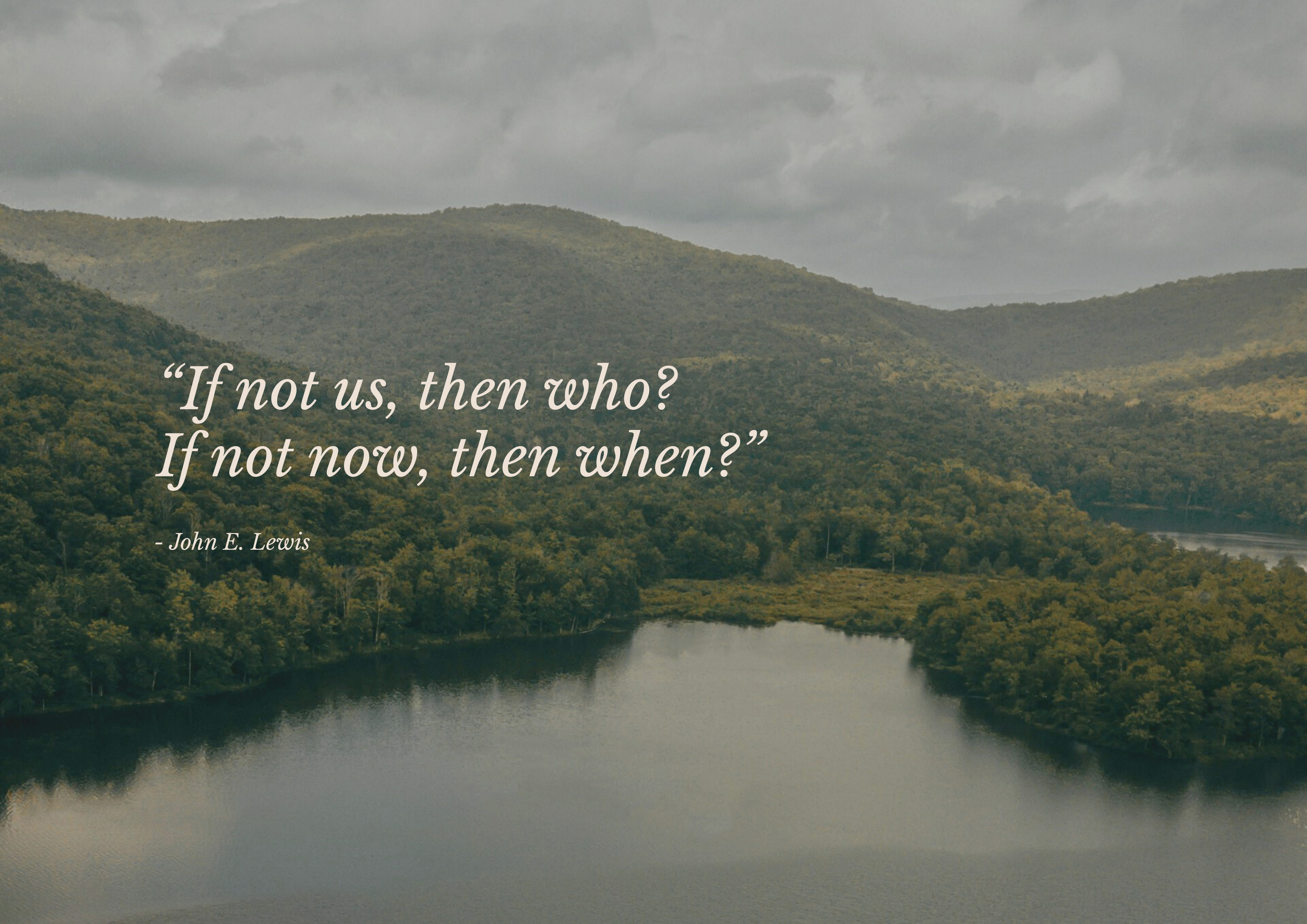
1. *Beyond the* Roadmap

A transition plan for the Danish building industry

ARTELIA
CEBRA
EFFEKT
Realdania
DREYERSFOND


"If not us, then who?
If not now, then when?"
- John E. Lewis

Reduction Roadmap Initiators: Sinus Lynge (EFFEKT), Mikkel Schlesinger (CEBRA), Steffen Maagaard (Artelia)

Report authors:
EFFEKT: Alex Ianchenko, Dani Hill-Hansen, Kasper Benjamin Reimer Bjørksov.
Artelia: Rasmus Søgaard, Steffen Maagaard.

Graphics:
EFFEKT: Adrian Dahlberg, Dani Hill-Hansen, Daniela Sofia Alcocer Castro, Haidy Mousa, Kasper Benjamin Reimer Bjørksov, Otto Hallstrup, Sinus Lynge, Sandra Czech, Vilde Livsdatter Sønderland.

Communication:
EFFEKT: Jeppe Krabbe, Liv Elbirk. CEBRA: Martin Møller Vilhelmsen, Mikkel Schlesinger.

Reduction Roadmap team:
EFFEKT: Dani Hill-Hansen, Emil Engelbredt, Jeppe Krabbe, Kasper Benjamin Reimer Bjørksov, Sinus Lynge CEBRA: Martin Møller Vilhelmsen, Mikkel Schlesinger.
Artelia: Rasmus Søgaard, Steffen Maagaard.

To reference this report:
Reduction Roadmap (2024) *Beyond the Roadmap: A transition plan for the Danish building industry* Version 1. 29. October, 2024. www.reductionroadmap.dk

Initiated by:

With support from:

A special thank you to the following experts for contributing essays to this report:

Stig Hessellund (Realdania) Anders Bjørn (DTU) and Joachim Peter Tilsted (University of Copenhagen), Ivana Stancic, Indy Johar, Oliver Burgess and Alicia Carvajal Rowan (Dark Matter Laboratories), Kirsten Gram-Hanssen (BUILD, Aalborg University), Anne Beim and Lykke Arnfred (CINARK – The Danish Royal Academy), Ludwig Engel (House Europe!), Mads Oscar Haumann and Marcus Feldthus (Post-Growth Guide) and Dan Hill (Melbourne School of Design at the University of Melbourne).

A philanthropic perspective on Reduction Roadmap as a data-driven path to the transformation of construction

Sometimes, knowledge and tools are created that are so remarkable that they push our level of ambition, our way of seeing the world, and spark debate. This is the case with the Reduction Roadmap, which has shown its potential to create a strong and guiding narrative framework for the green transition in the Danish construction sector. It is interesting how data and calculations can provide a crucial foundation for the development work of an entire industry. This connection between research and practice exemplifies how Realdania aims to contribute philanthropically to various initiatives, each of which, and collectively, can pave the way for the transformation of construction.

The calculation was easy to understand. Operational. And part of the initiative's name. In 2021, Realdania, in collaboration with the Villum Foundation, launched the initiative "Housing Construction from 4 to 1 Planet." A joint initiative focused on reducing the climate impact of housing construction in Denmark to a quarter of the 2020 baseline. From about 10 kg CO_2eq/m²/year for a newly built home to 2.5 kg CO_2eq/m²/year in 2030. The goal was set early in the initiative and calculated roughly based on Earth Overshoot Day, which in 2020 indicated that Denmark consumes resources equivalent to four planets.

Stig Hessellund
projektchef, Realdania
April 2024

Realdania is a philanthropic association that works to improve quality of life for everyone through the built environment. This includes, for example, urban development, construction, and preservation of important cultural environments. The association contributes to a wide range of projects and initiatives aimed at reducing the climate footprint of construction.

What do we do when we can no longer reduce gradually until we reach the goal? How can we build if there is no planetary budget we can build within? If we continue to build beyond the budget, we are drawing on the planetary overdraft and leaving the bill—with interest—to the future.

However, we lacked the real, scientifically validated reduction target where construction activities actually occur within the planet's capacity. We wanted this to ensure that we have the best available knowledge when we act, even if it means that the reduction target in "Housing Construction from 4 to 1 Planet" might not be perfectly aligned with the planet's absolute capacity. The exact target is not the most important in this context; it is about making the short-term, significant reduction, which is challenging enough in itself.

In January 2022, we received a proposal from CEBRA Architects, together with Aarhus University and EFFEKT Architects. They wanted to quantify a budget for construction within the planet's "Carrying Capacity." We combined forces and worked on a common reduction goal, which also received scientific validation of the global "safe operating space" from AU, SDU, DTU, and AAU. Thus, "Housing Construction from 4 to 1 Planet" gained a more precise baseline, and the Reduction Roadmap received a scientifically validated target.

White Paper and the 95%

In the summer of 2022, the researchers' white paper was published. The global budget required not a 75% reduction but a 95% reduction. How do you deal with such a number? How do we communicate this to the public? It was important to stay true to the researchers' work, but it was also a significant further reduction from our already ambitious goal in "Housing Construction from 4 to 1 Planet." Once we had reduced to 25%, would we then have to reduce again from scratch? We were concerned that the need for such a massive 95% reduction would be dismissed as unrealistic.

We let the research speak for itself. The Reduction Roadmap was developed as a stepwise reduction over time, where the first steps on the reduction ladder were realistic, and the difficulty gradually increased. We knew that many other reduction goals had already been set in the industry, including in our own 4 to 1 initiative. This is only natural in a time when both the climate and our knowledge of what needs to be done are rapidly evolving.

Since the launch of the Reduction Roadmap in 2022, the interest and commitment have impressed us, and it has been one of the most talked-about initiatives in the construction transformation for several years. With its spread has naturally come debate. A debate that we at Realdania welcome and see as a natural consequence when new, agenda-setting knowledge emerges.

The Planetary Overdraft

Reductions in the climate impact of construction have historically been relative to what we usually do. More "sustainable" material use may have reduced CO_2 emissions by 10% or 20% percent. But the reduction lacked a target. And the construction industry lacked an answer to the question: How much reduction is actually necessary for construction to be sustainable?

A budget for the planet's carrying capacity is therefore a breakthrough. A paradigm shift in the industry. Now we can set scientifically based goals for reducing the climate impact of construction. Since the launch of the Reduction Roadmap in 2022, based on data from 2020, the global climate impact trend has gone the wrong way. It has increased, not decreased. This means that the remaining budget within the 1.5°C warming limit of the Paris Agreement is running out. And researchers point to severe consequences of exceeding the 1.5 °C limit.

The absolute budget thus confronts us with several dilemmas. What do we do when we can no longer reduce gradually until we reach the goal? How can we build if there is no planetary budget we can build within? If we continue to build beyond the budget, we are drawing on the planetary overdraft and leaving the bill—with interest—to the future. The absolute paradigm shift therefore entails the difficult but necessary conversation about what the future of the construction industry can look like.

Between Research and Practice

Reduction Roadmap is a good example of how we at Realdania work philanthropically with various initiatives, each of which, and collectively, can show a way for the transformation of construction. We cannot and should not in Realdania create or drive the transformation. The industry must do that. But there is a special philanthropic role to play in helping to create new knowledge, look at risks and barriers, create an overview, and establish partnerships across the sector.

For example, what is needed for more biogenic materials such as straw, wood, eelgrass, and hemp to find their way into Danish homes and buildings? We are investigating this in the initiative "Paths to Biobased Construction," where we, in collaboration with industry players, aim to provide new knowledge, push the development of new materials, and test them in specific constructions.

And can we, with renovations and transformations, create new homes and housing environments that combine a low climate impact and resource consumption with high housing quality and good frameworks for communities? The houses that surround us already form the framework for our daily lives and are thus a cornerstone of our culture. There is a need for greater appreciation and preservation of the houses we have already invested CO_2 in constructing.

Sometimes through gentle renovation and other times with a more radical approach. This is what we are trying to explore in the "Preserve More" initiative.

These are just a few of the experiments we are currently undertaking with the sector. We support the green transition in construction on many scales—from the individual material to the home to the sector. The experiences from our work are shared, just like all other knowledge and experiences Realdania gathers through projects and initiatives. So, everyone can replicate the good solutions and minimize the inevitable mistakes in an experimental process. Supporting innovative processes that create new solutions and new knowledge is a central task for a philanthropic association like Realdania.

The Transition is Not Just About Reduction

The construction industry—like all other sectors—needs holistic, yet data-driven tools. Especially in a time of transition like the one we are facing. Many aspects of our society will be subject to revision in the coming years.

Ultimately, it is not just about reduction, but about creating unifying, positive narratives that address reduction needs and present scenarios for what we can achieve by setting goals for reducing climate impact. And working to set new goals for construction in terms of, for example, communities, a different aesthetic, other types of housing and workplaces, or environmental considerations. In this way, the Reduction Roadmap conveys a reduction need while supporting a conversation about what can provide us with a different—and perhaps higher—quality of life in the future. And life quality is Realdania's goal in everything we do.

Reduction Roadmap is not just about reducing the climate footprint but about a new way of setting goals for our society.

We look forward to seeing the Reduction Roadmap realize its potential to be the movement that bridges the gap from research to practice and decision-making for sectors other than construction. It will be exciting to see if more sectors follow the construction industry's lead, showing the way for the change that must happen in the coming years. Sector by sector, but also for society as a whole. And not least for future generations.

Reduction Roadmap is not just about reducing the climate footprint but about a new way of setting goals for our society.

Reading Guide

This document is constructed in two halves, or five parts. The Foreword serves as a catch-up on the Reduction Roadmap work done in 2023 - 2024. Chapter 1 and Chapter 2 frame the new perspective and preconditions embedded in this “Beyond the Roadmap” report and set the stage for targets and solutions presented in Chapter 3 and Chapter 4. Chapter 1 and 2 are more systemic, focusing on global trends and systemic understanding, where Chapter 3 and Chapter 4 focus in on the Danish context and the building industry as a solution space.

Foreword

The Foreword provides an update on the Reduction Roadmap 2.0 and Denmark’s historic efforts to align building legislation’s carbon limits with the Paris Agreement. It also introduces key insights and challenges the Reduction Roadmap team has encountered since the Roadmap’s 2022 launch. Topics include the debate between relative and absolute reduction targets, the effects of global warming on critical tipping points, and the rationale for shifting beyond a reduction-focused approach toward a more systemic, long-term perspective in this report - answering the question: "What lies beyond the Roadmap?"

Chapter 1: Checking infinite growth on a finite planet

In the first chapter, we discuss Limits to Growth and define the concept of the polycrisis, highlighting the interconnected global challenges that exacerbate environmental and social instability. We then examine the root cause of climate breakdown: overconsumption on a finite planet, driven by unchecked resource use and economic expansion. In this chapter we ask “What are the limits to growth on a finite planet?” Questioning whether continued growth is compatible with ecological stability and long-term resilience.

Chapter 2: Efficiency without sufficiency is waste

In the second chapter, we aim to answer the concluding question of Chapter 1 by exploring "How the growth imperative constrained our ability to achieve sustainable transition?" —Through the evaluation of the building industry's green strategies - such as energy efficiency, biomass construction, the circular economy, renewable energy, and carbon capture. Historical data reveals that while these solutions are crucial for a sustainable transition, their potential to reduce emissions cannot keep pace with exponential growth of socio-economic systems. Without setting limits to growth, these efforts will only further accelerate climate collapse. The chapter concludes with four "Preconditions of Practice" for navigating design solutions in an overshoot world.

Chapter 3: Moving beyond the Roadmap: building within limits

This third chapter emphasizes the need to move beyond the current reductionist approach to problem solving by shifting from harm prevention to regenerative practices that restore planetary health asking the question "How can we scale impact within the safe and just planetary boundaries?" It critiques the net-zero approach, arguing that true sustainability requires addressing the ecological deficit caused by overconsumption. The "Butterfly" framework is introduced as a tool to guide nations, municipalities, and industries in benchmarking progress on climate stability and ecosystem health, focusing on both reducing emissions and increasing biodiversity protection. The chapter concludes by urging a fundamental shift away from the growth-driven paradigm to one that prioritizes regeneration and ensures a sustainable future within safe and just planetary boundaries.

Chapter 4: Investing in a liveable future

This final chapter outlines a strategic approach to navigating global economic transitions over the next 50 years, focusing on the choice between degrowth by design or by disaster through systemic foresight. It defines preconditions for investments based on sufficiency and asks the question "How can business be redesigned to achieve the regenerative potentials of the butterfly?" - emphasizing the need for investments that are necessary, regenerative, and equitable, and introduces frameworks for future decision-making, including "Deep design for Business" and the "Three Horizons" for innovation.

In addition to chapters written by the Reduction Roadmap team, this report contains essay contributions from industry experts from around the world. It is through their bodies of work that we've become privy to many facts and points-of-views documented in this report. We hope their insights support a holistic understanding beyond our own expertise and create more clarity about where we are today, and where we need to go.

Closing Remarks

In the final section of the report we offer perspective and reflections on the limitations of the report. We identify areas that need improvement and potentials for future work.

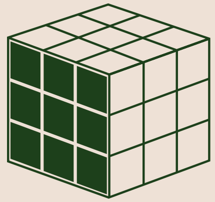
Understanding "Beyond the Roadmap" through core messages:

The following learnings represent the core messages we hope readers will take away from this report. Each point is grounded in comprehensive data analysis and supported by relevant literature, ensuring a robust foundation for our conclusions. Some of the points are basic understandings of natural systems, we believe are foundational to the approach taken in this report. Others are new insights we are happy to share.

Together these insights distill the essential findings and recommendations, offering a clear pathway for addressing sustainable development. By focusing on these core messages, readers can better understand the critical areas where meaningful action and policy shifts are both necessary and achievable. This report does not outline a single, prescriptive pathway: rather, it establishes the transition framework and destination targets.

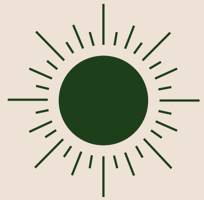
1. There are no infinite resources on a finite planet.

It is essential to recognize that there are limited resources on a finite planet, particularly given the unsustainable consumption rates of industrial societies. The idea of limitless economic growth is fundamentally incompatible with the Earth's physical limits. Fossil fuels, which have driven growth for centuries, are depleting and pushing us beyond critical environmental thresholds, thereby degrading ecosystems and threatening the foundations of life. Acknowledging and respecting these biophysical limits is vital for creating a sustainable and equitable future.



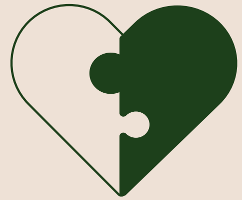
2. Everything is connected – nothing is off-site.

Shifting from narrow, isolated approaches to a wide-boundary mindset is crucial. This means understanding that everything is interconnected, and no issue exists in isolation. Tackling one environmental problem without considering its larger systemic impacts can create unintended consequences. Therefore, a holistic approach must be embraced to address the interdependence of ecosystems and societies - of which economy is a part. Recognizing that local actions have global repercussions, and nothing is truly "offsite" in a closed, planetary system.



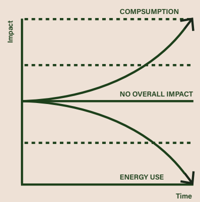
3. Nothing comes from nothing.

Every process, whether natural or industrial, requires an input of energy and resources. Such inputs impact the environment. A general failure to consider fundamental natural laws, like thermodynamics, has led to shortsighted "net-zero" policies that ignore the real costs and externalities of human activity. "Sustainable consumption" framed as a solution in a crisis driven by overconsumption is inherently flawed—even the best of practices is dependent on the consumption of materials from the living world. True solutions must focus on reducing resource demand from Earth's finite resources, while transition from net-zero to regenerative targets.



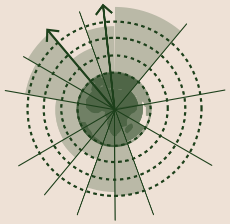
4. Justice is at the heart of sustainable development.

A sustainable future is unattainable without social justice. Overconsumption in wealthier nations has often come at the cost of poverty and exploitation elsewhere. A fair transition requires systemic change, prioritizing equity over profit and unchecked growth. Without justice, meaningful transformation is impossible; the well-being of all is interconnected. Continuing to support economic systems that benefit only a few will prevent the collective action necessary to address the Polycrisis. Ending unequal exchange between the Global North and Global South is a precondition for a sustainable future.



5. Impact potential of current strategies is impaired by the growth economy.

While some existing strategies and innovations may appear effective, they are fundamentally impaired by the growth economy. Rather than reducing resource consumption and production, many of these approaches end up perpetuating unsustainable consumption patterns. This misalignment highlights the urgent need to reorient strategies away from mere growth support and toward sustainable practices that are built on principles of sufficiency, within limits of the planet.

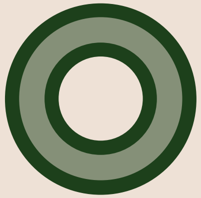


6. Doing no harm is not enough in a world in overshoot.

In a world that has surpassed six of the nine planetary boundaries, merely mitigating negative impacts is insufficient. The challenges ahead demand actions that not only reduce harm but also actively regenerate ecosystems. Relying solely on migration and adaptation strategies is no longer enough; effective approaches must integrate both mitigation of emissions and regeneration of the living world. Systemic solutions are essential to both address the reality of ecological overshoot and to foster a sustainable future for all living systems.

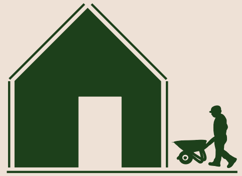
7. A framework for benchmarking against core Earth-system boundaries.

Within the report, a comprehensive framework: "The Butterfly" is established to guide the measurement of progress by benchmarking against two core planetary boundaries—climate stability and functioning ecosystems. This tool ensure that policies align with safe and just Earth-system boundaries. It emphasizes that sustainable progress cannot be achieved through reduction. Rather, active investments in net-positive regeneration contributions at a sufficient pace and scale are essential to expand Earth's biocapacity for a safer future.



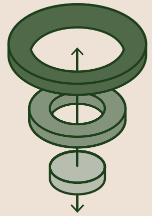
8. A pathway for Denmark to return to safe and just Earth-system boundaries

Applying the Butterfly Framework in Denmark, showcases a high-level model and pathway for regions or countries to return from being net negative to net-positive contributors. The method provides a roadmap for how Denmark can return to safe and just Earth-system boundaries in approximately 60 years. This approach proves that with the right policy and action it is possible to achieve true sustainable transition and long-term ecological balance within a generation.



9. The building industry as a catalyst for positive change

The report emphasizes how the building industry can play a vital role in driving large-scale restoration and regenerative efforts. By adopting the outlined framework and transforming its practices, the industry has the potential to shift from being part of the problem to becoming an integral part of the solution, fostering positive environmental and societal impacts.



10. Redesigning business and redirecting capital for a post-growth future.

The report offers tools and strategies for restructuring businesses and redirecting capital to align with safe and just planetary boundaries, shifting capital from being in service of finance to being in service of life.

Glossary

Biocapacity
relates to the regenerative capacity of our planet's ecosystems. The biocapacity metric, therefore, quantifies the renewal rate of ecosystems around the globe, tracking ecosystem's inherent ability to renew biomass.

Ecological deficit
when a population's ecological footprint (consumption of resources) exceeds its region's biocapacity (ability of nature to regenerate those resources).

Biosphere integrity
a metric that measures the status of all living things, defined by genetic diversity and net primary production of energy through photosynthesis. The biosphere integrity boundary has been crossed, as species extinctions are now much higher than in the past thousands of years, and humans are appropriating a disproportionately high amount of energy produced by nature.

Building industry
refers to a network of actors involved in planning, designing, constructing and operating buildings. Includes architects, engineers, real estate agents, contractors, builders, manufacturers, and suppliers of building materials, etc.

Carbon Equivalents (CO_2eq)
There are many different types of greenhouse gases (GHG) and CO_2eq. is shorthand for describing different GHG in a common unit. CO2 is the common unit selected because it is the most common GHG emitted by human activities. The CO_2eq. of a GHG can be determined by multiplying the amount of the GHG by its Global Warming Potential (GWP). In the body of this report, the term "carbon" and "CO_2eq" are used interchangeably, both meaning carbon equivalents.

Carbon Budget
refers to the total remaining amount of CO_2 that can be emitted while limiting global warming to 1.5°C.

Consumption-based emissions
a metric that tracks the emissions incurred by all goods consumed within a specific country, including imports. Consumption-based emissions are not the same as production-based emissions.

Holocene
is the geological epoch that began approximately 11,700 years ago following the last glacial retreat that is characterized by stable global climate patterns, which enabled the rise of agriculture and proliferation of human societies.

Deep Energy Retrofit
A comprehensive renovation aimed at significantly reducing a building's energy use, typically involving upgrades to insulation, HVAC, windows, and sometimes renewable energy systems, with the goal of achieving energy savings as apposed to a "light retrofit" which is a smaller-scale, cost-effective upgrade to improve energy efficiency, focusing on simple changes like lighting, thermostats, and minor insulation.

Ecological footprint
a metric that measures how much nature humans use to supply our needs and absorb our waste.

Financialization
the process by which financial markets become part of everyday lives and decision-making. In the context of the building industry, financialization describes when buildings become perceived more like financial assets and less like shelters.

Greenhouse Gases (GHG)
GHGs are any gas in the atmosphere which absorb and re-emit heat, thereby warming Earth's atmosphere. The predominant GHGs are water vapor, carbon dioxide ($C0_2$), methane, nitrous oxide, and fluorinated gasses, all of which have different chemical properties but are typically expressed in carbon equivalents (CO_2eq). When concentration of greenhouse gases in the atmosphere increased, the combined impact increases Earth's surface temperature, thereby changing climate on Earth.

Majority world
a term for a group of historically exploited countries that are elsewhere referred to as 'developing' or 'the Global South.' The term emphasizes that the majority of the world's population and land mass are in these countries.

Material footprint
the total amount of raw materials extracted globally to meet the consumption demands of an individual, community, or country.

Minority world
a term for a group of historically wealthy countries that are elsewhere referred to as 'developed' or 'the Global North.' The term emphasizes that these highly industrialized, colonizer nations are in the minority both in terms of population and land mass.

Overshoot
according to the IPCC, overshoot pathways exceed a specified

global warming level before returning below that level again during a specified period of time.

The Paris Agreement
is a legally binding, international treaty for climate change mitigation, that was adopted in 2015 by 196 of the world's countries during COP 21 in Paris. The goal of the Paris Agreement is to limit global warming well below 2°C, preferably 1.5°C scenarios (compared to preindustrial levels). In the context of the Paris Agreement, "overshoot" refers to a dangerous scenario in which humanity raises average global temperatures above 1.5°C relative to preindustrial levels before eventually reducing temperatures again.

Planetary boundaries
a scientific framework that describes the state of nine processes that regulate the stability and resilience of the Earth system. Once a planetary boundary is crossed, the risk of abrupt and irreversible environmental changes increases.

Production-based Emissions
a metric that tracks the emissions incurred by all production activities within the borders of a specific country (also known as territorial emissions). Production-based emissions do not track the impact of imported goods that are consumed in the country.

Polycrisis
a cluster of independent risks that create a compound effect, such that their overall impact exceeds the sum of their individual parts.

Redistribution
a type of building project that modifies the spatial plan to accommodate more users within the same footprint with the aim of reducing unused area.

Retrofit
a type of building project that modifies the envelope (insulation, windows, shading, air sealing) or systems (lighting, HVAC, water heating, appliances, etc.) with the aim of reducing total energy consumption.

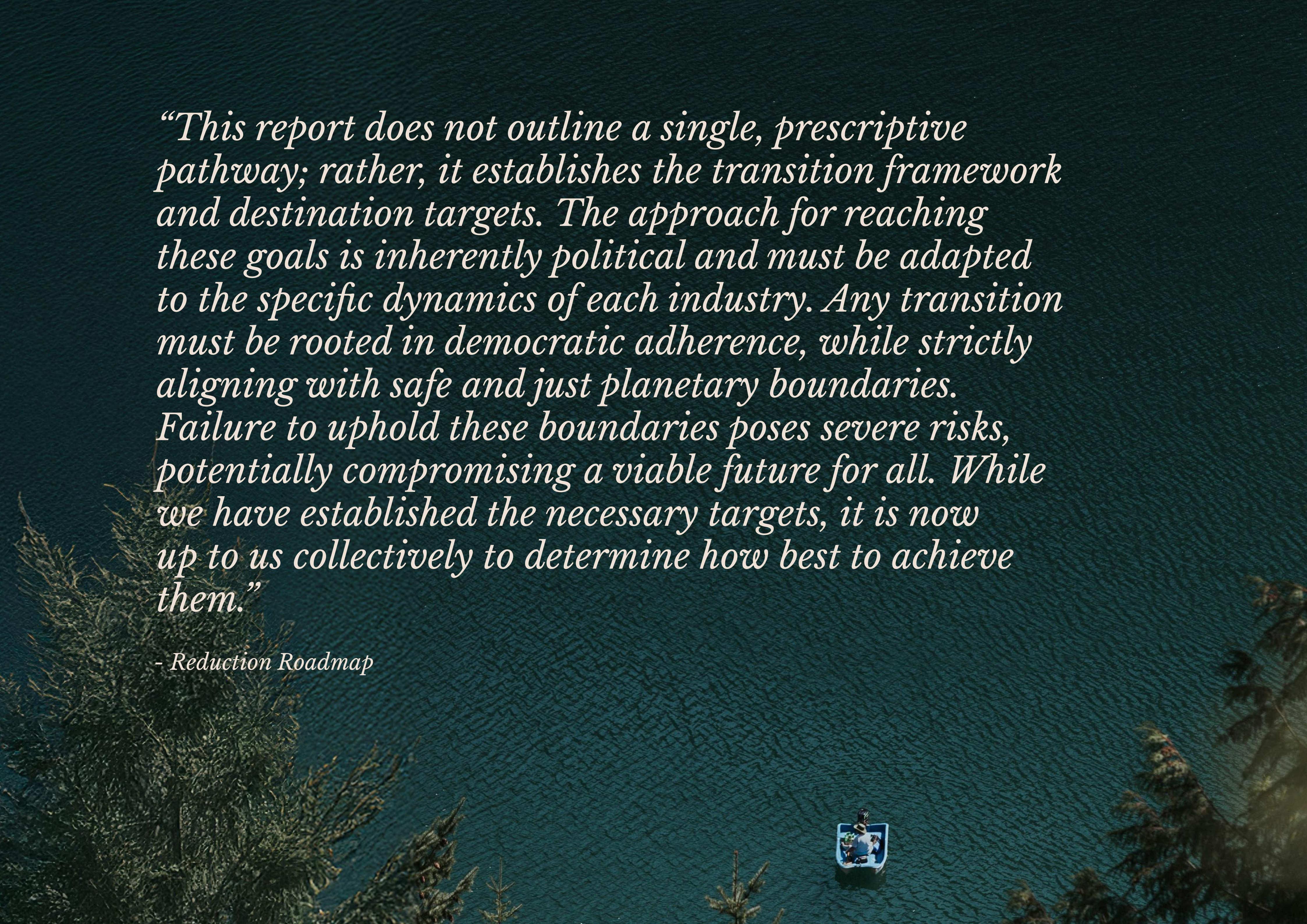
Regenerative Capacity
refers to Earth's regenerative capacity, defined as the maximum sustainable amount of resources it can supply.

Safe and Just Earth-System Boundaries (ESB)
defined to maintain Earth's biophysical processes which ensure a stable planet (safe boundaries) while protecting human well-being and equity (just boundaries). Based on the planetary boundaries framework, ESBs apply to critical systems like climate, biodiversity, freshwater, nutrient cycles, and air quality. Safe boundaries prevent ecosystem from exceeding critical tipping points by setting limits within which life-support systems can function effectively. Just boundaries address the need to minimize harm to vulnerable populations and ensure fair resource access.

Speculative Construction
a process where unused land is purchased, or a building project is planned and constructed without a formal commitment from specific tenants or buyers.

Sufficiency
policies, measures, and daily practices that avoid the demand for energy, materials, water, and land while delivering well-being for all humans within planetary boundaries.

Systemic Foresight
Systemic foresight is an approach to future planning that considers the interconnectedness and complexities of social, economic, environmental, and technological systems



"This report does not outline a single, prescriptive pathway; rather, it establishes the transition framework and destination targets. The approach for reaching these goals is inherently political and must be adapted to the specific dynamics of each industry. Any transition must be rooted in democratic adherence, while strictly aligning with safe and just planetary boundaries. Failure to uphold these boundaries poses severe risks, potentially compromising a viable future for all. While we have established the necessary targets, it is now up to us collectively to determine how best to achieve them."

- Reduction Roadmap

Foreword

What lies Beyond the Roadmap?

Reduction Roadmap

Since launch in 2022 the Reduction Roadmap has consistently pursued aligning the Danish building industry with Paris Agreement commitment and to scale impact within the planetary boundary for climate change. The Reduction Roadmap offers a clear narrative: where are we today, where do we need to go, and how long do we have to get there. Reduction Roadmap was timely launched before the inception of carbon legislation in the Danish building industry in 2023.

In 2023, the fundamental data informing the Reduction Roadmap changed — a group of internationally-recognized scientists updated the remaining global carbon budget and showed that, despite international policies and ambitions to reduce climate impact, half of the remaining carbon budget was used in less than three years[1] (Figure 0.1) . Based on this new knowledge, Reduction Roadmap was updated, shortening the timeline to reach target-level emissions from 7-12 years to 3-7 years.

The prospect of renegotiating the carbon limit in the Danish Building Regulations sparked the Reduction Roadmap mobilization campaign with a primary goal of aligning the carbon limit with Paris Agreement emission levels.

Learn more about the initial Reduction Roadmap project in the "Preconditions and Methodology" report, as well as background information on Reduction Roadmap 2.0, the <5,8 campaign and the Reduction Roadmap Organization all available through open-source at: www.reductionroadmap.dk.


Earth Syst. Sci. Data, 16, 2625–2658, 2024
https://doi.org/10.5194/essd-16-2625-2024
© Author(s) 2024. This work is distributed under the Creative Commons Attribution 4.0 License.

Open Access Earth System Science Data

Indicators of Global Climate Change 2023: annual update of key indicators of the state of the climate system and human influence

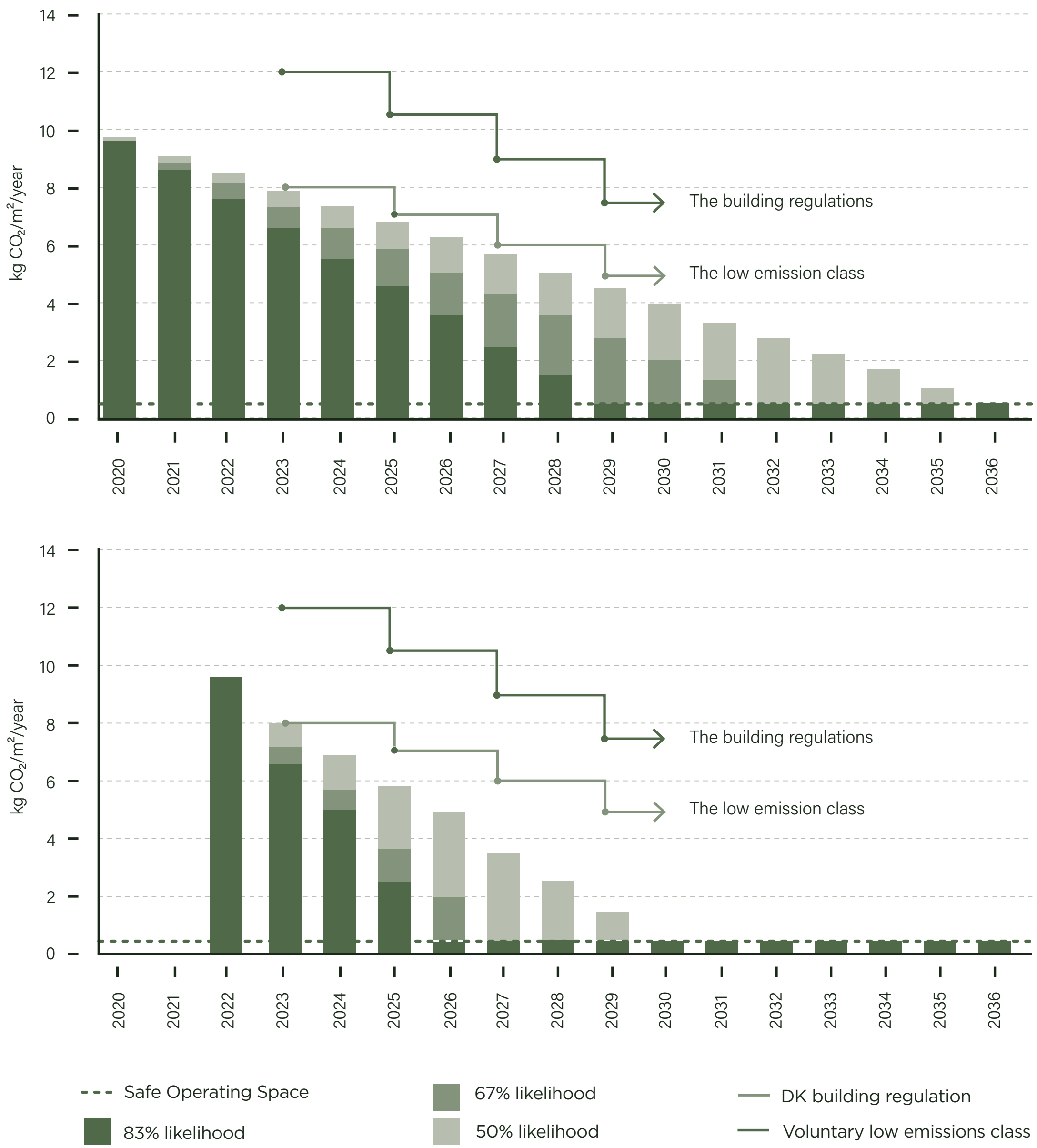
Piers M. Forster[1], Chris Smith[1,2,3], Tristram Walsh[4], William F. Lamb[5,1], Robin Lamboll[6], Bradley Hall[23], Mathias Hauser[7], Aurélien Ribes[8], Debbie Rosen[1], Nathan P. Gillett[9], Matthew D. Palmer[3,10], Joeri Rogelj[6], Karina von Schuckmann[11], Blair Trewin[12], Myles Allen[4], Robbie Andrew[13], Richard A. Betts[3,18], Alex Borger[45], Tim Boyer[15], Jiddu A. Broersma[45], Carlo Buontempo[14], Samantha Burgess[14], Chiara Cagnazzo[14], Lijing Cheng[16], Pierre Friedlingstein[18,19], Andrew Gettelman[40], Johannes Gütschow[20], Masayoshi Ishii[22], Stuart Jenkins[4], Xin Lan[21,37], Colin Morice[3], Jens Mühle[44], Christopher Kadow[23], John Kennedy[24], Rachel E. Killick[3], Paul B. Krummel[43], Jan C. Minx[5,1], Gunnar Myhre[13], Vaishali Naik[17], Glen P. Peters[13], Anna Pirani[25,26], Julia Pongratz[27,36], Carl-Friedrich Schleussner[28,29], Sonia I. Seneviratne[7], Sophie Szopa[30], Peter Thorne[31], Mahesh V. M. Kovilakam[40], Elisa Majamäki[41], Jukka-Pekka Jalkanen[41], Margreet van Marle[42], Rachel M. Hoesly[39], Robert Rohde[32], Dominik Schumacher[7], Guido van der Werf[38], Russell Vose[33], Kirsten Zickfeld[34], Xuebin Zhang[9], Valérie Masson-Delmotte[30], and Panmao Zhai[35]

[1]Priestley Centre, University of Leeds, Leeds, LS2 9JT, UK
[2]International Institute for Applied Systems Analysis (IIASA), Vienna, Austria
[3]Met Office Hadley Centre, Exeter, UK
[4]Environmental Change Institute, University of Oxford, Oxford, UK
[5]Mercator Research Institute on Global Commons and Climate Change (MCC), Berlin, Germany
[6]Centre for Environmental Policy, Imperial College London, London, UK
[7]Institute for Atmospheric and Climate Science, Department of Environmental Systems Science, ETH Zurich, Zurich, Switzerland
[8]Météo France, Université de Toulouse, CNRS, Toulouse, France
[9]Environment and Climate Change Canada, Victoria, Canada
[10]School of Earth Sciences, University of Bristol, Bristol, UK
[11]Mercator Ocean International, Toulouse, France
[12]Bureau of Meteorology, Melbourne, Australia
[13]CICERO Center for International Climate Research, Oslo, Norway
[14]ECWMF, Bonn, Germany
[15]NOAA's National Centers for Environmental Information (NCEI), Silver Spring, MD, USA
[16]Institute of Atmospheric Physics, Chinese Academy of Sciences, Beijing, China
[17]NOAA Geophysical Fluid Dynamics Laboratory, Princeton, NJ, USA
[18]Faculty of Environment, Science and Economy, University of Exeter, Exeter, UK
[19]Laboratoire de Météorologie Dynamique/Institut Pierre Simon Laplace, CNRS, École normale supérieure/Université PSL, Paris, France
[20]Climate Resource, Melbourne, Australia
[21]NOAA Global Monitoring Laboratory, Boulder, CO, USA
[22]Meteorological Research Institute, Tsukuba, Japan
[23]German Climate Computing Center, Hamburg, Germany (DKRZ)
[24]independent researcher: Verdun, France
[25]Euro-Mediterranean Center on Climate Change (CMCC), Venice, Italy
[26]Environmental Sciences, Università Cà Foscari, Venice, Italy

Published by Copernicus Publications.

Figure 0.1 - Indicators of Global Climate Change 2023 This report serves as an update to the global carbon budget defined earlier in the IPCC AR6.

Figure 0.2 - Reduction Roadmap 1.0 and Reduction Roadmap 2.0 compared to Danish building legislation (BR23) carbon limits. Source: Reduction Roadmap



Mobilizing the Danish Building Industry

In the fall of 2023, the Reduction Roadmap team embarked on an information campaign with a sense of urgency, appealing to align Danish building regulations with the Paris Agreement, based on Reduction Roadmap data (Figure 0.3). At the time, the carbon limits for BR25 (Danish building regulations for 2025) were being politically negotiated, offering the Danish building industry a unique opportunity to steer towards a significantly more sustainable direction.

Denmark was the first country to set CO_2 requirements for construction in 2023 and was also positioned to become the first country to implement the Paris Agreement in building regulations.

This campaign sparked commitment from 630+ organizations from the construction industry who co-signed the message to politicians that the building regulations carbon limit should be aligned with climate science to comply with the Paris Agreement. According to the data from Reduction Roadmap, this meant that emission requirements needed to be between 2.5 - 5.8 kg CO_2eq./m^2/yr in 2025.

The movement sparked commitment from political parties, municipalities, technical institutions, unions, private developers, pension funds and interest organizations. It also sparked a deal of debate and contention. Never the less, the historical campaign was the first time (to our knowledge) an industry asked politicians to enforce stricter legislation. We believe this support is indicative of the industry's readiness and willingness to participate in the sustainable transition.

After a delayed process, in May 2024 a political decision was finally taken. The result was a new average limit of 7.1 kg CO_2eq./m^2/yr in 2025 compared to the Reduction Roadmap data which proposed a limit of under 5.8 kg CO_2eq./m^2/yr. The agreement also slowed the future pace of reductions, compared to what was already agreed. This will result in a overshoot of the carbon budget by 120% between 2025 - 2030 as illustrated in Figure 0.4.

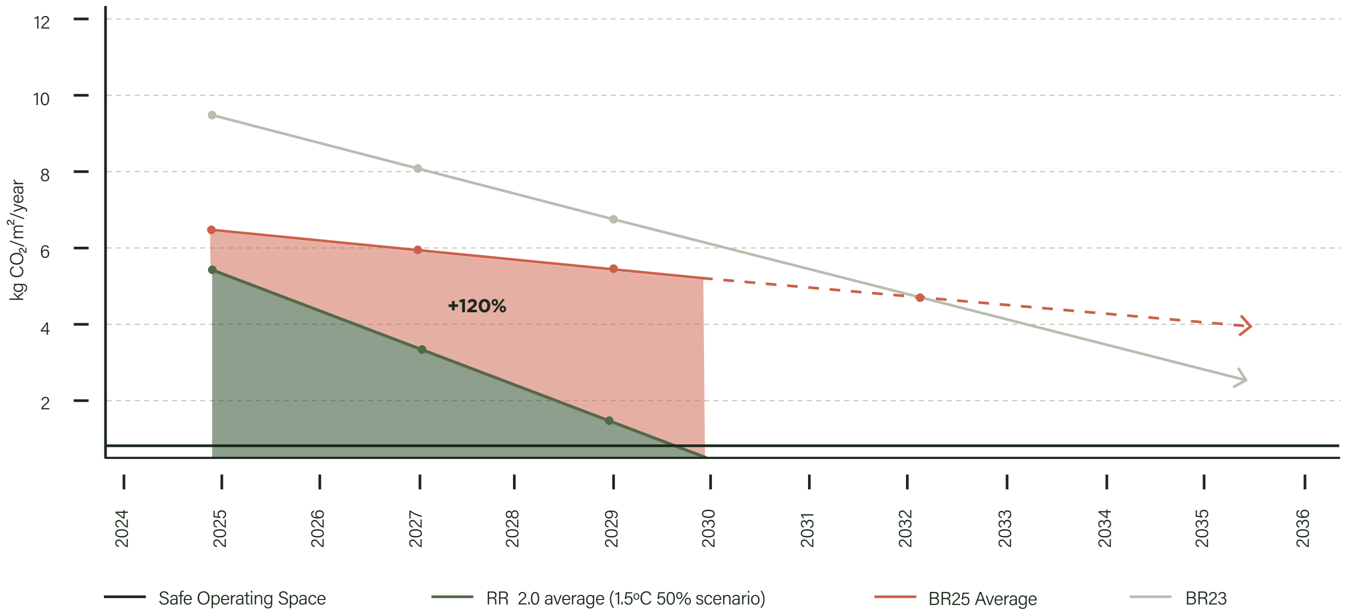
Figure 0.3 Reduction Roadmap information campaign material

Figure 0.4 - The Reduction Roadmap values compared to building industry's carbon budget according to the new threshold values

With the adopted threshold value for buildings' climate impact and the expected tightening toward 2030, the building industry's CO_2 budget will be approximately 120%* larger than the proposal from the Reduction Roadmap.

Additionally, the anticipated reduction rate has been significantly lowered from 1.5 kg CO_2-eq/m^2/year every two years to around 0.65 kg CO_2-eq/m^2/year. If this trend continues beyond 2030, it would mean that the building industry would be operating within a CO_2 budget aiming for a temperature increase of 2.0°C, with approximately 50% probability.

*This calculation assumes that the carbon limit covers a consistent rate and typology of construction over this time period.



"If we wait for the governments, it'll be... too late; if we act as individuals, it'll be too little; but if we act as communities, it might just be enough." – Rob Hopkins

Absolute versus relative reduction targets

The inability of Danish politician to align the building regulation with the Paris Agreement is indicative of a larger, systemic issue: There is a fundamental misalignment between national climate targets, often based on relative reductions in emissions, and the absolute carbon budgets defined by climate science.

A major issue lies in how policymakers conceptualize climate action. While many nations commit to reducing emissions by a percentage compared to a historical baseline (e.g., 70% reduction based on 1990 levels by 2030), these targets do not align with the finite global carbon budget that must be adhered to in order to limit global warming to 1.5°C[6]. Relative reduction targets can appear ambitious but still permit overshoot of emissions if overall economic activity and energy consumption continue to rise.

Climate science, however, emphasizes the need for strict absolute limits on cumulative emissions, meaning that even small, ongoing emissions are pushing the world beyond critical thresholds. To meet global climate goals, national targets should align with the remaining carbon budget, ensuring that emissions reductions are immediate and sustained, rather than merely relative to past levels.

Despite decades of international climate negotiations and COP meetings, global greenhouse gas emissions continue to rise. Governments have failed to meet the targets they set. For example, with the Paris Agreement the international community pledged to keep global warming below 1.5°C above pre-industrial levels. Yet, by 2023, as illustrated in Figure 0.5,the world experienced its hottest year on record, with global temperatures nearly reaching the 1.5°C threshold for an entire year[7] - threatening a push past internationally agreed targets and to cause catastrophic consequences for humanity and the planet[8].

The Reduction Roadmap project aimed to operationalize strict absolute limits in Danish building industry through the information campaign. The Danish politicians failed to align national regulation with international agreements - even though the Reduction Roadmap targets are consistent with the reduction value they are obligated to uphold.

