Eonas, 2045). Symbiotic fabrication processes were developed as an anachronistic practice, curiously borrowing concepts from both cutting-edge sciences of the day to seemingly old traditions. These practices could range from bio-composites and energy storage applications based on the pyrolytic decomposition of biological feedstocks (Lam et al., 2019; Vold, 2015; Wang et al., 2013) to mycelium-based fabrication technologies (Anandhavelu et al., 2017; Attias et al., 2017; Subban et al., 1996) and even clay-based ceramic electrodes (Ghidiu et al., 2014). These processes allowed tweaking the numerous physical and electrochemical properties explored and realized openly as a situated practice in the CRZs.

In essence, the symfabs developed from early 21st-century 3D printing techniques, tools that the citizen science movements had repurposed to include a range of bioprinting, semiconducting and fabrication processes. The symfab pods were attached to specific species of trees chosen for their unique terpene saps and resins. The procedures carried out on the organism were strictly on a mutually beneficial basis, in a way that prioritized the ecosystems’ well-being. Thus, it was only once the forest reached a certain maturity that the pods could be attached, with their fittings grafted onto the trunks of the trees to ensure a steady supply of resin to the systems. The pods were directly grafted into the capillaries of the tree trunks safely with precise methods and tools developed by the "people of the forest" as the organisms' cellulose fibers calloused around them. These pod fixtures were put on specific trees so long as they could produce the minor quantities of the necessary resin and process them on site, tuning their desirable properties. The additive manufacturing functions were housed in small multifunctional units, biologically synchronized to particular species, and generated artifacts with finely tuned material attributes. The integrated pyrolysis chamber produced biocarbon and residual energy and heat from organic matter that was locally available and cleared from the forest floor, done by experts within the occupation who had run and cared for these units. The pyrolysis process provided heat to power the 3D printing systems that manufactured the required commodities and repaired damaged devices.

The pyrolytic carbonization and graphitization byproducts of cellulose fibers (Figure 10 a-f) and terpene resins were directly processed from specified plant species. They were 'fine-tuned' for peculiar physio-chemical and optoelectronic properties ensuring divergent properties exploring bio-composite and bio-electronics applications (Figure 10 g). In some cases, organic fibers such as hemp and bamboo from permaculture establishments became precursors for fabricating high-quality carbon fiber feedstocks in advanced electronics applications. Interestingly, these processes were once closed intellectual property of now obsolete fossil fuel-derived polymer industries. The proliferation of these technologies and material processes yielded high-quality materials for in situ processing in these CRZ ecosystems, now open for the commons. Even though historical records remain incomplete, recent scholarship has tracked and attempted to collate what has often been referred to as "symbiotic fabrication" technologies. However, the phenomenon has many different regional nomenclatures (Khan & Shah, 2127).

Decades later, the "people of the forest" still occupy these sites and continue their conversation with the old growths. Their dedication to reciprocal regeneration

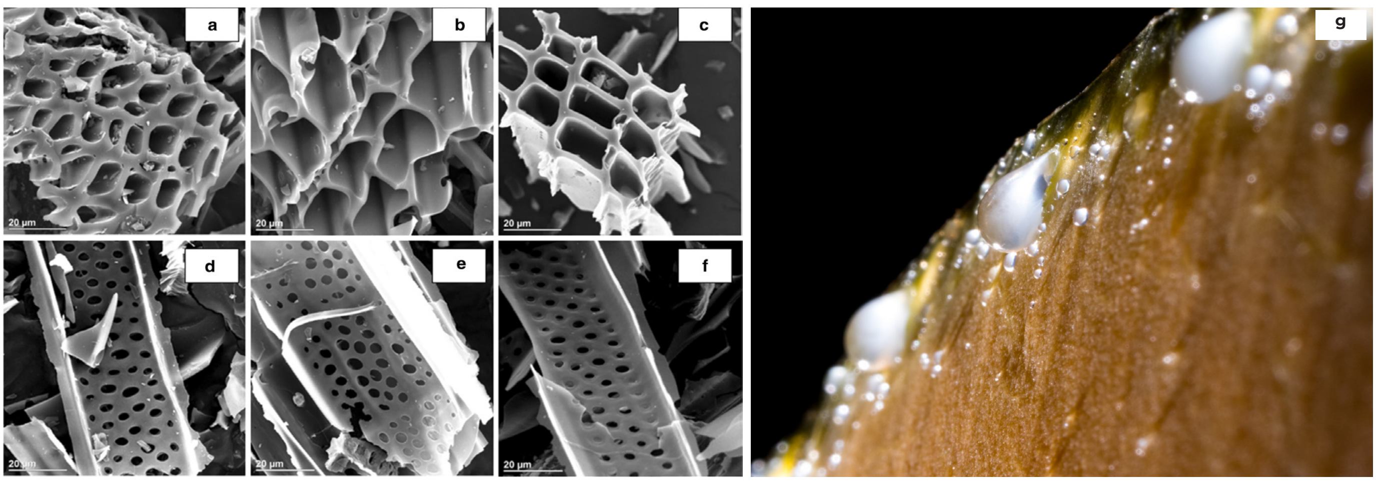

Figure 10 Well established methods of producing carbon nano-fibre from softwood (a, b, c) and hemp (d, e, f) using microwave pyrolysis. Image by (Wallace, Afzal, and Saha 2019). g) natural terpene resins found in tree veins have been further treated with green chemistry and atmospheric graphene producing advanced composites technologies on site that work with the sacred forest. Image by Ivan Radic.

has expanded to other CRZs. This collaboration created drastic shifts towards a reimagined socialized inquiry and redefined the purpose of open knowledge structures that opened scientific and technological pursuits to the larger society. In these regions, it is not uncommon for the local lore to attribute the phenomenon of symbiotic mutualism to a living forest that "heals" objects. Beyond epistemic nuances, these have created significant ripples in the social and cultural fabric as local populations today refer to these symfabs as "shrines," bringing their old and damaged artifacts or devices that needed restoring. Of course, it is all down to the collective creativity of these creative occupations to discover new ingenious ways to regenerate and sustain these new material cultures.

3. Discussion

It has been over a century since the release of the devastating biodiversity report confirming that the planet was entering into the 6th Mass Extinction (Díaz et al., 2019). The planetary ecosystems remain in precarious health as we tumble along an unknown path as the Hothouse earth. However, the state of the CO_2 concentrations in the atmosphere offers a somewhat optimistic yet cautionary tale. Early in the 2020s, CO_2 concentrations had reached 420ppm, way beyond the safe operating limits that could sustain human civilization, and predicted to cross 500ppm by 2100. This figure was reached in the summer of 2063 far faster than ever thought possible, just as the CRZs projects were picking up pace. The focus on CRZs attracted criticism that the soil carbon alone could not compensate for the fossil carbon in the atmosphere (Carrington, 2021). Today perhaps it is thanks to these integrated cultural ecosystem shifts that the CO_2 has dropped to 350-360ppm according to the latest measurements (Figure 11). However, whether human civilization can redeem itself for a long recovery remains an unresolved question.

However, we may do well to acknowledge and come to terms with cautious tales of recovery. Today, with rewilding of habitats in these protected biodiversity regions, the pan-indigenous preservation zones are the largest ever terrestrial ecological corridor wraps around the world connecting the CRZ habitats and are continually expanding to this day. Gaining a sense of the scale of these regions is still limited given the very limited geospatial surveys available (Balan et al., 2126). Perhaps only time will tell if the terrestrial biodiversity and ecosystem services will fully recover. Over the past century, many vulnerable species and ecosystems have found temporary refuge in these Climate Resilience Zones (CRZs). Although, these sites of ecological regeneration are no longer separate from zones of human habitation today. Many of these flourishing new-old growth sites have become sacred across many cultures and given the right of personhood. Sustained through generations of collaborations between indigenous peoples and local communities, the communities have shown form earth-bound indigenous relations to the land. Further studies are needed to confirm whether the biosphere regeneration amidst the 6th Mass Extinction has been worth the efforts to revive some of the planet's damaged ecosystems are still underway.

The revival and rewilding of dense old-growth forests have created geological forces that drive critical precipitation shifts to rainfall patterns in other parts of the world. Today's observations confirm what was once only marginal (Popkin, 2018), and very little was understood before (Garcia et al., 2016; Kooperman et al., 2018). These new geological gestalts allow for an even more drastic revival of ecosystems. While it is

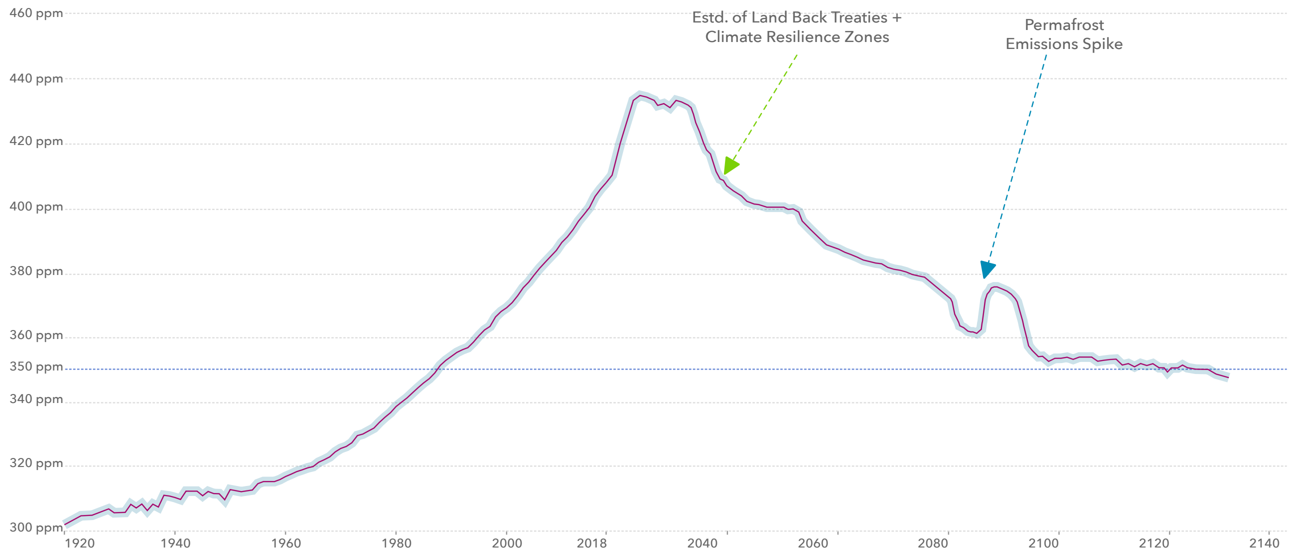

Figure 11 The rise, offseting and clamping down of Atmospheric CO_2 over two centuries. Image by (Richardson et al., 2129)

early to say whether some of the lost species due to habitat loss will ever return, it is noticeable that the forest ecosystems have responded to civilizational changes and are returning in places along with the biodiversity that seemed to be in line with observations. These climate-resilient belts have become open pastoral spaces for livestock once liberated from old factory slaughterhouses. Many of these regions have developed their colloquial material cultures, where different rainbow occupations of the CRZs continue to develop their methods and technologies. At the same time, the forest flourishes alongside them in their care.

However, we think that perhaps this very crucial shift in the zeitgeist ought to be celebrated. The common realization that human civilization's social and ecological well-being is directly compatible with ecological abundance can be attributed in no small measure to the CRZs. The CRZs demonstrate that it can be achieved even in a highly technological culture through the indigenization of worldviews, revealing other forms of knowing and being that have made the difference (Lakota, 2125). This tacit indigenization of knowledge-making and social enactment of regeneration efforts have seeped deep into regional perspectives. Open knowledge frameworks have only further accelerated this transformation of the material and ontological realities of the communities themselves. Societies were self-consciously re-designing associations and civilizational arrangements (Goldman, 2064). It was not surprising then that these sites became fertile ground for the emergence of 'symbiotic fabrication' processes as they did (Qiao & Sakharov, 2093).

It was not until recently, after decades of successful restoration of new forest ecosystems, that we now know why they have proved more resilient to climatic shifts and heat deaths and shared similar characteristics to old-growth ecosystems from the ancient world (Cech & Tarkovsky, 2108). The development of many scientific and technological breakthroughs discovered in this period was made possible substantially through these channels and what later became institutions of care (Lakota, 2125). These transformations were occurring noticeably mainly due to the role of the caring classes that had historically been marginalized from research and academic pursuits and were participating as equals (Goldman, 2064; Mirza, 2067). The legacy of the CRZs today cannot be separated from these contexts, which might be better understood as nucleation sites for the re-emergence of symbiotic ecological and cultural regeneration not seen before.

Therefore, despite hothouse earth, human civilization has rejuvenated the rural ecology, eventually easing the pressure off the stressed urban ecosystem. The latest observations confirm that these ecosystem-based cultures fulfill the essential material basis for human social satisfiers and free people to pursue a life of leisure and other creative endeavors (Devassy & Cole, 2130). Perhaps this needs to be understood in the context of the transformations reconstructed in this chapter. Amidst the complex historical tensions, a more habitable world was realized—a world that we continue to make and remake. The material and social well-being indicators have improved in real terms compared to the measures of social progress. This even though biodiversity and ecosystem services have been steadily recovering together with the civilizational footprint of human society drastically contracting in the same period. Much like our ancestors, there is no reason to believe this is our participation's end.

Societies in the 22nd century have tended to shift substantially on major social indicators on average, yet it has also done so within a technologically liberated culture. These shifts have meant a closed-loop industrial fabrication and consumption of high-quality material goods under a stewardship model with 'terrestrial' forms of knowledge-making and symbiotically mutual forms of making. It must be pointed out, however, that despite all the positive developments, caution yet must be maintained moving forward as the gains made possible by these strategies were only possible by reimagining reparations for ecological and social justice. We are of the position that if ever human social systems revert to the dehumanizing logic of domination and exploitation, this progress that we see today might be lost, and all will be to naught. Thus, we call for vigilance to ensure that the hard-fought social freedoms we enjoy today are sustained across generations, far beyond the Hothouse earth.

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Stewardship of Everyday Life

Illustration by Sephin Alexander

"We were constantly told about 'securing seats at the tables', but the tables were made from the bones of our ancestors and painted with the blood of the enslaved, and at some point, we got exhausted talking of chairs and started breaking tables instead."

— Aruká Juma & Anahira Watene in *Defend the Land and Water: The Struggle for Indigenous Sovereigneity and Autonomy (2041)*

3. Beyond Vaporware: Remembering the Blue Reparations Programs

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Introduction

For about 3.5 billion years, surface water on planet Earth nurtured the primordial conditions from which all known and unknown life has emerged. Within these geological frames, the human experiment emerged from countless accidental evolutionary bifurcations from which the entirety of civilization sprang. This blue planet has witnessed the passing of countless epochs even if suspended in a state of geological timelessness. Until recently, our popular notions of grand historicities assumed that what we civilization was an inevitable feature building on the timeless and the permanent, rather than a set of arrangements that were in a state of permanent fragility, requiring constant care, to say nothing of symbiosis. Arriving now at the 22nd-century hothouse climate, one finds the fingerprints of a human civilization strewn across the planetary hydrological systems. By mid 21st century, having already absorbed much of the energy from anthropogenic fossil emissions, the global ocean systems were poised to breach several climate tipping points and, in doing so, threatened the circulatory mechanisms of the planetary hydrosphere.

This chapter discusses the legacy of the global Blue Reparations coalitions and climate justice movements of the 21st century, the actions of which radically transformed and reshaped the socio-political constructs of the 22nd-century climate resilience. The Blue Reparations programs were set within the larger contextual view and other programs as interventions to defend, revive and regenerate the freshwater, glacial and marine ecosystems in dire states. Our discussions will explore this through certain technological archetypes, which were almost entirely indigenously developed, locally produced, and based on the most advanced open scientific knowledge available at the time. These include the “biomineralizers” bioremediating rare-earth minerals used in the Indo-Gangetic plains, the highly controversial “rainmaker” devices harvesting atmospheric rivers, and constructing artificial glaciers, to the electrified composite ‘black-coral’ reefs in the Sundarbans rehabilitating coral sea barriers. The account some of these strategies and artifacts from the Blue Reparations programs offer is a mixed bag of lessons to be learned. The cryosphere ecosystems have recovered the slowest, with efforts yet to bear long-term results.

Keywords:

Climate Change
Water
Reparations
Coral Restoration
Glaciers
Coral reefs
Cryosphere

While many communities have adopted new socio-technological practices and developed material cultures based on regenerating freshwater and many marine ecosystems, it is still premature to claim that the Blue Reparations strategies have succeeded. The reparations trajectories remain incomplete; many ecosystems are yet to recover and may never recover. In this incompleteness, however, we may yet secure the possibilities for those who come after us.

1. Life on a Blue Planet: From Sustained Abundance to Abrupt Dissonance

Historically, human societies have maintained a kinship with the water in all its phase states. Water has always been inseparable from what makes us instinctively human, constantly reminding us of our evolutionary connection with the planet. However, in the last couple of centuries, perhaps even millennia, the biosphere saw an unusual deviation from these synergies. The planetary biosphere was debased into a resource to be consumed, perceived as a lifeless 'externality' for the civilizational experiment, now suitable for mass consumption. Humanity would seem to be willfully sterilizing this primordial soup of life. The economic extraction and industrial commodification of the planetary ecosystems were breaching the ecological capacities of the global freshwater, glacial and marine ecosystems worldwide. What follows here is an attempt at understanding for those of us still trying to piece together the convoluted temperament of this experiment in ecocide and the necessary pathways that moved to transform it.

The paleoclimate archives that survive today have helped us piece together a story spanning hundreds of thousands of years, thanks to spectral analysis of the isotopic composition of old ice core data. What is understood from the analysis is that during the last glacial period (120,000–11,000 years ago), more than 20 abrupt periods of warming, known as Dansgaard–Oeschger (D–O) events, were known to have occurred (Dansgaard, 1985). The only time in the previous 60,000 years that Greenland's temperature deviated more than 1oC each decade was during such D–O events. When understood in the span of human history, the last time such changes were observed was about 12500 years ago. The glacial maximum of the last 'ice age' gave way to a warmer planet from which human civilization emerged. Thus, while it seems that abrupt climate change was a common phenomenon in planetary timescales, human activity over the past century forced shifts in systems that cannot be qualitatively accounted for from ice core data alone.

