THE CARBON COMMONS

DESIGN PRACTICE FOR A POST-GROWTH SOCIETY

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The Carbon Commons

Design practice for a post-growth society

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001 ■ Summary

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This dissertation examines how bio-based material design practice can contribute to a post-growth societal transformation by rethinking material, social, and cultural dimensions of technological production. I begin from the recognition that escalating climate and ecological crises signal the insufficiency of conventional sustainable design approaches. While sustainability-oriented innovation has led to many advances – renewable energy systems, bio-based materials, circular design strategies, and ecologically regenerative forms of agriculture or land management – these developments often remain embedded within growth-driven social and economic systems. Because modern economies are organized around the continuous expansion of production and consumption, sustainable design too frequently becomes constrained by the very dynamics that drive environmental degradation. As post-growth scholars argue, a society committed to limitless growth in material and energy consumption cannot remain within finite planetary boundaries.

This tension reveals a dual societal challenge. Technically, it calls for a transition away from fossil carbon toward regenerative design strategies: bio-compatible modes of production which return us to within planetary boundaries. Systemically, it calls for a transformation of the social structures, institutions, and cultural narratives that normalize high throughput to instead cultivate ways of living together that do more with less. Despite the relevance of post-growth debates to design, these arguments have received limited attention within sustainable and regenerative design discourse. This dissertation addresses that gap by exploring how bio-based material design practices can contribute to post-growth transitions and what such a reorientation implies for the infrastructures, social structures, and cultural imaginaries through which design operates.

To do so, the research engages with post-growth critiques of existing systems as well as alternative propositions for achieving social wellbeing within environmental limits. The analysis is structured across three layers of society: infrastructure, which concerns the material and technological means through which needs are met; social structure, which shapes how technologies are designed, organized, and governed; and superstructure, which encompasses the cultural values, ethics, and worldviews that inform what is perceived as desirable or necessary. The central chapters address these layers – first in turn, and then in synthesis – combining theoretical exploration with empirical and practice-based investigation.

Chapter 2 examines design at the infrastructural level by foregrounding materialization – the transformation of matter into technology – as a political process. Materials are not neutral: the selection of one material versus another aligns the designer with particular configurations of labour, energy, territorial control, and ecological impact. While contemporary sustainable design often focuses on substituting more sustainable or ethically sourced materials, such approaches do little to contest the dominant industrial structures organized around profit accumulation. Drawing on Illich's notion of conviviality, I explore convivial materialization as a potential design principle for post-growth infrastructure. Convivial materialization aims to challenge the industrial monopoly over how things are made, by emphasizing smaller-scale, accessible, autonomous, creative modes of production. For this, design must base itself on the use of convivial tools throughout supply and production chains: tools that are open-source, accessible, human-scale, low-energy, and adaptable to the creativity and aspirations of those who use them. Designers, in this framing, must critically navigate tensions between sustainable technologies that depend on complex, large-scale material supply chains and convivial technologies which may not deliver the kinds of scale, efficiency, quality, or comfort associated with current energy and material-intensive ways of living.

Chapter 3 shifts to the social structural layer by investigating how design can support alternative organizational models for managing regenerative infrastructures. Focusing on carbon sequestration as a critical climate mitigation strategy, the chapter proposes the concept of a Carbon Commons, to reframe sequestration as a social process through which communal objectives can be integrated into the technical goal of removing CO^2 from the atmosphere. Empirically, the chapter presents the results of a living lab, in which a carbon-sequestering garden was co-designed and built with a community centre. The living lab showed that, when treated as a commoning practice, carbon sequestration can be designed to regenerate ecosystems while simultaneously provisioning communities, as sequestered carbon can form the material basis for diverse bio-based and green infrastructures. The collective organization of sequestration further generates social value: it creates opportunities for people to collaborate, share, make decisions, and shape their environments together. In this way, sequestered carbon can become not only a regenerative resource but a catalyst for socio-economic relations that replace transactional, market-based logics with reciprocity, shared responsibility, and mutual care. However, governance remains a key challenge, as tensions between self-organization, local capacities, funding, public-sector support, and regulatory legitimacy test efforts to replicate and sustain such initiatives.

Chapter 4 turns to the superstructure layer by rethinking cultural assumptions about time. Because design materialises futures in the present, it is always entangled with temporal imagination. For post-growth design, a key question is whether design practices reproduce unsustainable futures or cultivate ones that remain open, livable, and regenerative. This chapter argues that engaging more-than-human temporalities is essential to this shift, as it attunes designers to the long-term ecological consequences of material choices. Where dominant conceptions of time are linear, measurable, and tied to progress, ecological and social systems unfold through diverse and relational rhythms. Aligning design with these rhythms can help anticipate unintended consequences and create space for regenerative possibilities to emerge. To explore this, the chapter foregrounds two interrelated capacities: noticing, which expands sensitivity to situated interdependencies, and care, which translates this awareness into sustained engagement. These ideas are explored through a real-world project: an experimental music festival stage designed to remain in its forested setting beyond the event itself. By anticipating its own transformation over time, the project reimagines material culture as contingent and evolving, illustrating how design might create regenerative 'ruins' that solicit more-than-human collaboration. At the same time, the chapter shows that this temporal reorientation is not without tension. Different temporalities foreground different values, often producing conflict between the pressure to deliver outcomes and the forms of collectivity and self-actualisation that emerge through slower, more responsive practices. Within this tension, design becomes less about resolution and more about learning to work with competing temporal demands.

Chapter 5 synthesizes insights from the earlier chapters by positioning regenerative design as a practical pathway for embedding post-growth principles into real-world projects. Through four design experiments, the chapter demonstrates how regenerative approaches can materialize post-growth principles across infrastructure, social structure, and superstructure. These experiments showed how design practices at different scales can reinforce one another, generating feedback loops that restore ecological systems, support convivial modes of production, and cultivate countercultural imaginaries oriented toward sufficiency, reciprocity, and care.

Chapter 6, the discussion chapter, synthesizes the findings by considering what a post-growth design practice entails through three interrelated lenses: imaginaries, materials, and design capacities.

Chapter 7, the conclusion chapter, summarizes the contributions, lessons learned, limitations, and future directions for research.

Together, this dissertation presents a cohesive argument: design can play a transformative role in advancing post-growth futures, but only when it critically confronts the structural drivers of ecological crisis and reorients its practices toward convivial, commons-based, and care-centered modes of world-making. Importantly, I argue that such a confrontation must occur through bio-based material practice, not apart from it, as societal transformation depends on reconfiguring the material foundations of the real economy – the means through which needs are collectively met. Ultimately, I call for a shift from designing for sustainability within growth-driven systems to designing toward post-growth futures – futures in which human and more-than-human flourishing guide technological development, and where design becomes a practice of ecological responsibility, social solidarity, and cultural transformation.

002 ■ ■ ■
Introduction

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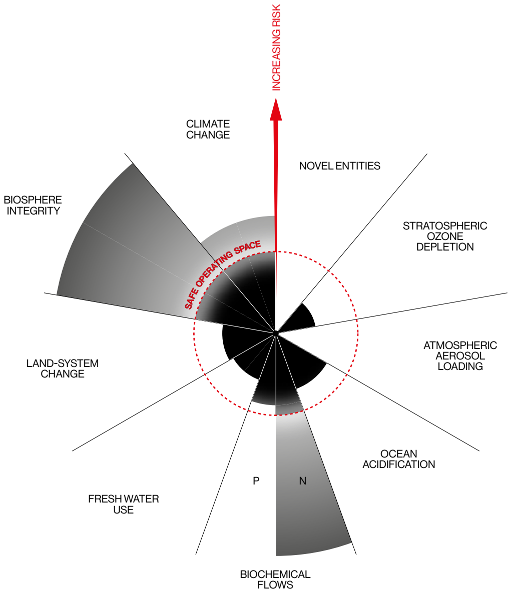
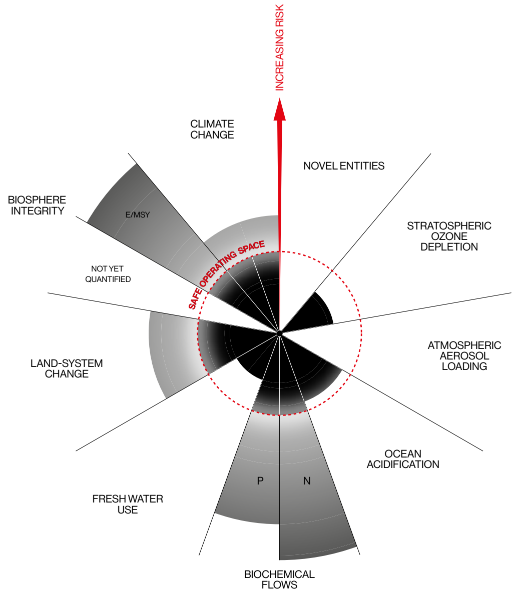
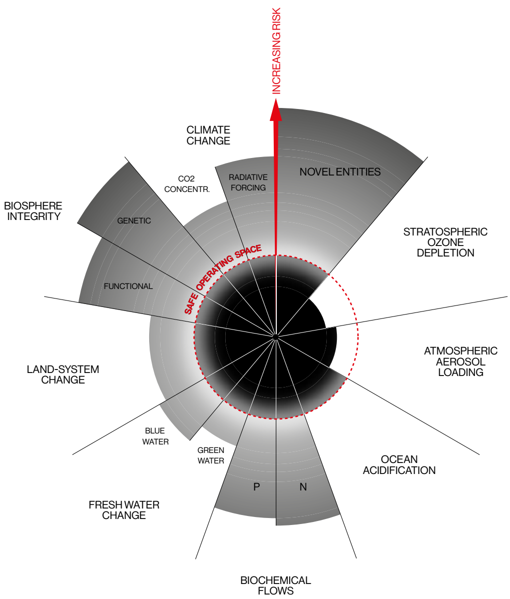


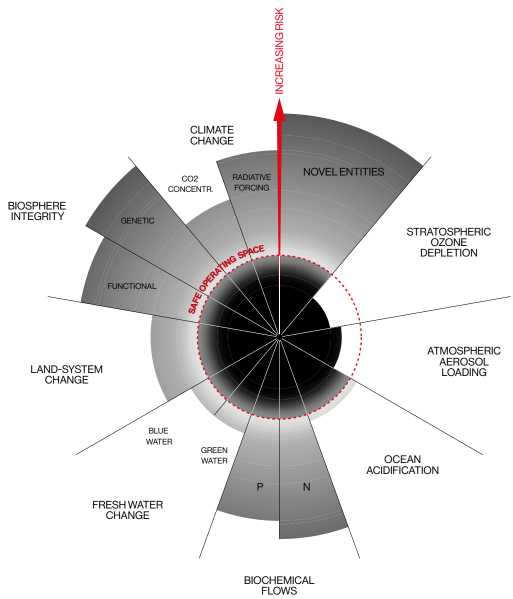
2009
7 boundaries assessed, 3 crossed



2015
7 boundaries assessed, 4 crossed



2023
9 boundaries assessed, 6 crossed



2025
9 boundaries assessed, 7 crossed

1.1.

RETHINKING SUSTAINABLE DESIGN FOR THE CLIMATE CRISIS

The accelerating climate crisis highlights the limitations of current approaches to sustainable design as a sufficient response to environmental breakdown. Although design, through its traditional role in technological development, has produced numerous innovations intended to mitigate environmental harm, mainstream approaches to sustainability have remained largely constrained by the imperatives of market expansion and financial profit (Escobar, 2018; Fry 2009; Manzini, 2015; Tonkinwise, 2015). As a result, efforts under the banner of sustainability have struggled to influence growing fossil carbon emissions, or the overshoot of planetary boundaries, at a time when societies are facing deepening climatic uncertainty (Latouche, 2009; Steffen et al., 2015).

Post-growth scholarship offers an alternative framing of this predicament: in an economy organized around aggregate growth of what is most profitable, sustainability solutions limited to technical interventions are unlikely to be sufficient to reign in carbon emissions in the timelines necessitated by climate change (Hickel, 2020; Jackson, 2017; Parrique, 2019). Instead, what is required is a reorientation of the political economy – how and why we produce, distribute, and consume resources – toward meeting human needs within ecological limits. Within this vision of a post-growth society – at once a critical assessment of what is wrong and a vision for what could be - design necessarily holds a critical role, as it is a discipline at the interface of the technical and the social dimensions of society. But to be an effective agent of change, design must extend beyond the development of sustainable, low-carbon technologies alone, equally working to build relations necessary for societal transformation and ecological regeneration, grounded in fairer systems of resource distribution and a culture of care and reciprocity with each other and our environment. This dissertation critically reassesses and builds on the traditions of design for sustainability to examine how design might contribute to a post-growth societal transformation, where environmental and social wellbeing reinforce each other.

Figure 1
The evolution of the planetary boundaries framework. Since the first assessment in 2009, human activities have led to increasing overshoot of planetary boundaries. Adapted from: Stockholm Resilience Center (2025), licensed under CC BY 4.0.

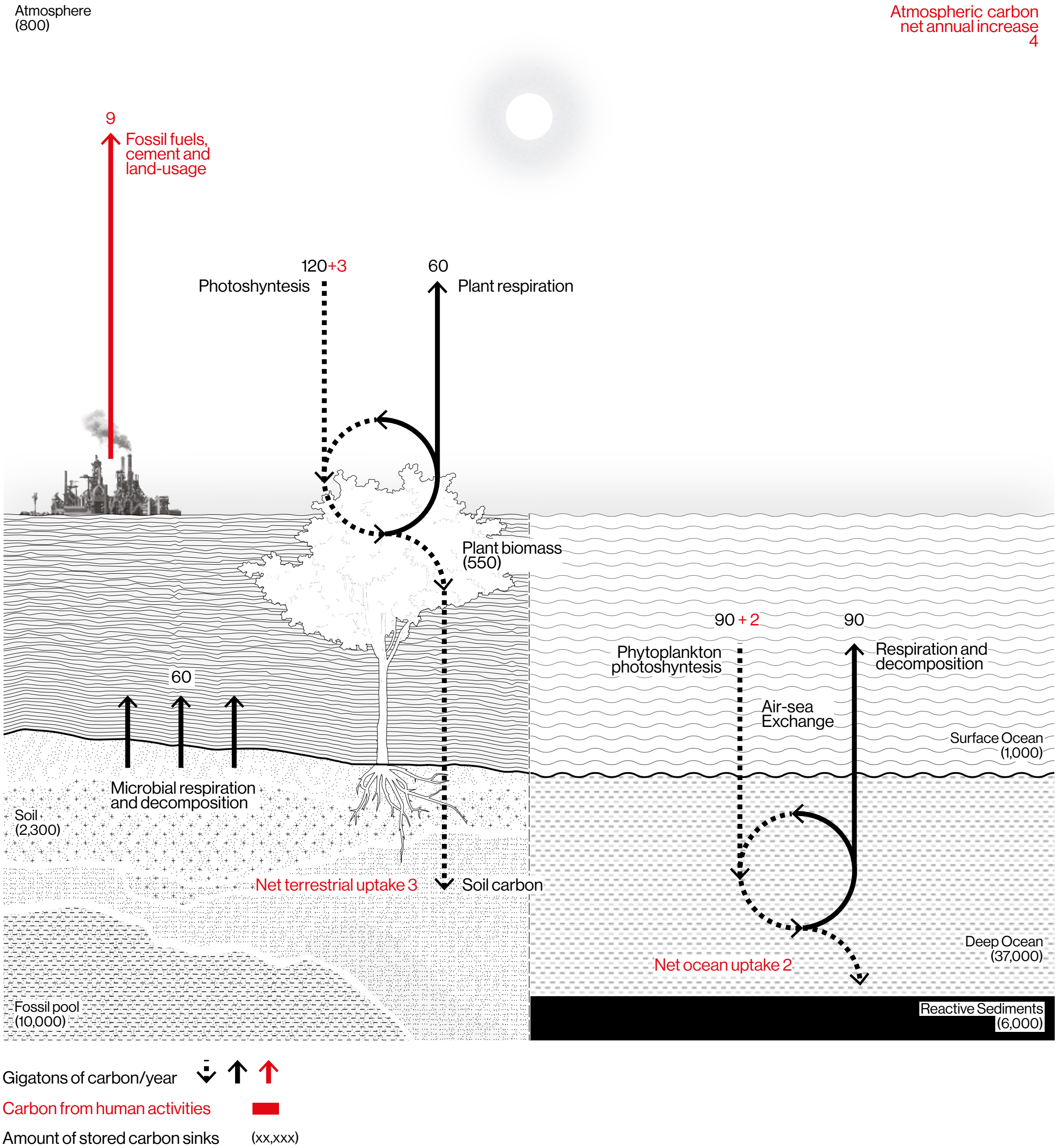
1.2.

A POST-GROWTH PERSPECTIVE ON THE LIMITATIONS OF SUSTAINABLE DESIGN

Climate change is one of the foremost existential challenges to humanity. Over the last 300 years, human activities have increased atmospheric carbon (CO_2) to levels not seen in 14 million years, destabilizing the climatic conditions under which civilizations have flourished (Hönisch et al., 2023). For those working in design, this should give pause. The modern world is fundamentally a world designed and built from fossil carbon (Malm, 2016). Products, infrastructures, cities, and institutions largely depend on a one-way flow of carbon: from the earth's bowels and into power plants, petrochemical refineries, cement kilns, and steel mills – ancient plant matter ultimately destined to become atmospheric CO_2 or latent material dispersed into the environment. As shown in Figure 1, this has had a significant disruption on the global carbon cycle. Because design shapes these material and energetic flows, rethinking how we design with carbon – shifting from fossil carbon to long-lived, regenerative, bio-based carbon – must be central to any meaningful climate response.

Yet this shift cannot be understood in isolation from the broader socio-economic forces that govern how materials, energy, and thus carbon circulate. The fossil era coincides with what Steffen et al. (2015) call the Great Acceleration: an exponential rise in population, GDP, energy use, and material throughput, mirrored by Earth-system changes such as atmospheric CO_2, ocean acidification, biodiversity loss, deforestation, and rising temperatures, as shown in Figures 3 and 4. Humanity now exceeds seven of nine planetary boundaries and is rapidly approaching the remaining three (PIK, 2025; Richardson et al., 2023). The rate of climate change is accelerating, with projections placing us near the Paris 1.5°C threshold far earlier than anticipated (Hansen et al., 2025). This intensifies the risk of crossing major tipping points, including collapse of the Atlantic Meridional Overturning Circulation, permafrost thaw, polar ice loss, and large-scale ecosystem collapse (IPCC, 2022; Steffen et al., 2018). Exceeding these tipping points will drastically compound risks, as one impact can reinforce the likelihood of another (Armstrong McKay et al., 2022), potentially resulting in a state of "hothouse Earth" characterized by uninhabitable regions, agricultural disruption, and deadly wet-bulb temperatures (Deutloff et al.,

Figure 3
The carbon cycle is the natural process of carbon atoms travelling between the atmosphere, oceans, soil, and living organisms. In addition, vast quantities of carbon lay dormant in carbon sinks. Human activities have disrupted this delicate balance by introducing an additional uni-directional anthropogenic flow from the fossil pool to the atmospheric and oceanic sinks. Adapted from US D.O.E. (2012) via Wikimedia Commons (public domain).


Atmosphere
(800)
Atmospheric carbon
net annual increase
4
9
Fossil fuels,
cement and
land-usage
120+3
Photoshyntesis
60
Plant respiration
Plant biomass
(550)
60
Microbial respiration
and decomposition
Soil
(2,300)
Net terrestrial uptake 3
Soil carbon
Fossil pool
(10,000)
90 + 2
90
Phytoplankton
photoshyntesis
Respiration and
decomposition
Air-sea
Exchange
Surface Ocean
(1,000)
Deep Ocean
(37,000)
Net ocean uptake 2
Reactive Sediments
(6,000)
Gigatons of carbon/year
Carbon from human activities
Amount of stored carbon sinks
(xx,xxx)

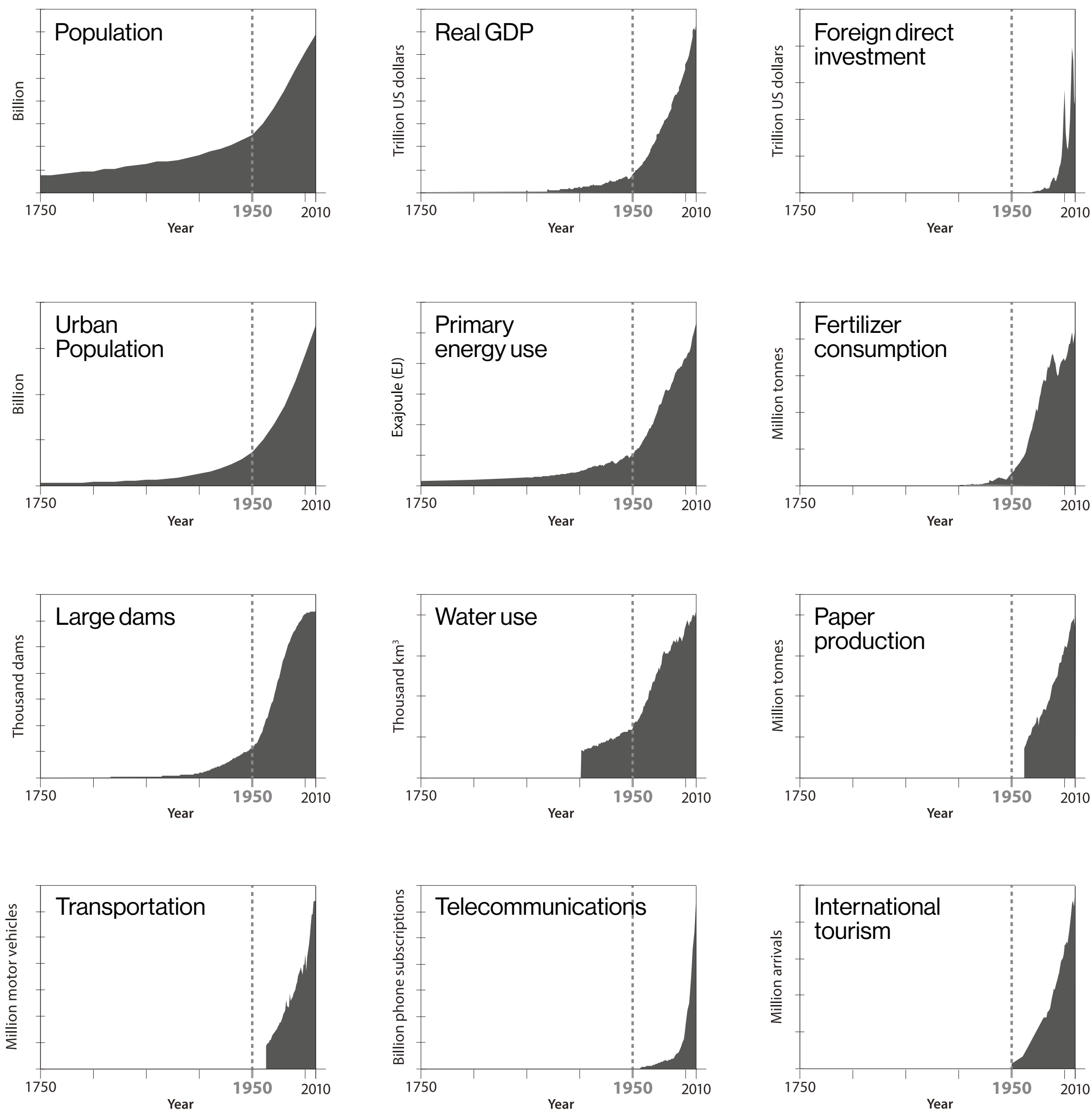
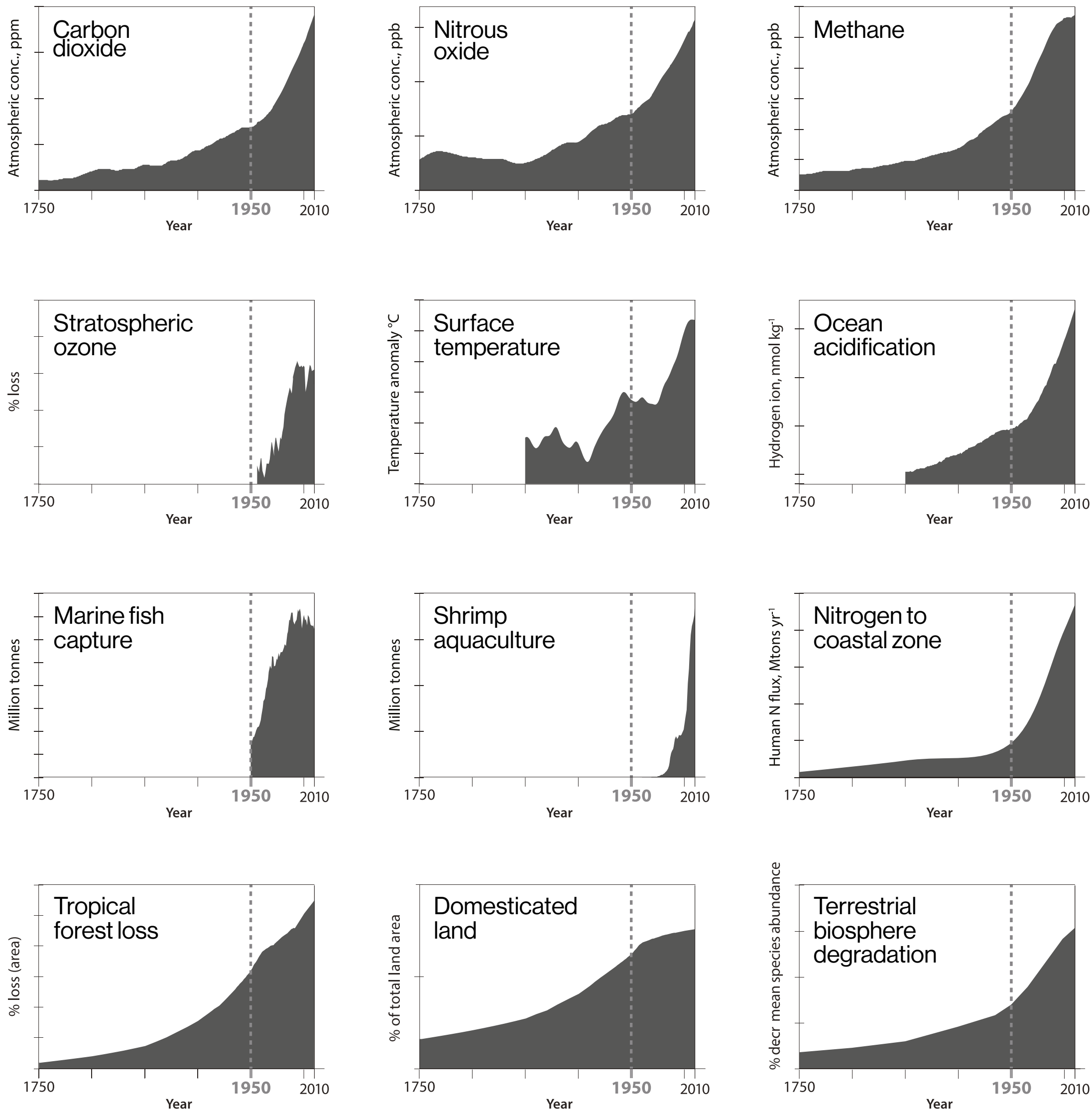


Figure 2
The great acceleration is understood as the moment in history where socio-economic trends (left) and earth-system trends (right) exponentially increase in the mid-20th century. Adapted from Steffen et al. (2015).


Carbon dioxide
Atmospheric conc., ppm
Nitrous oxide
Atmospheric conc., ppb
Methane
Atmospheric conc., ppb
Stratospheric ozone
% loss
Surface temperature
Temperature anomaly °C
Ocean acidification
Hydrogen ion, nmol kg⁻¹
Marine fish capture
Million tonnes
Shrimp aquaculture
Million tonnes
Nitrogen to coastal zone
Human N flux, Mtons yr⁻¹
Tropical forest loss
% loss (area)
Domesticated land
% of total land area
Terrestrial biosphere degradation
% decr mean species abundance
1750
1950
2010
Year

2025). Worryingly, ecological disruptions compound social risks such as displacement, conflict, poverty, and political instability (IPCC, 2022).

Against this backdrop, scholarship on limits to growth highlights how economic expansion is structurally embedded within global capitalist society, raising fundamental questions about its ecological viability (Hickel, 2020; Jackson, 2017; Kallis et al., 2025; Schmelzer et al., 2022). As Marx observed, the capitalist mode of production is intrinsically expansionary, organized around the M–C–M′ circuit of accumulation. This formula encapsulates the foundational logic of capitalism: investing money (M) to produce commodities (C) that yield more money (M'), a process made possible by private ownership of the means of production. For the better part of a century, economic expansion was not perceived to be problematic from an environmental perspective. When maps still contained blank spots, nature was considered inexhaustible, providing an endless supply of materials and energy, capable of absorbing ever-more human waste. This assumption permeated classical economic thought – including Marxist perspectives – which treated environmental conditions as external and unchanging (Georgescu-Roegen, 1971). But by the mid-twentieth century, it became clear that an economy premised on exponential growth was colliding with material and energetic limits. The Club of Rome's Limits to Growth (Meadows et al., 1972) demonstrated that perpetual expansion in a finite system risks systemic collapse, laying the foundation for ecological economics (Daly, 1996; Costanza et al., 1997).

Alongside ecological critiques, a distinguished tradition of critical thought has shown that the capitalist relations of production which underpin growth also produce social ills. From Marx's analysis of exploitation and alienation (1887) to Marcuse's critique of the one-dimensional society (1964) and Piketty's demonstration of capitalism's structural inequality (2014), scholars have argued that a society organized around capital accumulation as a primary objective generates systemic inequality, domination, and a loss of freedom. Postcolonial thinkers such as Fanon (1961) and Rodney (1972) further show how colonial extraction and racial hierarchies were foundational to such accumulation. Feminist scholars likewise reveal how accumulation depends on the devaluation and appropriation of unpaid care work, domestic labor, and social reproduction, still overwhelmingly performed by women (Mies, 1986). Contemporary research links global value chains, resource extraction, and financialization to persistent inequality and unmet social needs (Hickel, 2020). Together, this body of work illustrates that ecological crises and social injustices arise from the same expansionary logic of capital accumulation.

This recognition has catalyzed post-growth and degrowth scholarship, which aims to study how societies can achieve social wellbeing within planetary limits (Hickel, 2020; 2021; Kallis et al., 2025; Schmelzer et al., 2022; Jackson, 2017). Emerging from ecological economics, political ecology, and critical social theory, post-growth research begins by critically questioning both the ecological sustainability and social necessity of continually increasing GDP – a measure of economic throughput – especially in high-income countries where there is enough productive capacity to meet basic needs (Millward-Hopkins et al., 2020). Under the umbrella of post-growth, there are many related approaches such as Doughnut Economics (Raworth, 2018), wellbeing economics (Pouw, 2020), steady-state economics (Daly, 1977), and degrowth (Hickel, 2021). While their recommendations vary, these perspectives "converge on the need for qualitative improvement without relying on quantitative growth, and on selectively decreasing the production of less necessary and more damaging goods and services, while increasing beneficial ones" (Kallis et al., 2025, p. 62). They propose an economic shift from expansion to concepts like frugal abundance (Plomteux, 2024), conviviality (D'Alisa et al., 2015), or buen vivir (Kothari et al., 2014); emphasizing those things most important for achieving a good life. For design, this raises a crucial question: how can design practice contribute toward a post-growth societal transformation?

Addressing this question requires situating post-growth design within the longer trajectory of design for sustainability, a field that has developed since at least the 1960s through multiple, often overlapping, approaches. Early contributions foregrounded environmental responsibility and resource limits, framing design as a means to mitigate the ecological harms of industrial society (Fuller, 2008; Papanek, 1971). Subsequent approaches centered on eco-design, life-cycle assessment, and industrial ecology sought to reduce environmental impacts through improved efficiency within existing production systems (Graedel & Allenby, 1995; Fiksel, 1996). From the late 1990s onward, sustainability-oriented design expanded to include biologically inspired and regenerative paradigms such as biomimicry and cradle-to-cradle design (Benyus, 1997; McDonough & Braungart, 2002), alongside social and practice-oriented perspectives that shift attention from products to everyday routines, services, and socio-technical systems (Manzini, 2007; Shove et al., 2012). More recently, critical and speculative approaches, including work in environmental media and design futures, have examined how design mediates environmental knowledge, imaginaries, and power relations under conditions of planetary crisis (Bendor, 2018; Dunne & Raby, 2013). While these strands differ substantially in scope and method, many remain broadly compatible with economic growth as an underlying societal objective.

Within this diverse landscape, the dominant institutional and policy framework for sustainable design remains anchored in assumptions of continued economic expansion (OECD, 2011; Gareth et al., 2015; Shieh et al., 2025). Under the banner of green growth, approaches such as eco-efficiency, design for a circular economy, and circular product–service systems seek to reduce environmental impacts through resource efficiency, r-strategies, and service-based business models (Stahel, 2016; Bocken et al., 2014; Tukker, 2015). While these approaches have generated important technical and organizational innovations, they rarely confront the underlying drivers of unsustainability and tend to remain subservient to growth-oriented logics that prioritize private-sector competitiveness, scalability, and consumer appeal over systemic transformation (Fry, 2009; Hobson & Lynch, 2016; Corvellec et al., 2021).