The implementation of on-the-ground actions to transform these systems lags behind climate policy, which, in turn, falls even further behind climate science. Yet, in 2024, we cannot afford to wait. The planet is beyond the "safe" zone for climate change, and humanity will run out of a carbon budget to meet the 1.5°C goal by the end of this decade without immediate, deep, sustained cuts to our greenhouse

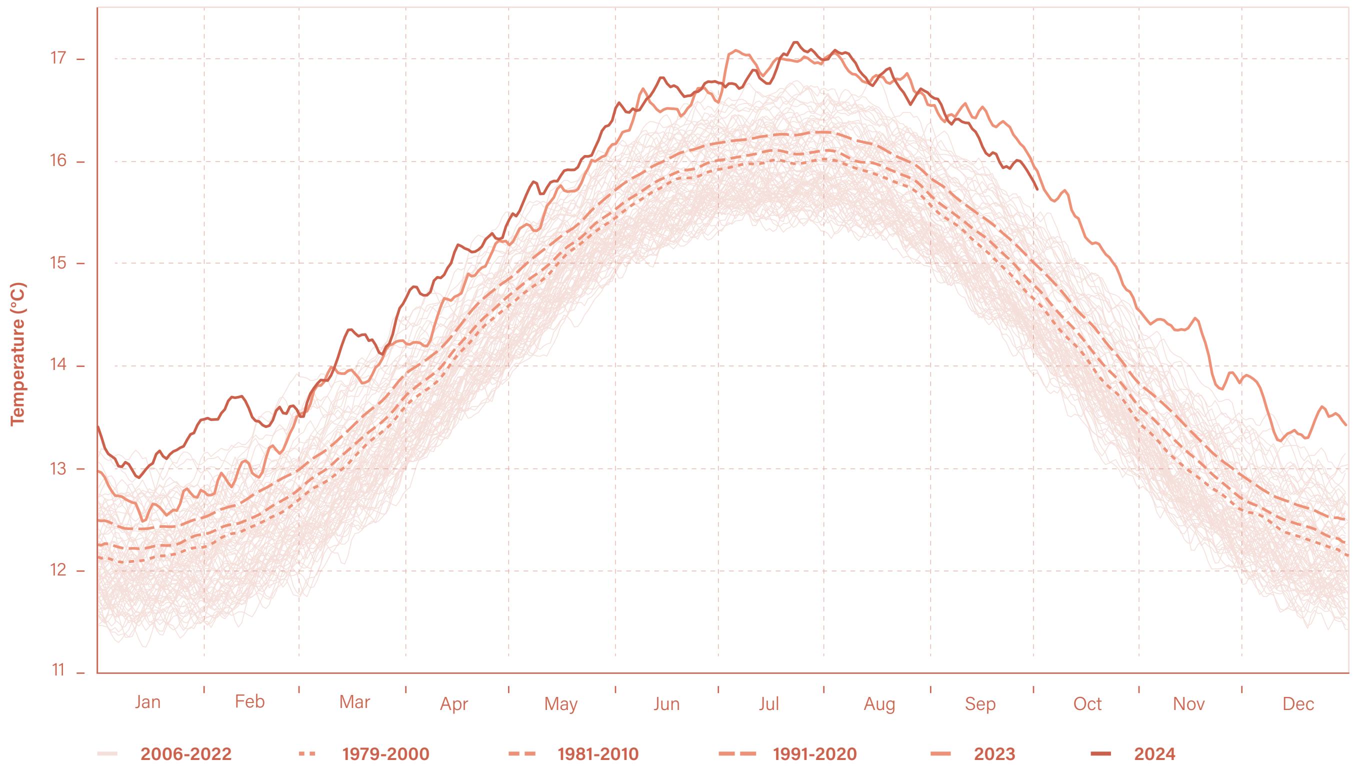


Figure 0.5 - Global daily surface temperature trends from 1979 - 2024. Source: University of Maine Climate Change Institute

Box 0.1: Remaining carbon budget

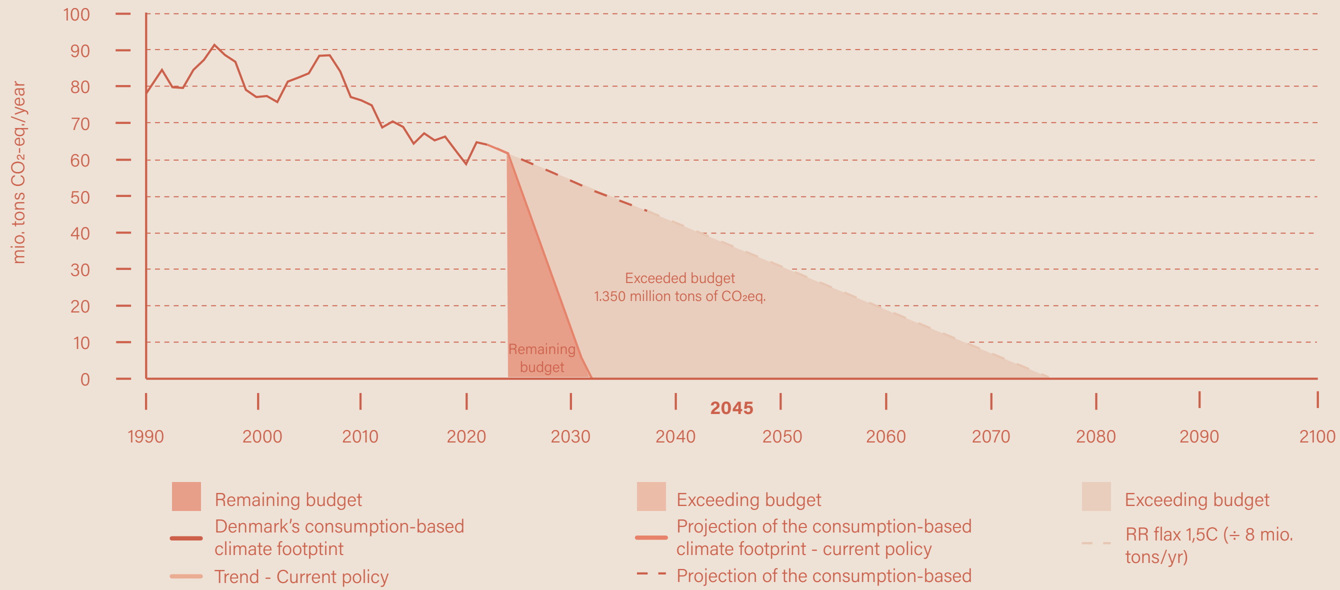
Based on the Paris Agreement, in 2018 the first detailed estimate of the remaining global carbon budget was provided in the Intergovernmental Panel on Climate Change's (IPCC) Special Report on Global Warming of 1.5°C.

Since that estimate, CO_2 emissions have continued to increase, while at the same time scientists have evolved the climate models used to estimate the remaining budget. Both developments have decreased the remaining global carbon budget much faster than expected[2] - reducing the estimated remaining global carbon budget from 300 - 500 gt CO_2 in 2020[3] to 100 - 250 gt CO_2 in 2023 illustrated in the top figure.

The bottom figure illustrates Denmark's historical consumption-based emissions, the required reduction path to stay within the country's share of the remaining GHG budget (based on an equal per capita allocation), and the current frozen policy, which, if projected with the same reduction rate, results in an overshoot of 1,350 million tons of CO2eq.

Estimates of remaining global carbon budgets until temperature limit of 1.5°C

Level of likelihood	Estimated remaining carbon budget in gigatons CO_2 from the beginning of			
	IPCC 2018	IPCC ARG WGI	Indicators of Global Climate Change	
	2018	2020	2020	2023
50%	580	500	400	250
67%	420	400	300	150
83%	N/A	300	200	100



gas emissions (see Box 0.1).

Professor Johan Rockström warns that we have only five years at the current rate of emissions before the carbon budget for 1.5°C is fully consumed, meaning we will lose the chance to keep global temperatures below this critical threshold[9].

The Reduction Roadmap demonstrated that to meet the 1.5°C goal, it would require reductions of 95% within 5-15 years—not by 2050 as many current policies suggest. This gap between the carbon budget and percentage reduction targets reveals a fundamental disconnect in the scientific understanding and strategic planning of global leaders, severely hampering effective action on climate change.

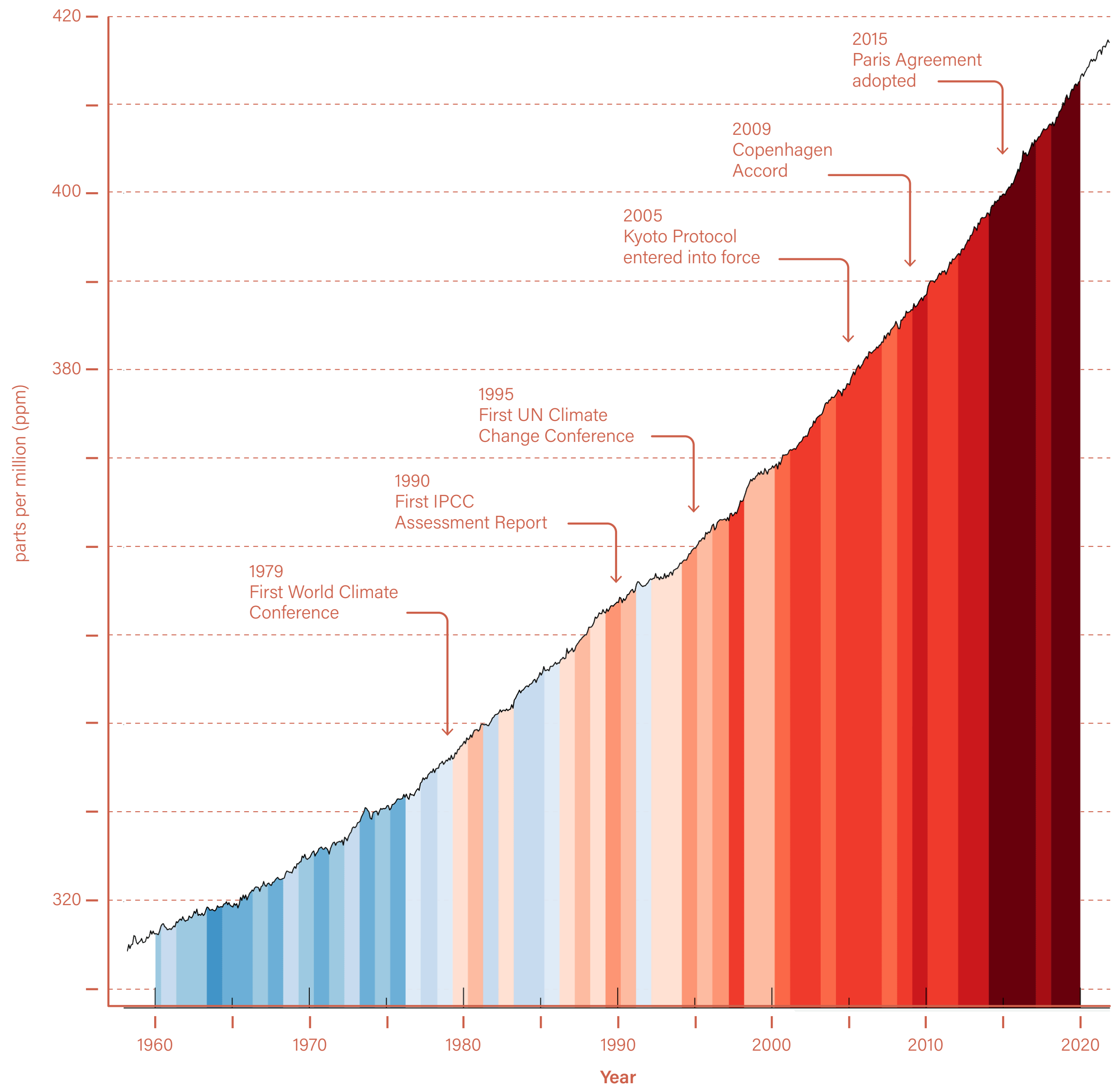


Figure 0.6 - Trends in atmospheric carbon concentration compared to global temperature change. Despite the increasing warnings from climate science, global climate compacts and summits have not led to meaningful global climate action. Source: The global warming stripes were developed by Professor Ed Hawkins at the University of Reading in 2018. You can find your own stripes at www.showyourstripes.info.

Figure 0.7 - Absolute versus relative reduction targets. The discrepancy between climate science and political targets results in overshoot of carbon budgets and failure to meet internationally agreed upon climate compacts. Source: Reduction Roadmap

Waning commitments for the Paris Agreement

The Paris Agreement is the strongest global policy response to climate change. The agreement is binding but does not specify to what extent the signatory countries should contribute to achieving the 1.5°C temperature target, which is why Denmark has adopted its own national climate policy (Figure 0.8).

Under the Danish Climate Law, the Climate Council provides impartial advice to the Minister for Climate, Energy, and Utilities on achieving climate goals. In 2019, the Council assessed that, based on an "equal per capita" approach and a linear reduction path, Denmark's target to reduce emissions by 70% by 2030 was aligned with the Paris Agreement's 1.5°C goal.

Since 2019, Denmark has not reduced production-based emissions quickly enough to meet the Climate Council's recommended trajectory, depleting its carbon budget faster than planned (Box 0.1). As a result, in 2022, the Climate Council declared Denmark's reduction target inconsistent with the Paris Agreement[11]. In addition, although Danish consumption-based emissions have decreased by 18% since 1990, the percentage of emissions related to Danish consumption in other countries has risen by 20%, while Danish emissions have decreased by 45%[12]. In 2023, the Climate Council deemed Denmark's climate efforts inadequate, urging greater action to reduce greenhouse gas emissions in line with global needs. In essence, not only has Denmark set insufficient relative reduction targets, Denmark also has failed to adhere to them.

Researchers like Joachim Peter Tilsted and Anders Bjørn have evaluated Denmark's climate policy, concluding that, when considering justice-based principles such as historical responsibility and capacity to act, Denmark's goals are insufficient to meet the global 1.5°C target making Denmark an "indebted culprit" [4].

The developing story of Danish climate policy reflects a core tension – even though it is difficult to formulate political decisions on targets that constantly change, that is exactly what society needs to do in the future.

DANISH CLIMATE LAW TIMELINE	
2016	**Denmark officially signs the Paris Agreement.** Its overarching goal is to hold "the increase in the global average temperature to well below 2°C above pre-industrial levels" and pursue efforts "to limit the temperature increase to 1.5°C above pre-industrial levels."
2020	**The Danish Climate Law is passed** Extract from the act (LOV nr. 965)[14] : § 1. The purpose of this Act is for Denmark to reduce greenhouse gas emissions by 70 percent by 2030 compared to the 1990 level, and for Denmark to achieve a climate-neutral society by no later than 2050, with the objective of the Paris Agreement to limit global temperature rise to 1.5 degrees Celsius in mind. Subsection 2. Denmark must actively work towards the objective of the Paris Agreement to limit global temperature rise to 1.5 degrees Celsius
2021	**Indicative climate targets for 2025 are added to the Danish Climate Law** Extract from the consolidated act (LBK nr. 2580)[15] § 1, Subsection 2. The purpose of this Act is furthermore for Denmark to reduce greenhouse gas emissions by 50-54 percent by 2025 compared to the 1990 level.
	14 Klima-, Energi- og Forsyningsministeriet, "Lov om klima", LOV nr 965 af 26/06/2020 § (2020), https://www.retsinformation.dk/eli/lta/2020/965. 15 Klima-, Energi- og Forsyningsministeriet, "Bekendtgørelse af lov om klima", LBK nr 2580 af 13/12/2021 § (2021), https://www.retsinformation.dk/eli/lta/2021/2580.

Figure 0.8 - The Danish Climate Law timeline and main goals translated into English.
Source: Reduction Roadmap

A 70% reduction target does not make Denmark a frontrunner. We need action beyond it


Anders Bjørn
Assistant Professor, Danish Technical Unviersity

Joachim Peter Tilsted
Postdoctoral Researcher, University of Copenhagen

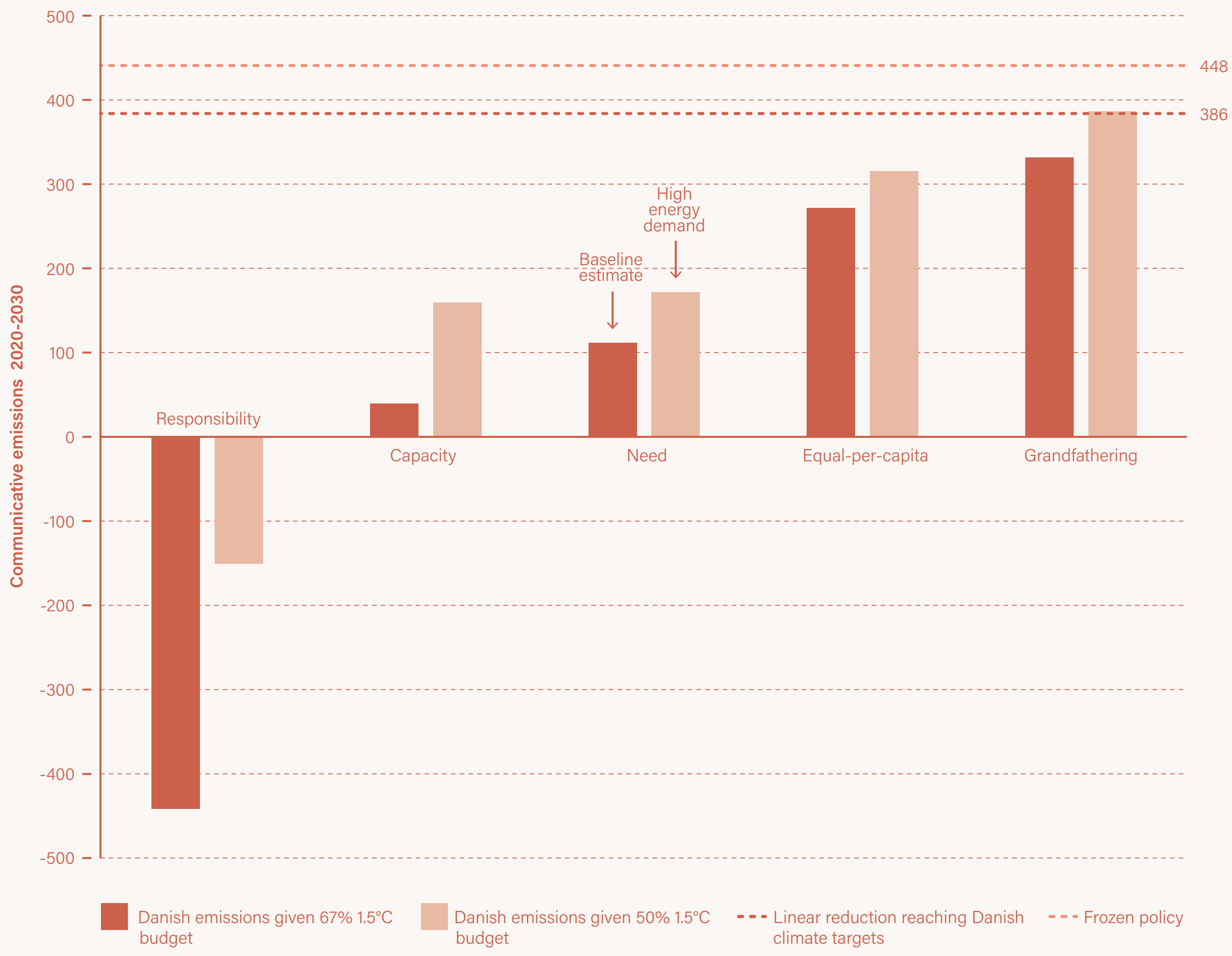
Danish climate policy debates often revolve around how Denmark can meet its official greenhouse gas emission reduction targets. By comparison, the targets themselves are rarely discussed. There exists a consensus-like perception that the targets enshrined in the Danish Climate Act from 2020 (of 50–54% reduction by 2025 and 70% reduction by 2030, both relative to 1990 levels) are aligned with the Paris agreement. This perception is embedded within the Danish Climate Act itself, which presents the 70% reduction target in context of the most ambitious goal of the Paris Agreement, namely, to limit global warming to 1.5 degrees. The 2020 Climate Act also refers to Denmark having a historic and moral responsibility to be a "frontrunner." With this framing, one could easily get the impression that the 70% target corresponds to a (more than) fair contribution from Denmark to avoiding global warming of more than 1.5 degrees. However, in a study from 2022[1] (and a follow-up research paper from 2023)[2], the Climate and Transition Council demonstrated that the 70% reduction target is not aligned with a fair share distribution of the mitigation efforts needed to stay within the 1.5-degree limit.

Allocating a share of the global carbon budget to Denmark

To explore alignment of the Danish climate targets with the Paris Agreement goal, the Climate and Transition Council took the (at the time) latest robust estimate of the global remaining carbon budget from 2020 onwards as the point of departure. This estimate was 230–440 GtCO2 and represents, simply put, the total amount of CO2 that can be emitted worldwide before global warming reaches 1.5 degrees. The reason that this amount is an interval and not a single number is that there is uncertainty in scientists´ understanding of how sensitive the climate system is to CO2 emissions. Hence, 230 GtCO2 is the amount for which 67% of considered model simulations agree that global warming will not exceed 1.5 degrees (the remaining 33% of model simulations predict a higher warming), while for 440 GtCO2, only 50% of simulations involve warmings of less than 1.5 degrees. To assign Denmark a share of this remaining budget (while also including other greenhouse gases than carbon and translating the cumulative budgets into emission pathways over time), the study then applied different principles from philosophical debates on burden sharing in relation to climate action.

An often-used framework for allocation is that of "equal per capita," which was also applied in the study. This approach implies that a country's right to emit greenhouse gases is proportional to its population. Taking 2020 as the starting

Figure 0. 9 - Cumulative Danish emissions from 2020 - 2030 under different approaches of burden sharing. The ilustration includes two reference scenarios, namely a linear reduction targets of 50-54% in 2025 and 70% in 20230 relative to 1990 emissions. Source: Figure 2. in Green frontrunner or indebted culprit? Assessing Denmark's climate targets in light of fair contributions under the Paris Agreement by Tidsted and Bjørn (2023).



"Denmark, like other rich countries, has since the beginning of the industrial revolution emitted more carbon per inhabitant than the global average. The atmosphere "remembers" these emissions, as they have contributed to the temperature increase that has already occurred..."

year for action, Denmark should aim for a higher than 70% emission reduction in 2030, according to this approach, even when the starting point is the riskiest global carbon budget of 440 $GtCO_2$. In other words, even if Denmark meets its 70% reduction target, the total emissions over time would be disproportionate to the Danish equal per capita share of the global carbon budget. Staying below 1.5 degrees of warming would therefore require fewer emissions per capita in the rest of the world.

There is, however, no strong moral ground to accept the equal per capita framework as a fair approach to burden sharing. Denmark is a high-income country that is, in principle, able to provide for the basic needs of its citizens while drastically lowering emissions and has the resources, geography, economic and engineering capacity to rapidly transition to low-carbon infrastructure. In contrast, low-income countries that are not in good positions for deep and rapid decarbonization (being constrained by a long legacy of historical, economic, and financial inequities and inequalities) should arguably not carry a similar mitigation burden. Instead, these low-income countries could legitimately prioritize securing necessities like food, water, sanitation, education, and electricity for all their peoples, in turn increasing energy and material use (and thereby climate impacts, all else equal).

On top of that, Denmark, like other rich countries, has since the beginning of the industrial revolution emitted more carbon per inhabitant than the global average. The atmosphere "remembers" these emissions, as they have contributed to the temperature increase that has already occurred (at least 1 degree) and thereby to the steady diminution of the global remaining carbon budget for 1.5 degrees of warming. From that perspective, Denmark could be said to be in "climate debt," meaning that it has emitted more than its rightful share. The size of this debt is then the difference between Danish per capita and global per capita emissions over a historical reference period. To compensate for this debt through climate mitigation in Denmark alone would require the net removal of carbon from the atmosphere.

Finally, there is an important time dimension at play that has implications when assessing the extent to which national climate targets align with the 1.5-degree Paris limit. While the 70% target was already insufficient at its inception in 2019, as demonstrated above, this concern is even more pertinent today. Because global emissions have remained at a high level since then (the results above assume rapid global emission reductions from 2020 onwards, but the pandemic only caused a temporary reduction in 2020, and emissions in 2023 were the highest ever recorded), the global remaining carbon budget is rapidly approaching zero. A recent scientific study estimates that another five years of current emission levels would take us past 1.5 degrees of warming with 50% certainty[3].

Ambitious targets alone, do not solve climate change

In highlighting different perspectives to evaluate Danish climate targets, we are not saying that Denmark should abandon its official 70% reduction target and instead pledge to be carbon negative tomorrow (or next year for that matter). This would be an empty promise. However, the study from The Climate and Transition Council clearly shows that the 70% reduction target by no means makes Denmark a climate "frontrunner" and that thinking of climate action as a matter of rank in this way takes focus away from Denmark as a causer of climate change and injustice.

All of this means that we dramatically need action beyond the 70% target. Rather than using the 70% target as a yardstick for what actions ought to be taken across industries, it is more relevant as a foundation from which to build the additional action needed to respect the pivotal 1.5-degree temperature limit. Initiatives from different segments of society (industry, municipalities, consumer organizations, etc.) for reducing GHG emissions at a more ambitious rate are therefore crucial.

Finally, it is crucial to avoid developing a tunnel vision on GHG reduction targets. The historical and current inequalities and inequities that help explain why the 70% target does not make Denmark a green frontrunner have implications that extent much beyond the imperative to accelerate GHG emission reductions. Questions of distribution remains just one aspect of climate justice and allocating the remaining carbon budget is just one aspect of distributive justice. Increased fairness on issues such as technology transfer[4], debt burdens[5], negative emissions[6] and loss and damage[7] are hence critical complements to ambitious climate targets.

"Questions of distribution remains just one aspect of climate justice and allocating the remaining carbon budget is just one aspect of distributive justice. Increased fairness on issues such as technology transfer, debt burdens, negative emissions and loss and damage are hence critical complements to ambitious climate targets."

References:

[1]Klima- og Omstillingsrådet, 'Er 70% Retfærdigt?' (Klima- og Omstillingsrådet, August 2023), https://www.klimaogomstillingsraadet.dk/wp-content/uploads/2023/08/Er-70-retfaerdigt.pdf.

[2] Joachim Tilsted and Anders Bjørn, 'Green Frontrunner or Indebted Culprit? Assessing Denmark's Climate Targets in Light of Fair Contributions under the Paris Agreement,' Climatic Change 176 (20 July 2023), https://doi.org/10.1007/s10584-023-03583-4.

[3] Climate Change 13, no. 10 (30 October 2023): 894–902, https://doi.org/10.1038/s41558-023-01848-5.

[4]Benjamin H. Bradlow and Alexandros Kentikelenis, 'Globalizing Green Industrial Policy through Technology Transfers,' Nature Sustainability 7 (26 April 2024): 685–87, https://doi.org/10.1038/s41893-024-01336-4.

[5]The Guardian, 'Severe Debt Burdens Thwarting Progress on Climate and Poverty, Says World Bank' (The Guardian, 11 October 2023), https://www.theguardian.com/business/2023/oct/11/severe-debt-burdens-thwarting-progress-on-climate-and-poverty-says-world-bank.

[6]Carlos Pozo et al., 'Equity in Allocating Carbon Dioxide Removal Quotas,' Nature Climate Change 10 (8 June 2020): 640–46, https://doi.org/10.1038/s41558-020-0802-4.

[7]Karen E. McNamara and Guy Jackson, 'Loss and Damage: A Review of the Literature and Directions for Future Research,' Wiley Interdisciplinary Reviews: Climate Change 11, no. 3 (4 December 2018), https://doi.org/10.1002/wcc.564.

+3ºC average globe
(land and sea)

+5ºC average
on land

+8ºC in urban
environments

Figure 0.10 - A 3°C average global temperature increase will be distributed differently across land, sea and region. Source: Illustration inspired by Dark Matter Labs and CIVIC SQUARE 3ºC Neighborhood Figure 4.

1.5°C and global tipping points

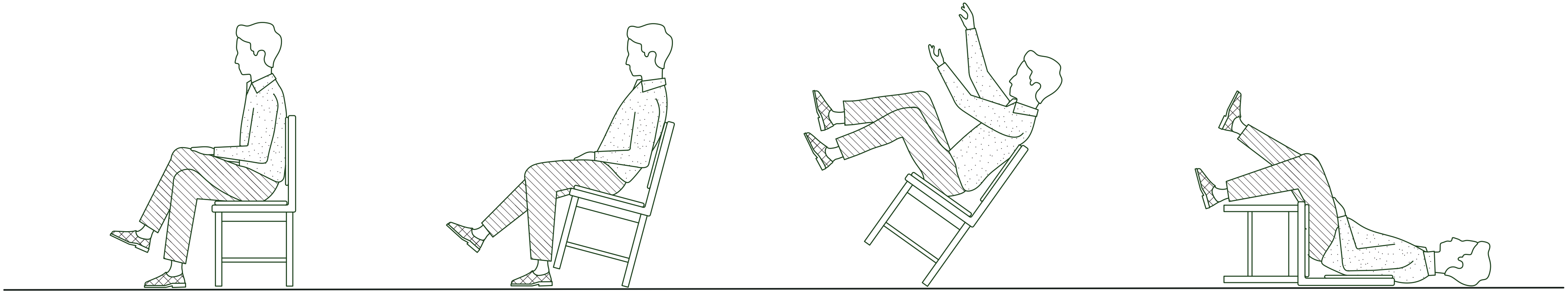
The 1.5°C threshold known from the Paris Agreement is not simply a goal or target set by policymakers: it represents a critical physical limit identified by climate science. At this level of warming, we face a significantly increased risk of crossing key ecological tipping points, which could trigger a "hothouse Earth" scenario,where catastrophic climate change becomes uncontrollable and irreversible[16].

Tipping points are critical thresholds in complex systems where small changes can cause irreversible shifts, leading to ecosystem collapse and biodiversity loss[16]. Examples include coral reef collapse, permafrost thawing, and Amazon rainforest dieback, which would disrupt climate regulation and create a more dangerous world (Figure 0.11 and 0.12). Scientific evidence suggests we risk crossing at least four of 16 major tipping points at 1.5°C of global warming, potentially triggering a domino effect of system collapses that would amplify warming and make catastrophic climate impacts unstoppable and irreversible[18 19 20]. Therefore, it is critical to remain below 1.5°C to avoid these irreversible changes to Earth systems[21 22].

The current carbon-cutting policies are insufficient to reduce emissions to 1.5°C[22]. Many climate scientists agree that it is highly probable humanity will experience a 2.5 - 3°C increase in global temperatures[23], with some suggesting even more severe increase, up to 10°C[24]. These estimates do not account for tipping points in the climate system, which could further accelerate warming.

Europe is warming at twice the global rate[25]. In a 3-degree world (Figure 0.10), the annual hottest day in most of Europe is 7°C hotter than now[26]. There is a growing risk of megadroughts that span large regions and last multiple years, causing severe degradation of food and energy supply. Sea levels could rise by more than 2 meters, permanently submerging many low-lying coastal cities, including Copenhagen. Almost 3% of all Danish houses suffer a 100-year flood event before 2071[27]. Multiple ecosystem services would be lost, compounding one another to unpredictable levels[49]. As illustrated in Figure 0.12 - a 3°C world will begin to look quite different from the 1.3°C we experience today.

Combined with the projected warming and the potential transgression of critical tipping points, we are facing a harsh reality. Drastic emission reductions are essential if we are to ensure a livable future for all.



Stable State
(Holocene)

The ecosystem is in a stable and balanced condition, similar to a person sitting securely on a chair.

Zone of Uncertainty
(Anthropocene)

The ecosystem starts to experience stress and instability, akin to a person beginning to tip on the chair, where stability is uncertain.

Tipping Point
(Near future)

A critical threshold, like the moment a person realizes they are about to fall. Tipping points are critical thresholds in a system where a small change can lead to a significant and often irreversible shift.

New State
(Future)

The system has undergone a significant change, comparable to the person now being on the floor, signifying a transition to a new and different state from the original stable condition.

Figure 0.11 - Understanding Earth-system tipping points. Source: Reduction Roadmap

Figure 0.12 A Schematic view of the tipping elements of the Earth climate system at risk from 1.5°C - 6°C scenarios Source: I. Lju. et al (2023) Teleconnections among tipping elements in the Earth system in Nature Climate Change

With 6 out of 9 planetary boundaries crossed, the balance in our ecosystems has been disturbed. Humanity cannot continue the current trajectory without devastating consequences, jeopardizing a livable future fall.

We must be more ambitious, systemic and rooted in science because: “We cannot succeed in delivering on the Paris Accord unless we take a full planetary boundary framework. We need to come back into the safe operating space, and it won’t be enough to just phase out coal, oil, and gas.” Johan Rockström

It is with the challenges of insufficient policy, relative target setting, global warming and rapidly approaching critical tipping points - we have widened the scope and move “Beyond the Roadmap” to scale building impact within planetary limits.

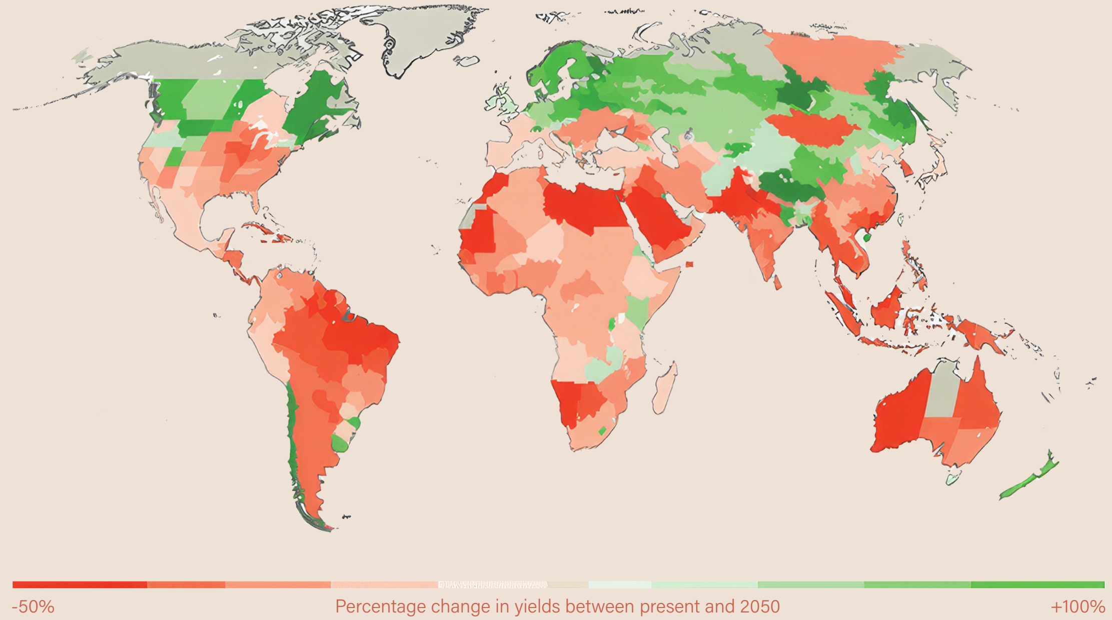
“We cannot succeed in delivering on the Paris Accord unless we take a full planetary boundary framework. We need to come back into the safe operating space, and it won’t be enough to just phase out coal, oil, and gas.” - Johan Rockström

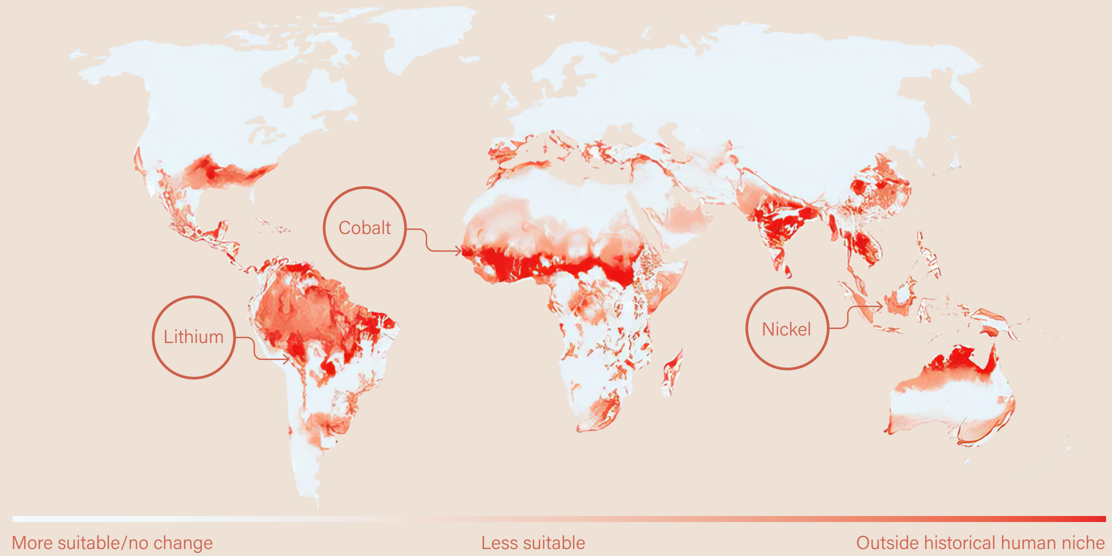
Box 0.2: 3°C on planet Earth

3°C increase is expected to significantly reduce agricultural yields, with key crops such as rice and maize potentially declining by 30% and 15%, respectively. This would exacerbate food shortages and increase the risk of starvation due to reduced food availability . In addition to the challenges posed to agriculture, a 3°C rise in temperature is likely to make certain regions of the world uninhabitable. It is estimated that approximately 3 billion people may be unable to survive in their current regions due to extreme heat. By 2070, entire regions and parts of the would likely become too hot for human habitation. This may lead to large-scale migration and heightened risks of hunger .

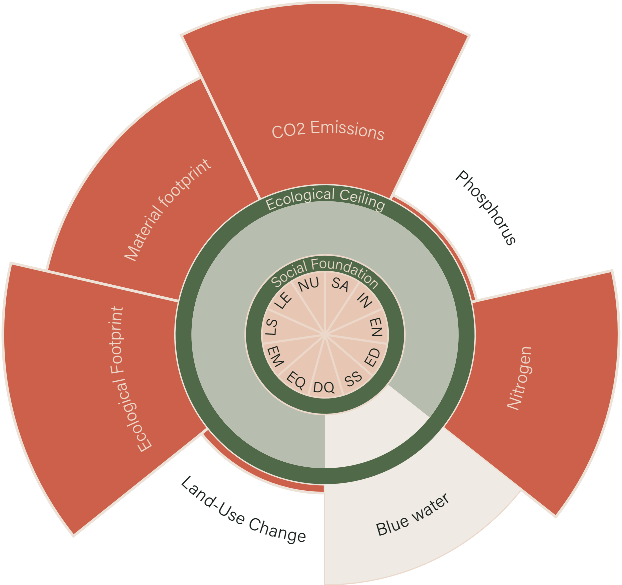
Notably, many of the regions at risk of becoming uninhabitable also contain significant reserves of rare earth materials, which are essential for the transition to renewable energy technologies. Without significant reductions in greenhouse gas emissions, both the ability to adapt to these temperature changes and the transition to a low-carbon economy could be severely hindered.

Sources: Timothy M et al. (2023). Quantifying the human cost of global warming in Nature Sustainability Xu et al. (2020) Future of human climate niche in proceedings of the national academy of sciences and Simpson, et al (2014). Adaptation Under the New the new normal of climate change: The future of agricultural extensions and advisory services.






"1.5°C is a physical limit,
it is not a political target."
-Professor Johan Rockström



LS – Life Satisfaction
LE – Life Expectancy
NU – Nutrition
SA – Sanitation

IN – Income Poverty
EN – Access to Energy
ED – Education
SS – Social Support

DQ – Democratic Quality
EQ – Equality
EM – Employment

Figure 0.13 - Danish Global Overshoot Doughnut
This visual demonstrates that Denmark is meeting the minimums of the social foundation, at the expense of the living world. Source: Fanning et al. (2021) The social shortfall and ecological overshoot of nations in Nature Sustainability

Scoping Beyond the Roadmap

Throughout the development of Reduction Roadmap 1.0 and 2.0, our understanding of climate science and its implications for building industry practices has evolved. For example, in 2023 the *Doughnut for Urban Development: A Manual* was published in collaboration with Aalborg University - BUILD, Danish Technical University, Doughnut Economic Action Lab, Green Building Council - Denmark, EFFEKT, Home.Earth, SLA, Sweco, Stockholm Resilience Center and Vandkunsten. This ground-breaking framework revealed new, essential understanding of the planetary boundary framework.

Given that the Reduction Roadmap has always had an ambition to expand scope to the other 8 planetary boundaries, this new understanding has shifted our approach to critical target setting. From the *Doughnut for Urban Development: A Manual* we glean several critical points of view that we bring into “Beyond the Roadmap.”

First, we adopt a more holistic approach, moving beyond ‘carbon tunnel vision’ to establish, for the first time, reduction targets for functioning ecosystems. This is an essential addition, because climate stability is dependent on functioning ecosystems and functioning ecosystems are dependent on climate stability. Therefore, setting targets for carbon reduction, without considering the natural world is insufficient.

Second, systemic issues needs to be addressed with systemic solutions. Therefore, we cannot look at the environmental issues in isolation, but must understand the socio-economic implications of the way we live here in Denmark in relation to the rest of the living world. To do so, we unpack the polycrisis and the root causes of the polycrisis.

Third, we move beyond the pursuit of scaling impact within the safe operating space of "doing no harm" and propose strategies that extend beyond these safe limits to regenerate the living world and "do more good." Nature has the power to be both a source for human needs and a sink to balance human impact – therefore we must begin restore its capacity to function.

Finally, we acknowledge that social well-being, whether here in Denmark or on a global scale, is embedded in planetary health. Therefore, with “Beyond the Roadmap” we address Denmark’s responsibility and role in being a real front-runner for the sustainable transition – which simply put, cannot happen without centering historic responsibility and justice within the scope of what we do. As such, we must redefine the purpose of the building industry and its businesses to achieve transformative ends.

With "Beyond the Roadmap" we open-up to a more systemic approach to problem understanding and problem solving. In moving beyond mere linear carbon reduction targets of "Reduction Roadmap" we risk being less precise and perhaps creating more questions than answers – but we believe the time calls for bold pursuits and better questions (Figure 0.14 - 0.17). Consistent with earlier work, our goal is to scale building industry impact within planetary limits. We aim to be objective, data-driven and aligned with climate science. We don't pretend to have all the answers – but we aim to define where we are today and where we need to go in the future. How we get there is up for discussion, dependent on new policy and perhaps more courage than we have ever witnessed.

This report does not outline a single, prescriptive pathway; rather, it establishes the transition framework and destination targets. The approach for reaching these goals is inherently political and must be adapted to the specific dynamics of each industry. Any transition must be rooted in democratic adherence, while strictly aligning with safe and just planetary boundaries. Failure to uphold these boundaries poses severe risks, potentially compromising a viable future for all. While we have established the necessary targets, it is now up to us collectively to determine how best to achieve them.

Welcome to "Beyond the Roadmap."

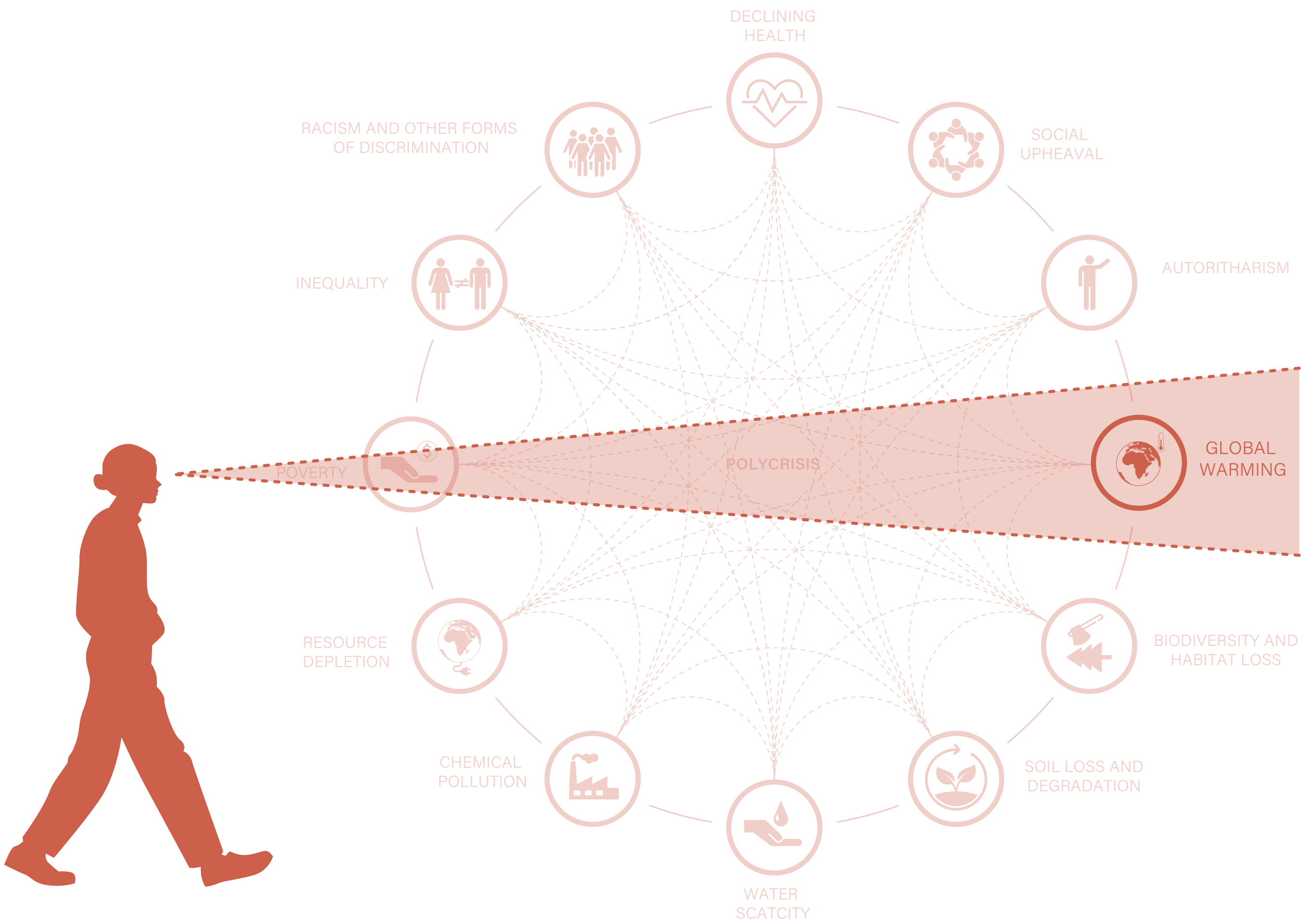


Figure 0.14 - Moving beyond the "Carbon tunnel vision" to meet the challenge of the Polycrisis. Source: Reduction Roadmap

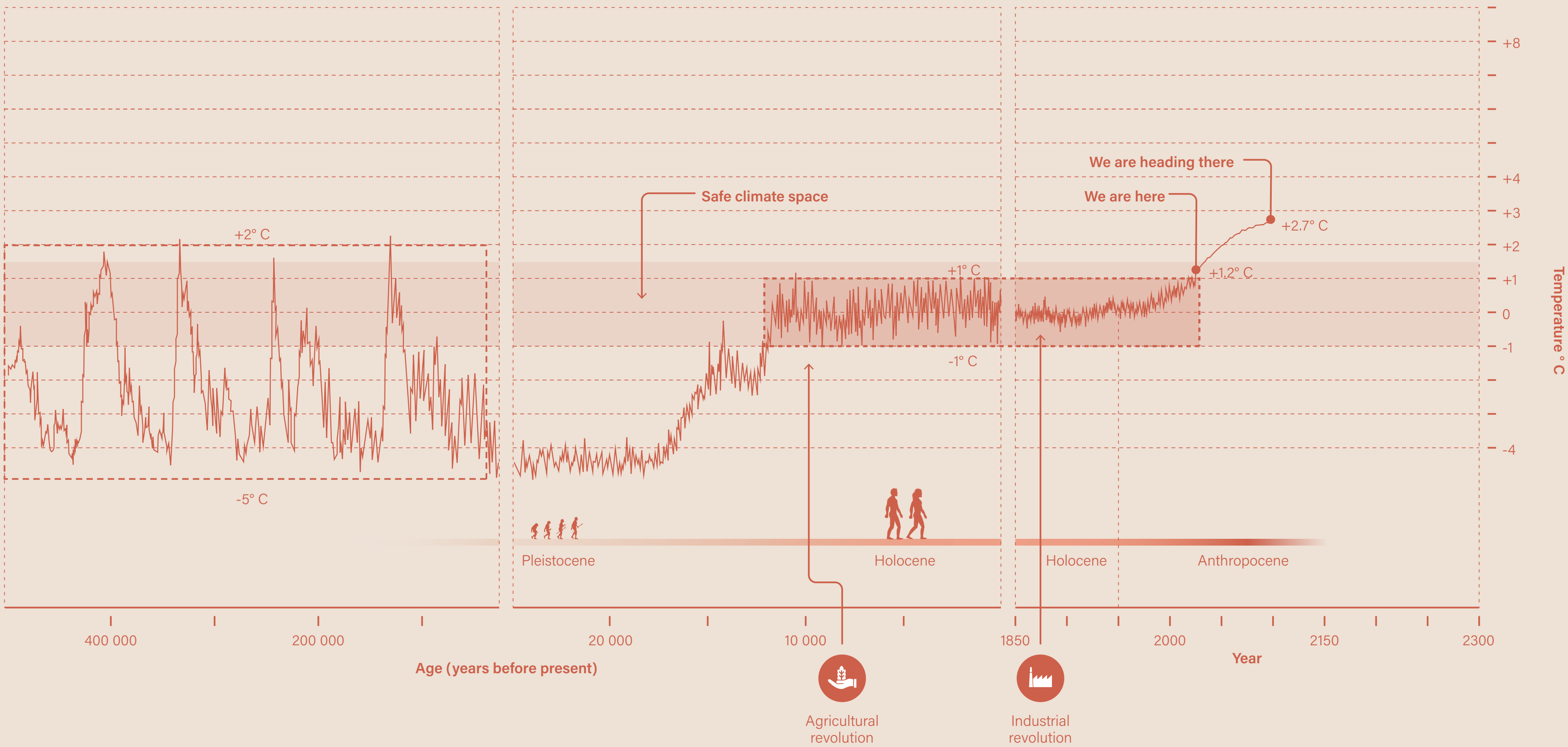


Figure 0.15 - Humanity's journey on Earth
For the last 2.6 million years, Earth has cycled through warmer and colder periods, primarily driven by changes in its orbit around the sun (known as Milankovitch cycles). Humanity's journey has been shaped by these cycles, with the Holocene epoch, which began about 11,700 years ago, providing the climatic stability and favorable environmental conditions that allowed humanity to thrive. The Holocene's gift of four distinct, predictable seasons enabled our ancestors to shift from nomadic lifestyles to settled agriculture and rapidly developing societies. Humanity continues to rely on this stability today. We depend on the mild, moderately wet world of the Holocene, with its permanent ice caps, flowing rivers, expansive forests, and abundant life. The Earth system, with all its life-supporting functions and self-regulating processes, has maintained these conditions. However, in recent decades, human activities have intensified, potentially pushing the planet beyond its capacity to remain stable. Souce: Rockström, J. (2024) The tipping points of climate change and where we stand, available on www.ted.com

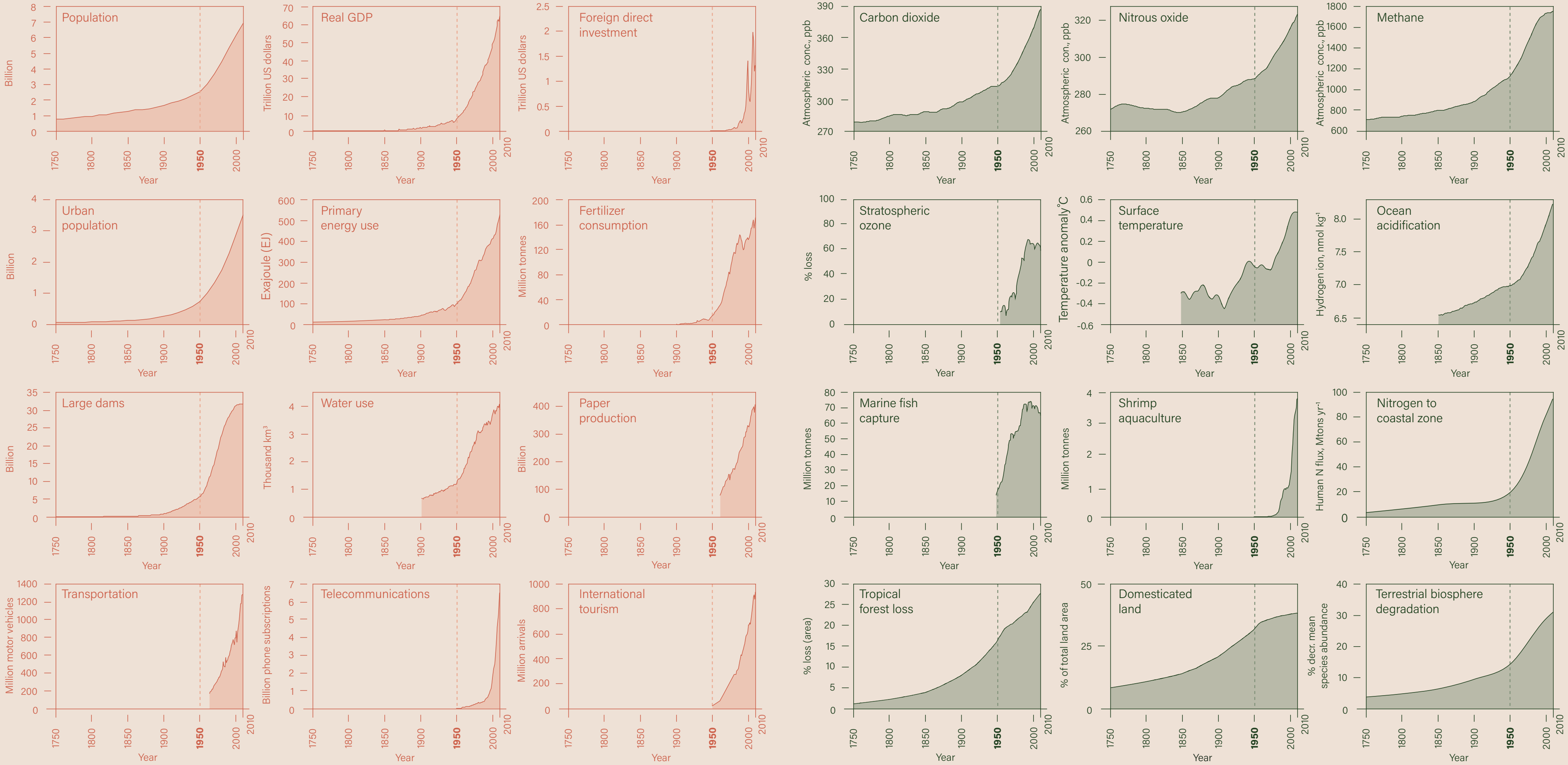


Figure 0.16 - The Great Acceleration
Socio-economic systems are now actively destabilizing the Earth-systems that have sustained human civilization for millennia, moving away from the stability of the Holocene and entering the Anthropocene. The "Great Acceleration" of human activity, which began in the 1950s, marks this critical transition. The Great Acceleration is characterized by unprecedented growth in industrialization, resource extraction, and environmental impact. As a result, ecosystems across the planet are beginning to exhibit signs of stress and instability. 25 out of 35 tracked vital signs for the planet (indicators) are at record extremes, signaling the fragility of the Earth's life-supporting systems under the pressures of anthropogenic change. Source: Steffen. W., et al. (2015) The trajectory of the Anthropocene: The Great Acceleration in the Anthropocene Review Figure 1 and Figure 2.