What was becoming explicit was that global warming was breaching levels that could only be described as 'abrupt climate change,' a highly contested term that described the nonlinear response of climate systems caused by external forcing (Jansen et al., 2020). While abrupt changes had arisen from internal mechanisms of the ocean, atmosphere, and sea-ice systems in the absence of external forcing in the geological past, this abruptness was attributed to excess global fossil emissions and was noted as such (IPCC, 2028; Jansen et al., 2020). The transition of the climate system into a new "stable state" was happening on a time scale faster than any level of responsible forcing that could be achieved (Raabi et al., 2073). This characteristic phase shifting of the planet's various climate mechanisms ensured a stable equilibrium over vast civilizational timelines.

However, with abrupt shifts in the climate system, fundamental mechanisms of the hydrosphere and cryosphere were unraveling. Along with them, unraveled the stability of the Holocene era that made this rendition of human civilization possible. With the emergence of ecocide powered by fossil carbon emissions, however, this stability was no longer a given, upending and breaching thresholds of the underlying circulatory dynamics of the planetary hydrological systems.

1.1. Cryosphere Dynamics

The earliest signs of these abrupt shifts in global climate were becoming pronounced in the cryosphere as global warming trends dramatically accelerated polar ice melts and glacial extinction events in the early 21st century (Engel, 2019). Elemental water has an unusually high capacity for the latent heat of fusion and evaporation. Water needs to absorb high amounts of thermal energy before it can undergo phase shifts, more so if the phase shifts in question are occurring on geological scales, heating a body of water on the planet. With the emergence of global industrial civilization, about ninety percent of all fossil-fuel-based thermal energy was being pumped into the oceans relentlessly, disrupting the planet's thermal regulatory mechanisms (Figure 1). The excess thermal energy absorbed in the oceans was melting the cryosphere, which until then had cushioned the impact of global heating but was quickly disintegrating.

Conservative estimates at the time calculated the average magnitude of this thermal energy absorbed by the oceans to be about one nuclear bomb every second since the 19th century (Carrington, 2019a). However, this was an average estimate across 150 years; at the turn of the last century, the estimate was closer to about eight atomic bombs per second, revealing the rather exponential growth of the planetary heat engine at work (Figure 1). At these scales, unforeseen planetary tipping points and abrupt shifts revealed how fragile these seemingly stable states were. By the early 21st century, this excess energy was also saturating the ocean depths, reaching tipping points at which the entire body of water on the planet itself was rapidly warming up the planet in turn (Cheng et al., 2020).

Early scholarship forwarned that the yearly extent of ice and snow was dramatically decreasing, especially in the Northern Hemisphere (Fountain, 2020; Gilbert & Kittel, 2021; Mallett et al., 2021). The staggering melting rates of polar ice caps caused an unprecedented and extensive reduction in volumes, variations, and extents of ice and snow cover, further sabotaging their critical role within the climate system. The devastation of the planetary poles was a critical tipping point that could disrupt the planetary circulation of heat, nutrients, and sediments (Mallett et al., 2021). With their large areas but relatively small volumes, their interactions and feedback at global scales, including solar reflectivity and ocean thermal management systems, were at risk. Warmer oceans drastically destabilized the ice formation patterns at the poles

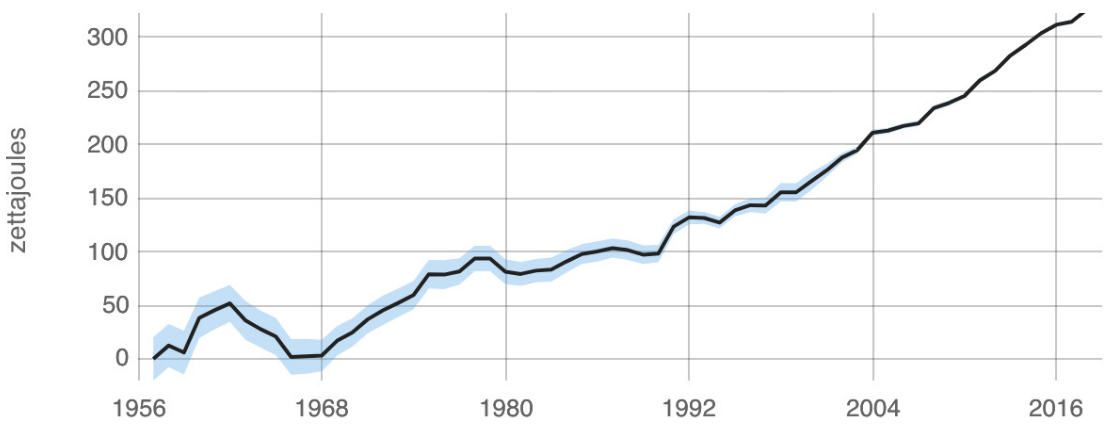


Figure 1 Data from 2020 showing extreme acceleration in absorbed global ocean heat content being absorbed in the ocean body. Image by NOAA/NCEI World Ocean Database (2021)

early 21st century (Figure 2 a,b). The two-continental ice sheets of Antarctica and Greenland with the high-altitude mountain glacier ecosystems around the world influenced global climate systems over geological scales, from millennia to millions of years.

By the beginning of the 20th century, the unthinkable Arctic 'ice-free summers' were becoming possible. With insufficient snow to reflect solar radiation, albedo effects further threatened to accelerate irreversible warming of the oceans into tipping points (Wadhams, 2017). On the southern poles, the Antarctic ice shelves suffered cleaving events as increasing glacial runoffs increased their vulnerability to "hydrofracturing," a process whereby ice shelves crack and disintegrate. Furthermore, a hotter planet meant the arctic ice-sheet regeneration rates could not keep up with melt rates spelling a spiral into collapse (Gilbert & Kittel, 2021).

Permafrost, once perennially frozen, was another casualty of this sustained warming noticed in the Northern high latitudes. Permafrost has been one of the cryosphere components most sensitive to warming, influencing soil water content and vegetation over continental-scale northern regions. Its degradation and melting were slowly exposing once frozen organic material in the soils and expected to release greenhouse gases into the atmosphere and increase the rate of global warming (Watts, 2020). The estimates of carbon emissions from this gradual permafrost thaw alone ranged from approximately 22 Gt to 432 Gt of CO_2 under a reduced emissions scenario which did not account for abrupt thaw and wildfire (Natali et al., 2021). In the context of the time, under a moderate emission scenario, carbon emissions from soil and permafrost were expected to increase 30% by the end of the century when accounting for wildfire compared to emissions from warming alone. Abrupt thawing events increased carbon emissions by 40% if fossil fuel emissions were not reduced (Natali et al., 2021). Fortunately, combining cold wave dynamics, drastic measures abolishing fossil emissions, and human interventions with artificial glaciers prevented abrupt thawing events. The emissions projections underestimated the social transformations clamping anthropogenic emissions budgets long term (Tosh & Varkey, 2110).

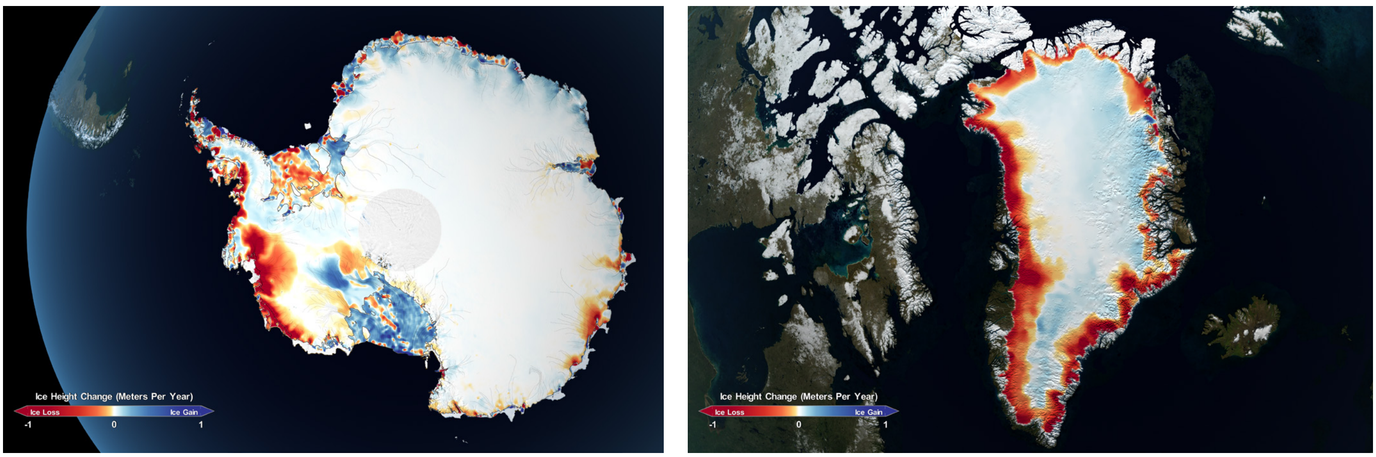


Figure 2 a) Changes in Antarctic land ice thickness as measured by the ICESat (2003-2009) and ICESat-2 (2018-) satellites. b) Changes in Greenland land ice thickness as measured by the ICESat (2003-2009) and ICESat-2 (2018-) satellites. Images by NASA's Scientific Visualization Studio Archives (2020)

As we discuss later in the following pages, even a century later, global attempts to mitigate and reduce the susceptibility of ice shelves to collapse with artificial glaciers have proven harder than previously thought. Despite promising results, the struggle to contain the sea levels to nominal levels remains precarious. As the warming trends continued, ice cores that recorded the historical periods of abrupt change over millions, even billions of years, remain lost forever. However, even today, the cryosphere's health, or whatever remains of it, is still universally considered a critical indicator of the Earth's climate system, which has remained particularly sensitive to hothouse warming.

1.2. Hydrodynamics

To further understand the implications of these shifts that pushed the planet into unforeseen unstable states, one might understand the hydrodynamic systems that sustained the stable states. One of these systems was the Thermohaline Circulation (THC) under the ocean waters which acted as a heat circulation system for the planet, much like a 'heat pump' (Figure 3). This heat pump under the ocean waters circulated heat energy between the equator and the two poles, depending on a delicate interplay of heat and salinity. The disruption of this heat regulation system was endangering the planet's dynamic regulatory and hydrological circulatory systems. With excess thermal energy absorbed by the ocean body of water and unprecedented freshwater melts from the Greenland ice sheets (Resnick, 2017), the fragile balance between ocean temperature and salinity was unraveling (Steffen et al., 2018). These conditions

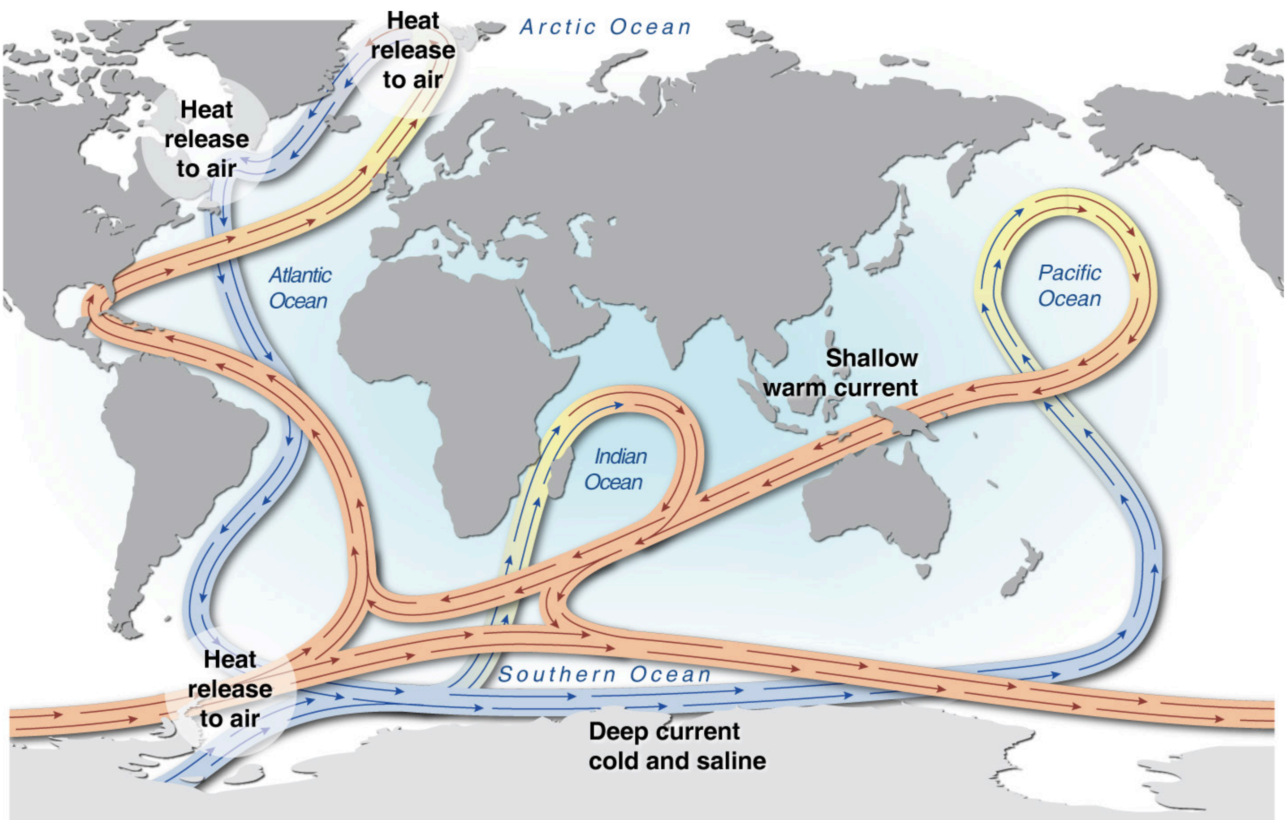


Figure 3 Thermohaline Circulation regulating global climate by releasing ocean heat to the atmosphere. Image by: Maphoto/Riccardo Pravettoni UNEP/GRID-Arendal, 2007

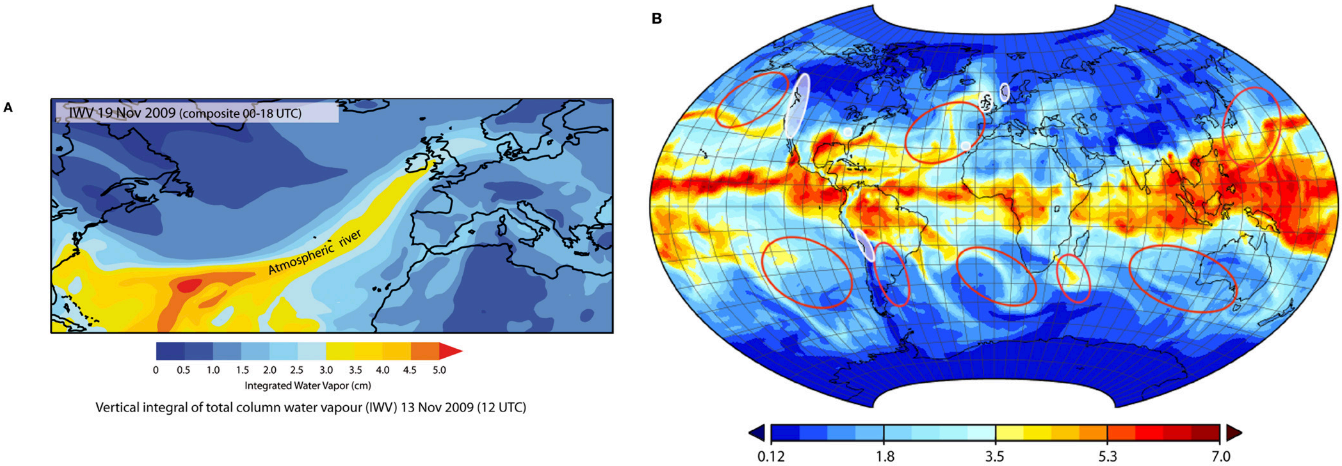


Figure 4a) An atmospheric river (AR) associated with extreme precipitation in 2009 that affected the United Kingdom (UK). b) Image shows a general distribution of areas of occurrence of ARs (red contours) White contours showed the continental areas where ARs linked with extreme precipitation and floods. Images by (Gimeno et al., 2014)

were unsuitable for a stable thermohaline circulation system, essential to maintain the planet's thermodynamic stability. Without the ocean's climate regulation function, it is impossible to maintain stable conditions for human civilization (Zanna et al., 2019).

Even as more of these hidden interactions between multiple tipping points began to be studied, warming trends continued at incomprehensible scales. Atmospheric systems saturated with fossil thermal energy and emissions threatened cloud formation procedures. Left unchecked, they could have disrupted the formation of stratocumulus clouds in specific regions and affected their ability to reflect solar radiation that helped cool the planet (Schneider et al., 2019). Had this tipping point been breached, Earth's temperature would have soared by 8 degrees Celsius, in addition to the 4 degrees of warming caused by the CO_2 directly (Schneider et al., 2019). Once broken up, these stratocumulus decks have only recently re-formed at the turn of the century if CO_2 concentrations dropped substantially below the levels at which the instability first occurred with an end to what was called the "business-as-usual" emissions scenario (Wolchover, 2019). Moreover, warmer oceans with higher surface evaporation rates ensured more moisture in the atmosphere, shifting global precipitation patterns unusually. Excess water vapor from warmer oceans and water bodies made its way to swell "atmospheric rivers" (Figure 4a, b).

These "rivers" in the upper tracts of the atmosphere were now carrying excess water vapor disrupted atmosphere dynamics, further intensifying hurricanes making landfall with far more energy than ever before as coastal storms and flash floods battered communities annually (Smith, 2018). The once-in-hundred-year climatic extremes such as storms and droughts became far more commonplace as global climate patterns created whole classes of people living precarious lives. With intensifying floods and droughts, the pressure on rain-fed food systems forced many regions into climate-fueled geopolitical conflicts. Abrupt climate changes in the geological past could be studied in how they influenced these profound hydrodynamic circulations, from deep oceanic thermohaline circulation to atmospheric rivers to stratocumulus cloud formations. The human-induced sabotage of these systems revealed the complex interactions responsible for the stability pre-industrial states took for granted until the mid-21st century.