Significant physical constraints and empirical evidence suggest that a circular economy is technically unfeasible when economic growth is assumed. Circular systems are limited by material degradation and by the simple fact that, in a growing economy, available waste streams are insufficient to replace continued material extraction (Corvellec et al., 2021). More fundamentally, the circular economy presupposes a rapid and comprehensive transition to renewable electricity, to replace existing fossil-based power generation and to supply additional demand from electrified transport and heating. Although renewable energy capacity has expanded rapidly, it has largely supplemented rather than displaced fossil energy, which continues to grow globally, a trend exacerbated by nuclear plant retirements over the past decade (IEA, 2024). Moreover, as Christophers (2024) demonstrates in his detailed analysis of renewable energy markets, prevailing market forces are failing to deliver the scale and speed of investment required, given the relatively low profitability of renewables. Together, these dynamics underscore the structural limits of capitalist market mechanisms in responding adequately to climate change via green growth.

Among the various strands of sustainability-oriented design, regenerative design aligns most closely with the concerns raised by post-growth scholarship and provides a technical foundation for much of the work that follows. Emerging primarily from architecture and landscape design, it seeks to situate human activity within living systems and bioregions, emphasizing ecological reciprocity, co-evolution, and long-term regeneration (Lyle, 1994; Reed, 2007). Like ecological economics, regenerative design challenges the separation of production from ecological processes by framing design as embedded within living systems rather than as a driver of efficiency or growth. However, despite this ecological orientation, regenerative design has often remained under-theorised in relation to broader political and economic questions. Issues of growth, accumulation, governance, and power are frequently left implicit, allowing regenerative principles to be absorbed into growth-oriented agendas.

From a post-growth perspective, it follows that to meaningfully address the climate crisis, design must integrate regenerative strategies for sustainability with alternative socio-economic and cultural systems that determine how energy and materials are used. This means shifting from designing for growth – more products, more markets, more throughput – to designing for ecological integrity, sufficiency, and wellbeing. Furthermore, and moving beyond critique, post-growth perspectives provide a framework for this reorientation, enabling us to reconceive design as a practice that supports regenerative systems, strengthens collective wellbeing, and cultivates ways of living that do not depend on perpetual accumulation.

Within this shift, designing with carbon – especially through long-lived, regenerative, bio-based materials – takes on new significance. Such materials can help mitigate climate change, regenerate ecosystems, and create socially relevant infrastructure simultaneously. But their transformative potential emerges only when embedded in a broader post-growth design paradigm equally aimed at transforming society writ large, from its growth-oriented political economy to its short-term consumer culture. Without this deeper alignment, even the most regenerative material practices risk being absorbed back into the growth logic that underlies the climate crisis itself.

1.3.

POST-GROWTH PERSPECTIVES ON TECHNOLOGY, POLITICAL ECONOMY, AND CULTURE

In this dissertation, I examine design practices that may support the transition to a post-growth society, while critically building upon design for sustainability. While I am particularly focused on how designers can work with carbon to address climate change, a post-growth framing implies that technical design-for-sustainability strategies must be rooted in alternative socio-economic relations and values. Post-growth perspectives expand attention from technological solutions to broader questions about how society provisions itself (Kallis et al., 2025). The question of provisioning involves not only technological means, but also the organization and distribution of resources among society, and the shared values that guide this process.

This perspective resonates with Andrew Feenberg's (1999; 2017) account of technology as both socially shaped and socially shaping, expressed through what he terms the "design codes" of society. These codes translate worldviews and interests into technical languages, often concealing their social significance behind an appearance of technical necessity. As Feenberg notes, design codes sit at the intersection of function and meaning, making them a site of social struggle over what technologies are, what they do, and what they should do. From this view, the potential value of design for post-growth lies in challenging dominant codes and developing democratic alternatives that embed wellbeing and collective interests into the development and distribution of technology (Bendor, 2022; Ibid.). In this way, design extends beyond shaping material outcomes to questioning why production occurs, who decides, and what values guide these processes.

To understand the dynamics between technology and the social forces that shape its design, development, and distribution, it is useful to adopt a structured analytical framework. For this purpose, I draw on Marvin Harris's cultural materialism, which offers a three-layered model of society, shown graphically in Figure 5. Harris (1979, p. xi) proposed a scientific theory of society "based on the simple premise that human life is a response to the practical problems of earthly existence." In this view, all societies depend on their environment to develop technologies that meet material needs, while also constructing socio-cultural arrangements to organize themselves in relation to those environments. Harris models society 'from the ground up' across three interrelated layers:

1. **infrastructure** comprises the technological means through which a society secures its needs from the environment

2. **social structure** refers to the political-economic systems that organize the production and distribution of infrastructure

3. **superstructure** encompasses the beliefs, values, and norms that shape cultural meaning and guide understandings of purpose.

This three-layered model provides a structure through which to examine the role of design in supporting a transition toward a post-growth society. It is worth acknowledging an apparent tension between adopting an analytical framework and the holistic, relational orientation that otherwise guides this dissertation. A structured framework risks fragmenting what is in practice an integrated reality, and sits uneasily with a research-through-design methodology that prioritizes the particular, the situated, and the experiential over the abstract and the categorical. However, I have found it useful to have a conceptual scaffold as a means of organizing the investigation and pulling on specific threads in each chapter. Harris's three-layer model is therefore used here in a limited and provisional way – to map the existing literature and sharpen the research questions, rather than as an organizing logic for the design work itself, which proceeds from a more integrative, practice-based sensibility.

With this in mind, in the following section each layer is considered in turn, drawing together insights from design research alongside concepts from post-growth discourse that suggest constructive directions for design practice. Based on this, key research gaps will be identified and refined into research questions which will be explored in the subsequent chapters.

1.3.1.

THE INFRASTRUCTURE LAYER: DESIGNING POST-GROWTH TECHNOLOGY

The infrastructure layer can be understood as the technical systems through which societies satisfy their needs. Today, this layer – alternatively known as the Technosphere – has grown to a staggering scale, now outweighing the entire mass of the biosphere (Elhacham et al., 2020) and constituting the primary driver of global carbon emissions through its dependence on fossil-ener-

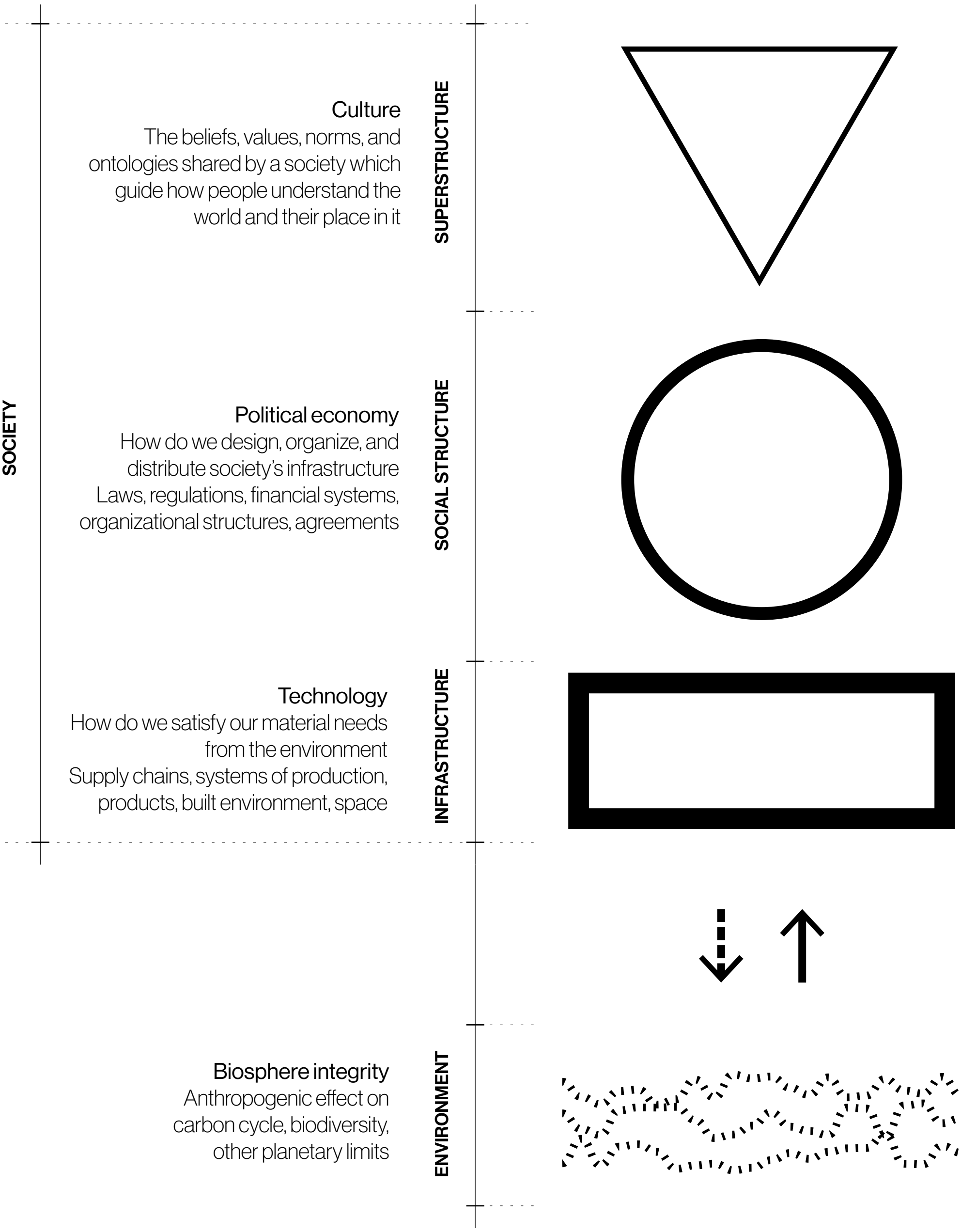

SOCIETY
SUPERSTRUCTURE
Culture
The beliefs, values, norms, and ontologies shared by a society which guide how people understand the world and their place in it
SOCIAL STRUCTURE
Political economy
How do we design, organize, and distribute society's infrastructure
Laws, regulations, financial systems, organizational structures, agreements
INFRASTRUCTURE
Technology
How do we satisfy our material needs from the environment
Supply chains, systems of production, products, built environment, space
ENVIRONMENT
Biosphere integrity
Anthropogenic effect on carbon cycle, biodiversity, other planetary limits

Figure 4 (left)
Marvin Harris' 3-layered societal model is used to structure the chapters of this dissertation. For each layer, a post-growth perspective is used to analyze the current situation and propose altneriatives which are explored through design. Based on Harris (1979).

gy-intensive materials, manufacturing, and logistics. Design plays a central role in shaping this infrastructure; through decisions about materials, technologies, and systems, designers directly participate in expanding (or reconfiguring) the Technosphere and its impact on carbon flows. Yet modern infrastructure continues to grow even where there is sufficient productive capacity to meet fundamental needs, particularly in high-income regions (O'Neill et al., 2018). This expansion is driven not only by economic forces but also by cultural assumptions embedded in design and innovation: the persistent belief that technological advancement equates to human progress (Harvey, 2010; Latouche, 2009), even when such advancement reinforces carbon-intensive technological lock-in. However, as Illich (1973) observed, the commodification of human needs tends to generate new forms of dependency and artificial demand, whereby goods and services create the very needs they claim to satisfy. This dynamic, further elaborated by Baudrillard (1998) and Jackson (2017), perpetuates a self-reinforcing cycle of consumption in which new commodities continually stimulate new desires, driving escalating resource extraction, material throughput, and waste – particularly in the form of CO^2. In this sense, design is not merely a response to needs; it actively constructs them, embedding societies deeper into unsustainable technological trajectories.

Well-intentioned sustainable design strategies – such as R-strategies or the adoption of sustainable materials – seek to mitigate these impacts through technological interventions (Bocken et al., 2016; Geissdoerfer et al., 2017). However, by addressing existing technical systems downstream of market imperatives and consumption-driven growth, the systemic potential of such interventions is limited. As Parrique (2019) makes exhaustively clear, the continued absence of absolute decoupling between economic growth and carbon emissions underscores the limitations of efficiency-based design approaches within growth-dependent systems.

Such evidence highlights the need to examine and challenge the underlying values (see superstructure) that guide sustainable technological development. Herbert Marcuse's concept of technological rationality (1964) remains pertinent here. According to Marcuse, efficiency, productivity, and technical control constitute the dominant, 'rational' measures of value in industrial society. Under these conditions, technology develops according to the priorities of vested interests, particularly the accumulation of capital. When technological rationality becomes the metric of evaluation, the role and agency of design is limited to that of a cog in a giant machine to maximize profits, which subordinates goals like environmental wellbeing, social use value or democratic participation in determining which technologies are produced and who benefits (see social structure). We see this with the roll-out of large, luxury, electric SUVs instead of low-cost and effective public transit; or with sustainable luxury fashion produced alongside unsustainable fast fashion, often by the same companies. Without critically challenging technological rationality, sustainable design remains constrained by profit objectives, while ecological and social welfare are of secondary concern – if at all.

In contrast to technological rationality, Ivan Illich's concept of conviviality (1973) offers an alternative value set to reorient technological design within a post-growth context (Schmelzer, 2022). In contrast to efficiency and productivity as design metrics, Illich imagines infrastructure based on the use of convivial tools: productive systems designed to enhance individual and collective autonomy rather than foster dependency on industrially produced commodities. Autonomy, here, is defined as the capacity to control the use of resources to satisfy one's own needs, to shape one's material reality according to needs, tastes, desires, creative aspirations, without infringing on the autonomy of others. Illich contends that unconstrained industrialization produces supposedly indispensable tools which, paradoxically, constrain personal freedom and exacerbate social frustration – a phenomenon he terms the "modernization of poverty" (Illich, 1973, p.67). Convivial tools, by contrast, enable individuals to exercise control over resources and the satisfaction of their needs. Convivial tools are compatible with low-energy, low-carbon socio-technical systems, as they minimize material and energy throughput by privileging human-scale, durable, and locally maintainable technologies over energy-intensive, centralized systems. Transitioning toward a post-industrial, convivial mode of production, should therefore create opportunities for diversified, locally adapted, collaborative, and environmentally regenerative forms of innovation (Deriu, 2015). In this sense, the shift from technical rationality to conviviality entails the development of techno-social systems that support personal creativity, collective initiative, and the generation of value beyond purely commodified measures – while disengaging from the fossil carbon economy.

Conviviality appears to offer a coherent framework to consider infrastructure for a post-growth society and is a recurring concept within post-growth scholarship (Muraca & Neuber, 2018; Vetter, 2018; Samerski, 2018; Ralph, 2021; Deriu, 2015). However, explicit attention to its application in design practice is still limited. One important theoretical contribution is Vetter's Matrix of Convivial Technologies, which defines five conviviality dimensions and connects these with different product design phases, highlighting the potential applicability and systematization of Illich's concepts into a coherent method. In addition to design theory, compelling precedents can be found in practice. A notable early example is the Whole Earth Catalog (Brand, 1968–1972), which functioned as a proto-design platform by curating tools, technologies, and knowledge intended to empower individuals and communities to meet their needs autonomously. Closely aligned with Illich's notion of convivial tools, the catalog foregrounded accessibility, user agency, repairability, and ecological awareness, prefiguring many principles central to Vetter's (2018) understanding of 'convivial technologies'. Contemporary expressions of these ideas emerge in contexts such as DIY maker communities (Smith et al., 2013), permaculture networks (Ferguson & Lovell, 2014), tool libraries and repair cafés (van der Velden, 2021), or urban and rural commons (Bollier, 2024). Low Tech Magazine (2025) serves as a notable contemporary hub, showcasing resource-conscious innovations – such as solar-powered websites, low-tech heat pumps, or open-source electric cargo-bike designs – illustrating how convivial practices can achieve reductions in energy use and carbon emissions (Low Tech Magazine, 2025).

A significant gap nevertheless remains when questions of scale are considered, which I investigate in Chapter 3. Aforementioned examples – like nearly all contemporary infrastructure – still largely depend on industrial raw-material supply chains and fossil capital. This does not mean that conviviality requires simply replicating vertically integrated, globe-spanning supply chains with convivial tools. Rather, it invites a distinction between scaling up and scaling out. This distinction between reframes the relationship between conviviality and contemporary digital infrastructure. Rather than treating standardization and digital connectivity as antithetical to convivial values, they can be understood as potential enablers of horizontal diffusion, allowing locally embedded practices to remain interoperable, replicable, and mutually reinforcing across contexts (Bollier & Helfrich, 2019; Bauwens et al., 2019). Platforms that facilitate tool sharing, open-source material databases, and distributed fabrication networks illustrate how digital means can serve convivial ends, provided they are designed to enhance autonomy rather than capture dependency (Carson, 2021). This aligns with emerging models of commons-based peer production and "design global, manufacture local" systems, in which shared digital knowledge supports localized, context-sensitive making (Bauwens et al., 2019). It also points to the importance of resisting extractive platform logics that centralize control and generate dependency (Srnicek, 2017). Taken together, this suggests the potential of prioritizing the horizontal diffusion of many small, locally embedded, and interconnected practices over the expansion and centralization of production within large, integrated systems (Bollier & Helfrich, 2019). However, we must equally note that many of the digital tools that may enable such a horizontal diffusion uneasily require certain industrial material inputs that are themselves dependent on non-convivial modes of production (Crawford, 2021).

The challenge then is to articulate a more general understanding of what convivial materialization processes could look like, expanding conviviality back across the productive webs that transform matter into products (including, importantly, digital and networked tools that may appear to support more convivial modes of production at the end of pipe). Some industrial supply chains may well remain necessary. But developing clearer criteria would allow for a more honest discussion about which infrastructures we might choose to forgo, and – especially for designers – how to design in ways that do not depend on the alienation of workers or the extraction of distant resource zones. This points toward a shift from globalized, carbon-intensive industrial production to more localized, bioregional, sustainable, and socially embedded systems of supply and production (Lyle, 1994; Reed, 2007; Wahl, 2016). Within this context, examining how designers select materials – what values shape those choices, and whose interests they support or exclude – becomes a crucial bridge. Such inquiry links the technical decisions of material design to the wider socio-political implications of production, enabling design practice to participate directly in shaping the material foundations of a post-growth society.

1.3.2.

THE SOCIAL STRUCTURE LAYER: DESIGNING WITHIN A POST-GROWTH POLITICAL ECONOMY

The social-structure layer, often described as the political economy, encompasses the systems through which societies organize the production and distribution of resources. While neoliberal free-market capitalism – advanced in the 1980s through deregulation, privatization, and market liberalization under leaders such as Reagan and Thatcher (Harvey, 2005) – has shaped much of the contemporary global order, it represents one contiguous expression of a wider industrial growth regime which future historians might point to as the defining characteristic of the modern era. State-led economies, including China's, similarly rely on capital accumulation, competitive market mechanisms, and large-scale industrial expansion, differing in governance but not in their orientation towards increased material and energy use (National Bureau of Statistics China, 2024). Across these contexts, growth and technological development are framed as efficient pathways to prosperity, obscuring their profoundly political character (Feenberg, 1999; Klein, 2007; Varoufakis, 2013). Decisions about the design and ongoing development of the technosphere remain largely inaccessible to the public, concentrated within technocratic, authoritarian, or oligarchic elites, while productive forces continue to be organized around maximizing GDP and industrial throughput (Harvey, 2005; Polanyi, 1944).

Post-growth scholarship highlights the limitations of economic systems organized around quantitative accumulation, whether market-driven or state-led, as they are implicated in ecological breakdown but also fail to meet social needs adequately (Hickel, 2020; Jackson, 2017; Raworth, 2018). Accumulation as an organizing principle channels investment toward high-return, often carbon-intensive sectors such as heavy industry, aviation, luxury construction, while essential but less profitable services remain underserved (Hickel, 2020). Furthermore, much that is excluded from financial calculus nonetheless sustains accumulation, as private interests benefit from what Harvey (2004) terms "accumulation by dispossession," whereby externalized costs such as CO_2 emissions and unpriced subsidies such as unpaid care work are systematically appropriated to support ongoing capital accumulation.

It is this wider political-economic context, sustainable design is routinely constrained by the logics of growth, positioning technical solutions downstream of the economic forces that drive ecological degradation and carbon lock-in. Even systemic approaches such as transition design, while attentive to complexity, often remain agnostic about the growth imperatives that shape the technological system itself, thereby limiting their transformative potential (Gaziulusoy & Houtbeckers, 2019). In contrast, Boehnert (2018) argues that design must actively challenge the economic orthodoxy of the Anthropocene by engaging with heterodox economic frameworks. Such frameworks foreground the household, the state, and the commons as alternative sites of economic organization, offering greater potential for recognizing and valuing both the provisioning services of ecosystems and the often undervalued labor of marginalized social groups (Boehnert, 2018, p. 355).

Within post-growth scholarship, rebuilding the commons is particularly emphasized as integral to creating an economy that supports both human wellbeing and ecological integrity (Shmelzer et al., 2022; Hickel, 2021). For design, this shift is especially significant: the commons offer an alternative socio-technical horizon under which designers are not merely creating products but working within open publics to shape the material, relational, and governance structures through which collective life is organized and sustained. As Bollier & Helfrich (2019) define it, the commons encompasses diverse social systems of self-provisioning and governance that exist largely beyond both state and market logics, relying instead on shared responsibility, social commitment, and collective stewardship. More than simply a mode of resource management, the commons represents a paradigm of social relations in which open communities co-create rules, knowledge, and relationships to (re)produce shared resources and, perhaps most importantly, meet concrete needs. This makes the commons a fertile terrain for design as it demands new forms of infrastructuring, new participatory practices, and new material cultures designed to expand access to resources, to do more with less.

Through this logic of abundance, commoning also offers a lived alternative to market-induced scarcity as it is rooted in cooperation rather than private accumulation (Bollier & Helfrich, 2019; D'Alisa, 2015; Euler, 2019). These ideas resonate strongly with decolonial and indigenous perspectives. Kimmerer, for example, discusses 'berry teachings' to illustrate relational forms of provisioning, noting that berries offer nourishment to other species while trusting that they will spread their seeds – a reminder that "all flourishing is mutual" (2013, p. 382). This relational ontology in which provisioning is embedded in cycles of reciprocity, care, and gratitude rather than extraction and exchange is not incidental to the commons but constitutive of it. Commoning, across many cultural traditions, has been sustained not primarily through rational governance mechanisms but through imagination, ritual, storytelling, and a sense of spiritual belonging to place (Bollier & Helfrich, 2019; Kimmerer, 2013). These dimensions of collective life – compassion, stewardship, tradition – are not ornamental; they are the affective and cultural substrate that makes long-term cooperation possible. Design that engages with commons-based practice must therefore attend to these registers, not only shaping material and governance structures but also nurturing the imaginative and relational conditions under which commoning can take root. Reimagining the economy through values embodied by the commons, which foreground reciprocity instead of transactionality, points to the possibility of an economy that can more effectively meet people's needs with less material and energy throughput (Euler, 2019). Yet before such systems can be realized, the challenge of collective ideation must be addressed, a challenge that foregrounds a potential role for design in shaping the imaginaries (Bendor, 2025), practices, and infrastructures of commoning.

Although an expanding body of scholarship has examined commons-based frameworks as pathways toward sustainability (Ostrom, 1990; D'Alisa et al., 2015; Bollier & Helfrich, 2019), little research has addressed how the commons might inform the governance, design, or material configuration of carbon flows within the economy, which is a question of central importance in addressing climate change. This constitutes a significant gap which I investigate in Chapter 4: while community-led, place-based forms of provisioning are well theorized, their implications for the design of carbon sequestration approaches remain largely unexplored. Strategies such as carbon sequestration and other forms of active CO_2 removal are increasingly recognized as essential to maintaining planetary stability (IPCC, 2022). Yet, as Malm and Carton (2024) observe, prevailing approaches are shaped by capitalist imperatives that favor centralized, profit-driven industrial pathways, reproducing extractive dynamics and deepening inequalities. Given my focus on carbon as both a tangible and a system-wide flow structuring the climate crisis, I am particularly interested in how carbon sequestration might be conceptualized, designed, and governed as a commons-based practice, and in the kinds of design imaginaries and infrastructural possibilities such a reframing could open for post-growth futures.

1.3.3.

THE SUPERSTRUCTURE LAYER: DESIGNING FOR A POST-GROWTH CULTURE

The superstructure[1] of a society – its beliefs, values, and norms – constitutes the cultural framework through which meaning is constructed and collective purpose is articulated. Far from being merely symbolic, this superstructure shapes the development of technology (Heidegger, 1977; Feenberg, 1999), guides the organization and distribution of resources (Polanyi, 1944), and informs the collective understanding of prosperity

[1] This use of "superstructure" departs from Marx's base–superstructure formulation, in which cultural and ideological forms are largely shaped by economic relations. Drawing instead on cultural materialism (Harris, 1979), the analysis treats material conditions, social organisation, and cultural systems as analytically distinct yet mutually shaping layers. This allows for a more reciprocal understanding of how technologies, and economic practices, and values co-evolve.

(Jackson, 2017; Raworth, 2018). As Jackson (2017) notes, contemporary notions of prosperity are deeply entangled with ideals of technological progress and material affluence, which, as we have seen, are intimately linked to the fossil carbon economy. Industrially produced consumer goods – whose appeal is continually reinforced through marketing – both emerge from these imaginaries and help to further reproduce them. Latouche (2009) further contends that the growth paradigm functions as an ideological construct, necessitating a transformation of societal values toward sufficiency and conviviality. Escobar (2018) emphasizes that design is itself a cultural practice that shapes ontologies – the ways in which people know and engage with the world – and as such plays a crucial role in imagining and enacting futures beyond capitalist modernity.

Within post-growth discourse, scholars increasingly emphasize the need to shift cultural understandings of well-being away from its association with individual material accumulation toward collective wellbeing sustained by a much lower material footprint aligned with ecological integrity and a stable carbon cycle (Kallis et al., 2024). Concepts such as conviviality and commoning begin to outline alternative visions of prosperity, foregrounding self-actualization and social connection as important immaterial dimensions of human well-being. Yet, as many post-growth scholars have noted, post-growth thinking also requires a fundamental reconfiguration of humanity's relationship with nature (Hickel, 2020; Jackson, 2017). Capitalist growth has historically operated through an expansionary territorial logic – colonizing lands, forests, seas, the atmosphere – while relying on a worldview that positions nature as distinct from, and subordinate to, humans (Foster, 2002). A post-growth society must represent a reversal of this logic, offering instead an opportunity for reciprocity, care, and ecological regeneration (Hickel, 2020). This is particularly important for designing with non-fossil carbon, as it implies infrastructure that depends on the living world for its sustenance. At both material and social levels, a post-growth economy should strive to replace extraction with reciprocal exchange: never taking more than another – whether human or ecosystem – can willingly or sustainably give, and ensuring processes of regeneration rather than degradation.

For this, more-than-human design offers a critical entry point by directly challenging the anthropocentrism that underpins mainstream design practice (Bellacasa, 2017; Braidotti, 2013; Harraway, 2016). Conventional design often assumes the designer's total control, narrowing attention to immediate user functionality while ignoring deeper questions of material origin, ecological entanglement, and post-use impacts (Fry, 2020). This limited spatial and temporal scope provides a false sense of security, masking responsibility for long-term environmental damage and erasing the perspectives of non-human stakeholders (Ibid; Adam, 2005). By contrast, more-than-human approaches insist on relational accountability, foregrounding the values, needs, and vulnerabilities of the wider living world (Bellacasa, 2017; Harraway, 2016; Tsing, 2015, 2017).

These relational values find powerful expression in Indigenous and traditional design cultures, which have long enacted more-than-human accountability through aesthetic and material practice (Kimmerer, 2019). Far from being merely decorative, the aesthetics of Indigenous artefacts – their ornamentation, symbolism, and craft – encode relational knowledge: stories of place, cycles of regeneration, obligations to non-human kin, and the accumulated wisdom of intergenerational stewardship (Abram, 1997). This suggests that aesthetic richness and ecological embeddedness are not in tension but mutually reinforcing, and points toward a vision of regenerative design that extends beyond the functional and utilitarian into the realm of meaning, memory, and responsibility.

Crucially, these aesthetic practices are not only spatially grounded but temporally expansive (ibid.). They are sustained through ongoing relationships with past and future generations, embedding long-term accountability within everyday acts of making. In this sense, they offer a lived model of the kind of temporal orientation increasingly called for in contemporary design discourse.

Central to this shift is a culture of long-term thinking, which climate change has made increasingly urgent (Krznaric, 2021; Rahm-Skageby, 2022). This foregrounds temporality as a crucial entry point for aligning practice with ecologically regenerative values and advancing more-than-human approaches. As design theorist Tony Fry (2020) argues, every act of design carries temporal consequences, enabling or foreclosing possible futures. The Anthropocene makes visible the profound and enduring impacts that were overlooked in the design of the modern world. How design engages with time, and the futures it anticipates or forecloses, is therefore central to reimagining practice in ways that sustain life on earth.

Recent work on more-than-human design and temporality responds to the ecological crisis by foregrounding the temporal dimensions of ecosystems and the extended timescales within which the Anthropocene must be understood (Itchioka & Pawlyn, 2021; Rapp et al., 2022). This marks a shift away from viewing time as solely a human cultural construction toward recognizing it as embodied and lived by non-humans as well. Designers are therefore called to attune themselves to ecological surroundings and interdependencies, cultivating renewed ethics and solidarity with non-humans (Light et al., 2017). Such a temporal sensibility has implications for both social and material dimensions of design, as all designed artefacts intrinsically derive from an environmental context and will leave traces that endure into near or distant futures. It also requires acknowledging humans as inseparable from other planet-shaping forces, positioning design in relation to the geological and ecological rhythms – the carbon cycle, the growth of a pine tree, or the lifespan of a bee – which underpin planetary stability (Rahm-Skågeby & Rahm, 2022).

However, despite this promising scholarship, a research gap remains, as much of the existing work on more-than-human temporalities in design remains largely conceptual or mediated through short-term, device-specific interactions with other individual species (Iketa et. Al, 2023; Iketa & Barati, 2023; Zhou et. Al, 2023). There is scope to further explore how design strategies might integrate these temporalities while still achieving concrete design intentions demanded by real-world projects, a gap which I address in Chapter 5. Addressing this gap is crucial to the possibility of bio-regional, ecologically regenerative economies designed to support the well-being of both humans and non-humans over time.

1.4.

RESEARCH QUESTIONS AND AIM

The aim of this dissertation is to examine how bio-based material design practice can contribute to a post-growth societal transformation by rethinking material, social, and cultural dimensions of technological production, beyond the logics of perpetual economic expansion and toward shared wellbeing. Emerging debates in post-growth scholarship point to the need for material practices that support ecological regeneration, social equity, and democratic governance. Yet the implications of these ideas for design – particularly within the context of design for sustainability – remain under-explored. This dissertation addresses this gap by investigating how designers might work with bio-based materials in ways that both respond to and actively shape post-growth futures.

To pursue this aim, the research is guided by four interconnected research questions. RQs 1-3 correspond to the prospective role of design within each of the three societal layers introduced in Section 1.3., while the fourth RQ aims to holistically synthesize insights within regenerative design practice.

RQ1: How can the selection of materials serve as a practical pathway for embedding post-growth socio-political objectives into the design and production of technology?

RQ2: How can carbon sequestration be conceptualized, designed, and governed as a post-growth practice?

RQ3: How can designers engage with more-than-human temporalities in practice to support ecological regeneration?

RQ4: How can regenerative design approaches across infrastructure, social structure, and super structure reinforce each other, catalyzing systemic change towards a post-growth society?

Together, these questions shape the conceptual and empirical trajectory of this dissertation, positioning bio-based material design as a site for reimagining socio-ecological relations in a post-growth context.

1.5.

METHODOLOGY

Post-growth transitions hinge not only on theoretical critique but on materially grounded experimentation with alternative socio-technical configurations. It is for this reason that I adopt a research-through-design (RtD) approach to explore the aims and research questions. RtD emphasizes the epistemic potential of designerly practices to generate situated and materially grounded knowledge (Stappers & Giaccardi, 2017); Zimmerman et al., 2007). Rather than treating design as problem-solving or production of artefacts, research through design foregrounds the capacity of prototypes, interventions, and material experiments to operate as sites of inquiry in their own right. Designing in real-world contexts allows reflection on how social, ecological, and technological relations are produced through design practice, making visible the values and negotiations embedded in technical systems.This synthetic, practice-based epistemology is deliberately distinct from the structured analytical frameworks used in the literature review, which serve to organize the theoretical landscape rather than to govern the design inquiry itself.

Beyond RtD, Critical Making provides an additional methodological foundation for my research by explicitly linking RtD with critical perspectives. Drawing from the Frankfurt School's tradition of critical theory, Ratto and Hertz (2019), who coined the term, frame "critical" explicitly as the denaturalization of dominant narratives of progress, efficiency, and growth through tactical, material interventions. This methodological match can be seen from the work of Kohtala and Ede (2019), who position critical making explicitly within post-growth transitions, identifying activist-makers who prototype alternative socio-technical realities through localized, participatory practices such as repair cultures, urban agriculture, and communal workshops. In this view, critical making becomes both methodological and political: a means of democratizing technological agency, integrating material experimentation with collective action, and cultivating convivial alternatives to extractive systems.