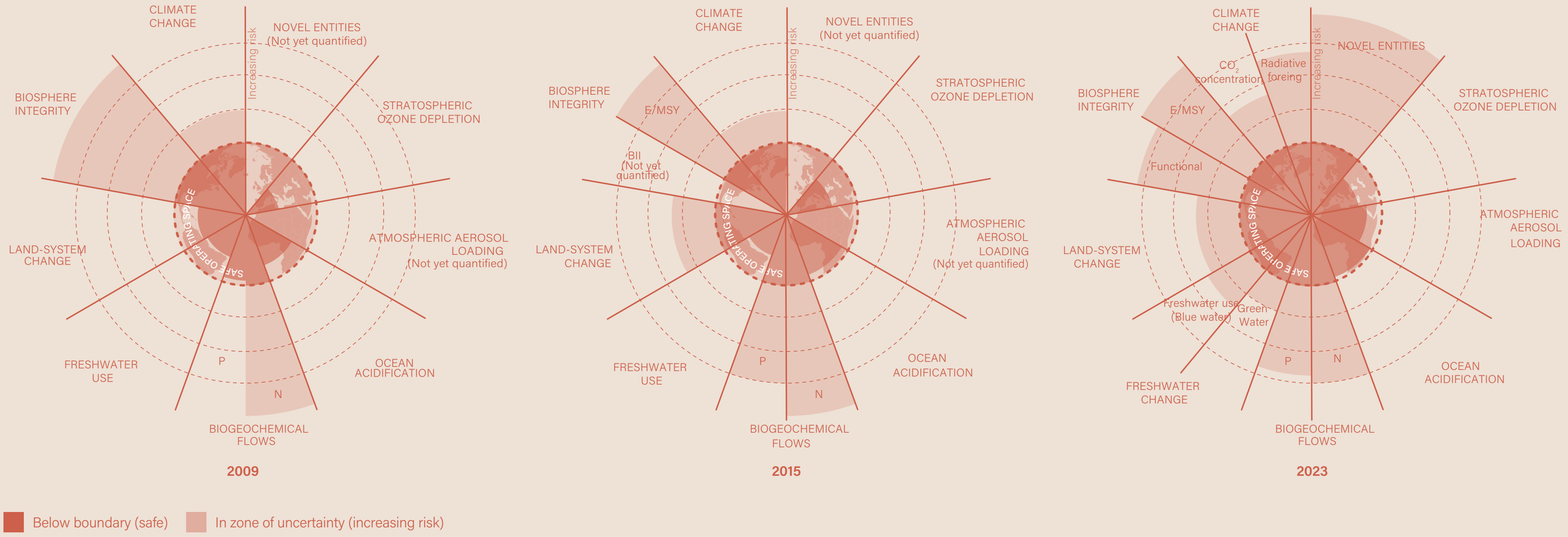


Figure 0.17 - Planetary Boundaries
The Great Acceleration has driven humanity to transgress six of the nine planetary boundaries, fundamentally destabilizing the Earth's life-support systems. Climate change, far from being the root cause, is merely a symptom of this broader ecological overshoot. Humanity now faces its greatest challenge yet: the urgent need to transcend the limited framework of "net-zero" strategies. Because doing "net zero harm" in a degenerative state does not return us back into the safe operating space. "To ensure a livable future for all, we must return within the safe and just planetary boundaries. This can only be achieved through the immediate implementation of regenerative strategies that bring humanity back within the planet's safe limits." Source: Stockholm Resilience Center

Foreword References

1. Piers M. Forster et al., 'Indicators of Global Climate Change 2023: Annual Update of Large-Scale Indicators of the State of the Climate System and Human Influence,' Earth System Science Data 15, no. 6 (2024): 2625–50, https://doi.org/10.5194/essd-15-2295-2023.

2. Zhu Liu et al., 'Global Carbon Emissions in 2023,' Nature Reviews Earth & Environment, 4 April 2024, 1–2, https://doi.org/10.1038/s43017-024-00532-2.
3. Paola Arias et al., 'Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Technical Summary.' (Intergovernmental Panel on Climate Change (IPCC), 1 January 2021), https://www.researchgate.net/publication/356344795_Climate_Change_2021_The_Physical_Science_Basis_Contribution_of_Working_Group_I_to_the_Sixth_Assessment_Report_of_the_Intergovernmental_Panel_on_Climate_Change_Technical_Summary.

4. Joachim Tilsted and Anders Bjørn, 'Green Frontrunner or Indebted Culprit? Assessing Denmark's Climate Targets in Light of Fair Contributions under the Paris Agreement,' Climatic Change 176 (20 July 2023), https://doi.org/10.1007/s10584-023-03583-4.

5. Monica Crippa et al., GHG Emissions of All World Countries, 2023, https://doi.org/10.2760/953332.

6. Piers M. Forster et al., 'Indicators of Global Climate Change 2023: Annual Update of Key Indicators of the State of the Climate System and Human Influence,' Earth System Science Data 16, no. 6 (5 June 2024): 2625–58, https://doi.org/10.5194/essd-16-2625-2024.

7. 'Copernicus: 2023 Is the Hottest Year on Record, with Global Temperatures Close to the 1.5°C Limit | Copernicus,' accessed 18 September 2024, https://climate.copernicus.eu/copernicus-2023-hottest-year-record.

8. Damian Carrington and Damian Carrington Environment editor, 'World's Top Climate Scientists Expect Global Heating to Blast Past 1.5C Target,' The Guardian, 8 May 2024, sec. Environment, https://www.theguardian.com/environment/article/2024/may/08/world-scientists-climate-failure-survey-global-temperature.

9. Rockström, J. (2024, June 4). Scale and speed. Keynote presented at the Berlin Aviation Summit. Potsdam Institute for Climate Impact Research.

10. Klimarådet, 'Rammer for Dansk Klimapolitik - Input Til En Ny Dansk Klimalov Med Globalt Udsyn,' 2019, https://klimaraadet.dk/sites/default/files/imorted-file/rammer_for_dansk_klimapolitik_0.pdf.

11. Klimarådet, 'Danmarks Klimamål - Hovedkonklusioner,' December 2022, https://klimaraadet.dk/sites/default/files/imorted-file/danmarks_klimamal_hovedkonklusioner.pdf.

12. Energistyrelsen, 'Danmarks Globale Klimapåvirkning,' Oktober 2023, https://ens.dk/sites/ens.dk/files/Analyser/hovedrapport_-_danmarks_globale_klimapaavirkning_-_global_afrapportering_2023.pdf.

13. Joachim Tilsted and Anders Bjørn, 'Green Frontrunner or Indebted Culprit? Assessing Denmark's Climate Targets in Light of Fair Contributions under the Paris Agreement,' Climatic Change 176 (20 July 2023), https://doi.org/10.1007/s10584-023-03583-4.'

14. Klima-, Energi- og Forsyningsministeriet, 'Lov Om Klima,' LOV nr 965 af 26/06/2020 § (2020), https://www.retsinformation.dk/eli/lta/2020/965.

15. Klima-, Energi- og Forsyningsministeriet, 'Bekendtgørelse Af Lov Om Klima,' LBK nr 2580 af 13/12/2021 § (2021), https://www.retsinformation.dk/eli/lta/2021/2580.

16. Lenton, T.M., Armstrong McKay, D.I., Abrams, J.F., Lade, S.J., Smith, S.R., Milkoreit, M., Loriani, S., Bailey, E., Powell, T., Donges, J.F., Zimm, C., 2023. The Global Tipping Points Report 2023. University of Exeter, Exeter, UK. Available at: https://global-tipping-points.org

17. Will Steffen et al., 'Trajectories of the Earth System in the Anthropocene,' Proceedings of the National Academy of Sciences of the United States of America 115, no. 33 (14 August 2018): 8252–59, https://doi.org/10.1073/pnas.1810141115.

18. Teng Liu et al., 'Teleconnections among Tipping Elements in the Earth System,' Nature Climate Change 13, no. 1 (January 2023): 67–74, https://doi.org/10.1038/s41558-022-01558-4.

19. 'Exceeding 1.5°C Global Warming Could Trigger Multiple Climate Tipping Points | Science,' accessed 18 September 2024, https://www.science.org/doi/10.1126/science.abn7950.
20. La Figure Scientifique de Gaïa | Tim Lenton, 2020, https://www.youtube.com/watch?v=FKjVpyqOZ2w.

21. United Nations Environment Programme, Emissions Gap Report 2023: Broken Record – Temperatures Hit New Highs, yet World Fails to Cut Emissions (Again) (United Nations Environment Programme, 2023), https://doi.org/10.59117/20.500.11822/43922.

22.Carrington and editor, 'World's Top Climate Scientists Expect Global Heating to Blast Past 1.5C Target.'

23.'Global Warming in the Pipeline | Oxford Open Climate Change | Oxford Academic,' accessed 18 September 2024, https://academic.oup.com/oocc/article/3/1/kgad008/7335889.

24. Naomi Klein, This Changes Everything: Capitalism vs. The Climate, Reprint edition (Simon & Schuster, 2015), https://www.simonandschuster.com/books/This-Changes-Everything/Naomi-Klein/9781451697391.

25. EEA, "European Climate Risk Assessment — Executive Summary" (Copenhagen: European Environment Agency, 2024), https://doi.org/10.2800/204249.

26. IPCC, "Climate Change 2023 - Synthesis Report," in Climate Change 2023: Synthesis Report., First (Geneva, Switzerland: Intergovernmental Panel on Climate Change (IPCC), 2023), 14, https://doi.org/10.59327/IPCC/AR6-9789291691647.

27. Giorgio Mirone and Johannes Poeschl, "Flood Risk Discounts in the Danish Housing Market" (Danmarks Nationalbank, October 22, 2021), https://www.nationalbanken.dk/en/news-and-knowledge/publications-and-speeches/archive-publications/2021/flood-risk-discounts-in-the-danish-housing-market.

28. Marsden et al., "Ecosystem Tipping Points: Understanding Risks to the Economy and Financial System."


"Our goal is to scale building industry impact within safe and just limits. We aim to be objective, data-driven and aligned with climate science. We don't pretend to have all the answers – but we aim to define - where we are today and where we need to go in the future. How we get there is up for discussion, dependent on new policy and perhaps more courage than we have ever witnessed."
- Reduction Roadmap

Chapter 1
Infinite growth on a finite planet

What are the limits to growth on a finite planet?

1.1 Limits to growth

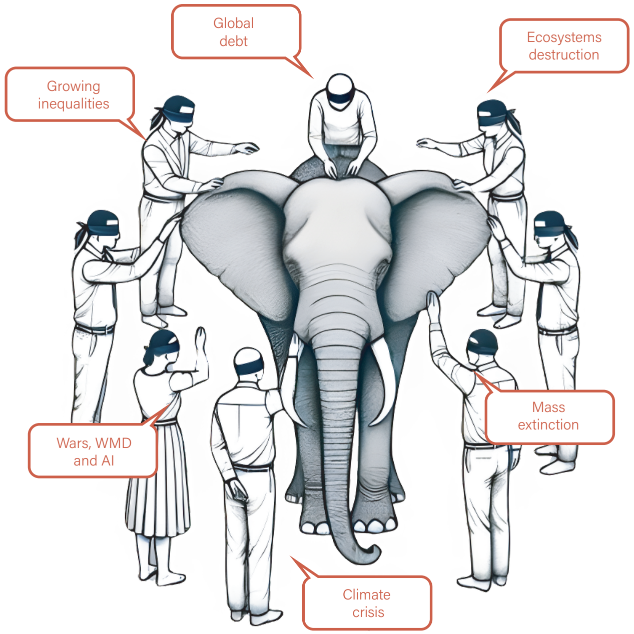


Figure 1.1 - Interconnectedness of crisis. We usually only focus on one crisis and fail to understand that they are interconnected. As such, we miss the deep roots of wicked-problems. Source: Reduction Roadmap & Tittha Sutta, Udāna, Khuddaka Nikaya,

To achieve sustainable development, the socio-economic systems must operate within planetary boundaries, while meeting the needs of all people. This destination is defined as the safe and just operating space for humanity[1]. Despite global commitments to sustainable development, no national economy has achieved this balance. As *Limits to Growth*[2] predicted already in 1970, exponential growth in economy, population, material use, and fossil fuels will soon exceed Earth's natural capacity to provide life-giving services. The original model predicted a decline in Earth systems between 2025 – 2028. Devastatingly enough, in 2024 a re-calibrated model revealed higher peaks in systems stress and delay in pollution effects, indicating that collapse may be more severe than initially modeled[3]. This acceleration leaves minimal time for mitigation efforts (Figure 1.2).

We often fail to address the crises we face because we treat them in isolation rather than as interconnected parts of a larger system (Figure 1.1). For example, the Reduction Roadmap has focused solely on climate change targets, limiting our understanding of the complexity of global issues. The *Limits to Growth* report highlighted the systemic and interwoven nature of the 'Polycrisis,' is defined as: "a cluster of interdependent global risks [that] create a compounding effect, such that their overall impact exceeds the sum of their individual parts."[62]

Although extinction is often referenced in terms of animals and plants, scientific evidence shows that within the context of the Polycrisis, humans are also at risk[3]. To illustrate this risk Box 1.1 describes the 6th mass species extinction[6] currently underway, in context to previous mass extinction events.

Overpopulation, ecosystem degradation, and the loss of millions of species trigger co-extinction, where species vulnerable to environmental changes disappear, causing a chain reaction that eventually impacts humans, who are deeply reliant on interconnected systems found in nature. Meaning, the collapse of ecosystems threatens biodiversity and human survival. And, the issue is not merely about climate change but rather ecological overshoot. As Tom Butler states, "In ecology, the term overshoot describes the phenomenon of a species becoming so numerous that it outstrips its habitat." Humanity is currently outstripping its habitat through rampant overconsumption - causing a collapse that is already underway (Box 1.2)

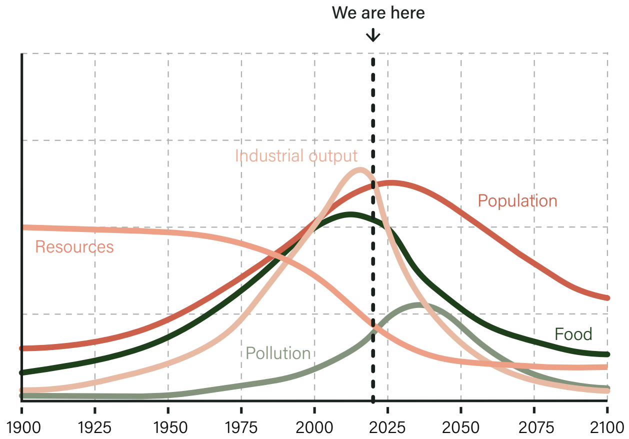
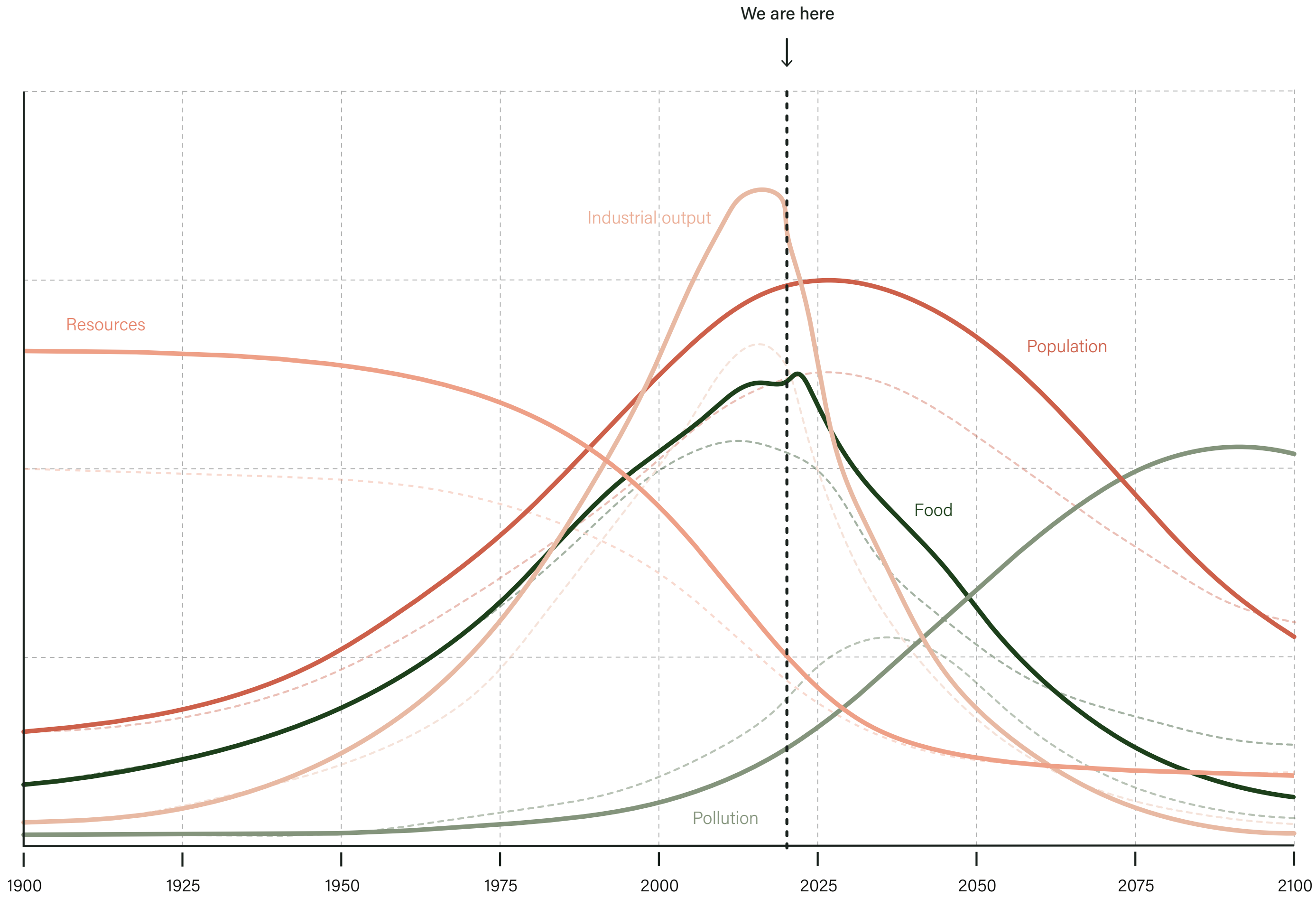


Figure 1.2 - Limits to Growth Illustrated above is the original 'Limits to Growth' BAU Model3. To the right the 2024 updated model is superimposed over the original 'Limits to Growth' model. Source: Meadows et al., (1972) 'Limits to Growth' and Nebel, A et al. 2024. Recalibration of limits to Journal of Industrial Ecology

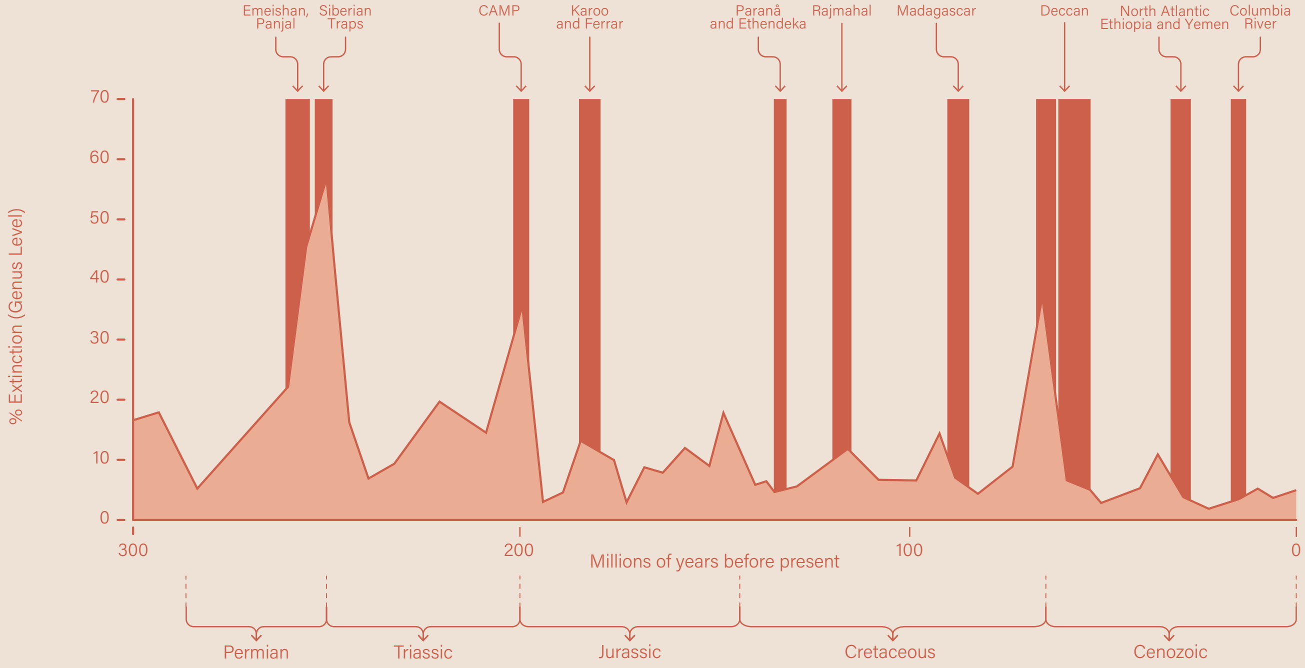


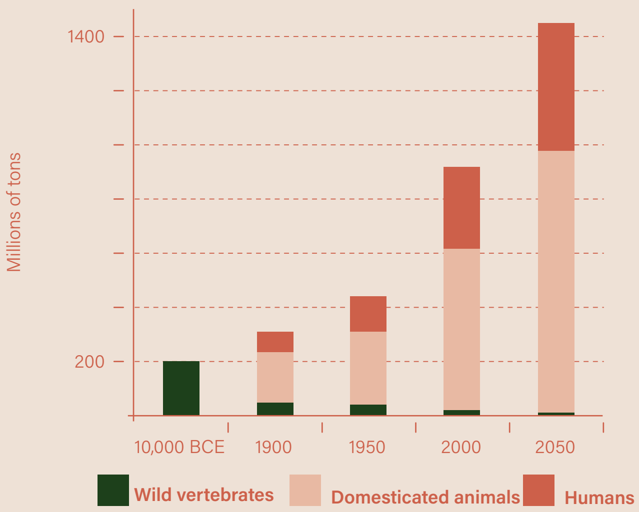
Box 1.1 - Understanding mass extinction

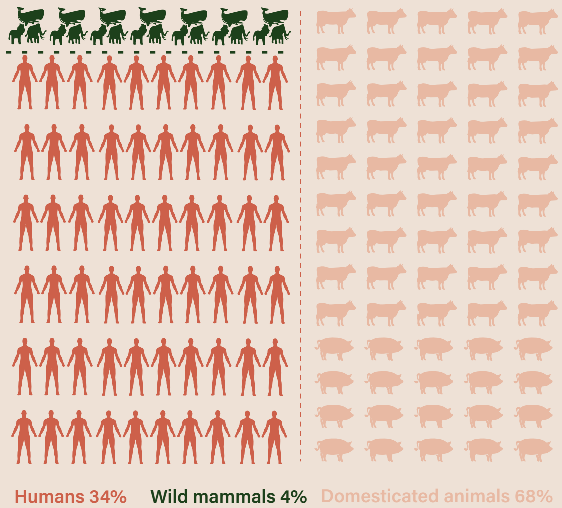
It is well established that many past mass extinctions were closely linked to significant carbon pulses, typically resulting from large-scale environmental disturbances. The **top figure** highlights the connection between these extinction events and carbon pulses, primarily driven by massive volcanic outgassing. The light red spikes indicate the percentage of genus-level extinctions over the past 300 million years, while the dark red bars show periods of immense carbon emissions caused by volcanic activity, which had catastrophic consequences for global biodiversity. Volcanic events such as the Siberian Traps and Deccan Traps released enormous amounts of carbon into the atmosphere, triggering mass extinction events[6].

Unlike these natural occurrences, today's carbon pulse is entirely anthropogenic, fueled by industrialization, deforestation, and unsustainable consumption patterns. This carbon surge is not a geological inevitability but a direct result of our overconsumption. If unchecked, it will lead to consequences just as catastrophic as those seen in previous mass extinctions—only this time, we are the architects of our own collapse[7].

The **bottom figure** illustrates that at present the biomass of wild terrestrial vertebrates has declined by 95% since 10,000 BC, while domesticated farm animals now outweigh all wild animals by 22 times. Livestock accounts for 62% of mammalian biomass, humans 34%, and wild mammals just 4%, reflecting the significant impact of agriculture on biodiversity. Scientists believe the planet is undergoing a sixth mass extinction, with 150 species going extinct daily, a rate 1,000 times higher than pre-human levels underscoring the rapid and unprecedented pace at which biodiversity is being eroded.[5]



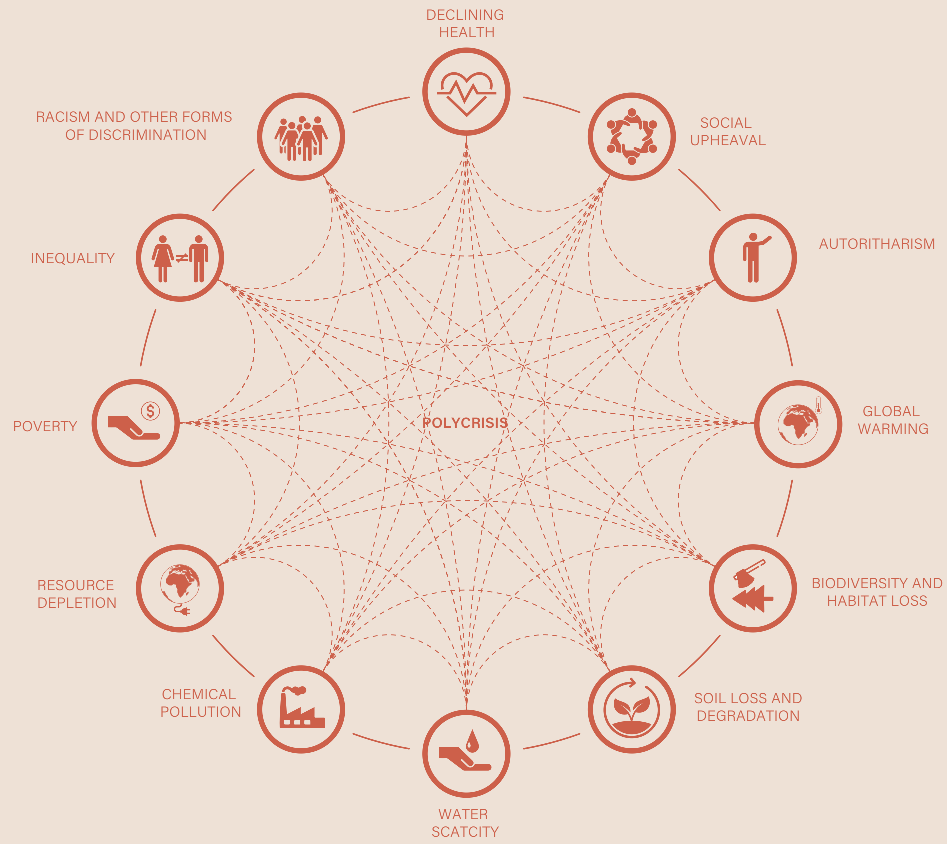




The Polycrisis is defined as “a cluster of interdependent global risks [that] create a compounding effect, such that their overall impact exceeds the sum of their individual parts.”

- Richard Heinberg and Asher Miller, ‘Welcome to the Great Unraveling’

Box 1.2 - Evidence of the Polycrisis



Global Warming:
Greenhouse gas emissions have never been higher. The Earth's average surface temperature has increased by about 1.3°C since the late 19th century[8]

Biodiversity and Habitat Loss:
Earth's wildlife populations have plunged by 69% in just under 50 years [9], and they are dying 100-1000 times faster than ever before[10]. Over 1 million species are at risk of extinction[10]. 75% of the world's surface and 66% of the marine environment have been destroyed and altered[11]. 80% of all insects on the planet have died[12].

Soil Loss and Degradation:
Of the Earth's soils, 33% are already degraded and over 90% could become degraded by 2050[13]. Clouds now contain microscopic pieces of plastic that in turn are causing "plastic rainfall", causing severe environmental degradation[14].

Water Scarcity:
By 2025, 1.8 billion people will be living in countries with absolute water scarcity. The water crisis already affects over 2 billion people globally with limited access to clean water. This is getting exacerbated by pollution, mismanagement, and climate change[15].

Chemical Pollution:
The worldwide plastic production is calculated to be 400.3 million tons in 2022[16] with 8 million tons ending up in the ocean[17]. Microplastics have been found in human blood, breast milk, and placentas. They have been linked to brain damage and other serious diseases[18].

Resource Depletion:
Extraction of raw materials is set to rise by 60% by 2060. Extractive industries including mining and farming are responsible for 50% of the world's carbon emissions and cause 80% of biodiversity loss[19].

Poverty:
More people live in absolute poverty today than ever before[37]. Over 700 million people live on less than $1.90 a day and nearly half the world's population live for just $5.5 a day.

Inequality:
1% of the world's population owns 50% of the world's wealth[21]. Unequal exchange and inequality have never been higher[36].

Racism and Other Forms of Discrimination:
Polarization has increased in several OECD countries over the past four decades[22] and instances of hate crimes and racial discrimination have surged globally[23].

Declining Health:
Global life expectancy has gone up, but we have fewer quality years because we are sicker than ever[24]. Lifestyle diseases are affecting around 75% of the population. Human fertility has declined by 50% since the 1950´s[25]. Rates of chronic diseases such as diabetes, heart disease, and cancer are increasing[26].

Social Upheaval:
Civil unrest around the world has doubled in the last decade[27]. Despite being more connected, people report higher levels of depression, loneliness, anxiety, and stress[28].

Authoritarianism:
The UN calls this age "A New Era of Conflict and Violence"[29]. Democratic backsliding and the rise of authoritarian regimes are increasing[30].

Consumption is the root cause of collapse

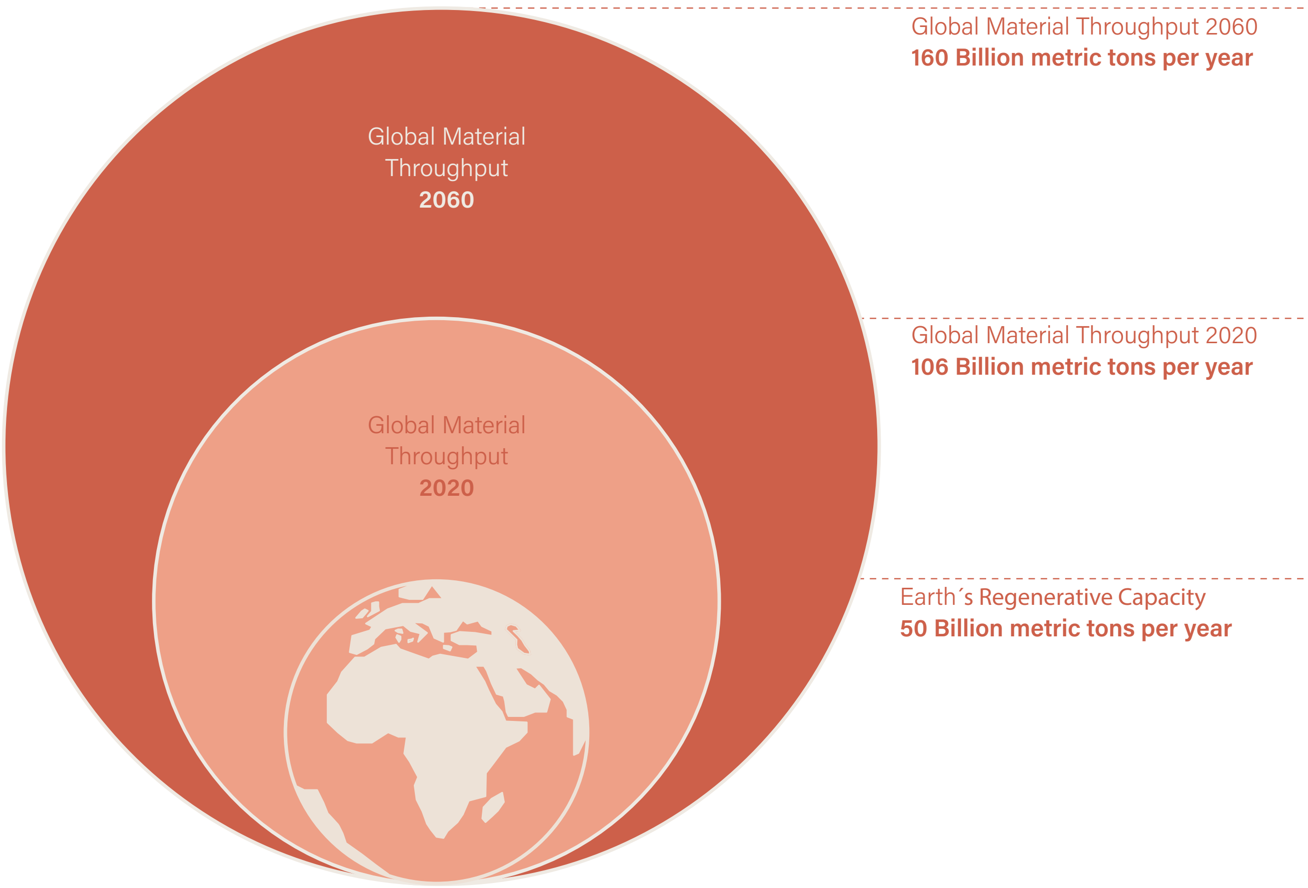
Material footprint is widely regarded as a reliable proxy for assessing environmental impact[31], making it particularly concerning that current material footprint trends are moving in the wrong direction. The Earth's regenerative capacity is estimated to be approximately 50 billion metric tons per year[32]. At present, global material throughput has reached 106 billion metric tons annually, just over double the Earth's limit , with projections estimating that by 2060, this figure will rise to 167 billion metric tons per year[33] as illustrated in Figure 1.3.

Over the past six years, global resource consumption has surged to reach nearly 75% of the total resources consumed throughout the entire previous century [34]. Today, anthropogenic mass is accumulating at an extraordinary rate of approximately 30 gigatons per year – equivalent to every individual on the planet producing their own body weight in artificial materials every week. To put this in context, the mass of human-made materials (anthropogenic mass) exceeded the total weight of all living biomass on Earth for the first time in 2020[35]. If current consumption pattern endures, this anthropogenic mass will be nearly three times greater than living biomass by 2060 (Figure 1.3).

This alarming consumption trend starkly illustrates the profound impact humanity has on Earth's systems and is one of the primary reasons we have transgressed six out of the nine planetary boundaries[36].

Over the past six years, global resource consumption has surged to reach nearly 75% of the total resources consumed throughout the entire previous century.

Figure 1.3 Earth's Regenerative Capacity compared to global material throughput in 2020 and 2060. Source: Reduction Roadmap



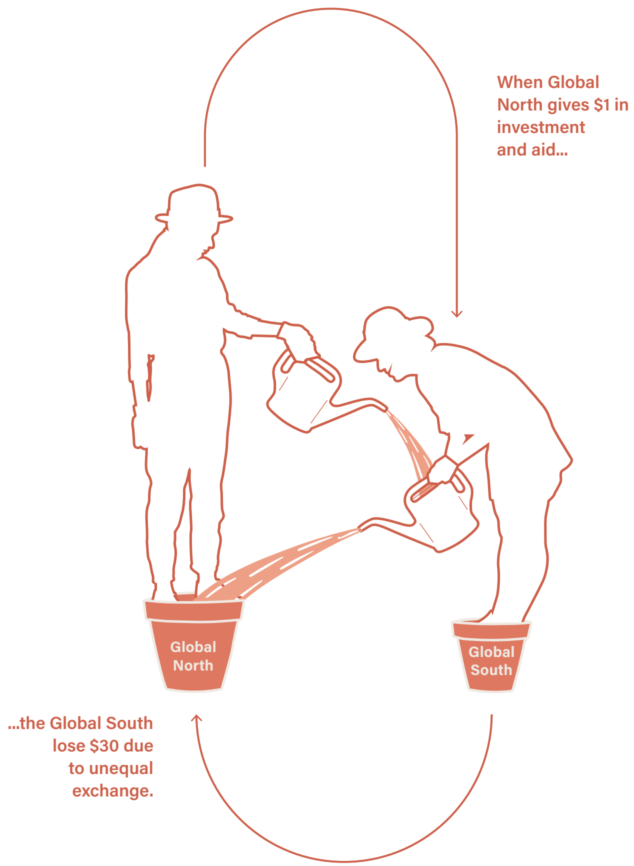


Figure 1.4 Unequal exchange between the Global North and the Global South. Source: Reduction Roadmap

Dynamics of unequal exchange creates over-consumption

High-income nations have disproportionately contributed to the depletion of the global carbon budget necessary to limit global warming to 1.5°C. The Global North has consumed approximately three times its fair share of this budget[37], effectively reducing the remaining emissions allowance for the Global South, which, in contrast, has largely remained within its allocated share.

The Global North is responsible for 92% of emissions exceeding safe planetary limits[38]. Since 1970, these high-income countries have also accounted for 74% of excess material consumption[32], disproportionately affecting low-emitting nations that suffer most from the adverse effects of climate change (Figure 1.6). The wealthiest 10% of the global population generates 49% of all emissions, while the bottom 50%, or 3.9 billion people, contributes to only 8% as illustrated in Figure 1.5. This inequality is further highlighted by the fact that just eight individuals possess as much wealth as the poorest 3.6 billion people combined[40].

Global inequality is deeply entrenched in economic structures that extract approximately $2.2 trillion annually from the Global South. Despite providing 90% of the world's labor, workers in these regions receive only 21% of global income [41].

For every dollar provided to the Global South in investment or aid, $30 is effectively lost due to the extraction of labor and raw materials[36] as illustrated in Figure 1.4. From 1990 to 2015, this transfer amounted to nearly one-quarter of the Northern GDP[42].

This unequal exchange drives Northern overconsumption. Despite narratives of global progress, the benefits of this advancement have been disproportionately concentrated within this wealthy minority. In fact, approximately half of the world's population continues to live on less than $5.50 per day. Benchmarks, such as the Basic Needs Poverty Line (BNPL), reveal a far more alarming picture: more people are living in absolute poverty today than at any previous point in history[43].

These examples highlight the need to create more just economic relations between the wealthiest and the poorest - to address both inequality and to mitigate further environmental degradation. Reducing the North's dependence on exploitation would shift consumption patterns toward sustainability, making just distribution of wealth a critical step towards meaningful decarbonization.

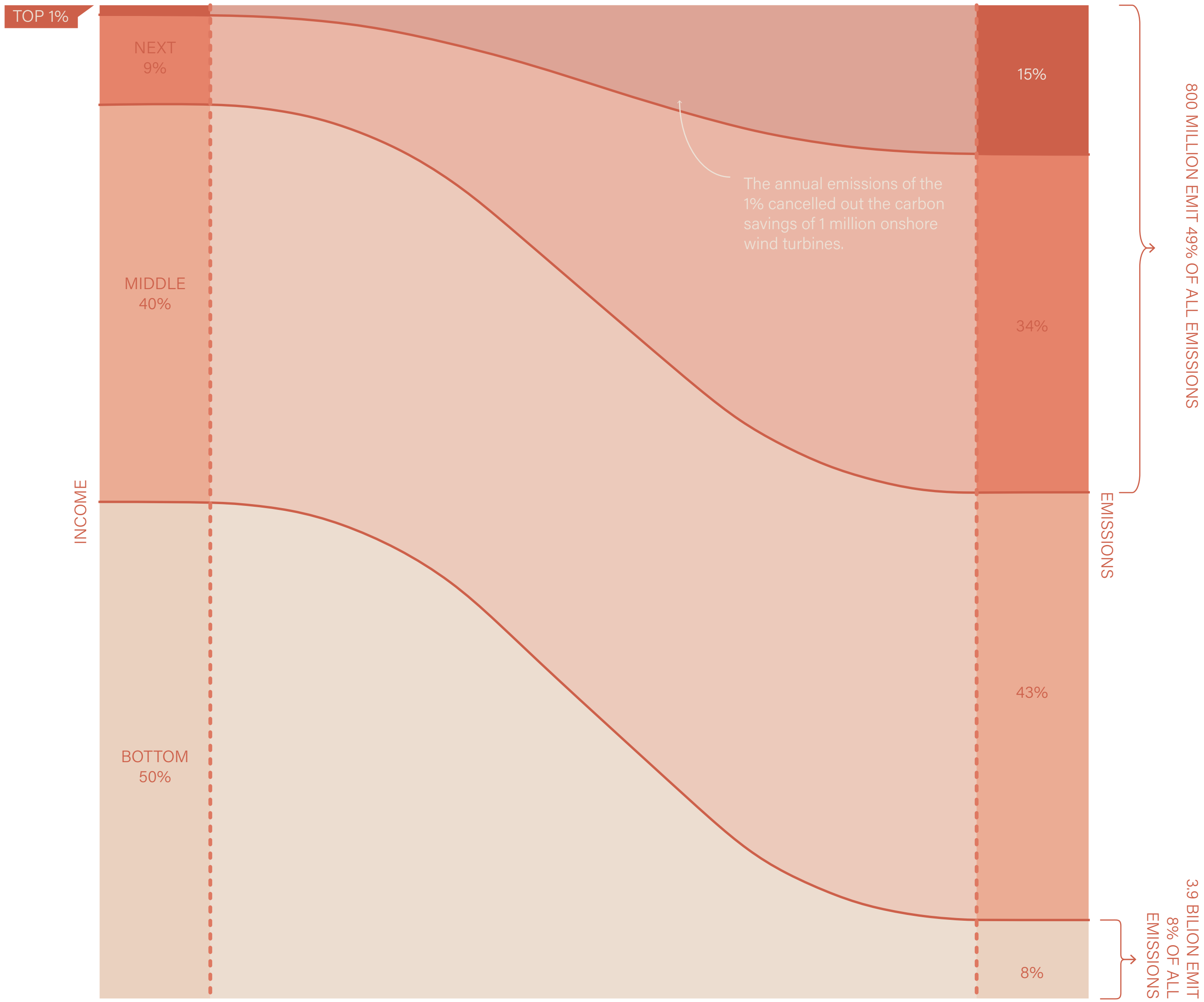


Figure 1.5 - Global wealth is distributed unequally
The wealthiest 10% of the global population generates 49% of all emissions, while the bottom 50%, or 3.9 billion people, contributes to only 8%. Source: Oxfam (2020). Confronting carbon inequality: Putting climate justice at the heart of the COVID-19 recovery. Oxfam Policy & Practice.