1.3. Marine Biodiversity

With the oceans absorbing CO_2 emissions, drastic shifts to the fundamental chemistry of ocean waters on the planet were being reported—the pH of surface ocean waters in 2020 fell by 0.1pH, an unprecedented 30 percent increase in acidity on a logarithmic scale (NOAA, 2020). Perhaps nowhere else was the urgency of the crises more apparent and dramatic than the impact on marine life, which found itself in a profoundly alienating ecosystem. Once teeming with life, the marine ecosystems became a lifeless afterthought and a dead receptacle for human civilization's externalities (Xia, 2020). A century later, despite our best efforts, much of this acidity remains in "dead zones" in the ocean, where pH values are twice as acidic. In some of these zones, the only creatures still surviving are the cyanobacterium Prochlorococcus (Figure 5) which have been remarkably resilient to the rising acidity and heating.

The oceans are called the 'lungs' of the planet today because of the ecosystem services of species such as the cyanobacterium Prochlorococcus, responsible for 5% of global photosynthesis, sequestering carbon dioxide. It remains a planetary driver of evolution, having fueled the explosion of early life in the oceans, and has been responsible for much of the oxygen in the atmosphere we breathe (Pennisi, 2017). Even though their revival in ocean pastures as critical zones of biodiversity has kept marine biodiversity afloat, they have had to adapt and survive to a warmer, more acidified ocean and recover from the ecosystem destruction of the past. However, it was a different story with coral reef ecosystems that were more vulnerable to

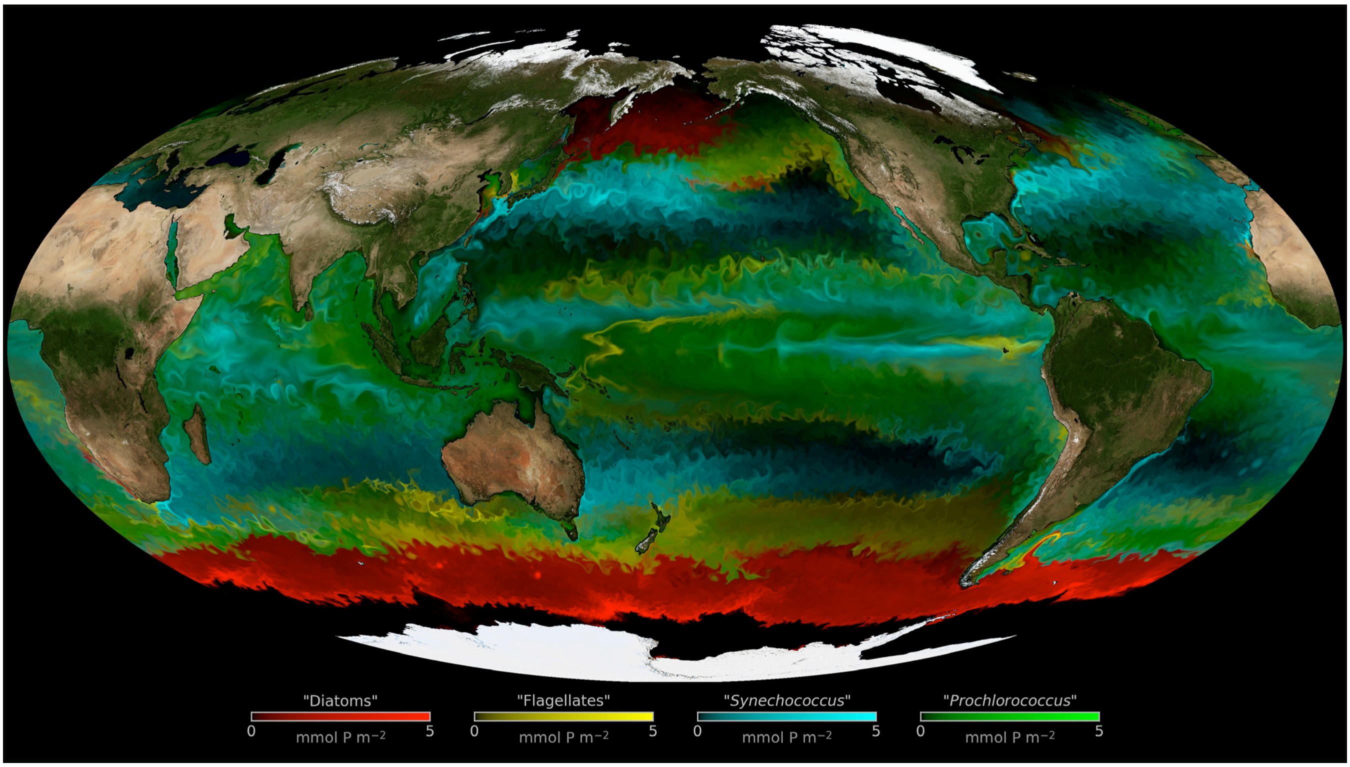


Figure 5 The sea's 'invisible pasture' depicts the most dominant types of phytoplankton in the world's oceans, with Prochlorococcus ruling much of the globe and bigger diatoms dominating nearer the poles. A multi-year model shows the distribution of 4 types of phytoplankton. Credit: MIT Darwin Project, ECCO2, MITgcm, Oliver Jahn (MIT), Chris Hill (MIT), Mick Follows (MIT), Stephanie Dutkiewicz (MIT), Dimitris Menemenlis (JPL), 2015

climate change-induced ocean acidification and warming. Given the escalating intensification of these parameters, corals were suffering major "bleaching events" in the late 20th and early 21st century as they continued to be decimated by climate feedback aggravated by human actions. Corals dramatically suffered heat deaths due to the severed symbiotic relationship between the algae and coral polyps and were nearly lost but revived through drastic intervention. The changes in the oceans were too overwhelming for corals to adapt, putting undue and dramatic stressors on the physiology of corals and other calcifying algal species. These species showed little to no evidence that acclimatization to these new acidic states would be possible in response. The abrupt acidification disrupted their calcification mechanisms by which calcium carbonate structures could be formed (Comeau et al., 2019; Cornwall et al., 2021; Kyriaku et al., 2089).

Accelerating coral declines brought to attention the devastating condition of marine biota cornered by heat deaths, exacerbated by other drivers such as habitat destruction from industrial sea floor trawling and overfishing. Thus, these weakened

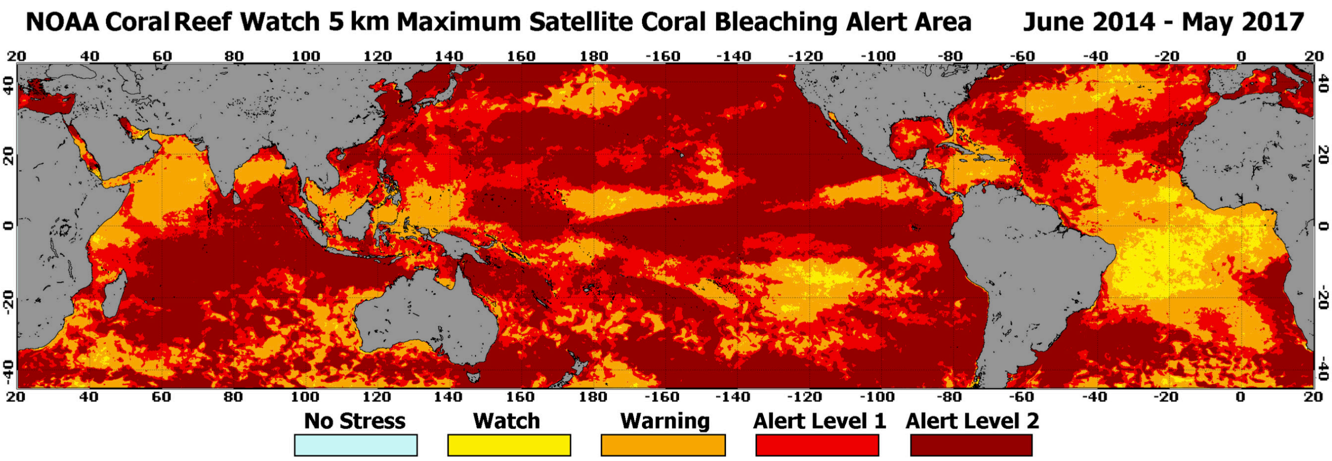


Figure 6 Above: A Bleached Coral. Image by XL Catlin Seaview Survey. Below, NOAA Coral Reef Watch's satellite Coral Bleaching Alert Area below showing the maximum heat stress during the Third Global Coral Bleaching Event from June 1, 2014, to May 31, 2017. Alert Level 2 heat stress indicated widespread coral bleaching and significant mortality while Alert Level 1 heat stress indicated significant coral bleaching. More than 70% of coral reefs around the world experienced heat stress causing bleaching and/or mortality during the three-year long global event. Image by NOAA Coral Reef Watch, 2017

reef ecosystems that had preserved marine biodiversity had declined to about one-fifth of their former cover with 1.5°C of warming. These ecosystems seemed well on their way to extinction with high coral mortality rates in massive bleaching episodes (Figure 6). Since the 1870s, more than two-thirds of the living coral on reefs were lost, accelerated by losses due to climate breakdown, while inaction further reinforced other climate tipping points (Díaz et al., 2019). As we discuss in later sections, their rehabilitation would require monumental shifts in human efforts through dedicated community restoration efforts to rejuvenate and revive these calcifying processes.

The predicament of coral reefs led to the decline of other fragile marine ecosystems illustrating in no subtle terms the onset of the sixth mass extinction. These extraordinary declines in the availability of bottom-living fish and a profound reorganization of seabed ecosystems accelerated with the nineteenth-century industrialization of fishing. For example, in one century, whaling killed about 2 million baleen whales taking with them the iron-rich manure, fertilizing otherwise impoverished waters, and creating the feedback loops of the rich food webs that the fisheries exploited. When the whale populations were hunted, the richly biodiverse ecosystems that depended on them collapsed, turning them into marine deserts (Yong, 2021). Industrial fishing thus became notorious for destroying marine biodiversity over the 20th and 21st centuries with their capacities accelerated using fossil fuel infrastructures, as mechanization and efficiency gains created larger capacities for industrialized expansion, enabling unfettered economic exploitation of ocean life (York, 2017). The now obsolete practice of 'Bottom Trawling' was responsible for more emissions than air travel at the time, releasing unprecedented amounts of 1 gigaton of CO_2 a year (Sala et al., 2021). These were also the least cost-effective fishing methods and would not have been profitable without economic subsidies. By the early 21st century, about half of fish stocks were classified as overexploited, and more than half of the ocean areas were subject to industrial fishing. Industrial fishing for global exports reduced global fish catches despite expanding geographically and penetrating deeper waters (Díaz et al., 2019). Fisheries were sweeping up crumbs from what used to be flourishing breadbaskets for coastal communities.

Consequent biodiversity reports signaled that many declining fish populations were moving poleward due to ocean warming leading to drastic local species extinctions in the tropics, further stressing local ecosystems and food security in these regions (Díaz et al., 2019). However, it was noted that this migration did not increase biodiversity in the polar seas as of the rapid decline in sea ice and ice-free arctic summers along with the enhanced ocean acidification of cold waters. With coastal waters having the highest levels of metals and persistent organic pollutants from industrial discharge and agricultural run-off, severe effects from excess nutrient concentrations in specific locations deteriorated fish and seabed biota (Díaz et al., 2019).

These very ecosystems provided sanctuary for corals to survive bleaching events (Greenwood, 2015) and sustained the fisheries providing for the coastal communities (Sato et al., 2005). These same mangrove-coral ecosystems had acted as sea barriers protecting from intense hurricanes in the region by absorbing the energy and from the subsequent storm surges and sea-level rise (Blankespoor et al., 2017). However, the losses and deterioration of these coastal marine ecosystems drastically reduced their ability to protect shorelines and the people and species that lived there from storms and hurricanes and their ability to provide sustainable livelihoods (Díaz et al., 2019). Just as the ever-increasing proportion of marine fish stocks and 'economically important species became overfished, marine ecosystem services worldwide were drastically declining in other ways (Figure 7). Coastal cities around the world were being devastated at an alarming rate by sea use changes such as coastal development, offshore aquaculture, mariculture, and bottom trawling and land-use changes such as onshore land clearance and urban sprawl along coastlines along with pollution of rivers and pollution from terrestrial sources upstream (Díaz et al., 2019). In the name of urban coastline development, the stripping of ecological shoreline protection made these shores more vulnerable to climate change aggravated hurricanes and storm surges.

With sea levels rising, coastal areas once protected by these natural coastal protections were consistently paved over and replaced with expensive technical infrastructures. These infrastructures incurred high future costs and still failed to provide synergistic benefits such as nursery habitats for edible fish or recreational opportunities that natural methods against storm surges (Díaz et al., 2019). The wilful decimation of coastal habitats further eroded their ecosystem services just as hurricane seasons intensified and battered sensitive coastlines year after year. The intensified hurricane seasons further threatened estuaries and deltas, habitats that were essential for marine biota and regional economies to flourish (Díaz et al., 2019; Penney, 2020). This

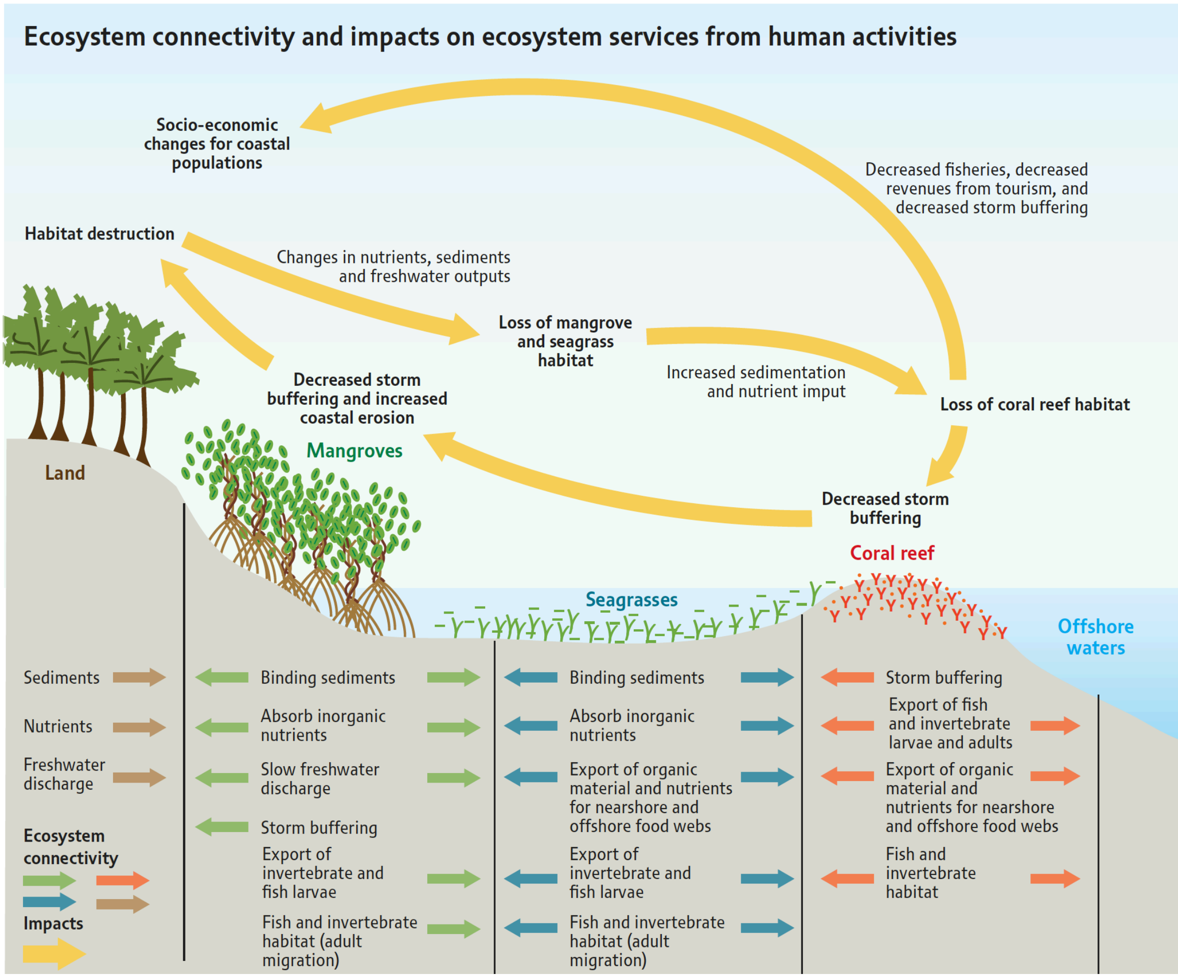


Figure 7 Diagram showing the ecosystem connectivity between mangroves, seagrasses, and coral reefs. Ecological and physical connectivity between ecosystems is depicted for each ecosystem: terrestrial (brown arrows), mangroves (green arrows), seagrasses (blue arrows), and coral reefs (red arrows). Potential feedbacks across ecosystems from the impacts of different human activities on ecosystem services are also shown (yellow arrows). Illustrated from (Silvestri & Kershaw, 2010)

persistent forcing of the planet towards the present-day volatile states created highly precarious conditions for most life on Earth (Raabi et al., 2073; Steffen et al., 2018). In that period, there were no indicators in the scientific literature that these rapidly intensifying evolutionary pressures would lead to the developing of new evolutionary traits that might help organisms adapt adequately. One must remember that these ecosystems had rarely experienced such existential stressors that were not extinction events. The past century saw their ecosystem integrity overwhelmed and fumbling to sustain and nurture life itself, let alone the measures of the ecosystem services they could provide human societies.

1.4. Of Freshwater Entanglements and True Human Costs

The fate of the oceans remained intertwined with the freshwater ecosystems and the terrestrial ecosystems that were overburdened. While these atmospheric rivers diverted moisture and further energized more powerful hurricanes and storms, atmospheric circulation, such as jet stream patterns, too, were being disrupted (Masters, 2019). Much of the global food supplies at the time were dependent on more than half of the world's freshwater aquifers were threatened, which depended on the stability of global precipitation patterns. Climate breakdown ensured further declines and disrupted precipitation patterns, causing extreme heatwaves and drought, and extreme floods with lasting consequences for a "just-in-time" system of globalized food production and distribution system which lacked the resilience to adapt to these precarious conditions (Min & Devi, 2052).