Research through design and critical making are particularly suited to this dissertation because they enable the exploration of ecological processes and socio-technical relations that are otherwise difficult to apprehend. By making and prototyping material systems, design can render invisible environmental dynamics – such as carbon cycling – tangible and experientially accessible. Making allows direct engagement with carbon as a material – wood, hempcrete, bio-composites, biochar, plants, compost – and with how its flows are shaped by human and nonhuman systems. Prototyping, in turn, creates shared spaces and emerging infrastructures in which relational governance, commons-based practices, and alternative cultural or ontological orientations can take form and be studied in situ. Crucially, embedding design practice in real-world contexts integrates social dynamics into the research process, allowing prototypes to operate as situated inquiries that expose tensions, possibilities, and forms of collective agency otherwise inaccessible through abstract analysis alone. This also has implications for my role as a design-researcher, which shifts from that of an external observer or solution-provider to a situated participant within the socio-technical systems I study or speculate towards. Being embedded in the material, social, and ecological relations that emerge through a design project requires negotiating ethical responsibilities, collective authorship, and power relations, and research-through-design allows these negotiations to become objects of inquiry in their own right.

The approach to critical making developed in this dissertation is grounded in my ongoing practice at Studio-Method, a research-oriented design studio I co-founded with architect Pedro Pantaleone in 2022, and enacted through a series of collaborative design experiments. Each project, whether a community garden, a festival stage, a small public building, or a ritual for soil regeneration, functions simultaneously as a functional intervention and as a site of inquiry into how post-growth values can be materialized through practice. Knowledge is generated and analyzed through a combination of fieldnotes, documentation of builds, participatory reflections with collaborators and community members, material testing, hands-on workshops, and iterative cycles of prototyping and redesign. These methods allow the research to trace how design practices give form to principles of sufficiency, care, regeneration, and commons-based stewardship, while also responding to context-specific needs and constraints.

1.6.

OVERVIEW OF CHAPTERS

The three-layered societal framework discussed in section 1.3. is used to structure this dissertation. A visual representation of the structure can be seen in Figure 6. Chapter 2 investigates post-growth infrastructure, chapter 3 looks at post-growth social structure, and chapter 4 looks at post-growth superstructure, while chapter 5 synthesizes insights from previous chapters in design practice. An overview of each chapter and the methods used can be found below. A note to the reader: I use ‘we’ in chapters that were co-written but ‘I’ when discussing chapters I wrote alone or the dissertation as a whole.

Chapter 2 creates a theoretical basis for understanding the socio-political consequences of materiality in and through the design process. We do this through an analysis of the way materials are selected during a design process, asking how designers determine whether a material is fit-for-purpose, which unveils existing functional, environmental, and ethical considerations. To this, we propose a missing category: the need to consider the social relations that emerge in the creation of materials across their supply chains. We then explore whether conviviality can serve as a framework for articulating materialization processes oriented toward post-growth, particularly by differentiating between forms of production organized through localized, socially embedded, and non-extractive relations, and ones which remain dependent on centralized industrial systems. This chapter is published in the proceedings of the Computing within LIMITS Conference 2023 (Bessai, Bendor, & Balkenende, 2023).

Chapter 3 explores the commons as a practical social and economic model to organize infrastructure for a post-growth society. This is done by focusing on one 'technology' in particular, carbon sequestration, a climate mitigation strategy which aims to remove CO^2 from the atmosphere. Following a critical analysis of green growth approaches to carbon sequestration, we argue that organizing these technical strategies as a commons increases the likelihood to deliver real reductions in CO^2 while also supporting community wellbeing. We refer to this approach as the Carbon Commons. These concepts are then put to practice, through a living lab taking the form of a carbon-sequestering public garden in Amsterdam. The results allow us to discuss both the potential of the commons in organizing carbon sequestration (which may be extrapolated to infrastructure more broadly), as well as the potential role of design in supporting the commons as an alternative social structure to capitalism. This chapter is under review in Degrowth Journal.

Chapter 4 explores how designers can engage with more-than-human temporalities in practice. The chapter begins with a critical analysis of the role of clock time – a particularly recent way of thinking about our relationship to the future – in organizing modern culture and its exploitative relationship to nature. We then explore how a more-than-human temporal perspective could provide a welcome antidote for a post-growth culture. Two existing concepts – noticing, and care – are explored for their practical applicability in a research-through-design project: the design and construction of a long-lasting bio-receptive music festival stage. This chapter is published in the proceedings of the Design Research Society Conference 2024 (Bessai, Bendor, & Balkenende, 2024).

Chapter 5 explores how the concepts proposed in the introduction and elaborated in chapters 2-4 – conviviality, the commons, and more-than-human temporalities – may converge in practice, through a series of design projects explicitly focused on ecological regeneration. Beginning with a summary of the previous chapters, I apply the three-layer framework in reflection of four of my own regenerative design projects, expanding on how theory and concepts developed in previous chapters play out in a situated, and real-world context.

Chapter 6, the discussion chapter, returns to the notion of post-growth design practice, reflecting on the research questions and placing the findings from each chapter in dialogue with one another. It does this by synthesising the findings across three integrative lenses: imaginaries, materiality, and design capacities. Put together, these three lenses foreground how infrastructure, social structure, and superstructure co-evolve in post-growth transitions.

Chapter 7, the concluding chapter, summarizes the key contributions, lessons learned, limitations, and suggests directions for future research.

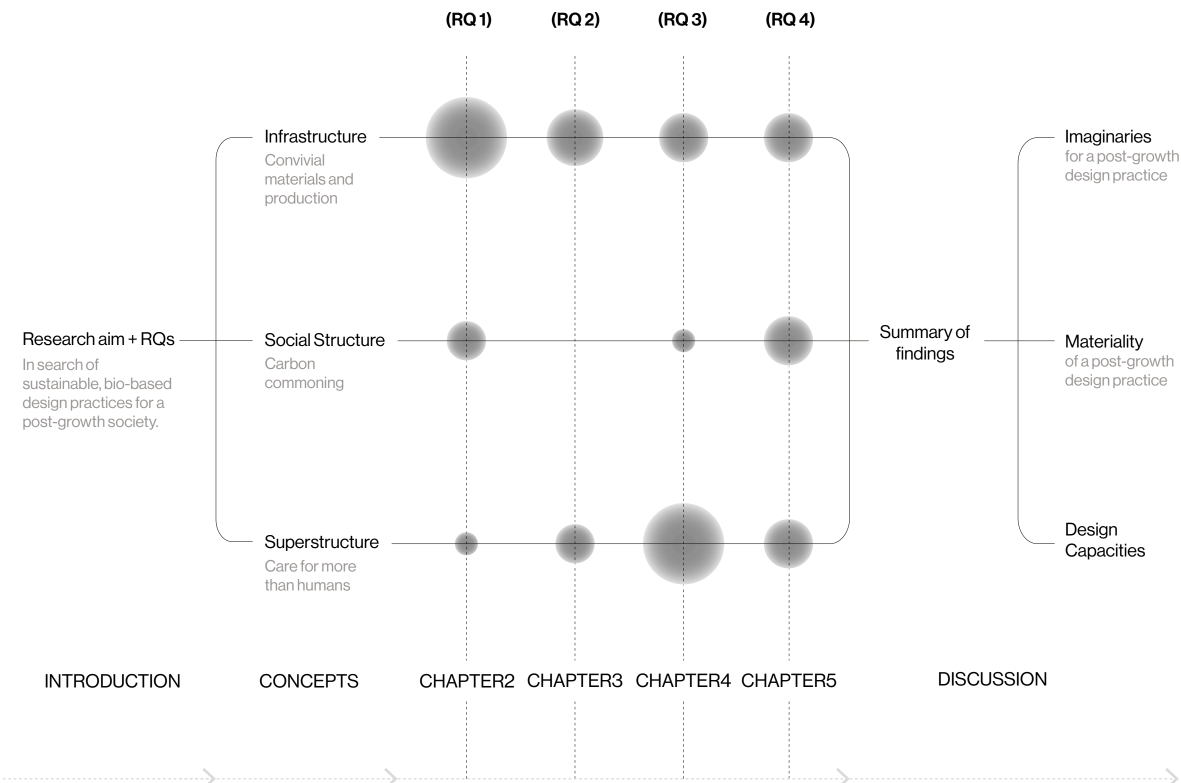


Figure 5
A diagramatic overview of the dissertation concepts, chapters, and synthesis.

003

Fit for Purpose. Four Dimensions for how Matter becomes Material

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p/ 060 ▪ 073

Materials form the basis of modern technological society. The extraction and processing of raw matter and the disposal of material things is at the heart of most of the environmental and social crises, and has important implications for the design and deployment of computation systems. In this paper, we present an analysis of the way in which materials are selected during the design process: how designers determine whether a given material is fit for purpose. While originally addressing specific functional or aesthetic purpose, with increasing urgency designers have begun to select materials that also consider a broader environmental purpose (eg. CO^2 footprint) or ethical purpose (eg. Fair Trade). The analysis also unveils a missing category: the need to consider the social relations that emerge in the creation of materials across their supply chains. Fit for political purpose is thus proposed to create a bridge between the nuts-and-bolts material design of technology and the socio-political impacts of its production.

2.1.

INTRODUCTION

The ubiquitous material dimension of human technology is of primary importance to the anthropogenic impact on our planet. Digital products, often touted as an immaterial and thus more sustainable alternative to physical ones, still face huge challenges in terms of their material footprint (Willenbacher, 2022). There is currently a race to increase the supply of necessary raw materials to fuel the growth of ICT (Nayar, 2021). The scale of designed things has grown exponentially, with the overall mass of the technosphere now outweighing all biomass on Earth (Elhacham et. Al., 2020). As the most recent IPCC report makes amply evident, human activity has greatly impacted the biosphere and climate, causing widespread adverse impacts to nature and people (IPCC, 2022). Design fundamentally makes use of materials to fabricate a desirable future, and yet the use of materials is jeopardizing that very future in unexpected and cataclysmic ways. Design, as Tony Fry (2009) puts it, "defutures". This paper explores how the notion of fit for purpose is evolving to address the many unfolding crises society (and designers) face. The trajectory we paint here is of design expanding to consider wider ecological, social, and political impacts.

Material is matter from which a thing is or can be made. However, in this shift – from matter to material – there is a complex process of transformation, involving multiple contexts, relations, and diverse human and non-human actors. We will refer to this transformative process as materialisation. Materials themselves are understood through their properties, which is the ascription of the quality of having material effects (Drazin, 2015, p.xxvi). Properties are fundamental to design, used to predict whether a given material is well suited for its designated purpose (Ashby & Johnson, 2014). Some are arrived at by intuition (guided by tacit knowledge or experience), others by reason or analysis. To the carpenter, wood can be sawed, painted, nailed, and will eventually rot; to the ceramicist, clay can be moulded into a variety of shapes, will cure under firing, yet is heat resistant; to the industrial designer, aluminum can be extruded, has a shiny silver color, and has a yield strength of 276MPa. Properties are what designers use to determine fit.

In this paper we trace the evolution of 'fit for purpose' across three dimensions: the functional dimension includes properties related to how well a material might help a product achieve its specified goal. The environmental dimension includes properties related to the environmental impact of material production, use and disposal. The ethical dimension includes properties related to the working conditions of those involved across the material supply chain. These first three dimensions align with the "triple bottom line" of sustainability, where the designer attempts to strike a balance between profitability, and impacts on people and the planet (Ashby, 2022). To these we propose a fourth, additional dimension, which considers properties related to the social and political structures and relations that exist across the supply chain – from the sourcing of raw matter to its readiness for use by designers.

Incorporating environmental and ethical consitderations into the design process has been an important shift towards minimizing the negative externalities of products across their life cycles. But thus far, these dimensions have proven inadequate to challenge the underlying economic paradigms that dictate continually expanded production and consumption of industrial goods. Empirical evidence shows that the societal goal of sustained economic growth will likely prevent society from avoiding environmental breakdown (Parrique, 2019; Hickel, 2021). Within capitalistic social and economic relations, even well-meaning considerations of environmental and ethical fit tend to revert to some level of subordination to profit. Many design theorists have begun to explore new territories for design that take a critical stance against what they see as the root of the problem: alternatively calling for transformational design (Krzarnic, 2021), regenerative design (Ichioka & Pawlyn, 2021; Mang & Reed, 2012), pluriversal design (Escobar, 2018), design futuring (Fry, 2009), or a reincorporation of spirituality and meaning to the design process (Walker, 2014). Building on these, we consider 'politically fit for purpose' as a new dimension to expand upon how designers consider materials. Our intention with this experimental paper is to lay the theoretical basis for understanding the socio-political consequences of materiality in and through design processes. The outcomes of our analysis would be relevant for those making decisions about the design, procurement, and deployment of computational systems.

2.2.

FUNCTIONALLY FIT FOR PURPOSE

The functional dimension of what it means to be fit for purpose often translates into the question of whether a material is fit for the specific purpose of the designed artefact. In the functional dimension, the scope of the design activity is limited to the specific intention of the designed object, and the specific users that will interact with it. In today's neoliberal market economy, this typically translates to whether a product will be purchased.

In pre-industrial times, craftspeople maintained a much closer relation to the origins of the materials they worked with.

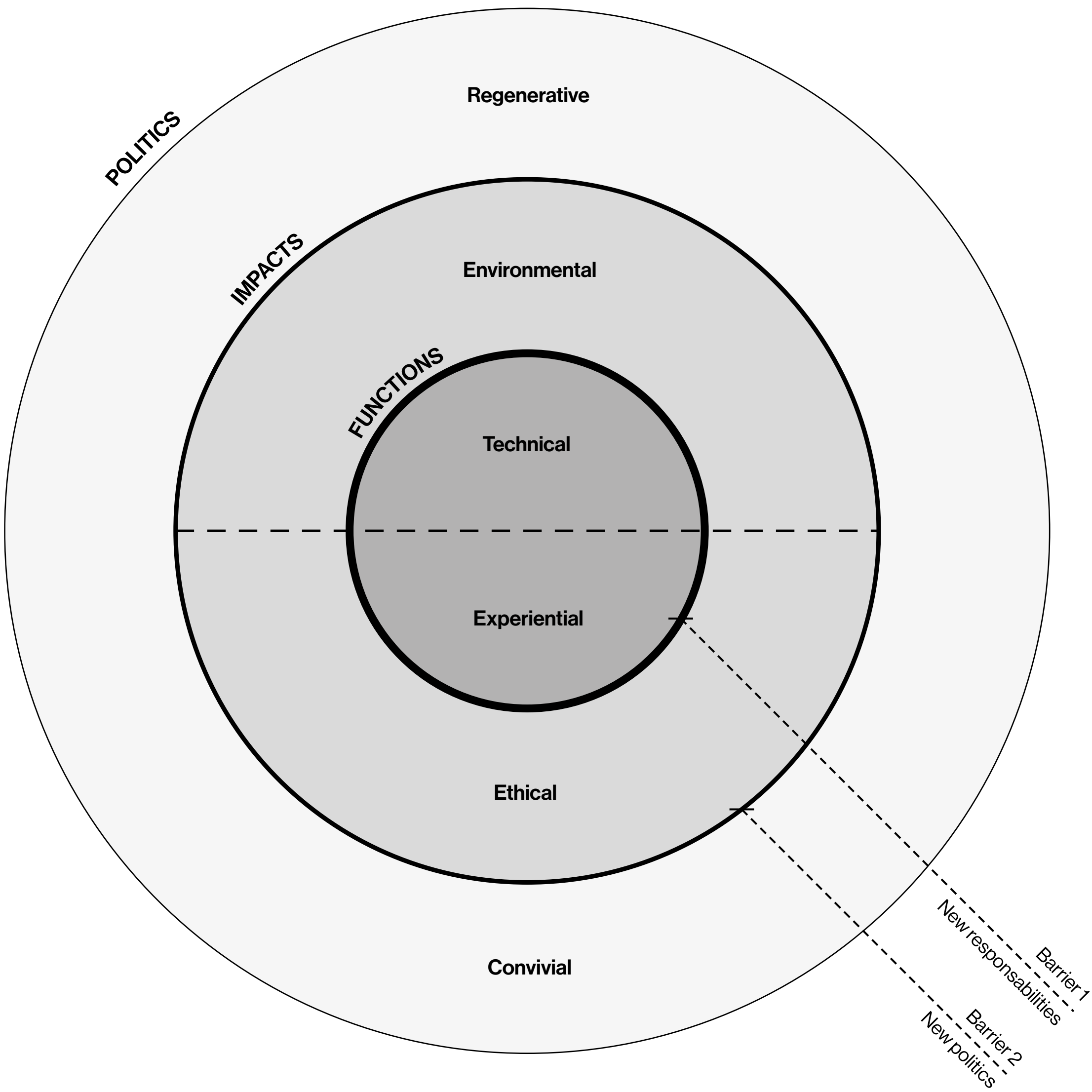

Figure 6
Four dimensions for determining material fit-for-purpose. The political dimension is proposed as a missing category to account for the social relations which emerge in the creation of materials across supply chains.

For instance, a carpenter might have selected a specific tree for a house, a ceramicist might have known the location of the best clay, and so forth. Because craftspeople had a direct hand in the transformation of matter into material, they developed tacit knowledge about the potential application of material for any given purpose (Sennett, 2008).

The scientific revolution brought with it a new rational approach to the characterisation of materials through quantifiable technical properties related to functionality. Mechanical, thermal, electrical properties all allowed for the ability to evaluate the behaviour of a proposed design. The tacit knowledge developed through physical experience was replaced with predictive formulae. While the craftsmen, architects, and builders of antiquity relied on codes developed heuristically or intuitively from an essential relationship to the materials available to them, modern approaches to materials are characterised by their quantification and manipulation via mathematical formulae (Sennett, 2008).

This changing approach to design went hand in hand with industrialization and the demand for mass-produced artefacts. To achieve uniformity in the output of production, quantifiable properties allow for the designer to determine the nature of an artefact a priori. But while tacit knowledge of a material is well-rounded – the craftsperson maintained a close relationship to the material and its origins, knowing its physical and tactile properties and workability – as mass-production led to the division and specialization of labor in the factory, design in the 20th century saw the division of labor between the designer and engineer (Feenberg, 2005). While slowly changing, this distinction is still relevant across much of the productive economy. According to Ashby (2014), in design, "materials have two overlapping roles: that of providing technical functionality and that of creating product personality" (p. 5). In this respect, he differentiates between two modes of design: technical design, which includes aspects that bear on technical functioning, such as mechanical or thermal performance; and industrial design, which includes aspects that relate to the aesthetic experience of a product, such as visual and tactile attributes, associations and perceptions, personality, and character. Finally, Ashby notes that economic viability of a product is to be considered across the design process, against which technical or aesthetic aspects are balanced: is a product's "value in the marketplace greater than its cost by a sufficient margin to justify the investment required to make it" (Ashby, 2014, p.18).

The selection of materials by designers is aided by databases of material properties, such as Ansys Granta Edupack, which provides hundreds of material attributes. Aesthetic or experiential approaches to the selection of materials by designers have only emerged more recently. Karana et al. (2015) note how aesthetic properties for the modern industrial designer are less well defined than technical ones: "The 'material' should also elicit meaningful user experiences in and beyond its utilitarian assessment. This requires qualifying the material not only for what it is, but also for what it does, what it expresses to us, what it elicits from us, and what it makes us do" (p. 35). Here, what is in question is an understanding of the properties of a material that qualify its embodied meaning in relation to its contextual use in a designed object (social, historical, etc.). Not considered are the broader implications of the design process on society or the environment.

2.3.

ENVIRONMENTALLY FIT FOR PURPOSE

As far back as the middle of the 20th century, Buckminster Fuller spoke of the need for scientists and designers to protect "spaceship planet earth's" finite life-giving capabilities for future generations, or to consider the environmental impact of humanity on a planetary scale (Fuller, 2008). Victor Papanek was perhaps the first to own up to the calamitous impact of industrial design, stating there are "only a very few professions more harmful than industrial design" (Papanek, 2019/1972, p. 1). At the time, these voices were outliers, and environmental degradation was mostly localized. But now, overwhelming scientific consensus on the global impact of human activities on the climate and biosphere have made environmental sustainability a mainstream concern. Consequently, environmental sustainability has become an increasingly important dimension in the determination of material fit for purpose.

The urgency of the threat from climate change has created an acute awareness of the need to reduce carbon emissions across all human activities. These emissions stem from the impacts that production has on the environment through the carbon emissions produced across the supply chain of a given material. But beyond climate change, humans are impacting the planet in a variety of other ways. Scientists have identified 9 planetary boundaries that quantify a safe operating space in which humanity can continue to prosper (Steffen et al., 2015). Overshooting these boundaries – freshwater use, land-system change, biosphere integrity, climate change, novel entities, stratospheric ozone depletion, aerosol loading, ocean acidification, and biogeochemical flows (phosphorous and nitrogen) – greatly increases the likelihood of irreversible environmental changes that put human welfare in jeopardy.

With modern supply chains, there are many steps in the transition from matter to material. The life cycle analysis (LCA) is an important development to systematically consider the environmental impacts across this transition. This approach aims to determine the environmental impacts of a product through its life, from the extraction and processing of matter to the manufacturing, distribution, use, and end-of-life of material (Cortes-Borda et al., 2022). An LCA begins with establishing the scope and boundaries of the product or system that is under consideration. For materials, this is typically 'cradle-to-gate', meaning the entire process is considered from the extraction of raw matter to the point at which the material arrives at the factory. The second stage, documented in the ISO14041 standard, involves data collection relating to all the mass and energy inputs and outputs across the scoped boundaries. Finally, these inventories are tabulated to give an overall value of the environmental impact of a material. To aid designers in selecting materials that are environmentally fit for purpose, material databases also provide tabulated data related to environmental footprints of materials (ibid).

Different materialisation processes will have different impacts on each boundary across the supply chain. As these are quantitative boundaries, in principle it is possible to quantify material properties for each using an LCA, by adding up the aggregate effect across a supply chain. But in practice it is difficult to do so. In a meta-analysis of 8200 journal articles that address LCA, Grubert (2017) shows a "dramatic proportional increase in attention to climate change and a corresponding decline in attention to human and ecosystem health impacts" (p. 148). For designers working with material databases or supplier data, climate change impact – or the carbon footprint of a material – is often the most readily available environmental property, while the others remain difficult to quantify.

Importantly, the environmental dimension expands the notion of 'fit for purpose' by broadening the scope of consideration beyond specific purpose to the wellbeing of natural systems. It provides the designer with an additional means to understand and respond to what goes on during the materialisation process.

LCAs are often useful in identifying where hotspots occur, allowing for a product to be optimized in its design to minimize the worst environmental effects. But, within the paradigm of expanding economic growth and given the inefficacy of globally decoupling economic growth from environmental impact (Parrique, 2019), efficiencies can only serve to minimize ongoing damage. Reimagining design as a means for social and ecological regeneration necessitates a political challenge to underlying growth-oriented ideologies (Hickel, 2021; Ichioka & Pawlyn, 2021; Walker, 2014).

2.4.

ETHICALLY FIT FOR PURPOSE

History provides ample evidence that the sourcing of material shapes the lives of people involved across the supply chain (Ghosh, 2021). The carpenter-craftsman might have a personal relationship with the lumberjack and mill from which his material is derived. But modern material supply chains are typically globally distributed and anonymous. Crawford and Joler's (2018) mapping of the complete supply chain of an Amazon Alexa device poignantly shows the breadth and complexity of the processes and labour needed to manufacture products we take for granted. Thinking about this process ethically means considering whether people involved in the supply chain have been treated fairly based on socially determined standards.

There are different approaches to assessing whether a material is ethically fit for purpose, but in general, it involves a consideration of the stakeholders entangled in the materialisation process. To this end, social life-cycle analyses (SLCA), originated from environmental life cycle analysis, have been developed. The SLCA considers the positive and negative social effects on stakeholders across the supply chain. Insofar as products are "made of stories about production and consumption impacts on the workers, the local communities, the consumers, the society and all value chain actors", designers have begun to consider how materials influence these stories (UNEP, 2009. p. 5). The SLCA approach thus attempts to extend the systematic rigor of LCA to the social impacts of materialisation. The UN guideline on SLCA considers 5 stakeholder categories: workers, local community, society, consumers, and value chain actors. Each stakeholder category is evaluated on seven impact categories, each of which has its own subcategories and associated inventory data (ibid). Due to the complexity and diversity of every supply chain, conducting a

SLCA is time-consuming and costly (Sakellariou, 2018).

Central to the SLCA is the desire to promote human well-being, which also gives rise to the difficulties of conducting SLCAs. Wellbeing, dependent on intangible contextual factors of a person's life situation, is not something that is easily quantifiable. With a basis in the UN's Sustainable Development Goals, social sustainability is first and foremost about providing people with basic physical necessities. This typically takes on an economic dimension (eg. fair trade). While there is ambiguity around what determines well-being, the UN appears correct in its acknowledgment that there is such a thing as 'not enough':

Without a minimum level of the basic physical necessities to life such as food, water, shelter, clothing and security, the human body will perish. Without a minimum level of opportunity and freedom, without opportunities to meet basic psychological needs for autonomy, competence, and relatedness (Deci, 1995), the body may survive while the human spirit withers within. (UNEP, 2009, p. 22)

Beyond minimum ethical standards of economic fairness, there is a difficulty in assessing wellbeing. Put differently, wellbeing is limited to the kind made possible under neoliberal capitalism. The more complicated goals of autonomy, competence, and relatedness are often replaced by a focus on financial equity. Fairtrade serves as an example, where ethical materialisation is based on fair financial compensation for small-scale farmers and communities. Iofrida et al. (2018) note how the social values, ethics and ideological positions that underlie the indicators of social impact are often unclear. SLCAs also tend to focus on the worker as the main stakeholder, "which shows the dominant thinking of CSR [corporate social responsibility] focusing on individuals directly involved in the production system as recipients of the production system effects" (Sotanpour, 2019, p. 2). This reflects an understanding of society as an aggregate of individuals as opposed to a collective or community (ibid.), the consequences of which is that "A perspective that considers how the development of a product would affect the social structure in which it will be embedded seems to be lacking" (Zamagni et al., 2011, p. 597). Even the UN guidelines on SLCA caution that this approach does not "provide information on the question of whether a product should be produced or not" and "does not in itself provide a breakthrough solution for sustainable consumption and living" (UNEP, 2009, p. 37). Sakellariou (2018) points out that the historical development of SLCA, having emerged from LCA, is based on an ideology of technopolitics or engineering reform, whereby ethical issues are best addressed by engineers themselves, through the increased application of expertise. The ethical dimension thus helps to optimize the status quo for greater equality but does not act to challenge the logic of growth that underpins production.

2.5.

POLITICALLY FIT FOR PURPOSE

Building on the first three dimensions and their critical assessment, we have identified a missing component in assessing fit for purpose: the political dimension. Governments and industry have been incorporating environmental and ethical considerations since at least the early 2000s, but this has not stemmed the growing environmental destruction or wealth inequality emerging from industrial production at scale (Azapagic & Perdan, 2000). The political dimension considers the relations between actors involved in the supply chain, and how these relations engender specific distributions of resources, wealth, and power. A growing number of voices point out that to fundamentally address the negative environmental and social impacts of design requires challenging deeply embedded structures based on growth-oriented economies and consumerism (eg. Ichioka & Pawlyn, 2021). This requires a challenge to the socio-political assumptions that underwrite the previous approaches to 'fit for purpose'. Not immune to such critiques, designers have begun to see how present conceptions of sustainable development will only serve to reduce unsustainability (Ehrenfeld, 2008). Overcoming the limits of sustainable development in providing lasting regenerative ecological and social impact will require what Arturo Escobar (2011) calls Transition Designs: "radical cultural and institutional transformations – indeed, a transition to an altogether different world" (p. 138; emphasis in origin). How then can we extend the notion of 'fit for purpose' to account for the need for such a transition? For designers, this means considering how "materials are 'vitalist', what they do and how they have effects, how they have meaning, how they are known, and what social and cultural forms happen through and around them" (Drazin, 2010, p.14). We believe that beyond simply having an environmental or ethical impact, the process of materialization may affirm or transform the societal structure in which it occurs.

Ivan Illich's (1973) notion of conviviality can help us to understand the political nature of materialisation and its effect on environmental and social wellbeing. While originally used to describe tools and their use, conviviality provides a lens that transcends previous environmental and ethical considerations of fit for purpose. Illich illustrates how industrial tools, once surpassing a given scale, tend to subordinate people to the position of "tool operator" (on the side of production) or "passive consumer" (on the side of consumption). In essence, he saw how industrial tools deny people and communities of autonomy in satisfying their own needs:

> *Tools are intrinsic to social relationships. An individual relates himself in action to his society through the use of tools that he actively masters, or by which he is passively acted upon. To the degree that he masters his tools, he can invest the world with his meaning; to the degree that he is mastered by his tools, the shape of the tool determines his own self-image. (Illich, 1973, p. 29)*

Illich argues that "convivial tools" offer a way to overcome the tendency of modern society to turn people into passive consumers of industrial goods:

> *Convivial tools are those which give each person who uses them the greatest opportunity to enrich the environment with the fruits of his or her vision. Industrial tools deny this possibility to those who use them and they allow their designers to determine the meaning and expectations of others. Most tools today cannot be used in a convivial fashion. (Illich, 1973, p. 29)*

Conviviality resoundingly calls for a transition away from the dynamic of industrial production and consumption, and the alienating and socially destructive effects of a world built on multiplying 'useful things for useless people' (Illich, 1973, p.43). Instead, it identifies a form of tools that can lead to self-actualization and community building across the supply chain. How, then, can the notion of conviviality be applied to processes of materialisation and not only to tools? And how can the designer consider this dimension in selecting whether a material is fit for purpose?

In Carbon Democracy, Timothy Mitchel (2011) analyses the history of democracy from the perspective of coal and oil production, showing how specific material qualities of coal and their early production infrastructures enabled the rise of democracy and workers' rights, while the transition to oil in the 20th century shifted power away from workers and concentrated it in the hands of multinational conglomerates to the detriment of democracy:

> *Coalminers played a leading role in contesting work regimes and*

the private powers of employers in the labour activism and political mobilization of the 1880s onwards.... The militancy of the miners can be attributed in part to the fact that moving carbon stores from the coal seam to the surface created unusually autonomous places and methods of work. (Mitchell, 2011, p. 19)

As Mitchell shows, the nature of coal production in the late 19th century led to relational impacts that promoted community, solidarity, democracy, and worker participation, because of the specific nature of mine work at the time. The lack of mechanization and institutional control over the tools of production at the time created a bottom-up, hands-on, communal working environment inside the mines. However, the transition to an oil-based economy meant the centralization of tools in the hands of a few, as oil could be extracted and transported via pipelines in an increasingly automated process. In this transition, workers were reduced to tool operators with minimal influence over the materialisation process. What is noteworthy in this example is how the specific characteristics of the materialisation process enabled a convivial social dynamic to emerge, one that challenged existing modes of production and associated exploitation. This dynamic was enabled both by the physical nature of the material (eg. coal is underground, solid, etc.) as well as that of the materialisation process (in the 1900s coal was mined using pick-axes and transported via steam engine).

When considering the political dimension of 'fit for purpose' from the perspective of conviviality, the tools used in the materialisation process become important. Tools include both physical equipment, from hand tools to large machinery, as well as the intangible aspects related to the organizational structures that dictate their use. Are the tools widely available or do they maintain a monopoly over the means to achieve a specific outcome? Are they accessible to all, or do they require specialized knowledge and training to operate? Do they consolidate power or wealth inequality in their ability to enable a large scale effect with relatively fewer operators? These questions all pertain to whether a materialisation process is convivial and, by extension, to the extent to which it may be regenerative and not merely ameliorative.

Plastics, most metals, and other technical materials are nearly all produced in a highly industrialized way, by corporations that operate at massive scales, and which promote the interests of shareholders over those of the workers or the environment. This is especially true of electronic and ICT systems reliant on rare

Figure 7 (right) Striking miners independently work a seam of coal in Sheffield during the 1893 United Kindom Miners Strike. The largely manual materialisation process of coal in the 19th century gave miners considerable power to disrupt production, which played an important role in their capacity to demand concessions from mine owners and advocate for workers rights. Source: Wikimedia Commons (public domain).

earth metals and other uncommon and highly technical materials (Willembacher, 2022). So, what materials then are convivially fit for purpose? Many natural materials can be produced in a decentralized and localized way, including softwood, bamboo (and other grasses), hemp (and other natural fibers), and more. We might also consider DIY or small-scale recycling as a promising approach to convivial materialisation. For example, Precious Plastics (https://preciousplastic.com/) is an open-source hardware recycling project that relies on the digital commons to share knowledge surrounding plans for recycling machinery. This project allows for recycling to operate locally, with a low bar to entry that is available to anybody with enough interest and motivation. A similar project from Kenya, Gjenge Makers (https://www.gjenge.co.ke/), enables the making of bricks out of household and industrial plastic on a local scale, thus reducing waste and creating convivial working opportunities. Another example is the budding communities surrounding bio-fabrication, where open-source cookbook style recipes offer anyone with a basic baking setup to produce their own materials – plastics, fake leathers, fabrics, etc. - from food waste or different bio-feedstocks. These communities also often rely on the digital commons for information sharing, with organizations such as Materiom (https://materiom.org/) making information available for free online.