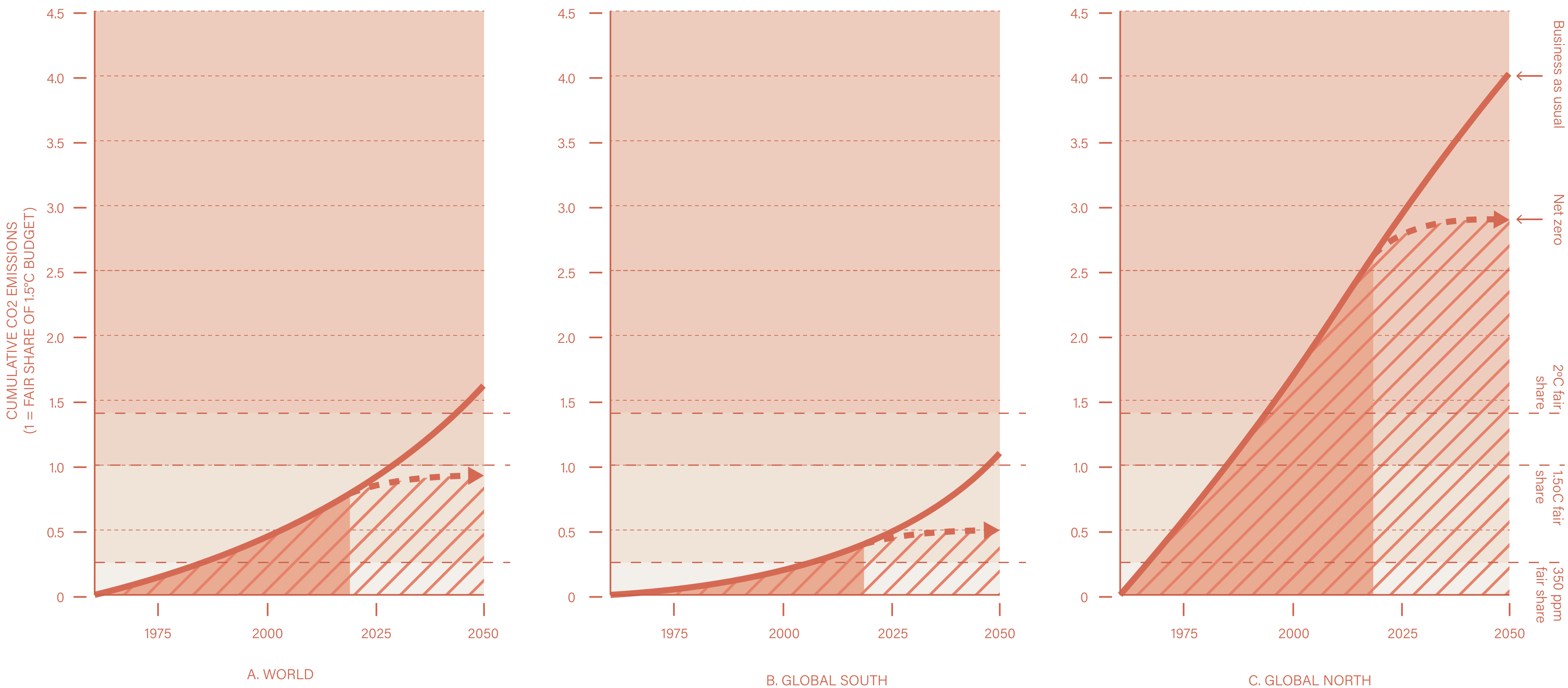


Figure 1.6 - Cumulative CO2 emissions worldwide and by region in relation to fair shares of global carbon budgets. The illustration presents historical trends from 1960 to 2019 and projected trends from 2020 to 2050. A: World. B: Global South region. C: Global North region. With the historical emissions shaded in the dark red area. Source: Fanning and Hickel (2023) Compensation for atmospheric appropriation in Nature Sustainability Figure 1.

Justice is at the heart of sustainable development.

The evolving polycrisis has shifted the focus toward security across various sectors, including information, food, and technology. Many efforts are now aimed at achieving geographical autonomy, as illustrated by Europe's migration policies and the U.S. Inflation Reduction Act. 6262 However, in a deeply interconnected global system, where actions in one region affect others, the idea of national self-sufficiency is not feasible, and true security can only be achieved by recognizing humanity's interdependence[63 63].

As climate disasters escalate, they devastate habitats, exhaust critical resources such as water and food, and force human migration on a large scale[88]. The influx of displaced people overwhelms host regions, triggering competition for resources, heightened tensions, and social unrest, which can spiral into conflict, societal breakdown, and political instability—conditions that leave vulnerable populations easily exploitable. Local crises quickly amplify into global challenges, as weakened systems compound each other[44 62]. As we lose predictable weather patterns, unpredictability threatens economic insurability. Without economic insurability there is a risk of collapsing capital markets, and with them social infrastructures[44 45]. This phenomenon is illustrated in Figure 1.7. In this interconnected world, no catastrophe is isolated.

As researchers in the *Underestimating the Challenges of Avoiding a Ghastly Future* article emphasize "The scale of the threats to the biosphere and all its lifeforms—including humanity—is so great that it is difficult for even well-informed experts to fully grasp."

As described in previous subsection, creating equitable and just exchange relations between the Global North and Global South is necessary for curbing overconsumption. Experts from the IPCC AR6 (2022) describe this necessity as: "There is a rapidly narrowing window of opportunity to enable climate resilient development... where development trajectories are shaped by equity, and social and climate justice."[8]

To achieve this, Gupta et al. (2024) advocate for systemic changes in resource distribution and economic practices to address overconsumption and reduce environmental degradation driven by inequitable access to life's necessities and resource use: "an Earth-system justice approach is needed to identify fair solutions to the interrelated environmental crises.[64]"

This vision incorporates justice as an essential factor for planetary safety, stating that humanity's stability on Earth relies on safe and just management of its resources and climate-sensitive actions that reflect the varying vulnerabilities of different communities. Anders Bjørn and Joachim Tildsted point out in their essay, countries like Denmark have a historic responsibility and financial capacity to go beyond policy to address global inequalities through the regeneration of the living world. We elaborate on how safety and justice are applied to building industry specific targets in Chapter 3 - Box 3.1.

In summary, climate collapse is not just an ecological issue but also social - justice is at the heart of sustainable development.

To address the issues of the Polycrisis, it is important first understand its origins.

"Sufficiency without efficiency is waste."
- Samuel Alexander

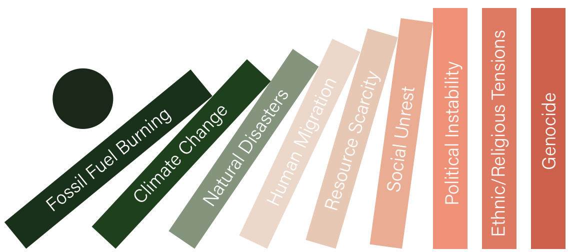


Figure 1.7 Destabilized systems often possess the ability to spread destabilization to other systems.
Source: Reduction Roadmap

1.2 How did we get here?

Economic growth: development goal of the 19th and 20th centuries

Around 1860, we tapped into a new, abundant energy source: fossil fuels. This energy revolution enabled the emergence of complex civilizations and fueled an explosion in productivity[7].

By combining energy with materials and technology, we created products that hold significant cultural and monetary value. However, the byproducts of this process—pollution, chemicals, and greenhouse gases began accumulating, introducing widespread environmental challenges.
Since the mid-20th century, industrial nations have been in the pursuit of economic growth. Economists, recognizing that overproduction of goods had contributed to the Great Depression, spurred government and industry leaders to collaborate on developing a new socioeconomic model: consumerism. Advertising encouraged people to consume more, while consumer credit made it possible. This, in turn, generated more profits, jobs, returns on investments, and tax revenues. The economy became something measurable through gross domestic product (GDP) and manipulatable via interest rates, with perpetual growth as the goal[46]. Energy is the foundation of all economic activity - there is not a single component of GDP that does not rely on energy. This insight underscores the fundamental role of energy use in driving productivity, in the form of both labor and capital[47].

A productivity explosion

The transition to fossil fuels in the 19th century not only revolutionized productivity but also laid the foundation for the consumer-driven economies of the 20th century, where energy-intensive industries have become inextricable with economic growth.

Fossil fuels have vastly increased human productivity by providing energy far beyond what human or animal labor could achieve. For example, a single barrel of oil contains about 1,700 kWh of energy, while a human generates only 0.6 kWh per day, meaning it would take about 11 years of work to match the energy in one barrel. Today, our consumption of fossil fuels is equivalent to the labor of 400-500 billion workers, highlighting our dependence on this energy. This reliance traps excess heat in the Earth's atmosphere, releasing the energy equal to 400,000 Hiroshima bombs daily[7] (Box 1.3).

Waiting for the green revolution

While energy efficiency has improved—with the energy

Box 1.3 - A productivity explosion

Fossil fuels have revolutionized human productivity by providing energy on a scale that far surpasses what human or animal labor could ever achieve. To illustrate, a human generates only about 1/10th of a horsepower, while a truck can harness the power of 300 horses, and an airplane can generate the equivalent of 100,000 horses. These vast energy outputs would be impossible to reach through human or animal labor alone.

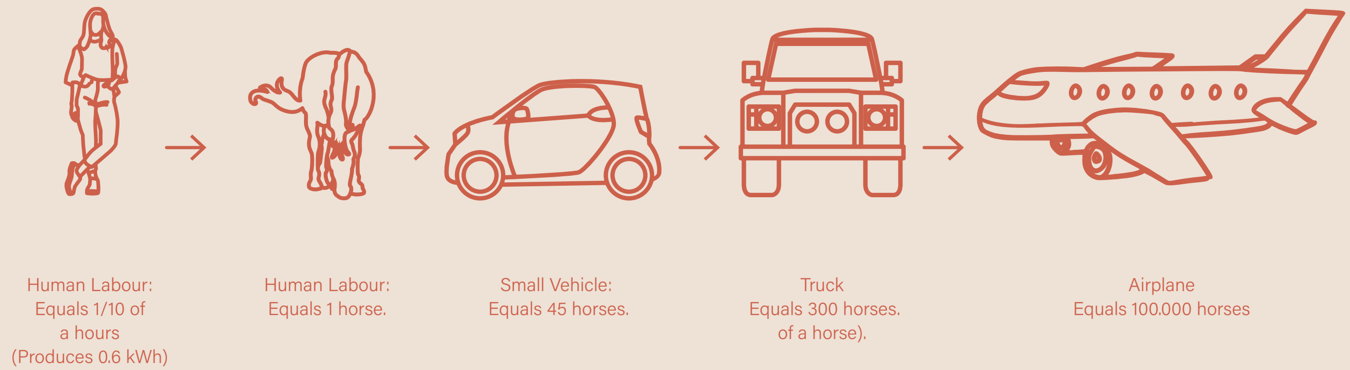
At the core of this transformation is the incredible energy density found in fossil fuels. A single barrel of oil contains about 5.7 million BTUs or 1,700 kilowatt-hours (kWh) of energy. In comparison, a human daily work output only produces about 0.6 kWh of energy. If that person worked 250 days a year, their annual output would be just 150 kWh—barely a fraction of what's in one barrel of oil.

To match the energy in a single barrel of oil, a person would need to work about 11 years. However, since a barrel of oil is only about 40% efficient in converting energy into useful work, it would effectively require closer to 4.5 years of labor.[7].

Today, we consume the equivalent of 100 million barrels of oil, coal, and natural gas per year. This amount of energy is akin to having an army of 400-500 billion workers at our disposal, underscoring our deep reliance on this vast sea of energy to maintain the systems of growth and production we've come to depend on .

Fossil fuels have vastly increased human productivity by providing energy far beyond what human or animal labor could achieve. For example, a single barrel of oil contains about 1,700 kWh of energy, while a human generates only 0.6 kWh per day, meaning it would take about 11 years of work to match the energy in one barrel. Today, our consumption of fossil fuels is equivalent to the labor of 400-500 billion workers, highlighting our dependence on this energy[7]. This reliance also traps excess heat in the Earth's atmosphere, releasing the energy of 400,000 Hiroshima bombs daily[48].

Source: Inspired by Nate Hagen in A Systems Approach Towards a (More) Sustainable Future: An Invitation to Academia, talk, 2024



The transition to fossil fuels in the 19th century not only revolutionized productivity but also laid the foundation for the consumer-driven economies of the 20th century, where energy-intensive industries have become inextricable with economic growth.

intensity of the global economy decreasing by about 1.2% per year since the 19th century—the reliance on fossil fuels is staggering Figure 1.8[7]. In fact, over the past 30 years, fossil fuels have consistently accounted for 81.5% of total energy consumption as illustrated in Figure 1.9. This is because the global demand for energy continues to grow at a pace that far exceeds the capacity of renewable energy development. Contrary to the promise of a "green energy revolution," we have experienced more of a "green addition," where new energy sources are added to the mix without displacing fossil fuels[49].

The issue of fossil fuel exaggerated is exasperated by Jevons Paradox which suggests that efficiency improvements, often lead to an overall increase in consumption. Explaining why, as processes become more efficient and costs decrease, individuals and industries often use more energy, offsetting the savings from efficiency gains—this is also known as the rebound effect. Understanding this phenomena, Samual Alexander stated: "Efficiency without sufficiency is waste" meaning that without setting limits to consumption, gains in efficiency alone are not enough to reduce demand[50].

The relentless rise in global energy consumption demonstrates that renewable energy, while crucial, is currently insufficient to reverse our dependence on fossil fuels. This example illustrates that in a growth-dependent economy, we cannot rely on technological fixes to scale impact within planetary limits[51]. This trend is expanded upon in Chapter 2 where other symptoms of growth dependency are presented.

In pursuit of green growth

The idea of green growth has dominated global environmental policy in the last decade, with support from the Organization for Economic Co-operation and Development (OECD), the United Nations Environment Program (UNEP), the European Commission, and the World Bank[52]. Proponents of green growth envision a world where economic growth and environmental degradation decouple absolutely and permanently – GDP increases, while resource extraction and environmental pressures decrease. Decoupling was enshrined as a global objective in the UN Sustainable Development Goals[53]. In the context of the climate emergency, green growth claims it is possible to reach two types of decoupling at sufficient pace and scale to meet Paris Agreement goals – (1) resource use from economic growth, and (2) greenhouse gas emissions from economic growth. Neither has happened.

A decade has passed since the idea of green growth gained traction, but retrospective reviews agree – there has been no evidence of absolute and sustained decoupling of resource use from economic growth. Despite this, leaders

Figure 1.8 - The energy intensity of the economy. how much energy we use to generate $1 of GDP—has improved by about 1.2% since 1800. Contrary to the promise of a "green energy revolution" we have experienced more of a "green addition." The issue of fossil fuel expansion is exagerated by Jevons Paradox which suggests that efficiency improvements, often lead to an overall increase in consumption. Source: Source: Our World in Data (2021) and Nate Hagens (2023) A systems approach towards a more sustainable future: an invitation to acadamia talk.

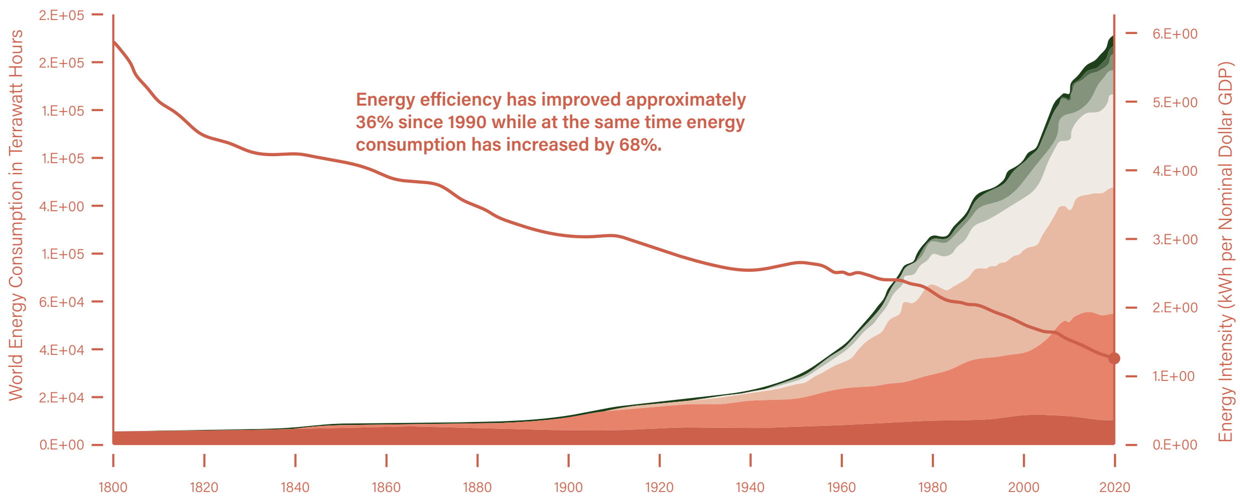
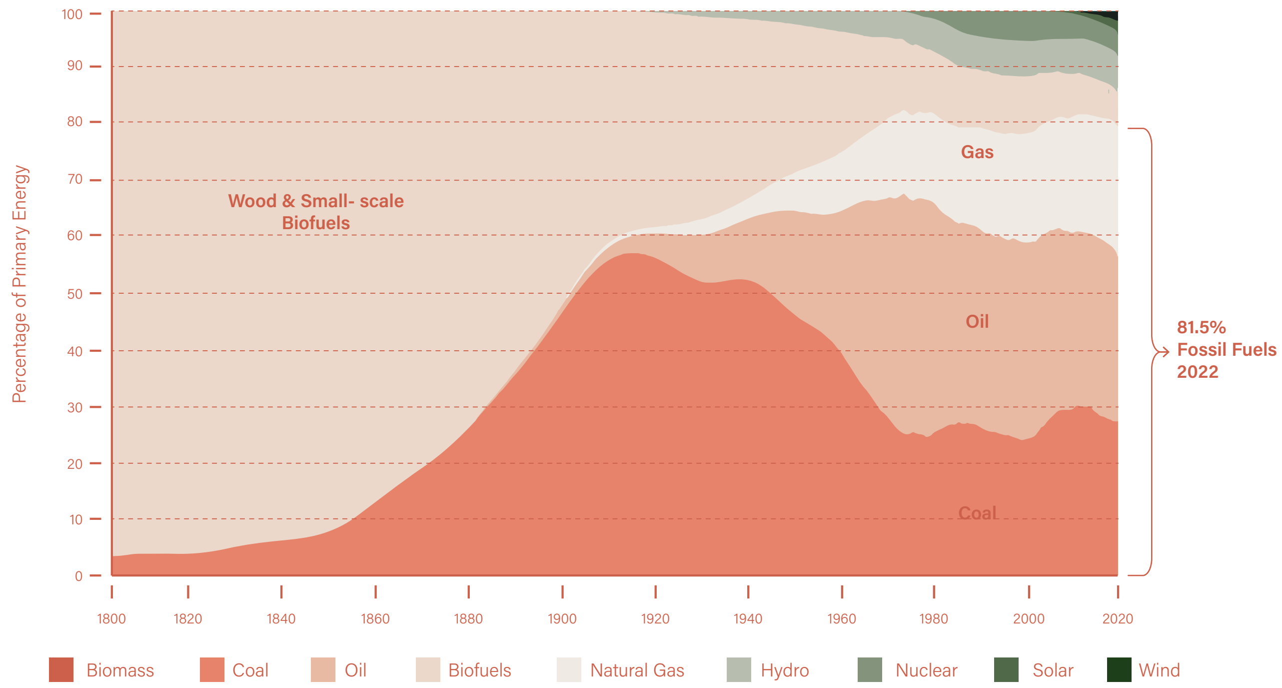


Figure 1.9 - Fossil fuel still acounted for 81.5% of primary energy consumption in 2022. Source: Data from before 1965 come from Vaclav Smil (2017) and from 1965 to present from BP statistical Review of World Energy.

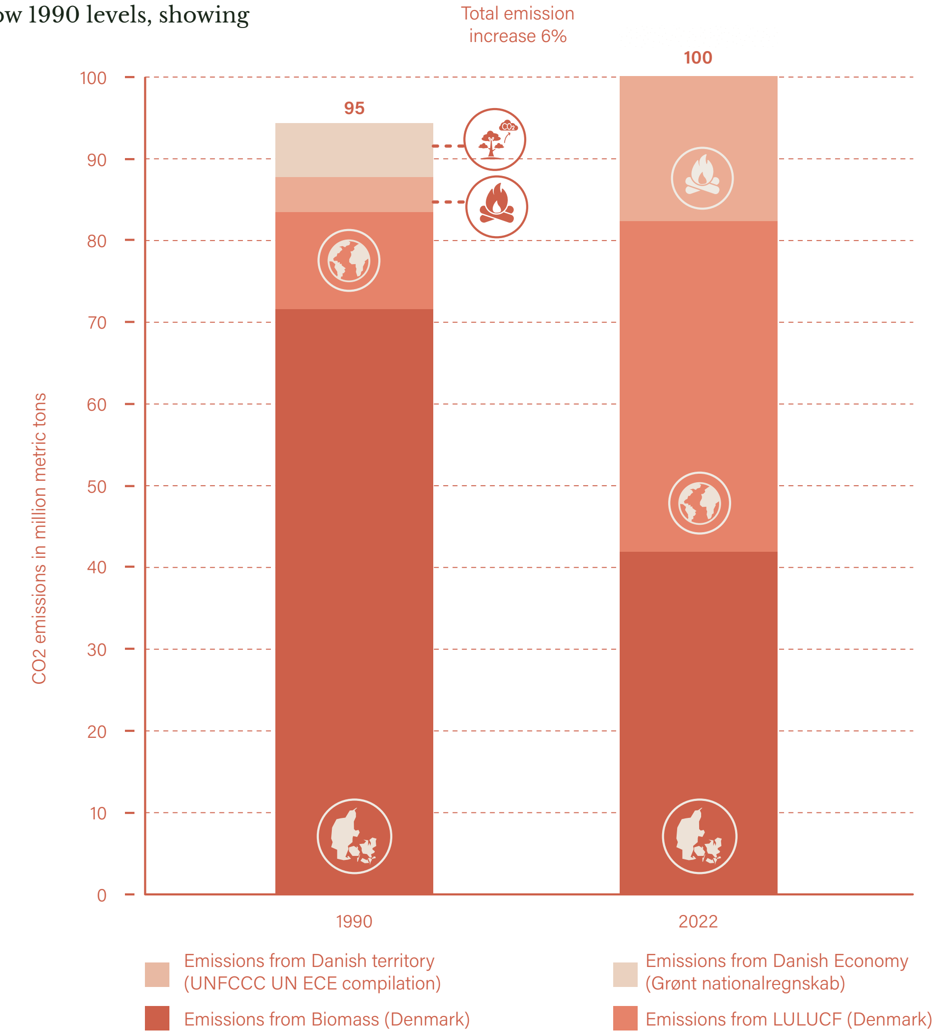


continue to assure us that technology and innovation through "green growth" will solve the climate crisis, but the idea of absolute decoupling—separating economic growth from environmental harm—is not supported by empirical evidence[54].

While some nations claim to have achieved decoupling by reducing CO_2 emissions while growing their economies[55], global data shows no evidence that this can happen at the speed and scale required to address climate change[56]. Even in countries that claim to have decoupled, the reality is less optimistic: "territorial emissions in many developed countries appear to be decoupling from CO_2, but their consumption-based emissions may be causing other territories to emit more CO_2" suggesting that wealthy nations may have simply "outsourced their environmental impacts" by shifting their carbon emissions to developing countries through international trade[58].

When examine data closely, most models neglect emissions from key sectors such as biomass, biogas, aviation, and international transport. When these emissions are included, the picture changes drastically. For instance, data from Denmark shows that emissions linked to the Danish economy have increased by 6% since 1990 (Figure 1.10). These figures are derived from the Green National Accounts, which adhere to the guidelines of the System of Environmental-Economic Accounting established by international organizations such as the UN and the World Bank. This system quantifies the climate impact associated with Danish GDP (See Box. 4.2) on GDP) but notably excludes certain investments, such as those from pension funds and subsidiaries located abroad. Comparing the emissions to Danish GDP, material footprint, and energy consumption, Figure 1.13 suggests a potential decoupling trend. However, neither emissions, material footprint, nor energy consumption has fallen below 1990 levels, showing

Figure 1.10 Total emissions linked to the Danish economy have increased by 6% since 1990. Source: Danish National Green Accounts



that no reductions have occurred. This means that the "relative decoupling" is far from happening at the necessary scale or pace to meet international commitments.

This point is further articulated by the UN's BIOS scientific team: "The existence of decoupling in a bounded geographical area or economic sector does not, as such, mean that decoupling is happening in a wider context."[57] What the planet needs is decoupling in an absolute sense. Despite best efforts, absolute decoupling is not happening today. This can be attributed to the "Growth knot" (Figure 1.11)

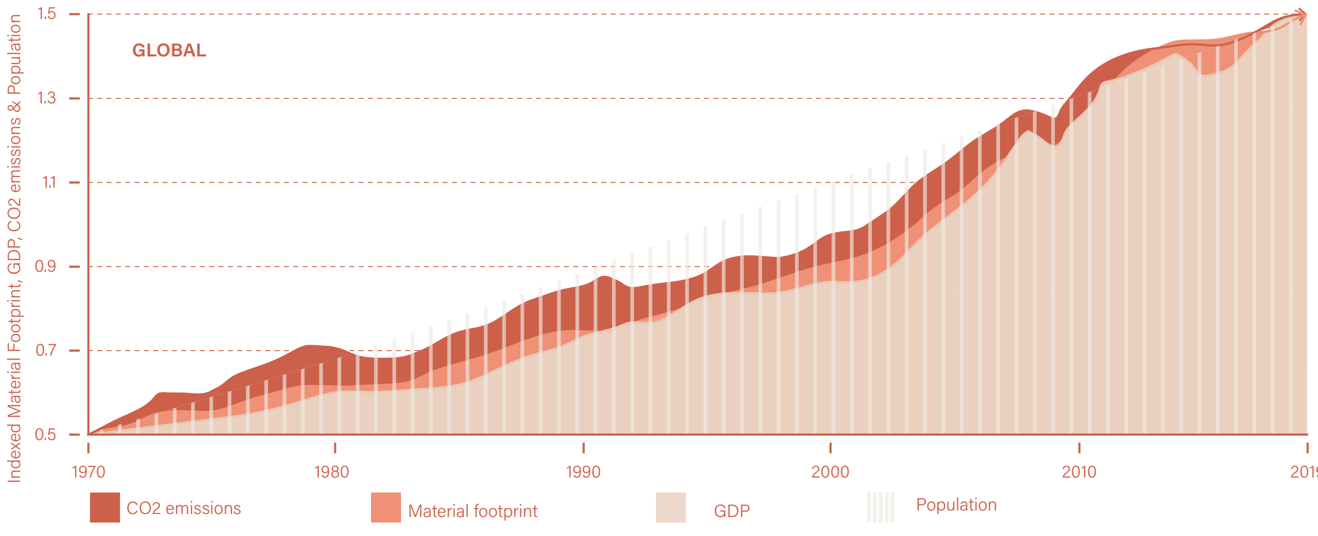


Figure 1.12 - In growth-driven economies, there is a strong correlation (ranging from 0.86 - 0.99) between economic growth, material footprint, energy use, and CO2 emissions. Source: World Bank, Global Carbon Atlas, Global Material Flows Database and Labyrinth Consulting Services, Inc.

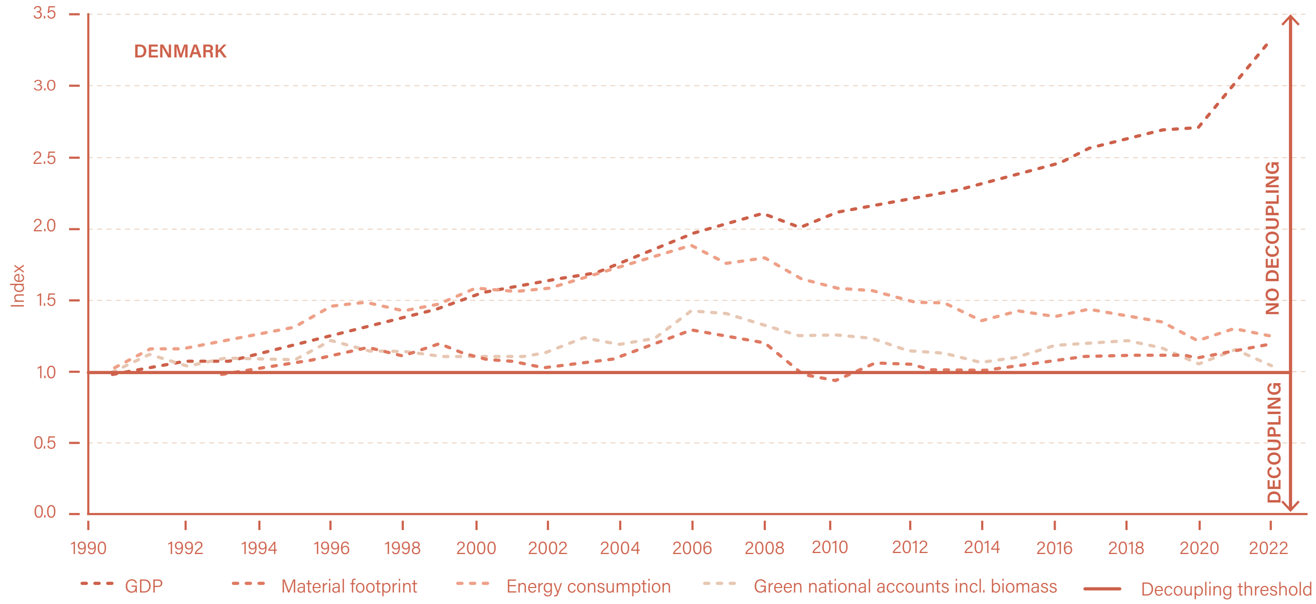


Figure 1.13 - Danish correlation between material footprint, GPD and GHG emissions.
Since 1990, the correlation between Danish GDP, greenhouse gas emissions from the national economy, material footprint, and energy consumption reveals a trend of relative decoupling from GDP growth. Despite this relative decoupling, emissions, along with energy and material consumption, have not declined since 1990, indicating that Denmark remains off track in meeting its international commitments. Source: Danish Green National Accounts

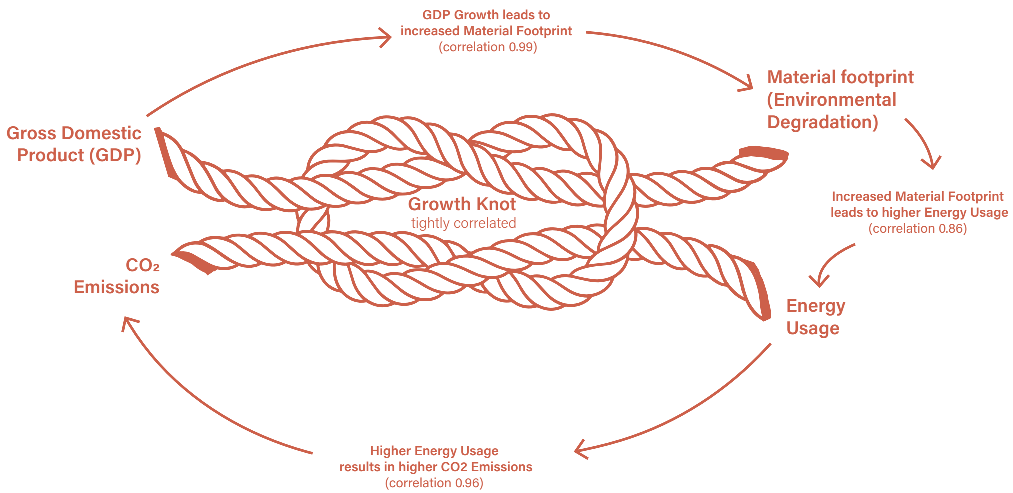
The growth knot is tightly wound

In growth-driven economies, there is a strong correlation between economic growth, material footprint, energy use, and CO2 emissions[58]. As GDP rises, the demand for raw materials and energy increases, particularly in energy-intensive sectors like manufacturing and construction. This close correlation (ranging from 0.86 to 0.99) shows that economic growth drives material consumption, energy use, and emissions[59] (Figure 1.12). Known as the "growth knot," (Figure 1.14) this self-reinforcing cycle makes it difficult to reduce carbon emissions and resource use within an economic system designed for exponential growth, which is why there is not empirical evidence for "green growth" happening at a sufficient pace and scale. As such, the pursuit of economic growth as a global paradigm and national governance pursuit is in opposition with the pursuit of sustainable development.

Given the urgency to scale human impact within planetary limits, we believe the pursuit of green growth must be abandoned in favor of sustainable development.
In 2023, energy-related CO2 emissions increased by 1.1% while GDP increased by approximately 3%; this is known as relative decoupling[60]. Relative decoupling is not the Paris Agreement-aligned trajectory of sustained, drastic decrease in CO2 emissions. Emissions need to reduce by 12% per year – this means an absolute decoupling of energy consumption from GDP growth that is eight times faster than the historic, observed rate of decoupling in industrialized nations[52].

The last decade was about identifying what to do to mitigate climate change; this decade is about doing it fast enough. Unfortunately, evidence shows we cannot sustain economic growth while reducing greenhouse gas emissions at a sufficient pace and scale. If the countries who have achieved relative decoupling of their CO2 emissions from economic growth between 2013 and 2019 continue on their present trajectory, it would take 220 years to reduce their emissions to Paris-compliant levels – a time-frame that the planet does not have[61].

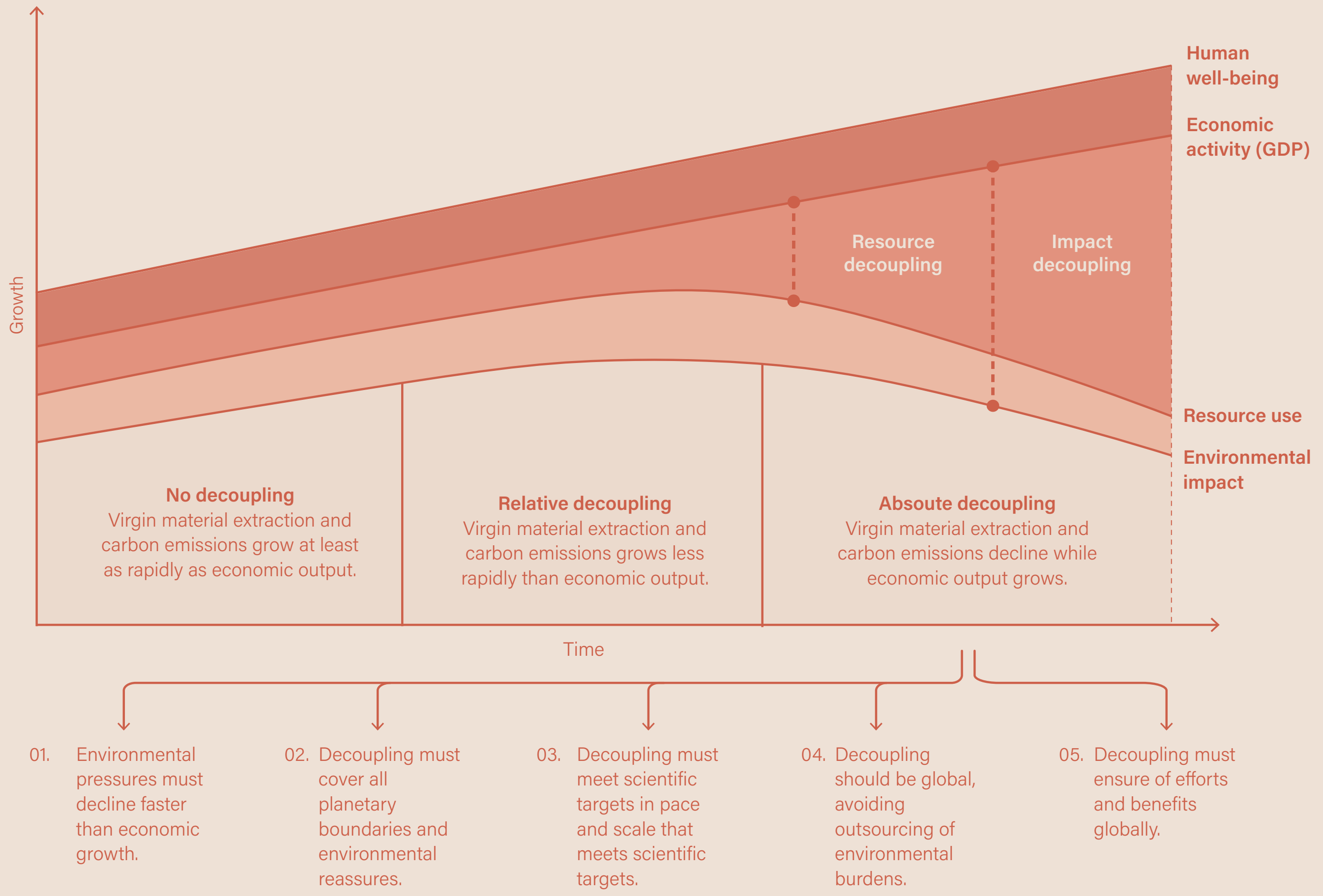
Figure 1.14 - The "Growth Knot" demonstrates that overconsumption is caused by the high correlation between GDP, C02 emissions, material usage, and environmental degradation. In growth-driven economies, GDP growth is strongly correlated with an increase in the Material Footprint (correlation 0.99) (Nature Communications, 2020) . An increased Material Footprint subsequently leads to higher Energy Usage (correlation 0.86) (Carbon Tracker, 2021) . As energy usage rises, it directly results in greater CO2 Emissions (correlation 0.96) (Carbon Tracker, 2021) . Therefore, as economies grow, the associated rise in GDP drives more material consumption and energy use, which, in turn, leads to higher carbon emissions. Source: Reduction Roadmap



Box 1.4: Towards absolute decoupling

Proponents of green growth envision a future where economic growth and environmental degradation are absolutely and permanently decoupled. In such a scenario, GDP continues to increase while at the same time resource extraction and environmental pressures decrease. Source: illustration inspired by Lendager and Vind *A Change Makers Guide to the Future* (2018) figure 04 on Decoupling with original Reduction Roadmap text.

To move towards absolute decoupling, five critical pre-conditions must be met:
1. Environmental pressures must decrease faster than economic growth.
2. Decoupling must address all planetary boundaries and environmental pressures.
3. Decoupling must occur at a pace and scale that meets scientific targets.
4. It must be global, avoiding the outsourcing of environmental burdens to other nations.
5. Equitable and just distribution of benefits must ensured on a global level.



Chapter 1 References

1. Kate Raworth, Doughnut Economics: Seven Ways to Think Like a 21st-Century Economist (White River Junction, Vermont: Chelsea Green Publishing, 2017), https://books.google.dk/books/about/Doughnut_Economics.html?id=7A4lDgAAQBAJ&redir_esc=y.

2. Donella H. Meadows and Club of Rome, The Limits to Growth; a Report for the Club of Rome's Project on the Predicament of Mankind (New York, Universe Books, 1972), http://archive.org/details/TheLimitsToGrowth.

3. Arjuna Nebel et al., 'Recalibration of Limits to Growth: An Update of the World3 Model', Journal of Industrial Ecology 28, no. 1 (February 2024): 87–99, https://doi.org/10.1111/jiec.13442.

4. Gerardo Ceballos et al., 'Accelerated Modern Human–Induced Species Losses: Entering the Sixth Mass Extinction', Science Advances 1, no. 5 (5 June 2015): e1400253, https://doi.org/10.1126/sciadv.1400253.

5. Lior Greenspoon et al., 'The Global Biomass of Wild Mammals', Proceedings of the National Academy of Sciences 120, no. 10 (7 March 2023): e2204892120, https://doi.org/10.1073/pnas.2204892120.

6. Andrew D. Saunders, 'Large Igneous Provinces: Origin and Environmental Consequences' 1, no. 5 (2005): 259–63, https://doi.org/10.2113/gselements.1.5.259.

7. A Systems Approach Towards a (More) Sustainable Future: An Invitation to Academia, 2024, https://www.youtube.com/watch?v=bE7Bbnvf4ko.

8. IPCC, Climate Change 2022 Mitigation of Climate Change: Working Group III Contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change, 2022, https://www.ipcc.ch/report/ar6/wg3/.

9. Patrick Greenfield and Max Benato, 'Animal Populations Experience Average Decline of Almost 70% since 1970, Report Reveals', The Guardian, 12 October 2022, sec. Environment, https://www.theguardian.com/environment/2022/oct/13/almost-70-of-animal-populations-wiped-out-since-1970-report-reveals-aoe.

10. 'Accelerated Modern Human–Induced Species Losses: Entering the Sixth Mass Extinction | Science Advances', accessed 16 September 2024, https://www.science.org/doi/10.1126/sciadv.1400253.

11. IPBES, 'Global Assessment Report on Biodiversity and Ecosystem Services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services' (Zenodo, 4 May 2019), https://doi.org/10.5281/zenodo.6417333.

12. 'Insect Decline in the Anthropocene: Death by a Thousand Cuts | PNAS', accessed 16 September 2024, https://www.pnas.org/doi/full/10.1073/pnas.2023989118.

13. Luca Montanarella et al., 'Status of the World's Soil Resources: Main Report', FAO, 2015, https://www.researchgate.net/publication/285597377_The_Status_of_the_World's_Soil_Resources.

14. 'Plastic Cloud: New Study Analyzes Airborne Microplastics in Clouds', ScienceDaily, accessed 16 September 2024, https://www.sciencedaily.com/releases/2023/09/230927155426.htm.

15. Derek Vollmer and Ian J. Harrison, 'H2O ≠ CO2: Framing and Responding to the Global Water Crisis', Environmental Research Letters 16, no. 1 (January 2021): 011005, https://doi.org/10.1088/1748-9326/abd6aa.

16. P. G. C. Nayanathara Thathsarani Pilapitiya and Amila Sandaruwan Ratnayake, 'The World of Plastic Waste: A Review', Cleaner Materials 11 (1 March 2024): 100220, https://doi.org/10.1016/j.clema.2024.100220.

17. 'New Study Shows Plastic in Oceans Is on the Rise', accessed 16 September 2024, https://www.nationalgeographic.com/science/article/150212-ocean-debris-plastic-garbage-patches-science.

18. Benedetta Tuvo et al., 'Microplastics and Antibiotic Resistance: The Magnitude of the Problem and the Emerging Role of Hospital Wastewater', International Journal of Environmental Research and Public Health 20, no. 10 (18 May 2023): 5868, https://doi.org/10.3390/ijerph20105868.

19. United Nations Environment Programme, 'Global Resources Outlook 2024: Bend the Trend - Pathways to a Livable Planet as Resource Use Spikes' (Nairobi: International Resource Panel, 2024), https://wedocs.unep.org/handle/20.500.11822/44902.

20. 'Nearly Half the World Lives on Less than $5.50 a Day', World Bank, accessed 16 September 2024, https://www.worldbank.org/en/news/press-release/2018/10/17/nearly-half-the-world-lives-on-less-than-550-a-day.

21.Martin-Brehm Christensen et al., 'Survival of the Richest: How We Must Tax the Super-Rich Now to Fight Inequality' (Oxfam, 16 January 2023), https://doi.org/10.21201/2023.621477.

22. Levi Boxell, Matthew Gentzkow, and Jesse M Shapiro, 'NBER WORKING PAPER SERIES CROSS-COUNTRY TRENDS IN AFFECTIVE POLARIZATION', 2020, https://doi.org/10.3386/w26669.

23.'Racism, Xenophobia Increasing Globally, Experts Tell Third Committee, amid Calls for Laws to Combat Hate Speech, Concerns over Freedom of Expression | Meetings Coverage and Press Releases', accessed 16 September 2024, https://press.un.org/en/2016/gashc4182.doc.htm.

24. 'We're Spending More Years in Poor Health than at Any Point in History. How Can We Change This?', World Economic Forum, 5 April 2022, https://www.weforum.org/agenda/2022/04/longer-healthier-lives-everyone/

25. Zoran J. N. Steinmann et al., 'Resource Footprints Are Good Proxies of Environmental Damage', Environmental Science & Technology 51, no. 11 (6 June 2017): 6360–66, https://doi.org/10.1021/acs.est.7b00698.

26. Stefan Bringezu, 'Possible Target Corridor for Sustainable Use of Global Material Resources', Resources 4, no. 1 (11 February 2015): 25–54, https://doi.org/10.3390/resources4010025.

27. United Nations Environment Programme (UNEP), 'Global Material Flows and Resource Productivity' (United Nations Environment Programme (UNEP), 2016), https://www.unep.org/resources/report/global-material-flows-and-resource-productivity-assessment-report-unep.

28. Circle Economy, 'The Circularity Gap Report 2024' (Amsterdam, 2024), https://www.circularity-gap.world/2024.

29. Emily Elhacham et al., 'Global Human-Made Mass Exceeds All Living Biomass', Nature 588, no. 7838 (December 2020): 442–44, https://doi.org/10.1038/s41586-020-3010-5.

30. Katherine Richardson et al., 'Earth beyond Six of Nine Planetary Boundaries', Science Advances 9, no. 37 (15 September 2023): eadh2458, https://doi.org/10.1126/sciadv.adh2458.

31. 'Compensation for Atmospheric Appropriation | Nature Sustainability', accessed 18 September 2024, https://www.nature.com/articles/s41893-023-01130-8.

32. Jason Hickel et al., 'National Responsibility for Ecological Breakdown: A Fair-Shares Assessment of Resource Use, 1970-2017', The Lancet. Planetary Health 6, no. 4 (April 2022): e342–49, https://doi.org/10.1016/S2542-5196(22)00044-4.

33. Jason Hickel, 'Quantifying National Responsibility for Climate Breakdown: An Equality-Based Attribution Approach for Carbon Dioxide Emissions in Excess of the Planetary Boundary', The Lancet Planetary Health 4, no. 9 (1 September 2020): e399–404, https://doi.org/10.1016/S2542-5196(20)30196-0.

34. Tim Gore, 'Confronting Carbon Inequality: Putting Climate Justice at the Heart of the COVID-19 Recovery', 2020, https://www.oxfam.org/en/research/confronting-carbon-inequality.

35. Jason Hickel et al., 'Imperialist Appropriation in the World Economy: Drain from the Global South through Unequal Exchange, 1990–2015', Global Environmental Change 73 (1 March 2022): 102467, https://doi.org/10.1016/j.gloenvcha.2022.102467.

36. Jason Hickel, Morena Hanbury Lemos, and Felix Barbour, 'Unequal Exchange of Labour in the World Economy,' Nature Communications 15, no. 1 (29 July 2024): 6298, https://doi.org/10.1038/s41467-024-49687-y.

37. Dylan Sullivan and Jason Hickel, 'Capitalism and Extreme Poverty: A Global Analysis of Real Wages, Human Height, and Mortality since the Long 16th Century,' World Development 161 (1 January 2023): 106026, https://doi.org/10.1016/j.worlddev.2022.106026.

38. Natalia V. Bhattacharjee et al., 'Global Fertility in 204 Countries and Territories, 1950–2021, with Forecasts to 2100: A Comprehensive Demographic Analysis for the Global Burden of Disease Study 2021,' The Lancet 403, no. 10440 (18 May 2024): 2057–99, https://doi.org/10.1016/S0140-6736(24)00550-6.

39 'Chronic Diseases Taking "Immense and Increasing Toll on Lives", Warns WHO | UN News,' 19 May 2023, https://news.un.org/en/story/2023/05/1136832.

40. Lewis, 'Civil Unrest Around the World Has Doubled in Last Decade,' Vision of Humanity, 8 October 2020, https://www.visionofhumanity.org/civil-unrest-on-the-rise/.

41. U.S. Department of Health and Human Services (HHS), 'Our Epidemic of Loneliness and Isolation' (U.S. Department of Health and Human Services (HHS), 2023), https://www.hhs.gov/sites/default/files/surgeon-general-social-connection-advisory.pdf.

42. United Nations, 'A New Era of Conflict and Violence,' United Nations (United Nations), accessed 16 September 2024, https://www.un.org/en/un75/new-era-conflict-and-violence.

43. 'When Democracies Autocratise,' UNDP, accessed 16 September 2024, https://www.undp.org/future-development/signals-spotlight-2023/when-democracies-autocratise.

44. Designing Our Futures (Media Evolution, 2024), https://www.youtube.com/watch?v=knDC8hXDdhE.

45. Corey J. A. Bradshaw et al., 'Underestimating the Challenges of Avoiding a Ghastly Future,' Frontiers in Conservation Science 1 (13 January 2021), https://doi.org/10.3389/fcosc.2020.615419.

46. Richard Heinberg and Asher Miller, 'Welcome to the Great Unraveling,' Post-Carbon Institute, 2023, https://www.postcarbon.org/publications/welcome-to-the-great-unraveling/.

47. Mathew D. Rose, 'Steve Keen - Labour Without Energy Is a Corpse; Capital Without Energy Is a Sculpture,' Brave New Europe (blog), 21 May 2019, https://braveneweurope.com/steve-keen-labour-without-energy-is-a-corpse-capital-without-energy-is-a-sculpture.

48. James Hansen: Why I Must Speak out about Climate Change, 2012, https://www.youtube.com/watch?v=fWInyaMWBY8.

49. Our World in Data 2021. Data Published by Energy Institute Review of World Energy; Vaclav Smil (2017), Energy Transitions: Global and National Perspectives, 2nd Edition.

50. M. Giampietro and K. Mayumi, 'Unraveling the Complexity of the Jevons Paradox: The Link Between Innovation, Efficiency, and Sustainability,' Frontiers in Energy Research 6 (2018), https://doi.org/10.3389/fenrg.2018.00026.

51. Louise Ellegaard Fich, Silvia Viola, and N. Bentsen, 'Jevons Paradox: Sustainable Development Goals and Energy Rebound in Complex Economic Systems,' Energies, 2022, https://doi.org/10.3390/en15165821.