The Hindu-Kush region best encapsulates how the human scale was entangled and enmeshed in the crises the Blue Reparations project meant to address (UNCAC, 2044). By the mid-century, the Himalayan glaciers were facing an accelerated melting of their cryosphere triggered by unprecedented heatwaves that annually engulfed the region, severely affecting glacial melts that provided fresh water to billions of people downstream. With the shrinking of the Himalayan glaciers, the groundwater and lakes were quickly drying up. The Indian Monsoons that once replenished them started to deviate (Steffen et al., 2018). With the Hindu-Kush Himalayas experiencing a drastic retreat of mountain glaciers (Figure 8a), billions of people were feeling parched for

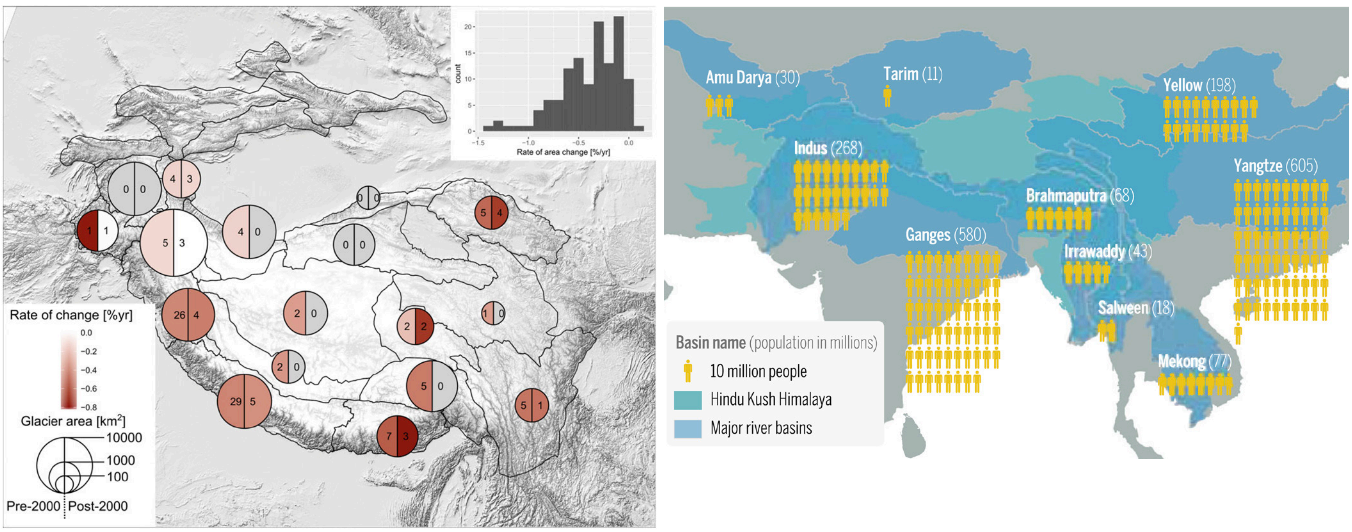


Figure 8a Loss of glacier cover in the Hindu Kush Himalayas. Image by Bolch et al., (2019). b) The human impact of basins fed from Hindu-Kush glaciers. Image by Scott et al., (2019)

water in a region historically referred to as “the third pole” or “Asia’s water tower” (Figure 8b). Climate-sensitive variations of glacial melts and precipitation flow from shifting Indian Monsoon patterns were disrupting the flow of the rivers Indus, Ganga, and the Brahmaputra. The accelerating rates of retreat of Himalayan glaciers directly threatened the sustenance of billions of people both upstream and downstream in one of the most fertile biodiverse regions in the world (Bolch et al., 2019).

These once water-rich regions were the food basket for the world and home to some of the most pristine biodiversity sites on the planet. The Himalayan glacial melts exposed the global dimensions of the crisis. They exacted an unquantifiable human cost, paid for by those least responsible, the most vulnerable populations living in an unjust social order (Carleton, 2017). The resistance movements to these developments had forewarned of what these infrastructures stood for and that they would lead to the unraveling of these delicate freshwater ecosystems would at the expense of the health, sustenance, and amenities of local communities (Gadgil & Guha, 1994; Juma & Watene, 2041). The ecological struggles in the region serve as a reminder to those of us trying to understand the contentious false binaries of preserving ecology or pursuing progress. Often, these once sacred ecosystems were dammed for electricity, exploited for irrigation for industrial farming, or industrial effluents through colonial and neo-colonial arrangements. The residual wastes of toxic metals and effluents had leeched far and wide.

Under the old guard, extractive industrialization tuned for growth for its own sake became confused with intentions of development and as a measure of progress. In that narrative, the complexities of freshwater ecosystems got swept up in a near enthusiastic fervor for development. However, like many other ecosystems at the time, the narrative implied the reduction and commodification of these living ecosystems as mere resources. One of the great myths back then was that water was a scarce commodity like any other and had a price for access. Under this logic, it was a self-fulfilling prophecy. By the early century, one-fifth of freshwater globally was utilized for rapid urbanization and expansion of industrial capacities worldwide. With ‘progress’ and ‘development’ synonymous with industrialization, one-fifth of freshwater globally was being utilized in rapid urbanization and expanding industrial capacities across the world. Under this program, it was a self-fulfilling prophecy. Encroachment of the urban fabric onto freshwater capacity proved itself a short-run experiment as urban spaces faced groundwater shortages from overexploitation (Wheeling, 2019). So, it came to pass that the onset of climate breakdown drastically altered seasonal flow volumes, reducing glacial run-offs and decreased flows in sub-basins along with declining pre-monsoon flows posed significant threats to irrigation, hydropower, and ecosystem services.

It may have been possible that these ecosystem services provided by nature could be replaced. For example, high-quality drinking water could be sourced from artificial wetland ecosystems that filter pollutants or through human-engineered water treatment facilities. However, the natural ecosystems were being decimated far faster that might never be replaced (Díaz et al., 2019). The Hindu-Kush region gives us a glimpse into the high rates of decline state of most of the planet’s inland waters, wetland, and freshwater ecosystems at the time. Curiously enough, the same precipitation dynamics that fed river and lake ice, along with glaciers and ice caps with their smaller areas and volumes, reacted relatively quickly to climate effects, influencing ecosystems and human activities on a local scale (Díaz et al., 2019). The ecosystem services in the regions were also revealing previously unaccounted emissions from underwater microbial decay of organic matter in ponds and lake ecosystems spread across the world (Boycott-Owen, 2019; Kraemer et al., 2021).

By the 21st century, many of the world's fragile pond, river, and lake ecosystems wore the scars of such developments, at times even literally decaying under the burden of their weight. Dam infrastructures had aged to the point of disrepair. With more frequent climate emergencies, these dilapidated infrastructures were an ecological disaster waiting to happen (Pearce, 2021). These infrastructures promised to secure water sovereignty, and energy security with hydropower were doing more harm in the long run. They were altering habitats for all freshwater organisms, blocking fish migrations, causing continued habitat fragmentation and degradation, and requiring ever-larger infrastructural requirements to stay functional. Barely half of all rivers longer than a thousand kilometers remained free-flowing over their entire length, often only in remote regions that were quickly encroached (Pearce, 2021).

Furthermore, despite promises of progress and efficiency, over 80 percent of global wastewater was discharged into the environment without treatment. With 300–400 million tons of heavy metals, solvents, toxic sludge, and other wastes from industrial facilities dumped into the world's waters each year. Excessive application of agricultural fertilizers meant that run-off toxins from fields and farms entered freshwater and coastal ecosystems, producing hypoxic zones decimating marine life (Díaz et al., 2019). The precarious global shifts in the hydrological cycles threatened essential water, irrigation, and sanitation infrastructures, making societies more vulnerable, and aggravating existing social frailties, tensions, violence, and conflict. After all, water security had implied the capacity of populations to safeguard sustainable access to adequate quantities of potable water for adapting to higher climatic and hydrological variability. Given the critical nature of the urgency, societies needed to work towards successfully stimulating transboundary water security and regional cooperation. Nevertheless, in this climate, geospatial political structures themselves were undergoing crises.

1.5 The Crises of Imagination: No Way Forward, No Way Back and No Way Out

What was being enacted upon the planet's life-giving hydrosphere was but a reflection of the crises in human society. In this period, social relations became commodified, and pursuits for accumulation reached the physical limits of the biosphere. A profound alienation had set in at the heart of the larger social body, and human civilization was beginning to cannibalize itself (Forbes, 2010). From what we can gather, this profound alienation was rarely recognized for its profound consequence. It might as well have been hiding in plain sight, given how deeply normalized it had been. Its consequences were for all to see, paralyzing the social imagination, which sought total annihilation for human and non-human others. This disposition sometimes took the form of disintegrating social discourse, regression in social mobility, and, more fundamentally, even collapse of social institutions of care (Sarnai & Solongo, 2118). The phrase 'climate apartheid' came to be applied to define this era where such contortions further exacerbated socioeconomic inequities even when confronted with a collapsing biosphere (Carrington, 2019b)—humanity was at war with itself.

Societies now disillusioned could not see themselves as participants in the process of civilization or rather did not see it as a civilization worth saving (Ponkh, 2031; Zerrano, 2036). Many violent nationalistic movements emerged during this time, further eroding social contracts and continued to breach ecological limits along with them.

This early period undermined the rights to life, water, food, housing, democracy, and the rule of law for billions of people. These fossil-powered geopolitical regimes at the time systematically undermined democratic foundations and denied basic social contracts in the face of an accelerating climate and ecological crises under scrupulous ventures (ICC, 2039). It had seemed that the world was merely held together by mass hallucinations and the threat of violence (Tlouse & Wakkari, 2130). Later scholarship revealed these to be the reactions to obfuscate the fact that the global economy was already bursting at the seams, reaching planetary limits of capital accumulation—the declining rate of profits, limited new frontiers for growth, and exhaustion of the existing ecological commons (Alex & Mehrawi, 2080; Anh, 2028).

Interestingly, bereft of better imaginations, many of these mechanisms were recreating the same patterns responsible for the crises in the first place. Even as climate scientists the world over raised alarms over the arctic melt (Jansen et al., 2020; Wadhams, 2017), fossil fuel economies instead saw the Arctic and Antarctic melts as an opportunity to extract new oil resources in previously inaccessible oil fields under the ice (Crowley & Rathi, 2020; Dunn, 2019). This pursuit of new oil and gas exploitation in the Arctic was illegal under numerous sovereign constitutional statutes (ICC, 2039; Joselow, 2021; Sjåfjell & Halvorssen, 2016). Elsewhere, the race toward renewables had also kicked off a muted rush of deep-sea mining programs threatening the scouring of the rich biodiversity-laden ocean beds to extract rare earth metals in the form of polymetallic nodules (McCarthy, 2020). Economic regimes grew ever more desperate to find a stable source of planetary resources to stay afloat in declining climates attempting to resort to military aggressions over resources to secure the conditions for continuing the ecocidal global order as it existed (Ahmed, 2020).

Essentially, these social orders based on the economies of war with nature were also at war with themselves. Plastics, the hailed engineering materials derived from fossil crude, would cycle through the planetary system and return to humans as microplastics. The fast-moving consumption cycles of goods meant it was not long before much of the planet was swimming in discarded plastic (Samy, 2129). Once at sea, sunlight, wind, and wave action accelerated their decay into small particles: the microplastics (MPs) (A. Thompson, 2018). Their effects were seen in aquatic environments infiltrating terrestrial, freshwater, and ocean food webs, saturating all of the living ecosystems on the planet along the way (Barrett et al., 2020; Botterell et al., 2019; A. Thompson, 2018). These non-biodegradable materials were vectors for environmental pollutants, eventually circling back to be ingested by humans in food and water sources. Microplastics were accumulating in human tissues and organs such as the human placenta (Carrington, 2020; Ragusa et al., 2021) or even affecting human fertility with endocrine-disrupting chemicals (D'Angelo & Meccariello, 2021). What microplastic circulation did was detrimental to long-term animal and human health. The glaringly obvious lesson thus was that within the larger circulations of hydrological systems within finite planetary boundaries, every ecosystem was both upstream and downstream.

One may wonder if this valuable lesson could have been learned in a less cataclysmic way. Nevertheless, these issues exposed some contradictions and entanglements more than others. Human civilization was only as fragile or resilient as the human imagination, and by extension, its human and non-human nature allowed it to be. There was a sense that a different world might just have been possible. However, without foreseeable or actionable changes to the fundamentals of what was once called civilized life, the baselines for climate action kept shifting, and the world, it seemed, would rather be 'managed' into extinction (Tlouse & Wakkari, 2130). Perhaps it is no surprise today that much of the global economic system from the last century seems like an elaborate global ritual of climate denial. Either by total abolition or by the sixth mass extinction, the era of fossil extraction was to end.

2. Water is Life: Reparations Worthy of the Name

Considering the constantly shifting baselines for climate action, amplifying crises, and the legitimacy of global institutions collapsing, it was not long before climate insurrections globally began springing up. Despite facing brutal repression and genocide, the ancestral land and water defenders, and other indigenous Earth accomplices, were at the forefront. These frontlines of climate justice movements could no longer be subdued by force, inspiring new hope among the so-called 'margins,' winning back sovereignty and reclaiming ancestral lands again (Juma & Watene, 2041; UNCAC, 2043). Communities most affected by the crises were also beginning to wrestle democratic power back, coalescing around each other. Their actions forced these institutions to come to the table as equals in climate assemblies and citizen climate councils. The Global Climate Assemblies (GCAs) were among the many climate action coalition networks that were popping up spontaneously on the promise of new alternative democracies and consensus-building (Dirik & Chen, 2029).

This period termed a period of rekindling, marked the coming together of the global climate justice coalitions towards sustaining and regenerating the commons in a mutually respectful alliance with the indigenous cultures (Tlouse & Wakkari, 2130). Critical to these social transformations were the ancestral land and water defenders whose victories secured sovereign rights of nature (UNCAC, 2056) in trying to address these challenges facing the world given the challenge at hand (Wehi et al., 2021). With sovereign lands and waters returned to indigenous earth liberation movements, industrial economies pursued a more concerted effort at the time were instituting drastic degrowth measures (Tlouse & Wakkari, 2130). The Blue Reparations Project was thus formulated specifically by many such global climate councils for restoring and regenerating freshwater, marine, and glacial ecosystems (UNCAC, 2044). The Blue Reparations Project complemented the Climate Reparations program (CLIMAREP) with its holistic climate action policy frameworks and institutional transformations enabled by the foundations laid by autonomous coalitions of Indigenous Land and Water Defenders towards native sovereignty and bioremediation programs (UNCAC, 2043).

The global institutional structures were shifting, with economies winding down with planned degrowth and universal social services (Coote, 2021) established. Together with a greatly diminished workweek (Fabre, 2032), globally equitable Universal Living Income protocols were implemented. These were complemented further with simultaneous debt-jubilees that canceled wide-reaching financial debts (Hampton & Kuruvila, 2092). These mechanisms finally shifted global productive labor away from debt-servicing industries notorious for creating cyclical economic and climate turmoil. Soon enough, people from all walks of life saw remarkable improvements in quality of life, with an everyday life decoupled from one's economic worth. These steps dramatically eased some of the political tensions caused by extreme economic inequality that had seemed irreconcilable initially, relieving pressures on the working and marginalized caring classes (Lai, 2056; Mirza, 2067). These intersectional coalitions of abolition movements called for a "collective harmony" instead of war and weapons of mass destruction, abolition of global and local institutions of domination and oppression, abolition of the workweek, and alienating labor— building a "genuine freedom worthy of the name" (Hampton & Kuruvila, 2092). These climate coalitions prefigured the conditions for a 22nd-century civilization 'worthy of the name' to emerge as the renewal of social contracts and social guarantees were underway globally (Lai, 2056; Mirza, 2067).

It was eventually conceivable to live in a world decoupled from the material climate impact of economic systems without social collapse, which was pivotal for building momentum for climate action. This decoupling drastically reduced the civilizational pressures on the planetary ecosystems bringing about realigning socio-economic priorities which focused on radically improving quality of life measures for human societies and addressing essential social freedoms that had been eroded and unfulfilled under previous regimes.

2.1 Technological Commons and The Question of Open Technology

The sands of social and cultural momentum were shifting towards collective climate action. At the same time, ecological regeneration also opened questions of how to sustain and stay on course with these shifts for the long run. The question of technological development, however, remained a concern. What would be necessary for creating the technological breakthroughs for transitioning the essential technological infrastructures that were integrally fossil dependent until then? The technocratic techno-optimism of that era was characteristically rose-tinted, often uncritical of the extent to which technological stratagems could allow for climate mitigation heading into the 22nd century (Keyßer & Lenzen, 2021). Nevertheless, even if one is not a techno-optimist, it may be essential to develop an understanding of what changed to witness the technological developments over the past century.

The technological overdevelopment of the industrial era had not been accompanied by deep thinking about the social realities constantly changing with the climate and ecological crises. Until mid 21st century, a planned, high-tech industrialized economy was only possible with the direct and indirect support of imperial economies of war. These channels provided the grounding for much of the fundamental research that led to profound technological breakthroughs in industrial societies, mandated through inflated war budgets and co-opted into corporatized monopolies (Noble, 1977; Ubumwe, 2114). The access to commodify these discoveries was allowed as a direct decision of the national economic programs to create competitive monopolies for private agents of what was essentially publicly funded research, i.e., the commons. This dynamic formed the foundations for high-tech competitive war economies for the last two centuries.