Considering manufacturing through its political dimensions surfaces an interesting dilemma with respect to the materials required for many of the sustainable technologies proposed in the energy transition. Electrification will require vast amounts of critical minerals, for solar panels, wind turbines, and ICT products that can enable digitisation. Could these be sourced sustainably, ethically, and convivially? Here, we might take inspiration from Low Tech Magazine, where simpler alternatives to high-tech solutions are proposed (see for example the article "how to build a low-tech solar panel" where Low Tech investigates possibilities for solar PV that do not rely on rare-earth metals). Ultimately, we should be critical about 'solutions' requiring systematic and large-scale roll-out of materially complex technologies under the banner of sustainability.

Figure 8 (above)
The Extrusion Pro is an open-source design from Precious Plastic that can extrude recycled plastic into a mould. Precious plastic has designed a range of open-source machinery for processing recycled plastic that can be built from widely available materails, making this a prime example of Convivial Materialisation. Image by Precious Plastics (2025), licensed under CC BY 4.0.

In sum, the political dimension provides a new lens through which to consider material fit for purpose that might overcome the limitations of the other three dimensions, namely their inability to take a critical view of the connection between material use in design and the socio-political effect of their production. Specifically, it asks designers to consider the political nature of the materialisation process and what kind of social relations and power structures it upholds.

2.6.

CONCLUSION

The first three dimensions presented in this paper (functional, environmental, ethical) illustrate how designers currently decide whether a material is fit for purpose. To these we propose an additional, political dimension that addresses the limitations of the first three, namely that they fail to challenge the entrenched, political drive towards capitalist materialisation processes. We have shown that optimizing material choice for environmental or ethical impact does not challenge the paradigm of continual economic growth, and the accumulation of power, wealth, and capital that is typical of materials produced at industrial scale. The four dimensions increasingly expand the scope of design, and thus challenge designers to consider more aspects when determining whether a material is fit for purpose. In this sense, the political dimension of 'fit for purpose' asks the designer to look beyond the specific purpose of their design task and to consider the systematic drivers of broader social or environmental effects. Here, conviviality is suggested as an alternate approach to that of the industrially produced materials familiar to industrial designers. Eschewing scale, efficiency, and institutionalization, conviviality favors processes that are available and accessible to all. Decentralized models of production in combination with open-sourced information can provide new and interesting opportunities for convivial materialisation. In effect, political fit for purpose provides an alternate dimension from which we can evaluate the design of all material things and transition away from the destructive tendencies of growth-oriented industrial production, and towards social and environmental well-being.

004 The Carbon Commons. Carbon sequestration for a post-growth society

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This article introduces the Carbon Commons as a theoretical and practical framework for reimagining carbon sequestration within a post-growth context. Although carbon sequestration is central to most climate mitigation pathways, it has received little attention in post-growth discourse, where it is often overshadowed by critiques of green-growth strategies and their limited capacity to challenge the social and economic forms driving emissions. Instead, we argue that organizing sequestration as a commons can address these limitations by rooting climate mitigation in community defined values, needs, instead of the profit-oriented logics of the market. We then present findings from a living lab in Amsterdam – an experimental carbon-sequestering public garden co-created with a community centre – which demonstrates how sequestration can become meaningful when woven into everyday practices that meet immediate social needs. Across provisioning, social life, and governance, sequestered carbon operated as a shared material, a social mediator, and a political catalyst. While modest in scale, the living lab revealed how community-embedded sequestration can cultivate belonging, agency, and stewardship. We conclude that carbon commoning offers a post-growth pathway in which ecological benefits emerge through the collective shaping of place and the strengthening of communal life.

3.1.

INTRODUCTION

Carbon sequestration, also referred to as carbon dioxide removal or negative emissions, is a climate mitigation strategy that aims to remove CO_2 from the atmosphere and store it in long-term sinks (IPCC, 2023; Minx et al., 2018). Approaches to carbon sequestration include industrial technologies that capture and inject carbon underground (Fuss et al., 2018), nature-based solutions that enhance storage in soils, forests, and oceans (IPCC, 2023; Kabish et al., 2017), and construction practices that embed carbon in biobased materials (Arehart et al., 2021; Churkina et al., 2020; Kinnunen et al., 2022). In theory, the logic is appealing: if CO_2 emissions drive global warming, removing CO_2 should help reverse it. Yet, as scholars have pointed out, sequestration techniques differ widely in their capacity, environmental impacts, and social implications, raising doubts about their viability as a central pillar of climate policy (Carton et al., 2021; Gunderson et al., 2020; Malm & Carton, 2024; Palazzo Corner et al., 2023).

Despite repeated warnings from the Intergovernmental Panel on Climate Change that achieving the Paris Agreement goals requires a rapid phase-out of fossil fuels (IPCC, 2023), global emissions continue to rise (IEA, 2025). In this context, carbon removal has become an increasingly attractive policy tool, promising to reconcile continued economic growth with climate stabilization (Malm & Carton, 2021). This paper critically questions that promise and asks, how might carbon sequestration be organized differently – beyond market logics and techno-optimism – to align with the principles of ecological integrity, social justice, and democratic governance?

The growing reliance on carbon removal reflects what Malm and Carton (2024) term "Overshoot Ideology", the belief that societies can exceed safe emission limits now and depend on future technologies to clean up later. This ideology allows policymakers and industries to sustain the illusion of progress while deferring systemic change. In practice, carbon sequestration often serves as a form of status quo maintenance (Gunderson, 2020), reconciling ongoing fossil-fuel expansion with the rhetoric of sustainability. Under the banner of 'net zero', governments and corporations pledge future removals to offset present emissions, effectively postponing decarbonization.

To move beyond these contradictions, post-growth scholarship offers a significantly different starting point. Post-growth thinkers argue that the pursuit of perpetual economic expansion is fundamentally incompatible with planetary boundaries, and that climate stabilization depends on reducing energy and material throughput rather than relying on speculative green-growth techno-fixes (Hickel, 2021; Jackson, 2011; Parrique, 2019). From this perspective, large-scale carbon removal appears less as a solution than as a continuation of the same growth logic that underpins the climate crisis.

Yet even within post-growth frameworks, societies must still address historical and residual emissions. Recent modeling shows that some level of sequestration will remain necessary to avoid dangerous warming scenarios (Hickel et al., 2021; Kikstra et al., 2024; Moyer, 2023; Slamersak et al., 2024). The challenge, then, is not whether to pursue sequestration, but how to organize and design it in ways that reflect post-growth values – emphasizing ecological integrity, democratic participation in the economy, just distribution of resources, and social wellbeing over accumulation and profit (Jackson, 2011; Pouw, 2020; Raworth, 2017). Addressing this challenge is this paper's overarching aim.

To explore how we might organize carbon sequestration for a post-growth society, we turn to the commons as a potential socio-economic model. The commons refer to collectively managed resources and the social commoning practices through which communities govern and share them according to collectively defined needs and values (Euler, 2019; Jakob & Edenhofer, 2014; Perkins, 2019; Schmelzer et al., 2022; Singh, 2019; Wittel & Korczynski, 2023). Rather than relying on markets or centralized control, commons-based systems emphasize reciprocity, cooperation, and care. From community-managed forests to open-source knowledge platforms, such arrangements demonstrate that resources can be governed effectively outside of profit-driven frameworks (Bollier, 2014; Le Crosnier, 2012; Ostrom, 1990). Beyond resource management, commoning embodies a relational ethos that contrasts sharply with the competitive individualism of capitalist markets, designed around interdependence and abundant access to resources rather than artificial scarcity and exchange (Euler, 2019; Stavrides, 2016). As Bollier (2024, p. 293) notes, commoning marks a shift "from a world defined by individualism, calculative rationality, and material self-interest in markets, to one that is richly relational in all directions". These principles suggest a powerful lens for reimagining carbon sequestration not as a tradable asset, but as a shared ecological responsibility embedded in collective life.

Building on this perspective, we propose the Carbon Commons as both a theoretical and practical framework for reimagining carbon sequestration within a post-growth context. The Carbon Commons envisions sequestration as a communal, participatory practice through which carbon is treated as a shared resource rather than a commodity. Technical design strategies – such as restoring ecosystems to enhance carbon absorption or constructing shared infrastructures from carbon-storing materials – can thus be collectively organized and maintained to meet local needs and aspirations. But beyond carbon as a shared resource, carbon commoning can cultivate what Bollier (2024) calls an "onto-shift", changing how we perceive reality and relationships in favor of a worldview grounded in reciprocity, collective responsibility, and care. The Carbon Commons therefore invites a shift from technocratic, efficiency-driven models of carbon management to ones that recognize sequestration as a social and cultural process, designed and embedded in place. Through this reframing, sequestration becomes not a distant technological fix but a lived practice of ecological and social stewardship.

To enact and study these ideas in context, we established a living lab in collaboration with a community center in Amsterdam (see more in section 4). The living lab served as a participatory environment for experimenting with the Carbon Commons concept through the co-production of a public garden that functioned as a shared carbon sink. Within this setting, community members collectively designed, fabricated, and maintained carbon-sequestering elements in materials, soils, and plants, transforming the technical process of sequestration into a social practice of commoning. The living lab thus operated as the methodological site through which we explored how carbon sequestration might be designed and organized in line with post-growth and commons-based principles. Given that the research was conducted by an external team of design experts, we pay particular attention throughout to the role of designers as situated actors, examining how specialist knowledge and positional privilege shape the commoning process, and what this implies for design practice in post-growth climate futures.

The paper proceeds as follows. Section 2 examines the political economy of carbon sequestration, critically analyzing dominant industrial approaches and identifying nature-based alternatives more aligned with post-growth values. Section 3 develops the theoretical framework of the Carbon Commons, drawing on commons scholarship to propose commoning as an organizing principle for sequestration, while acknowledging the challenges and contradictions of commons-based governance in practice. Section 4 introduces the living lab methodology and the Amsterdam community centre context in which the Carbon Commons was enacted and studied. Section 5 presents and analyzes the findings through Bollier and Helfrich's Triad of Commoning – provisioning, social life, and governance – reflecting on the role of designers across each dimension. Section 6 concludes by drawing out the theoretical contributions of the Carbon Commons framework and the practical lessons it offers for designers, community practitioners, and policymakers working toward post-growth climate futures.

3.2.

THE POLITICAL ECONOMY OF CARBON SEQUESTRATION

The dominant "green growth" strategy for addressing climate change assumes that technological innovation can decouple economic expansion from carbon emissions, allowing societies to grow while reducing environmental impact (OECD, 2011; Shieh et al, 2025). Yet, there is little empirical evidence for such absolute decoupling at the global scale (Parrique, 2019). While efficiency improvements can lower the carbon intensity of production in specific sectors, they rarely reduce overall emissions, an effect known as the Jevons' Paradox. Rather than reducing environmental pressures, efficiency often accelerates economic growth and, consequently, total emissions (Hickel & Kallis, 2020). The limits of technological solutionism point to a deeper issue: the structural features of capitalism that make continuous economic expansion appear both necessary and desirable. The problem, in other words, is not merely a technical one but a social and systemic one.

Within a political economy of green growth, carbon becomes deeply commodified. Private actors invest in carbon-offset schemes and speculative credit markets, while corporate net-zero pledges promise climate responsibility without requiring fundamental economic transformation. As Palm (2024, p.1) observes, this framing reduces the climate crisis to a problem of carbon management, rather than one of political economic choices and ecological limits. The result is a depoliticized vision of climate action which privileges measurement, accounting, and techno-solutions over systemic change. In this way, carbon removal becomes a tool for business-as-usual, legitimizing continued fossil-fuel dependency under the guise of innovation and corporate sustainability.

These contradictions are clearly visible if we look at the technologies underpinning the "circular carbon economy" (Palm, 2024, p. 1). Within the dominant climate policy frameworks, including the majority of IPCC's 1.5°C or 2°C emission pathway scenarios, two large-scale carbon removal methods are most prominent: bioenergy with carbon capture and storage (BECCS) and direct air capture (DAC) (Fuss et al., 2018; IPCC, 2018; 2022; Minx et al., 2018). Both rely on industrial processes to capture CO_2 and store it underground – the former by burning biomass for energy and capturing emissions, the latter through chemical filtration of air. While these technologies are often presented as neutral tools for climate mitigation, a closer look reveals that they reinforce the very political-economic structures driving the crisis. First, they enable the privatization of public investment in climate action. Oil and gas companies have positioned themselves as essential partners in developing these technologies, lobbying for carbon tax revenues and public funds to be directed toward capture and storage infrastructure that they alone have the capacity to build (Occidental Petroleum, 2024). Despite decades of research and billions in investment, carbon capture and storage delivers negligible results in terms of net atmospheric removal, less than 0.1% annual CO^2 emissions (Rasool & Moiz Hashmi, 2025; Wang et al., 2021). Second, these technologies serve to prolong the fossil fuel economy. Occidental Petroleum, a major oil and gas producer, exemplifies this trend. In 2023, Occidental announced they would acquire Carbon Engineering, a leading DAC firm, with plans to use captured CO_2 for enhanced oil recovery. This is a process that injects captured CO_2 into depleted wells to extract more crude oil. The company's stated aim is to produce "net-zero oil" and thereby secure a long-term role for fossil fuels in the global energy mix, explicitly in service of shareholder value (Occidental Petroleum, 2023). Finally, large-scale deployment of BECCS or DAC would entail severe social and ecological trade-offs. Modeling suggests that achieving the necessary sequestration volumes through BECCS could require converting an area comparable to 6-45% of global cropland into bioenergy plantations (Braun et al., 2025). This would intensify pressures on food systems, biodiversity, and land rights, particularly in the Global South. In effect, both BECCS and DAC displace the burdens of decarbonization onto ecosystems and communities while preserving existing power structures. In this light, capitalist forms of carbon sequestration demonstrate a new variation of the Jevons' Paradox: technologies intended to mitigate emissions become instruments for reproducing the growth imperative, deepening dependence on fossil fuels and extractive logics. The result is not a break from the fossil economy but its technocratic rebranding under the banner of sustainability.

If industrial carbon capture reproduces the very dynamics it claims to counter, what might an alternative approach look like? Many nature-based strategies suggest more promising directions, capable of addressing both social and environmental needs. Regenerative agriculture, for instance, can increase soil and biomass carbon while improving biodiversity, food security, and farmer livelihoods (Niether et al., 2020). Similarly, adding biochar to soils enhances nutrient and water retention, improving plant growth (which sequesters additional carbon), while storing carbon in the soil for millennia (Wang et al., 2016). In urban contexts, green spaces like parks, community gardens, and green roofs can strengthen social ties, provide leisure and food, and improve local climate resilience while acting as carbon sinks (Kinnunen et al., 2022; Quaranta et al., 2021; Rogge & Theesfeld, 2018; Sharifi, 2021). Construction-stored carbon seeks to transform the built environment from a carbon source to a carbon sink by using bio-based materials such as mass-timber, straw, or hempcrete, which capture carbon during plant growth and locks it into buildings for decades or centuries (Bjånesøy et al., 2023; Churkina et al., 2020; Pittau et al., 2019). The potential scale of urban carbon storage is significant, possibly exceeding that of forests per unit area (Talvitie et al., 2022). Importantly, such approaches can also deliver social co-benefits. For example, public housing projects designed and built with mass timber could provide affordable homes, embedding carbon in the urban fabric while simultaneously generating social solidarity (Bianchij & Costa, 2024; Hafner et al., 2020; Pittau et al., 2019). These strategies share key features: they are nature-based, socially embedded, and multifunctional. They generate ecological and social value simultaneously rather than subordinating one to the other. As such, they suggest a fundamentally different orientation to carbon sequestration, grounded in collective benefit rather than accumulation and profit. In the next section we take this insight further by exploring the potential for carbon sequestration to be designed and organized as a commons.

3.3.

COMMONING CARBON: RECLAIMING SEQUESTRATION AS A SOCIAL-ECOLOGICAL PRACTICE

As the previous section showed, many nature-based carbon sequestration strategies hold the potential to deliver climate mitigation while generating significant social benefits. The question, then, is what prevents these strategies from being more widely implemented. When economic life is organised around profit, environmental stewardship is structurally cast as a cost. As the system stands, is always less profitable to farm regeneratively, to preserve urban land for green space instead of commercial development, or to build with bio-based materials. A different approach to climate mitigation therefore requires a different economic logic – one capable of integrating unquantified social and ecological values into decisions about what kinds of carbon-related infrastructures are invested in, designed, built, and sustained.

Figure 9
Carbon capture installation at the Heidelberg cement factory, Brevik, Norway. Scheduled to start operating in 2025, it will be the first commercial-scale use of CCS in cement production. While many attempts have been made to advance CCS in industry over the years, the pace of development has been far slower than what climate mitigation scenarios require. Source: Wikimedia Commons, Licensed under CC BY 4.0.

The commons provides such a framework by grounding the organisation of resources and infrastructure in shared needs and values rather than profitability (D'Alisa et al., 2015; Bollier, 2014; Bollier & Helfrich, 2019). In commons scholarship, the "commons" refers both to systems of shared resources and to the social practices – commoning – through which communities collectively govern, use, care for, and reproduce those resources (ibid.). Commons systems tend to prioritise need-satisfaction by enabling open participation in governance and collective decision-making about what gets produced and for whom (Moreira & Fuster Morell, 2020). When applied to carbon sequestration, a commons approach could reorient efforts away from extractive optimisation (maximising biomass yield at the expense of communities or biodiversity, for instance) and toward what communities deem essential. The Carbon Commons thus extends Jakob and Edenhofer's (2014) argument for organising key social resources – public housing, parks, schools, water, and public transport – as commons capable of sustaining social welfare in an age of climate uncertainty. Importantly, commons governance is not limited to natural resources; it can equally sustain complex socio-technical systems, as demonstrated by large-scale peer-produced knowledge infrastructures such as Wikipedia, which show how collective stewardship can scale while remaining open, participatory, and non-commodified.

When framed through the commons, carbon becomes embedded in a wider constellation of values understood qualitatively and relationally rather than financially. Communities engaged in stewarding soils, forests, or materials for their carbon-cycling capacities can connect this work to broader concerns: healthy environments, shared spaces, opportunities for creativity and learning, and the ability to meet basic needs without relying on extractive market systems. Carbon sequestration thus becomes inseparable from the flourishing of the ecosystems and social relations that sustain it. This inevitably makes governance more complex and negotiated than a singular metric of cost per tonne of CO_2. Yet it is precisely this complexity that enables commons systems to account for the full spectrum of what is required for a good life.

A commons lens therefore reframes carbon sequestration from a costly, end-of-pipe climate solution into a shared resource and a collective project of ecological and social reproduction. Rather than concentrating responsibility in industrial actors, commoning invites communities to co-produce, steward, and democratically govern the flows of carbon that sustain life. This perspective aligns with post-growth insights that mitigating climate change requires transforming not only infrastructures but also the social relations and value systems that underpin them (Euler, 2019; Hickel, 2021). As Varvarousis and Kallis (2017, p.128) argue, commons-based practices can prefigure economies built around "new forms of 'common-wealth' – wealth that no longer relies on more and more money." The Carbon Commons thus reimagines prosperity as the joint restoration of ecological integrity and social well-being, positioning carbon sequestration not as an economic burden but as a shared pathway toward a post-growth future.

Realising this vision, however, is far from straightforward. Scholarship on actually existing commons reveals persistent challenges around power dynamics, hybridity, and fragility. Commons governance frequently operates in entanglement with state regulation and institutional compromise rather than as a clean alternative: governmental actors participating in collaborative governance often revert to centralised, managerial logics that impede the deliberative and consensus-oriented processes on which commoning depends (Meerkerk, 2024). Hybrid arrangements between commons and market or state institutions carry their own risks, and a politics of hybridity, while sometimes necessary, requires embedded transformative strategies that resist co-optation by more powerful actors (Schmid, 2021). Moreover, the autonomy that commons-based practices seek to cultivate is not an end-state but a condition requiring constant renewal; it emerges within existing socio-economic institutions while simultaneously depending on new ones to be sustained (Savini, 2022). Acknowledging these tensions is essential for a realistic account of the Carbon Commons, and it is precisely these dynamics that surface in our empirical findings in section 5.

3.4.

A CARBON COMMONS LIVING LAB

We now turn to what the carbon commons may look like in practice, by reflecting on the results of a living lab established in collaboration with a community centre in Amsterdam. During the 'Carbon Commons Living Lab', we tested how sequestration practices might be integrated into neighbourhood life, while simultaneously contributing to shared social and ecological value. Rather than introducing a predefined technical intervention, we sought to design carbon sequestration within a process of commoning.

3.4.1.

LIVING LABS AS METHODOLOGICAL GROUND

We conducted our research in the context of a living lab, an experimental real-world environment that integrates research, innovation, and everyday life while engaging citizens as co-creators rather than research subjects (Evans & Karvonen, 2013; Rizzo et al., 2021). Central to our methodological grounding was the role of design — and, relatedly, of designers as situated actors. The research team consisted of design and engineering researchers based at a Dutch university, more highly educated than most participants in the community centre and not from the Netherlands themselves. As external experts, we brought disciplinary knowledge and institutional resources that community members did not have equal access to, an asymmetry that inevitably shaped the dynamics of co-creation and that we reflect on explicitly across section 5. Working through a research-through-design process (Stappers & Giaccardi, 2017), the living lab became not only a site for observing situated practices but a means of materially exploring alternative socio-technical arrangements. Prior scholarship has shown that design is fundamental to generating new imaginaries and configurations for sustainable socio-technical systems (Pineda et al., 2024). Within sustainability-oriented living labs, design has also been used to bridge technical and social innovation by experimenting with both how technologies are shaped and the social relations into which they are embedded, enabled, produced, and used (Belfield & Petrescu, 2024).

Building on this foundation, we reframed the living lab itself as a commoning process. Rather than positioning participants as users or stakeholders of a predefined intervention, we approached all those involved as commoners who collectively shaped both the material intervention and its modes of governance. This reframing allowed us to focus on carbon sequestration not merely as a technical challenge but as a shared social and ecological process, enacted and negotiated through collaborative design within the living lab.

3.4.2.

CONTEXT AND SETUP

The community centre that hosted the living lab is a lively social hub in a dense, multicultural neighbourhood characterized by residential tower blocks and limited green space. When we first arrived, the atmosphere was vibrant and chaotic: the sound of kickboxing lessons for children mingled with gentle chatter over tea, the smell of lunch from the community kitchen lingered in the hall. Posters advertising concerts, workshops, and youth programs covered the entrance walls. Our entry into the community centre was facilitated by an existing contact – a university acquaintance of the lead author – who works as a community programmer. This relationship provided an initial layer of trust and understanding, important for negotiating our presence as external design researchers.

We began by introducing the idea of carbon sequestration to the community programmers. The concept was initially unfamiliar, but it sparked curiosity once the abstract explanations of CO_2 shifted to a conversation about designing and building something useful and lasting for the community. To expand the presence and visibility of the community centre within the wider neighborhood, the programmers expressed a desire to create a garden and usable public space on the sidewalk between the parking lot and the building (Fig. 1-3). The co-producton of this garden became the focal point of the living lab.

Through a series of preliminary meetings, we established a core team consisting of the three community programmers alongside an external architect versed in participatory design who was invited to participate in the project. Together, we decided to embed our project within an existing initiative called Technical Lab, a month-long program offering technical education to local youth. This alignment was both strategic and symbiotic: it provided access to funding, offered a ready-made structure for workshops, and allowed us to link the (still) abstract concept of carbon sequestration to tangible, hands-on activities. During early meetings with the centre's Board, reactions varied: one advisor with a scientific background was particularly drawn to the environmental focus, while others connected more with the vision of a garden that would draw people in from the street and provide space for gatherings. This difference in resonance became a productive tension throughout the project, shaping how sequestration was translated into shared language and practice.

As we came to know the centre better, we realized that the commons already existed in informal ways. Some people were employed by the centre; others volunteered in exchange for food, coffee, or access to space for their own activities. Children drifted in and out freely after school, and the building functioned as a safe social space that blurred the line between public and private. Our project, therefore, would not create a commons, but amplify and materialize its existing practices through the lens of carbon sequestration.

3.4.3.

DATA COLLECTION AND ANALYSIS

Across the design, construction, and a six-month period of community use, we noted the evolution of the project through our own observations and informal conversations with commoners. These were recorded in a process of daily journalling following site visits, which yielded in total 18 entries. In addition, we conducted four semi-structured interviews with core team members following the construction phase. All semi-structured interviews followed the same format: interviewees were asked to reflect on which community values and needs were evident across the project; how important was the carbon sequestration aspect of the project, and which sequestration techniques were most beneficial for what the community deemed important; and how well the project was able to foster ‘commoning practices’, or social relations based on reciprocity, participation, and collective action. In addition, interviewees were asked to reflect on the hurdles encountered, from community buy-in, to permitting challenges, to the team’s facilitation role. Interviews were transcribed and analyzed together with the journal observations using a process of thematic analysis (Braun & Clarke, 2006). Coding considered technical aspects, social aspects, stakeholder roles and responsibilities, and challenges. The analysis was then used to synthesize the insights we discuss next.

3.5.

THE CARBON COMMONS

CO-DESIGN: MAKING SPACE TOGETHER

The co-design of the garden unfolded as an iterative process between the authors, the architect, the community programmers, the broader community, and external municipal stakeholders. Our first step was to map existing desires and needs through a simple public survey. The survey listed possible outdoor features – planter beds, picnic tables, jeux-de-boules, an activity board – but also invited open suggestions. Responses emphasized greenery,

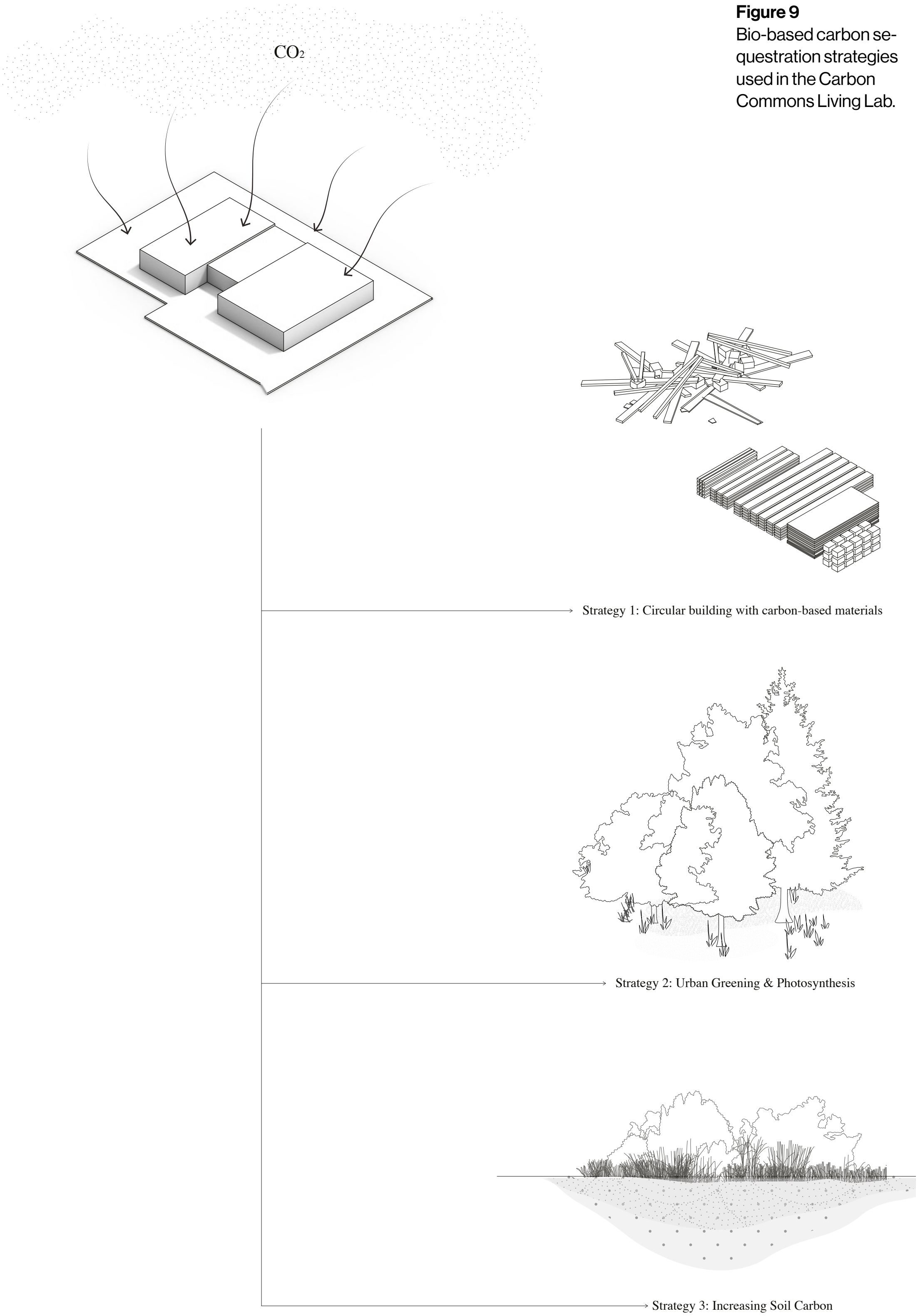

Figure 9
Bio-based carbon sequestration strategies used in the Carbon Commons Living Lab.

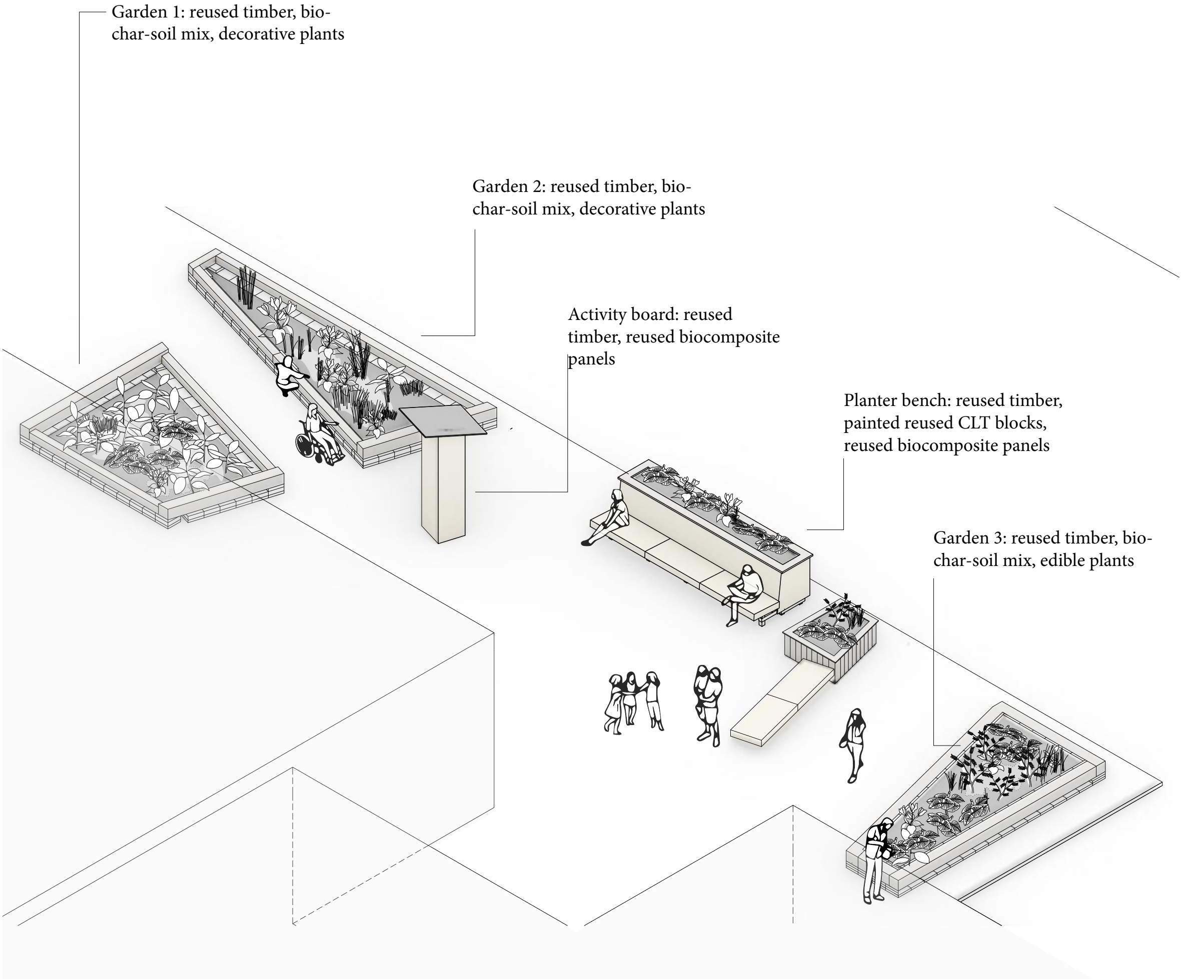

Figure 10
Axonometric drawing of the carbon sequestering garden.