52. Jason Hickel and Giorgos Kallis, 'Is Green Growth Possible?,' New Political Economy 25, no. 4 (6 June 2020): 469–86, https://doi.org/10.1080/13563467.2019.1598964.

53. United Nations, 'Transforming Our World: The 2030 Agenda for Sustainable Development,' 2015, https://sdgs.un.org/publications/transforming-our-world-2030-agenda-sustainable-development-17981.

54. Timothée Parrique et al., 'Decoupling Debunked – Evidence and Arguments against Green Growth as a Sole Strategy for Sustainability' (European Environmental Bureau, July 2019), https://eeb.org/library/decoupling-debunked/.

55. 'Many Countries Have Decoupled Economic Growth from CO2 Emissions, Even If We Take Offshored Production into Account - Our World in Data,' accessed 19 September 2024, https://ourworldindata.org/co2-gdp-decoupling.

56. 'World Economies' Progress in Decoupling from CO2 Emissions | Scientific Reports,' accessed 19 September 2024, https://www.nature.com/articles/s41598-024-71101-2.

57. T. Vadén et al., 'Raising the Bar: On the Type, Size and Timeline of a "Successful" Decoupling,' Environmental Politics 30, no. 3 (16 April 2021): 462–76, https://doi.org/10.1080/09644016.2020.1783951.

58. 'Scientists' Warning on Affluence | Nature Communications,' accessed 18 September 2024, https://www.nature.com/articles/s41467-020-16941-y.

59. 'Supporting-Document-To-Rolling-The-DICE-How-Did-We-Get-Here.Pdf,' accessed 18 September 2024, https://carbontracker.org/wp-content/uploads/2023/07/Supporting-Document-To-Rolling-The-DICE-How-Did-We-Get-Here.pdf.

60. International Energy Agency, 'CO2 Emissions in 2023 - A New Record High, but Is There Light at the End of the Tunnel?,' March 2024, 5, https://www.iea.org/reports/co2-emissions-in-2023.

61. Jefim Vogel and Jason Hickel, 'Is Green Growth Happening? An Empirical Analysis of Achieved versus Paris-Compliant CO2–GDP Decoupling in High-Income Countries,' The Lancet Planetary Health 7, no. 9 (1 September 2023): e759–69, https://doi.org/10.1016/S2542-5196(23)00174-2.

62. Johan Rockström, "Berlin Aviation Summit, 4 June 2024" (Keynote, Berlin, Germany, June 4, 2024), https://www.pik-potsdam.de/members/johanro/240604_jr_script-aviation-summit.pdf.

63. United Nations Environment Programme, Emissions Gap Report 2023: Broken Record – Temperatures Hit New Highs, yet World Fails to Cut Emissions (Again) (United Nations Environment Programme, 2023), https://doi.org/10.59117/20.500.11822/43922.

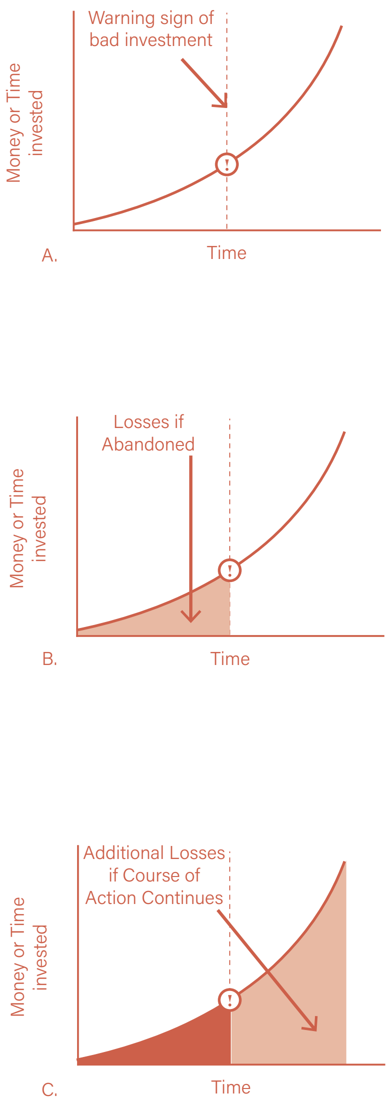
64. Gupta, J., Bai, X., Liverman, D. M., Rockström, J., Qin, D., Stewart-Koster, B., ... & Gentile, G. (2024). A just world on a safe planet: A Lancet Planetary Health–Earth Commission report on Earth-system boundaries, translations, and transformations. The Lancet Planetary Health, 8(10), e813-e873. https://doi.org/10.1016/S2542-5196(24)00042-1

“The scale of the threats to the biosphere and all its lifeforms—including humanity—is so great that it is difficult for even well-informed experts to fully grasp.”

- Corey J. A. Bradshaw et al., ‘Underestimating the Challenges of Avoiding a Ghastly Future’, Frontiers in Conservation Science

Chapter 2
Efficiency without sufficiency is waste

"How has the growth imperative constrained our ability to achieve a sustainable transition?"



Towards a sufficient building industry

The aim of this chapter is to illustrate that the strategies we have based the building industry transition on may hold promise; however, they are not solutions within a growth-based economy, but rather effective responses for a sufficiency-based one. To sustain our growth-based system, we produce various strategies, these strategies are often framed as solutions but, when they enable the continued expansion of the economy, inadvertently perpetuating business-as-usual.

This chapter aims to show that while current strategies for transitioning the building industry offer potential, they are insufficient within a growth-based economy. These strategies—including green growth, energy efficiency, renewable energy, wood/biomass use, circular economy practices, and carbon dioxide removal technologies (CDR and CCS)—are often labeled as solutions but primarily serve to sustain economic expansion, perpetuating business-as-usual approaches.

In a growth-driven system, innovation and technology are viewed more as opportunities for financial gain than for reducing production and consumption, which fundamentally limits their impact on mitigating ecological harm. Addressing climate and ecological crises requires strategies that confront the root issue: overconsumption. However, many current strategies remain entrenched due to the sunk cost fallacy 1, where prior investments bias industries and policymakers towards maintaining ineffective approaches, hindering meaningful transformation (Figure 2.1).

Figure 2.1 The Sunked Cost Fallacy
A) Despite signs that conventional building practices are ineffective in a growth-driven economic model, investments continue due to reliance on established but unsustainable methods. B) Considering Change: Although it's clear that current practices result in environmental and economic losses, the industry hesitates to abandon them, driven by the sunk costs of past investments and infrastructure and future policy commitments. C) Escalating Impact: Persisting with traditional, growth-focused solutions leads to mounting environmental and financial costs, even though more sustainable options are available.

We must address the root cause of impact: overconsumption - rather than wait and hedge our bets. It's time to step off the escalator of endless growth and reorient focus towards using the innovation methods aligned with sufficiency principles.

This chapter does not question the intent behind current strategies but seeks to reveal how they could be truly effective within a sufficiency-based model that prioritizes ecological balance and well-being overgrowth. Aligning these initiatives with growth objectives constrains their capacity to reduce environmental pressures, as they ultimately drive higher consumption and production.

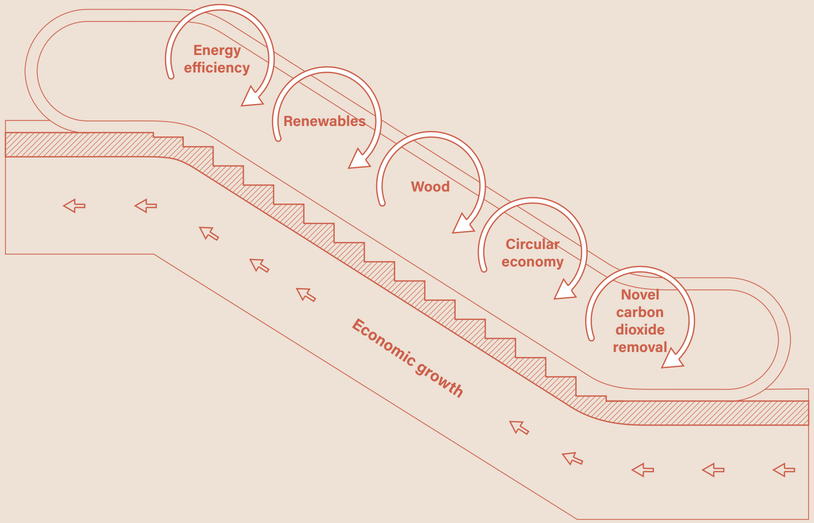
This distinction is crucial unleash potentials for genuinely addressing the Polycrisis. The building industry must abandon its role in perpetuating a growth-based economy that serves financial interests above all else. Instead, it must transform into a sector that builds in service of life—prioritizing ecological balance and social well-being. This shift is essential for the industry is to become part of the solution.

We must address the root cause of impact: overconsumption - rather than wait and hedge our bets. It's time to step off the escalator of endless growth and reorient focus towards using the innovation methods aligned with sufficiency principles (Figure 2.22).

The following chapters will explore a framework designed to enable systemic change within the construction industry. This framework will outline the pathways for transitioning from a model focused on profit and expansion to one rooted in sufficiency and regeneration. By adopting this new model, the building industry can play a pivotal role in creating a future where the built environment supports both people and the planet.

Finding the agency and means to navigate the polycrisis, and to prevent their collapse, requires a recognition of some of the obstacles and berries keeping us from intervening in meaningful ways. Based on key learnings from Chapter 1 and Chapter 2 the following section details four "Preconditions for practice" for moving towards building within planetary boundaries.

Within a growth-based economy, innovation and technology are primarily viewed as opportunities for financial growth, thereby undermining their ability to effectively reduce planetary pressures.



However, in a sufficiency-based economy, innovation and technology are used to increase well-being while reducing production and consumption, making these effective responses for the polycrisis.

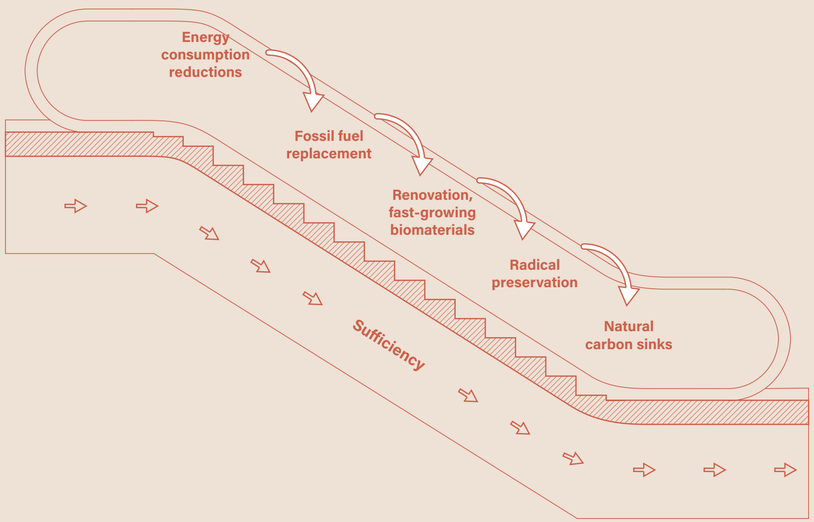


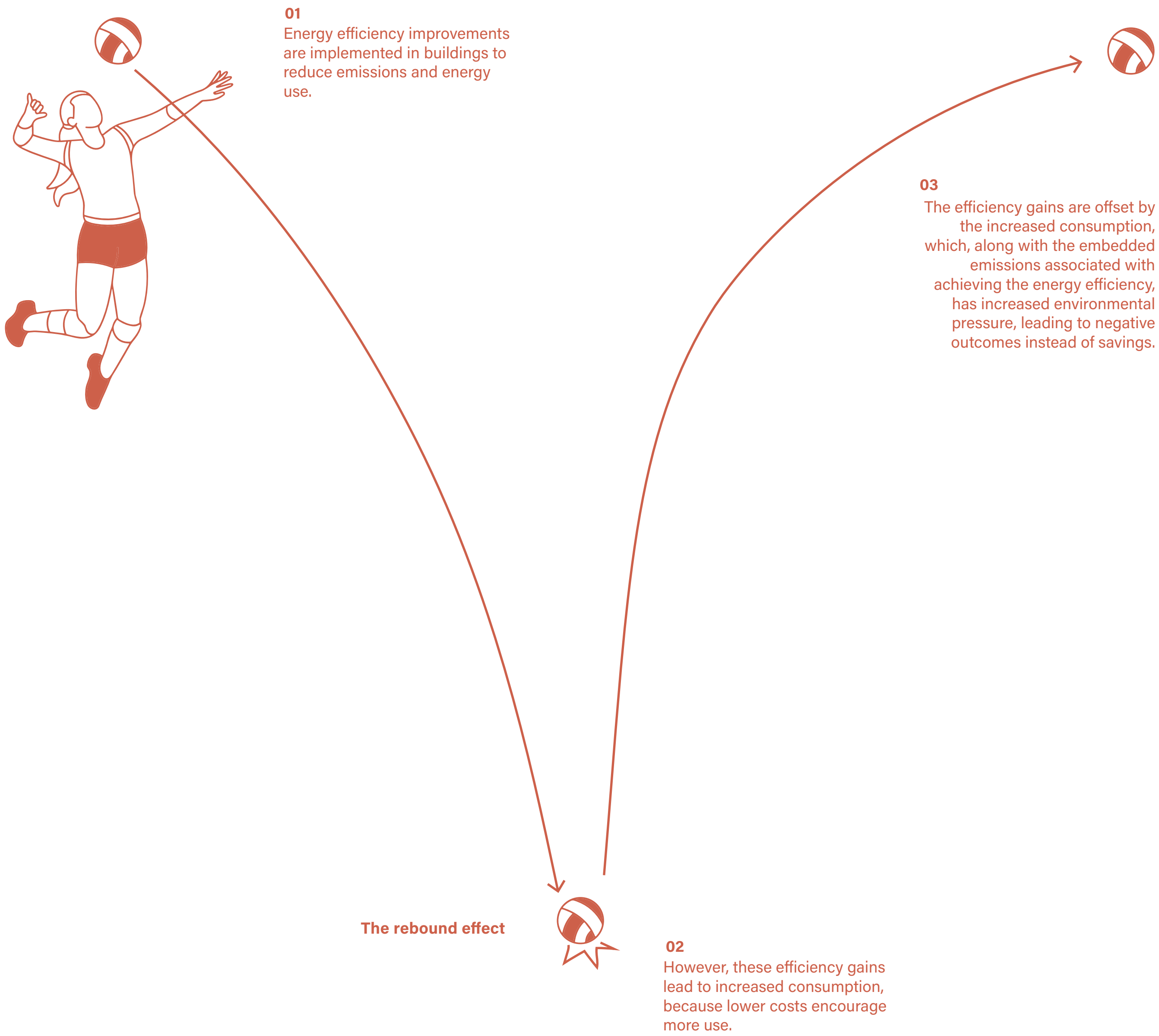
Figure 2.22 - From the escalator of endless growth, where innovation and technology are primarily used as an opportunity for financial growth - to the sufficiency-based economy where innovation and technology are used to increase well-being, reducing production and consumption. Source: Reduction Roadmap

How has the growth imperative limited the impact potential of energy efficiency?

The goal of improving energy efficiency in new buildings has been to reduce operational energy consumption and lower the carbon footprint. However, rather than decreasing overall consumption, the improvements have led to a rebound effect, where energy savings per square meter have been offset by a larger total building area.

Although investments in energy efficiency – improved mechanical systems, tighter envelope designs, better lighting equipment, passive solar design – have been perceived as highly effective in lowering energy costs and increasing energy productivity, long-term, economy-wide rebounds are becoming evident. This phenomenon, described in Chapter 1 as "Jevons Paradox" and referred to by Kristen Gram Hansen as "the rebound effect," highlights the unintended consequences of such improvements.

Research based on European countries and the U.S. shows that energy efficiency improvements result in rebound effects of 78% - 101%, meaning most of the energy savings are offset by increased demand. In some cases, the rebound exceeds 100%, leading to backfire, where energy consumption increases[3]. This issue is further exacerbated



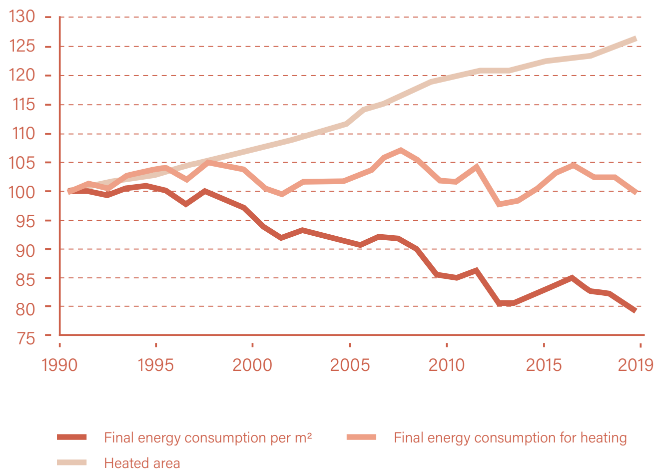


Figure 2.1 - Energy consumption for heating by the Danish residential sector (single family) houses and apartments) from 1990-2022.
Source: Energistatistikken 2022

when considering the additional emissions associated with the materials required to implement these improvements, underscoring a significant limitation of using this strategy in a growth-based economy.

In its AR6 report, the IPCC confirms that global emissions have rebounded. While improvements in energy efficiency and cleaner energy sources have reduced emissions from fossil fuel use, these gains have been outweighed by increased emissions from growing activity in industries such as energy supply, transport, agriculture, and buildings[4].

In Denmark, the total final consumption for heating by the residential sector has not changed since 1990[5] (Figure 2.1). Although some may see this as a success during a period when Denmark's population grew by about 700,000, this stagnation is not enough to effectively respond to the Polycrisis. The Danish trajectory is consistent with other minority world nations – even though advances in building policy and practice have resulted in a 20% decreased energy use per square meter, the total amount of conditioned square meters has grown by approximately 25%, effectively cancelling out projected energy use reductions[6].

This trend will continue if we keep building at a consistent rate– any efficiency gains through new heat pumps or novel insulation materials will be negated, as long as the amount of comfort-conditioned built area increases.

But in this problem also lies a solution – in the AR6, the IPCC quantifies that for minority world nations like Denmark, avoiding the demand for energy services through sufficiency policies has roughly double the potential to reduce greenhouse gas emissions compared to construction of new high-performing buildings[7].

Since 85-95% of all existing buildings in the EU are expected to still be standing in 2050, and more than 220 million units (85% of the EU's building stock) were built before 2001, with 75% being energy inefficient, the European Green Deal emphasizes energy retrofits as a key action[8]. Across the EU, the Renovation Wave initiative aims to renovate 35 million inefficient buildings by 2030 by increasing the annual renovation rate to 3%[9]. For the EU to reach net-zero, 146 million buildings need to be renovated by 2050[10]. Although deep energy retrofits are widely recognized as an effective way to mitigate greenhouse gas emissions, it is important to acknowledge that retrofits carry an embodied emission cost. A recent report finds that if existing buildings undergo typical energy retrofits by 2050, this action alone will use up 8.5% of the remaining global carbon budget for a 1.5°C compliant world[11] (Figure 2.3).

Reductions in energy consumption were negated by the expansion in built area; moreover, the embedded emissions associated with this increase in square meters escalated consumption, thereby amplifying pressures on planetary boundaries and exacerbating environmental harm rather than mitigating it.

Energy efficiency must not be misinterpreted as a call for endless construction of new high-performance buildings. In Denmark, deep energy retrofits of the existing building stock and a halt to the expansion of built area is how Denmark can enact the "efficiency without sufficiency" concept defined in Chapter 1.

Figure 2.3 - Retrofits carry an emodied carbon cost. For the EU to reach net-zero, 146 million buildings need to be renovated by 2050. It is important to acknowledge that retrofits carry an embodied emission cost. A recent report finds that if existing buildings undergo typical energy retrofits by 2050, this action alone will use up 8.5% of the remaining global carbon budget for a 1.5°C compliant world. Source: European Commission (2020), 'Renovation Wave: The European Green Deal,'

Kirsten Gram-Hanssen
Professor, BUILD AAU Copenhagen

Why the building efficiently has not led to lower energy consumption, and what we should do about it

Danish homes account for nearly a third of Denmark's total energy consumption, representing a significant portion of the country's emissions. For more than 30 years, there has been strict regulation on new construction, requiring the documentation of low energy design before a new house can be built. In recent years, similar regulations have applied to the renovations of existing buildings. Given this context, one would expect that Denmark's energy consumption for heating homes has decreased over the years. However, as shown in Figure 2.4, this is not the case. Today, we use the same exact amount of energy to heat our homes, as we did 30 years ago.

If we are to ensure that society operates within planetary boundaries in the future, it is important to understand why this efficiency hasn't resulted in lower consumption. There are two parallel explanations for why efficiency improvements haven't led to reduced consumption. At the same time our homes have become more efficient we have turned up the heat, and we live in increasingly larger homes.

Turning up the heat in energy efficient homes

The fact that we turn up the heat in our homes depending on how well-insulated they are can be illustrated by comparing buildings' energy labels with their actual consumption. For example, people often maintain a warmer temperature in newer, more efficient houses compared to older, less efficient ones. As shown in Figure 2.5, the calculated energy consumption for G-rated homes is much higher than for A-rated homes. This is not surprising, as the energy label is designed to show exactly that. Energy labels calculate how much energy is needed to evenly heat the entire home to 20 degrees Celsius.

However, if we look at the actual energy consumption in the same homes, we see that in G-rated homes, people use only about half the amount of energy for heating, while in A-rated homes, they use significantly more energy than the energy label calculations predict. When comparing the actual energy consumption across different energy classes of houses (the red bars in Figure 2.5), the difference between the best and worst-insulated homes is much smaller than the theoretical calculations predict.

This isn't particularly surprising. If you live in an older, poorly insulated house, you typically wear slippers and a thick sweater, and maybe only heat the rooms you use. On the other hand, we often see that the temperature in

Figure 2.4: Energy use in Danish households from 1920-2020. In the climate-adjusted consumption (red line), adjustments have been made for whether the winter was particularly warm or cold, allowing the consumption to be compared year by year, regardless of the weather. Source: Danish Energy Agency.

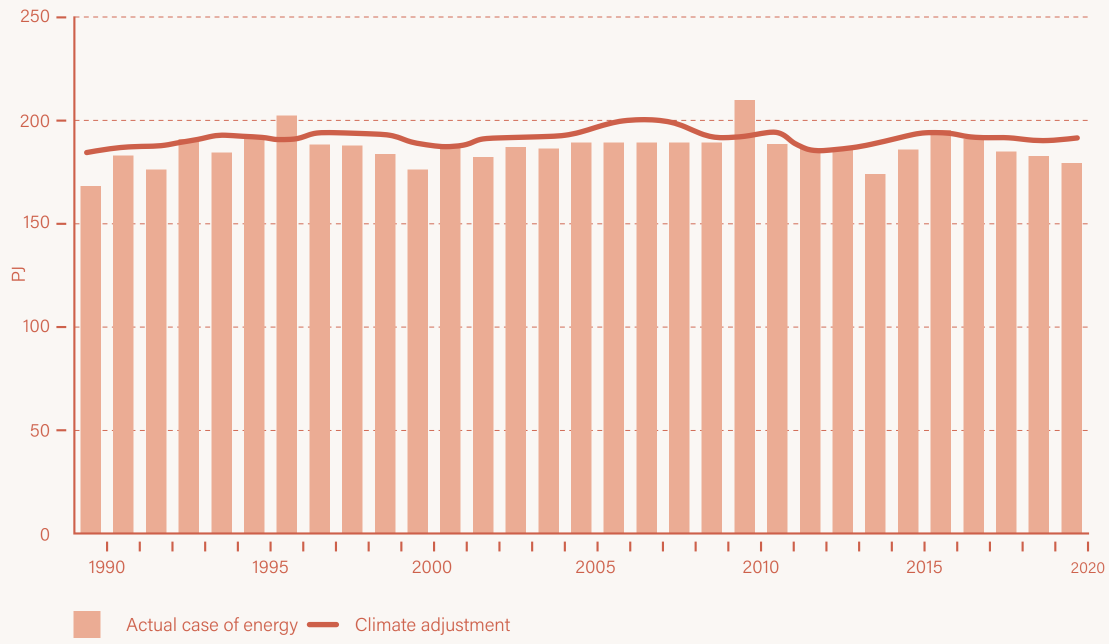
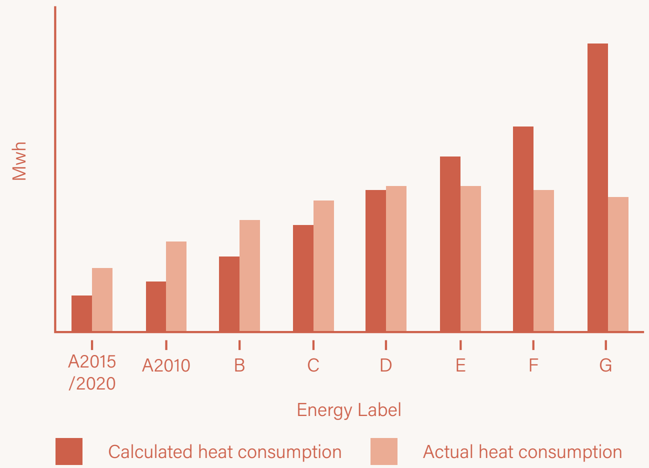


Figure 2.5: Comparison of calculated and actual energy consumption by energy labels and delivered heat consumption for more than 100,000 single-family homes from 2019-2021. Source: Hansen and Gram-Hanssen 2023.



modern, highly insulated homes is much higher than the 20 degrees assumed in the calculations, with residents going barefoot and wearing t-shirts indoors during the winter. People adjust their heating and clothing habits depending on how efficient their home is, and this is a key part of the explanation for why we don't achieve the expected savings from making our buildings more efficient.

We live with fewer people, in increasingly larger homes

Another reason why we don't achieve the expected savings from energy-efficient homes is that we live on increasingly more square meters per person. This is because the size of individual homes is increasing and because household sizes are decreasing. In Denmark today, the most common household type is a single person living alone, representing about 40% of all households. The second most common household size is two people. As shown in Figure 2.6, almost 75% of all homes in Denmark are occupied by only one or two people, whereas what is often referred to as a "nuclear family"—two parents and two children—is relatively rare, accounting for only 15% of all households.

In contrast, a large portion of the housing stock consists of family homes, specifically built for the nuclear family constellation. About 40% of all Danish homes are single-family houses, in addition to this townhouses and apartment buildings, which are also constructed as family homes. This creates a mismatch between the type of housing available and the demographic of households we have. There has been a demographic shift in the population, but not in available housing.

Energy Efficiency, Rebound Effect, and the Normalization of High Consumption

Energy efficiency is the focus of building policy in Denmark and the EU, aimed at reducing household energy consumption. But does this policy work? If we look at the graph in Figure 2.4, which shows that energy consumption in Danish households has remained largely unchanged over the past 30 years, despite significant political efforts to improve energy efficiency, the answer seems to be an obvious no. However, is the policy entirely ineffective? No, it is not.

If we consider the energy efficiency of, for example, electrical appliances, the policy has worked in the sense that individual appliances have become more efficient. The problem is that we now have significantly more and larger electrical appliances, which offset the technical efficiency gains. Similarly, with building efficiency, if we look at heating a single square meter of a home, there has been an improvement in efficiency, but at the same time, we are living in increasingly larger homes. Over the past 30 years, the average living space per person has increased by

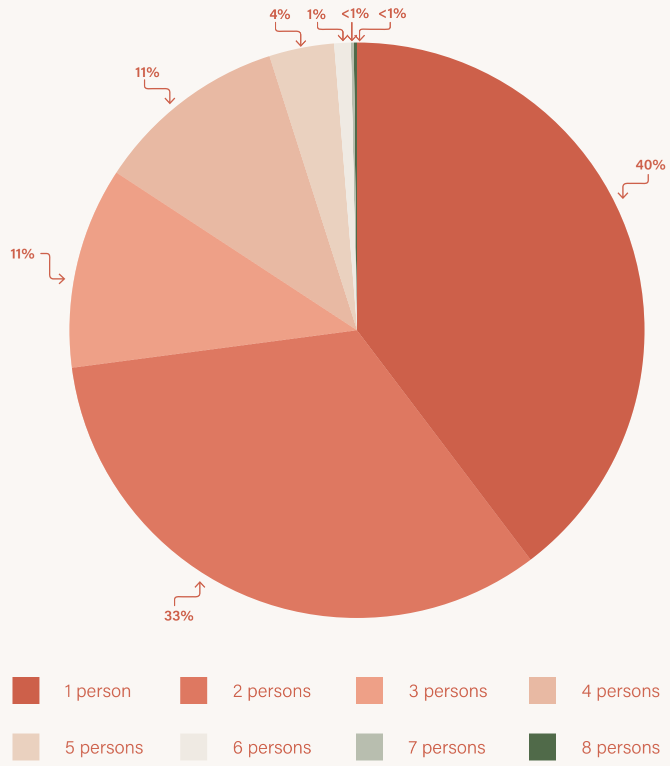


Figure 2.6 Danish household sizes Source: Statistics Denmark

An energy policy that focuses only on making homes and appliances more efficient, without considering the development of norms and lifestyles, cannot reduce energy consumption.

around 6 square meters, now exceeding 53 square meters per person.

The relationship between energy efficiency and behaviour is well known and is internationally referred to as the "rebound effect." The rebound effect was originally conceived and explained in economic terms. For economists, the simple explanation is that when something becomes cheaper, such as heating your home, you can afford more of it, which means you turn up the heat. This is called the direct rebound effect. You might also choose to spend the money saved on heating on something entirely different, like a flight to Thailand. This is called the indirect rebound effect. In this simplified economic explanation, the consumer appears as a rational actor who has a clear understanding of all expenses related to energy consumption, with or without energy efficiency improvements.

However, sociological research suggests that consumers rarely have such an overview, so the mechanism of increased consumption because of energy efficiency can also be seen as a psychological mechanism. If someone knows they have an energy-efficient home, they may think they don't need to be as cautious about saving energy.

Regardless of the explanation for the rebound effect, there is broad agreement about its existence, and research suggests that 20-60% of the estimated savings are likely to be offset by higher consumption.

The rebound effect can also be seen in a broader societal context, where ideas for what is considered normal change over time alongside what is technically possible. Before showers were installed in all homes, it was not common to bathe every day, and a bathroom in a home was a luxury 100 years ago, whereas today it is common for family homes to be built with multiple bathrooms. Before 2000, it was not necessary for ordinary people to have a computer at home, and it was certainly not common for everyone to have their own PC and mobile phone. What is considered normal and necessary for everyday life changes with technological advancements.

An energy policy that focuses only on making homes and appliances more efficient, without considering the development of norms and lifestyles, cannot reduce energy consumption. This is also evident in Figure 1, where energy consumption has not decreased in the past 30 years. Politically, it can be seen as a success that energy consumption has not increased over the past decades, despite economic growth and population increase during the same period. Whether or not it is a success or failure also depends on the political objective.

When Enough is Enough: A Question of Sufficiency

If the political goal is to move towards living within planetary boundaries and not just maintaining the status quo of our consumption, but reducing actual household energy use, some researchers argue that we need to focus on sufficiency, not just efficiency. Sufficiency implies a policy that addresses the question of 'When is enough, enough?'

Since the 1960s, most people in the Western world have experienced increasing material wealth, with larger homes heated to higher temperatures and equipped with more and more electrical appliances. The question, however, is whether quality of life has necessarily improved alongside this material growth. As a result, researchers and other experts are asking if we need to include additional parameters in energy policy to succeed in reducing energy consumption in both our homes and everyday life. The challenge is to identify the policies that could be used to address this issue, which requires understanding the multiplicity of drivers behind increased consumption. Some point to the growth-oriented economy, underpinning our society, as the root of the problem.

To address sufficiency in household energy use, one could examine the experiences of people who deliberately consume less. This could involve choosing to live in a much smaller home, such as tiny living phenomena, or living in co-housing community where space and resources are shared. It might also be relevant to examine how society's laws and institutions support or hinder these experiments. For instance, there have been cases where municipalities were reluctant to grant building permits for co-housing communities, a problem that has to some extent been overcome, as this form of living has become more common.

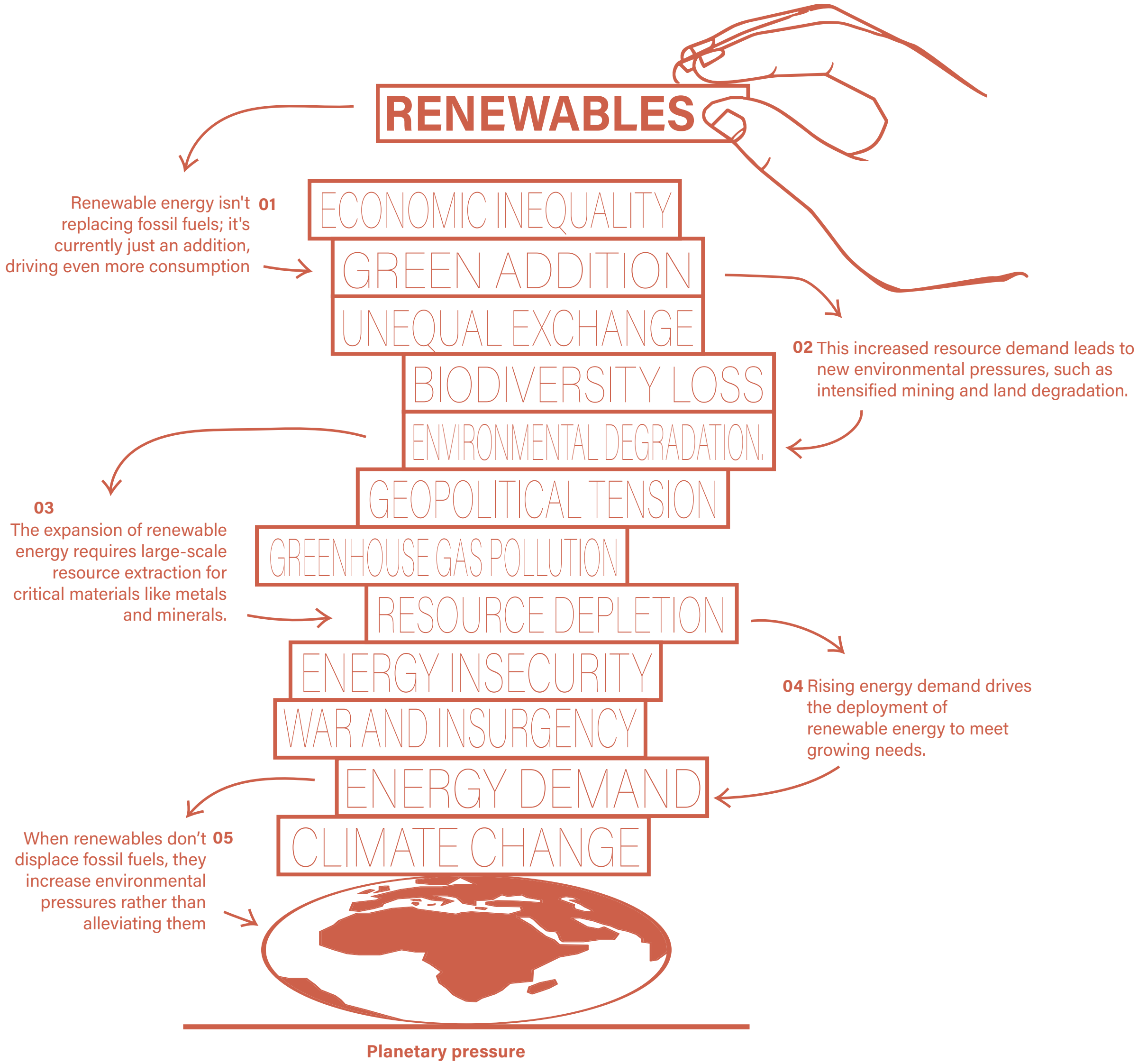
To conclude, lifestyle is not just an individual choice—we are also dependent on policies, to support choices that lead to actual lower consumption.

The question, however, is whether quality of life has necessarily improved alongside this material growth....The challenge is to identify the policies that could be used to address this issue, which requires understanding the multiplicity of drivers behind increased consumption. Some point to the growth-oriented economy, underpinning our society, as the root of the problem.

How has the growth imperative limited the impact potential of renewable energy?

The goal of deploying new renewable energy sources is to decrease consumption of fossil fuels, thereby a reduction in greenhouse gas emissions. To date, the transition to renewable energy has not and shows no promise of, effectively replacing fossil fuels and biomass within the current economic system that is dependent on growth. Furthermore, the embodied costs of renewable technologies place a strain on communities and ecosystems near and within extraction sites of non-renewable minerals. Together these conditions exacerbate the Polycrisis.

Scenarios that meet the Paris Agreement's 1.5°C target while continuing global economic growth—and without relying on technologies that remove carbon from the atmosphere or extreme efficiency improvements—predict that renewable energy capacity will need to grow 50 times larger by 2050 compared to 2019 levels. In contrast, scenarios that do not prioritize economic growth predict a smaller increase in renewable energy capacity, growing by 11 to 25 times[12] . Therefore, expanding consumption and production significantly increases the pressure on the renewable energy transition, making it harder to achieve - resulting in what is described as "green addition" in Chapter 1.



Although Denmark is both producing and consuming the most non-fossil fuel energy in its history, this transition is largely made possible by switching to biomass, which, when burned, emits more carbon to the atmosphere than fossil fuels per generated energy unit.

The renewable energy transition comes at a cost to the planet– compared to 1 kWh of fossil energy, 1 kWh of renewable energy requires approximately 10 times more metals[13]. The IEA projects that by 2040, total mineral demand from clean energy technologies will increase in the range from two- to four-fold, depending on the stringency of sustainable transition policies[14]. As such, the global demand for renewable energy worsens the consumption problem.

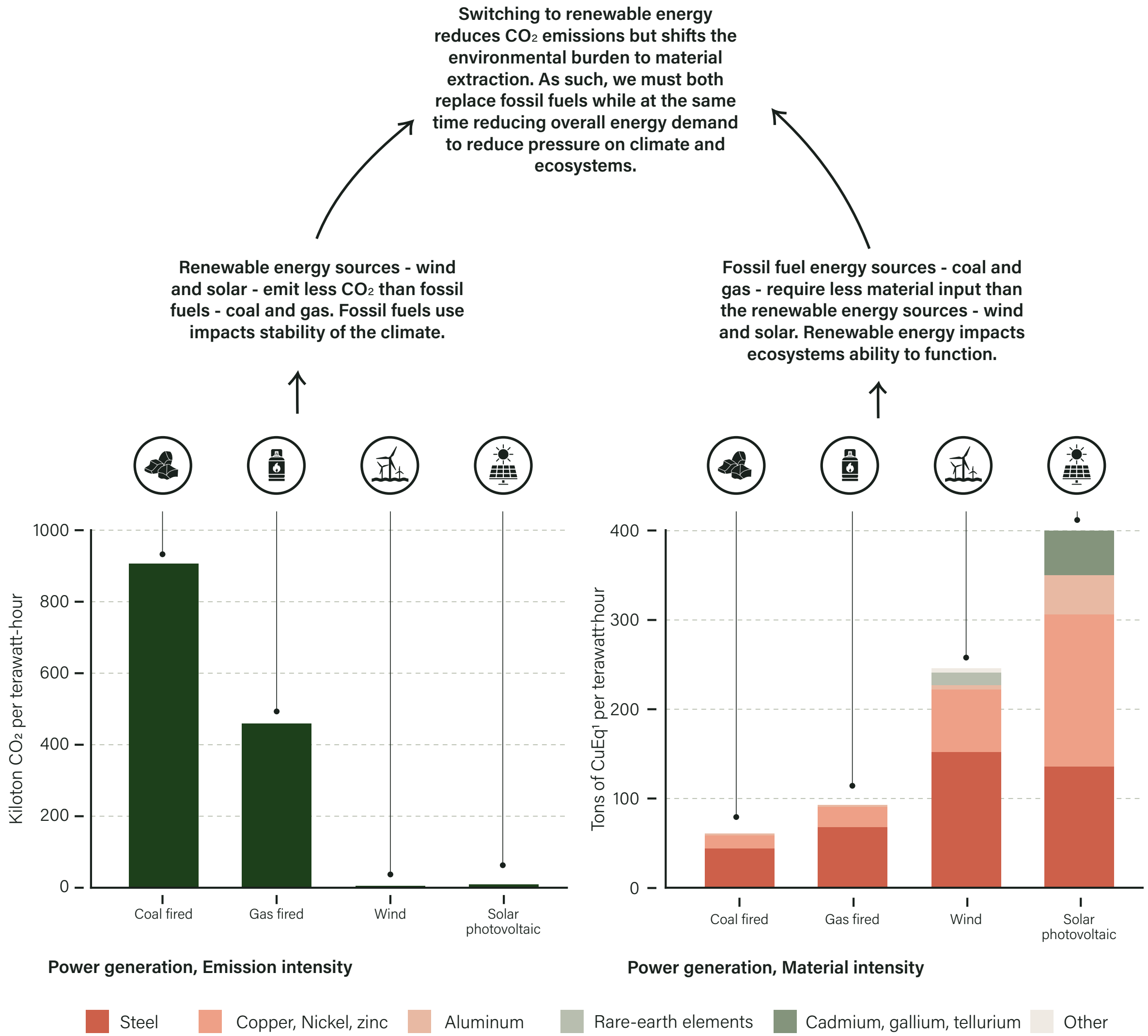
The extraction of raw materials is expected to increase by 60% by 2060, further burdening extractive industries that already account for 50% of global carbon emissions and contribute to 80% of biodiversity loss. Furthermore, mining finite minerals necessary for the renewable energy transition puts strain on local environments and communities near mining sites.

Since 2010, The Business & Human Rights Resource Centre has tracked human and environmental rights impacts of mining the six minerals that are key to the energy transition – cobalt, copper, lithium, manganese, nickel, and zinc. More than 500 allegations of abuse by transition mineral mining companies have been registered to date, with attacks against human rights defenders and water pollution taking center stage predominantly in the majority world[15]. As the renewable transition mineral rush grows more intense, human and environmental rights must be upheld in global agreements, to avoid the risk of worsening on-going human rights abuse and corruption[16].

As of 2023, the combined share of wind, solar, and biomass in the Danish energy generation mixes for electricity was at 73% [17]. Although Denmark is both producing and consuming the most non-fossil fuel energy in its history, this transition was largely made possible by switching to biomass, which, when burned, emits more carbon to the atmosphere than fossil fuels per generated energy unit. For this reason, the definition of biomass as a renewable and carbon-neutral energy source is highly debated. In this report, "renewable energy" will therefore refer specifically to energy from wind and solar sources, excluding biomass combustion (Box 2.5)

In 2022, renewable energy (excluding biomass) constituted 34% of the total energy generated in Denmark. The other half is primarily generated through combustion of wood pellets, with some contribution from biogas, municipal waste, and liquid biofuels. Renewable energy generation is not the same as consumption, since electricity is traded across borders both directly and in terms of indirect electricity used to create consumer goods. The share of non-fossil fuel energy for electricity consumed in Denmark in 2022 was just under 40%, and the share of renewables within that, lower still[19]. In other words, Denmark is not yet halfway

Figure 2.7 - Significantly reducing emission intensity with low-carbon technologies will demand higher material input. This is crucial because renewable energy sources like wind and solar, while climate-friendly, will impact ecosystems through increased material demands, whereas fossil fuels undermine climate stability. Therefore, a sustainable energy transition requires reducing overall energy demand. Source: Azevedo, M. et al. (2022) 'The raw-materials challenge: How the metals and mining sector will be at the core of enabling the energy transition', McKinsey & Company available at mckinsey.com



to achieving a fully renewable energy economy. Renewable energy cannot replace biomass and fossil fuels if Danish energy consumption continues to grow. The transition will not be meaningful if new wind and solar farms only add capacity to meet the increasing demand for electric homes, cars, and industries, without shutting down fossil fuel or biomass plants.

Shifting away from fossil fuels and biomass is essential for reducing global warming. However, economic and infrastructure expansion creates unnecessary pressure on the renewable transition, both in terms of technical feasibility and the environmental and social impacts on communities near mineral extraction sites. Since 2000, electricity demand in buildings has grown five times faster than improvements in the carbon intensity of power[20]. Although Denmark is perceived as global leader in renewable energy, overconsumption in the building sector risks making the goal of 100% renewable energy unattainable (Figure 2.8).

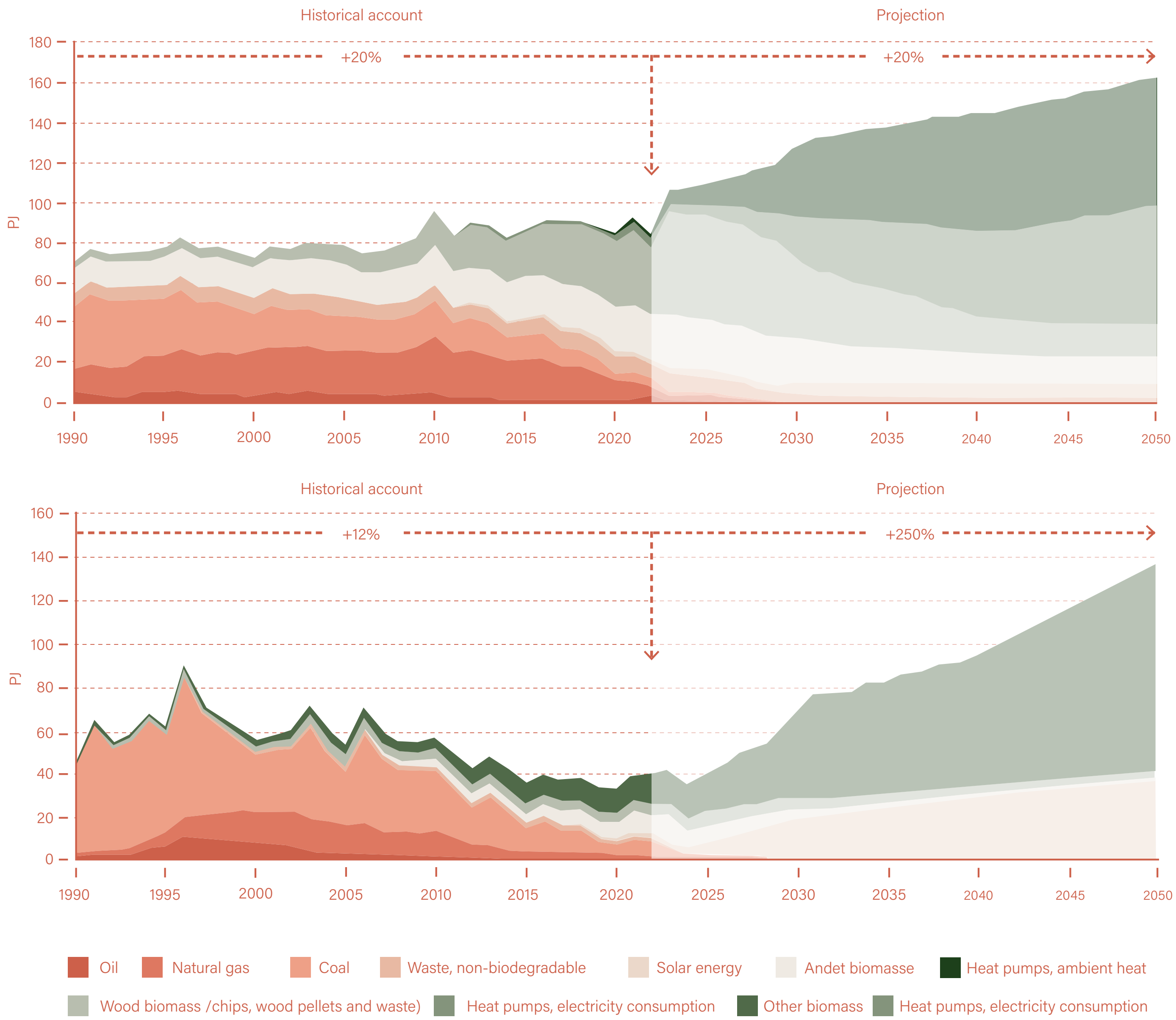


Figure 2.8 Historical fuel consumption for electricity and heat production and forecast of future demand up to 2035 in Denmark. Source: Energistyrelsen, "Klimastatus og -fremskrivning 2023" [18]

Box 2.1: Biomass as an energy source

When bioenergy production was conceived, the idea was, that it would serve as a carbon-neutral approach to the green transition of the energy sectoThe harsh reality is, that harvesting, transporting and burning biomass for energy generation immediately releases greenhouse gases into the atmosphere, with long-lasting climate consequences.

The European Union has long included biomass combustion in its definition of renewable energy, therefore granting subsidies wood pellet power plants. Denmark is one of the leading adopters of bioenergy production in Europe, despite being a wood importing country. In 2018, 87% of the wood consumed in Denmark was burned for energy generation[21].

However, scientists are reevaluating the classification of biomass as renewable. The definition of bioenergy as "carbon-neutral" relies on the assumption that wood can be regrown, even though burning wood pellets immediately releases carbon into the atmosphere. This definition fails to account for the fact that forest regrowth can take 50 to 100 years—time that the planet cannot afford in the context of the climate emergency. Additionally, forests are one of humanity's most effective tools for mitigating climate change, yet forest ecosystems are also vulnerable to its effects. With the increasing frequency of wildfires, droughts, and pest infestations, it remains uncertain whether future forests will regrow in areas that have been clearcut.