Ultimately, these programs reinforced a race towards expanding capacities for extraction, accumulation, and redistribution of the social, ecological, and technological commons. However, this would lead to a glut of overproduction designed for affluent consumption across the globe (Noble, 1977; Thirumalai & Halden, 2087). Technological optimism also tended to present itself as bearing the weight of leading civilization out of the messy, problematic concerns plaguing humanity. It was a convenient picture to paint if one needed to be at the cutting edge of silver bullets. It is indisputable that there were profound leaps in technological breakthroughs in this period; however, the gains of these innovations for larger society were not creating abundance but detracted from it. This period saw a technological proliferation in society channeled through complex neo-colonial market mechanisms considered extraordinarily wasteful and inefficient, even for social redistribution (Chin, 2019; Thirumalai & Halden, 2087). When faced with climate and ecological collapse conditions, these high-tech 'economies of war' tended to seek out somewhat predictable patterns of "a war of all against all" to preserve a hegemonic order of domination and control (Ahmed, 2020; Thirumalai & Halden, 2087). There were not enough resources to bring global society technologically on par with everyone. Even if one disregards that silver bullet solutions may not necessarily be a good thing, one might argue that the purpose of such systems, beyond their claims, was never intended for mass emancipation in the first place. Climate reparations instead called for the creation and sustainment of long-term climate-resilient infrastructures focusing on the quality of life, powered by truly renewable energy transitions across the world (Doon, 2035; Rahman et al., 2096).

One of the ways to do so was to institute global technology transfer programs that would accelerate proliferation and knowledge transfer distributed for climate-resilient infrastructures. With the passing of the ecocide and reparations acts forced on by public climate assemblies and referendums on climate actions, renewable technologies opened up from closed and obsolete 'intellectual property' IP (Krets, 2048). These technologies were built on publicly funded research and could not be closed under private property as doing so would violate access to the commons and climate resilience. Technology transfer mechanisms were thus put in place to open industrial patents and technologies to the public domains (Krets, 2048). Open technology movements were free to use closed intellectual property (IP) for developing climate resilience infrastructure without legal repression.

Technology transfer programs also meant the distribution and capacity building of production technologies, training methods, and techniques to ensure the necessary proliferation of essential climate-resilient infrastructures globally. Climate reparations funds reserved conditions to incorporate a municipal level transition framework with cooperative community self-managed technology hubs that diffused key breakthrough technologies to communities. They were tasked to "exapt"—to reimagine the purpose of these fossil technologies to long-term sustainable functions. Numerous high-precision fabrication capacities skills from high-tech consumer technologies available at the time, such as the semiconductor, aerospace, and war industries, were also being exapted and repurposed to support new developments in essential climate infrastructures (Krets, 2048).

These would become key to capacity building for Universal Basic Services (Coote, 2021; Gough, 2019) through various means for redirecting resources from destructive economies of war (Fabre, 2032). Curiously enough, the trajectories of development these technologies took, driven by the creative movements now free to participate in regional citizen science chapters working with fundamental design and research academies given that a treasure trove of patents had become available for social needs (Chen, 2031; Ngata, 2076). It would lay the groundwork for critical infrastructures that emerged from the climate reparations projects and supported technological breakthroughs globally (Bhim & Larsson, 2124; Khan & Shah, 2127; Ngata, 2076). With growing institutional platform cooperatives of municipal fabrication workshops, citizen science movements and research institutions developed the fabrication and distribution channels for these essential climate infrastructures within localized community networks.

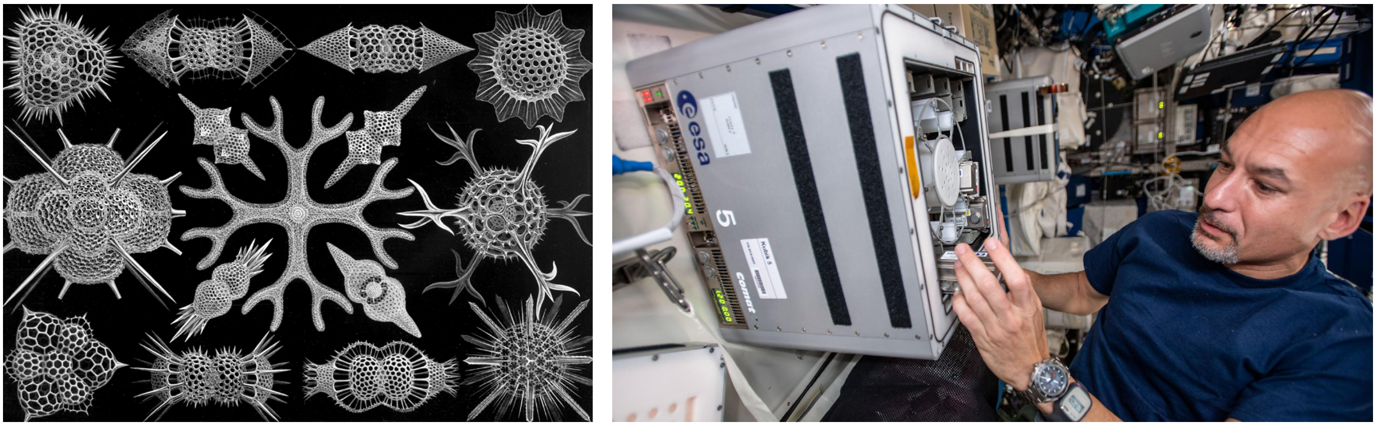
2.1.1 Bioremedial Fabrication Technologies: Biomineralisers

With the conceptual legal framework of IP and patents obsolete and practically abolished since the reparation acts (Bhim & Larsson, 2124), global industrial infrastructures could be directed and retooled towards climate-resilient infrastructure production, the developments of which compiled and opened the technological commons (Ngata, 2076). Cooperative agreements rather than legal conflicts shaped what was to follow. We discuss these in some of these open-tech movements which shaped the technological foundations of the 22nd century, where designers and technologists were no longer trying to design new market desires. Instead, this cross-pollination focused on creatively discovering new ways to build regenerative synergies between essential human needs, its material footprint, and ecological limits (Khan & Shah, 2127). Thanks to the transformation of the energy grids to municipal level energy production and distribution, and with industrial activities subdued, aging dam infrastructures could be dismantled, starting with those that posed existential risks to both river ecosystems and the human habitation that depended on them (Hernandez et al., 2062). These actions demonstrably reduced soil erosion, sedimentation, and pollution runoff in downstream freshwater and marine ecosystems, developing remarkable resilience to climate-induced shocks (Rahman et al., 2096).

The Climate Resilience Zones (CRZs) had already established momentum for a holistic, regenerative, agroecological approach to terrestrial ecosystem and biodiversity revival movements (Hernandez et al., 2062). The appropriate integration of climate-resilient infrastructures considerably improved sanitation systems. At the same time, flood control complemented age-old indigenous wetland management practices, helped reclaim marshes and urban fishponds, and revived surface and underground freshwater aquifers throughout urban-rural regions (Goldman, 2064; Hernandez et al., 2062). These actions proved pivotal in improving soil moisture dynamics in the CRZs and created managed water abundance in the drought-hit regions. Furthermore, they helped curb toxic nutrient runoffs from agriculture and replenished rivers and underground aquifers while simultaneously developing storm and flood control systems in other CRZs (Hernandez et al., 2062).

Considerations for the escalating climate emergencies in the water-stressed regions of the world prompted many voluntary citizen science chapters focused on contributing with technological capacity-building. These actions complemented the indigenous land and water defense plans, which carried out extensive water conservation and restoration of their once sacred rivers and lakes. In the Gangetic floodplains, many freshwater ecosystems had degenerated over centuries of industrial exploitation and leaching of toxic effluents (Rahman et al., 2096). These desecrated freshwater and marine ecosystems were remediated, relying on promising biological methods that degraded and captured target pollutants.

In due time it turned out to be an effective way to revive and clean up these habitats. It was far more effective and ecologically sound than other remediation alternatives. One such method was Biomining which was already a mature technology at the time. Biomining could be applied to ecologically extract metals from ores and other mineral sources without the need for ecocidal mining operations. The minerals were biologically mineralized or 'biomineralized' in an ecologically regenerative manner with the help of prokaryotes, fungi, or plants which could biologically leach minerals from their ores using natural means (Brisson et al., 2016; Qu et al., 2019; V. S. Thompson et al., 2018). Biomining and bioleaching could simultaneously recover these crucial metals and minerals with the help of microorganisms that also remediated the soil and water in the process. Biomineralization has always been a widespread phenomenon in nature, synthesizing minerals, silicates, diatoms, carbonates, and calcium phosphates in organisms often to form structural features (Figure 9a).



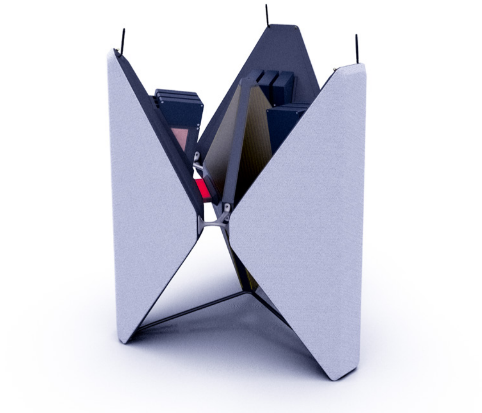
Figur 9a. An illustration of biomineralized opaline silica in the microfossils of polycystines of the subclass Spumellaria, Illustration by Ernst Haeckel in Kunstformen der Natur (Artforms of Nature), (1904). b) Astronaut Luca Parmitano places biomining reactors into a centrifuge onboard the International Space Station. Credit: NASA, 2020

The numerous bioremediation methods practiced in the CRZs strengthened collaborations between indigenous water defense and volunteer citizen science movements. Devices called "biomineralizers" (Figure 9b) used to be experimental prototypes of biomining experiments from space programs. Biomineralisers were essentially bioreactor technology that combined wastewater electrolysis with microbial biomining that was well understood (Contreras et al., 1981; Tartakovsky et al., 2011). However, it was moving out of labs and into the field, applying these electro-biochemical processes effectively to clean up nitrates, phosphates, and heavy metals from freshwater ecosystems (Anwar & Hoang, 2052). With open-technology transfers, these biomineralisers, released to the public domain, developed into biomining rigs at distributed scales, fabricated by the municipal fabrication coop-shops (Bhim & Larsson, 2124; Ngata, 2076).

The development of biomineralisers (Figure 10a) was a culmination of social energies applied natural methods within a burgeoning regenerative culture expressed in the technologies that emerged from this new application. Unlike the troublesome industrial processes of scale, biomineralisers could address bioremediation and rare earth mineral extraction. They could do so at the point of contamination at the local scale and do so with a mutually beneficial restoration and remediation process in collaboration with microorganisms native to the ecosystem, cultured and not genetically modified. It was finally possible to apply biomining to clean-up sites where centuries of industrial effluents had contaminated water bodies and embankments with mostly the same rare-earth minerals and metals at the time.

The mycelial-carbon cartridges (Figure 10b) developed for this operation inoculated with strains of mycelium or bacteria chelated and sequestered the rare earth minerals from the water carbon medium (Colins & Ariel, 2062). The biomineralisers would float in waters that would be "nutritious" for the native biomineralizing biota. The individual mycelium-carbon cartridges were designed to inoculate with biomes that could concentrate specific minerals (Colins & Ariel, 2062). Their tuned saturation rates depend on the type of metals to be biomined and on the microbial strains inoculated in the cartridge biomes (Khan & Shah, 2127). These processes worked under room temperature conditions and sequestered cartridges in low yields. However, they sequestered rare earth minerals that were of very high purity.

These yields were adequate for further processing in the community fab-labs or



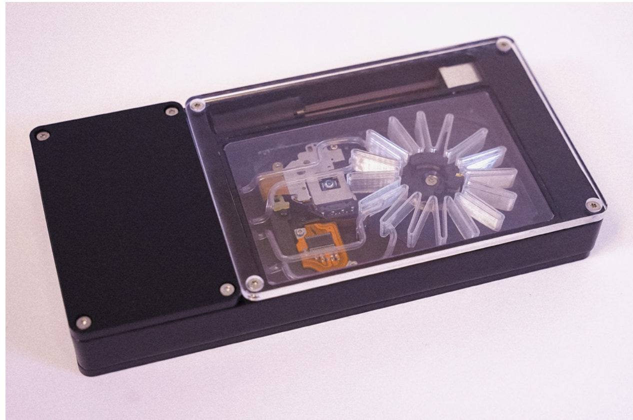


Figure 10 a) A Biomineralising rig. b) Biomining cartridges that harvest rare-earth for community biomining. Images by Vahidi et al., (2118)

workshops for producing socially useful and ecologically regenerative technologies locally. Furthermore, the ecocide ruling and fossil abolition had also dissolved many of the global financial institutions and the generous subsidies and favorable financial programs for the expansive mass industrial footprint of the Technosphere (Bernes, 2019; García-Olivares & Solé, 2015). Even so, these processes were not viable at the same economies of scale, given that many of the world's mining sources depleted ahead of the total renewable energy transition. The monumental failure of deep-sea mining for rare-earth minerals and the simultaneous need for mineral recovery of rare-earth minerals from obsolete infrastructures signaled the coming of age of these renewable fabrication processes (Thirumalai & Halden, 2087).

2.1.2 Down to Earth: Emergence of Community Symbiometallurgy

Biomineralisers paved the way for early developments and discoveries in the field of Symbiometallurgy, with much of the fundamental principles in application still intact. Symbiometallurgy, a fusion of 'symbiotic-biological-metallurgy,' is a subset of symbiotic fabrication techniques which have emerged over the past century and have created open alternatives that filled the vacuum of engineering materials left behind by the abolition of fossil fuels and much of the polymer industry (Khan & Shah, 2127). Under open tech protocols, the maturity of fabrication capabilities and the precision methods needed to build on these techniques have accelerated enough in the syndicated coop-shops continue to be sites of such designed experiments and exponentially expanded upon the applications of these biomineralisers. The bioaccumulation and bioavailability rates have improved leaps and bounds through the respectful use of biomining and biomineralization processes in synergistic relations with the material environment. Today, biomineralization is the only viable means to concentrate many commonly needed minerals (Figure 11).

The bioaccumulation of minerals proved to be a more rational method for refining minerals. Their success with depleted rare-earth minerals proved viable for other minerals like iron, copper, zinc, cobalt, magnesium, and gold. These systems were ideal for local production and consumption of high-tech goods anticipated to be mined from asteroids or by destructively trawling the deep ocean floor. Over a century of radically transformed and contracting footprints of the 'Technosphere's laid the groundwork for these to emerge. With the inevitable aging of legacy technological infrastructures, it was not long before biomining rigs became essential to sequester metals and minerals from obsolete technological infrastructures. Thus,

Figure 11 Popular Biomining practises that have become normal for harvesting rare earths using the biomineraliser technologies for production in symfabs. Image by Vahidi et al., (2118)

reimagining traditional fabrication methods also allowed biomineralisers to enhance the recovery of metals like lithium, cobalt, gold, tantalum, nickel manganese, cobalt, nickel, and zinc, preventing them from leaching back into the ecosystems that were meticulously remediated (Vahidi et al., 2118).

Symbiometallurgical technologies have, in the past decades, expanded into the processing of silicates, laterites remediating mine waste dumps from the past, as well as sulfide ores and uranium ores (Chihiro et al., 2123; Vahidi et al., 2118). However, misconceptions aside, symbiometallurgy has been fundamentally antithetical to genetic manipulation for extractive ends but created symbiotic stewardship systems relying on ecosystem flourishing (Vahidi et al., 2118). It is also perhaps the only ecologically responsible alternative for sequestering heavy rare earth minerals (Figure 11) and platinum group metals, sometimes even radioactive waste from freshwater bodies with the help of microbes (Vahidi et al., 2118).

Biomineralizers continue to be deployed for bioaccumulating radioactive elements from nuclear waste sites where bioremediation methods seem to have shown remarkable possibilities (Zenlin, 2109). The promise of these strategies was embraced across regions historically contaminated by industrial plunder like the recently revealed nuclear and toxic contamination zones where neutralizing radionuclides remains critical (Chihiro et al., 2123). The effectiveness and long-term ecological standpoint of bioremediation and reimagined material capacities have allowed communities to not revert to regressive relationships with their ecosystems. The development of the symbiometallurgical fields over the past century has shown how critical these minerals resources remain to our understanding of the natural processes beyond just fulfilling material human needs. Symbiometallurgy goes further in mapping the ecological processes of bioaccumulation and bioavailability, where nutrient and mineral flows can give us an overview of the health of our ecosystems across space and time in ways that were once unthinkable (Vahidi et al., 2118). Beyond these explicit traces, these practices further allow us to understand the spheres of the ecosystems in thriving, periodically dependent on human actions and at times independent of them. Instead, these practices open spaces for the myriad ways in which the human and the non-human entanglements can be revealed.

2.1.3 Of Rainmakers, Ice Stupas and Artificial Glaciers

It is essential to understand that this period of social regeneration and social guarantees had unleashed a lot of the energies in societies repressed for long under precariousness. Therefore, not all technologies adopted for the Blue Reparations initiatives were bereft of controversy and complications. With climate-induced annual drought seasons aggravating, there were real dangers to unchecked freshwater scarcity in a region facing extreme drought seasons. In the Gangetic plains, confronted with the fluctuating Indian Monsoon season and unstable glacial melts in the Himalayan region, acute water shortage became a crisis that needed action. Many in the open design and open-tech communities suggest "atmospheric river" harvesters, called Rainmakers. Open Design Communities developed the rainmakers to support the restoration efforts of step wells, wetlands, river, and lake reclamations projects in the CRZs, replenishing them as needed. These were possible from the early cache of opened patents under the technology transfers and developed by the open design communities (Gautam et al., 2053). These lighter-than-air structures could condense atmospheric water vapor with their hydrophilic surfaces and structures and precipitate them over the dried-up reservoirs (Gautam et al., 2053).

By mid-century, the rainmakers (Figure 12) were shared further within the open science and tech communities. Many journals supporting these actions, including this one, published these proposals and specifications (Gautam et al., 2053). The scales of operations needed to be practical for a community meant that they could only be deployed at highly localized scales to replenish local aquatic ecosystems and biodiversity. These impacts paled compared to the effects of successful implementation of the CRZs, which showed drastic promise in creating a net precipitation surplus and influencing precipitation patterns at a more extensive worldwide scale as new old-growth forests found their roots in CRZs (Hernandez et al., 2062). Curiously enough, while many of these developments made these rainmakers redundant for these purposes, their actions would prove crucial to another goal—glacial revival.