Figure 12 (left)
The garden in the summer following construction. The Bench-planter incorporates a variety of reused bio-based materials, including bio-composite panels, reused massive CLT blocks, and construction timber. IN the garden, summer herbs have been planted in a carbon-rich soil infused with Biochar.

Figure 13 (above)
The garden in the summer. To the right, the olive tree planted by the community, symbolizing resilience and staking their claim over public space in the neighborhood.

Figure 14 (left)
Massive Elm 'CIty-wood' sourced for the Carbon Commons garden. An amsterdam-based sawmill processes trees felled within city limits due to construction or wind-fall.

Figure 15 (above)
Technical lab workshop 1. Volunteers prepping the site by removing concrete tiles.

Figure 16 (top-left)
Construction timber waste wood, reused for garden elements.

Figure 17 (top-right)
Prepping CLT blocks for painting activity.

Figure 18 (left)
Plants for garden, sourced from local garden shop.

Figure 19 (right)
Biochar being produced from con-struction off-cuts in Amsterdam using the Kon Tiki method.

Figure 20 (top-left)
Explaining the project to municipal gardening crews working around the neighborhood.

Figure 21 (top-right)
Workshop 1, shovelling soil into one of the gardens.

Figure 22 (left)
Workshop 2. Collective painting activity to protect and decorate the CLT benches.

Figure 23 (right)
Technical lab workshop 3. Planting the gardens.

comfort, and conviviality: “a place for outdoor meals”, “planters”, “space for children to play”.

We translated these responses into an initial design, which was prototyped in 1:1 spatial layouts using tape on the pavement, and invited spontaneous feedback from passersby. Some people paused to give comments; others walked through the taped outlines, informally testing the proposed circulation. For many, it was the first tangible sign that something might change. Through these everyday exchanges, the design gradually took shape.

The concept of carbon sequestration remained in the background during this phase. We found that direct discussions of sequestration often alienated participants as they appeared too technical, or too abstract. Instead, we worked through material metaphors: soil health, greenery, reused wood. This subtle translation allowed us to embed sequestration materially – through biochar-enriched soil and carbon-storing wood – without imposing scientific language that was inaccessible to the community.

Through this iterative process, we developed a technical design in collaboration with the architect. The final proposal featured three large planters, several benches, and an activity board for public announcements (Fig. 1-3). The design was also influenced by locally available materials from bio-waste streams (Fig 4-9, Table 1), which could be salvaged to store carbon and avoid incineration (CE Delft, 2020): from an urban sawmill we salvaged large timber beams cut from felled municipal trees (eg. due to safety or wind-blow) from a pile of construction waste we gathered useful posts; we also made use of donated bio-composite panels and large CLT timber blocks. Softwood components were treated for weather resistance. In addition, we produced biochar with the wood offcuts of our project in collaboration with a local NGO that specializes in this process, to be added back to the soil inside the gardens.

Some of our initial technical design ambitions had to be adjusted. We had hoped to experiment with hempcrete to demonstrate carbon-negative construction, but its permanence conflicted with the temporary lease of the site and the Board’s practical concerns. Instead, the focus shifted toward flexibility and maintenance. At one point, we debated whether to prioritize fast-growing biomass crops for carbon drawdown (eg. bamboo) or to plant edible species preferred by residents. The latter won. Participants wanted food and flowers, not only climate utility. This moment demonstrated a recurring point: the social drives of a group may not always coincide with the most technically efficient approach. The co-design phase thus became not only about shaping a physical garden but also about negotiating meaning and ownership. Decisions were made collectively, though often informally around coffee tables, during workshops, or while watching kids play.

3.5.2.

CO-BUILDING: LEARNING AND DOING

Embedded in the Technical Lab, the co-building phase became the most dynamic moment of the project (Fig. 10-14). Over three weekends in the late summer, around twenty local youth (aged 8–22) participated in workshops to construct the garden. The atmosphere was energetic. On the first day, children eagerly began prying up the concrete tiles to make space for soil. Shouting and laughing could be heard from a distance, as young children competed to lift the heavy tiles and wheelbarrows of soil.

The workshops were designed to engage the younger participants with accessible activities like painting or planting. Between workshops, we completed the more complex carpentry tasks, often drawing in curious bystanders who stopped to help. This led to many organic learning moments, for instance showing a teenager how to use a drill. We had several long chats; with the municipal gardeners, who were curious about our project and the sustainability gains; or with a group of teachers who had come to view the community center and learn about what was going on there. In one memorable moment, a group of teenage girls scolded an older man for throwing trash into the new planters they had just finished working on – a small but telling sign of emerging stewardship. Through such moments, the act of making together became an education in both material and social care.

Decision-making was equally improvisational during construction. When benches seemed too close to the entrance, we consulted a few parents leaving the centre at sunset, and their suggestions directly informed the final layout. These spontaneous interactions were part and parcel of the process, where shared responsibility unfolded through conversation and action rather than formal meetings.

One significant challenge with such an approach emerged during the building phase: an unexpected permitting complication with the municipality. While we had understood that the municipality has already granted all necessary approvals for the garden, midway through construction a different municipal department visited the site and informed us that additional permissions were required. Over the following months, we entered a process of negotiation, redesign, and compliance, working with municipal staff to adjust several elements to meet safety and accessibility standards. Ultimately, this cooperation resulted in a temporary two-year permit that enabled the garden to remain in place. This was a win for the community center, but a hindrance to the carbon sequestration goals of the project, which would require a much longer lifespan. While the situation was at times demanding, it proved instructive, revealing how grassroots experimentation and municipal governance operate with different logics, and how creating space for commoning within public systems requires sustained dialogue, translation, and mutual adjustment. The persistence of all involved demonstrated that such processes, though laborious, can build new forms of partnership.

3.5.3.

CO-USE: LIVING WITH THE GARDEN

After securing the permits and implementing the necessary changes, the garden was inaugurated with a spring celebration, and the community planted two symbolic olive trees, as well as a variety of vegetable seeds. The once-empty strip of pavement became a hinge between the building and the neighbourhood (Fig. 16-18). Cars no longer parked there; instead, people gathered on benches, children played on the edges of the planters, and evening events spilled outdoors. During summer, community dinners and performances were occasionally held in the new space, while in quieter months, a few dedicated neighbours tended the plants.

Over time, the garden's appearance evolved. In the beds, vegetables emerged alongside some less desirable nettles and weeds. Maintenance fluctuated with the seasons and people's availability. On hot days, some planters dried out; trash occasionally blew in. Yet, despite its imperfections, as of writing, the garden persists as a living commons: as an ordinary, working landscape shaped by care and neglect alike. As one community member remarked, "It's better like this than empty".

Next, we reflect on the carbon commons living lab using Bollier and Helfrich's (2019) "Triad of Commoning". The Triad identifies three central components of commoning – provisioning, social life, and peer governance – highlighting the interdependence of material, relational, and institutional dimensions that together sustain the commons. The triad is "based on the premise that commoning is primarily about maintaining relationships – among people in small and big communities and networks, between humans and the non-human world, and between us and past and future generations" (Bollier & Helfrich, 2019, p. 93). Each dimension of the triad was variably enacted in the living lab, revealing both the potential and the limitations of carbon commoning as a post-growth practice. Furthermore, for each dimension we reflect on our own positionality as design-researchers and generalize

Table 1
Materials and estimated carbon sequestration potential of garden

Material	Volume [m³]	Density [kg/m³]	Mass [kg]	Carbon Content [%]	Carbon sequestered [kg-C]	CO²-eq sequestered [kg-CO²]	Lifespan [years]
Elm 'city-wood'	1.4	560	784	0.5	392	1437.3	10
Larch 'city-wood'	0.42	560	235.2	0.5	117.6	431.2	10
3rd life re-used hard-wood from dock piles	0.09	850	76.5	0.5	38.25	140.3	20
Reusded CLT Blocks (originally trade samples)	0.5	430	215	0.5	107.5	394.2	20
Reusded plywood panels	0.05	430	21.5	0.5	10.75	39.4	2
Donated biocomposite panels	0.16	850	136	0.2	27.2	99.7	50
Soil	5	1400	7000	0.01	70	256.7	5
Biochar from construction offcuts	0.125	100	100	1	100	366.7	>1000
Total					863.3	3165.4	

this to prospective roles for design in facilitating the Carbon Commons.

3.5.4.

PROVISIONING WITH CARBON

Provisioning, in Bollier and Helfrich's triad, refers to the collaborative production and upkeep of shared resources. Rather than treating goods or infrastructures as commodities, commons-based provisioning emphasizes making and maintaining "useful, durable things that have ongoing social importance" (2019, p.165). When applied to carbon sequestration, this means co-creating and caring for things made from sequestered carbon. Instead of outsourcing sequestration to industrial systems, communities directly engage with the material processes that hold carbon in soils, vegetation, and built structures, turning climate action into a shared, regenerative practice.

In the living lab, provisioning appeared through experimentation with three sequestration strategies: adding biochar to the soil, storing carbon in timber-based constructions, and replacing concrete with permeable, planted surfaces. Each method offered a pathway not only to store carbon but to produce new forms of shared value. The clearest expression of "useful and durable things" was the garden itself. What had been a derelict strip of pavement became an extension of the community centre. It became a place where children could play, where neighbors could gather, and where food and plants could grow. It hosted dinners, workshops, and informal encounters. It became a recognizable symbol of the community's presence – materialized, for example, in the olive trees planted as a symbol of diversity and resilience.

Provisioning also unfolded through the project's alignment with the community centre's existing Technical Lab. Because the Lab already provided youth with practical skills and creative outlets, our role as designers involved extending these motivations toward ecological and material practices. Workshops on working with reclaimed timber, for instance, supported self-provisioning that could empower future projects well beyond the garden. In this way, the living lab produced not only physical objects but also capacities, skills, and confidence – resources equally essential to commons-based provisioning.

A critical lesson, however, was that provisioning was almost never understood by participants as carbon sequestration. Our early emphasis on CO_2 removal felt abstract and disconnected from lived experience of the community center. When framed scientifically or quantitatively, sequestration appeared “too academic” or even a “luxury” in a context shaped by immediate concerns such as social isolation or lack of youth spaces (Hutak, 2020). While climate change was acknowledged as important, it was often perceived as distant from daily life. The use of biochar made this gap visible: although it is an effective long-term carbon sink, the material carried little meaning for participants because it was introduced outside a hands-on, relational context. Had biochar been integrated into a participatory workshop, it might have become a sensory, shared practice. Instead, its technical benefits remained abstract, whereas the garden – something participants could see, touch, and shape – generated an immediate sense of ownership.

This gap points to a broader insight: what makes carbon sequestration meaningful within a commons is not simply its climate efficacy but its relational embeddedness in community life. Relational embedding differs from technical embedding (e.g., storage underground) by strengthening connections between people, materials, and place. Bio-based materials in buildings or landscapes can store carbon while physically reshaping shared environments (Churkina et al., 2020); nature-based approaches can create green, biodiverse, socially vibrant public spaces (Kabisch et al., 2017; Raymond et al., 2017). These interventions do more than capture carbon –they create opportunities for communities to remake their surroundings in ways that deepen belonging and resilience.

Seen this way, it becomes clearer why industrial negative-emissions technologies often fail to produce meaningful social or ecological outcomes: oriented toward efficiency and profit, they remain detached from the relational contexts that give sequestration its capacity to sustain life. By contrast, embedding carbon into shared practices – in gardens, buildings, infrastructures, or skills – offers a different paradigm, where carbon becomes a medium through which communities cultivate ties to each other and their environments.

Designers as embedded technical mediators

As designers we played a mediating role within this process of provisioning. Our responsibility was not merely to supply technical expertise but to translate sequestration techniques into accessible community practices. Following Schranz (2023), design here functioned as an embedded mediator between technical and social domains: a relational practice of inhabiting, explaining, and co-working alongside participants. Working in public view, discussing design decisions on site, and demonstrating material processes turned technical knowledge into shared know-how. This embeddedness blurred conventional boundaries between expert and layperson. Such interactions transformed specialized design knowledge into a common resource, strengthening local capacity for maintenance and future adaptation. Provisioning thus extended beyond immediate construction to include the exchange of skills and knowledge.

3.5.5.

SOCIALISING THROUGH CARBON

Within Bollier and Helfrich's triad, the social life of the commons refers to the relational and cultural practices that allow a commons to endure. Commoning is not only a mode of resource management but a shared way of being together (Stavrides, 2016). Patterns such as "cultivating shared purpose and values", "ritualizing togetherness" and "deepening communion with nature" (Bollier & Helfrich, 2019) describe how purpose, cooperation, recognition, and everyday interaction with place reproduce the commons as a social world. For carbon sequestration, this dimension is essential: technical efficiency alone cannot ensure that carbon stays stored in soils, vegetation, or materials. Long-term stewardship depends on communities who identify with, and care for, the ecologies that hold carbon. Co-design processes can nurture these relationships by cultivating social bonds around shared work (Bassetti et al., 2018), turning environmental maintenance into a collective practice of mutual care rather than a technical obligation.

In the living lab, the social life of the commons emerged most vividly through the embodied practices of co-design, co-production, and co-use. Workshops brought together diverse participants to dig, plant, paint, cook, eat, and improvise solutions side by side, cultivating a shared purpose: to create a space the group could use, inhabit, and genuinely call its own. These activities ritualized togetherness – whether through meeting regularly to work, celebrating milestones such as the garden's opening, or gathering around symbolic elements like the planting of the olive tree. Carbon therefore functioned less as a technical target than as a pretext for assembling, learning from one another, and collectively shaping the environment. For many, participation also offered a chance to contribute creatively and meaningfully: to beautify the neighborhood, to steward the local ecosystem, and to act on desires for self-actualization often excluded from routine urban life.

In doing so, the project began to suggest the contours of what Illich (1973) describes as a more convivial mode of production: social, engaged, participatory, and oriented toward human autonomy. As Illich argues, modern societies often rely on tools and systems that, while indispensable, diminish the capacity of people to shape their own material worlds. Conventional, expert-driven models of carbon sequestration reflect this pattern, reproducing technical lifeworlds in which most people are positioned as passive consumers rather than co-producers. By contrast, the garden offered moments of conviviality that resisted what Euler (2019) calls the enclosure of social life within the commodity form.

The sociality of the carbon commons did not end with construction. Everyday acts of maintenance – watering plants, sweeping leaves, repairing benches – continued to sustain the garden as a site of relationality. These mundane routines translated carbon from an atmospheric abstraction into a lived practice of care, reinforcing what Weber (2019) identifies as a latent ecological bond linking people with the more-than-human world. In this sense, carbon commoning supported forms of social production oriented toward participation, creativity, and self-actualization. The technical work of sequestration became inseparable from the work of building community.

Looking beyond this case, these dynamics highlight a broader lesson: for carbon sequestration to function as a commons, it must become socially meaningful. Whether through a community managed forest, collective repairs of bio-based buildings, or neighborhood stewardship of green infrastructures, sequestration acquires durability when it is woven into everyday rituals, relationships, and shared identities and purpose. This relational embedding allows carbon to act not only as a climate instrument but as a medium for cultivating collective life. As provisioning already suggested, the social life of the commons is not an addition to carbon sequestration – it is one of the primary conditions through which a Carbon Commons can take root and expand.

The designer as facilitator of commoning rituals

Our role as designers here was one of facilitating and ritualizing : creating conditions for participation, learning, coming together around the materiality of carbon. By organizing workshops, structuring accessible building tasks, and making design decisions transparent, we supported the emergence of informal social structures around the project. For many participants, the process opened up new forms of social recognition. Youth who attended the workshops gained visible ownership over the space, while the community centre's programmers integrated the garden into their regular activities. The material presence of the carbon-storing garden thus anchored social life, as it became a backdrop for events, teaching, and everyday encounters.

3.5.6.

GOVERNING CARBON INTO THE FUTURE

In Bollier and Helfrich's terms, governance is "a reliable means by which commoners can build authentic, living relationships among themselves, and in so doing, develop a coherent, stable commons" (2019, p. 127). Governance is therefore less an institutional blueprint than a regenerative social process that continually rearticulates roles, norms, and shared expectations. Within carbon sequestration, this dimension becomes particularly challenging. The atmosphere and biosphere already form a planetary carbon commons historically enclosed and exploited (Bellamy Foster, 2022; Weber, 2019). Local initiatives such as community forests, cooperative green spaces, or neighborhood gardens represent situated expressions of this commons, requiring forms of governance that accommodate both everyday stewardship and broader climate responsibilities. Peer governance thus becomes the connective tissue that enables commoning practices be reproduced and 'scale out' (Dengler & Lang, 2021), shaping how credibility, responsibility, and benefits are collectively negotiated. Yet it is also the most fragile dimension, as practices of commoning must navigate established institutional and technical regimes.

In the living lab, provisioning and social life were readily enacted, but peer governance emerged only partially and with difficulty. Because the project was situated on municipal land, relied on external funding, and operated within safety and accessibility guidelines, governance quickly became a shared concern across community members, designers, and municipal actors. These interdependencies were workable during implementation, yet they complicated the question of long-term responsibility: who ultimately governs the Carbon Commons once initial facilitators withdraw? How can governance ensure the long-term lifespan of bio-based or green infrastructures mandated by the technical necessity of carbon sequestration, which may extend beyond the lifespan of the original designers or users? While residents could informally maintain the garden, issues of liability, ownership, and ongoing accountability remained unresolved. The project thus exposed a structural tension within carbon commoning: sequestration requires monitoring, upkeep, and material longevity, while the social practices that give sequestration meaning are fluid, adaptive, and relational. Peer governance must bridge these temporalities by finding ways to align the quantitative rhythms of carbon accounting with the lived time of commoning.

The challenges encountered with the municipality highlighted one potential future direction for governance: the possibility of public–commons partnerships that can stabilize such initiatives without subsuming them (Bollier & Helfrich, 2019). Rather than governing through command or incentives, governments can play an enabling role by providing infrastructure, equipment, expertise, and funding that allow communities to assume shared responsibility for local carbon stewardship. As Bollier & Helfrich (2019) note, public institutions possess unique capacities to establish "macroplatforms" which can facilitate or hinder climate accountability within the commons. For example, safety standards for public space that can be achieved by communities themselves, interoperable tools for measuring carbon sequestration, or finance mechanisms which are accessible at the local level but geared toward long-term ecological and social value. These forms of support do not replace peer governance but make it viable, helping align community initiative with broader climate mandates over the long run. Governing carbon into the future thus requires a layered model in which community self-organization, municipal recognition, and state-enabled infrastructures work in concert. With such arrangements, carbon commoning could move beyond isolated experiments and evolve into a durable institutional form capable of contributing to post-growth climate futures.

Designers as translators

As designers we occupied a mediating role in this governance gap. Acting as intermediaries between the community and external authorities, or between social needs and technical climate mitigation concerns, we translated the immediate and lived language of commoning into bureaucratic formats for permit applications, safety reports, technical designs, and funding proposals. As Parker and Schmidt (2017) observe, such mediation is essential for negotiating between public-sector gatekeepers and collective rights to use space.

Rather than treating technical oversight and bureaucratic compliance as external burdens, design may be particularly suited to reimagine these as elements of a collectively negotiated peer governance. Facilitated by designers, communities could, for instance, develop open-source carbon logs, shared maintenance calendars, or distributed monitoring and design knowledge-sharing. Seen this way, the work of design is not to bridge two worlds but to help cultivate new ones: governance infrastructures that grow out of everyday practices, reflect local values, and remain open to more durable, long-term alliances.

3.6.

CONCLUSIONS

Across Bollier & Helfrich's Commoning Triad – provisioning, social life, and governance – the Carbon Commons Living Lab reveals how carbon sequestration can be reframed as a relational, community-driven practice. Provisioning transformed carbon into shared material and spatial infrastructure; social life animated that infrastructure through ongoing collective action; and governance exposed the institutional tensions that determine the Carbon Commons' capacity to endure across timescales necessitated by carbon sequestration.

Theoretically, the Carbon Commons makes a distinct contribution to both post-growth and commons scholarship. While post-growth literature has extensively critiqued market-based carbon removal, it has paid comparatively little attention to how sequestration might be positively organised outside of those logics. The Carbon Commons fills this gap by proposing commoning as a concrete socio-economic framework for sequestration that treats carbon not as a tradable asset or technocratic target but as a shared material embedded in collective life. In doing so, it extends commons theory into a domain where it has rarely been applied, and offers a conceptual bridge between post-growth economics and the practical design of carbon-storing infrastructures and landscapes.

For technical designers concerned with carbon sequestration or climate mitigation more generally, these dynamics redefine professional roles. The designer becomes an infrastructural mediator who embeds technical expertise within communities, facilitates social processes, and helps to navigate interfaces with and across governance systems. This triadic role aligns design with Bollier and Helfrich's understanding of commoning as a living, evolving practice rather than a fixed model. For practitioners more broadly, including community organizers and local policymakers, the living lab offers several concrete lessons. Carbon sequestration becomes meaningful to communities not through scientific framing but through material and social embeddedness: gardens, buildings, and shared infrastructures that people can shape, use, and identify with. The role of expert designers in such processes is necessarily relational and political, requiring active attention to power asymmetries and a commitment to redistributing knowledge and agency rather than delivering solutions. And durable carbon commoning depends on enabling institutional arrangements, for instance flexible municipal governance, accessible funding mechanisms, and long-term stewardship structures that can outlast any single project or team.

Ultimately, the Carbon Commons points toward a different approach to organizing technology for a post-growth future grounded in collective needs and values rather than the logic of profit maximization. Carbon, in this view, is not merely a pollutant to be managed cost-effectively, but a medium through which new techno-social relations can be formed. By provisioning together, sustaining social life, and negotiating governance, communities can transform sequestration into a practice of shared ecological responsibility that sequesters not only carbon, but also value, meaning, and collective agency.

005 Designing with more-than-human temporalities

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Time is a crucial element in design, and even more so when it comes to designing for sustainability. Many designers approach sustainability from a problem-solving perspective, according to which time is linear (and therefore quantifiable) and the future is predictable (and therefore designable). Designerly time appears quintessentially modern and human. A welcome antidote can be found in more-than-human design perspectives, where a multitude of actants and agencies and their appropriate temporalities are given consideration and space. In this paper we add to such approaches by exploring in practice two ways to engage with more-than-human temporalities: noticing and care. We illustrate how these approaches may give way to new design practices by discussing the conceptualization and construction of a music festival stage in France. We argue that such design practices integrate ecological care into the design process by attuning the designer to the different scales and rhythms of ecosystems and their more-than-human members.

4.1.

INTRODUCTION

The precarious future marked by climate change and ecological collapse is the backdrop against which we must consider the role of design in the world. Many have begun to question its implication in the profit-centered corporate systems of production at the root of the environmental crisis (Irwin, 2015; Escobar, 2011; Walker, 2006; Wahl, 2016; Fry, 1998). While climate change has become a de-facto concern for designers, many approach sustainability as a complex problem that could be solved by merely switching to electric cars or to recycled plastic, for instance (Bendor, 2018). While logical, these technology-centric approaches do little to question the relationship between humans and the environment. They overly simplify the problem to that of “measurable or quantifiable data...[which] leads to abstraction in relation to the everyday life of most people, only to be left with the hope that the newest technology (always in the future) will ‘solve’ those issues” (Avila, 2022, p.36). However, history shows us that technology always has unintended and unpredictable consequences (Fry, 1998; Verbeek, 2016). Extraction, waste, toxicity, environmental degradation – all seem endemic to globalized industrial production, inescapable results of the modern drive for progress. These externalities demonstrate the fallacy that technological innovation – switching one energy source to another, or one material to another – will alone improve the situation. Problematically, modern culture is geared towards a narrow anthropocentric framing of progress (financial growth, convenience), while ignoring the delicate interconnections and interdependencies between human culture and the living, life-supporting capacity of ecosystems.

More-than-human design (MtHD) begins to reckon with the anthropocentrism typically underlying modern design practices. Invariably, as the industrial design profession co-evolved with mechanization, its roots are intertwined with the extractive and exploitative nature of industrial production and capitalism (Papanek, 1971). But promisingly, as sustainability concerns have gone mainstream, design researchers have taken up the task of reorienting design towards practices that value all life, “searching for alternative design approaches to support the wellbeing of the entire planet without necessarily prioritizing one species over others” (Coskun et. Al., 2022, p.1). At the core of MtHD is an appreciation of the complex interconnection of technological, social, and ecological systems, which has blurred the distinction between 'human', 'nature', and 'technology' (Braidotti, 2013; Harraway, 2016). Moving away from closed-systems with clear teleology, emphasis is placed instead on the relational nature of design through concepts such as actor-networks (Latour, 1992), assemblages (Tsing, 2015), or string figures (Harraway, 2016). In this switch, agency becomes distributed in both things and other species, thus questioning the designer's ability to independently define or control the outcome of any design (Kuijer and Giaccardi, 2018; Coulton, 2019; Wakkary, 2021). Thus, the future emerges unpredictably from unfolding relations between actors– ecosystems, water, weather, landscapes, climate, for instance (Cielemecka, 2019; Fry 2009). The question then becomes which actors does design bring together, and who, or what, is prioritized? How, with all this complexity, can we work towards a desirable and livable future for the many? By challenging the human-centered dominion over the planet, "practices that enable the perception of new registers for cohabitation, [and] renewed aesthetic standards to perceive the hostility of the retraction of life" might be developed (Avila, 2022). Importantly, only in acknowledging the agency of other things in co-constituting designed outcomes, we can begin to design with a greater humility, caution, and care for all life.

As we will explore in this paper, the way designers conceptualize time is an important ingredient to reframe design within ecology, and not outside of it. The distributed understanding of agency in a complex and interconnected world of collapsing ecologies and emerging technologies necessitates a different perspective of time than the modern one – acknowledging multiplicity, temporal coordination, contingency, and emergence. Specifically, we criticize the modern, Western productivist view of time as linear, constant, quantified, and tied to notions of progress (Kumar, 1978; Mumford, 1963). Such a conception of time does little to acknowledge the temporal differences that exist across places, peoples, and ecosystems. Importantly, ecological relations require taking different timescales into account (Bird Rose, 2012).

Following an analysis of the problematic aspects of modern technoscientific time, this paper contributes to the ongoing discourse around more-than-human temporalities, by exploring how such temporalities can prompt design practices that are ecologically situated, sensitive to other beings, relational, and regenerative. We do this by exploring two concepts – noticing and care – that can be helpful temporal tools for designers.

We then test these concepts in practice, exploring what they mean for designing. To do so, we describe and analyze the design and construction of an experimental stage for a music festival. The festival was situated in a forested valley, a permanent home for a diversity of species, and a temporary gathering place for humans. As we will show, noticing local temporalities and making time for care in design can shift our approach to enacting changes in the material world, towards a more humble and symbiotic co-habitation within ecosystems.

4.2.

TEMPORALITIES IN DESIGN

MODERN TIME

Mainstream design is steeped in the rationalism of science and technology. From the enlightenment onwards, scientific developments were embodied in technologies of increasing complexity and might. This went together with an instrumentalization of the environment for human purposes. Narrowly framing problems in terms of their individuated mechanical principles meant that designers could systematically optimize tech for greater speed, efficiency, and output while failing to see the delicate interconnectedness of social and natural phenomena (Banham, 1980). Now, this combination of thinking-and-doing (design and production) has manifested itself in a planet completely under the influence of humans and increasingly under strain.

With a mechanized view of the world (Dijksterhuis, 1961) emerged the modern conception of time (modern time): linear, quantifiable, accelerating with technological progress. Following the industrial revolution, the time to travel from A to B shrunk with the steam engine; the time to work no longer depended on daylight; the time for crops to grow no longer depended on natural growth and nutrient cycles of plants and animals. Everything could be shortened, increased, or sped up, and time became something to be optimized, controlled (Mumford, 1932; Odell, 2023). Clocks were useful to organize labor, structuring society around regimented work hours (ibid). Manufacturing processes were designed to optimize productivity at the expense of worker skilling and self-actualization (Marx, 1906). Just as at work productivity goals became pervasive, reducing the time to produce an output, in domestic life this productive drive pervaded our sense of time – think of short but effective workout videos, side hustles, packing everything into the best possible vacation.

Modern life paced to a hurried, productive, daily grind, feels strange against the precarious temporal backdrop of the 'end of history', the sixth extinction, the Anthropocene.

Sociologist Barbara Adam's work extensively critiques the relationship between modern time and environmental damage, and the fallacy of approaching sustainability from this temporal perspective. She writes:

> *"Our understanding of the temporal dimension of socio-environmental life is pretty much exhausted with knowledge about the time of calendars and clocks, ... intimately tied to the conceptual principles of Newtonian physics and the linear perspective, which encompass within their knowledge frame assumptions about linear causality on the one hand and reversibility on the other, as well as abstraction, rationalisation and objectivity" (Adam, 2005, p.8).*

Problematically, a universal, abstract, notion of time fails to reckon with the multiple local temporalities of functioning ecosystems, and the latent, emergent, and unpredictable effects of technologies on those ecosystems. In this sense, time plays a role in abstracting design practice from environmental reality. Functioning ecosystems and geosystems work at differing timescales – think pollinators, soil fertility, or aquifers. Since designing is about the future, if we imagine this future through a productivist anthropocentric virtualization (clock time, predictions, problem-solving) we risk attempting to control ecology as opposed to fitting within it, caring for it, and co-existing. Futures become reduced to one future.

4.2.2.

MORE-THAN-HUMAN TIME

If modern time goes hand in hand with industrial society and its domination over the living-web, what other approaches could work differently? Before the clock, time was largely associated with natural cycles and embodied experiences. As anthropologist David Abram observes:

> *"To indigenous, oral cultures, the ceaseless flux that we call 'time' is overwhelmingly cyclical in character. The senses of an oral people are still attuned to the land around them, still conversant with the expressive speech of the winds and the forest birds, still participant with the sensuous cosmos. Time, in such a world, is*

not separable from the circular life of the sun and the moon, from the cycling of the seasons, the death and rebirth of the animals – from the eternal return of the greening earth" (Abram, 1997, p.112).

From the Pintupi tribesmen of Australia to the Apache and Sioux Nations of North America, time was connected with place, attuned to the seasons, plants, animals. Interestingly, this local, cyclical, sensorial time brings with it a different perspective of agency. While modern time situates agency squarely in the hands of the human, pre-modern cultures tend to have a much more distributed notion of agency, where different creatures, important places, weather, the sun, were all understood as having a role in creating the future alongside humans (Bastian, 2009).

In its reaction against the anthropocentrism of modernity, more-than-human approaches have begun to consider the importance of other temporalities, more closely resembling the cyclical, local and situated ones of pre-modern societies. We see this temporal turn beginning within Human Computer Interaction (HCI), responding to the accelerating deployment of digital systems and their social effect on users fractured routines, attention and mental wellbeing (Odom et. al, 2012; Cheng et. al., 2011; Lindley, 2015; Pschetz; 2013;). Taking a more general perspective on the relation between time and design, Pschetz et al. (2018) propose Temporal Design to look at time as a plurality, "emerging out of relations between cultural, social, economic and political forces", with the goal of helping designers to enable more inclusive ways to understand time. Design-researchers have been exploring these temporal relationships through a variety of artefacts, such as a habitat for silkworms that generates ambient music (Iketa et. Al, 2023), a slow computer that incorporates algae into its computation (Iketa & Barati, 2023), or a cyano-chromic interface that "overcomes" the "temporal dissonance" between humans and micro-organisms (Zhou et. Al, 2023). The scope of these projects takes non-humans as mono-species, abstracted, lab-ready, confined to a vessel or dish or tank, and relates to them through "relatively short-term interactions, delimited to situations of use or specific devices" (Rahm-Skågeby & Rahm, 2022). Here, we contribute to the discourse by a) acknowledging ecology and its temporalities as a complex and interconnected web; b) refusing to mediate human-ecological relations with a layer of digital technology for the sake of "innovation!"; and c) trying to apply these concepts to a real-world project, thus considering how they might influence production on a larger scale.

We are inspired by recent work on MtHD and temporality which more substantially addresses the unfolding ecological crisis by acknowledging the importance of temporalities to functioning ecosystems, as well as the longer timeframes from which we must situate the Anthropocene (Rapp et. Al, 2022). What we see here is a shift away from a plural but human-centric understanding of time as a cultural construction, instead seeing time as something that is also experienced, embodied, or lived by non-humans. It calls on designers to begin to pay attention to our ecological surroundings (Light et. al, 2017); to consider relations and interdependencies with non-humans that might bring renewed ethics and solidarity with the living world more broadly. This requires placing an importance on materiality, situating each design action within the wider more-than-human web, challenging designers to ask what traces will persist into the near and distant future. This "includes acknowledging that humans are inseparable from other planet-shaping powers", meaning attention must be placed on the relation between design activities – i.e. production – and the geological and ecological rhythms of a stable planet (Rahm-Skågeby & Rahm, 2022).

As more-than-human time is multifaceted and locally contingent, how can designers incorporate this into real-world design projects? In the subsequent section, we outline two concepts that are useful to explore more-than-human temporalities, which, importantly, exist outside of the frames and rhythms of industrial society, and thus challenge the hegemonic perspective of time as linear, quantified, commodified, and progressive.

4.2.3.