The promise of bioenergy to prevent the release of greenhouse gases into the atmosphere has not been fulfilled. When wood is harvested, processed into pellets, transported, and burned, it ultimately adds two to three times more carbon to the air than fossil fuels for each kilowatt-hour of energy produced[23]. While bioenergy was seen as a transitional step away from fossil fuel dependency, it should also be phased out in industrial settings in favor of wind and solar energy in the future.

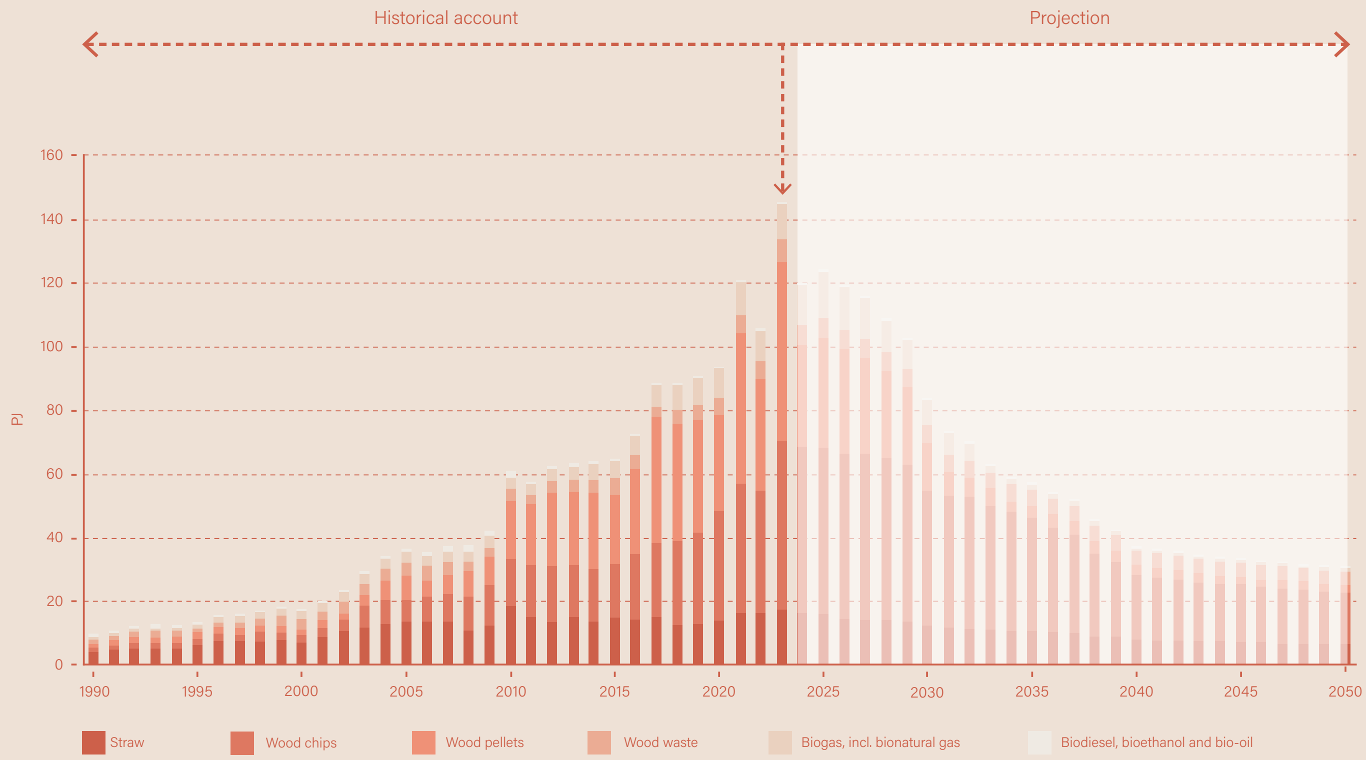
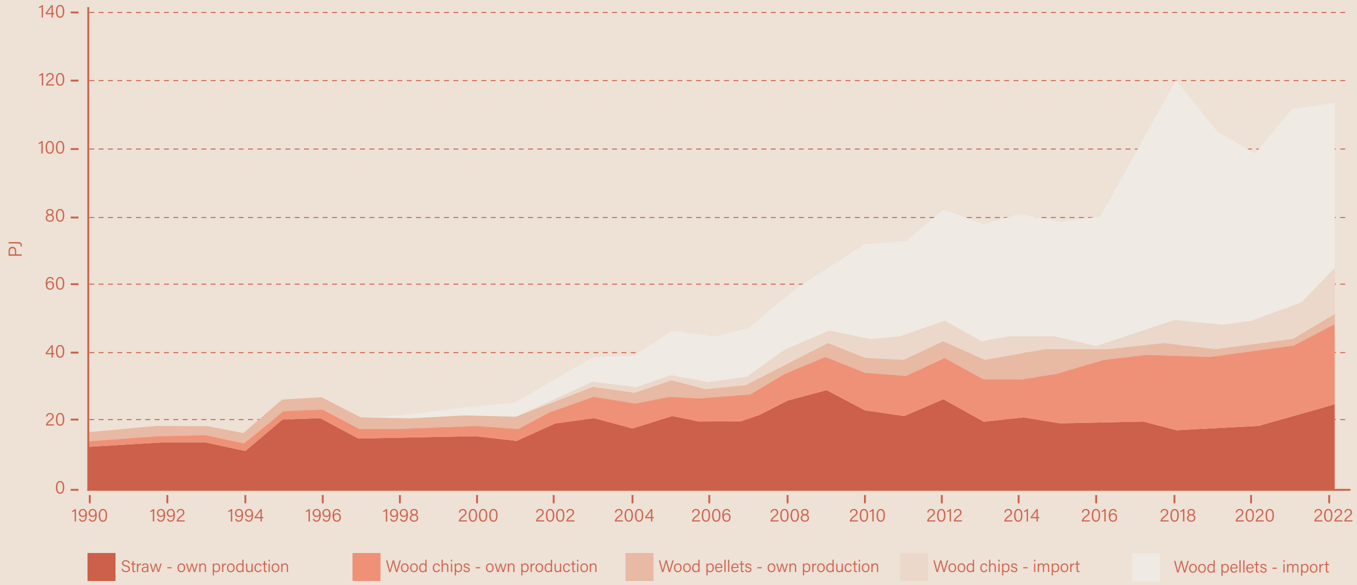


Figure 2.9 Use of biofuels in the Danish electricity and district heating sector. Source: "Energistatistik 2022"; Energistyrelsen, "Analyseforudsætninger til Energinet 2022"

Forests are one of humanity's most effective tools for mitigating climate change, yet forest ecosystems are also vulnerable to its effects. With the increasing frequency of wildfires, droughts, and pest infestations, it remains uncertain whether future forests will regrow in areas that have been clearcut.

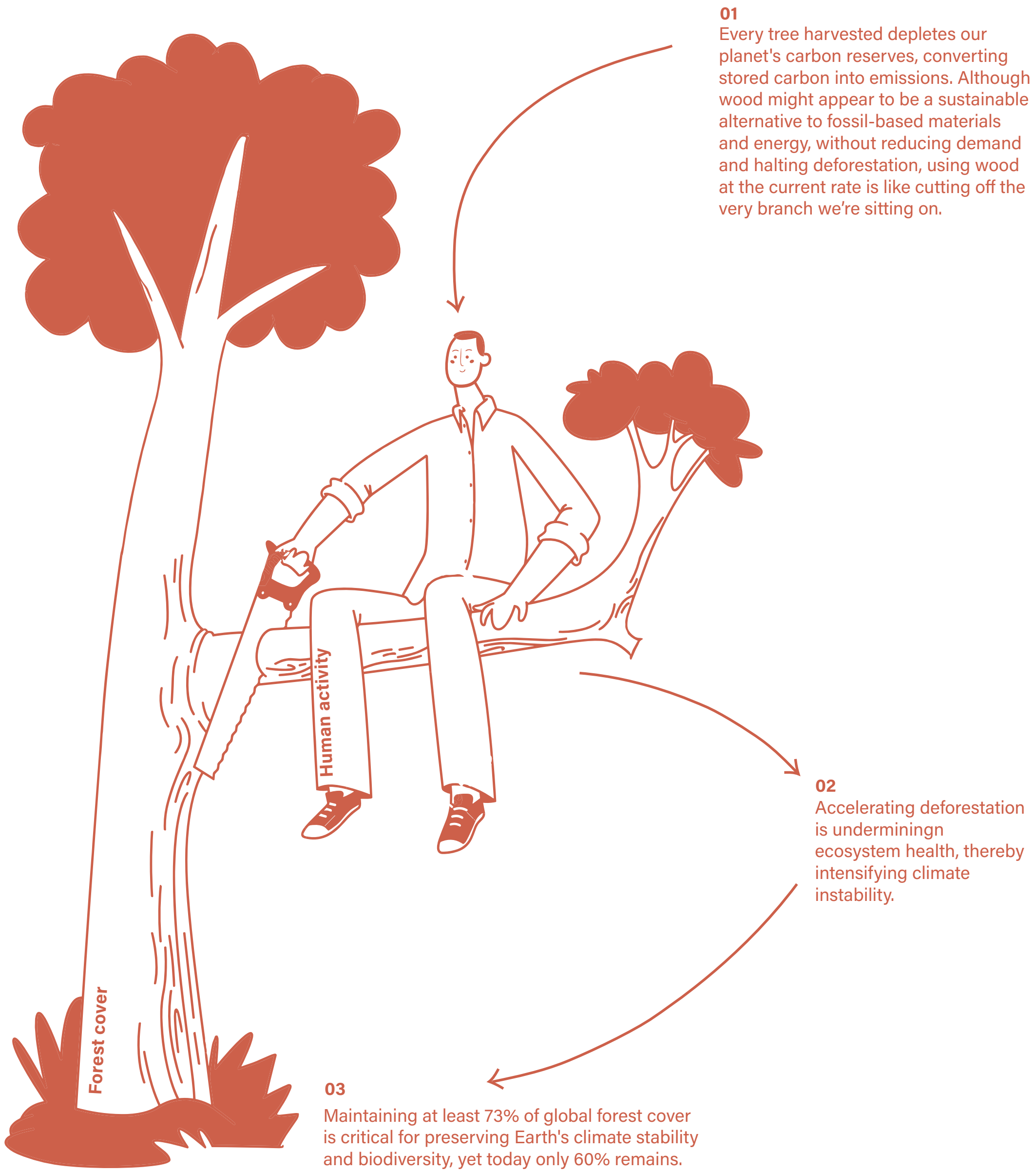
Figure 2.10 Denmark's total domestic production and import of biomass. Straw is also imported, but is not at a visible scale in this grapth. Source: Denmark Statistics, 2024.



How has the growth imperative limited the impact potential of wood (as a building material)?

To reduce the climate impact of construction and carbon intensive materials like concrete and steel, the building industry is increasingly turning to wood as a sustainable alternative. While this shift aims to lower emissions, it has also led to a higher demand for wood, which puts additional pressure on already-stressed planetary boundaries like land-use change and biosphere integrity.

Wood, along with other biobased materials such as straw, hemp, bamboo, eelgrass, and fungi, presents a promising solution for addressing climate challenges. These materials offer multiple advantages: they can reduce environmental impact, support rural economies, enable prefabrication in construction, and create meaningful spaces that speak to human senses.[29] Recent advancements in wood construction technology have additionally allowed for taller and more innovative hybrid wooden structures, offering the promise of soaring higher while reducing – not eliminating – our reliance on concrete and steel[30]. In Denmark, enthusiasm for biobased construction is spurred by initiatives and prototypes constructed in both professional and academic contexts[31].



...when evaluating the overall impact of wood utilization, it is crucial to consider both the amount of wood used and the carbon emissions associated with the parts of the tree that are not utilized.

While wood-based materials come from a renewable resource, they are also finite, emphasizing the importance of increasing resource efficiency through the cascading use of wood. The cascading use concept aims to maximize the added value and reduce environmental impact by prioritizing applications with high economic return before reusing, recycling, and ultimately burning wood for energy purposes. This approach has much in common with the circular economy but is focused specifically on bio-based materials. By maximizing the economic value of biomass through multiple lifetimes, cascading use can enhance resource efficiency, potentially increasing wood availability for other uses by up to one-third.

Ensuring the cascading use of wood also requires alignment among forest management practices, industrial processes, and legislative frameworks. This alignment is essential for achieving an efficient use while alleviating some of the environmental pressures caused by the growing demand for wood[32].

Despite the potential benefits of wood-based construction, environmental claims about wood-based building materials are only valid if the wood originates from sustainably managed forests. This means that any carbon "credit" for using wood is only legitimate if the forest is replanted and its ecosystem remains functional. Third-party forest certifications, such as those from the Forest Stewardship Council (FSC), provide some assurance in this regard. For instance, FSC-certified forests in various North American biomes have been found to store more carbon on average compared to uncertified forests, underscoring the role of certification in ensuring sustainable forest management[33]. Quantifying the impact of using wood as a substitute for traditional building materials is technically complex and influenced by several factors, including the specific product in question, the material being replaced, the expected lifespan of each, and the amount of wood effectively utilized. While wood is often viewed as a sustainable option, it's important to recognize that only a portion of a harvested tree is used in construction or other products. A significant amount—including roots, branches, and bark—is typically left in the forest to decompose or is burned. Furthermore, milling processes generate additional waste, such as chips and sawdust, which are often discarded or incinerated.

These practices result in the release of carbon into the atmosphere that would otherwise remain stored if the forests were undisturbed. Therefore, when evaluating the overall impact of wood utilization, it is crucial to consider both the amount of wood used and the carbon emissions associated with the parts of the tree that are not utilized[34 35]. Figure 2.12 illustrates the utilization of wood in Denmark in 2018. Of the total wood used, 85% was dedicated to energy production (including both centralized and household usage), while only 9% was used in buildings[36].

Figure 2.11 - Net emissions and removals in different forest carbon pools and subcategories, including harvested wood products (HWP) as reported in the EU GHGI 2023 [39]

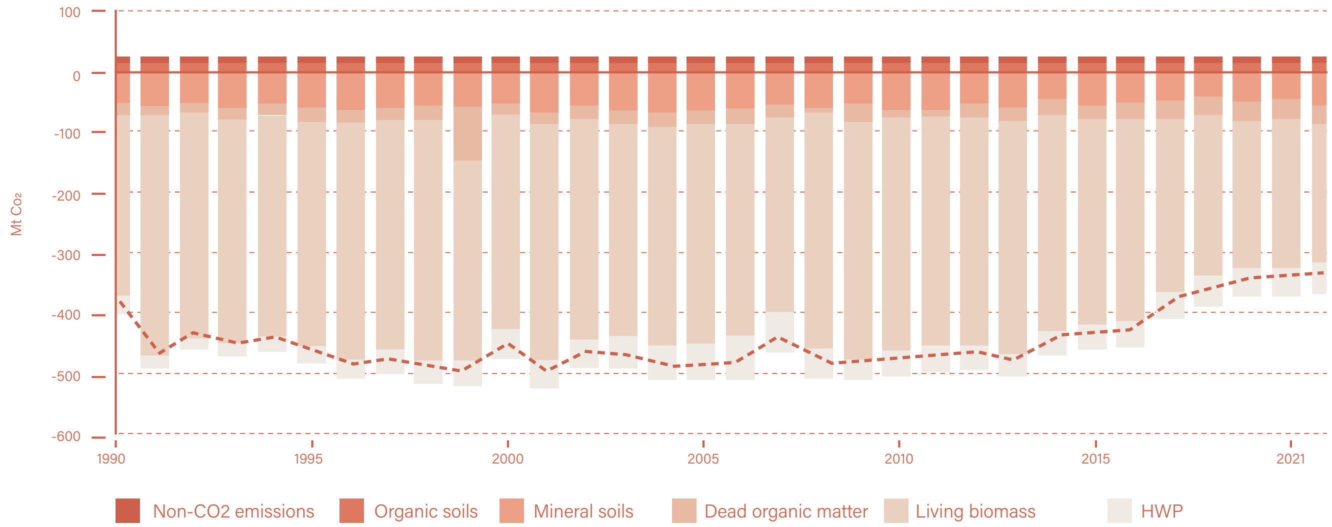


Figure 2.12 - Danish consumption of wood broken down by economy in 2018. Source: Brownell II, P. H., Iliev, B. E., & Bentsen, N. S. (2023). Wood flows through the Danish economy. Department of Geosciences and Natural Resource Management, University of Copenhagen. IGN Report No. March 2023[39].

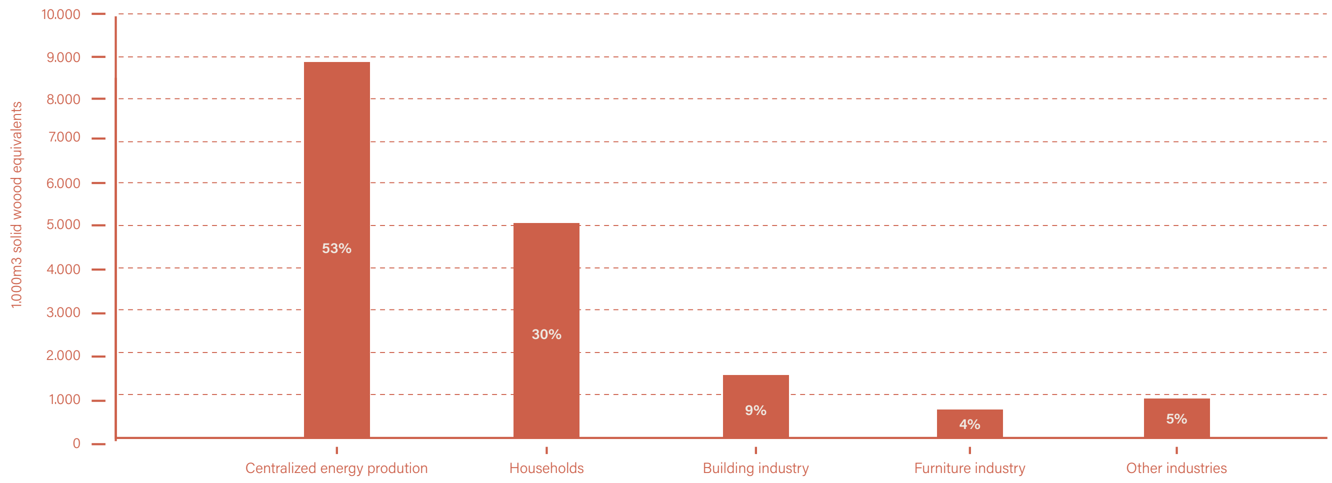


Figure 2.13 - When the IPCC charts available climate mitigation options, the power of forests is unmatched by nearly any other technology.
Source: IPCC AR6

If forests are managed sustainably and harvested selectively, this approach can create conditions that promote growth and regeneration. Selectively removing a small number of trees allows the remaining ones to benefit from increased light, space, and resources, which can lead to improved growth rates. Furthermore, when all parts of harvested trees are utilized, this practice can result in a net increase in carbon sequestration compared to forests that have reached their carbon saturation point.

To achieve higher harvest levels while maintaining carbon storage in forests, a strong commitment to sustainability and ongoing reforestation efforts is essential. The rising demand for timber in construction must be supported by robust legal frameworks, effective forest certification schemes, and the empowerment of local communities. Additionally, addressing illegal logging and exploring alternatives like bamboo and other plant fibers in tropical and subtropical regions are crucial strategies. It is also vital to preserve biologically valuable or vulnerable forests as reserves to protect their ecological integrity[37].

As shown in Figure 2.11, carbon uptake in EU forests is declining due to a decrease in net annual growth and an increase in both mortality rates and harvesting. This rise in harvesting is partly driven by a shift towards more intensive forest management practices focused on timber production, which may not support maintaining or enhancing carbon sinks. These practices often involve the use of fast-growing species and monocultures, which can reduce the resilience of forest ecosystems. To reverse the decline in forest carbon sinks, it is essential to adopt climate-smart forest management practices[38].

As such, the increasing reliance on forests for carbon mitigation is leading to the depletion of one of the most effective natural carbon sinks, while being used to support claims of "net-zero" energy solutions. At the same time, this reasoning is being applied to justify continued construction and expansion, which contributes to ongoing environmental degradation.

Although biobased materials like wood are being promoted as sustainable alternatives, large-scale construction using these materials requires a substantial increase in wood harvesting. Forests play a critical role in biodiversity, global hydrology, and erosion regulation, and large-scale timber production can disrupt these functions[40].

Meeting growing construction demands with mass timber would significantly increase pressure on forests. By 2050, timber, paper, and other wood uses (excluding fuel) are

Although biobased materials like wood are being promoted as sustainable alternatives, large-scale construction using these materials requires a substantial increase in wood harvesting. Forests play a critical role in biodiversity, global hydrology, and erosion regulation, and large-scale timber production can disrupt these functions[40].

expected to rise by 90% compared to 2010, resulting in the harvest of 800 million hectares of forest—an area the size of the continental U.S. Annual emissions from these harvests could reach 3.5-4.2 billion tons annually, accounting for over 10% of current global CO2 emission. Shifting to mass timber for 50% of new construction would double industrial wood demand by 2050, requiring unsustainable harvests from both preferred and non-preferred forest types[41]. (Figure 2.14)

According to the IPCC (Figure 2.13), forests offer one of the most powerful climate mitigation solutions available. Combined efforts to halt the conversion of natural ecosystems, scale up reforestation and afforestation, and improve forest management are projected to mitigate 8.5 $GtCO_2eq$/year. For comparison, improvements in building efficiency are expected to mitigate 1.5 $GtCO_2eq$ per year[42].

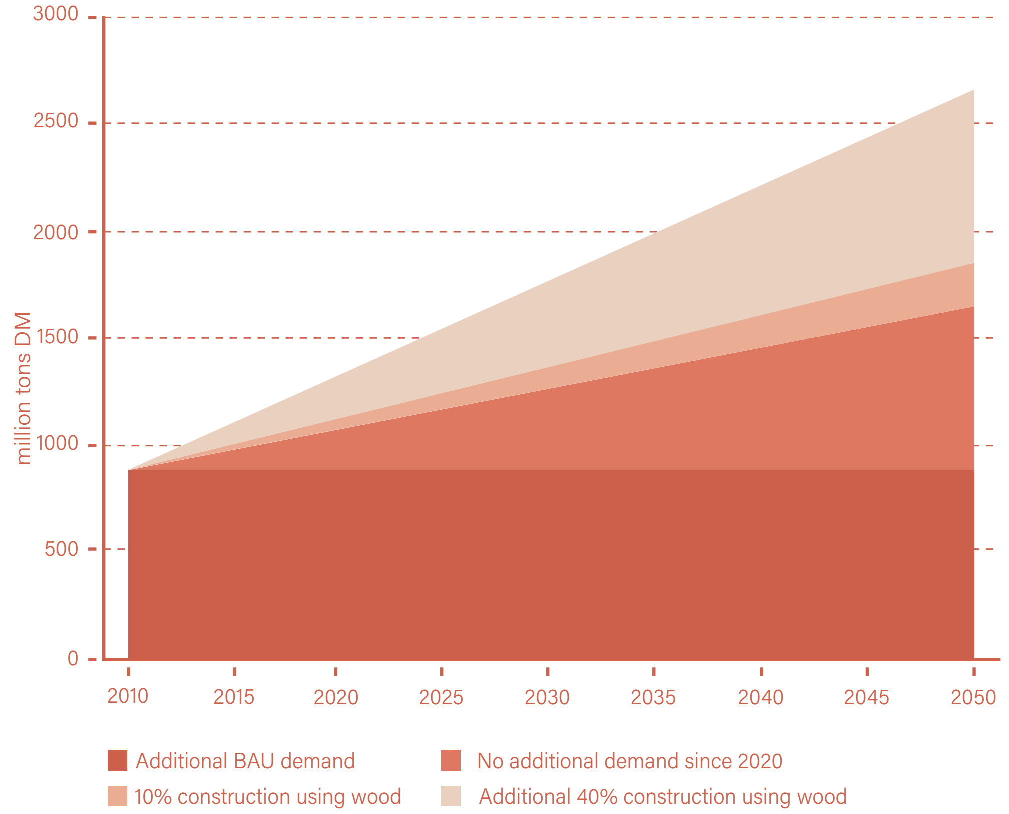


Figure 2.14 - Mass timber could great increase global timber demand.
Source: Churkina et al. (2020) Adapting additional wood demand scenarios

How has the growth imperative limited the impact potential of Circular Economy?

The circular economy is a design strategy aimed at decoupling economic growth from material use, gaining traction over the past decade. However, the potential for a fully circular society remains limited within a growth-dependent economic system. As a result, the circular economy has yet to achieve reductions in material use or environmental impact.

Perhaps unsurprisingly, the mines we dig, the oil wells we drill and the forests we cut down are the largest predictors of environmental damage. Material extraction is responsible for more than 60% of global annual greenhouse gas emissions, and nearly all total biodiversity loss[47]. In the second half of the 20th century, the world economy seemed to be "dematerializing," with GDP growing faster than material use. However, this trend reversed in the 21st century, as material extraction surged rapidly[13]. As described in Chapter 1, since 1970 the global annual rate of material extraction has tripled and material consumption remains unequally distributed – minority world countries consume materials at a rate six times greater than majority world countries[49].

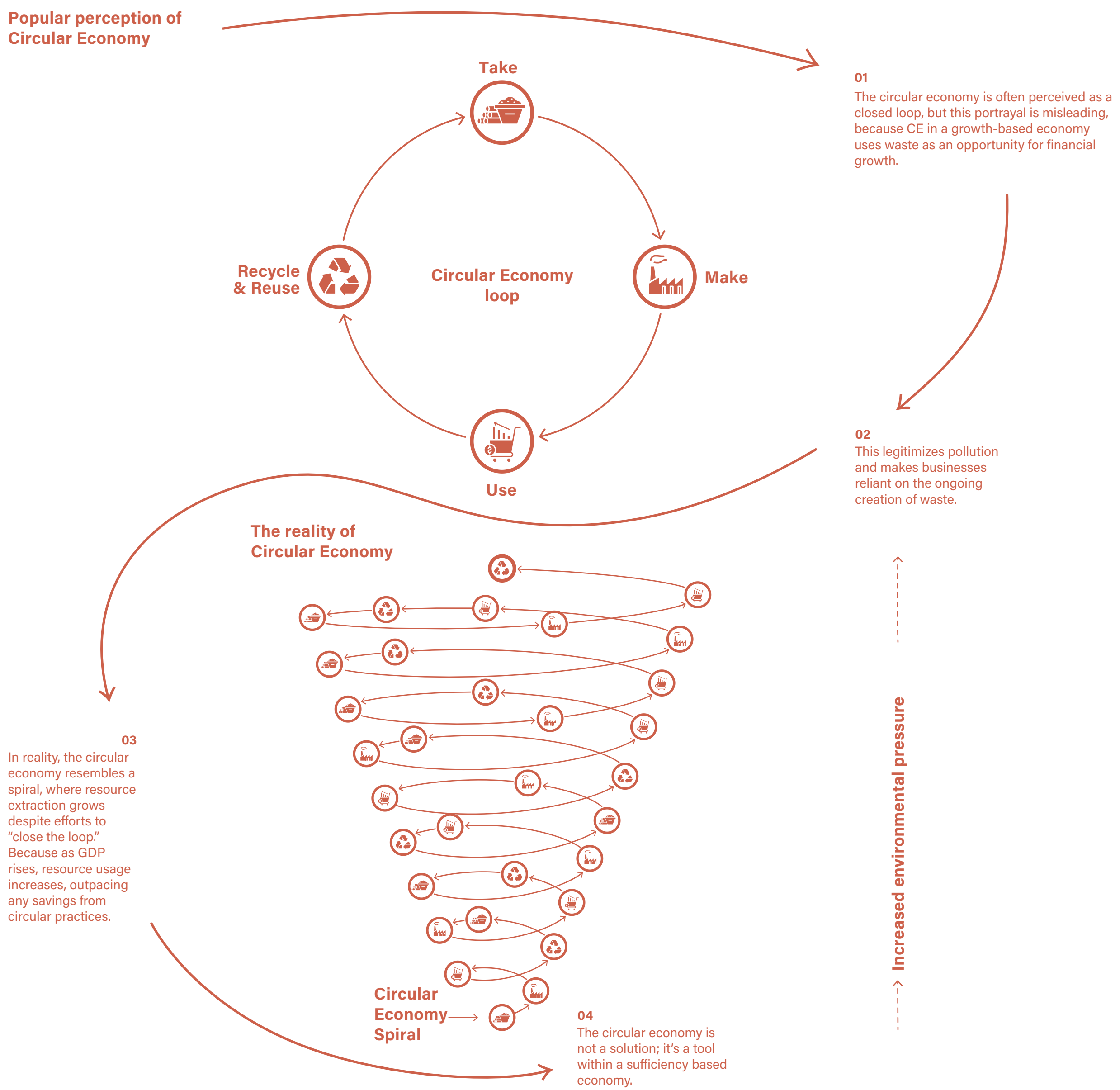


Figure 2.15 - Since 1970 the global annual rate of material extraction has tripled. Source: United Nations Environment Programme, "Global Resources Outlook 2024: Bend the Trend - Pathways to a livable planet as resource use spikes"

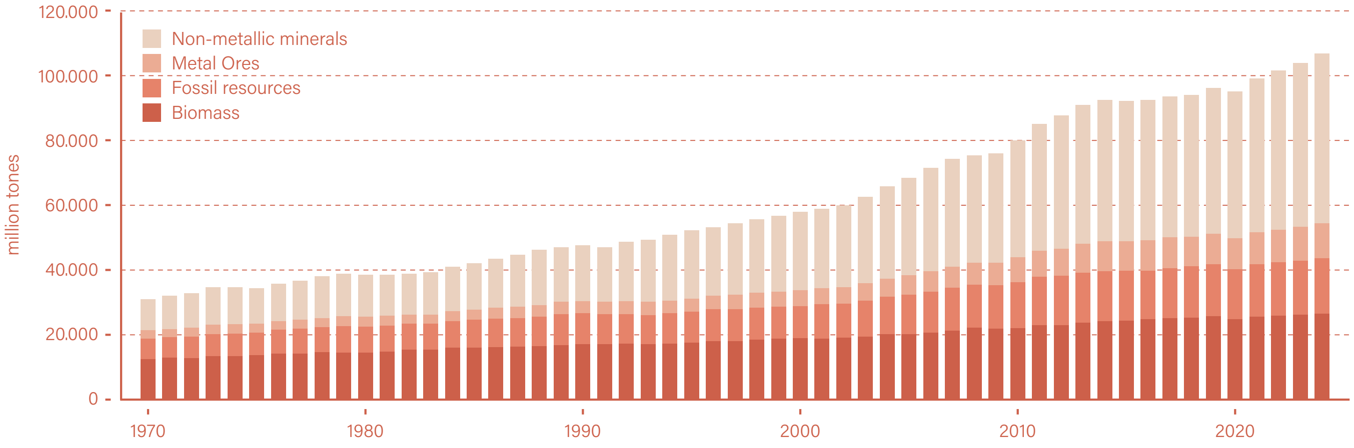
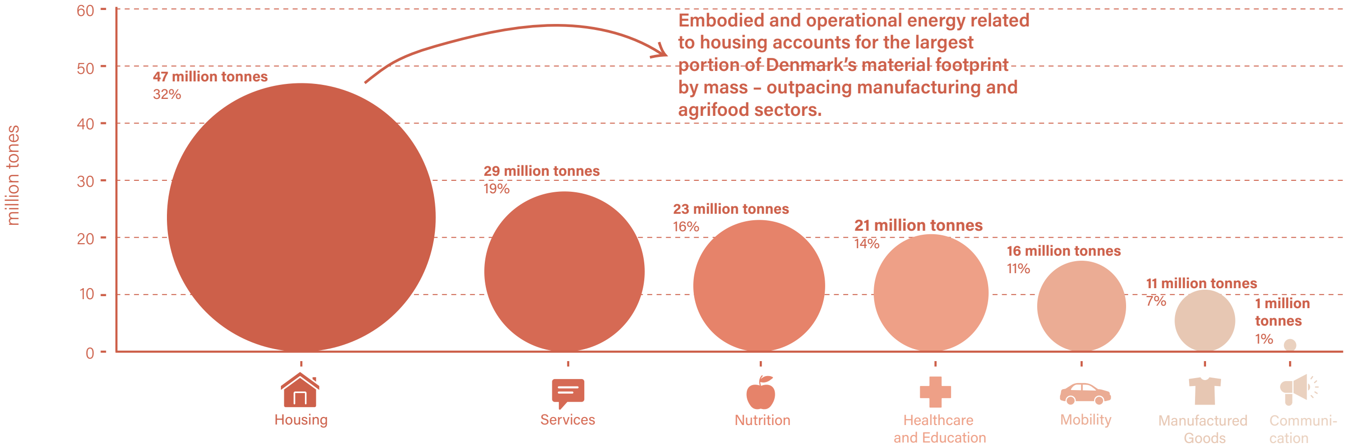


Figure 2.16 - Danish material consumption across various sectors in society. Construction of housing accounts for 32% of Denmark's material footprint by mass. Source: Circularity Gap Report - Denmark (2023)



The building industry offers the largest opportunity for transitioning material flows from linear to circular.

The import-heavy Danish material economy falls into this pattern, as it externalizes nearly three-quarters of extraction beyond its borders . The building industry is at the center of material extraction, as buildings use almost all the planet's cement, 26% of produced aluminum, 50% of steel and 25% of all plastics[48].

The average Dane consumes 24.5 tonnes of virgin material every year – roughly the weight of 16 African elephants. This staggering consumption is outweighs the global average of 11.9 tonnes and triple the estimated ecological ceiling of 8 tonnes .

Out of the 142.2 million tonnes of virgin materials that are consumed in Denmark every year, approximately 50% are directed into building and infrastructure stock - meaning those materials will not become available for recycling for decades to come. This is relatively high compared to neighboring EU nations, who are directing 20-35% of consumed material into this type of long-lasting stock. The building industry offers the largest opportunity for transitioning material flows from linear to circular as in Denmark, construction currently consumes more virgin materials than agriculture and manufacturing sectors[48].

In the context of the imperative to halt environmental damage through a radical decrease in material extraction, the promise of the circular economy to keep products "in circulation through processes like maintenance, reuse, refurbishment, re-manufacture, recycling, and composting" becomes highly relevant[49]. While there is some ambiguity about the definition of the circular economy, the concept has gained many supporters in the policy and business arenas[50]. The European Union, for example, positions its Circular Economy Action Plan as one of the "main building blocks of the European Green Deal", while in Denmark, Danish Industry has declared an ambition for Danish companies to become "world leaders in circular business models by 2030"[51].

But do circular economies really reduce material extraction? A recent analysis of 28 European countries between 2010-2019 found that initiatives such as, creation of circular jobs and novel incentives for the use of recycled material did, in fact, reduce annual domestic extraction of virgin material by 13 million tonnes. However, in the same period, domestic material extraction to increase by 50 million additional tonnes each year, dwarfing the positive impact of circularity by a factor of four[52].

In the context of buildings, a recent report found that without a change in demand for new square meters, even switching to an ideal zero-waste economy (where all materials coming out of the existing building stock are reused without consideration of technical barriers) is projected to only replace 11% of demand for virgin materials by the construction sector in the EU[53].

Circularity is inherently a well-intentioned concept, when it is not used in service of a business-as-usual narrative of economic growth. The foundational texts on circularity position it as a catalyst of a systemic change with many social and environmental benefits– such as broader participatory decision-making by local communities, nourishing of cultural diversity, reestablishing caring links with the natural environment, reduction of chemical pollution and an increase in physical health[54]. The Ellen MacArthur Foundation similarly stresses the importance of biological regenerative cycles, giving them equal weight to industrial ones. However, dominant business-led narratives often reduce these humanistic dimensions of the circular economy to continue selling more products, with a higher recycled material content, with the promise of more jobs and more economic growth[55].

Circular economy in its current incarnation lies in its entanglement with the growth-oriented paradigm of economic development. Essentially, transforming waste into a resource within this model does not inherently challenge the production of waste; rather, it tends to validate ongoing pollution under the guise of resource efficiency. The primary function of most circular economy frameworks is to catalyze financial growth rather than to genuinely curtail consumption[56]. This is particularly concerning given that the empirical evidence suggests a disproportionate relationship between economic growth and resource extraction. Specifically, data indicates that a 1% increase in Gross Domestic Product (GDP) correlates with a rise in resource extraction by approximately 0.3% to 0.6%. Moreover, the increase in resource extraction driven by GDP growth is up to four times greater than the resource savings accrued through circular economy initiatives[57].

These findings provide empirical support of a disconnect between circularity as an original concept and absolute decoupling – no matter how circular economies become, they cannot reduce pressure on the environment within the growth paradigm. Every re-use scenario requires input of material and energy[13], no matter how small – and recycling material again and again while maintaining high quality takes progressively more and more energy . In other words, “circles are not spirals, and for growth to occur, spirals with ever-increasing radii are required. Furthermore, spirals of economic growth create equivalent spirals of environmental damage” .

The increase in resource extraction driven by GDP growth is up to four times greater than the resource savings accrued through circular economy initiative.

Deep circularity

Current circularity models are merely linear extraction in disguise

Circularity holds great potential for addressing some of the biggest challenges we face in combating climate breakdown. By replacing linear extractive models with regenerative and fully circular systems, we can decouple our economy from resource extraction and its negative environmental impacts, with the potential to reduce greenhouse gas emissions by 50% [1].

However, current circularity models are flawed, and true circularity is not actually being achieved, despite widespread use of the term and broad claims. The global economy is now only 7.2% circular, Denmark 4%, and in decline. Material recovery rates across the EU remain low[2], while material extraction continues to rise[3]. This means that the majority of resources are being wasted or dispersed as emissions[4], whilst over 90% of material inputs are from virgin sources, further degrading land, polluting ecosystems and harming biodiversity globally. Current recycling and up-cycling methods still rely on a high percentage of virgin materials; create inseparable material compositions which prevent future reuse; and use polluting processes.

Simply put, circularity cannot exist in the context of the current linear growth economy.

We need to focus on systemic circularity and just economy

No product or material can be truly circular within an economy that remains fundamentally linear and extractive in every aspect of its operations. We need our systems to be redesigned to allow for circularity, and we need to stop focusing on circular products and start focusing on circular systems.

Systemic circularity refers to circularity with a systemic perspective in which broader implications and shifts are considered and combined to unlock a deeply circular, dematerialized and regenerative economy. Transitioning towards it requires infrastructural transformations across logistics and technology, legislation and policy reforms, investments and finance, science-based targets and new-gen education, civic engagement and culture all shift in unison.

Ivana Stancic, Indy Johar, Oliver Burgess & Alicia Carvajal Rowan

Dark Matter Laboratories

Simply put, circularity cannot exist in the context of the current linear growth economy.

Loops of Deep circularity

Deep circularity (DML, A new Economy for Europe's Built Environment) encompasses many aspects (Figure 2.17), some of them being:

1. Maximum circularity of non-biodegradable materials: Prolonging their use and recirculating non-renewable materials, such as metals, glass and stone and composites such as concrete or plasterboard, will require a range of infrastructural and behavioural shifts. These include integrating a scientific understanding of material properties and manufacturing processes to enable circularity; logistics and storage networks; citywide material data registries; regulatory innovations; and new financing mechanisms, all developed in combination.

An example of this reality is a city banning the use of virgin materials in the building industry, redirecting all innovation into reuse, repurposing, upcycling (withou and City-as-a-resource models of harvesting waste material, developing detoxification methods and technologies for city-scale material reuse networks.

2. Biodegradable materials are by nature circular: Biomaterials, grown and harvested using regenerative land management practices, are a foundational part of a future circular system as well as providing carbon sequestration and storage. Maximising the use life of bio-based building materials, to prevent the premature release of sequestered carbon and protect standing forests and other biomaterial resources, is critical. This transition will require a deep understanding of systemic impacts, to avoid further global biodiversity and land degeneration in the name of green growth. The goal is to ensure that any modifications to the built environment contributes to a positive environmental impact, effectively turning the construction industry into a force for environmental restoration.

An example of this reality is planting new bioregional forests (not using the existing ones) across the city, regeneratively harvesting the timber and other biomaterials for retrofitting or repurposing existing building stock or underused industrial sites for e.g. affordable housing. This would provide both a local source of biomaterials as well as carbon sequestration and regeneration of soils, contributing to a localised bio-economy.

3. Circularity of use:
Sharing models and maximising the use of spaces and products is necessary to increase utilisation of global material stocks. Shifting business models from private ownership to shared ownership or right to use models. This would ensure that producers maintain responsibility for the entire lifecycle of a product, encouraging preventative maintenance, repair and refurbishment practices to extend product life cycles; and incentivising strategies like recovery, repair and remanufacturing; and unlocking new sharing

models. By keeping materials and products circulating in the economy, their value is retained for as long as possible. An example of this reality is a city limiting the number of private cars. Currently cars are unused 95% of the time , yet we keep producing new cars. If a city decides to maximise their use ratio and develop a regional sharing system, we can cut the majority of new car production and free up some of the ~50% of urban space currently devoted to car infrastructure[5].

4.Re-operationalising of existing instead of producing new:

By maximising the utilisation of current buildings and products, their programmatic flexibility and modularity, we tackle issues like vacancy, underuse, and inefficiency. Through densification, repurposing, and adaptive reuse, we ensure that use of existing structures and products are maximised before producing new ones, zeroing out the environmental costs associated with excessive new construction and production.

An example of this reality is a City re-operationalising its work-life infrastructures, by supporting flexible use of all vacant spaces as places for hybrid work across the city. That would restructure daily routines and minimise unhealthy commute. Putting in use vacant and underused spaces would minimise the need to build new.

Figure 2.17 Aspects of Deep Circularity

Systems levers for Deep circularity

A deeply circular future will require transformations across the system, such as:

4.1. Cultural shifts building awareness amongst citizens, as future consumers and voters supporting actors driving policy, fiscal, regulatory, contractual changes. The awareness can be built through media campaigns (e.g. DML, Les Materialistes), foresight workshops or public events.

4.2. New-generation education systems must evolve to meet the future demands, integrating crafts, bioengineering, technology and logistics for maximising use efficiency or integral value accounting, botany, regenerative farming and permaculture, as well as adopting new holistic and systems approaches.

4.3. New financial instruments and fiscal incentives are needed to manage material circularity at scale. These include city-scale integrated value balance sheets; end-of-life sinking funds to cover disassembly, recertification and reuse; differential discount rates on materials based on their circularity; utilisation-linked pricing or other fiscal measures that incentivise reuse. Carbon treasuries, bioregional multi-capital banks (e.g. DML, Bioregional Financing Facilities) would also be essential.

4.4. Circular business models that shift from private ownership to shared ownership, crowd-sharing and access – for example manufacturers offering leasing or material trusts that retain ownership and incentivise material take back and recirculation. Or crowd-owned (e.g. DML, Radicle Civics) and maintained resources, ensuring a full efficiency of use of spaces, resources, materials.

4.5. Regulatory innovations that move away from prescriptive requirements (e.g. building performance requirements) towards outcome-based regulations that foster market innovation and enable designs tailored to local material availability. Simultaneously, new digital tools can help policymakers to navigate existing regulations and formulate new policies that unlock circularity (e.g. DML, CircuLaw) ,

4.6. New operational infrastructure must be developed for disassembling, processing, testing, re-certifying and storing materials and building components, alongside local and regional, low-carbon transport and logistics networks (e.g. DML, Material Registry). Products and buildings for maximum lifespans and disassembly, implementing adaptable space programming and demountable fit-outs, detoxification technologies, quality assurance processes and certifications will be critical.

References:
1 Ellen MacArthur Foundation, 'Completing the Picture: How the Circular Economy Tackles Climate Change,' 2019, https://www.ellenmacarthurfoundation.org/completing-the-picture.

2 European Environment Agency, 'Waste Recycling in Europe' (European Environment Agency, n.d.), https://www.eea.europa.eu/en/analysis/indicators/waste-recycling-in-europe.

3 United Nations Environment Programme, 'Global Resources Outlook 2024: Bend the Trend - Pathways to a Livable Planet as Resource Use Spikes' (Nairobi: International Resource Panel, 2024), https://wedocs.unep.org/handle/20.500.11822/44902.

4 Circle Economy, 'The Circularity Gap Report - Denmark,' August 2023, https://www.circularity-gap.world/denmark.

5 'Cars Are Parked 95% of Time: Let's Check' (Reinventing Parking, 23 February 2013), https://www.reinventingparking.org/2013/02/cars-are-parked-95-of-time-lets-check.html.

4.7. Digital infrastructures and interoperable data registries containing shared datasets on resources across cities, regions, or countries, enable circular systems. New digital booking platforms that enable more efficient use of buildings and public spaces (e.g. DML, Re:Permissioning the City) will help to increase utilisation of the existing.

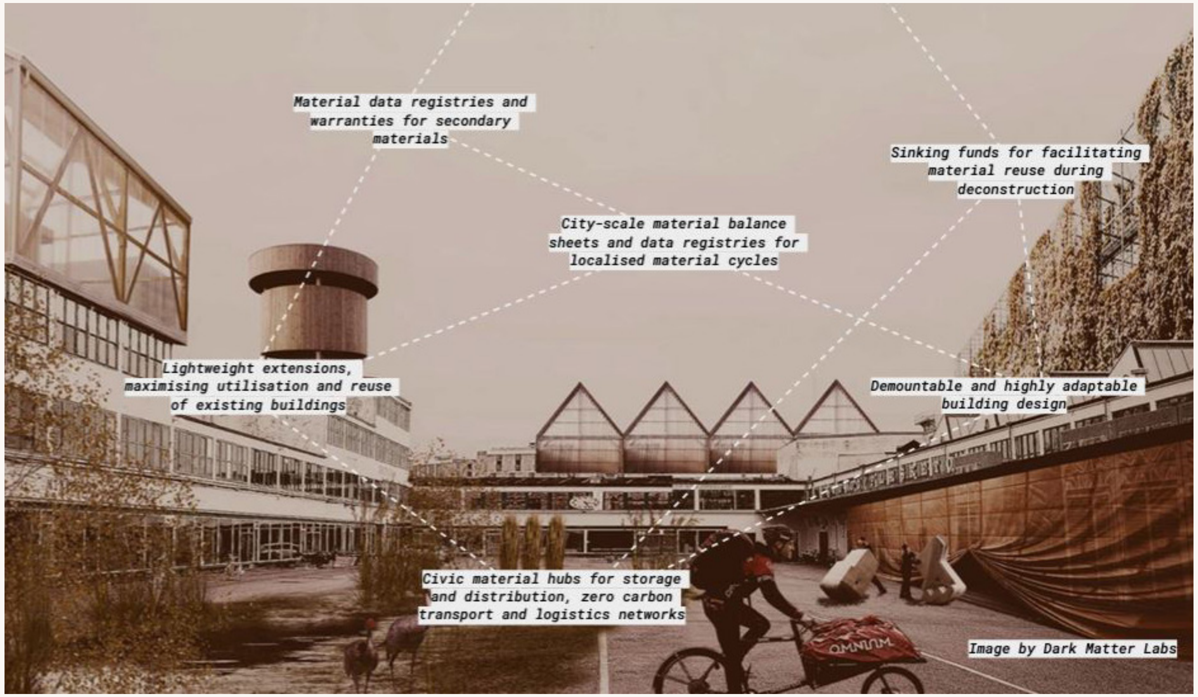
4.8.New models of relation to land and nature are essential, shifting from extractive supply chains to local, regenerative supply loops. This includes developing local biodiverse material forests, zero-carbon local transport methods like cargo bikes or trains, adopting non-polluting, community-based construction practices. This means managing resources in a way that enhances the environment, such as regenerative agriculture and rewilding (e.g. DML, Lawns campaign) as part of the new resource economy.

Conclusion

Deep circularity is essential for ensuring a liveable future within planetary boundaries. To achieve this, we must first acknowledge that true circularity is not being practised in the current system. Secondly, we need to establish a shared understanding of science-based indicators and targets, as well as a clear definition of what genuine circularity entails. Thirdly, it's crucial to recognize the systemic changes required to make this shift possible. Finally, we must realise that this transformation is achievable if we focus on building local capacities for collaboration across the policy, economic, educational, and civic engagement sectors in driving local systems innovation.

The transition to Deep Circularity is profound and complex, but once we get its deep codes right, the path forward becomes straightforward.