Communities in the Hindu Kush Himalayas had long invented a practice of making artificial glaciers called "Ice Stupas" (Divya A, 2020) and came across plans for these rainmakers and proceeded to develop them for their ends. They planned to deploy rainmakers to save the sacred Himalayan glaciers from melting. The deployment of rainmakers to accelerate the production of Ice Stupas (Figure 13) or artificial glaciers forced the region's people to redesign their rainmakers for this more urgent use, to control and replenish the mountain glaciers they relied on for freshwater bodies. These actions were their last ditched effort to save their sacred glaciers from catastrophic melting. In effect, the rainmakers tuned to serve as glacial ice "nucleation" sites that

Figure 12 Atmospheric Rainmakers harvesting freshwater for arid regions. Image by Gautam et al., (2053)

could allow glacial melts to refreeze and act as artificial glaciers, hopefully growing more glaciers along the way passively. These artificial glaciers were built by lean practices through community action, responding to receding glaciers and preserving the culture and history of those who depended upon the mountain glaciers threatened under the Hothouse conditions. The successes of these communities in documenting and modifying these rainmakers inspired many climate action groups wanting to build on the success of the 'Ice Stupas by applying similar strategies at the scale of the Arctic and Antarctic glacial revival, scaling these processes to revive the cryosphere at the poles (Rogers et al., 2121).

Admittedly, many rainmaker developers were harboring particular legacies from a techno-positivist past. The regeneration of lakes and ponds for a local community was feasible in technological terms. However, the scales at which the Arctic and Antarctic glaciers needed to be regenerated were nothing short of geoengineering and rightly called out for it (Zaidi, 2056). Various climate assemblies published their deliberations about the possible unforeseen consequences of a system this broad in scale and scope. Such geoengineering efforts had possibilities of wielding terrifying power over those without them and their myriad possibilities of abuse by unregulated powerful rogue actors. Even if the artificial glaciation schemes developed under community supervision within the democratic checks and balances of the Blue Reparations program, it was legitimate for anyone to be concerned about them, having studied the social and political turmoils from early in the century. These devices were thus exclusively reserved following strict protocols for the critical revival and recharging of the cryosphere to prevent catastrophic melts, whether at the Arctic and Antarctic glaciers, the melting permafrost, or mountain glaciers in the Himalayas. Whatever

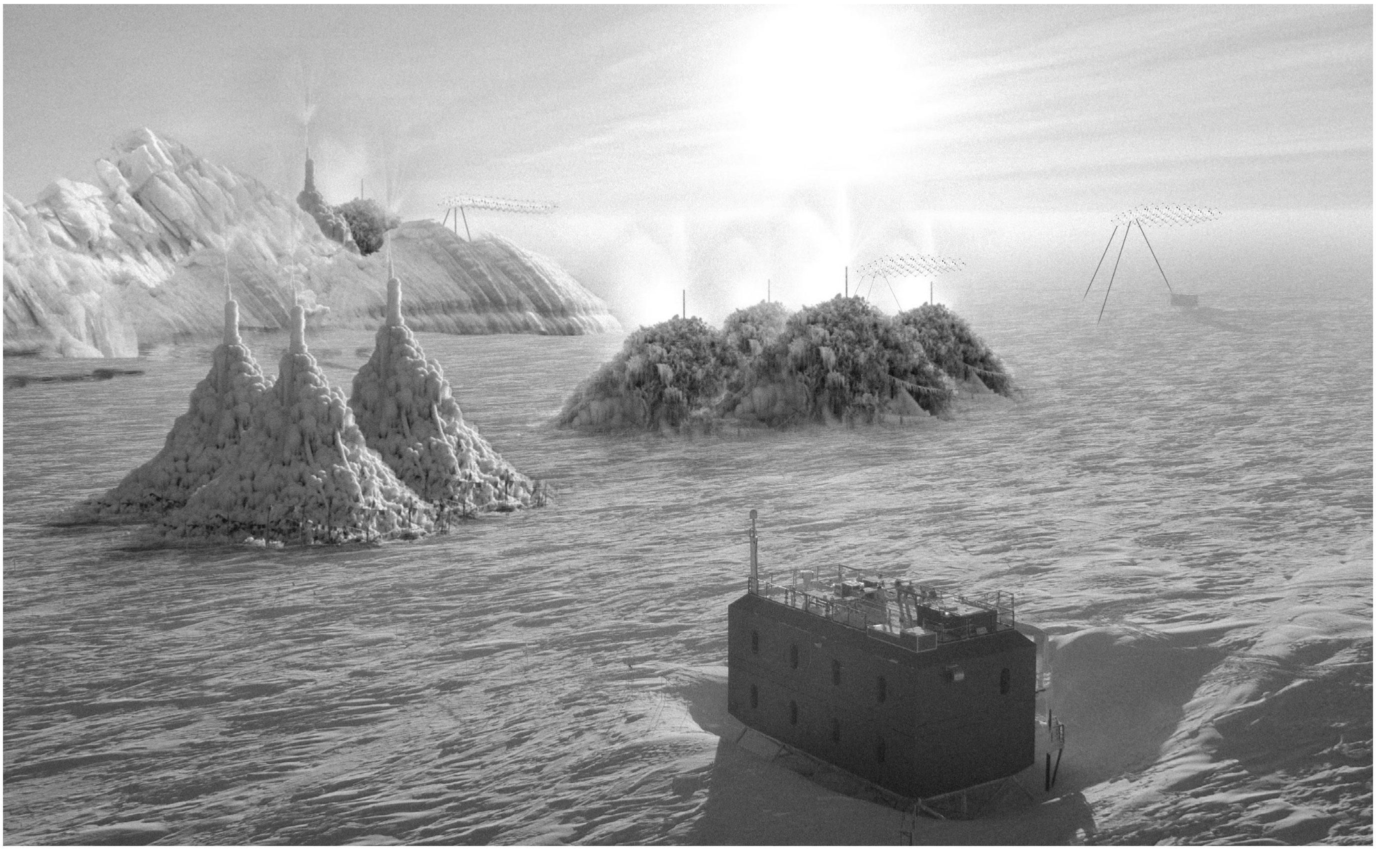


Figure 13 Early documented attempts at Rainmakers being used in making Ice Stupas in Antarctica. Image by Rogers et al., (2121)

glacial ice has recovered in the cryosphere today is thanks to the dedicated recovery programs carried out by the many climate action councils, such as the Antarctic Climate Treaty, carrying out efforts for regenerating artificial glaciers in the south pole (Padmanaban & Holdren, 2079).

To this day, the cryosphere continues to be particularly sensitive to Hothouse warming and a critical indicator and regulator of the Earth's climate system. The last decade of stratospheric flyby surveys has shown recoveries of ice measure volume in the cryosphere (Portho & Arivu, 2130). Despite having stemmed shifts towards the decline in overall ice volume, with the inadvertent change from old to young ice, such artificial glaciers are still considered a Faustian bargain (Rogers et al., 2121). Thus, climate regeneration expeditions to the Arctic and Antarctic glacial nucleation sites deploy rainmaker devices to create artificial glaciers. However, they are still seen with great skepticism and are not considered a long-lasting solution. Almost a century since its inception, this work is still ongoing to save whatever remains of the glacial, Arctic, and Antarctic Ice sheets, given that these ecosystems might have many longer-lasting consequences beyond their long-term recovery.

2.2 Making Kin with the Pale Blue Dot

The global struggles to revive the cryosphere's integrity have revealed the scale of our planetary crises with the hothouse climate settling in. No analog in the entirety of our evolutionary history could prepare a response fast enough or articulate enough to confront these profound scales and intensities of the oceans in the face of the sixth mass extinction event (Ceballos et al., 2017). Societies had to acknowledge the unthinkable. If there was to be any hope of a revival of oceans, it needed a reparations program on par with the colossal scale of the challenge. Globally, the Blue Reparations projects and the total abolition of fossil fuel infrastructures had already made industrial fishing and trawling of the high seas uneconomical. Given the vulnerability of coastal settlements, industrialized marine fisheries and the economic extraction zones in the open seas were abolished, making way for the marine equivalent of climate resilience zones. Coastal communities were reviving marine life and ocean pastures of their own accord as they wrested back control of fisheries from extensive industrial holdings and economies of war (Rahman et al., 2096; UNCAC, 2043). What followed is a testament to the rekindling community efforts, which laid the foundations of 22nd-century climate resilience.

The loss of many reliable satellite monitoring systems aiding with sensing and monitoring systems went dark (Chakraborty et al., 2076). Without geospatial monitoring infrastructure, the ancestral water defenders developed other means of continued regeneration and reparations for the planet. These alternative means were rooted in creating an “instinctive capacity for tacit forms of learning, seeing and doing” (Juma & Watene, 2041; Sarnai & Solongo, 2118). Thus, localized action went ahead, inseparable from everyday life having to understand and adapt to these changing conditions—for there was neither a mythical past to revert to nor a fictional nature to resurrect. The toll on marine ecosystems from overfishing, trawling, and fossil extraction was far too significant, leaving little room for returning to a primordial state in an ocean that had already moved on. With support from the Blue Reparations programs, communities returned to their ancestral lands, rebuilding and reclaiming shorelines that the seas had ravaged. Even large urban settlements such as the vulnerable coastal cities like Hong Kong, Mumbai, New York, and Shanghai saw their climate councils rally to protect their shorelines from hurricanes and storm surges. Their intentions would culminate in attempts to grow offshore natural sea barriers by rehabilitating mangrove-corals ecosystems as levees and storm breakers.

These ecological sea levees were integrated ocean permaculture zones that established a mutually reinforcing cycle of conservation, regeneration, and fisheries built on local indigenous knowledge striving together with marine biologists and local citizen science chapters (Tlouse & Wakkari, 2130; Vici et al., 2087). These levees proved effective in dissipating hurricanes and conserving and restoring marine ecosystems regenerating overfished stocks. These actions complemented other actions that prevented, deterred, and eliminated illegal, unreported, and unregulated fishing; encouraged ecosystem-based fisheries management; and controlled and addressed plastics pollution in ocean gyres (Rahman et al., 2096). In the 22nd century, these sites became new marine hubs of biodiversity restoration and increased connectivity between ocean habitats. In practice, these practices would end up on planetary scales over thousands of square kilometers, mutually reinforced by being both an adequate shoreline protection and creating new zones of resilient climate zones for marine biodiversity well into the 22nd century (UNCAC, 2129).

2.2.1 The Electric Coral Rehabilitation Project

While methods for coral restoration had been studied and suggested in the past (Boström-Einarsson et al., 2020), the processes that succeeded were the ones that strategically combined multiple efforts of electrified artificial reefs and coral propagation through asexual and sexual reproduction means (Suman & Monyeki, 2117). With the advancements in 3D fabrication practices of these fibers, undersea coral restoration efforts were well on their way to producing composite carbon-negative mineral accretion reefs. The techniques needed recreational reef divers and citizen scientists to gather coral gametes and build carbon-limestone composite reefs. Coral gametes would be harvested from specific coral species, bred with other members of the same species autonomously or manually, and grown in nurseries to ensure the highest chances of resilience to bleaching events (Goreau, 2012; Vici et al., 2087). Coral polyps harvested from different coral species were deposited onto tetrapod-shaped limestone structures (Figure 14 a) and embedded onto the artificial composite reefs (Chamberland et al., 2017; Suman & Monyeki, 2117). This sexual propagation and mineral accretion technology accelerated the regeneration of corals, rehabilitating them onto new sea walls habitats integrated with mangrove forests (Suman & Monyeki, 2117).

Mineral accretion technology, or the “bio-rock” method, discovered about two centuries ago, was a breakthrough method for creating these large scales artificial coral levees and restoring coral ecosystems, even reported to have brought back severely eroded beaches (Goreau & Prong, 2017; Vici et al., 2087). These mineral accretion methods were at their cores based on rudimentary seawater electrolysis apparatus running with low voltage and low current for decades on end. Mineral Accretion methods used a cathodic mesh structure made from conductive carbon fibers to conduct low current and low voltage electricity (approx. 1.5 V). The mineral aragonite was deposited on these fiber substrates (Figure 14 b) to produce a high-strength carbon-limestone composite (Suman & Monyeki, 2117) and, in many cases, decommissioned and abolished deep-sea oil rig infrastructures adapted for artificial reefs. These were being moved to specific offshore locations and repurposed into these sea barriers and coral restoration platforms, applying mineral accretion technology in deep-sea circulating waters and nutrients from the depths (Suman & Monyeki, 2117). The electrolytic process of mineral accretion technology played a crucial role for the coral organism to build their carbonate shells without expending excess energy, which it could use for growth instead.

The slow electrolysis was advantageous to ensuring stable conditions for coral growth. The system allowed the coral organism to control their calcifying fluid (CF) chemistry in the seawater by improving the bioavailability of carbonate ions and dissolved inorganic carbon (DIC) for coral growth. This process strengthens the

Figure 14 a) Coral Polyps planted on tetrapod structures. Image by (Chamberland et al., 2017). b) Biochar Carbon fibre with micro aragonite composite. Image by (Suman & Monyeki, 2117).

saturation of carbonate ions within the CF which is approximately three to four times greater than the surrounding seawater (Kyriaku et al., 2089). In essence, this led to the faster production of the organism's skeletal structure with localized pH control, given the acidic state of much of the surrounding acidified oceans and the heat capacities of the seawater (Kyriaku et al., 2089). These methods showed the possibility of drastic recovery rates for coral reefs, even for damaged ecosystems (Goreau & Prong, 2017; Kyriaku et al., 2089).

In many regions, these mineral accretion structures have a distinctive black shade to artificial reefs. The artificial reef structures based on organic carbon fiber (Figure 14 b) acted as carbon sinks with organic carbon locked within the complex woven geometries 3D printed on-site. The electrochemical deposition of calcium and magnesium salts from the sea helped create crystalline aragonite structures to create the substrate for the reef forms. The aragonite would be electrochemically deposited on cathodes made from conductive carbonized organic fibers (Halden, 2094; Hilbertz, 1979; Suman & Monyeki, 2117). These reef production techniques were carried out by marine conservationists in the shallow waters, surveying and gathering coral gametes from the last remaining coral habitats.

The conservationists cultivated the polyps in coral nurseries and transferred them onto the new sea walls growing the mangrove-coral coastlines in specific hurricane resilient patterns (Ganguli & Nakamura, 2047). Repurposed oil rigs were shipped to the coral rehabilitation sites and 'woven' with electrified fiber into coral-positive structures built to initiate mineral accretion systems. These reef structures woven from conductive carbon fibers formed self-healing carbon-aragonite structures and made the rehabilitated coral ecosystems highly resilient to acidified oceans (Goreau, 2012; Kyriaku et al., 2089; Suman & Monyeki, 2117). It was possible to build limestone structures on any conductive, non-corrosive material in any shape or form given the right conditions, even over thousands of square kilometers.

2.2.2 The Black Coral Marshes of the Sundarbans

The diverse coral regeneration cultures familiar today have varying origins. They have taken unique cultural forms, witnessing the emergence of many new celebratory cultures around the coral sea walls' rehabilitation and regeneration programs. Today, these sites of intergenerational pioneers of marine preservation and cultures have revived and regenerated biodiversity through deliberation between old and new techniques, addressing climate justice within the framework, but this was not clear how this would come about. It is common today to think of these mangrove-coral reef regeneration zones as the sites for turning around and course-correcting the trajectories that our marine hydrodynamic systems were once inevitably heading towards (Portho & Arivu, 2130). Global climate mitigation strategy and community-driven ecosystem resilience programs have survived well into the 22nd century.

In the Sundarbans marshes, these cultures of resilience and abundance have seeped into the local folklore around these artificial coastal reefs. The composite reefs that host the mangrove-coral rehabilitation efforts are colloquially called black coral or 'Kalo Probal' in Bangla. These coral structures, not to be mistaken for black coral species, are named after the black color of the carbonized organic fibers woven to make the carbon composite structures of the reefs. The coral mashes around the Sundarbans are by no means the first to employ this practice. However, they were famous for regenerating these coastal ecosystems' biodiversity at a much faster rate than anywhere else in the world (Suman & Monyeki, 2117; Vici et al., 2087). The coral architecture movements from the Sundarbans led to similar methods for such non-human architecture. They are expressions of vernacular practices of growing mangrove and coral reef structures alongside coral nurseries and replanting them on new salt marshes that help keep the coastal waters calm (Halden, 2094). In the 22nd century, these reefs have grown into coral levees, their growth astounding even their proponents.

Coastal settlements have chosen to reconnect with their ecosystem and celebrate it in the form of festivals. Such events have remained intricately linked to biodiversity restoration efforts even after decades of continued practice. Given how much more fragile and urgent it was to restore the coastal communities, support from the citizen science movements was a welcome change. However, before the Blue Reparations programs, the region had borne some of the worst climate and ecological catastrophes, devastated by storm surges and hurricanes, displacing millions early last century. Thus, even as the energy of annual hurricanes predictably intensified, when storms in the region made landfall, it was meeting more resilient climate infrastructures. What had dramatically shifted was the social ecology of the landscape as cultural and technological cascades synchronized in merely a couple of decades in the region, directly connecting the ecosystem regeneration and human well-being (Devassy & Cole, 2130).

One of these needs was to build the Sundarbans mangrove ecosystem from near-total devastation by planting naturally grown sea barriers of mangrove and coral. The tools used were appropriated from fossil fuel infrastructures and adapted for these purposes while fulfilling the essential human needs of the community (Suman & Monyeki, 2117). Soon enough, the region was lighting up with renewed cultural energy, and forms of technological disobedience for climate resilience had come to articulate a socially and ecologically responsible technology based on self-determination, which was not unheard of (Oroza & Marchand-Zanartu, 2009; Yu & Pabst, 2051). The textile industries in the region were repurposed their fabrication methods by the communities who ran these institutions, shifting towards new experiments in socially-useful production. Similar guerrilla design movements shared and transcribed open-tech alternatives for rehabilitating these coral levees. This journal has been popular in these communities for publishing many of their early plans (Ganguli & Nakamura, 2047). Given the seriousness of the climate emergency here, the emergence of practical ways to grow such coral levees in socially and ecologically responsible ways required local and institutional collaborations with native communities, designers, architects, and ecologists who were trying to articulate a technological renaissance by communities at the forefront and transforming social contexts at the time (Ngata, 2076).