CONCEPT 1: NOTICING

The first concept we will explore is noticing. To notice is to become aware, to pay special attention, to register, to treat something as worthy of recognition. Here, we draw from the work of Anna Tsing (2015; 2017), where noticing is a way to recognize the interconnections between social, political, cultural, and environmental systems. Noticing as a research tool undermines the totalizing narratives of capitalism, searching instead for specific situated instances of collaboration and diversity. We also build from the work of Rosen et. al (2022), who focus on the "situated experience of noticing, and in particular how it moves attention from the experience of self to the experience of oneself as part of the environment".

Noticing in the context of design urges designers to work towards projects that draw attention to both the beauty of the more-than-human world, and the pain that human activities are causing (Light et. al., 2017). Several researchers have explored how digital technologies might enhance our ability to notice: interactive gloves for mushroom foraging that can sense moisture (Liu et. al, 2018), or different sensing technologies in the context of gardening (Rosen et al., 2022). But we question the literal translation of noticing to digital implements that create legible data for humans: are we not failing to notice how the production of these technologies is damaging somewhere else? Noticing as an ontological tool, situating design and its material impacts within the wider ecological space, is perhaps a more valid approach to reorient design in general – to reconsider how we produce things to meet our needs. In short, noticing is a way of being in the world. To translate this to design, a perspective on its materiality is key, where decentering the human designer begins by "noticing, reading and appreciating the material's life history prior to and extending beyond the design moment without framing it solely in terms of its value to humans" (Dew and Rosner, 2018, p.9). We stress here that the material impact of design must be acknowledged.

Importantly, noticing is a way to challenge the frame of modern time: "Each living thing remakes the world through seasonal pulses of growth, lifetime reproductive patterns, and geographies of expansion. Within a given species, too, there are multiple time-making projects, as organisms enlist each other and coordinate in making landscapes." (Tsing, 2015, p.21). What we suggest is that noticing the more-than-human temporalities and rhythms that are intertwined in and through the design process can shed light on those parts of design which might exist outside of the drive for productivity. Understanding whose time is prioritized can be useful to notice the exploitation or commodification of some for the benefit of others. As a design becomes manifest in the form of a material artifact, new relations emerge through reconfigurations of matter. For instance, a wooden bench might connect an oak tree, a lumberjack, an owl, a trucker, a sawmill, a carpenter: a network of actors all with distinct tempos. How do their temporalities relate to one another? In what Tsing refers to as polyphony, does one rhythm make space for another, creating an overarching musicality, or is drowned out by the monotone of human production and progress?

4.2.4.

CONCEPT 2: CARE

The second concept we will explore is care. Joan Tronto defines care as “everything that we do to maintain, continue, and repair ‘our world’ so that we can live in it as well as possible. That world includes our bodies, our selves, and our environment, all of which we seek to interweave in a complex, life-sustaining web” (Tronto 1993, p. 103). The lack of care in modern neoliberal society has led to what The Care Collective (2020) decries as a “crisis of care”. A focus on individuality, personal well-being, and self-improvement has eroded social and communal relations, with people less able to care or be cared for (Place, 2022). Care is intrinsically relational and reciprocal, as it moves beyond empathy alone, to an active engagement in providing for someone or something (Key et. al, 2022).

In Matters of Care (2017), Maria Puig de la Bellacasa considers care in a more-than-human context. For her, care implies a relational ontology, beginning with an acknowledgement that every living being gives and receives care in some capacity. At a most basic level, entities are entangled with one another, and the benefit of one can be the benefit of another. For example, she discusses how soil ecology research has begun to view “soil communities” as living entities, composed of organic matter and minerals, but also a diversity of organisms. Bellacasa suggests that including humans as part of soil communities opens space for human-soil relations structured around care, where “the carer also depends on soil’s capacity to ‘take care’ of a number of processes that are vital to more than her existence” (ibid, p.192). Here, care “brings us to thinking from the perspective of the maintenance of a many-sided web of relations involved in the very possibility of ecosystem services rather than only of benefit to humans” (ibid, p.188).

Importantly, she shows how this means tuning into the different temporal rhythms of that being cared for:

> *“By exploring this elusive but important feature of the doings of care – that is, the recalcitrance of the temporality of care to the productionist rhythms - care time entails ‘making time’ to get involved with a diversity of timelines that make the web of more-than-human agencies” (ibid, p.171).*

In this formulation, care differs from productivity, with the former emerging from an appreciation, involvement, and support for other species, without necessarily receiving a direct benefit. Thus, care implies making time to give back. Understanding the important reciprocal care relations between humans and other species also means valuing other times as much as our own (Otkay et. al, 2023). Thus, care implies patience for the times of other species, such as seasonal changes, decomposition, nutrient cycles, or plant growth.

Applying care to design means replacing a one-sided extraction of value with a reciprocal, mutually beneficial relationship between design and the more-than-human world it invariably draws upon. With this, "alternative engagements with time are at stake that not only evoke a different mode of production, but a different mode of life, including a different relationship to work" (De la Bellacasa, 2017, p.200). This involves taking a step back from the function-oriented time typically central to a project (getting the thing built as efficiently as possible). To bring other species into the fold of design, to care about the reciprocal relations between design and other species, means making time. Importantly, this approach begins to erode the narrow temporal boundaries of production and human use, expanding the responsibility of the designer. In this sense, design becomes a question of what activities can simultaneously combine more-than-human care while attending materially to human needs. Given this material relationship between design and the environment, we emphasize materiality as an important point of consideration.

4.3.

METHOD FOR PRACTICAL EXPLORATION

In what follows, we explore noticing and care for more-than-human time in a real-world project: the design and fabrication of a stage for a music festival in southern France. The festival occurs yearly in a forested valley, and so the organizers, conscious about the impact of their festival on the local ecosystem, issued a design brief to incorporate sustainable and regenerative practices into the stage design. The location for the stage was fixed, as were certain technical requirements (location of AV equipment). In response, we proposed a stage concept that attempted to increase biodiversity, by remaining on site for use by other species over the course of the entire year.

Looking at design from a more-than-human lens forces the designer to acknowledge that each project is locally and contextually situated. For this reason, exploring how these concepts might affect practice requires practicing design insofar as only a real project can bring together different actors, generate relations, and leave space for the unknown. During the design process, the design researcher kept an ongoing journal to record events, relations, or interactions that were pertinent. In addition, we documented extensively with photos and videos. These resources were then used to reflect on how noticing and care influenced the design and construction process of the stage.

4.4.

ASPECTS IN PRACTICE

DIFFERENT TIMES: A FESTIVAL IN A MORE-THAN-HUMAN VALLEY

The context of the music festival is an interesting case to explore how different temporalities overlap and influence the relationships between more-than-human actors. The festival DNA draws on its natural setting, which offered a nice starting point in terms of the human-ecological relations. Importantly, we began the design process by acknowledging the clear power imbalance between the way festivals typically use space, as temporary visitors, and the way the ecosystem is the space. Time helps us understand how these relationships are imbalanced. The festival consists of a two-day human gathering of several hundred people, while many of the species that inhabit the forest valley are permanent residents and experience a disturbance to their normal temporal patterns. Collapsing the separation between 'the festival' and 'the valley' means acknowledging that both play a critical role in constituting the specific assemblage that occurs in this place. Thus, our design approach tried to bridge the temporalities of both festival and valley. Acknowledging the stage as a perturbation, but also a part of the temporal patterns of the valley, opened a design space in which we could expand the notion of "users" or "stakeholders" to include other species. In this light, we designed the stage to remain on site for the year (figures 1 and 2).

4.4.2.

NOTICING THE VALLEY'S RHYTHMS

With this, noticing involved paying special attention to what more-than-humans the stage would bring together, and the temporal rhythms of these different actors. While we had a productive aim – to build a stage – we were curious how we could bridge with other temporalities unrelated to our design goal.

Noticing took two different stages: noticing from afar, during the design process, and noticing on site, during the building process. The project reality required us to design remotely, while we acknowledged the need to consider the local context. Noticing afar thus consisted of desktop research, with the help of an ecologist, on the biotopes existing in the area, and on the climate, increasingly hot and dry. We noticed the presence of commercial lavender fields, cattle, and horses; satellite imagery showed the valley a green refuge among a sea of agricultural uses; a small creek flowing through the valley is a vital source of water in the hot summer months. A combination of maps, photos and videos from the festival organizers, later accompanied by conversations with people on site, helped create a picture of the more-than-human population of the area (Figure 3). The difficulty here led us to favor a design that we intentionally left open-ended; with a modular scaffolding structure that could be adjusted on-site; with a certainty that the actual stage would surely differ from our drawings.

During our research we also discovered ruins of gothic and roman churches surrounding the festival site. We noticed how these ruins, in their post-use collapse, became reabsorbed into the landscape and appropriated by different species. For instance, plants grew out of the walls, birds nested on the collapsed ramparts, and the crumbling structures provided shade and structure for animals to dwell. From this vantage of deep-time, natural local materials have the benefit of seamlessly returning to the earth without disturbing the shorter temporal rhythms of other species – whether with wood decomposing or stone remaining steadfast. Much like Bellacasa's example of soil as a multi-species life-web, a ruin is an apt analogy for such a system extended to the domain of architecture or design.

We set up camp for two weeks before the festival, immersing ourselves in the valley throughout the build-up (figure 4). There we became absorbed in the valley's rhythms, assisted by a lack of cell reception that isolated us from the outside world. Working hours were influenced not by the clock but by the availability of daylight and the heat of the sun. We noticed the grass, cut before we arrived, slowly beginning to grow again, while the paths we used to walk from our camp to the construction site became pronounced, as our footsteps compressed the ground. We began to observe the specific drainage of water around the stage, accounting for the way water flowed by adjusting the foundations and building drainage ditches. We noticed the insects underneath the earth as we cleared soil, trying not to damage the roots of an old tree.

The slow rhythms of the valley were soon contrasted by the bustle of preparations for the festival. To acquire tools, we had to consider store opening hours. To source part of the material (the rest was reclaimed on site), we had to deal with the schedule of the lumber yard. A small generator hummed noisily against the quiet chatter of birds, allowing us to work and live into the dark. A certain productive energy persisted, as we had to finish the stage in time for the festival. Several days of rain forced us to place tarps over our build site.

Meals and work meetings would structure and punctuate our working days, a point of relaxation and a coming together away from production. Noticing also led to speculating, as we begun to imagine the ways in which our stage would be taken over by the valley's temporalities by the slow growth of grass, ivy, and plants upon the structure, to the slower decomposition of the wood and compost we embedded within it.

4.4.3.

CARE FOR THE VALLEY

In the project, caring meant making time – both in design and construction – to integrate ourselves and our stage in the situated web of relations existing in the forest. To integrate, and not just to extract, means giving as well as receiving. This manifest itself as work that went beyond the purposes of the festival, for the sake of developing a mutually beneficial relationship with the forest. We considered the way the stage could bring together and mediate relations between different users of the space. This mediating potential extends beyond our ability to fully control it through design, thus asks us to tread lightly. Thinking at different timescales helped us to consider the stage from different perspectives. At a most basic level, it is useful for the festival. But, moving beyond this narrow framing of our design, and expanding on its being as a part of the valley community, we unlock new possibilities for what design might be. As a herd of grazing animals moves through a grassland, they care about others by providing important nutrients to plants and grasses in the form of their manure. How might this analogy be extended to that of a festival? What

Figure 24 (left)
A butterfly resting on a pair of wire cutters. The temporality of construction and the temporality of the forest coming together for a fleeting moment.

Figure 25 (top)
The worksite in the forest.

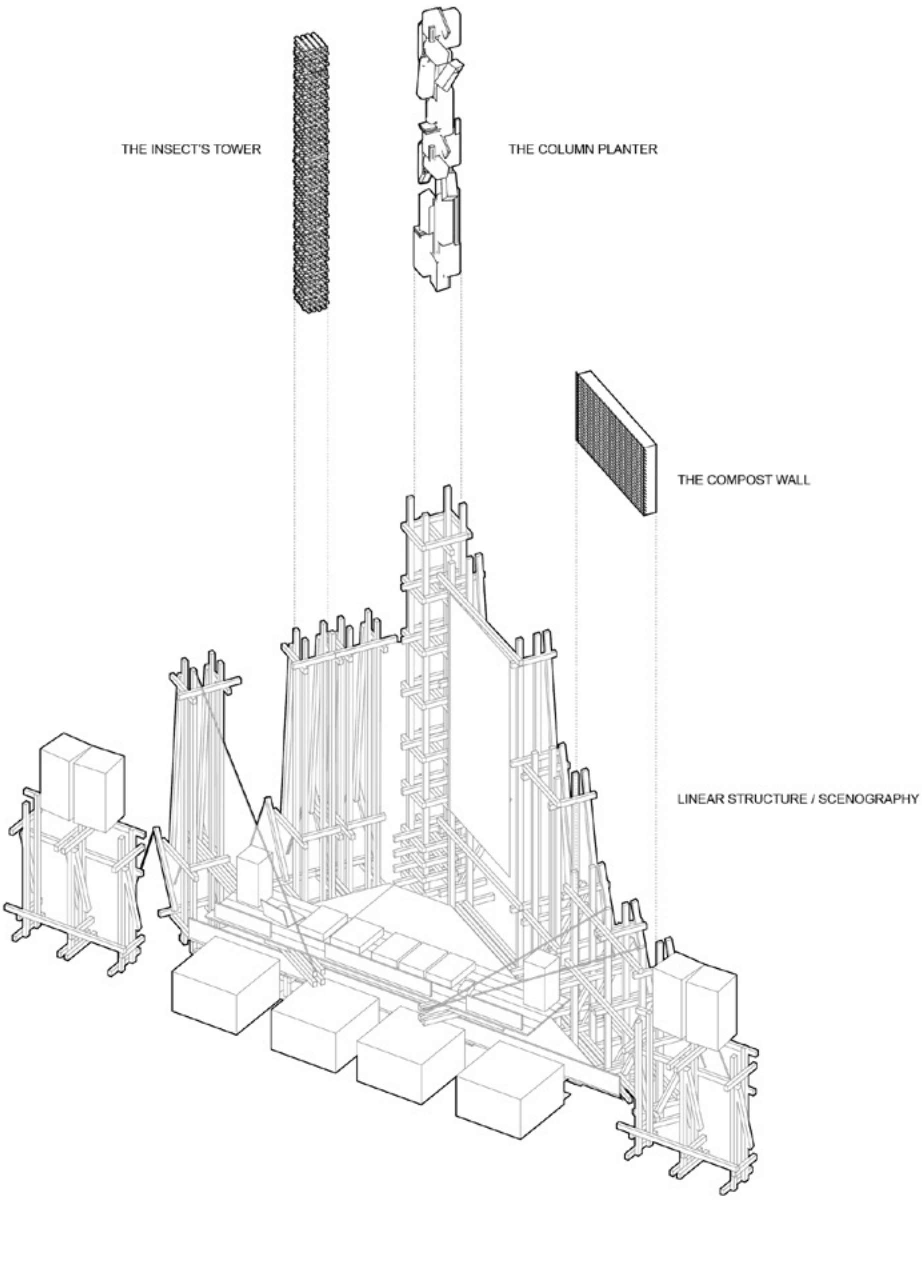
THE INSECT'S TOWER
THE COLUMN PLANTER
THE COMPOST WALL
LINEAR STRUCTURE / SCENOGRAPHY

Figure 26 (left)
The regenerative ruin stage design. The stage is designed as a scaffolding to house three 'regenerative actors', which are designed for more-than-human use outside of the timeframe of the festival.

Figure 27 (below)
A model of the regenerative actors built remotely. As designers, we had attempt to imagine how non-human users might appropriate the stage, shifting our attention from human time to what comes after humans have left.

Figure 28 (left)
Back view of the stage, built around a large pine tree growing at an angle. The design was adapted on site to accomodate what already had a claim to this space.

Figure 29 (above)
The rock-column is designed with small rodents or birds in mind, creating a porous space that can double as habitat, both while the stage is standing as well as farther into the future once the wood has completely decayed.

Figure 30 (left)
The compost wall is a scenographic element that is built from organic matter displaced during construction.

Figure 31 (above)
The wood tower is based off of the concept of an 'insect hotel'. Wood offcuts from constructon are stacked vertically. As they decompose, they create habitat for insects.

Figure 32
An image of the stage during the day, before the festival began.

Figure 33
The stage at night, during the festival. The porosity of the design frames the forest as a scenographic element, emphasizing the locality as integral to the festival.

if we consider ourselves as just as much a part of 'nature' as the birds, bees, trees, grasses, and soils?

We started by considering the persistence of the materials assembled as "stage" into the year, and how they might co-evolve with the ecosystem. What does this mean concretely for the design? The forest exists in continual cycles of growth and decay, and, as the stage is a 'dead' object, its biological materials will undergo decomposition over time. This was used as a design feature, with elements purposefully built to decompose, and in the process creating biomes for different species to adapt. Three of these 'regenerative actors' were drawn from natural landscaping practices aimed at promoting biodiversity and species habitat. The first, a wall made of compost, was intended to hold waste generated over the course of the festival, arranging it spatially to act simultaneously as an ornamental feature of the stage as well as to promote insect habitat post-festival (figure 5). Second, we included a column made of wood, intended to decompose over time. The wood placed here consisted of off-cuts from the construction process, turning the waste generated during the construction of the stage over to wood bugs and other insects which thrive on decomposing material. Finally, we included a column made of rocks, in which soil was embedded. The intention here was to provide habitat to small mammals as well as birds and enable plants to grow on the structure.

4.4.4.

REFLECTIONS

The design of the stage as something that will touch multiple timescales – staying onsite for years, co-evolving with the forest, becoming a ruin – raised interesting questions for festival organizers as well as festival goers as they became aware of these other timescales. What will happen next year when the festival returns? Who will care for the stage, for its upkeep and use, while caring for the other species that also make use of it? People joked "what if a bird sets up its nest in the rock tower, what will we do at next year's festival?" Interestingly, the stage already was provoking a dialogue, or a negotiation, around the use of space relative to other species, to a broad public audience which unlike at a design-fair, did not come to consume discourse. The presence of the stage in-situ for longer than is ordinary, and its planned but unpredictable co-evolution, challenges everyone to think more broadly about the festival as having a continual material existence there, challenging the logic of consume-dispose we are all accustomed to. This dialogue is the first step in creating lasting practices of care, shifting design from a passing human endeavor to continual more-than-human negotiation, an instance of designing-with (Wakkary, 2021).

Ultimately, there were

clear contrasts between the productive approach to time that a festival buildup invokes, and the non-productive more-than-human timescales that work through the festival site. The stage brought awareness to the temporalities of other actors – the nesting patterns of a bird, or the decay of wood – but also of the human time pressures that make noticing and caring more difficult. Here is where the challenges – financial, logistical, technical, practical – of applying theory in the real world become visible. While our process had clear limitations – eg. the need to design remotely – making time to pay attention to and care for things outside of the functional scope of the project is already a step in the right direction. Finally, we note that this opening-up means embracing contingency, leaving room for unexpected but symbiotic relationships to emerge across design, especially ones that propose a more caring form of being-together.

4.5.

CONCLUSION

More-than-human temporalities can help us to unveil the complex, interdependent, reciprocal relations that make up the web of life. Noticing other temporalities outside of the productive timeframe of a project can help designers to see which actors are prioritized over others. It is within these other tempos that we can make time to care for overlooked stakeholders, acknowledging that what is good for life is good for humans.

From our experience, noticing and caring both required a situated framing of the project: knowing the specific location, materials, neighbors, weather, climate. In a very alive way, this coming together of actors implies a complex dynamic of different temporalities, rhythms, and tempos. This is difficult to grasp with abstractions, and is best experienced, sensed, felt, in all its specificity. In this sense, design must be rooted, and thus we challenge design as implicated in a globalized system of extraction and production. The material nature of design means it will invariably influence specific places and ecologies. Thus, we ask how design practices can aim for a higher degree of rootedness, meeting the material needs of humans while simultaneously taking responsibility for the other species that also help us to meet those needs.

As design projects human intentionality into the future, how can we ensure that our agency does not stifle that of other beings – that our time is not the only time? In a more practical sense, we ask also how the material supply and eventual dispersion that design draws upon (both of which include their own temporalities outside of a design project) can act symbiotically within place-specific ecologies? To conclude, the overlapping temporalities of both matter flows and life-gatherings must be considered with all the imagination, empathy, and care that design can muster if we are to reorient design in service to life.

006 Designing within limits

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Transitioning to societies that operate within planetary boundaries poses a complex challenge for designers: addressing systemic drivers of unsustainability while remaining grounded in local, ecological contexts. This paper explores how regenerative design offers a compelling framework for this transition by aligning societal systems with the regenerative capacities of the Earth. I examine regenerative design across three interconnected levels: infrastructure, as the technologies through which society meets its needs in harmony with natural systems and their metabolic flows; social structure, as the political economy rooted in commons-based resource management which prioritize local needs over profit-seeking; and superstructure, as the cultural values oriented toward long-term ecological thinking as opposed to the short-term, distracted nature of consumer culture. Drawing on four design projects, I illustrate how regenerative approaches at each level can be mutually reinforcing, catalyzing systemic change that supports a return to operating within planetary boundaries.

5.1.

INTRODUCTION

The progressive march beyond planetary boundaries underscores the critical need to transition towards sustainable societies. Already in the 1960s the pioneering designer Buckminster Fuller recognized that society must be designed within the limits of Earth's self-regenerating system to enable its long-term viability (Fuller, 2008). However, the incremental approach to sustainable design that has gradually emerged since has fallen short of this goal (Irwin, 2015). At large, it is difficult to locate anything designed which is not a burden on the environment. Most of what passes as sustainability is merely "less bad", more new stuff with reduced environmental impact (Braungart & McDonough, 2008). This form of sustainability problematically fails to challenge an economy and consumer culture entangled with environmental degradation (Fry, 2020). In response, the growing field of transition design explores how designers can generate change across complex and multiscale socio-technical and socio-ecological systems (Irwin, 2015; Irwin, 2018; Pineda et al., 2024). However, there are limited examples of how transition design can be applied to materially grounded practices that are both locally situated and ecologically responsive, while aiming to catalyze systemic change towards sustainability (Bisson et al., 2022). We argue that the concept of regenerative design may be useful to fill this gap.

Regenerative Design seeks a mutually beneficial relationship between human needs-solving and ecological wellbeing (Mang & Reed, 2012). This begins by acknowledging that human societies are fundamentally part of the biosphere: "the entirety is interconnected... natural systems, human social systems, and the conscious forces behind their actions." (Reed, 2007, p.675). What then is the influence of design upon nature's capacity to self-regenerate? Can it lead to mutually beneficial outcomes? Humans have a sound technical understanding of how to restore ecosystems, replant forests, do regenerative agriculture, increase biodiversity. Regenerative product design is technically possible, as most pre-industrial technology made from local bio-based materials would attest. But, like sustainability, regenerative design faces difficulty in challenging the socio-political and cultural system-drivers which limit its implementation, or in articulating an alternative vision (Plaves et al., 2024). There appears "a need for methodologies to bridge the higher system levels with the product and the material level" (Asbjörn Sörensen et al., 2024). Central to these challenges is understanding how material conditions and cultural processes relate to one another.

For this, we make use of a three-layer societal model proposed in Marvin Harris' Cultural Materialism, to unpack how regenerative design must operate at different levels. Harris proposed a scientific theory of human society "based on the simple premise that human life is a response to the practical problems of earthly existence" (Harris, 1979, p. xi). According to Harris (1979), any society can be considered through three layers:

1. Infrastructure is the totality of technology through which a society satisfies its needs from the environment.

2. Social Structure is the political economy which organizes the production and distribution of resources

3. Superstructure is the beliefs, values, and norms guiding how people understand their place and purpose in the world: its culture and patterns of thought

While Harris' work emphasized the influence of infrastructure on the other two layers, we claim that regenerative design implies making simultaneous and self-reinforcing changes across all three. We turn to what these changes might look like below.

5.1.1.

REGENERATIVE INFRASTRUCTURE

The infrastructure layer is familiar to designers as it concerns materials and technology. However, a system-level understanding of the totality of technology, its directionality, and influence on the biosphere is important to flesh out. Modern infrastructure is a megamachine designed to expand itself in scale and complexity, using the tools of industrial production and globalized extractive supply chains (Mumford, 1967; Crawford, 2021). Fossil fuels provide the power to extract ever-more materials and energy (Malm, 2016). This expansion is driven not primarily to meet society's fundamental needs, but to generate profit (Harvey, 2010). However, the profit-seeking motive is often disguised behind a fetishization of technical progress and innovation, harbingers of a world of complete convenience and instantaneous satisfaction (Marcuse, 1964; Jackson, 2011). Designers will find this logic familiar, as most design work is to develop innovative products misaligned with the broader needs of society: designing new SUVs, or smart home appliances, as ecosystems and climate collapse under the weight of perpetually expanded extraction and waste dumping. The Anthropocene and its ghastly consequences for the biosphere are direct byproducts of the infrastructure layer of industrial modernity.

How might regenerative infrastructure be designed? First, it must fit within ecological limits. This means design should work with, not against, natural processes and metabolic flows, while enhancing their ability to regenerate (Mang & Reed, 2012). Within a well-functioning ecosystem, materials are cycled, and nothing is wasted. Similarly, a regenerative approach to materials would see "waste equal food", either as biological nutrients for living systems, or as inputs for technical cycles which retain material quality (Braungart & McDonough, 2008). The bio-economy in particular signals the possibility of supply chains where material and food production simultaneously enhance the capacity of ecosystems to regenerate (Morseletto, 2020). Biomaterials can also benefit the climate when used to build long-term infrastructure that sequesters and stores carbon (Churkina et al., 2020; Bjanesoy et al., 2023). Importantly, regenerative design must consider place, as it will have to "start with the limits of the land" from which materials are extracted, determined by what "regenerative agriculture...backed by a long-term vision for resource conservation, can produce" (Material Reform, 2020, p. 70). It is from within these constraints that societies will need to decide what kind of infrastructure is best suited to their wellbeing, and how it gets organized.

5.1.2.

REGENERATIVE SOCIAL STRUCTURE

The design discourse has begun to recognize that capitalism, the social structure of modernity, is a major hurdle in implementing sustainability, which aims to create forms of value not easily priced (eg. biodiversity), and account for costs which are otherwise externalized (eg. CO^2) (Fry, 2009; Boehnert, 2018; Walker, 2014). But, as "it is easier to imagine the end of the world than the end of capitalism", designers mostly work within its profit-seeking mandate (Wizinski, 2022). Sustainability then becomes framed as an 'innovation strategy' or a 'growth opportunity', at odds with ecological limits (ibid.). At a system level, capitalism drives perpetual economic growth through the accumulation of surplus value, which is relies on fossil fuels and is coupled with environmental degradation (Malm, 2016). Importantly, this growth is not necessarily aligned with what is needed for social wellbeing, it is simply directed towards what is profitable (like SUVs). This profit-driven orientation shapes market outcomes in a way that prioritizes return over equity or need (Wizinski, 2022). While proponents would argue that free markets lower costs as they spur competition and entrepreneurship, they do a poor job at just distribution and tend to increase inequality over time (Piketti, 2014).

Regenerative design should be based in a social structure which respects ecological limits, orients production towards social and ecological wellbeing, and promotes equitable resource distribution. These points are directly aligned with economic perspectives like Degrowth (Hickel, 2020) Post-Growth (Kallis et al., 2025), Wellbeing Economy (Pouw, 2020), or Donut Economy (Raworth, 2018). But high-level economic models are often challenging to grasp at the design scale (Asbjörn Sörensen et al., 2024). For this, we have found the commons a more useful model to practically apply in projects, while aligning with system-level economic goals. In a commons, resources are organized and managed based on the principles of sharing and collective decision-making (Bollier, 2014). Sharing importantly increases the overall access to resources while reducing the need for new growth (Euler, 2019; Schmelzer et al., 2022). Furthermore, the collective decision-making built into the commons, which can be facilitated by participatory design, implies a more equal approach to determining what should be produced and for whom (Leitheiser et al., 2021). This approach replaces profit with a broader definition of value meant to be continuously contested and revised by an open-ended community. Though this process of negotiation, humans, non-humans, and their environments naturally organize around mutualistic principles for the benefit of the whole, more closely aligned with the way ecosystems function: “participants in a commons digest the commons and provide nourishment for it at the same time. ...Only behavior that allows for the productivity of the whole ecosystem over the long-term and does not interrupt its capacities of self-production can survive and expand” (Weber, 2019, p. 98). For regenerative design, the commons create space for place-based approaches to design which align with ecological principles and local needs, unconstrained by the impetus to generate profit.

5.1.3.

REGENERATIVE SUPERSTRUCTURE

The superstructure of Western modernity (which is constantly exported to the rest of the globe as the dominant ideology of free-market consumer capitalism) is multifaceted, having evolved alongside industrial technology and capitalism, while being rooted historically in Judeo-Christian religions as well as Western liberal philosophical principles stemming from the enlightenment (Mumford, 1934; Habermas, 1985). However, the increasing secularization of society has seen the dissolution of many of the spiritual institutions which provided humans with purpose (Walker, 2013). Without the prospect of an afterlife, or a legacy, humans seek immediate satisfaction through material consumption (ibid.). Design plays a particularly important role in propagating this modern consumer culture, by manufacturing desires, through artefacts or experiences, accompanied by slick marketing (ibid.). The whole package is designed to be irresistible: “buy now!”.

Regenerative design should challenge the immediacy and distracted nature of consumer culture and align society towards a long-term ecological vision (Wahl, 2016). While what counts as superstructure includes various ontological and epistemological positions, time plays a crucial role in how we relate to the world, and we have found it useful to link regenerative design to the superstructure level. Productivity mandates that everything should become quicker, as time is money (Jackson, 2021). Subdividing time into equal parcels may be suitable for organizing labor and increasing efficiency, but it does not reflect the pace at which different ecological processes unfold and interact (Brand, 2018). Neither does it represent the lived qualitative experience of time, which “may help us to reconnect with place, to live more fully in the moment and become effective agents of change” (Ichioka & Pawlyn, 2022, p. 69). Disconnecting from the hurried pace of capitalist production may allow design to engage with ecology at a more fundamental level, nesting human economy within a longer-term vision for ecological regeneration (ibid.). For this, Krznaric’s notion of Cathedral Thinking (2021) is useful as it suggests we think about setting the foundations for something that future generations will finish. But we can equally apply Cathedral Thinking in reverse. What has been left behind for us to build upon? If we must limit new infrastructure to align with planetary boundaries, then what is already here is as a material inheritance to safeguard for future generations: the foundation for a culture of caretaking, of maintenance, of reuse. Building a regenerative culture is complex, but qualitative and long-term perspectives on time may allow designers to begin thinking holistically about design as part of ecology, as “a meshwork of affiliations through which aliveness unfolds in ecosystems and history” (Weber, 2019, p. 4).

5.1.4.

CRITICAL MAKING AS A PRACTICE-BASED RESEARCH METHOD

We have outlined some perspectives on how regenerative design can help usher a sustainable transition at the infrastructure, social structure, and superstructure levels. We now turn to a case study of four different projects which explore these concepts in practice. While the 3-layer framing is useful as a conceptual tool to organize theory, in practice there is a messier relationship between the layers. For instance, working with certain materials also has an influence on the aesthetic and cultural significance of an artefact, while the Commons involves material resources as well as community values. As such, experimenting with these concepts in practice is useful to paint a more complete picture of what regenerative design might entail. The projects presented may be best described as a form of critical making, following “a desire to theoretically and pragmatically connect two modes of engagement with the world that are often held separate – critical thinking, typically understood as conceptually and linguistically based, and physical ‘making’, goal-based material work.” (Wesseling & Cramer, 2022, p. 174). With this definition, critical making aligns with the desire to explore how regenerative design might counteract the localized material impacts and higher-level systemic drivers of unsustainability.

5.2.

THE VRIJLAND PLAYGROUND

How can regenerative design engage communities? The Vrijland Playground explores how a stockpile of biobased building blocks might form the material basis for a commons premised upon community-based, participatory, circular construction practices. The project is located at a community centre on IJburg,

Figure 34 (left)
An arch built as a temporary installation from the stockpile of blocks. We built this to demonstrate how, with simple geometries and connectors, an infinite number of designs are possible.

Figure 35 (above)
The Vrijland Playground during 'Beach Opening Day'. Children and passerbys were invited to engage with the stockpile of materials.

a newly developing suburb of Amsterdam. Around IJburg, the visible presence of wooden offcuts, pallets, and debris is a constant reminder of the material footprint of new construction. Could its waste be transformed into an opportunity for situated regenerative design practices? We saw an opportunity for a project which would up-value waste materials – particularly wood - while equally inviting people to share in the creative process of spatial design. The shiny new condos and wide brick boulevards offers residents few opportunities to participate in shaping and evolving their neighborhood. Through play, we tried to help residents engage with the metabolic (i.e. material) flows of their place, planting a seed of agency and long-term care.

Infrastructure: Upvaluing waste bio-material into reconfigurable kit-of-parts

The stockpile consists of approximately 300kg of reused wood from surrounding construction sites. The material was cut into 8 sizes of standardized blocks which pack tightly in wooden boxes. At a material level, the goal was to upvalue locally sourced biomaterials into something long-lasting, acting in a regenerative capacity to sequester carbon by avoiding emissions associated with waste-to-energy incineration. The approach was to transform waste into a standardized and neatly storable kit, which could then be used as a larger version of typical children's blocks, or combined with reversible connectors to make more complex and functional objects. The standardized nature of the building blocks offers the potential for open-ended play, while signaling that they are intended for reconfiguration as opposed to permanent use. By creating a tidy storage system, discrete pieces become a kit-of-parts, a singular object whose value is more easily discernable to the community. Waste no longer resembles waste, only potential.