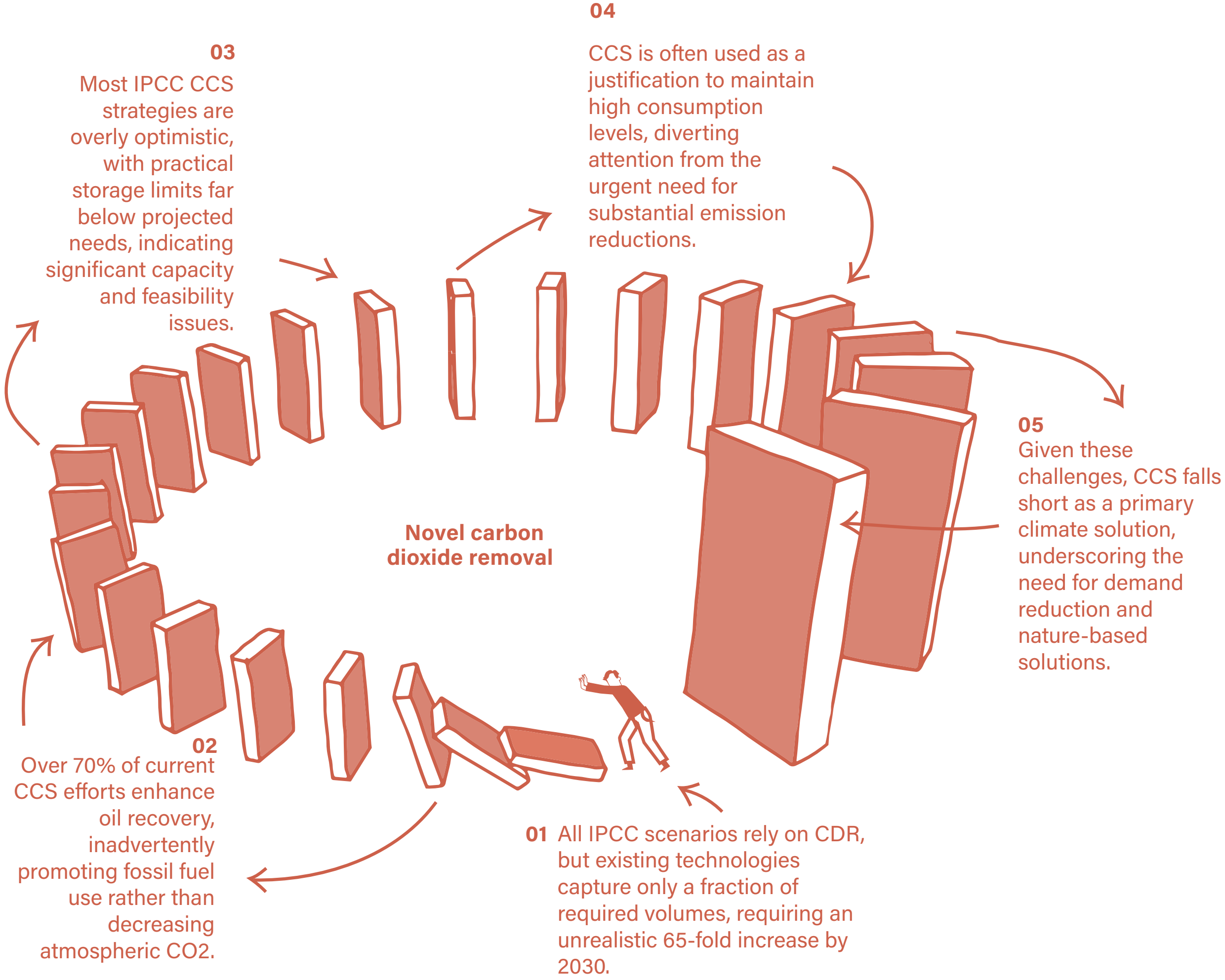
Figure 2.18 - Principles of circularity. Source: DML A New Economy for Europe's Built Environment White paper



How has the growth imperative limited the impact potential of Novel carbon dioxide removal?

The goal of novel carbon dioxide removal solutions (CDR) like carbon capture and storage (CCS) is to ensure we stay within Paris Agreement emission levels. Unfortunately, novel CDR solutions are not developing at a sufficient pace and scale for effective climate action within the current growth-dependent system. Unless consumption behaviors change, reliance on these solutions increases risk of long-term burden shifting from one transgressed planetary boundary to another.

Carbon dioxide removal (CDR) encompasses any capture of CO2 from the atmosphere and storage for decades to millennia because of human intervention. All scenarios laid out by the IPCC that limit warming to 2°C or lower include CDR[7], identifying broad range of CDR methods that can be implemented both on land and in the oceans. T The IPCC defines nature-based approaches as practices that have been used for centuries (afforestation, agroforestry, and improved forest management) while others rely on technological innovation and are relatively new (direct air carbon capture and storage and ocean fertilization).[7] Less than 0.1% of current annual CDR results from novel methods[59] (Figure 2.19). The rest come from conventional management of land and other non-novel methods (Figure 2.20).



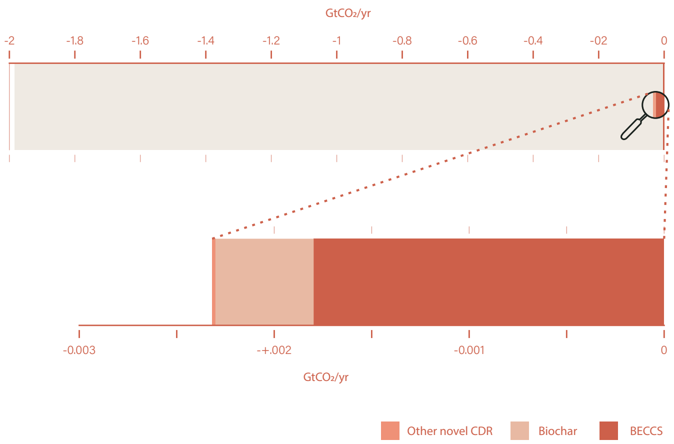


Figure 2.19 - Total current amount of carbon dioxide removal, split into conventional and novel methods ($GtCO_2$/yr). Almost all current carbon dioxide removal comes form conventional management of land and a tiny fraction of all current carbon dioxide removal results from novel methods. Source: Smith et al. (2023) State of Carbon Dioxide Removal - 1st Edition.

In the context of this report, the focus is on novel carbon dioxide removal (CDR) methods, such as carbon capture and storage (CCS) and carbon capture and utilization (CCU). The report critically assesses whether these technologies have the potential to decouple economic growth from the greenhouse gas emissions produced by the building industry. To date, the development of large-scale CCS projects has been slow. Global climate targets demand annual CO2 storage rates of approximately 1 gigaton per year by 2030, growing to around 10 gigatons per year by 2050.

Despite the goal, the maximum potential of all CCS projects currently in development, construction, or operation is only 361 megatons per year, far below the target[60]. To put this in perspective, with the CCS projects currently in operation which store less than 1 megaton per year, reaching even the lower end of the 2030 goal would require a 65-fold increase in carbon removal rates[61]. The main barriers to scaling up CCS are financial and social, not technological—projects typically take 7 years or more to develop, making it unlikely that current plans will significantly contribute to reducing emissions by 2030[66].

The IPCC draws an important distinction in the AR6 – CCS applied to CO2 from fossil fuel use is not considered a valid carbon dioxide removal method, since it does not remove CO2 from the atmosphere[7]. Unfortunately, as of 2023, 71% of operational CCS facilities worldwide are used for enhanced oil recovery[66], primarily benefiting the fossil fuel industry by accelerating oil extraction. This both undermines the technology's intended purpose of reducing emissions and is misaligned with the IPCC's targets.

An important recent trend in CCS is the shift away from vertically integrated projects towards networks, where capture facilities are not located in the same place as storage. For example, the North Sea is regarded as the preferred site for CO2 storage in Northern Europe – and such a storage facility would serve as a 'hub' for carbon captured in projects from Denmark, Norway, and the UK. The network-hub design relies on transport of liquefied CO2; the dominant mode of transport in operational CCS projects is by pipeline, followed by combined methods and shipping by sea[66].

This infrastructure demands both resources and energy– and both steel and shipping industries are currently off-track from Paris Agreement goals. As of 2023, the steel industry accounted for about 8% of global CO2 emissions, second only to oil and gas, while shipping contributed 2%, with shipping emissions steadily rising since 2008[62].

The planet cannot afford to expand CCS networks without also addressing the impact of the supporting infrastructure on the planetary boundaries.

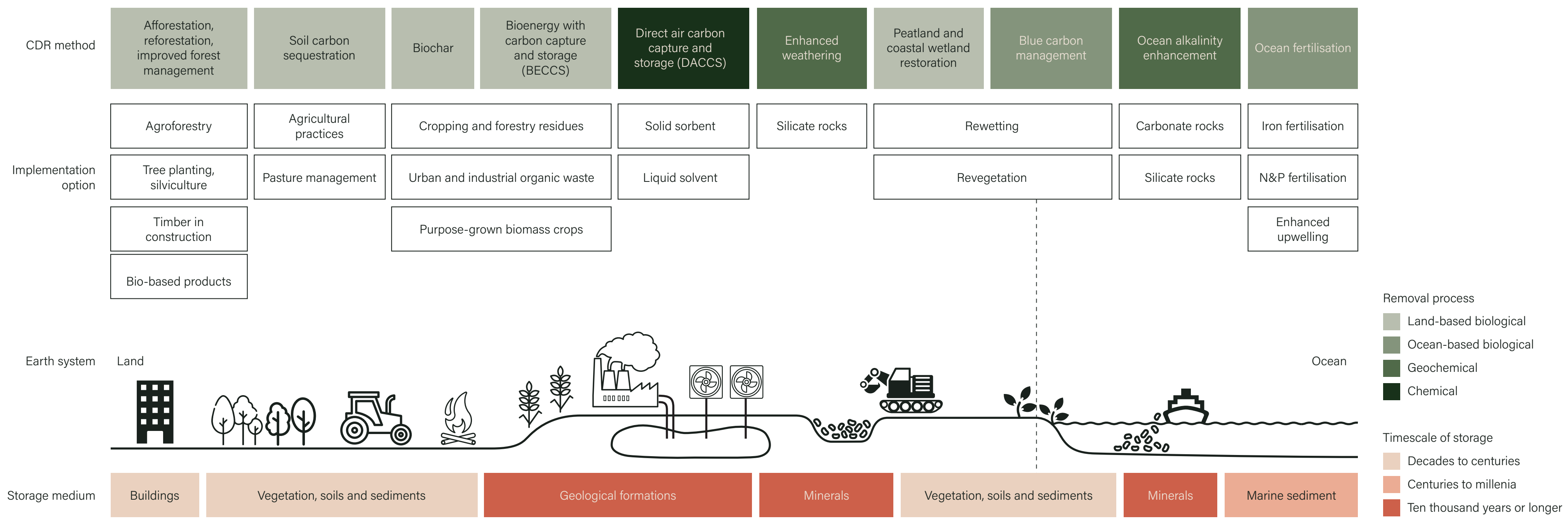


Figure 2.20 - Carbon dioxide removal taxonomy. Methods are categorised based on removal process (green shades) and storage medium (for which timescales of storage are given, red shades). Main implementation options are included for each CDR method. Note that land-based implementation options can with several CDR for example, agroforestry can support soil sequestration and provide biomass for biochar or BECCS. Source: adapted from Minx et al (2018) in IPCC AR6 - Working Group III Contribution

The IPCC stresses, carbon dioxide removal cannot serve as a substitute for deep emissions reductions (Figure 2.21). Only mitigation addresses the human causes of climate change[63]. The role of CDR technologies like CCS should be limited to offsetting residual emissions from hard-to-transition sectors and supporting long-term net-negative CO2 levels, particularly when burning non-reusable biomass[7]. While CCS can help at the margins, it cannot achieve the large-scale emission reductions needed to prevent a climate crisis. This requires taking fossil fuels offline.

Paris Agreement-aligned scenarios rely heavily on negative emission technologies also assume unrealistic levels of energy-GDP decoupling, two to four times higher than what's been observed since 2005[64]. Despite advances in technology, rising consumption has consistently outpaced its environmental benefits, making it impossible to fully decouple economic growth from environmental impact[65].

If the building and upstream industrial sectors rely on carbon dioxide removal to offset the impact of expanding built environments, we will fail to solve the Polycrisis.

Recent research indicates that most of the IPCC's CCS strategies are overly optimistic and largely unfeasible. While the IPCC projects a global CO2 storage rate of 2-30 GtCO2 per year by 2050, this target faces significant geological and economic constraints, making it unrealistic.

A more attainable global storage rate is closer to 5-6 GtCO2 annually[66]. This suggests that achieving the IPCC's scenarios will likely require not only technological advancements but also substantial demand-side reductions to align with the feasible scale of CCS deployment.

CDR cannot keep up with rapid economic growth, and depending on it shifts the CO_2 burden to the energy sector, increases land and material use[67]. As detailed in Chapter 1, the stakes are unprecedented. Given the persistent and dependable qualities of nature, the industry should shift towards investments in nature-based solutions for CO2 capture over the high-stakes gable of CDR.

Despite advances in technology, rising consumption has consistently outpaced its environmental benefits, making it impossible to fully decouple economic growth from environmental impact.

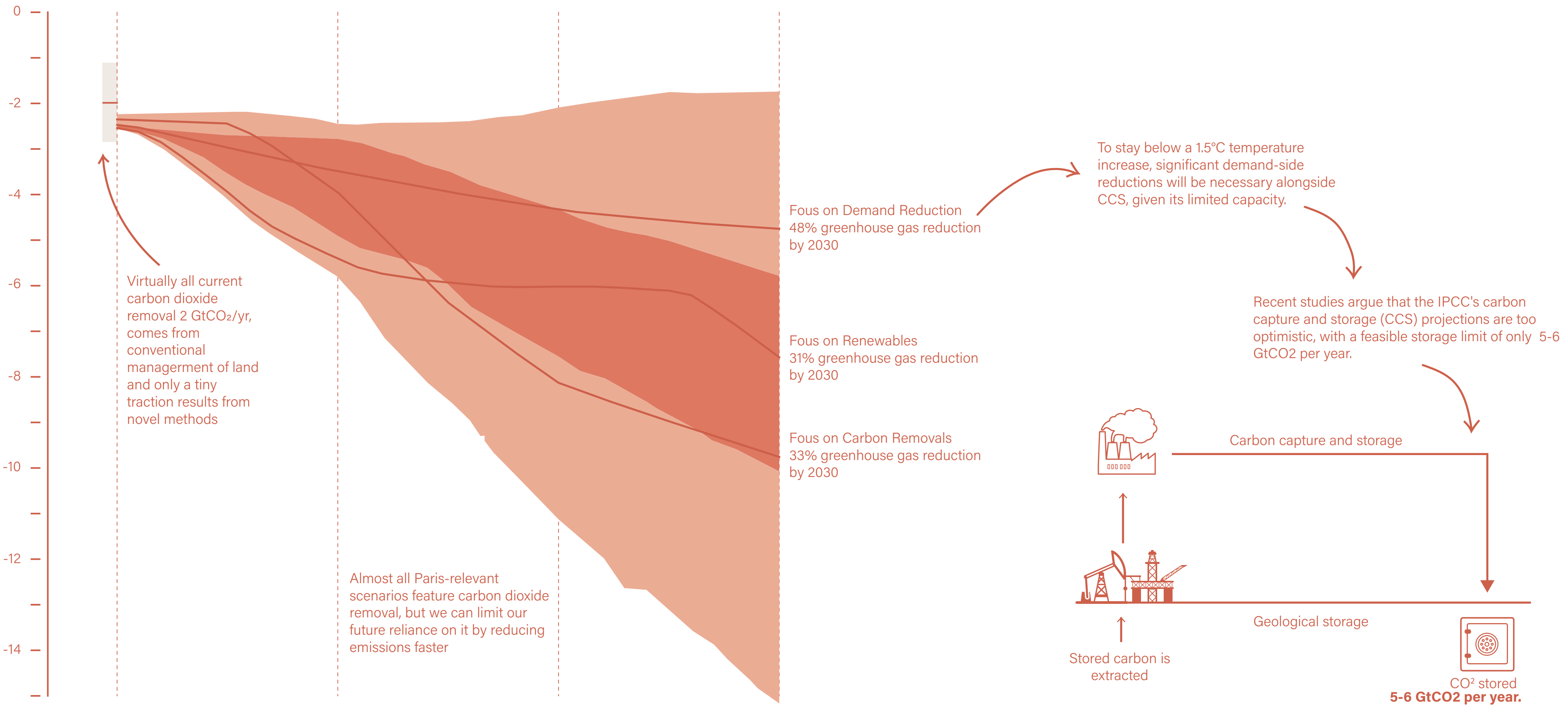


Figure 2.21 Carbon dioxide removal is a feature of all scenarios that meet the Paris temperature goal, in addition to reducing emissions. Source: Smith, S. et al. (2023) State of Carbon Dioxide Removal - 1st Edition.

Chapter 2 References

1.Hal R Arkes and Catherine Blumer, 'The Psychology of Sunk Cost,' Organizational Behavior and Human Decision Processes 35, no. 1 (1 February 1985): 124–40, https://doi.org/10.1016/0749-5978(85)90049-4.

2.Harry D. Saunders et al., 'Energy Efficiency: What Has Research Delivered in the Last 40 Years?,' Annual Review of Environment and Resources 46, no. 1 (2021): 135–65, https://doi.org/10.1146/annurev-environ-012320-084937; Anne Berner et al., 'Do Energy Efficiency Improvements Reduce Energy Use? Empirical Evidence on the Economy-Wide Rebound Effect in Europe and the United States,' Energy Economics 110 (1 June 2022): 105939, https://doi.org/10.1016/j.eneco.2022.105939.

3. Anne Berner et al., 'Do Energy Efficiency Improvements Reduce Energy Use? Empirical Evidence on the Economy-Wide Rebound Effect in Europe and the United States,' Energy Economics 110 (1 June 2022): 105939, https://doi.org/10.1016/j.eneco.2022.105939

4. IPCC, 'Climate Change 2023 - Synthesis Report,' in Climate Change 2023: Synthesis Report., First (Geneva, Switzerland: Intergovernmental Panel on Climate Change (IPCC), 2023), 5, https://doi.org/10.59327/IPCC/AR6-9789291691647.

5. International Energy Agency, 'Total Final Consumption (TFC) by Sector, Denmark, 1990-2021,' Energy Statistics Data Browser – Data Tools, 2022, https://www.iea.org/data-and-statistics/data-tools/energy-statistics-data-browser.

6. Kirsten Gram-Hanssen, Bæredygtig Praksisomstilling i Teori Og Handling (København: Hans Reitzels Forlag, 2022), https://hansreitzel.dk/products/baredygtig-praksisomstilling-bog-54555-9788702332292.

7. IPCC, Climate Change 2022 Mitigation of Climate Change: Working Group III Contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change, 2022, 993, 1261, https://www.ipcc.ch/report/ar6/wg3/.

8. European Commission, 'Renovation Wave: The European Green Deal,' October 2020, https://energy.ec.europa.eu/topics/energy-efficiency/energy-efficient-buildings/renovation-wave_en; European Commission, 'Renovation Wave,' 2023, https://energy.ec.europa.eu/topics/energy-efficiency/energy-efficient-buildings/renovation-wave_en.

9. Circular Buildings Coalition, 'Towards a Circular Economy in the Built Environment - Overcoming Market, Finance and Ownership Challenges,' June 2023, https://www.circularbuildingscoalition.org/resources.

10. "With 25% of Europe's Greenhouse Emissions Coming from Buildings, Scientists Suggest Fundamental Policy Changes", 6. February 2021, https://easac.eu/media-room/press-releases/details/with-25-of-europes-greenhouse-emissions-coming-from-buildings-scientists-suggest-fundamental-policy-changes.

11. Sven Bienert et al., 'Embodied Carbon of Retrofits. Ensuring the Ecological Payback of Energetic Retrofits' (Wörgl, Austria: Institute for Real Estate Economics (IIÖ, Austria), Carbon Risk Real Monitor (CRREM), September 2023), https://www.epra.com/application/files/4416/9582/6042/Report_Embodied_carbon_vs_operational_savings_Sep23.pdf.

12. Lorenz T. Keyßer and Manfred Lenzen, '1.5 °C Degrowth Scenarios Suggest the Need for New Mitigation Pathways,' Nature Communications 12, no. 1 (11 May 2021): 2676, https://doi.org/10.1038/s41467-021-22884-9.

13. Timothée Parrique et al., 'Decoupling Debunked – Evidence and Arguments against Green Growth as a Sole Strategy for Sustainability' (European Environmental Bureau, July 2019), https://eeb.org/library/decoupling-debunked/.

14. International Energy Agency, 'Mineral Requirements for Clean Energy Transitions – The Role of Critical Minerals in Clean Energy Transitions,' IEA, March 2022, https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions/mineral-requirements-for-clean-energy-transitions.

15. Caroline Avan et al., 'Transition Minerals Tracker: 2022 Analysis' (Business & Human Rights Resource Centre, June 2023), https://media.business-humanrights.org/media/documents/2023_Transition_Minerals_Tracker_JX5pGvf.pdf.

16. Clare Church and Alec Crawford, 'Green Conflict Minerals: The Fuels of Conflict in the Transition to a Low-Carbon Economy' (Winnipeg, Manitoba, Canada: International Institute for Sustainable Development, August 2018), https://www.iisd.org/publications/report/green-conflict-minerals-fuels-conflict-transition-low-carbon-economy.

17. International Energy Agency, 'Share of Renewables, Low-Carbon Sources and Fossil Fuels in Power Generation, Denmark, 1990-2022,' IEA, 21 December 2023, https://www.iea.org/data-and-statistics/data-tools/energy-statistics-data-browser.

18. Energistyrelsen, 'Klimastatus Og -Fremskrivning 2023,' Spril 2023, https://ens.dk/sites/ens.dk/files/Basisfremskrivning/kf23_hovedrapport.pdf.

19. International Energy Agency, 'Renewable Share (Modern Renewables) in Final Energy Consumption (SDG 7.2), Denmark, 1990-2020,' IEA, 21 December 2023, https://www.iea.org/data-and-statistics/data-tools/energy-statistics-data-browser.

20.Dan Hill and Mariana Mazzucato, 'Modern Housing: An Environmental Common Good,' IIPP WP 2024-03, UCL Institute for Innovation and Public Purpose Working Paper Series (Council on Urban Initiatives, February 2024), 8, https://www.ucl.ac.uk/bartlett/public-purpose/publications/2024/mar/modern-housing-environmental-common-good.

21. Prescott Huntley Brownell II, Bogomil Emilov Iliev, and Niclas Scott Bentsen, 'Wood Flows through the Danish Economy,' IGN Report (Frederiksberg: Department of Geosciences and Natural Resource Management, University of Copenhagen, March 2023), https://ign.ku.dk/english/publications/.

22. Philip B. Duffy, Richard A. Houghton, and William Moomaw, 'Forest Bioenergy and Climate Change - Policy Brief,' January 2018, https://assets-woodwell.s3.us-east-2.amazonaws.com/wp-content/uploads/2021/02/14152450/Forest_Bioenergy_and_Climate_Change.pdf.

23.Peter Raven et al., 'Letter Regarding Use of Forests for Bioenergy,' 11 February 2021, https://www.saveparadiseforests.eu/wp-content/uploads/2021/02/Scientist-Letter-to-Biden-von-der-Leyen-Michel-Suga-Moon-Re.-Forest-Biomass-February-11-2021.pdf.

24. Danmarks Statistik, 'ENE2HO: Energiregnskab i GJ (Oversigt) Efter Tilgang Og Anvendelse Og Energitype,' accessed 3 July 2024, https://sdg.statistikbank.dk/statbank5a/SelectVarVal/Define.asp?MainTable=ENE2HO&PLanguage=0&PXSId=0&wsid=cflist.

25. Energistyrelsen, 'Klimastatus Og -Fremskrivning 2023,' Spril 2023, https://ens.dk/sites/ens.dk/files/Basisfremskrivning/kf23_hovedrapport.pdf.

26.'Energistatistik 2022' (Energistyrelsen, n.d.), accessed 19 December

2023; Energistyrelsen, 'Analyseforudsætninger Til Energinet 2022', accessed 20 September 2023, https://ens.dk/sites/ens.dk/files/Hoeringer/af22_-_offentligt_datasaet_-_endeligt_-_opdateret.xlsx.

27. Lizzie Crook, 'Mass Timber "Definitely Not the Right Way to Go" Says Benjamin Kromoser', Dezeen, 23 March 2023, https://www.dezeen.com/2023/03/23/benjamin-kromoser-timber-revolution-interview/.

28. Chris Foges, 'Timber Construction Is a Silver Bullet for Climate Change', RIBA J, 5 September 2022, https://www.ribaj.com/culture/profile-joachim-schellnhuber-bauhaus-earth-climate-emergency-trees.

29. Frances Yang and Andrew Lawrence, 'Wood: Like Never Before', in The New Carbon Architecture: Building to Cool the Climate, by Bruce King (Gabriola Island: New Society Publishers, 2017); Vandkunsten Architects, Wood, 1st edition (Stockholm: Arvinius + Orfeus Publishing, 2021).

30.MGA | Michael Green Architecture, The Case For Tall Wood Buildings: How Mass Timber Offers a Safe, Economical, and Environmental Friendly Alternative for Tall Building Structures, Second, 2017, https://thecasefortallwood.com/wp-content/uploads/2017/02/2017-01-24-THE-CASE-FOR-TALL-WOOD-SECOND-EDITION.pdf.

31. Torben Valdbjørn Rasmussen et al., 'Biogene Materialers Anvendelse i Byggeriet', BUILD Rapport (Institut for Byggeri, By og Miljø (BUILD), Aalborg Universitet., 2022), https://vbn.aau.dk/ws/portalfiles/portal/467134787/BUILD_Rapport_2022.09.pdf; Anne Beim, Lykke Arnfred, and Henriette Ejstrup, Biogenic Construction - Materials, Architecture, Tectonics (Cinark - Royal Danish Academy, 2023), https://issuu.com/cinark/docs/til_issuu_23.03.2023_biogenic_construction_bg_fina; Henning Larsen, Plant a Seed: Designing with Wood and Biobased Materials, 2023, https://henninglarsen.com/news/new-publication-designing-with-wood-and-biobased-materials; Københavns Universitet et al., 'Veje Til Biobaseret Byggeri: Dialogmøde'; Torsten Sack-Nielsen et al., 'Fra Marken Til Byggeri: Evaluering Af Biogene Materialers Betydning for Byggeriets Planetære Grænser', 2024.

32. European Environment Agency, EEA Report 08/2023, The European biomass puzzle

33.Forest Stewardship Council US, 'Towards Climate Smart Forestry: Increasing Carbon Storage in the Working Forests of Canada and the United States', November 2023, https://us.fsc.org/en-us/newsroom/newsletter/id/1318.

34. Prescott Huntley Brownell II, Bogomil Emilov Iliev, and Niclas Scott Bentsen, 'Wood Flows through the Danish Economy', IGN Report (Frederiksberg: Department of Geosciences and Natural Resource Management, University of Copenhagen, March 2023), https://ign.ku.dk/english/publications/.

35. Tim Searchinger et al., 'Wood Is Not the Climate-Friendly Building Material Some Claim It to Be', 20 July 2023, https://www.wri.org/insights/mass-timber-wood-construction-climate-change.

36. Brownell II, P. H., Iliev, B. E., & Bentsen, N. S. (2023). Wood flows through the Danish economy. Department of Geosciences and Natural Resource Management, University of Copenhagen. IGN Report No. March 2023

37. Churkina, G., Organschi, A., Reyer, C.P.O. et al. Buildings as a global carbon sink. Nat Sustain 3, 269–276 (2020). https://doi.org/10.1038/s41893-019-0462-4

38. Glen Peters, 'Carbon Uptake in EU Forests Has Declined in the Last Decade? But Why? Forest Growing Slower or Increased Losses?', n.d., https://x.com/Peters_Glen/status/1759504210939269348/photo/1.

39. Korosuo, A., Pilli, R., Abad Viñas, R. et al. The role of forests in the EU climate policy: are we on the right track?. Carbon Balance Manage 18, 15 (2023). https://doi.org/10.1186/s13021-023-00234-0

40. Lindsey Wikstrom, Designing the Forest and Other Mass Timber Futures (Taylor & Francis, 2023), https://www.routledge.com/Designing-the-Forest-and-other-Mass-Timber-Futures/Wikstrom/p/book/9781032023946.

41. IPCC, 'Climate Change 2022 – Impacts, Adaptation and Vulnerability: Working Group II Contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change', in Climate Change 2022 – Impacts, Adaptation and Vulnerability: Working Group II Contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change, 1st ed. (Cambridge University Press, 2023), https://doi.org/10.1017/9781009325844.

42. Katherine Richardson et al., 'Earth beyond Six of Nine Planetary Boundaries', Science Advances 9, no. 37 (15 September 2023): eadh2458, https://doi.org/10.1126/sciadv.adh2458.

43. Johan Rockström et al., 'Safe and Just Earth System Boundaries', Nature 619, no. 7968 (July 2023): 102–11, https://doi.org/10.1038/s41586-023-06083-8.

44. United Nations Environment Programme, 'COP15 Ends with Landmark Biodiversity Agreement', UNEP (blog), 20 December 2022, http://www.unep.org/news-and-stories/story/cop15-ends-landmark-biodiversity-agreement.

45. Nicolai Bo Andersen, 'Space Justice', Magasin for Bygningskunst Og Kultur, 23 April 2024, https://bygningskunstogkultur.dk/nr-7-2024/space-justice.

46. Abhijeet Mishra et al., 'Land Use Change and Carbon Emissions of a Transformation to Timber Cities', Nature Communications 13, no. 1 (30 August 2022): 4889, https://doi.org/10.1038/s41467-022-32244-w.

47. United Nations Environment Programme, 'Global Resources Outlook 2024: Bend the Trend - Pathways to a Livable Planet as Resource Use Spikes' (Nairobi: International Resource Panel, 2024), https://wedocs.unep.org/handle/20.500.11822/44902.

48. Circle Economy, 'The Circularity Gap Report - Denmark', August 2023, 6, https://www.circularity-gap.world/denmark; Circular Buildings Coalition, 'Towards a Circular Economy in the Built Environment - Overcoming Market, Finance and Ownership Challenges', June 2023, 36, https://www.circularbuildingscoalition.org/resources.

49. Ellen MacArthur Foundation, 'Circular Economy Introduction', accessed 19 March 2024, https://www.ellenmacarthurfoundation.org/topics/circular-economy-introduction/overview.

50. Julian Kirchherr, Denise Reike, and Marko Hekkert, 'Conceptualizing the Circular Economy: An Analysis of 114 Definitions', Resources, Conservation and Recycling, no. 127 (15 September 2017): 221–32, https://doi.org/10.2139/ssrn.3037579; Hervé Corvellec, Alison F. Stowell, and Nils Johansson, 'Critiques of the Circular Economy', Journal of Industrial Ecology 26, no. 2 (2022): 421–32, https://doi.org/10.1111/jiec.13187.

51.European Commission, 'A New Circular Economy Action Plan For a Cleaner and More Competitive Europe', COM/2020/98 § (2020), https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1583933814386&uri=COM:2020:98:FIN; Danish Industry, 'Danish Industry's Circular Economy Policy', accessed 20 March 2024, https://www.danskindustri.dk/politik-og-analyser/di-mener/miljoenergi/cirkular-okonomi/.

52. Marco Bianchi and Mauro Cordella, 'Does Circular Economy Mitigate the Extraction of Natural Resources? Empirical Evidence Based on Analysis of 28 European Economies over the Past Decade', Ecological

Economics 203 (1 January 2023): 107607, https://doi.org/10.1016/j.ecolecon.2022.107607.

53. Circular Buildings Coalition, 'Towards a Circular Economy in the Built Environment - Overcoming Market, Finance and Ownership Challenges', June 2023, 60, https://www.circularbuildingscoalition.org/resources.

54. Rebecca K. M. Clube and Mike Tennant, 'The Circular Economy and Human Needs Satisfaction: Promising the Radical, Delivering the Familiar', Ecological Economics 177 (1 November 2020): 106772, https://doi.org/10.1016/j.ecolecon.2020.106772.

55. Ellen MacArthur Foundation, "The Butterfly Diagram: Visualising the Circular Economy", set 20. marts 2024, https://www.ellenmacarthurfoundation.org/circular-economy-diagram.

56. "Beware the false hope of recycling", set 8. oktober 2024, https://www.nature.com/articles/d41586-022-03645-0.

57. Marco Bianchi and Mauro Cordella, 'Does Circular Economy Mitigate the Extraction of Natural Resources? Empirical Evidence Based on Analysis of 28 European Economies over the Past Decade', Ecological Economics 203 (1 January 2023): 107607, https://doi.org/10.1016/j.ecolecon.2022.107607.

58. Keith Ronald Skene, 'Circles, Spirals, Pyramids and Cubes: Why the Circular Economy Cannot Work', Sustainability Science 13, no. 2 (1 March 2018): 8, https://doi.org/10.1007/s11625-017-0443-3.

59. Stephen Smith et al., 'State of Carbon Dioxide Removal - 1st Edition', 29 January 2023, https://osf.io/w3b4z/.

60. Global CCS Institute, 'Global Status of CCS 2023: Scaling Up Through 2030' (Melbourne, Australia: Global CCS Institute, 2023), 8, 67, 75, 77, https://www.globalccsinstitute.com/wp-content/uploads/2024/01/Global-Status-of-CCS-Report-1.pdf.

61. S. Boehm et al., 'State of Climate Action 2023' (Berlin and Cologne, Germany, San Francisco, CA, and Washington, DC: Bezos Earth Fund, Climate Action Tracker, Climate Analytics, ClimateWorks Foundation, New Climate Institute, the United Nations Climate Change High-Level Champions, and World Resources Institute, 2023), 144, https://climateactiontracker.org/publications/state-of-climate-action-2023/.

62. World Economic Forum, 'Net-Zero Industry Tracker - 2023 Edition', Insight Report, November 2023, 10, https://www3.weforum.org/docs/WEF_Net_Zero_Tracker_2023_REPORT.pdf.

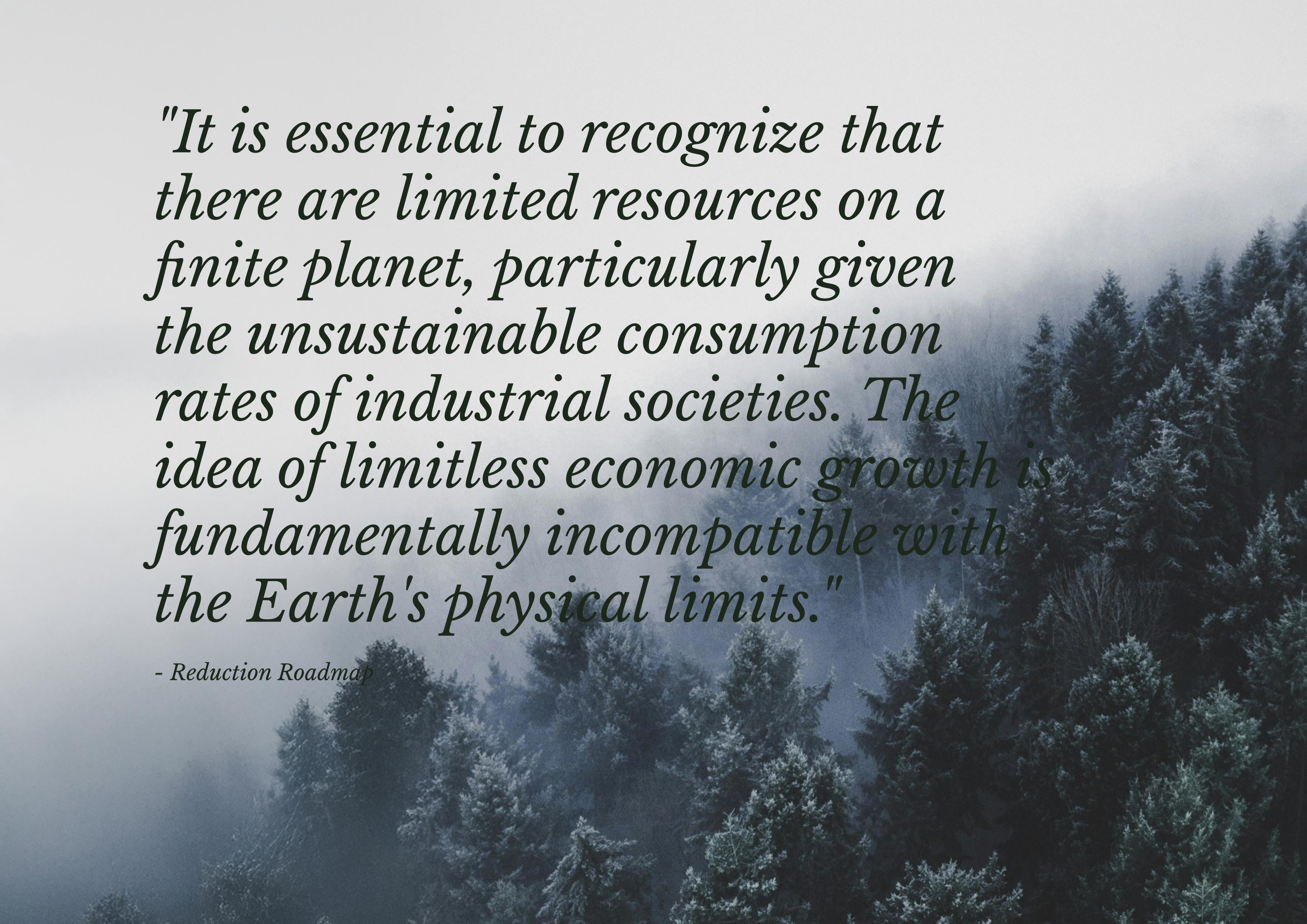
63. UNESCO COMEST, 'Report of the World Commission on the Ethics of Scientific Knowledge and Technology (COMEST) on the Ethics of Climate Engineering' (Paris, 28 November 2023), 9.

64. Lorenz T. Keyßer and Manfred Lenzen, '1.5 °C Degrowth Scenarios Suggest the Need for New Mitigation Pathways', Nature Communications 12, no. 1 (11 May 2021): 8, https://doi.org/10.1038/s41467-021-22884-9.

65. Thomas Wiedmann et al., 'Scientists' Warning on Affluence', Nature Communications 11, no. 1 (19 June 2020): 3107, https://doi.org/10.1038/s41467-020-16941-y.

66. Yuting Zhang, Christopher Jackson, and Samuel Krevor, 'The Feasibility of Reaching Gigatonne Scale CO2 Storage by Mid-Century', Nature Communications 15, no. 1 (28 August 2024): 6913, https://doi.org/10.1038/s41467-024-51226-8.

67.Kevin Anderson and Glen Peters, 'The Trouble with Negative Emissions', Science 354, no. 6309 (14 October 2016): 182–83, https://doi.org/10.1126/science.aah4567.


"It is essential to recognize that there are limited resources on a finite planet, particularly given the unsustainable consumption rates of industrial societies. The idea of limitless economic growth is fundamentally incompatible with the Earth's physical limits."
- Reduction Roadmap

Chapter 3
A transition plan towards the safe operating space

How can we scale impact within the safe and just planetary boundaries?

The Butterfly emphasizes that we cannot achieve sustainable progress solely through reduction; instead, we must actively expand Earth's capacity by investing in net-positive regeneration contributions.

Introduction

The first two chapters of this report laid the foundation for expanding the scope of Reduction Roadmap by exploring the concept of the polycrisis driven largely by economic growth and the unsustainable consumption of finite resources – defining the why.

Now, in Chapter 3, building on the principles of practice, attention is turned to a critical question: "How can the building industry operate within the safe and just boundaries of Earth systems?" – defining the how.

This chapter is dedicated to examining strategies the Denmark and the building industry can adopt to address the ecological deficit, guided by a comprehensive approach that goes 'Beyond the Roadmap' and it's 1.5°C carbon budget.

The approach is grounded in a dual strategy: Mitigating carbon emissions while simultaneously fostering regeneration of the natural world. While Reduction Roadmap will remain relevant over the next 5-10 years, the urgency of the climate crisis necessitates a long-term, holistic plan—a shift from focusing solely on emissions reduction to slowing down resource consumption and enabling long-term regenerative practice. This shift is described in Box 3.1.

This approach is defined as the "Butterfly Framework" (hereafter referred to as the Butterfly) - introduced in this chapter to address the pressing question of how Denmark as a nation can operate within planetary limits and to what extent the building industry can be a part of the solution. The Butterfly emphasizes that we cannot achieve sustainable progress solely through reduction: instead, we must actively expand Earth's capacity by investing in net-positive regeneration contributions.

The Butterfly is unique because it synthesizes a new understanding of planetary systems with actionable commitments across multiple levels - from global to national, down to industry and individual buildings. This multi-tiered approach ensures that sustainability goals are not only addressed at a macro scale but also translated into concrete actions at every level, from international agreements to national policies, industry standards, and building-specific practices. It combines climate stability and functioning ecosystems targets - setting a new course for development. This framework outlines pathways for transitioning from a model focused on profit and expansion to one rooted in sufficiency and regeneration

Unlike previous strategies, the Butterfly addresses the Polycrisis systematically, recognizing the importance of coordinated efforts across sectors such as land-use and agriculture to create resilient, holistic solutions. By moving beyond the narrow focus of "carbon tunnel vision" and integrating regenerative practices, the Butterfly represents a novel shift in environmental action—laying out a path that balances reduction with regeneration for a truly sustainable future.

By moving beyond the narrow focus of "carbon tunnel vision" and integrating regenerative practices, the Butterfly represents a novel shift in environmental action—laying out a path that balances reduction with regeneration for a truly sustainable future.

Box 3.1 - From Planetary boundaries to Safe and Just Earth-System Boundaries (ESB)

In the Foreword and Chapter 1, we discuss that climate collapse is not just an ecological issue but also one of social safety and justice. Achieving true sustainable development requires a more equitable distribution of resources in the future. This is not only a matter of fairness but also a strategy to curb the overconsumption habits of the global North. As Anders Bjørn and Joachim Tildsted point out in their essay, countries like Denmark have a historic responsibility and the financial capacity to go beyond policy to address global inequalities through regeneration of the living world.

The "Beyond the Roadmap" approach and the Butterfly Framework presented in this chapter builds upon the ***Doughnut for Urban Development: A Manual***, which emphasizes creating a safe and just future for all as the goal for development. Thus, we move beyond viewing the Planetary Boundary safe operating space as the endpoint and instead propose a long-term, systemic approach to guide Danish development within the safe and just ESB – so that Denmark can contribute to the creation of stable climates and functioning ecosystems.

These boundaries, outlined in the Lancet Planetary Health–Earth Commission report ***A Just World on a Safe Planet*** by Gupta et al. (2024), define limits that maintain Earth's biophysical processes (safe boundaries) while also protecting human well-being and equity (just boundaries). The planetary boundaries framework applies to critical systems such as climate, biodiversity, freshwater, nutrient cycles, and air quality. Safe boundaries aim to prevent ecosystem tipping points by establishing limits within which life-support systems can function effectively, while just boundaries ensure that vulnerable populations are protected, and resources are distributed fairly.

In this report, Gupta et al. combines the safe and just vision of Doughnut Economics with the earth-system science behind the Planetary Boundaries framework. They describe the objective as: "to minimize harm and ensure access to essential resources, while addressing the drivers of Earth-system change and vulnerability and the institutional and social barriers to systemic transformations, and include reducing and reallocating consumption, changing economic systems, technology and governance."

With the same approach of the Reduction Roadmap, we translate these core objectives into operational, ecological targets for Denmark through the Butterfly Framework.

Understanding Ecological Deficit

In has been since the 1970s that the world's population last lived within Earth's sustainable capacity (Figure 3.1). For Denmark and other affluent nations, this threshold was crossed even earlier (Figure 3.2). Since then, ecosystems have faced increasing depletion and pressure, creating an accumulating ecological deficit. This day is marked each year by Earth Overshoot Day, which in 2024 happened on March 16 for Denmark and later on August 1 globally[1].

Chapters 1 and 2 emphasize that simply reducing harm is insufficient to address the polycrisis; focusing on "net-zero" reveals a misunderstanding of our urgent situation. Arguing that net-zero is enough is like a company deeply in debt claiming to have a healthy economy simply because it has stopped taking on new loans.

True sustainability requires regenerative actions that exceed net-zero, or merely reaching the safe operation space, moving us within planetary boundaries through net positive measures at a sufficient pace and scale. This approach doesn't just aim to reverse past transgressions but seeks to build a stable, enduring framework to create climate stability and ecosystem health.

Beyond Net Zero: From degeneration towards regeneration

This report re-frames the discourse around environmental sustainability by advocating for a fundamental reassessment of our current models, which must account for the ecological deficit created by the over-consumption detailed in chapters 1 and 2.

As Professor Johan Rockstöm says -
"We cannot succeed in delivering on the Paris climate agreement unless we take a full planetary boundary framework. We need to come back into the safe space of planetary boundaries… and it won't be enough to just phase out coal, oil, and gas."[58] As such, it is imperative to reverse the existing paradigm by reducing unnecessary environmental pressures such as resource extraction, greenhouse gas emissions, and ecosystem degradation - while simultaneously enhancing biocapacity, regenerating soil, re-wilding, reforestation, with the goal of regenerating the living world more than we degenerate it. This is the first step towards moving humanity back to the safe and just operating space defined by planetary boundaries.

Understanding the concept of ecological deficit makes it evident that merely achieving net-zero emissions and halting further degradation of natural ecosystems will not

True sustainability requires regenerative actions that exceed net-zero, or merely reaching the safe operation space, moving us within planetary boundaries through net positive measures at a sufficient pace and scale.

Figure 3.1 Global ecological deficit. The last time humanity lived within the sustainable capacity of Earth was in 1970. Source: Material footprint Network

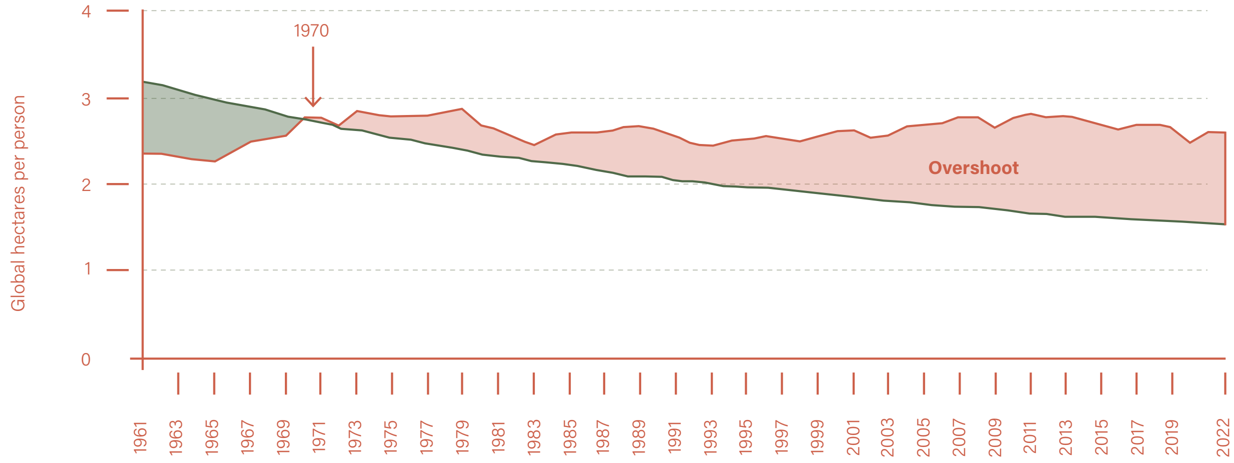
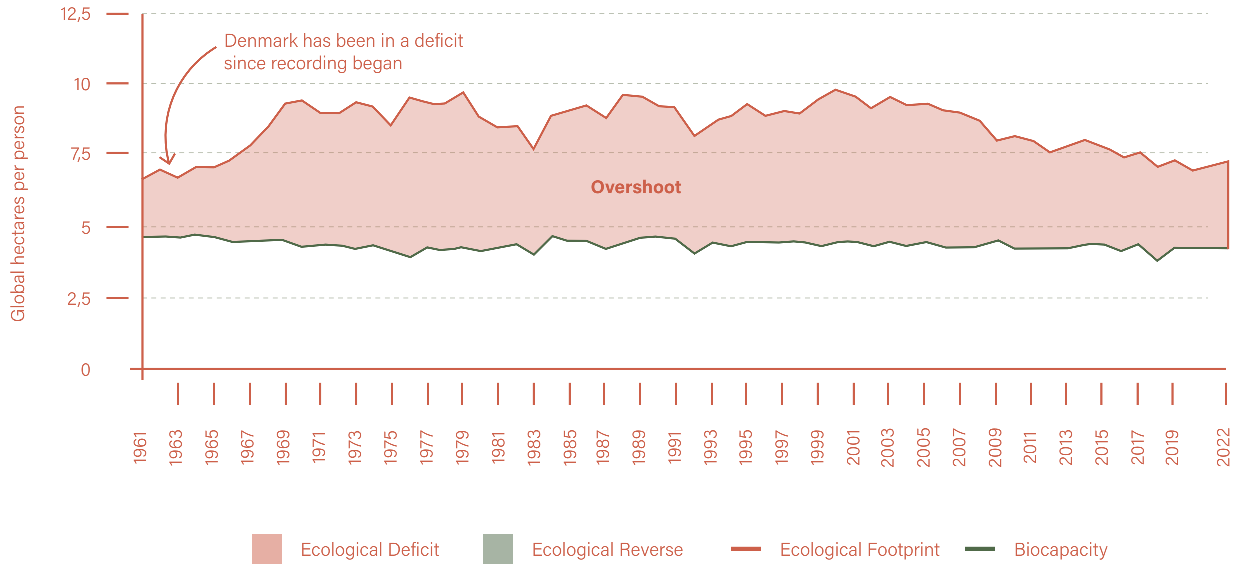


Figure 3.2 Danish ecological deficit. For Denmark, ecological deficit began before recorded data was available. Source: Material footprint network



Climate change and biodiversity loss are core boundaries because, once substantially transgressed, they can independently drive the Earth system away from the stability of the Holocene and into a new, less predictable state. Furthermore, the two systems are interconnected as climate stability is dependent on healthy ecosystems and healthy ecosystems are dependent on climate stability. Together, they create the conditions conducive to life on Earth .

suffice to bring us back within planetary boundaries, as these thresholds have already been transgressed. Therefore, "Doing net zero harm" in a degenerative state state fails to get us back within the safe and just limits of the Earth's systems (Figure 3.3). If sustainability is the future goal, such a state will only be reached by immediately deploying regenerative strategies to halt global warming and balance the ecological deficit accumulated by our degenerative system.