Today, the local folklore speaks of the resurgence of the black coral and mangrove forests. The stories of the fisherwomen, coral conservationists, and citizen scientists whose dedication and efforts helped seed the first generation of mangrove-coral belts under adverse conditions continue to be celebrated in the regional lore even today. The direct connections between the ecosystem restoration of artificial mangrove-coral reefs have brought about overall prosperity to the region, culminating in an annual tradition of ecosystem restoration and coral seeding. Every spring, around the coastal towns and villages of the Sundarbans, people from all walks of life come together to celebrate the tradition of seeding new coral patches and building the coral walls (Figure 15). Such festivals ensure fish habitats, regenerate local biodiversity, and create possibilities for long-term resurgence and revival of local community life for coastal populations worldwide. These coral ecosystems protected urban and rural coastal ecosystems from hurricanes and stormwater surges while increasing the

Figure 15 Kalo Probal: Early experiment in the electrified composite reefs. Coral seeding festivals popular with coastal communities apply a mix of seeding techniques for ecosystem restoration. Image by Vici et al., (2087)

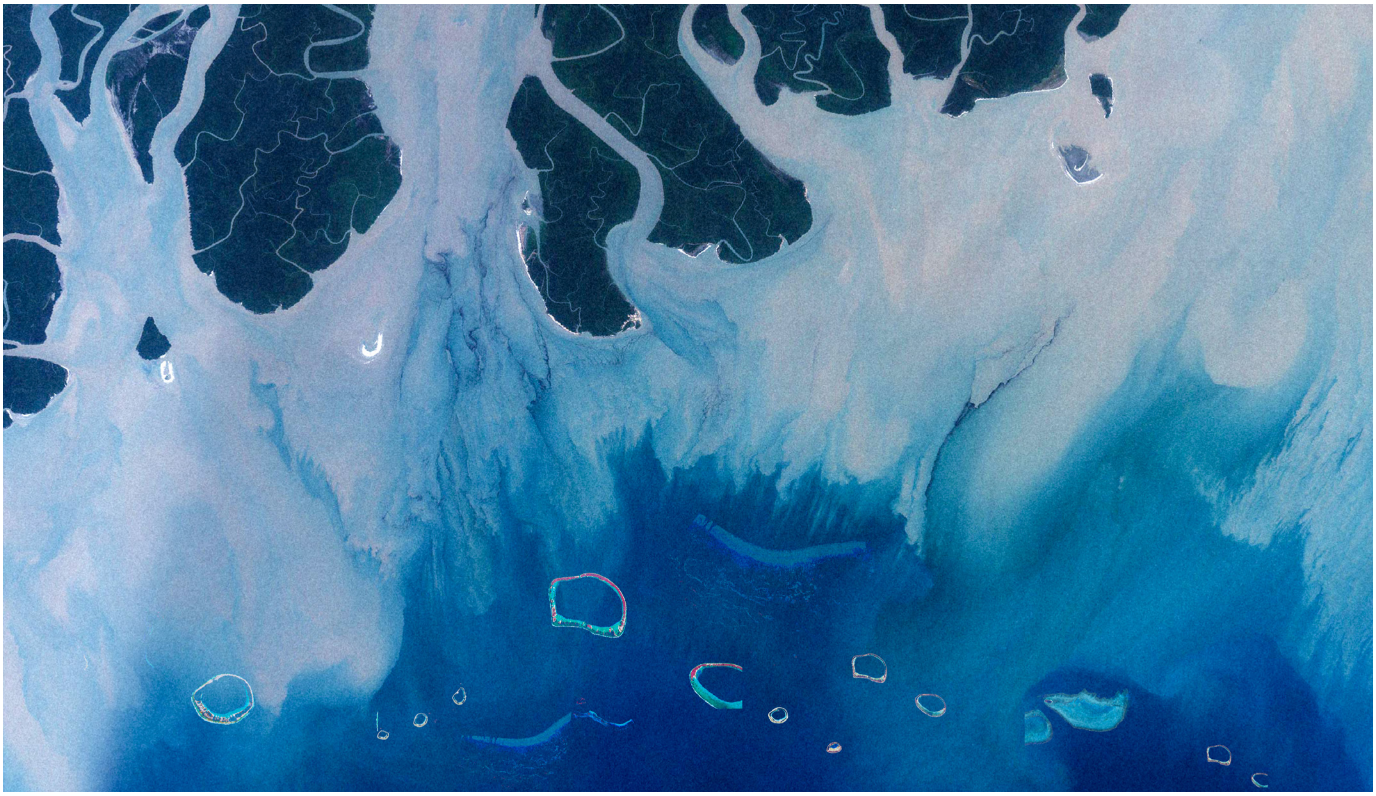


Figure 16 Present day Composite Mangrove-Coral Sea Walls off the Coast of Sundarbans as seen from high altitude climate mapping. The near infrared data is overlaid here to make some areas on the reefs jump out in bright red relief. The near infrared band best gathers the electromagnetic signature of a thriving ecosystem. Image by (UNCAC, 2126)

fisheries and livelihoods of vulnerable people across the world's coastlines.

These black coral levees (Figure 16) have become sites of long-term 'blue carbon' sinks. Given the scales, these practices resemble the scale of historical carbon drawdown practices, such as the Terra Preta in the Amazonas (Halden, 2094). Almost a century later, the rehabilitation and the exponential growth of these coral reef barriers have created exclusive marine ecological corridors. From the few remaining satellites in low Earth orbit, we know that these are the most prominent artificial undersea habitats complemented on the ground by the Pan-Indigenous autonomous zones (Portho & Arivu, 2130). The switch from industrialized fishing to local permaculture-based fishing practice brought back fish species and further accelerated ecosystem recovery reaching new positive feedback loops with mangrove-coral ecosystems that have become new local havens for biodiversity (UNCAC, 2129). Today, these rehabilitation sites integrated within local cultures based on indigenous knowledge connect global marine ecosystem regeneration, resilience, and abundance (Devassy & Cole, 2130). With marine habitats and species recovering thanks to human intervention, ocean warming and acidification acceleration trends have been showing consistent slowdowns over the first decade of the 22nd century, remarkable considering this was unthinkable at one time.

3. Discussion:

Our ancestors, the indigenous land and water defenders, spoke of the centuries of colonization of the Earth. For them, it was "not as a dark chapter in history, but a book that was constantly being written where most of the world was living in someone else's story, the responsibility, and consequences unknown to those who wrote it" (Juma & Watene, 2041). This tell-tale sign of the darkest chapter in human history seems to have been erased from geological ice core records, marking its presence by the very absence. The 22nd century reads like a different book, with the promise of indigenous sovereignty and sustainment founded on progressive harmony with the natural world as we reconnect to this alienated yet habitable world.

Such metamorphoses have emerged worldwide and seeped into the material and technological culture as necessary and socially beneficial. These have marked significant shifts in the material cultures around the world leading up to the deliberate emergence of symbiotic fabrication methods and practices today. Furthermore, the complete overhaul of the industrial and agricultural regimes globally has refocused social energies toward developing innate creative capacities for locally fabricated, socially-useful goods through citizen science and open technology movements. Even though one removes the rose-tinted lenses of techno-optimism, there is no denying that open-technology and citizen science frameworks have reinvigorated technological exaptation possibilities.

Biomineralizers were one such technological exaptation that we discussed that manifested in the open tech societies. Symbiometallurgy and biomining remain the only viable means for bioaccumulating and refining numerous mineral ores and radioactive elements needed for the slow fabrication syndicates. Unsurprisingly, they have aided in dramatically easing the pressure on natural ecosystems from exploitation. The contraction of existential pressures due to civilizational activity on these ecosystems has allowed them to recover the once lost wetlands habitats and regenerate groundwater aquifers. The prevention of contamination of coastal ecosystems further downstream, drastically cutting down hypoxic zones at sea and further bringing water security for millions of communities creating massive public health gains along the way. These ecological capacities were needed to build climate resilience initiatives such as CRZs and local scales of terrestrial biodiversity initiatives of regenerative, agroecological shifts in food that was to have radical changes' downstream'.

While it is hard to say if the oceans will ever truly recover from centuries of exploitation, new studies point out that the regeneration of mangrove-coral sea walls has created biodiversity refuge for marine life and provided coastal communities with sustenance and climate resilience. While regeneration rates in many of these regions have been remarkable, much work remains incomplete to ensure the long-term stability of these achievements. Even though Himalayan glaciers have shown signs of return, there is much to say about the instability of the Antarctic and Arctic ice remain a concern. It is still too early to tell whether the efforts to grow artificial glaciers can succeed. However, concerns over permafrost melts, thermohaline circulation, and the hydrological cycles remain urgent.

Often, historical literature tends to attribute the drastic recovery of the planet's freshwater ecosystems to the total global abolition of fossil fuel infrastructures. While reasonable, the simultaneous reinforcement of these actions aided the renewal of social contracts and decoupled social well-being from economic growth, and material throughput cannot be underestimated. Despite these concerns, it seems that a more abundant world is still possible. Suppose there is ever a substantive legacy of the Blue Reparations programs. In that case, it will read as an unfinished book, serving as a testament to taking up the long-overdue responsibility of regenerating our kinship with the vitality of this primordial 'soup of life,' by far the only blue planet in the known universe that we can call a relative.

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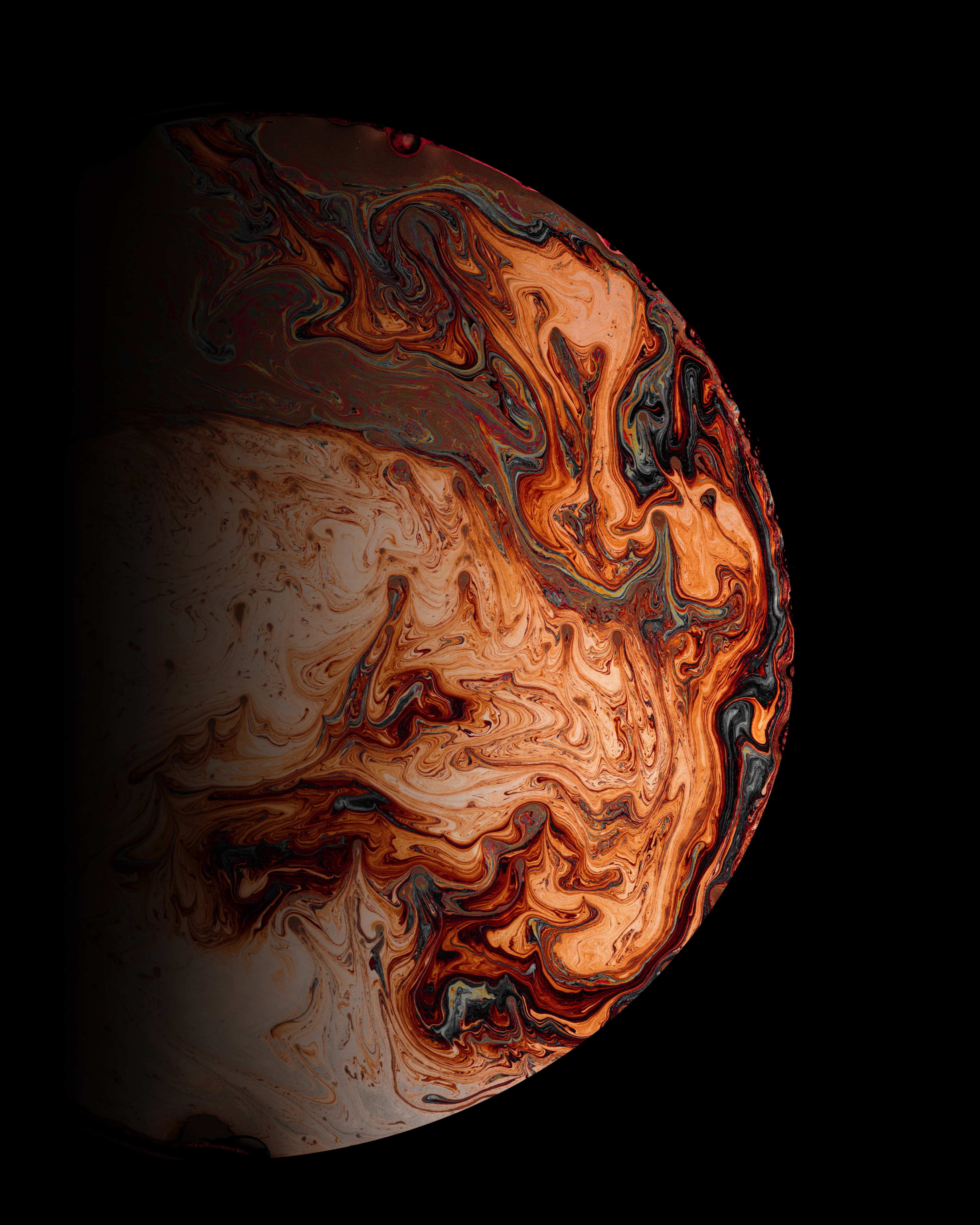

“Strictly extrapolative works of science fiction generally arrive about where the Club of Rome arrives: somewhere between the gradual extinction of human liberty and the total extinction of terrestrial life.”

— Ursula le Guin, Introduction to The Left Hand of Darkness (1976)

“Apocalyptic idealization is a self-fulfilling prophecy. It is the linear world ending from within. Apocalyptic logic exists within a spiritual, mental, and emotional dead zone that also cannibalizes itself. It is the dead risen to consume all life.”

— Jack Forbes, Columbus and Other Cannibals (2008)

4. Postscript

This publication and the associated artifacts are fragments of a 'design fiction.' Although one may be mistaken to read it as science fiction, it is an experimental undertaking from a design standpoint. It is part design fiction (Bleecker, 2009), part-fictional research paper (Lindley & Coulton, 2016), part literature review, and a designed artifact from a just future. This research artifact is an outcome of a 'research through/by design' doctoral project titled, ReFuturing Studies: ReHumanizing Futures Through/by Design. Although it may read like science fiction, it is not. Written through 2020-21, with the COVID-19 global pandemic still raging, all the references before 2021 in this design fiction rely on a comprehensive discussion of peer-reviewed publications on the various themes in question. Eventually, global climate actions that follow after 2022 have been speculative, fictionalized accounts of global climate actions. While these references may be fictional, they have been developed with studied deliberation and care, suggesting possibilities. This design fiction aims to engage with the possibilities and opportunities of societal transformations towards climate action that may be available to realize long-term sustainable futures as we head into our uncertain climate futures.

The first half of each chapter explores the legacies of climate inaction as a compressed literature review discussing the scattered tales of roads not taken and sensibilities not cultivated. This move has been made to understand why, despite the vast scholarship and knowledge generated on the urgency of the crises, a more profound understanding of climate action still seems evasive while a deep sense of climate despair has been normalized. Therefore, even while more carbon was emitted into the atmosphere knowingly than was ever done in ignorance (Wallace-Wells, 2019), baselines for climate action were continuously being shifted (Jackson et al., 2011). It would seem then that knowledge alone "is not the road that leads to understanding, because the port of under-standing is on another shore" and requires a 'different navigation' (Max-Neef, 2009). The research group ReFuturing Studio at AHO has focused on attempting this 'different navigation' based on that position. It is precisely the possibilities and challenges of this new navigation that informs this publication.

The social assumptions this research project bases itself on are in deliberate contrast to the many dystopian climate imaginaries that tend to gravitate towards a "warning of things to come," of futures none of us may want to inhabit (Tonkinwise, 2014). Despite the unequivocal conclusion about our climate futures, these tendencies to construct climate despair seem more in tune with elaborate expressions of climate denialism that continue to be deeply internalized in our social imagination (Klein, 2014). As the chapters progress, they articulate the possibilities that might be available to us—a 'designerly' agency beyond climate despair that can be realized beyond the systemic constraints of our present paradigm. It may yet be possible to comprehend and address the wickedness of such an existential predicament. Furthermore, since it is impossible to prove and predict this future, this design fiction is not concerned with mapping out all its idiosyncrasies in detail.

This design fiction suggests a 2°C-2.5°C warmer world in the coming century; the latest IPCC report indicates this figure as an intermediary trajectory of warming trends for 2100. Warming at 1.5°C is already a disaster, and a 2°C world may already trigger feedback loops beyond our control. 2°C is a guaranteed death sentence for millions of people. Therefore, limiting emissions must act as if the goal was 1.5°C rather than 2°C, which is being proposed as a more 'reasonable' goal. Therefore, whether we can consider the forest and the trees becomes an existential question. Breaching the 1.5°C limit represents more than itself. Behind it lies yet unknown threats and the complex entanglements of the climate and ecological crises—biodiversity and ecosystem services, agricultural declines, farmer deaths, socio-economic inequality, hunger, social justice, long-term sustainability, the sixth mass extinction and good quality of life (Díaz et al., 2019). Whether the change is by design or collapse, the quality of these choices remains relevant to human and planetary well-being no matter what thresholds we cross in this century, be that in the social, climate, or both.

Ultimately, the purpose of such design fiction is not to claim how exact this future will be but to create a critical dialogue about a more hopeful future if certain fundamental assumptions of our present paradigm were to change. If it paints a 'utopian' conclusion, it is not by appealing to extrapolate the system that exists today a hundred years into the future. It is by attempting to "refuture" what has already been defutured, to reclaim the dehumanized futures of ecological crises by regaining our humanity, what Freire refers to as the task of rehumanization (Freire, 2014). This rehumanization is what the term 'refuturing' in the title of the publication alludes to, which arguably requires a designerly re-imagining, re-thinking, and 're-humanizing' of futures to break the constantly narrowing frames of "Business as Usual" BAU. Refuturing requires opening up 'pluriversal' possibilities that suggest climate actions today, which may bring about a radically different future when one arrives in it.

Furthermore, refuturing is about imagining radical hope when none may seem forthcoming, even as the planet becomes increasingly uninhabitable for the human species (Wallace-Wells, 2019). However, one must note that re-humanizing utopias do not imply that alternative futures will be bereft of any conflict. They will remain highly contested spaces with many paths emerging, diverging, and converging again. In these contested, pluriversal spaces 'where many worlds exist,' deliberations on mutual concerns may be worked through by practices of conviviality and autonomy (Escobar, 2018). These may be reflexive learning in action with the biosphere as a species. The re-humanized futures would be those we may consciously consent to, keeping room for dancing, laughter, play, fun, leisure, creativity, and even boredom—which seems impossible to imagine today.