Social Structure: Sharing the agency of design

On IJburg, new housing is delivered as a finished product and design is left to experts – architects, urban planners, landscape designers, playground manufacturers. Expanding the urban commons implies creating public space that people can make their own, use freely, and contribute to, strengthening the relationship to place. For this, design and construction processes must be open to participation. With this goal in mind, we reimagined a playground as a stockpile of materials, where children can rearrange and reconfigure the space they use. The physicality of a piece of wood sparks a universal understanding in its potential for human ends, and there appears a common drive to engage with materials in a world that is increasingly immaterial and delivered ready-for-consumption. Through play with materials, we hoped to catalyze a new sense of potential when kids see waste in their neighborhood. Over time, the stockpile might expand. Eventually, the whole neighborhood is shared as a playground of materials.

Superstructure: From object to collection of pieces – design as a cyclical process

If material is held in common, design ceases to be a finished object but a cyclical process of reconfiguration, a collection of materials brought together in different ways at different moments in time. Products designed for consumer culture are worth the most when they are new, designed to create maximum satisfaction at the moment of consumption. On the other hand, a material commons allows for novelty and value to be recurrently generated into the future, as part of the process of designing and building together. In this sense, the playground is a form of Cathedral Thinking, but without a fixed end design objective. Like a garden over the seasons, the playground takes a malleable form over time: a whole city, a dragon, multiple towers, lava-games, colorful patterns, mazes, temporary seats and stools, large sculptures. If regenerative design is a cyclical material process, it is less about projecting human intentionality firmly into the future, and more about adapting, reconfiguring, playing, modifying things together.

5.3.

THE VERTICAL ARCHIVE

How does regenerative design reshape our sense of beauty? The “Vertical Archive” is a monument built from waste wood, salvaged from demolition containers and meticulously stacked into a vertical containment structure. Once full, the structure becomes an archive of gathered materials, showcasing the rich patterns of urban bio-waste. The project is located at what used to be Weelde, a post-industrial greenfield occupied by a range of grassroots initiatives – artist ateliers, a restaurant, a community garden. Weelde embodied many of the bottom-up, collective, and community-oriented values antithetical to capitalist urban development, but was unfortunately evicted as the city moved to redevelop the area. Given this context, the monument aims to challenge the ongoing processes of urban demolition and redevel-

Figure 36 (above)
The Vertical Archive, a long-term stockpile of waste wood scavanged from around Rotterdam West. Photograph by Riccardo De Vecchi.

Figure 37 (right)
Passing through the Vertical archive. Photograph by Riccardo De Vecchi.

opment, which result in material waste but often also gentrification and social exclusion. As an ode to the abundance of waste and the potential of reuse, it gestures towards another vision of urban development, one that would not seek to erase and rebuild but to remember, reconfigure and regenerate what is already there.

Infrastructure: DIY carbon capture and storage

During one month, approximately 2.5 tonnes of waste wood were gathered for the project – from abandoned piles on site and demolition containers in the surrounding neighborhoods. The process of scavenging materials was equally a process of mapping the material metabolism surrounding the site. Together with a team of volunteers, we proceeded to clean up the city, capturing waste carbon, and storing it in our vertical structure. DIY carbon capture and storage. 4.5 tonnes of CO^2e. The more material in our structure, the better. Given this principle, the design allowed for all material to be utilized in the construction: low-value chip-board, discarded plywood, wooden planks, timber off-cuts and old logs could all be puzzled into a fit-for-purpose mosaic, increasing the regenerative potential of the structure as a carbon sink. The result is a construction that overturns the logic of optimization and efficiency. By designing for quantity over quality, the abundant presence of waste is turned into a regenerative opportunity.

Social structure: The city as an urban mine, or as a material commons

All the materials we gathered were free, as many contractors prefer to give material away instead of paying for disposal. Waste is available and abundant, upvaluing it regenerative. With this mentality, designers might begin to look at the city as an already existing urban material commons, waiting to be put to collective use. Over time, the city starts to become an urban mine. A simple bike ride becomes a treasure hunt. Importantly, we experienced that making from waste invites participation through the process of scavenging. While the materials are financially free, they take time and effort to gather, carry, load, unload, process. This process is not efficient, but neither is it alienating. We had volunteers join us after work, for the fun and collective experience of building something large together. Unlike the development plans that ultimately led to Weelde's eviction, we wanted to show how the city could become not just a place to consume, but a place to appropriate, to clean up, to actively create together.

Superstructure: Weathering, patina, & a long-term material culture

Through the building process, we began to appreciate urban space as a mosaic of discrete pieces in flux through time: part of an old shelf, someone's kitchen renovation, a pile of scrap wood in a shed. Everything has a history and a future. Regenerative design must work towards a material culture more in tune with these longer timescales. For this, the aesthetic dimension of waste is intriguing, particularly its specificity, texture, and patina. Celebrating these qualities invokes a form of sustainable design that is fundamentally different from technical approaches like recycling or remanufacturing, which erase any sense of the past state to deliver a product equally new to the new one. Instead, regenerative design might see difference as a mark of quality, as it represents an origin story and sparks imagination towards a long lifespan. This could equally extend to the production of biomaterials, reflecting the bioregions from which they originate, or the year in which they were produced, much like the concept of terroir with food, or aged wines (Rigobello & David Evans, 2024).

5.4.

BECOMING WORM

Can we design regenerative rituals? For today's younger generation, the club or the music festival is a place where stress from the alienation of modern life can be released. Club music turns the beat of factory-line productivity into something emancipatory, collective, healing. We imagined Becoming Worm to harness this energy towards soil regeneration. The Ritual consisted of bringing people together to build a hügelkultur. This is a low-tech method to create carbon-rich raised bed planters which also improve soil water and nutrient retention. It is a material practice of reconfiguring biomass to enhance the aliveness below our feet. We combined this physical 'design' process with music and dance, utilizing the bodily energy released to churn up the soil, mix together the compost, arrange leaves, sticks, dirt, while simultaneously socializing the activity of soil regeneration.

Figure 38 (left)
The Becoming Worm workshop invited visitors to build a Hugelkultur, a method of layering organic matter to produce a carbon-rich raised planter bed.

Figure 39 (above)
Music was used to ritualize the building process, creating an atmosphere of togetherness while contrasting the immediacy of dance with the long-lasting nature of the hugel.

Infrastructure: Reinforcing ecological processes, working with what is alive and dead

Here, natural bio-materials – forest litter, sticks compost, soil - are reconfigured to create a form more conducive to life above and below ground. The project took place in rural France, around Burgundy, on a farm in a valley next to vast Douglas fir plantations. The production forest is a monoculture, and this ecological imbalance results in mosses that kill much of the understory. Once a forest is harvested, the soils are tilled by industrial machinery, resulting in a poor soil quality prone to erosion. At the valley floor, the soil has been compacted by centuries of pasturage. Relying on this dead matter, which at present is overabundant and quickly decomposes, the hügelkultur was created. Thus, the materials needed to construct this 'soil infrastructure' are local, regenerative, available, abundant. Beyond this, the fertile soil becomes the basis for new materials and food to be grown with reduced fertilizer or water needs.

Social structure: Ecological care as a shared ritual

We combined this ancient gardening practice with a modern ritual familiar to young people: a dance party. The stage was set, a circle of compressed turf surrounded by mounds of the different material inputs: piles of soil, sticks, logs, compost, hay. During the workshop, different songs were selected to punctuate the stages of Hugel building, and to set the mood of a particular activity. An intense opening song was chosen to invoke an experience of being in the soil (deep drones are what worms listen to). Next, a percussive track helped engage the body in tilling and aerating the soil, using old farm tools. A slower, more contemplative piece accompanied people as they placed logs in a spatial composition. As the pace quickened, the sticks and compost were added. Finally, extasy, energy, chaos, as shovels and hands threw soil into the air to land on top of the mound. The workshop closed with a sparkly, mystical ambient track of arpeggiated synth riffs, sounds to reflect the quizzical growth of nitrogen fixing plants. Their seeds were ceremoniously sprinkled above the mound of organic matter. As the workshop ended, and the direct in-the-body engagement receded, people return to chatting, sitting around, reflecting. Now they must wait until next year, and the year after, for the soil to do its thing.

The ritual explores two different temporal perspectives interesting for regenerative design. The first is the flow-state, which is provided by the music, dancing, and bodily engagement. This is akin to what Bergson (1910) describes as duration, or the subjective experience of time. In modern society, technology shortens attention spans, leading to a culture that is rarely present. Becoming Worm strives for the opposite: to engage directly with a place, with other bodies, with nature, locked in with no distractions. By centering this engagement on the aliveness of soil, the group's awareness becomes attuned not only to each-other but to the wider ecosystem. In this way, the ritual is implicitly designed with a sense of mutualistic care. Looking beyond the ritual itself, we also come across a longer temporal perspective, equally foreign to the hurried productivity of time-is-money. A thing was made collectively – a hügelkultur. But it is not ready now, and not for us. Empathy with nature and long-term perspective are both implicit outcomes of the ritual.

5.5. THE READING ROOM IN THE FOREST

How can we scale up regenerative design? The reading room in the forest is a small building made from 96% reused and locally sourced materials. It explores how regenerative design might address more fundamental and utilitarian needs, in this case shelter. The project was built in a botanical garden being developed in a UNESCO village. Previously an abandoned horticultural school that once housed 500 students, it includes 8 acres of arboretum and gardens, and a large school building being transformed into a residency and campus for ecological research. But its history goes back to the 19th century Colonies of Benevolence, where poor and destitute from Amsterdam were transplanted to this marshland to make it productive. While some prospered (it was the first instance of public schooling in the Netherlands), others who failed to fit its rigid social model fled to the hinterlands. There, according to the local law, if they were able to erect a house overnight with a smoking chimney, they were legally allowed to remain. To do so, they would stockpile materials, or dig sod, until they would have enough to quickly make a structure. We took this as inspiration for the Reading Room, an apt analogy for how emancipation from a failing system may be found in making new communities with what is ecologically available, locally situated, abundant.

Figure 40 (above)
The Reading Room in the Forest. An experimental buidling made almost entirely from bio-based demoition waste. Photograph by Riccardo De Vecchi.

Figure 41 (right)
Foundation detail of The Reading Room. The building design minimizes impact on the site, and rests on a foundation of reused concrete blocks which extend down to the sand layer. Photograph by Riccardo De Vecchi.

Figure 42 (left)
Interior of The Reading Room. The building explores re-generative design at a larger scale, where local, bio-based material practices can provide qualities that challenge existing building practices. Photograph by Riccardo De Vecchi.

Figure 43 (above)
Waste materials being sorted and cleaned during the Reading Room buidling process.

Infrastructure: Sourcing regenerative materials at a larger scale

The structure was built with materials from the site and surroundings. About half was found for free or donated, the rest purchased from a local demolition company. As the school building was being renovated for the new residency, its waste provided much of the initial stockpile: beams, posts, etc. In addition, we were able to secure polycarbonate greenhouse panels from a demolished greenhouse for weatherproofing (fossil-based, but capable of protecting the reused lumber from the elements; these panels would have eventually made their way to the incinerator). We obtained waste wool from local farmers that we washed for insulation. The large structural timbers were purchased: old floor joists, pine, spruce, Douglas fir. But over the project, new material sources would constantly emerge – a barn filled with wood painted black from a municipal project, a new stockpile of wall joists from the building. We worked from a loose design, which was continually adapted to the available material.

Social Structure: A network of sharing

The project underscored the realization that when building regeneratively at larger scales, there becomes an inevitable need for a larger community. Relying on and contributing to a community is less efficient than the market. We needed to remove nails from free materials, or learn how to use borrowed tools, or instruct volunteers. We also had to lend a helping hand to other projects, or explain the project to neighbors. It was about giving and receiving. Through neighborly chit-chat we were given a pile of beams in an old barn, and three bags of wool from a recent shearing. While these kinds of community-oriented social relations are missing in globalized supply chains, they are often engrained in the countryside, where traditions are long to die (Raftowicz et al., 2024). In old times, it was common for a whole village to come together to help raise a barn. Tapping into existing communities where sharing comes naturally is easier than starting from scratch. We tried to sustain this ethos of sharing with the design itself. It does not have a lock and is always open for any neighbor to come inside, to read a book, to enjoy the serenity of the forest.

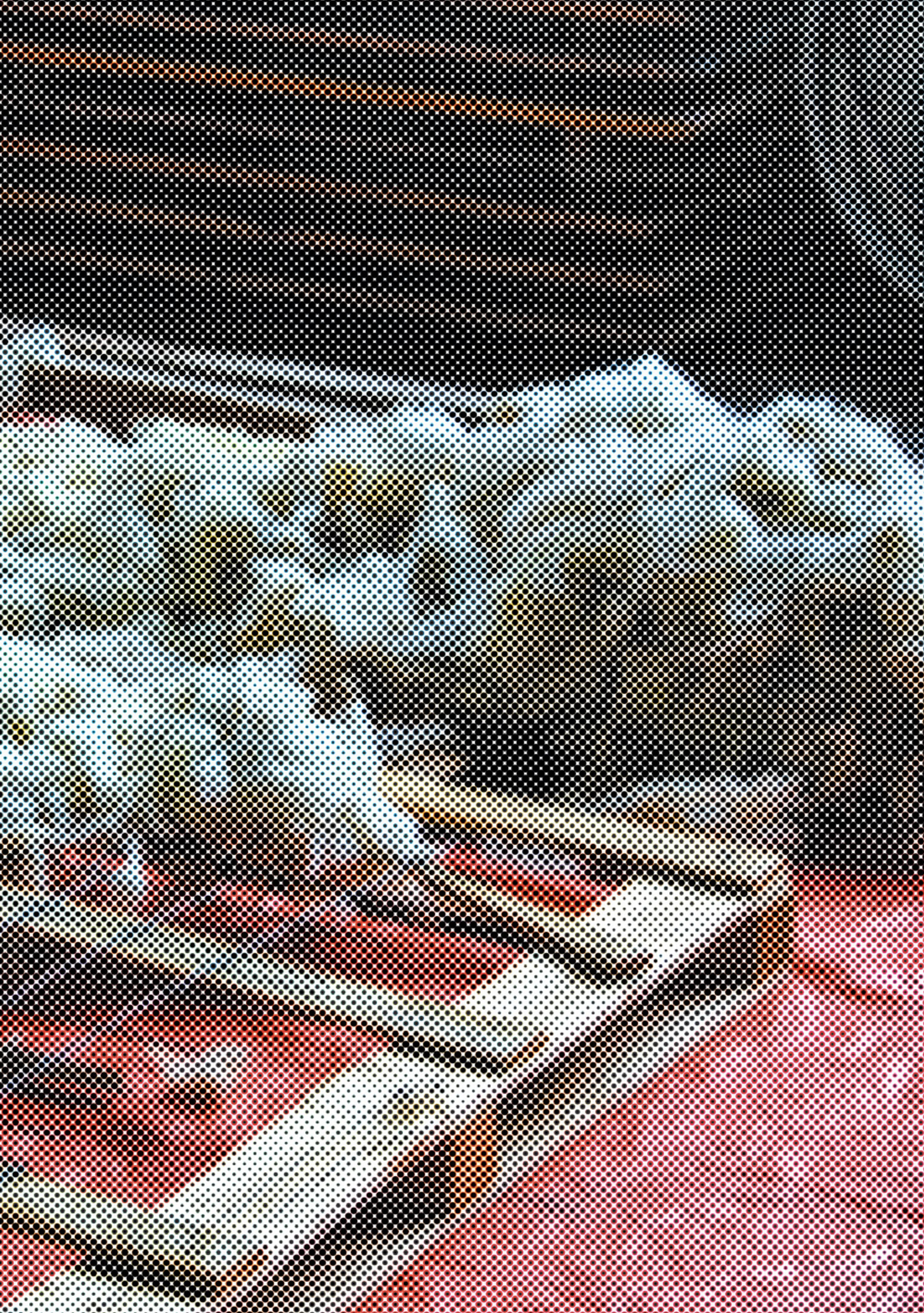
Superstructure: Deep-time nomadism

Once an infertile swamp, the garden now exhibits an impressive forest with startling biodiversity. This was made possible by centuries spent nourishing the soil, tending to the garden, pruning the trees, planting new ones. It is an impressive example of the potential of humans to act in a long-term ecologically regenerative capacity. But the building permit was limited to 5 years. Within this temporal window, the building is merely a visitor from the perspective of the oak trees or the thick layer of fertile soil. If a cathedral is not an option, then a tent is equally interesting to consider. Accordingly, we designed the building to be modular, temporary, and open-ended. There are only dry, reversible connections. The interior dwelling is made from pre-fabricated modular panels, intended to be removable but also expandable, to anticipate potential future needs, to be relocated if necessary. It sits on temporary, non-invasive foundations, elevated from the forest floor. Relative to long ecological timescales, all human infrastructure is short-lived and temporary. We may draw on inspiration from Nomadic cultures: their infrastructure was minimal, temporary, multi-purpose, based on necessity, and designed to come from and be reabsorbed by the land.

5.6.

CONCLUSION

Given the state of planetary overshoot, society must transition to fit within the biosphere. We claim this implies making simultaneous and complementary changes to society across its infrastructure (technology), social structure (political economy), and superstructure (culture). Regenerative Design is well-suited to the challenge, as it takes a whole-system perspective, without limiting the agency of design to act concretely. Through four case studies, we demonstrated what this agency might begin look like in practice. We indicated the potential of local bio-based or reused materials to root design to place, fundamentally surfacing the environmental context that is always present. Designing with these materials can at once satisfy needs, locally regenerate ecosystems, but also sequester carbon to benefit the global climate. At a social level, we showed how design can escape the limits of profit-seeking by orienting itself towards the commons, where sustainability and social wellbeing are legitimate aims to guide how resources are organized. For this, regenerative design necessarily begins by connecting with or building communities, leading to an open-ended process of participation, negotiation, collaboration, and sharing. With these relations, the commons works towards sufficient abundance, meeting group needs with what is already here, without needing to extract more. Finally, we explored how to reorient design towards longer timescales, away from a hurried and distracted consumer culture. Inspired by Kzarnic's concept of Cathedral Thinking, we propose that laying a foundation for future generations means caring for the future without seeking to control it. Whereas modernity has often colonized the future – imposing rigid visions and deterministic outcomes – regenerative design seeks to decolonize it, embracing openness, adaptability, and the possibility of reconfiguration. It is a future not predetermined but cultivated – evolving, participatory, and alive.



007 Discussion

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6.1.

RECAP OF AIM AND CHAPTERS

Post-growth scholarship critiques the systemic drivers of ecological overshoot and calls for reorganizing production and consumption around what is socially necessary and ecologically viable rather than financially profitable (Hickel, 2020; Kallis et al., 2025). Rather than framing prosperity through the quantitative expansion of capital, post-growth perspectives emphasize qualitative dimensions such as well-being, equity, and ecological stability (Jackson, 2017; Raworth, 2018). Within this context, design has an important but underexamined role: not only as a means of delivering marginal sustainability gains within existing systems along the lines of green growth, but as a practice capable of translating post-growth principles into material, social, and cultural forms.

This dissertation positions design as a mediating practice in post-growth transitions by foregrounding carbon as a socio-technical material. Rather than treating carbon solely as an emissions metric, the research examines how carbon shapes infrastructures, social arrangements, and cultural narratives, and how design interventions across these layers can support equitable transitions away from carbon-intensive systems and toward carbon-sequestering ones.

To analyse these dynamics, the dissertation adopts an analytical framework distinguishing between infrastructure, social structure, and superstructure, providing a lens for understanding how technologies, governance arrangements, and culture interact in post-growth design practice. As noted in the methodology, this analytical framing carries an inherent tension: structuring knowledge into layers risks fragmenting what is, in practice, a deeply integrated reality. The design projects themselves demonstrate this: in each case, material choices, governance arrangements, and cultural meanings proved inseparable in practice, confirming that the three-layer framework functioned most usefully as a heuristic for entering the literature rather than as a faithful model of how post-growth design actually operates.

With this caveat in mind, let us return to the overarching aim of this dissertation, which has been to examine how bio-based material design practice can contribute to a post-growth societal transformation by rethinking material, social, and cultural dimensions of technological production. This aim was approached through four interrelated research questions:

RQ1: How can the selection of materials serve as a practical pathway for embedding post-growth socio-political objectives into the design and production of technology?

RQ2: How can carbon sequestration be conceptualized, designed, and governed as a post-growth practice?

RQ3: How can designers engage with more-than-human temporalities in practice to support ecological regeneration?

RQ4: How can regenerative design approaches across infrastructure, social structure, and superstructure reinforce each other, catalyzing systemic change toward a post-growth society?

Chapters 2–4 addressed these questions at the levels of infrastructure, social structure, and superstructure, with particular attention to RQ1–RQ3, while Chapter 5 extended this analysis by examining how design practices integrate these layers within experimental context-specific projects, addressing RQ4 and speculatively exploring the systemic potential of regenerative, post-growth-oriented design.

6.2.

INTEGRATING FINDINGS ACROSS IMAGINARIES, MATERIALITY, DESIGN CAPACITIES

While the preceding chapters examined these questions in relation to specific contexts and analytical layers, the discussion chapter adopts a more integrative perspective. Rather than revisiting each research question sequentially, it synthesizes the findings through three interrelated lenses: imaginaries, materiality, and design practices. Together, these lenses foreground how cultural meanings, material choices, and situated forms of action can co-evolve in post-growth transitions.

The first lens, imaginaries, draws attention to the role of worldviews in shaping sociotechnical systems. As Taylor (2004, p. 23) describes, social imaginaries refer to "the ways people imagine their social existence... and the deeper normative notions and images that underlie these expectations." Design contributes to this dynamic by making imaginaries tangible, actionable, and aesthetic: through material and spatial interventions, it can surface and mobilize alternative ways of organizing production, consumption, and sociality (Bendor, 2025).

The second lens, materiality, focuses on how post-growth values become operational through material choices and production processes. Materialization is not understood as a neutral or purely technical act, but as a site where political, ecological, and social commitments are enacted. Within this research, bio-based and carbon-sequestering materials function not merely as substitutes for fossil-based alternatives, but as vehicles through which conviviality, commoning, care, and regenerative logics become concretized. Material choice thus becomes a critical point at which post-growth imaginaries are translated into durable socio-technical arrangements.

The third lens, design capacities, foregrounds the situated and prospective role of designers in enabling post-growth societal transformations. Across this dissertation, I argue that systemic change is not designed top-down; it is enacted through situated practice that align imaginaries, material pathways, and social arrangements over time. Rather than positioning designers as problem-solvers optimizing predefined objectives, this lens emphasizes design as an ongoing practice of negotiation, care, and responsiveness.

Together, these three lenses structure the discussion that follows. By synthesizing the findings across imaginaries, materiality, and design capacities, the chapter articulates how design can contribute to post-growth transitions not through isolated interventions, but through the alignment of cultural meanings, material pathways, and situated forms of action.

6.3.

NEW IMAGINARIES FOR A POST-GROWTH DESIGN PRACTICE

Across the chapters, design is approached as a practice that extends beyond functional or technical performance to challenge the social, ecological, and political conditions underpinning fossil-carbon-intensive ways of living. Together, the projects and analyses assemble a set of interrelated post-growth imaginaries which can orient design practice: a redefinition of progress as conviviality, the commons as a just and effective mode of economic organisation, and a politics of care that is attuned to more-than-human temporalities.

6.3.1.

CONVIVIALITY: AN ALTERNATIVE TO TECHNICAL PROGRESS

Conviviality, as developed across this dissertation, offers a way of reimagining progress beyond efficiency and productivity. Drawing on Illich (1973), it foregrounds people's capacity to shape the material conditions of their lives through autonomous, cooperative, and meaningful work — underpinning what I describe as convivial materialisation: the ability to meet needs through material practices that support agency, learning, and self-actualization across supply chains. This redefinition of progress has concrete material implications. If progress is understood not as commodity accumulation but as the cultivation of productive agency, then questions of how technologies are made, from what materials, and under what conditions move to the centre of design practice.

Materialisation can be understood as a network of social and ecological relations connecting technologies to systems of labour, energy use, territorial control, and environmental impact. Material choices therefore align designers with particular forms of production and governance, either reinforcing or challenging dominant, centralised, and profit-oriented systems. While contemporary material selection frameworks increasingly incorporate environmental and ethical criteria, they often overlook these broader socio-political relations — obscuring how materials are entangled with industrial systems organised around scale, intellectual property, and shareholder value. Reorienting materialisation around conviviality therefore entails asking different questions of materials and techniques: whether they are accessible or monopolised; whether they can be learned, adapted, and shared; whether their provenance is legible to those who work with them; and whether their extraction and processing involve or exclude the people who ultimately use them. Understood this way, conviviality is not simply a property of finished tools or products but a quality that can be traced back through the constituent materials and supply chains from which technologies are made — and material selection becomes the moment at which designers can most directly intervene in this chain.

The projects in this dissertation demonstrated this concretely, working primarily with bio-based and reclaimed materials — locally sourced timber, biochar, waste wood, organic matter — that proved well suited to convivial materialisation because they are widely available, workable with accessible tools, repairable, and largely decommodified. Yet the experiments also revealed important limitations. Not all materials meet convivial criteria equally: bio-based and reclaimed materials tend to be biologically legible, locally variable, and embeddable within community governance, whereas many materials central to contemporary technological infrastructure — rare earth metals, industrial polymers, semiconductors — are structurally non-convivial, with opaque, globally dispersed supply chains inaccessible to non-specialists. This asymmetry points toward a structural condition that a genuinely post-growth convivial materialisation practice cannot ignore: in wealthy industrialised contexts, convivial making frequently rests on globalised supply chains that have displaced their non-conviviality elsewhere, outsourcing extraction and alienated labour to the Global South. Asking not only whether a material supports autonomy at the point of use, but whose labour and whose environments made that availability possible, is therefore a necessary and uncomfortable dimension of convivial material practice.

Figure 44
Designing for Conviviality. Instead of increasing productivity, conviviality means finding ways to include people in the production process with the goal of enabling creativity and self-actualization. In this photo, neighbors are brought into the buidling process, both in terms of design and production. The chalk outline of the garden was used to visualize the design at 1:1 before beginning construction.

These insights point toward convivial materialisation not merely as a revised set of design criteria but as a genuinely alternative imaginary for material practice — one that displaces the dominant framing of material selection as a technical and environmental optimisation problem and replaces it with a fundamentally different set of questions. Where the dominant imaginary asks how a material performs, what it costs, and what its carbon footprint is, convivial materialisation asks who can access and work this material, whose labour produced it, what social relations it supports or forecloses, and whether the communities who use it can govern, repair, and adapt it over time. Inhabiting this imaginary changes what designers notice in a material, what they value in a supply chain, and what counts as a successful outcome. It also has an irreducibly aesthetic dimension: convivial materials carry expressive qualities — grain, texture, patina, the marks of making and repair — that communicate provenance and invite sustained engagement. Learning to work with these material qualities, rather than smoothing them out in pursuit of industrial finish, is part of what convivial materialisation demands aesthetically — and developing the craft knowledge needed to do so beautifully remains one of the most open challenges for post-growth design practice.

6.3.2.

THE COMMONS: A FAIRER ECONOMIC SYSTEM

Where conviviality reorients the material basis of design, the commons reorients its economic logic. A post-growth design practice requires a reorientation away from profitability and market dominance as a guiding design agenda, toward an economic imaginary in which production is oriented toward the abundant satisfaction of collectively defined needs. This shift foregrounds questions that exceed market rationalities: what infrastructures and systems of provisioning are best suited to sustain equitable and ecologically viable ways of living?

Design within a commons imaginary becomes a fundamentally different kind of practice — more attentive, more humble, and more situated. Rather than the heroic designer imposing form upon context, commons-based design calls for careful listening, relationship-building, and ongoing stewardship. It shifts attention from the general to the particular: from scalable solutions to situated responses, from finished products to evolving infrastructures, from authorship to participation. Crucially, the commons cannot be designed in abstraction and dropped into place. It is slowly built — through sustained engagement with communities and institutions, through repeated acts of care and repair, through the gradual cultivation of trust, shared governance, and collective capacity (Bollier & Helfrich, 2019). For designers, this implies a fundamental redefinition of professional identity: from deliverer of solutions to infrastructural mediator, a role aligned with participatory design traditions (Björgvinsson et al., 2012). This triadic role requires active attention to power asymmetries, a commitment to redistributing knowledge and agency rather than consolidating expertise, and a willingness to remain engaged long after the conventional design process would have concluded.

In response to RQ2, the Carbon Commons reframes carbon sequestration as a relational, community-driven practice rather than a technical or market-driven one. Dominant approaches frame carbon as a unit to be optimised, traded, or enclosed within industrial systems — assumptions that materialise in capital-intensive solutions like Direct Air Capture, which attract investment from industries like Big Oil and ultimately serve as a form of status-quo maintenance (Gunderson et al., 2020; Malm & Carton, 2024). By contrast, in the Living Lab (Chapter 3), carbon was positioned as a means of provisioning the community — enabling the creation of a shared outdoor space, strengthening social bonds, and catalysing new governance practices — demonstrating concretely that sequestration can be socially meaningful rather than merely technically managed. In the Regenerative Ruin (Chapter 4), the commons imaginary was extended further to include non-human processes: by designing the structure to be gradually absorbed by the forest, governance was expanded to incorporate ecological succession and more-than-human temporalities in ways that post-growth economics has theorised but rarely materialised in practice (Bollier & Helfrich, 2019).

The question of quality — and whether commons-based production can compete culturally and aesthetically with industrial alternatives — proved one of the most persistent and unresolved tensions across the projects. Unlike the conviviality section, where aesthetic challenge concerns the expressive qualities of materials themselves, here the challenge is one of authorship: collective and participatory making processes do not automatically produce objects of refined aesthetic resolution. This tension was lived throughout the research, constantly negotiating between design sensibility — the desire for coherence and aesthetic ambition — and the imperative to keep processes genuinely open. Craft knowledge has been progressively eroded by industrial modernity, and the cultural benchmarks against which things are judged remain shaped by industrial norms of finish. The answer is not to close down participation in favour of professional authorship, but to pursue a more demanding design challenge: developing aesthetic languages in which distributed authorship, material honesty, and the traces of collective making become legible as quality rather than incompleteness — and in which the productive capacity of the commons can be expressed with enough cultural force to constitute a genuine alternative to dominant consumer goods.

The commons functions as a post-growth design imaginary not primarily because it offers a better governance model, but because it reorients the entire purpose and posture of design. Where market-oriented design asks what will sell, commons-based design asks what is needed, by whom, and under what conditions of shared ownership and care. Where the dominant imaginary makes individual consumption visible and collective stewardship invisible, the commons imaginary reverses this: foregrounding interdependence, situated knowledge, and the slow work of building and maintaining shared life (Bollier & Helfrich, 2019; Euler, 2019). For designers, inhabiting this imaginary means accepting a more modest and more demanding role simultaneously — relinquishing authorial control while taking on greater responsibility for the social and ecological consequences of what is made, how it is governed, and whether it endures.

6.3.3.

A POLITICS OF CARE

Optimisation has long structured design's methods and criteria for success, privileging control, acceleration, and predictability in ways that rely on a narrow understanding of time — one that obscures the slower, cyclical, and uneven temporalities through which ecological systems regenerate (Adam, 2005; Fry, 2009). When design is governed by compressed temporal horizons — project cycles, market rhythms, return-on-investment calculations — it routinely externalises ecological and social costs. From a post-growth perspective, these temporal mismatches are not accidental failures but structural features of growth-oriented design, revealing a fundamental incompatibility between optimisation and the dynamics of living systems.

Figure 45
Instead of an economy oriented around profit, designing for the commons orients production around collectively defined needs. With this logic, designing for the commons invokes a different kind of practice: more attentive, humble, and situated. In the photo, results from What a Waste (2024), an experimental residency exploring what it means to inhabit a temporary space together. With 8 other practices, we used waste to build necessary infrastructure to live in common for a week. Photograph by Lars Duchateau.

In response to RQ3, this dissertation advances a politics of care as a central imaginary for post-growth design, understood here as a practice-oriented and relational mode of organising design work rather than a moral prescription. Following Tronto (1993) and Puig de la Bellacasa (2017), care encompasses the practices through which worlds are maintained, repaired, and sustained — foregrounding interdependence, uncertainty, and ongoing responsibility rather than seeking to eliminate friction or compress time. Central to this is the capacity to notice: to attend to seasonal rhythms, material transformations, moments of human connection, and emergent relations that exceed conventional design timelines. As McGilchrist (2019) argues, truly noticing requires a fully engaged, subjective immersion in the world — an attentiveness that is holistic and relational rather than instrumental and particularising. This way of attending aligns closely with the intentions of a care-based design practice: noticing is not merely an attitude but a discipline, with specific implications for how designers engage with sites, materials, and communities over time. Care extends this attentiveness into sustained engagement, repositioning design as participation in long-term processes of co-adaptation with human and non-human actors.