In attempting to imagine a refutured response to our wicked crises, certain sensibilities were cultivated while others were ignored. These sensibilities have been based on different assumptions for a new paradigm to suspend disbelief within the design fiction. That said, some of the climate reparations pathways discussed here may even be construed as politically impossible and create unsavory and unsettling experiences for some readers, raising concerns and challenging some of our deeply held 'rules' of our existing paradigm. It is not to say that all challenges to the paradigm must be unsettling or even a means to climate action. Inevitably, in this process, these fictions speak for those that do not yet exist, as surrogates that pose questions and explore possibilities to reflect and act based on a different definition of civilization. It may appear disrespectful, even within a fictional world where the narrative places the burden of transforming sustainable actions onto an amorphous collective of voices "from the margins"—the indigenous and marginalized peoples of the world, for whom the climate apocalypse is an everyday reality, while those responsible for the crises continue BAU (Althor et al., 2016; Carrington, 2019; Chancel & Piketty, 2015).

This work does not intend to disrespect, 'other', or caricature the people spoken of in this publication. Instead, these speculative voices are intended as reflections for conviviality, to understand our predicament more profoundly. One can hope that this publication is an invitation to a critical yet speculative reading for understanding the opportunities for action, many of which are remarkably low-hanging..” The most recent scholarship at the time of writing suggests that many of the societal transformation strategies suggested here are not only viable but would be radically transformative for ensuring human and ecological well-being while simultaneously staying below the 1.5°C threshold (Fazey et al., 2020; Folke et al., 2021; Keyßer & Lenzen, 2021; Kuhnhenn et al., 2020). The need to renew the social contracts globally proposes freeing human societies to participate in climate action. It may be possible for us to be less ‘productive’ for a fossil-fuelled economic engine and more focused on a more leisurely, caring ecological society that guarantees a good quality of life (Coote, 2021; Gough, 2019).

As communities build towards local and global climate resilience with local, sustainable fabrication and consumption methods, they can be scaled out instead of scaling up. This strategy may allow for multi-level integration of renewable energy infrastructures designed for long-term sustainability. It might be instituted within mutually reinforcing carbon-negative cascades while simultaneously fulfilling essential human needs. For this to be realized, societal transformations may be needed that frame this adaptation of technologies for social and ecological needs. These climate-resilient infrastructures might use open technology transfers and citizen science to continue formulating diverse forms of ecological and material abundance in a world without cheap fossil fuels through a decolonized climate reparations framework. These issues are layered tacitly in the artifacts explored in the design fiction that embeds the diegesis of decolonization and climate justice, making these futures imaginable, sense-able, and doable today. A more detailed reference list of the technologies can be found discussed in the appendix of technologies that follow.

The artifacts designed in the publication suggest a path towards indigenization of everyday life for those of us non-indigenous. This path is propositioned not to achieve some mythical primordial state but as a ‘self-conscious political project’ towards cultures of mutual thriving, grounded yet flourishing within the planetary ecologies, which may prove essential as climate and ecological breakdown continues and perhaps even beyond that. In designerly practice, the artifacts often become a means to reflect in action, think, and re-think propositions through tacit knowing. This exercise may hopefully demonstrate a refutured understanding of long-term sustainability by design. In this pursuit, the artifacts might be realized today, though speculative. From biomineralisers to electrified coral reefs and rainmakers, from forest seeders to symfabs, from organic algae-chitosan battery printers to 3D printed optical solar structures within municipal energy grids to the energy rituals of the fictional Masisi people— these are all based on speculations of existing fundamental technological literature.

The aspects of long-term sustainability expressed in these diegetic artifacts may hopefully give the reader an idea that long-term sustainability could still be achievable. However, technological progress does not have to rely on archaic notions of technocratic solutionism. It does not need to depend upon extractive, colonial models that narrow human possibilities rather than expand them. The propositions for open technology transfers and open science movements move towards a glimpse of more profound leaps toward “poetic” technologies to emerge rather than the bureaucratic ones aimed at dehumanizing technology (Graeber, 2018; Noble, 1984; Zuboff, 2019). The journal also offers perspectives on who develops these technologies in a new paradigm, posing questions of care and social reproduction that go into creating those hands and the resources that create them, perhaps even freely sharing these capacities as social life becomes strategically de-commodified. Here, under liberatory conditions, climate-resilient technological infrastructures may even proliferate relatively faster than ever deemed possible, perhaps taking a different social and ecological trajectory than the one we have become accustomed to today.

Admittedly, the wicked complexity of the climate and ecological crises (Morton, 2016) cannot be merely 'solutioned-away' by silver bullets alone. There may be certain limits for designers alone to address these issues (Dorst, 2019). This design publication on its own cannot account for every minutia of these issues—whether planetary social life in a 2°C-2.5°C hothouse world is even possible or accurately predictable is far beyond the scope of this publication. However, it might be possible to have a 2°C world within BAU and still be a harrowing climate dystopia beyond imagination. Many of these visions are perhaps already ever-present in the dystopian visions we are familiar with today. Instead, the focus of this exercise is to suggest possibilities of a different nature, towards the imagination of climate action based on true decolonization and climate justice through 'effective' climate reparations, which is in constant tension with the 'efficient' colonial logic of BAU. For this to come about, it requires navigating unfamiliar waters and drawing creative 'red threads' between seemingly disjointed phenomena and concerns to be able to glimpse at counter-hegemonic arrangements and paradigmatic possibilities of long-term sustainable transformations.

However, even if one imagines these different paradigms, they cannot be expected to come about independently, nor could they ever come about precisely as prescribed. Regardless of the choices ahead, constant cooperative efforts would be needed for essential needs to be fabricated ecologically, cared for, nurtured, socially reproduced, and sustained if desired, requiring efforts across multiple generations. This multi-generational practice will need to be complemented by stringent ecocide regulations and frameworks by literally decolonizing the land, water, air, and even outer space. Beyond that, ecosystem services may need to be remediated and regenerated by instituting reparations for the biosphere. Thus, this design fiction attempts to contribute with possibilities which disciplines than design have been articulating for a pluriversal imagination, which this publication speculates. Perhaps far more capable minds can dream more profound imaginaries beyond these speculations that have been naïvely oversimplified here or may even be conservative on some issues.

This publication presents the refutured possibilities of our climate pasts, presents, and futures, embedded within a deep entanglement of our definitions of 'civilization' that are yet to be reconciled. Whatever forms of climate actions the future holds may need constant negotiation. The future we create will need deep conviviality, autonomy, and cooperation, which may help us make and remake the world just as intimately as we normalize the arrival of climate dystopias today. The 22nd century will still emerge; whether it is a more hopeful climate-resilient future like the one speculated in this publication or one that sees the human civilization race over the precipice of extinction is still an open question. With the realities of climate inaction as they are today, the former offers a creative possibility for radical hope, however narrow. In contrast, the latter provides a predictable lack of choice in the matter. The prospects of a long-term sustainable civilization worthy of the name, if there ever is to be one, may yet depend on the possibility that the human species, with all its ingenuity, realizes forms of becoming indigenous to its life-giving biosphere.

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5. Appendix of Technologies

The artefacts explored in the journal is situated in a world having undergone societal transformations for climate action. Alternative development pathways are pursued to realize a tapestry of strategies centred around climate justice which transform the material cultures of civilization, subverting its extractivist relationship to planetary ecosystems. The speculative reading of these technical papers grounding these technologies are both old and new, some cutting edge and some ancient, some based on modern science and some others based on indigenous practises. In many cases, the studies have been interpreted or speculated upon rather creatively to certain extremes, beyond what the studies' authors intended. However, these are not to extrapolate what exists but to speculate "what if"—as a creative exercise to open different trajectories which as the reader may have glimpsed in this journal might enable technological leaps 'exapted' towards socially useful production for fulfilling essential human needs, which were once applied for unsustainable consumption.

This journal makes a case for how technological development might reach profound leaps where pursuing genuine climate agency and participation which could further feedback into turn, suggesting the possibilities of an epistemic shift within an autopoietic process. However, such creative leaps are not a guarantee of 'success' and may even lead to undesirable outcomes as the Rainmakers suggest. Therefore, the artefacts represent certain product archetypes from this speculative future world that may emerge for these purposes. The renewed social contracts may have made apparent to the reader that long-term sustainable technologies are framed within a more ecological worldview, expanding the quality of human and non-human life in the climate resilience zones. They also suggest a shift in the material relationship towards pluriversal symbiotic cultures that may yet hold the promise of more profound technological leaps as discussed through symbiotic fabrication and symbiometallurgy.

It is by no means to say that these are the only archetypes that may be possible. Perhaps better minds can fill in with possibilities of essential needs in more ways than have been explored here. What follows in this section is an overview, a bibliography of the technical papers for those interested in pursuing the studies grounding these speculations. These may be useful to understand better and perhaps realize the designed artefacts one finds explored in the journal. It is by no means an exhaustive list of the readings that one could explore, although one could always expand on them.

Ch 1: Glocal Energy Cultures: Realising 22nd Century Radical Indigeneity and Beyond

1. Municipal Micro Grids:

A holistic, distributed carbon negative energy grid at the local level which is part of the climate resilient infrastructure based on regenerative principles. It essentially integrates combined heat and power systems (CHP) some based on Stirling cycle based reversible alternators for long term maintenance-free operation. This system also includes regenerative sanitation and waste management practises that are integrated within municipal agroforestry frameworks. Solar energy in the form of light and heat is concentrated and redirect through more fiber optic concentrating systems (Amara et al., 2011; Gorthala et al., 2017; Jaramillo & Río, 2002) and used in combined heat and power modules for cooking and heating indoor thermal environments. Organic waste is carbonised through microwave pyrolysis (Hoseinzadeh Hesas et al., 2013) or solar pyrolysis (Ayala-Cortés et al., 2019) to be produce carbon rich mediums in fermentation toilets to be used to supercharge the carbon matter which would be further used as soil amendments rich in nitrogen and phosphorus organic fertilisers closing the nutrient loops while simultaneously localising power production and consumption. The pyrolysis process carbonised organic waste in a carbon cascade (Bates & Draper, 2019; Hassan et al., 2019) with resulting outcomes of heat, syngas and bio-oils could further be used in soil amendments, batteries, and bioplastics in mutually reinforcing carbon cascades.

a. 3D Printed Optical Solar Structures

Locally fabricated solar structures directly convert thermal and visible spectrum of solar radiation within optically tuned solar cells (Bag et al., 2017) which are aerosol coated 3D printed optical fibres coated with perovskite solar inks (Bag et al., 2017). These cells however also consist of phase change materials that can extend the efficiency by using phase change properties that can be utilized for infinite cycles of thermal energy storage which can be redirected when solar radiation is inadequate such as nighttime or winter sun (Goli et al., 2013; Liu et al., 2017; Yang et al., 2016)

b. 3D Printed Organic Batteries:

The energy storage system consists of biologically grown algae-chitosan based batteries and ultracapacitors which are produced locally for storing electrical energy (Salimi et al., 2019; Wang et al., 2015). Their fabrication depends on the controlled ultrasonic levitation of stock material (Azadi et al., 2021; Marzo & Drinkwater, 2019) and fabrication of composite batteries from finely tuned pyrolytic processing of carbon rich organic fibers and raw stock which create a carbon capture based organic batteries and carbon based ultracapacitors (Gabhi et al., 2017; Huggins et al., 2014; Salimi et al., 2019), (Anandhavelu et al., 2017; Attias et al., 2017; Subban et al., 1996), algae-paper based batteries and ultracapacitors (Salimi et al., 2019; Wang et al., 2015). Chemical energy to thermal energy conversion is carried out through the reversible Stirling cycle of plasma combustion of syngas (Punčochář et al., 2012) further reducing pollutants from microwave pyrolysis (Hoseinzadeh Hesas et al., 2013)

2. Energy Rituals of the Fictional Masisi People:

The indigenous traditions in energy cultivation of the Masisi people is based on the technical adaptation of integrating fiber optic solar cells (Bourzac, 2009) coated with graphene (Casaluci et al., 2016) along with a fungal microbial fuel cell (MFC) (Gajda et al., 2015) that feeds off radioactive soils (Qu et al., 2019). The mycelial properties are also applied to their radiation shielding suits. The cell structures of the staff and the arrangements are based on 'hierarchical biomimetics' inspired from the naturally occurring optical structures such as the glass sponge (Sundar et al., 2003) and in hairs of polar bears (Preciado et al., 2008). The indigenous community focusses on applying myco-remediation for cleaning up the radioactive soils in their regions (Joshi et al., 2011; Whiteside et al., 2019) and the mycelium are also able to produce energy from radioactive sources (Dadachova et al., 2007).

Ch 2 Becoming Terrestrial: Of Climate Resilience Zones, Symbiotic Fabrication and Ecosystem Regeneration

1. Forest Seeders and Firefly Seeders in the Climate Resilience Zones

In the Climate Resilience Zones, replanting and reconnecting the old growth forests of the world brings back biodiversity. This is done with the help of Forest seeding devices that use 'seed balls' to establish new, old growth forests. These seed balls (Fukuoka, 1978; Guest, 2019) use a carbonised medium 'supercharged' with nitrogen and phosphorous from biological sources (Ngatia et al., 2019; Zhou et al., 2019; Zhu et al., 2019). Furthermore, the carbonised biochar medium is also inoculated with mycelium spores that are aid in establishing old growth forests, further enhancing the availability of nutrition rejuvenating the soil microbial health linking resource sharing root networks of plants to the old soils, spreading out mycorrhizal networks (Tsing, 2015; Whiteside et al., 2019). These seed balls being spread across in a randomised patterns using 'creative' forms of ecology (Miyawaki, 1999, 2004) by seeding old growth forests which offer far more resilient forms of biodiversity recovery. These forest seeders are used to restore the soils and regenerate terrestrial ecosystem services, complementing conservation efforts including biomass production from agriculture and forestry, storage, filtration and transformation of nutrients and water; biodiversity habitats; raw material sources and carbon sinks (Hammer et al., 2014; Lehmann & Joseph, 2009; Ngatia et al., 2019). Such a practise is based on a well-studied phenomenon of the 'Terra Preta' soils in the Amazons (Glaser et al., 2001).

2. Symbiotic fabrication technologies in the Sacred Forests: SymFabs

The SymFab units allow for localised, ecological forms of hi-tech production and consumption of advanced composites using "symbiotic manufacturing". The carbonisation of organic matter and fibres (Rajapaksha et al., 2015; Tsang et al., 2015) are applied to create effective replacements of high-performance composites from organic sources (Haneef et al., 2017) for socially useful fabrication systems (Smith, 2014) which are carbon sequestering by integrating into local industrial production for advanced technological applications (Lam, Azwar, et al., 2019; Wang et al., 2013). The pyrolytic carbonisation of these natural fibres when processed as bio-composites produced from organic fibres (Vold, 2015) with in situ processing of plant-based resins (O'Donnell et al., 2004; Turner et al., 2019) that can even be used to create high clay based ceramic electrodes (Alqadoori, 2018). Much of this is also possible with biomimetic forms of 'symbitronic computational interfaces' (Adamatzky, 2018; Gow & Morris, 1995) which mediate the interactions between these fabrication infrastructures to maintain and nurture the ecological processes.

Ch 3. Beyond Vaporware: Remembering the Blue Reparations Programs

1. Biomineralisers

Biomineralisers suggest a means to refine rare earth minerals from their ores using biological processes of biomining and bioleaching (Brisson et al., 2016; Qu et al., 2019; Thompson et al., 2018). Biomineralisers also apply these methods combining them with wastewater electrolysis for bioremediation (Contreras et al., 1981; Tartakovsky et al., 2011). Together with biochemical processes of microbial growth using a carbon medium providing for a proven, effective, and cheap means to clean up nitrates, phosphates and heavy metals from freshwater ecosystems (Mani & Kumar, 2014;

Wang, Yu, et al., 2019; W. Xu et al., 2015; Yang et al., 2019). The yields are in line with the needs of a slow fabrication process. Certain strains of fungi and species of plant organisms have been known to biologically leach minerals from ores as part of their metabolism (Brisson et al., 2016; Qu et al., 2019; Thompson et al., 2018). In addition to copper and gold production, biomining can also be applied in local scales to refine elements such as cobalt, nickel, zinc, and uranium. Biomining has been applied in the processing of sulfide and uranium ores (Schippers et al., 2013).

2. Rainmakers

Rainmakers are structures composed of autonomous modular/woven structures (Beeby & White, 2010; Rojas et al., 2013) that act as moisture accumulation devices which work on solar radiation alone (Zhao et al., 2019). They are meant to offer a last-ditch effort for harnessing moisture from atmospheric rivers and redirecting it to provide access to freshwater where it might be needed as rainfall becomes precarious for agroforestry needs and even used to build receding glaciers and polar ice caps with Ice Stupas. These Ice Stupas which are being implemented in the Himalayas (Divya A, 2020) may offer glimpses of possibilities given new cultural practises of replenishing and expanding new glaciers could emerge were they to be incentivised and linked to community action which perhaps would be better suited for local resilience. Rainmakers themselves advance these practises with advanced biological fabrication methods and materials (Attias et al., 2017; Haneef et al., 2017; Karana et al., 2018), tuned for using biomimetic principles and even some techniques of harvesting water from these atmospheric rives (H. Kim et al., 2017) and electric field propulsion for navigation (H. Xu et al., 2018).

3. Mineral Accretion Technologies: Electric Black Coral

The implementation of mangrove-coral sea walls is designed to provide protection from intense hurricanes and more energetic storm seasons in regions most vulnerable to climate extremes by absorbing the energy and from the subsequent storm surges and sea level rise (Blankespoor et al., 2017). These ecosystems like the climate resilience zones (CRZs) on land are meant to rehabilitate coastal communities by stemming storm energy but also provide sanctuary for corals in order to survive bleaching events (Greenwood, 2015), revive fisheries and sustenance to coastal communities (Sato et al., 2005) while also reviving marine biodiversity. These electrified reefs however are made from cathodic deposition of aragonite which can be used as architectural material (Hilbertz, 1979) which make possible highly resilient and accelerated artificial reefs scalable (Goreau, 2012). Known as the "biorock" method, it was showing possibilities for recovery of coral reefs at incredible rates even if damaged beyond repair (Goreau & Prong, 2017) by combining with traditional 'seeding' and coral nurseries and aid in rapid recovery (Chamberland et al., 2017).

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