Across the projects, this temporal reorientation took concrete form. Rather than being fully predetermined, design decisions emerged contingently from sustained engagement with places, communities, and material conditions. Structures were designed

to weather and decay; infrastructures evolved through collective stewardship; designs were treated as provisional and unfinished rather than fixed or final. In each case — whether allowing ecological succession to shape the Regenerative Ruin or involving the community in constructing the Carbon Commons garden — the value of rapid delivery and conventional resolution was offset by immaterial values: environmental compatibility, collectivity, and ecological attunement. These are not compensations for slower work but evidence that care-based design operates according to a different accounting of what counts as a successful outcome, one in which the quality of relationships sustained over time matters as much as the finish of what is produced.

Figure 46
Designing for a Politics of Care means asking which worlds are maintained, repaired, and sustained when we practice design? The Compost Wall in the Regenerative Ruin was an attempt to care for the bugs, worms, bacteria, and mycelia, which are fundamental to all ecosystems but rarely acklowledged by design.

This orientation is not without tension. A politics of care cannot imply inaction or endless deferral — there are moments when goal-oriented action and decision-making are necessary. The tension is therefore not between action and inaction but between different modes of doing: one oriented toward speed, closure, and output, and another toward responsiveness, accountability, and giving space. In practice, this required constant negotiation — for instance, between the slow rhythms of ecological growth and the funding timelines and institutional expectations within which the projects were embedded. Navigating this tension was one of the most persistent practical challenges the research encountered, and one that points toward the need for new institutional forms capable of hosting long-term, care-based design work.

These temporal tensions carry an aesthetic dimension distinct from those raised in the preceding sections. Here the aesthetic challenge is not material expressiveness or collective authorship but legibility across time: how do objects and spaces communicate care, weathering, and ecological process as value rather than neglect or incompleteness? Collective, time-based making does not automatically produce things that register as beautiful within dominant cultural frameworks shaped by industrial norms of finish and resolution. Yet this is not a deficit to be corrected but a deeper cultural challenge: developing aesthetic languages in which the visible traces of weathering, adaptation, repair, and ecological succession become legible as quality. This requires a shift in what is understood as desirable — away from the smooth, efficient, and fully resolved, and toward the expressive, the situated, and the alive. Aesthetics, in this sense, is not separate from a politics of care but the form through which care makes itself visible, felt, and culturally compelling.

A politics of care functions as a post-growth design imaginary not because it romanticises slowness or refuses ambition, but because it reorients the entire temporal logic through which design operates. Where optimisation asks how quickly and efficiently an outcome can be delivered, care asks what relationships, responsibilities, and ecological commitments must be sustained for an outcome to endure. Where the dominant imaginary treats time as a resource to be compressed, the care imaginary treats it as a medium to be inhabited — attending to the rhythms of living systems rather than overriding them. For designers, inhabiting this imaginary means accepting uncertainty and remaining accountable beyond the moment of production. It means measuring success not by the resolution of a finished object, but by the quality of the ongoing relationships — between people, materials, and ecosystems — that design helps to cultivate and sustain over time.

6.4.

THE MATERIALITY OF A POST-GROWTH DESIGN PRACTICE

As societies move away from fossil-carbon economies, downscale production, and attempt to restore the biosphere's regenerative capacity, design is increasingly required to do more with less. With reduced fossil extraction, greater responsibility falls on living systems to supply the materials upon which design relies, making carbon a strategic focal point. Rather than treating bio-based materials as inputs for new commodities, a post-growth design practice approaches them as sites of relationship, through which designing with carbon links convivial forms of production to ecologically regenerative processes. Responding to RQ1, in post-growth transitions, materiality is not a neutral substrate for design ideas, but the medium through which social values endure, erode, or are transformed over time.

6.4.1.

CARBON-SEQUESTERING AND REGENERATIVE MATERIAL PATHWAYS

Within the context of ecological overshoot, materials that are bio-regional, biologically derived, or waste-based constitute important conditions for regenerative design practice (Lyle, 1994; Reed, 2007; Wahl, 2016). In this dissertation, bio-based materials are understood primarily as materials whose production and regeneration are embedded within ecological cycles. Examples include timber, hempcrete, biochar, compost, soil. These materials are not treated as neutral inputs but as shared resources whose extraction, use, and renewal require collective governance and responsibility. While industrially synthesised bio-based polymers exist, the focus here is on materials that allow designers to remain closely engaged with ecological processes, places, and the social relations through which these materials are managed.

Bio-based material pathways offer two key possibilities for ecological regeneration. First, plant-based materials can temporarily sequester atmospheric carbon within the built environment (Chapter 3), reframing carbon not as an externality but as a material whose stabilisation becomes part of design practice. Second, these materials can emerge as by-products of ecologically regenerative activities such as forest management or regenerative agriculture, where ecosystem health is prioritised and material production becomes a secondary outcome. In this framing, material production is no longer the primary objective of land management, but one outcome among others. At the same time, the capacity for materials to function in this way depends on how they are sourced, governed, and cared for over time. Materials thus become carriers of ecological care not by default, but through ongoing practices that embed cyclical and long-term temporalities into design, making regeneration materially tangible while remaining contingent on sustained attention and responsibility.

In addition to newly grown biomass, this research engages with residual organic materials commonly classified as bio-waste. Designing with these residual streams, particularly low-grade or heterogeneous materials that are often destined for incineration (CE Delft, 2022), reintroduces carbon into slower, socially meaningful cycles of use before its eventual release. From a commoning perspective, the key question is not simply technical efficiency, but how these material flows are governed: when value is extracted, for what purposes, and under whose control.

An important implication of bio-based material pathways concerns product longevity. Long-living artefacts and infrastructures can function as extended carbon stores, but only insofar as they are embedded within practices of maintenance and adaptation that are collectively organised and sustained over time. Rather than equating durability with permanence, post-growth design understands longevity as relational and contingent: materials remain in use through repair, reinterpretation, and shared stewardship, all of which require ongoing effort and negotiation. In this sense, longevity is not a material property alone, but an outcome of commoning practices that must be continually renewed in order to sustain materials over time. This points to an underexplored aesthetic dimension of maintenance. For practices of care and upkeep to be sustained collectively over time, the objects and spaces being maintained must be worth caring for not just functionally, but emotionally as well. An aesthetics of maintenance would therefore not be applied after the fact but designed in from the outset, through the choice of materials that age beautifully, surfaces that accumulate meaning through use, forms that invite ongoing attention rather than passive consumption, and so on.

Beyond ecological regeneration, regenerative material pathways open a relational space for design practice. While bio-regional sourcing can reduce transport-related energy use, its more significant effect lies in enabling designers to remain accountable to the landscapes and communities from which matter is drawn. Across the projects presented here, from locally sourced timber in the Carbon Commons Living Lab to waste wood collected across Rotterdam in the Vertical Archive, material choices became opportunities to cultivate attentiveness, responsibility, and reciprocity, though not without negotiation and constraint. In this way, regenerative material pathways can embody principles of sufficiency and appropriate technology (Schumacher, 1973), supporting material systems that are grounded in place, proportional in scale, and governed as commons. At the same time, such arrangements remain contingent on ongoing care, coordination, and the willingness to work within limits, underscoring that ecological regeneration and collective care are sustained practices rather than inherent material qualities.

It becomes apparent that these material pathways are not without tension. While bio-based and regenerative materials promise alignment with ecological cycles, they also expose frictions between ecological time and project-based design logics. Processes of growth, decay, and regeneration unfold slowly and unevenly, often in conflict with project funding, institutional expectations, and mainstream design processes. In practice, working with such materials frequently required negotiating delays, uncertainty, and increased labour which challenge and even stand in contradiction with conventional design contexts. Rather than resolving these tensions, the projects presented here make them visible and generative, revealing how regenerative material practices challenge dominant assumptions about efficiency, productivity, and control.

6.4.2.

CONVIVIAL CARBON

Throughout this dissertation, materials have also proven central to enabling or constraining convivial modes of production. The choice of materials, and the infrastructures through which they circulate, strongly influence whether design reinforces industrial dependencies or supports more democratic, situated, and reciprocal forms of making. In Chapter 2, I introduced convivial materialisation as a framework for understanding how material processes can enable participation, learning, and local autonomy, particularly in contexts that seek alternatives to industrial modes of production.

Convivial materialisation is characterised by accessible production techniques, decommodified or low-cost material flows, and opportunities for communities to engage directly in making, maintaining, and repairing their environments. The design experiments presented here illustrate how this operates across contexts: local timber and biochar in Carbon Commons (Chapter 4), second-hand materials used to construct the Reading Room (Chapter 5), and organic matter in Becoming Worm (Chapter 5). In each case, material choices supported forms of shared agency while also engaging ecological processes, though in ways that remained situated and contingent, demonstrating how material practice can mediate between social participation and environmental regeneration.

Approached through this lens, carbon itself can be understood as a convivial material. Its stabilisation, storage, and transformation become not only technical challenges but opportunities for shared stewardship and collective agency (Chapter 3). Together, regenerative and convivial material pathways show how post-growth design principles become operative through matter. Rather than simply reducing environmental impact, they create openings for reconfiguring relationships between people, resources, and the temporalities of ecological systems. Materiality thus functions as a connective tissue between imaginaries and practice, grounding abstract principles in situated, lived processes.

At the same time, convivial materialisation emerged across the projects not as a stable condition but as a fragile and ongoing achievement. While shared material practices enabled participation and learning, they also depended on sustained coordination, effort, and often unpaid or under-recognised labour. In this sense,

Figure 47 (above)
Waste bio-materials taken directly from construction bins formed a large part of the material supply used across projects.

Figure 48 (right)
Local bio-based material supply chains are also fundamental to a post-growth society. Stadhout, an urban saw-mill processing waste wood drawn from within the city limits of Amsterdam, is one such example.


MANILOADER

conviviality did not replace industrial logics so much as coexist uneasily alongside them, requiring continual negotiation to avoid being subsumed by pressures of efficiency, scalability, or convenience. This tension underscores that conviviality is not a fixed outcome of material choice, but a practice that must be actively maintained within broader socio-technical constraints.

6.5.

POST-GROWTH DESIGN CAPACITIES

Regenerative transitions toward a post-growth society do not arise from isolated design interventions or from changes at a single systemic level. Instead, they emerge through practices that align infrastructures, social arrangements, and cultural imaginaries over time. Building on the preceding discussion of conviviality, commons, care, and materiality, this section identifies five important capacities for a post-growth design practice. These capacities overlap and reinforce one another, enabling designers to work simultaneously across infrastructure, social structure, and superstructure. From this perspective, and responding to RQ4, systemic change is not an outcome of design intent alone, but something gradually composed through practice.

Connecting

Connecting is a capacity concerned with actively creating and sustaining relationships between people, materials, and ecological systems. Rather than treating context as a backdrop for design decisions, connecting involves deliberate relational work: assembling actors, making interdependencies visible, and enabling forms of coordination that support collective wellbeing and ecological regeneration.

Across the projects in this research, connecting was typically the first step to embed design within existing social and ecological networks. This included building relationships with community members, negotiating shared aims, and attuning to the material and ecological dynamics of specific sites. Importantly, connecting extended beyond human actors to include landscapes, material flows, and more-than-human processes like growth, decay, and weathering.

In Carbon Commons (Chapter 4), connecting centred on establishing relationships between a community centre, carbon-sequestering materials, and local governance structures, allowing sequestration to function as a shared practice rather than a purely technical intervention. In Regenerative Ruin (Chapter 5), connecting foregrounded ecological relationships, linking human use to forest dynamics and long-term habitat formation. In both cases, design operated as a connective practice that aligned social needs with material and ecological processes rather than imposing predefined solutions.

Experimenting

Experimenting is a capacity through which designers generate situated knowledge by intervening materially and socially under conditions of uncertainty. Rather than optimising solutions or validating predefined outcomes, experimenting involves staging provisional arrangements of materials, practices, and relationships in order to explore alternative ways of meeting needs.

In this dissertation, experimenting followed naturally from the research-through-design methodology. Design experiments were framed as open-ended engagements with complex and changing situations in which outcomes could not be fully anticipated. This approach acknowledges that ecological regeneration and post-growth transition are wicked problems (Rittel & Webber, 1973; Tonkinwise, 2015), requiring designers to work iteratively and responsively, without guarantees of success.

Across Chapters 3-5, experimenting involved working with available materials and situated needs, constructing temporary configurations, and observing how they were taken up, adapted, or resisted over time. In Vertical Archive (Chapter 5), material experimentation with waste wood revealed new spatial and social possibilities. In Carbon Commons (Chapter 3), carbon-sequestering material processes became a catalyst for collective engagement. In Regenerative Ruin (Chapter 4), experimentation unfolded through long-term exposure to weathering, growth, and decay, allowing ecological processes to shape the project's evolution.

Crucially, experimenting in a post-growth context requires humility. Designers must accept uncertainty, take risks, and learn from failure, recognising that unintended consequences are inevitable and even desirable. Experimenting thus becomes a practice of attentiveness and learning which enables design to engage with complexity without reducing it.

Translating

Translating is a capacity concerned with mediating between different forms of knowledge, values, and constraints so that collective action becomes possible. Design's long-standing ability to operate between social, technical, and aesthetic domains becomes particularly significant in the context of post-growth transition, where projects must navigate between diverse actors, scales, and institutional settings.

Across this research, translating involved articulating community aspirations, material possibilities, and ecological concerns in ways that could be negotiated by different stakeholders. This required moving between everyday languages of communities and the more formal vocabularies of policy, regulation, and technical performance. Translation here did not reduce complexity, but sought to communicate social and ecological values as projects interfaced with institutional systems.

In the Living Lab (Chapter 3), for example, design mediated between locally grounded experiments in carbon sequestration and governmental frameworks of sustainability and innovation. Translation enabled community-based practices to engage planning processes, funding structures, and regulatory requirements, while institutional constraints were fed back into design decisions and adapted back to consider communal priorities.

As a post-growth design capacity, translating supports alignment between grassroots initiatives and broader systems of provisioning without reducing them to market or technocratic logics. It enables designers to work across difference – between communities and institutions, values and standards – while maintaining a commitment to collective wellbeing and ecological responsibility.

Materialising

Materialising is a capacity that responds directly to the material nature of the climate crisis. Climate change is driven by how materials – particularly carbon – are extracted, transformed, and stabilised through design and infrastructure. For designers, material decisions therefore shape ecological impacts, social relations, and the long-term viability of ways of living. A post-growth design practice places materialisation at the centre of intervention.

This research shows that materialising must be understood as a social practice. Materials are embedded within relations of labour, governance, access, and ecological dependency. When designers select materials and techniques, they align their work with particular systems of production, maintenance, and care. Socialising materialisation means making these alignments explicit and designing material processes that support collective agency, shared responsibility, and ecological regeneration rather than enclosure or extraction. In this sense, materialisation serves as the moment where post-growth values become durable – embedded in matter, infrastructure, and everyday use.

In practice, this involves working with bio-based and reclaimed materials, favouring accessible and repairable techniques and tools, and situating material processes within local ecological cycles. These choices reduce dependence on fossil-carbon infrastructures while creating opportunities for participation, learning, and care. Materialising thus shifts design from delivering finished objects toward shaping material systems that can be collectively made, maintained, and adapted over time.

Alongside these practical orientations, materialising must also engage with aesthetics. Bio-based and reclaimed materials carry their own expressive qualities – grain, texture, patina, the marks of use and repair – that, when allowed to speak, communicate care, provenance, and ecological embeddedness in ways that most industrially produced things cannot. The challenge is to develop material languages that make these qualities culturally legible and emotionally compelling: things that attract not through novelty or perfection, but through their capacity to resonate at a deeper, more innate register. This is not a secondary concern but a condition of possibility for post-growth design, because without aesthetic appeal, even the most ecologically sound material practice will struggle to displace the seductive pull of dominant consumer culture.

Adapting

Adapting is a capacity concerned with the ongoing modification and care of material systems as conditions change over time. While experimentation addresses how designers learn under uncertainty, adapting focuses on what happens once interventions are in use: how they are maintained, repaired, and reconfigured as social needs, ecological processes, and material conditions evolve.

Design scholarship has long recognised that artefacts and systems change through use and appropriation, and recent policy developments have further foregrounded maintenance and repair (European Commission, 2020) Post-growth design builds on this work by placing adaptation at the centre of practice. Under conditions of ecological constraint and climate uncertainty, designers can no longer assume stable contexts or fixed requirements. Adapting becomes a way of working with change rather than attempting to eliminate it.

Across this research, adapting involved designing material arrangements that could evolve through weathering, decay, ecological succession, and changing patterns of use. For example, in the Regenerative Ruin (Chapter 5), the festival stage was intentionally designed to transform through environmental processes and ongoing negotiation between human and more-than-human actors, while in the Living Lab (Chapter 4), adaptation occurred as approaches to sharing and taking care of the public garden were refined over time.

As a design capacity, adapting extends responsibility beyond the moment of production. It positions design as an ongoing engagement aligned with the temporalities of care and regeneration, sustaining material arrangements through time rather than optimising them for short-term performance.

6.6.

TOWARDS A POST-GROWTH DESIGN PRACTICE

Taken together, these capacities point towards a vision of design practice which can support post-growth transition by operating across infrastructure, social structure, and superstructure. Rather than delivering optimised solutions, the designer's role emerges as relational, provisional, and situated. Designers connect relationships, experiment under uncertainty, translate across domains, materialise social and ecological values, and remain engaged through adaptation and care. Through this sustained involvement, design contributes to post-growth transition not through singular interventions, but through ongoing participation in shaping and maintaining the material conditions of everyday life.

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7.1

CONTRIBUTIONS

This dissertation makes a number of interrelated contributions to design research, post-growth scholarship, and the broader project of imagining and enacting sustainable futures. Together, they advance a post-growth design practice oriented around care, conviviality, and ecological regeneration, positioning design not as a means of optimising existing systems but as a mode of stewardship and worldmaking capable of participating in deeper societal transformation.

A post-growth framework for design practice

The research makes a foundational theoretical contribution by positioning post-growth theory as both a critical and generative framework for rethinking design's role in societal transformation. Where mainstream sustainability discourse has largely operated within green growth and technological efficiency paradigms, this dissertation demonstrates that such framings obscure the socio-political and cultural foundations of ecological crisis. By reframing sustainability as a question of socio-economic relations, cultural values, and material governance rather than technological innovation alone, the research advances a coherent post-growth design practice and offers a foundation for reimagining design as a relational and politically situated discipline. In doing so, it bridges post-growth economics, political ecology, and design theory in ways that neither field has fully developed alone.

Convivial materialisation

A second contribution lies in the development and operationalisation of convivial materialisation as a design framework. Building on Illich's concept of conviviality, the research reframes material selection not as a technical or environmental act but as a socio-political one: material choices align designers with particular systems of labour, governance, and ecological impact, either reinforcing or challenging dominant, centralised, and carbon-intensive modes of production. Convivial materialisation offers designers a set of critical questions – whether materials are accessible or monopolised, learnable or opaque, regenerative or extractive – that move beyond existing environmental criteria to foreground collective agency, shared responsibility, and bioregional embeddedness. This framework was developed not abstractly but through sustained material experimentation across the projects, where locally sourced timber, biochar, waste wood, and organic matter became vehicles for participation, learning, and ecological care.

The Carbon Commons as a post-growth design imaginary

Third, the research makes an original contribution to both design and post-growth scholarship by conceptualising carbon sequestration as a commons-based, community-driven practice – what this dissertation terms the Carbon Commons. Against dominant approaches that frame carbon as a unit to be optimised, traded, or enclosed within industrial systems, the Carbon Commons reframes sequestration as a relational practice rooted in situated community needs and values. The Living Lab demonstrated this concretely: sequestered carbon became simultaneously a shared material, a social mediator, and a political catalyst, enabling the co-production of a valued neighbourhood space for food cultivation, education, workshops, gathering, and care. This contribution speaks not only to design research but to the communities and institutions that might support and sustain such approaches as models for community-led, regenerative provisioning.

A politics of care attuned to more-than-human temporalities

Fourth, the dissertation advances a politics of care as a central imaginary and organising ethos for post-growth design. Rather than a moral prescription, care is developed here as a practice-oriented and relational mode of design work: one that foregrounds noticing, maintaining, and remaining accountable to human and non-human actors over time. This contribution reorients design away from optimisation – with its compressed timelines, predefined objectives, and drive toward closure – toward a sustained engagement with the slower, cyclical, and uneven temporalities through which ecological systems regenerate. Across the projects, this temporal reorientation took concrete form: structures were designed to weather and decay, infrastructures evolved through collective stewardship, and design decisions emerged contingently from ongoing observation and negotiation rather than being fully predetermined. The politics of care thus extends and deepens existing work on maintenance, repair, and appropriation by situating these practices within an explicitly post-growth and more-than-human frame.

Five post-growth design capacities

Fifth, the research identifies and articulates five practical capacities – connecting, experimenting, translating, materialising, and adapting – that together constitute a situated, relational, and provisional model of post-growth design practice. Rather than prescribing methods or tools, these capacities describe the kinds of ongoing engagement through which design can contribute to post-growth transition across infrastructure, social structure, and superstructure simultaneously. They position the designer not as a problem-solver delivering optimised solutions, but as a collaborator, mediator, and steward who remains engaged with the social and ecological consequences of design over time. As a contribution to design practice, this offers a coherent alternative to both the heroic designer model and the service-oriented facilitation model, grounded in the specificity of what post-growth transition actually demands.

Research-through-design as post-growth inquiry

Finally, the dissertation makes a methodological contribution by demonstrating that research-through-design is not only an appropriate but a necessary methodology for post-growth inquiry. By treating design experiments as sites of knowledge production in their own right, the research generates situated, materially grounded insights that abstract theoretical frameworks cannot produce alone. Across the projects, theory and practice co-evolved through engagement with real social, material, and institutional conditions, producing new understanding of where post-growth principles hold, where they fail, and what they demand in practice. In this sense, the dissertation extends traditions of research-through-design and critical making by foregrounding their epistemic value for inquiries into alternative socio-material futures, contributing a model of embedded, iterative design research that integrates empirical experimentation with critical theory in the service of post-growth transition.

7.2

LESSONS LEARNED

If the contributions outlined above represent what this research has added to existing knowledge, the lessons learned represent what the research revealed about the conditions, limits, and difficulties of putting post-growth design into practice.

These are not failures to be minimised but insights that emerged precisely because the projects were conducted in real social, material, and institutional contexts, and are therefore as much a part of the dissertation's knowledge contribution as its theoretical frameworks.

Convivial materialisation is an objective, not a palette

Conviviality cannot be achieved simply by choosing the right materials — it must be actively pursued as an objective, in a similar manner to how performance is pursued today. Working primarily with scrap wood and bio-based materials proved instructive precisely because these materials made convivial criteria legible: they were locally available, workable without specialist equipment, and largely decommodified. But the projects also revealed the limits of this approach honestly. A modern society cannot be built from scrap wood, and many of the materials intrinsic to things like digital technologies assume structural conditions such as globalised supply chains, displaced extraction, outsourced labour. The lesson is therefore not a list of approved materials but a set of questions that might be applied to all materials and production processes: who can access and work it, whose labour produced it, what social relations does it support or foreclose, and whether the communities who use it can govern, repair, and adapt it over time.

The commons demands a redefined design role

A central lesson is that producing shared artefacts proved insufficient on its own to constitute a commons. What mattered equally, and what proved far more difficult, were the relational and governance structures through which things were collectively made, maintained, and adapted: the agreements, habits, and mutual accountabilities through which shared stewardship became possible. But the projects also revealed a further challenge: for the commons to be sustainable beyond experimental contexts, it must produce things that meet real needs and generate shared value — and this is where design expertise becomes genuinely strategic. The designer's role is therefore triadic: simultaneously technical, social, and institutional — embedding material expertise within communities, facilitating governance, and helping to reshape the institutional arrangements that determine whether commons-based production can endure. Design education has yet to fully reckon with what this demands, tending to foreground material and spatial skills while underequipping designers for the relational, organisational, and productive dimensions of commoning.

Care and speed are in tension

Working with ecological and social temporalities consistently produced richer, more meaningful outcomes than project-based logics oriented toward delivery and closure. And yet this way of working conflicted repeatedly with the expectations of funders, institutions, and collaborators shaped by conventional design timelines. This tension cannot be dissolved through better project management or smarter planning – it reflects a structural incompatibility between the temporalities of living systems and the temporalities of institutional and market logics. A key lesson is therefore that post-growth design requires not only new practices but new institutional containers: forms of support, funding, and evaluation that are themselves oriented toward care, longevity, and adaptation rather than output and efficiency.

Analytical frameworks are useful entry points but inadequate maps of practice

The three-layer analytical framework drawn from Harris proved valuable for organising the literature and sharpening the research questions, but consistently broke down when brought into contact with actual design situations. In every project, infrastructure, social structure, and superstructure were so deeply entangled as to be practically inseparable: a material choice was simultaneously a governance decision and a cultural statement, and treating these as distinct layers distorted more than it clarified. The lesson here is methodological as much as theoretical: post-growth design research needs frameworks that can hold complexity and integration rather than resolve it into categories, and research-through-design is better suited to this task than structured analytical models.

Aesthetics is a condition of possibility, not an afterthought

Finally, the projects revealed aesthetics as a significant and undertheorised challenge in post-growth design practice. The research did not set out to make this argument, but it became unavoidable: objects and spaces that do not generate authentic emotional attachment are unlikely to be maintained, culturally sustained, or capable of competing with the seductive appeal of dominant consumer goods. Collective and participatory making processes do not automatically produce things of aesthetic resolution, in part because craft knowledge and manual skill have been progressively eroded by industrial modernity, and in part because the cultural references against which such objects are judged remain overwhelmingly modernist. The lesson is not that post-growth design must capitulate to dominant taste, but that developing new aesthetic languages is as urgent and demanding a design research challenge as any of the material or governance questions this dissertation has addressed.

7.3

LIMITATIONS

Despite the contributions outlined above, this research has several important limitations that should be acknowledged.

First, the projects were small-scale, voluntary, and community-based, and share similarities in scale, material, setting, and mode of access: all draw heavily on recovered wood, operate at an outdoor community scale, and were embedded in relatively receptive social contexts. A broader range of project types, including digitally mediated commoning practices, knowledge-intensive infrastructure, or projects operating within more constrained institutional settings, would have strengthened the generalisability of the findings. More fundamentally, the gap between the convivial practices demonstrated here and the scale of transformation demanded by the climate crisis remains unresolved, and the research makes no strong claim to have bridged it.

A second limitation concerns aesthetics. The projects consistently prioritised participation, ecological grounding, and accessibility over aesthetic ambition. Within dominant modernist cultural frameworks, outputs that emerge from collective, low-tech, and care-based making processes risk being perceived as makeshift or provisional rather than compelling, limiting their capacity to displace the pull of consumer culture. As argued in the discussion, developing aesthetic languages adequate to post-growth values is an unresolved challenge that future work must take seriously.

Third, the convivial and commons-based making processes explored here depended heavily on sustained coordination, voluntary effort, and unpaid labour. While this reflects the relational and gift-based logics of commoning, it also raises questions about long-term viability, equity, and the conditions under which such practices can be sustained beyond experimental or research contexts.

Fourth, working with ecological temporalities – growth, decay, weathering, and regeneration – frequently conflicted with project funding cycles, institutional expectations, and conventional design timelines, constraining what was achievable within the research period and underscoring the structural incompatibility between care-based design and project-based institutional logics.

Finally, the use of Harris's three-layer analytical framework sits in tension with the holistic, integrative sensibility of the research-through-design methodology. While this tension is acknowledged and discussed, it is not fully resolved, and Harris's deterministic origins remain somewhat at odds with the post-growth values the research seeks to advance.

7.4.

FUTURE DIRECTIONS FOR RESEARCH

While this study has outlined the conceptual and practical foundations of post-growth design, many questions remain about how such practices can take root, endure, and scale within existing societal systems. The following sections identify key areas for further inquiry, focusing on the institutional, temporal, and material conditions necessary to sustain post-growth design over the long term.

Addressing concrete needs

Future research should move toward addressing concrete, needs-oriented applications of post-growth design. While speculative and exploratory projects have proven valuable for expanding imaginaries and testing alternative modes of materialization, a key challenge remains in connecting these insights to the everyday realities of things like housing, mobility, food production, electronics, renewable energy, and so on. As demonstrated in Carbon Commons, the viability of post-growth approaches ultimately depends on their capacity to become relevant to people's daily lives and material needs. This involves reorienting design from envisioning alternatives in the abstract toward developing feasible, context-specific infrastructures that enable sufficiency, conviviality, and ecological regeneration.

Enabling long-term projects

A second important direction for future research lies in developing the capacity for long-term engagement in projects rather than short-term, one-off interventions. While this study sought to incorporate long-term orientations across its projects, most interventions remained experimental and temporally constrained. Projects such as The Carbon Commons Living Lab (Chapter 4) or The Regenerative Ruin (Chapter 5) illustrate this tension clearly: both address ecological processes – carbon sequestration, soil regeneration, ecological succession – that unfold over decades or even centuries, far exceeding the duration of typical design research.

Enabling long-term projects therefore raises critical questions about the political and institutional scope of design: what designers can realistically influence, where their agency is limited, and how their work can be sustained beyond the lifecycle of an initial project. It calls for identifying the collaborators, networks, and governance structures necessary to support design as an ongoing practice of care. Future research might explore what kinds of institutions – such as universities, municipalities, or public design laboratories – are best positioned to host and sustain long-term experimental work that bridges research, practice, and community life. Embedding design more deeply within enduring social and ecological relationships could provide insight into how interventions evolve over time, adapting to shifting conditions while maintaining alignment with post-growth principles.

Exploring the scale limits of post-growth materialization

A final direction for future research concerns questions of scale in post-growth materialisation. Throughout this study, I frequently relied on waste or bio-based materials as accessible, locally available, and largely decommodified regenerative resources within a Northern European context. When considered beyond these situated settings, however, such approaches reveal important limitations. Contemporary societies remain deeply dependent on material-intensive systems for transportation, digital communication, and (renewable) energy, whose supply chains are embedded in extractive and environmentally damaging processes. This raises fundamental questions not only about how regenerative material practices might be expanded, but also about which forms of material provisioning should be expanded at all, and under what social and ecological conditions.

Rather than assuming a singular scale at which post-growth material systems must operate, this research points to scale as a contested and political question. Post-growth perspectives often emphasise scaling out rather than scaling up, yet how such distributed approaches might meaningfully respond to global ecological pressures remains unresolved. Future research could therefore investigate how different modes of scaling, such as replication, federation, modularity, or localization, can shape the social, ecological, and political consequences of how infrastructure is produced. Design can contribute here by exploring how material practices are embedded in particular territories and communities, and by prototyping alternative supply chains grounded in regional ecologies, collective governance, and sufficiency-oriented values

Aesthetics and craft

A further direction for future research concerns the aesthetic dimension of post-growth design. As this dissertation has argued, regenerative design cannot rely on ecological or ethical arguments alone to displace the appeal of dominant consumer culture – it must also produce things that are to be desired, that strike an emotional chord and generate genuine attachment. This requires developing new aesthetic languages adequate to convivial and commons-based practice: languages in which the visible traces of collective making, weathering, repair, and ecological process read as quality rather than incompleteness. Closely related is the question of craft. The erosion of manual skill and craft knowledge under industrial modernity emerged across the projects as a structural barrier to aesthetic resolution in participatory making. Future research should therefore investigate how craft knowledge can be recovered, taught, and embedded within commons-based design practice – not as nostalgia, but as a practical condition for producing things of lasting cultural and emotional value.

Indigenous and traditional design knowledge

This research has drawn selectively on indigenous scholarship – particularly through Kimmerer's relational account of provisioning – but has not engaged systematically with indigenous and traditional design cultures as sources of aesthetic, material, and governance knowledge. This represents a significant gap. Many of the principles explored in this dissertation – place-based making, ecological stewardship, commoning, care, and the integration of symbolism and function – have been practiced and refined by indigenous cultures for centuries, often under other names and within richer aesthetic and spiritual frameworks than post-growth theory has yet developed. Future research should engage directly and reciprocally with these traditions, not as historical precedents to be appropriated, but as living bodies of knowledge that can challenge, deepen, and reorient post-growth design scholarship in fundamental ways.

7.5.

CONCLUDING REMARKS

Post-growth design begins with a quiet refusal to see the world as a stockpile of resources awaiting extraction and commodification. It is an invitation to exist otherwise, to design not for accumulation but for continuance, not for progress as expansion but for progress as the proliferation of conviviality, enhancing people's "freedom to make things among which they can live, to give shape to them according to their own tastes, and to put them to use in caring for and about others" (Illich, 1973, p. 11) In this view, design can become something different than the act of imposing form upon matter, but of listening, attuning, and responding – a dance with the materials, communities, and ecologies that sustain life.

Across this discussion chapter, design has unfolded as a living practice: connecting with what already exists, experimenting with what could be, translating between the technical and the social, materializing care into form, and convivially adapting to change. It is an art of staying with the world, of tracing the fragile threads between people and places, technologies and soils, futures and the debris of the past.

To design in a post-growth world is to take part in the slow work of reweaving these threads – cultivating conviviality where there was alienation, stewardship where there was extraction, and imagination where there was only efficiency. It is, ultimately, to rediscover design as a way of participating in life's ongoing regeneration.

009 References

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