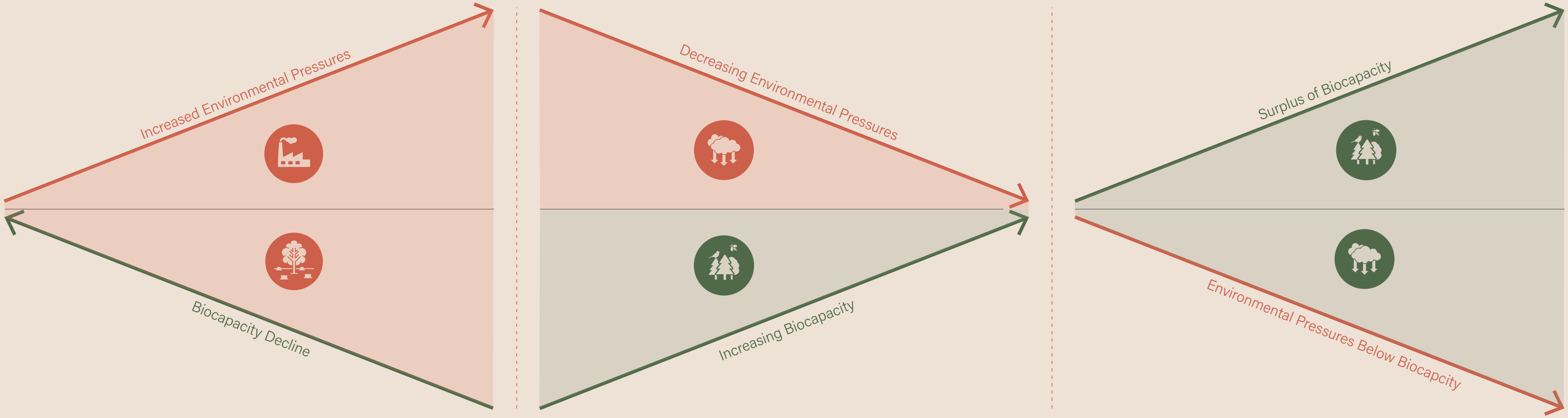
Beyond the Roadmap proposes a paradigm shift in how we approach development, moving from merely mitigating carbon emissions to actively regenerating the living world. This framework aims to instill a new mindset, empowering the building industry to transition from being a contributor to environmental degradation to becoming a proactive agent of ecological restoration and resilience.

Much like how the Reduction Roadmap offers a structured approach for guiding the Danish building industry back within the safe operating space for climate change, "Beyond the Roadmap" extends this framework by exploring pathways that move beyond the safe operating space. It introduces a new model, which includes targets for the two core Earth-system boundaries: Climate Stabilty and Functioning Ecosystems.

Core system boundaries

Our political system as well as the building industry remain trapped in a narrow "carbon tunnel vision," where climate policies prioritize reducing CO_2 emissions almost exclusively. While addressing carbon is essential, this singular focus is insufficient to secure a truly sustainable future. However, change is slowly emerging with initiatives like "Den Grønne Trepart," which integrates both nature and climate goals. However, these efforts are still insufficient as they are not aligned with targets defined in climate science. Additionally, ongoing discussions around water quality signal a shift toward a more comprehensive, holistic approach to sustainability.

As Earth system scientist Johan Rockström aptly explains: *"We are deep in the climate crisis. We are deep in the red of the climate boundary. But what the climate boundary science shows clearly is that even if we were successful in phasing out fossil fuels, we would still breach the 1,5-degree Celsius boundary if we do not come back in the safe space of the biosphere boundaries...It is so few people who really recognize that 30% of the carbon dioxide that we emit from fossil fuel burning, is actually absorbed by intact nature on land. It is thanks to the biodiversity and the intact forest systems in particular, that are buffering this... And if you don't have a healthy planet, that capacity of buffering that stress, is reduced... So, my fear is that we are shooting ourselves in the foot emitting greenhouse gasses and causing the climate crisis and at the same time making the planet in her weakest state to deal with that crisis."*[2]



The status - "Where we are":

Environmental pressures increase while biocapacity declines.
We are exceeding the Earth's limits.

The Transition - "Aligning with Global Commitments":

Environemtnal pressures decrease, biocapacity increases to meet at equilibrium (net zero).
Stopping further harm but not reversing the damage.

The Destination - "Where we are going":

Environmental pressures fall below biocapacity as it continues to rise.
Regenerating more than we consume, moving towards a sustainable future.

Figure 3.3 From increasing environmental pressures to creating a surplus of biocapacity. Source: Reduction Roadmap

Rockström's insight emphasizes the need for a comprehensive planetary boundary approach. Accurately measuring Earth system boundaries is complex and resource-intensive, yet essential for sustainability. This requires a robust, systems-based measurement framework that considers data gaps, technological costs, ethical allocation, and international fairness.

Despite these challenges, the *Doughnut for Urban Development: A Manual*[3] offers critical new understanding of the planetary boundary framework. As show in Figure 3.4 our planet has two core systems: Climate stability, which mostly relates directly to climate change and ocean acidification, and functioning ecosystems, which mostly relates directly to global biodiversity loss and land-use change on both land and sea.

Climate change and biodiversity loss are core boundaries because, once substantially transgressed, they can independently drive the Earth system away from the stability of the Holocene and into a new, less predictable state. Furthermore, the two systems are interconnected as climate stability is dependent on healthy ecosystems and healthy ecosystems are dependent on climate stability. Together, they create the conditions conducive to life on Earth .

Building on this work "Beyond the Roadmap" presents the Butterfly framework as a holistic framework to benchmark "where we are today" and "where we need to go" in relation to these two core earth-system boundaries.

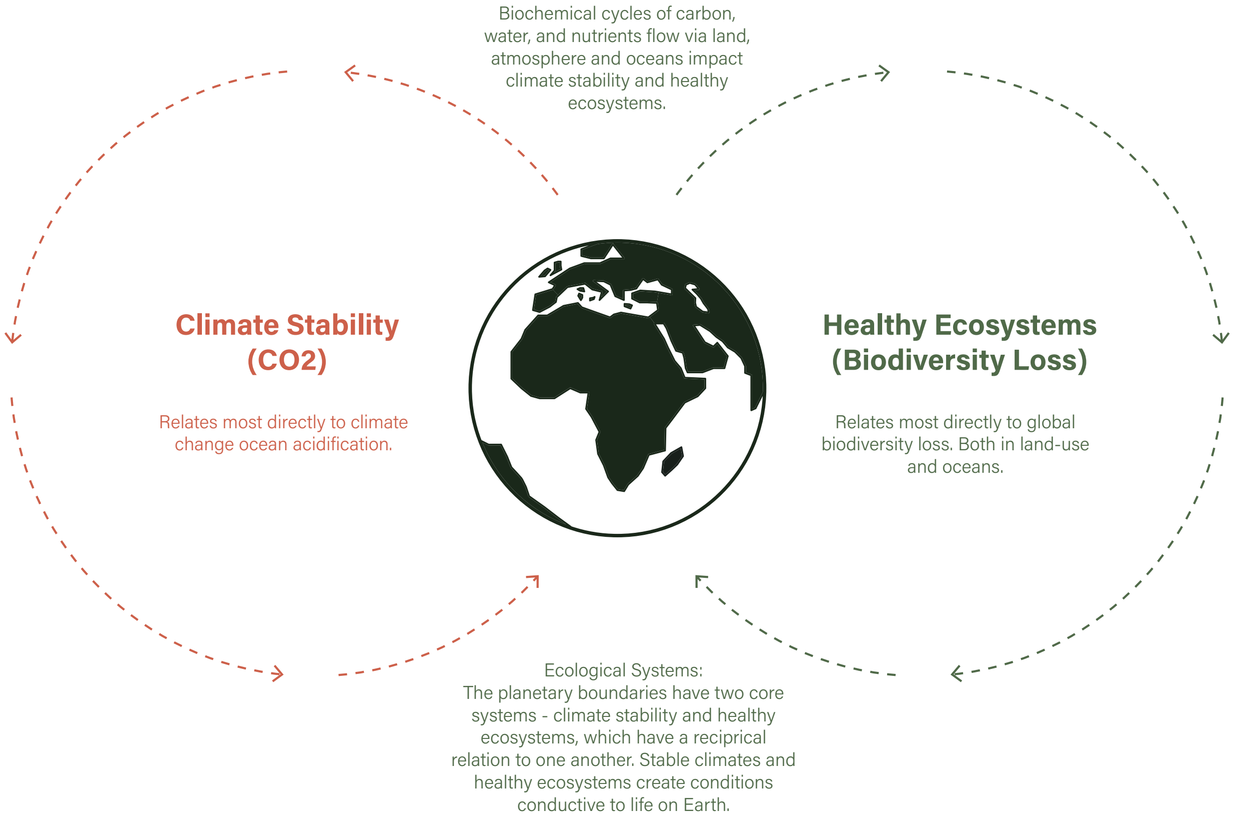
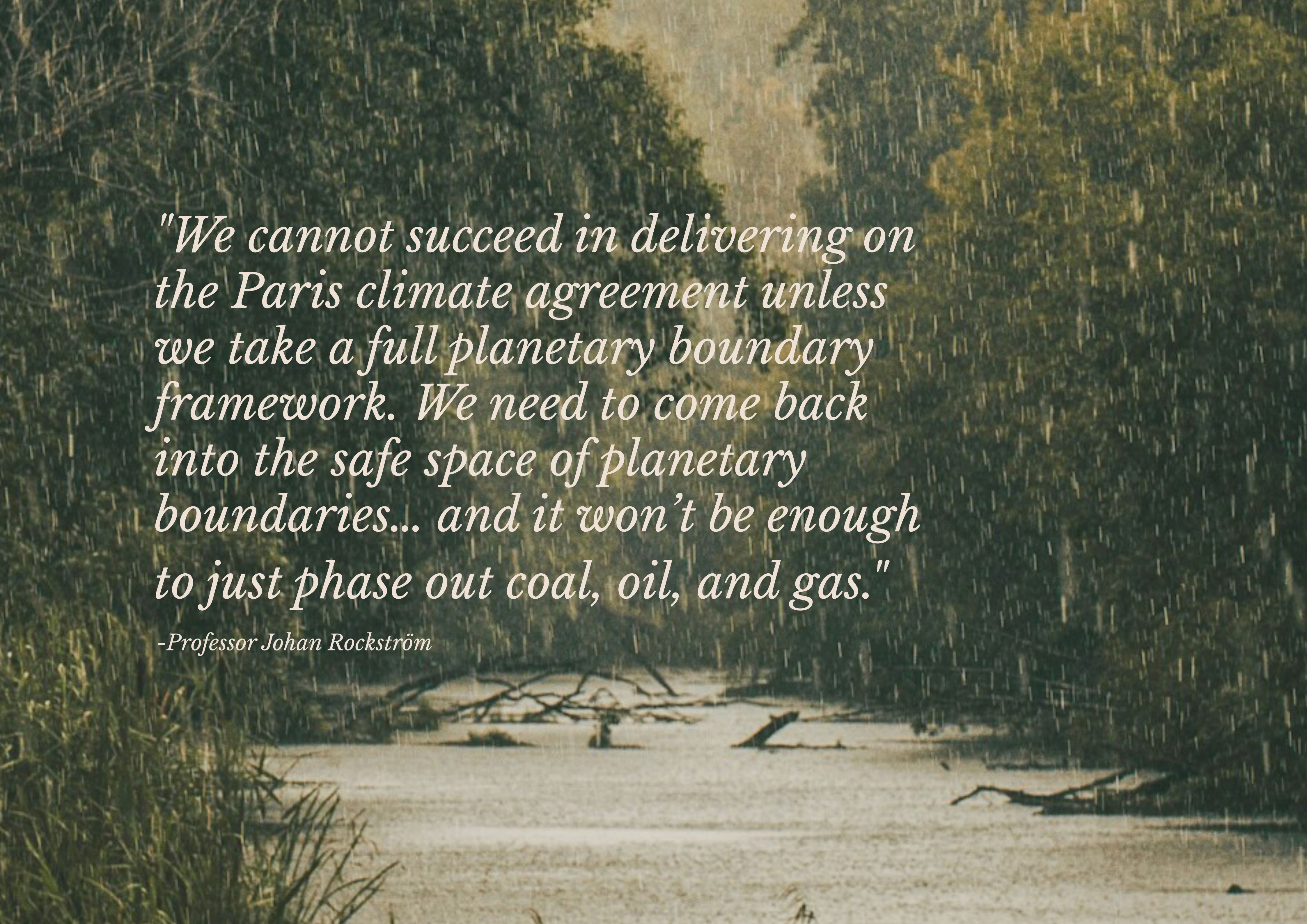


Figure 3.4 - Core Earth-System Boundaries Climate Stability and Healthy Ecosystems. Source: Doughnut for Urban Development A Manual - Figure 19 adapted from an original concept by Sarah Cornell, Tiina Häyhä and Holger Hoff (unpublished work).


"We cannot succeed in delivering on the Paris climate agreement unless we take a full planetary boundary framework. We need to come back into the safe space of planetary boundaries... and it won't be enough to just phase out coal, oil, and gas."
-Professor Johan Rockström

The Butterfly

The Butterfly framework offers a structured approach for a diverse range of users, including nations, municipalities, industries, and even products like buildings, to establish science-based targets aligned with planetary boundaries. It focuses on two key indicators:

• Greenhouse gas emissions (measured in CO_2 equivalents)
• Biodiversity loss (measured by the area of land to be restored and protected).

The selection of these indicators demonstrates a strategic approach to addressing core systems boundaries. CO_2 equivalents provides a holistic view of climate impact, crucial for reducing global warming potential across various greenhouse gases and ensuring climate stability. In contrast, the protected nature indicator (Figure 3.5) offers a tangible measure of biodiversity conservation efforts and restoration needs, essential for maintaining ecosystem services and resilience against environmental changes. The selection of these indicators is further detailed in Table 3.1.

Together, these indicators signify the current state of environmental health and equip policymakers, researchers, and conservationists with the tools to track improvements, plan interventions, and achieve the long-term goal of regaining planetary health. By focusing on these metrics, the Butterfly framework ensures a robust and actionable pathway towards a stable climate and functioning ecosystems[4].

Protected nature aims to conserve significant land-based environments to support biodiversity and climate stability. Protected areas are designated regions managed to preserve their natural conditions and biodiversity, and can include both conservation, restoration and rewilding. Protection standards should adhere to those defined by the International Union for Conservation of Nature (IUCN), area-based conservation measures (OECMs) and CSAs (Conservation Stewardship Areas). These vary from strict nature reserves with limited human activity to more flexible other effective conservation and restoration measures. This range enables diverse management approaches essential for safeguarding ecological integrity and promoting sustainable use across different landscapes.

Range & standards:

•IUCN Category 1 (Strict Nature Reserves): Areas managed primarily for scientific research and monitoring, with very limited human activity.
•OECMs (Other Effective Area-Based Conservation Measures): Areas that are not formally designated as protected but are managed in ways that contribute to the conservation of biodiversity and ecosystem services.
•CSAs (Conservation Stewardship Areas): Areas managed for retaining vegetative cover and preventing emissions, which can also be designated for biodiversity protection.

Figure 3.5 Defining "Protected Nature" including range and standard indicators. Source: Reduction Roadmap.

	CO2eq as an Indicator for Climate Stability	Land-use as an Indicator for Functioning Ecosystems
Definition	CO2eq (carbon dioxide equivalents) is a metric comparing emissions of various greenhouse gases based on global warming potential (GWP).	Protected nature as a percentage of land area (global, bio-regional, national) indicates biodiversity conservation levels.
Comprehensiveness	**CO2eq accounts for various GHGs:** includes CO_2, methane, nitrous oxide, ensuring all relevant emissions are considered for policies.	**Direct Impact on Biodiversity:** Protected areas provide natural habitats, promoting biodiversity and ecosystem functionality.
Alignment with Global Standards	**Aligns with international agreements:** CO2eq is compatible with frameworks like the Paris Accord, aiding global collaboration.	**Adheres to biodiversity targets:** Supports Aichi Targets, 30x30 goals, and safe Earth boundaries for biodiversity health.
Actionable Insights	**Provides insights for policy and action:** Enables clearer understanding of environmental footprints to prioritize emissions reduction.	**Guides conservation priorities:** Identifies coverage gaps, supports strategic planning for biodiversity preservation efforts.
Limitations	**Oversimplification of interactions:** CO2eq doesn't capture non-gaseous factors like land-use changes and may lack alignment with specific policy goals.	**Variable effectiveness:** Effectiveness depends not only on management quality and external pressures but also on the condition and quality of the protected nature itself, all of which can significantly influence ecosystem assessments.[5]
Scientific Robustness	Both indicators are scientifically established and provide a reliable basis for policy, requiring context-specific applications to address conservation and climate goals effectively.[6]	

Table 3.1 Qualifying the selected indicators for the Butterfly - CO2eq for Climate Stability and Land-use for Functioning Ecosystems Source: Reduction Roadmap

3.2 Methodology

The Butterfly methodology uses the key indicators to establish benchmarks across three distinct stages to guide actions toward the safe and just Earth system boundaries: the status, the transition, and the destination. This approach provides a structured framework to assess, align, and target environmental impacts, fostering long-term stability and ecological balance (Figure 3.6).

1. The Status – "Where We Are"

This stage assesses the current environmental impact of key indicators, providing a clear picture of ecological effects by comparing existing practices with planetary thresholds. The objective is to establish a baseline that enables an assessment of the changes needed to ensure alignment with safe and just planetary targets.

The CO_2eq indicator measures the total greenhouse gas emissions from all sources, offering a comprehensive overview. For more specific measurements, such as those for individual countries, industries, or services, consumption-based emissions are utilized. This accounting method considers both direct emissions and those embedded within goods and services, providing a more complete understanding of the emissions associated with consumption[7]. As such, consumption-based emissions provide a more accurate reflection of a nation's emissions and differ from the territorial emissions reported to the UN.

The nature indicator is determined by evaluating the amount of land currently protected. This figure is compared to established targets for land protection, identifying the gap between current protection levels and the baseline. This assessment helps determine the additional protection needed to return to safe and just planetary limits.

2. The Transition – "Aligning with Global Commitments"

The transition stage focuses on aligning practices with global environmental commitments, forming the baseline for the Butterfly methodology. This phase involves setting clear, measurable targets to guide incremental progress toward safe and just Earth system boundaries, which is essential for implementing sustainable practices over the next half-decade while balancing practical realities with environmental imperatives.

The transition target for CO_2-eq. emissions is set to align with the 1.5°C target of the Paris Agreement[8], requiring reductions to a global "safe operating space" of 2.5 Gt CO_2-eq./year[9]. The rate of transition toward this target

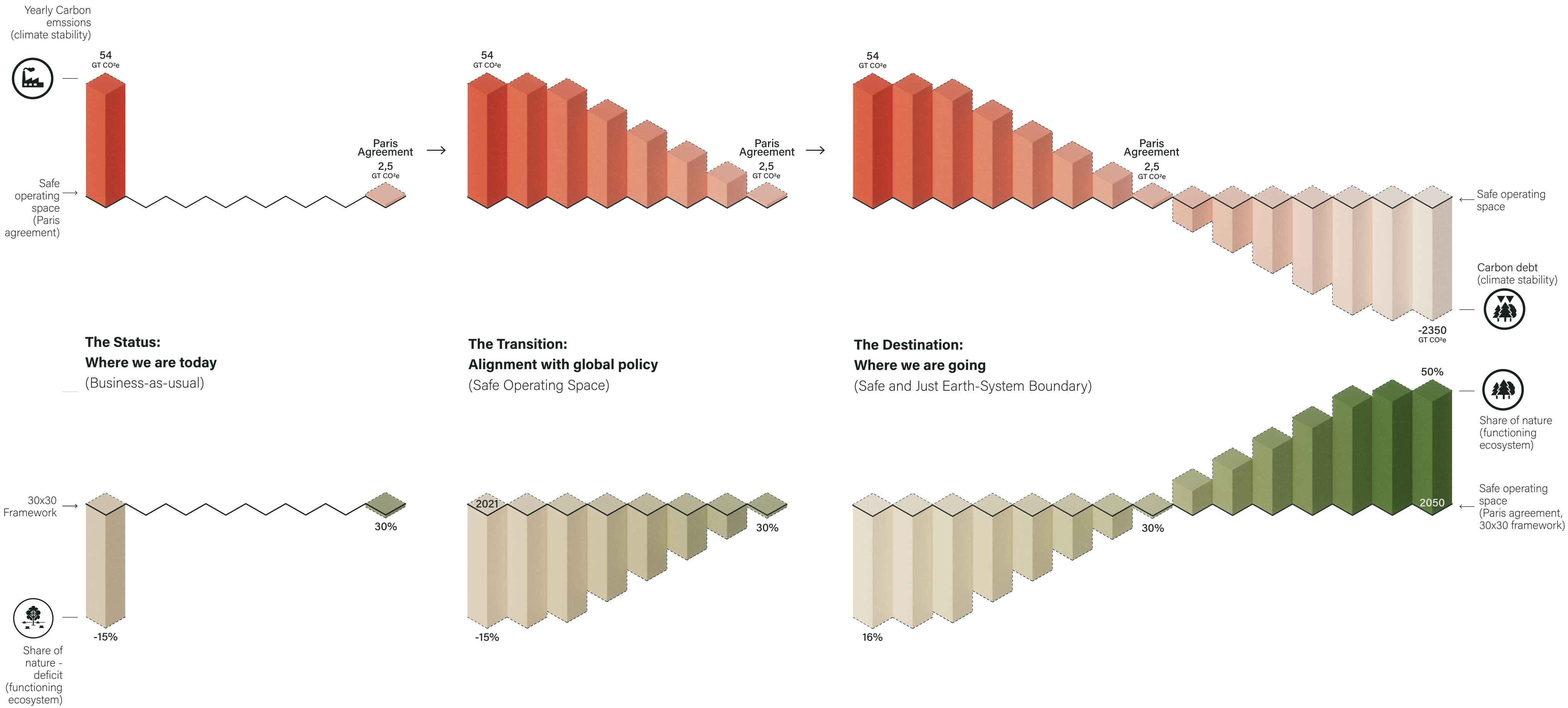


Figure 3.6 - Understanding the Butterfly methodology. The top part of the figure illustrates targets for Climate Stability (carbon reduction) in red. The bottom of the figure illustrate targets for Functioning Ecosystems in green.. The shift from "where we are today" in 2024 towards "where we are going" in 2050 happens in two phases. First, there is a shift from "The Status: where we are today" towards "The transition: Alignment with global policy." Secondly, there is a shift from alignment with global policy towards "The Destination" alignment which entails with Safe and Just Earth-System Boundaries. Source: Reduction Roadmap

varies based on factors such as global, national, industry, or individual contexts, allocation methods - including equal per capita, sufficiency, or safe and just approaches – as well as estimates for the remaining CO_2 budget (83%, 67%, or 50%)[10]. It is crucial that any strategy employed ensures alignment with the 1.5°C carbon budget, as exceeding this threshold risks crossing critical tipping points. (As described in Chapter 1 – 1.5°C and tipping points).

The transition target for protected nature is set to align with the 30x30 Kunming-Montreal Global Biodiversity Framework (hereafter 30x30 Framework), endorsed by nearly two hundred countries, including all of Europe. This goal is also part of the EU's biodiversity strategy and focuses on expanding protected areas, restoring ecosystems, rewilding landscapes, and ensuring effective monitoring and adaptation to achieve these conservation objectives.[11] Such activities have many benefits as described in Table 3.2

3. The Destination – "Where we are going"

The destination stage involves setting clear, science-based targets to ensure that humanity returns to safe and just limits within the Earth system boundaries. This step goes beyond international commitments, aligning with climate goals to safeguard climate stability and functioning ecosystems. It is critical for ensuring long-term ecological resilience and aligning activities with the Earth's capacity to support life.

Benefits Of Protectine Wild Nature and Regeneratine Biodiversity		
	Reversing Biodiversity Loss	Protects critical habitats and species, helping to halt biodiversity decline and preserve essential ecosystem functions.
	Ecosystem Services	Conserves ecosystem services like pollination, nutrient cycling, soil health, marine ecosystem vitality, and clean drinking water.
	Climate Corridors	Provides safe pathways for species migration and adaptation in response to environmental changes, bolstering ecosystem resilience.
	Public Health	Reduces human-wildlife interactions, lowering the risk Of zoonotic disease transmission, including diseases like COVID-19.
	Economic Benefits	Supports cost-effective, nature-based solutions, promotes sustainable activities, and reduces future costs related to environmental degradation and health crises.
	Food and Water Security	Protects watersheds, promotes clean water availability, and supports sustainable agricultural practices, ensuring long-term resources.
	Climate Action	Reduces C02 emissions by removing agricultural land from production and restoring carbon-rich soils; increases carbon storage by converting former fields to wetlands, grasslands, and forests.
	Synergy with Climate Goals	Demonstrates a mutually reinforcing relationship between biodiversity conservation and climate objectives, enhancing climate resilience through ecosystem protection.

Table 3.2 - Benefits of Protecting Wild Nature and Regenerating Biodiversity. Source: Reduction Roadmap

The objective is to establish targets that not only prevent further damage to the planet but also enable active restoration in the pursuit of recovering ecological deficits. The target for CO_2eq levels aims to bring us back within Earth's safe and just limits, defined by scientists under the Safe and Just Planetary Boundaries framework[12]. This target is set at a maximum 1°C increase from preindustrial levels, corresponding to 390 parts per million (ppm) as illustrated in Figure 3.8. As we are already exceeding this boundary, it is essential to do more than merely reduce emissions; we must actively remove CO_2 from the atmosphere to restore safe levels.

The target for protected nature is based on a broad scientific consensus advocating for the protection of 50-60% of the planet's land to ensure long-term stability for both biodiversity and climate[13]. This goal includes identifying an additional minimum of 20% of land beyond the 30x30 Framework. It also emphasizes the importance of restoring degraded lands and creating wildlife corridors to connect fragmented ecosystems[12]. Protecting and restoring 50% of Earth's land will help reverse biodiversity loss, prevent CO_2 emissions from land-use changes, and harness the natural carbon sequestration capabilities of ecosystems—collectively bringing humanity back within safe environmental limits (Figure 3.7)[12].

Box 3.1 - Kunming-Montreal Global Biodiversity Framework

The Kunming-Montreal Global Biodiversity Framework[15], adopted on December 19, 2022, during the UN Biodiversity Conference (COP15), sets a bold and historic plan to tackle global biodiversity loss. Central to the framework is the 30x30 goal, which commits nations to protect 30% of the planet's land and oceans by 2030. The initiative, involving 196 Parties to the UN Convention on Biological Diversity (CBD), is designed to safeguard critical ecosystems, ensuring that both nature and humanity can thrive in the face of accelerating biodiversity decline.

The framework aims to restore 30% of degraded ecosystems and ensure the sustainable management of biodiversity, with the overarching goal of halting biodiversity loss by 2030. A key element is placing 10% of all land and marine areas under strict protection, meaning they are fully shielded from activities that could harm their biodiversity. These strictly protected zones are vital for preserving vulnerable species and ecosystems, allowing them to regenerate without human interference.

By aiming to protect one-third of the planet's land and marine areas within the next decade, the Kunming-Montreal Framework represents one of the most ambitious international conservation efforts in history. If successful, it could significantly slow the rate of species extinction and restore ecosystems vital for planetary health, making this a defining decade for global conservation efforts.

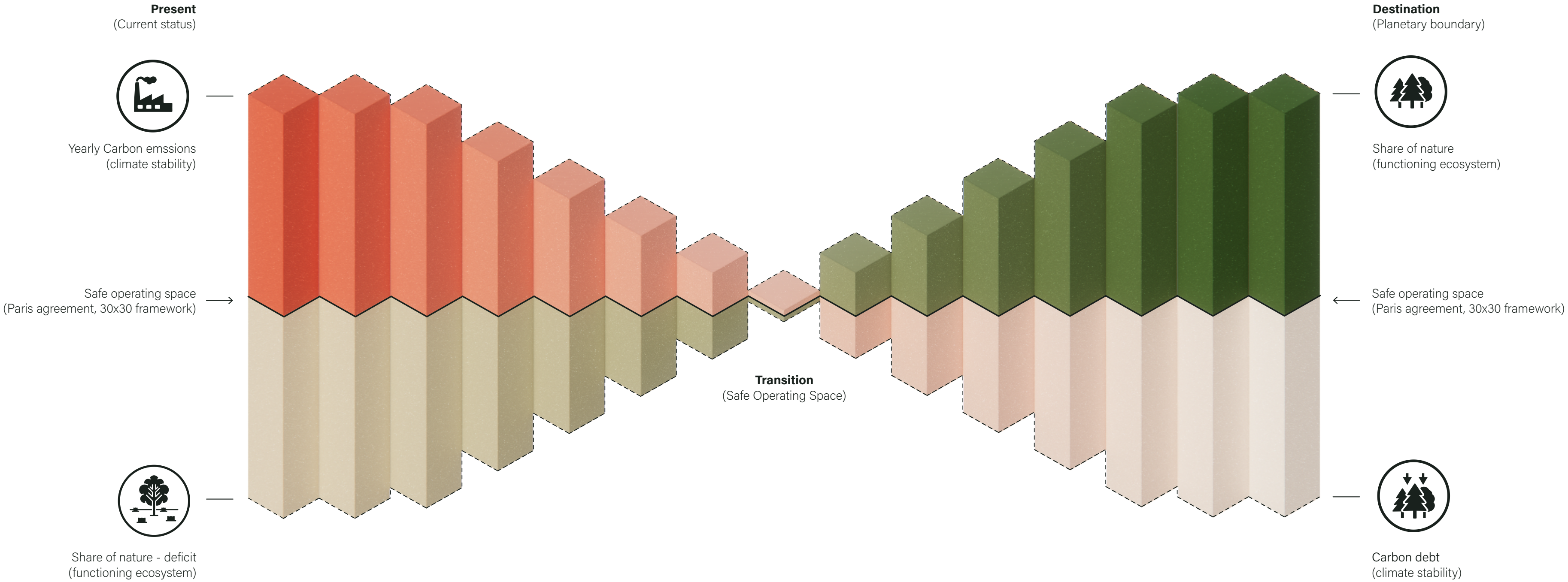


Figure 3.7 - The Butterfly Framework is illustrated identifying targets and indicators without specific data points. Source: Reduction Roadmap.

Box 3.2 Carbon Debt

Globally, the planetary boundary for CO2, set at 350 ppm, has been exceeded, with current atmospheric levels reaching approximately 420 ppm. This overshoot has led to a significant global carbon debt. Restoring climate stability and achieving a safe and just limit - defined as a 1°C temperature rise above pre-industrial levels (around 390 ppm CO2) (Figure 3.8) - requires actively removing greenhouse gases from the atmosphere.

Although carbon debt is a global concern, it can be assigned to individual nations. Using the methodology developed by Jason Hickel[25], Denmark's carbon debt is estimated at 800 million tons of CO2 equivalent, based on its equal per capita share of the global debt. However, When considering Denmark's historical emissions since 1850, its industrial legacy reflects a greater responsibility for climate damages, raising the total carbon debt to 2.4 billion tons of CO_2eq. These estimates assume that the 1.5°C goal of the Paris Agreement will be achieved without overshoot, limiting atmospheric CO2 levels to a maximum of 435 ppm.

The concept of carbon debt is essential for achieving climate justice, as it highlights the historical accountability of wealthier nations like Denmark, which have benefited from extensive industrialization and fossil fuel consumption. Like described in the Foreword in an essay by Bjørn and Tildsted , Research indicates that high-income countries bear a disproportionate share of responsibility for climate damages. Consequently, addressing this carbon debt requires not only significant reductions in future emissions but also active carbon removal. This approach supports a more equitable global climate strategy that respects planetary boundaries.

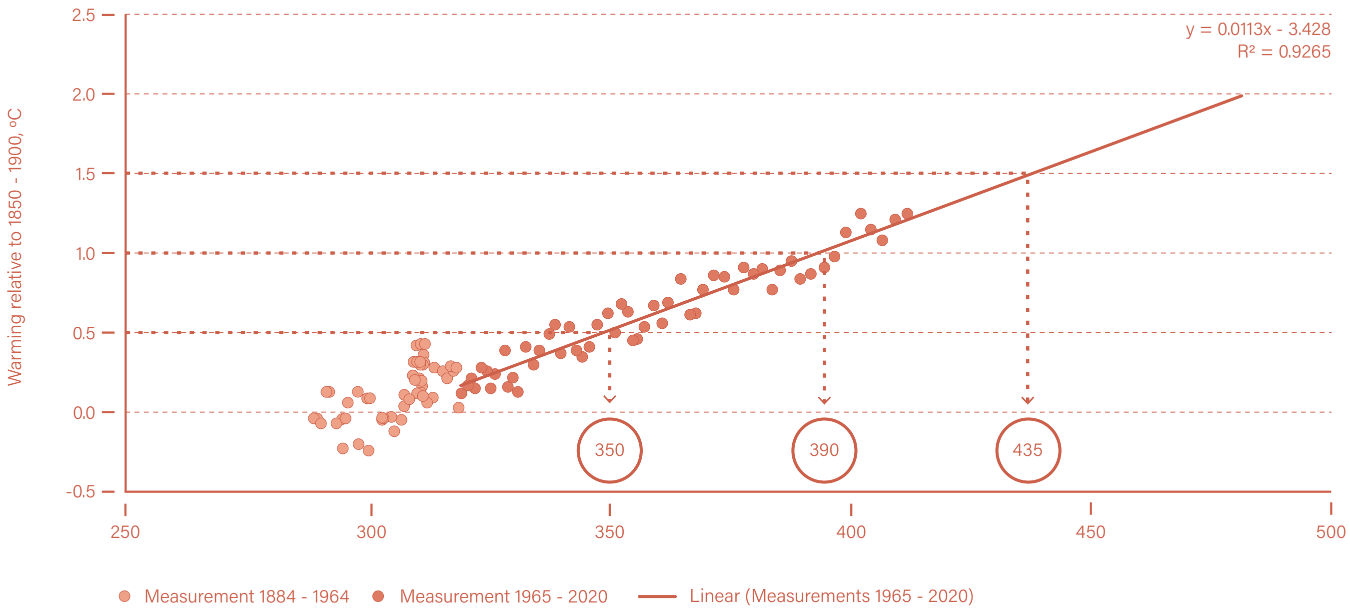


Figure 3.8 - Historical measurements of temperature increase and atmospheric concentrations of CO_2eq. Source: Mauna Loa Observatory[14]

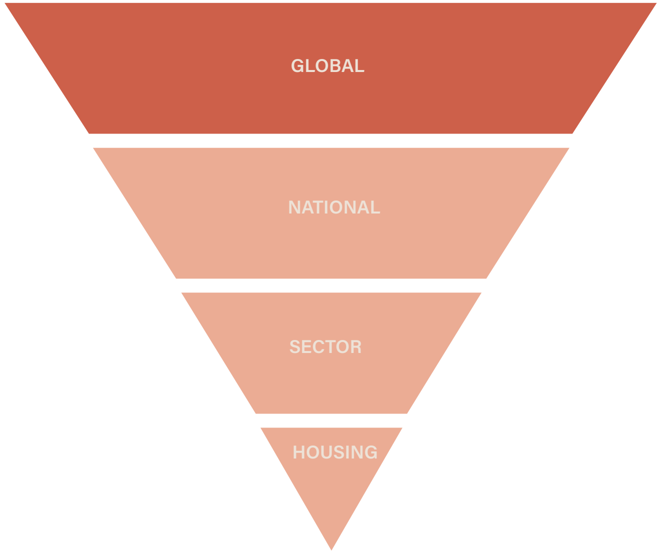


Figure 3.9 - The Butterfly is first applied on a global level. Source: Reduction Roadmap

3.3 Global and Danish application

This section illustrates the applicability of the Butterfly model in both a global and Danish context. To effectively utilize the model, it is essential to establish specific variables, including scope, allocation principles, and targets. The chosen parameters will influence the model's outcomes, affecting the timelines, scale, and methods required to achieve the desired objectives.

As outlined in Chapter 1, the urgency of returning to safe environmental limits is undeniable. Immediate action is crucial, as each additional year of overshoot heightens the risk of crossing critical tipping points. While the Butterfly methodology aligns with international agreements like the Paris Agreement and the 30x30 Framework[8, 11]- globally recognized commitments endorsed by most nations - these agreements alone are not sufficient to guarantee a sustainable future for all. Therefore, the destination targets are designed to guide us back within safe and just planetary boundaries, ensuring a fair and socially equitable transition in 2050.

Global (Figure 3.10)

- **Status - "Where we are":** In 2021, global greenhouse gas emissions reached 54 gigatons of CO2eq.[15] , with atmospheric CO_2 concentrations at approximately 420 parts per million[16]. At the same time, only 15% of the world's land was under protection[13].

- **Transition - "Aligning with Global Commitments":** To limit global warming to 1.5°C, global GHG emissions must be reduced by 96% to reach the safe operating space of 2.5 gigatons of CO_2eq. pr. year[9]. This transition target should be reached as swiftly as possible, while staying within the remaining greenhouse gas budget of approximately 390 gigatons of CO_2eq.[17]. Additionally, to comply with the 30x30 Framework, an extra 15% of terrestrial areas must be protected and restored before 2030.

- **Destination - "Where we are going towards 2050":** To revert to the safe and just Earth system boundary for climate stability, defined as a maximum temperature increase of 1°C from preindustrial levels[12], approximately 1,100 gigatons of CO_2eq. must be sequestered to reduce the atmospheric CO2 level to 390 ppm[18]. Similarly, to restore safe limits for functioning ecosystems, it is necessary to protect and restore ecosystems across 50% of all terrestrial surfaces by 2050[12, 13].

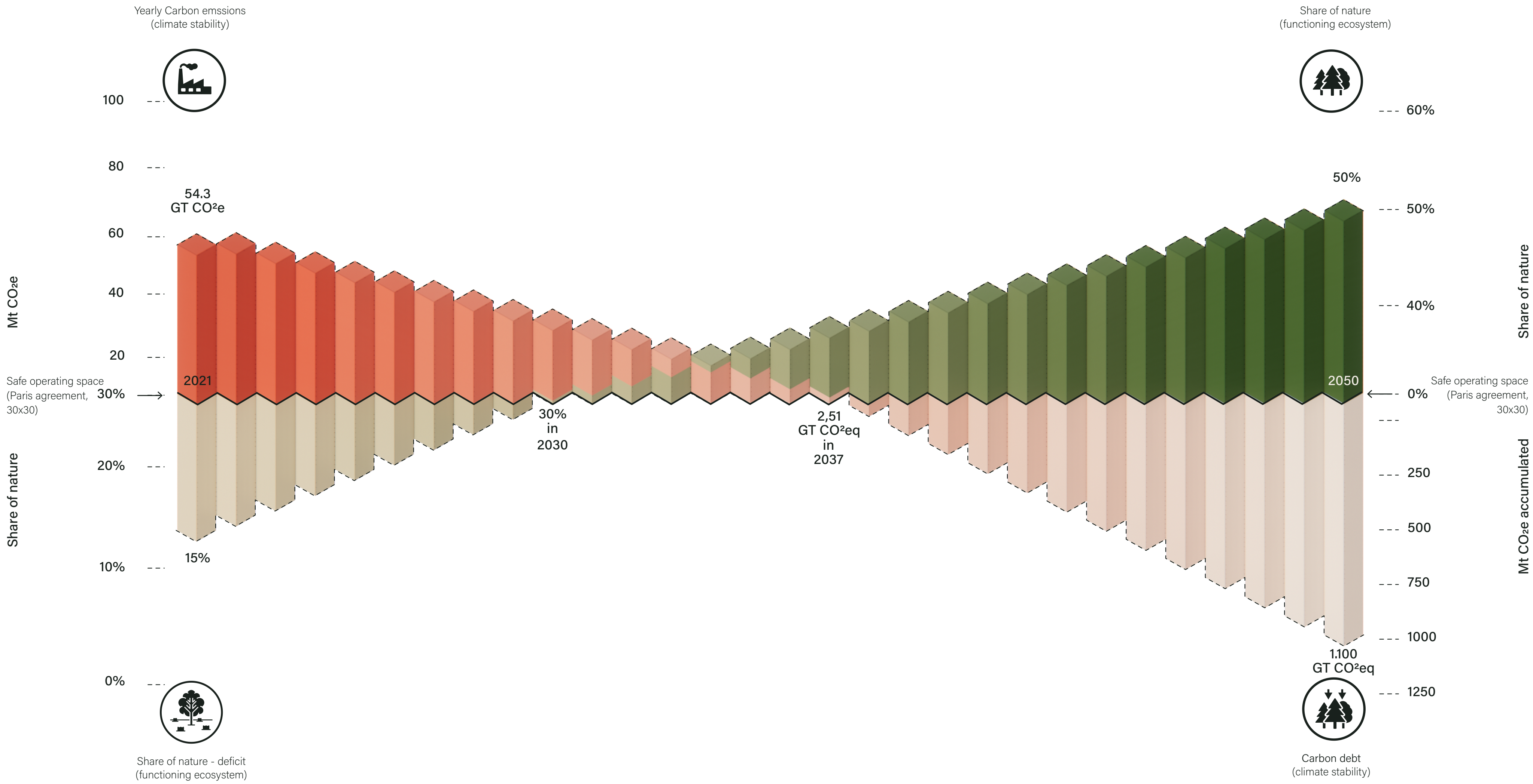


Figure 3.10 The Global Butterfly is illustrated identifying targets and indicators with global data. To reach global commit to the Paris Agreement 1.5C carbon budgets the safe operating space must be reached by 2037. To reach the global commitment to the 30x30 framework 30% of land must be protected by 2030. To reach the Safe and Just ESB for Climate Stability the global carbon debt of 1.100 GT CO_2-eq must be sequestered by 2050 and to reach the safe and just ESB for Functioning Ecosystems 50% of global land should be protected nature by 2050. Source: Reduction Roadmap

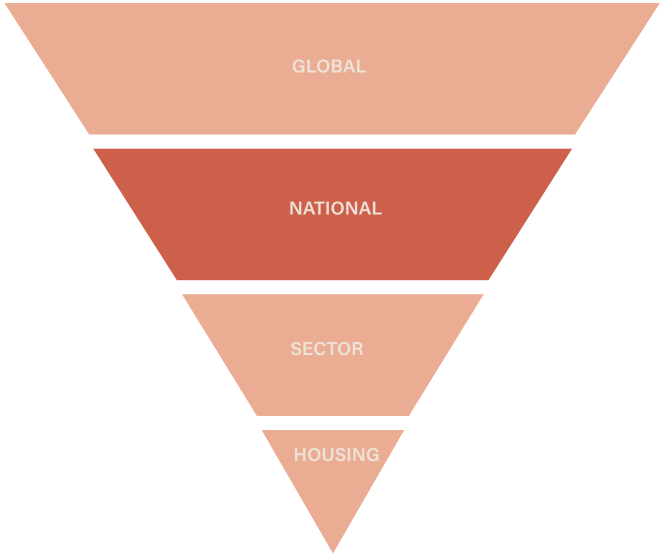


Figure 3.11 - The butterfly is applied at the national level. Source: Reduction Roadmap

Denmark (Figure 3.12)

• **Status - "Where we are":**
In 2021, Denmark's consumption-based greenhouse gas emissions reached 65 mio. tons of CO_2eq.[19]. At the same time, 10% of the land was nature however, only 1.6%[20] was designated as protected nature, underscoring Denmark's status as the second most cultivated country in the world[21].

• **Transition - "Aligning with Global Commitments":** To limit global warming to 1.5°C, Danish GHG emissions must be reduced by 97% to reach the Danish safe operating space (equally per capita) of 1,7 mio. tons of CO_2eq. pr. year[22]. This transition target should be reached as swiftly as possible, while staying within the remaining greenhouse gas budget of approximately 270 mio. tons of CO_2eq[23]. Additionally, to comply with the 30x30 Framework, an additional 28% of the Danish areas must be protected and restored before 2030.

• **Destination - "Where we are going towards 2050"**: To fulfill its per capita responsibility within the safe and just Earth system boundary for climate stability, Denmark must sequester a carbon debt of 800 million tons of CO_2 equivalents. This effort is crucial for contributing to the global goal of reducing atmospheric CO_2 concentrations to 390 ppm. Additionally, to restore safe limits for functioning ecosystems, it is essential to protect and restore ecosystems across 50% of all Danish areas by 2050.

While immediate action is ideal, particularly given Denmark's high historical emissions[24], one could argue that a 2050 target is too late. However, the year 2050 was chosen to allow for benchmarking with global indicators, ensuring a coherent framework for tracking progress and aligning efforts internationally (Figure 3.12).

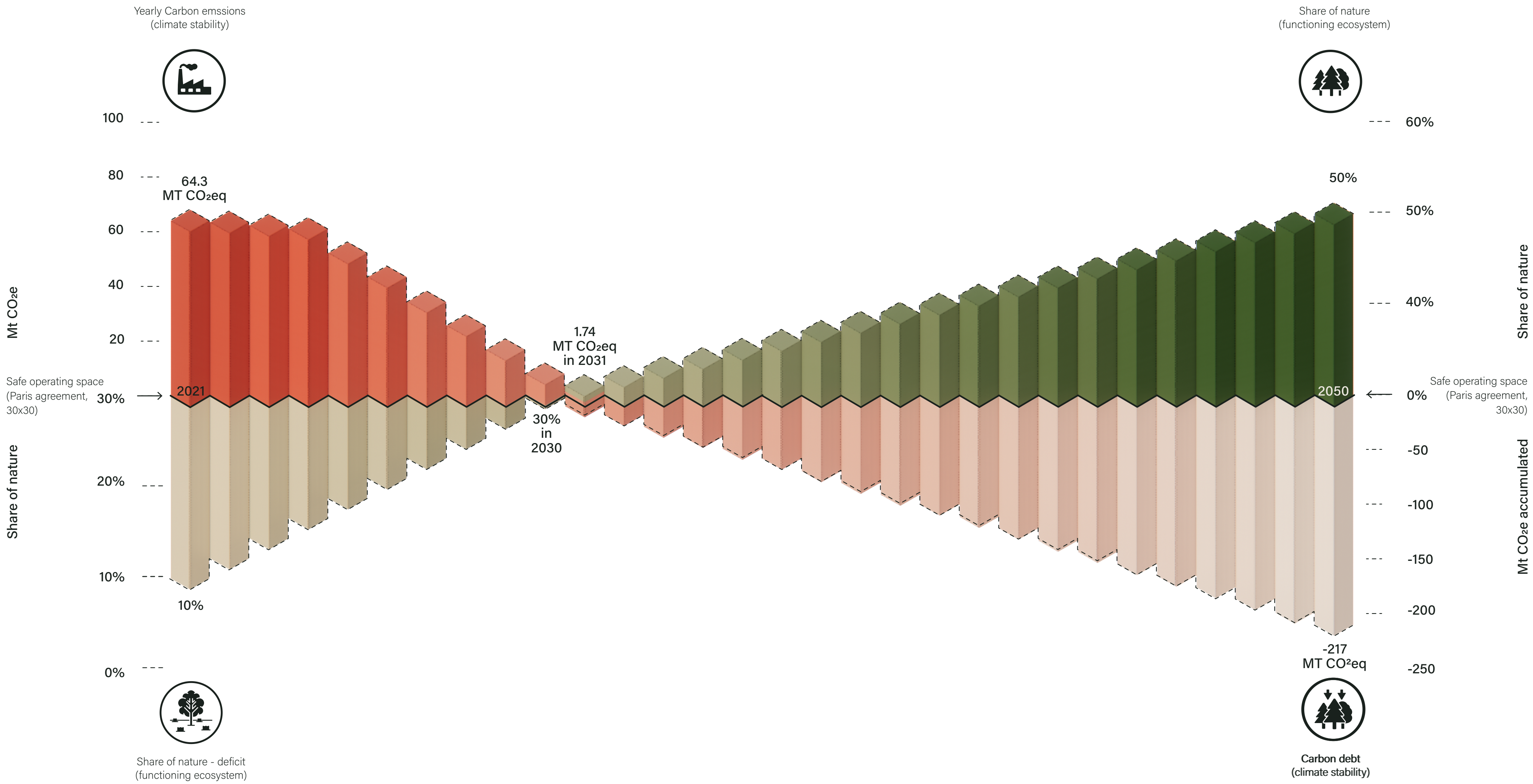


Figure 3.12 The Danish Butterfly is illustrated identifying targets and indicators with global data. To reach Danish commit to the Paris Agreement 1.5C carbon budgets the safe operating space must be reached by 2030. To reach the Danish commitment to the 30x30 framework 30% of land must be protected by 2030. To reach the Safe and Just ESB for Climate Stability the Danish carbon debt of 800 GT CO_2eq must be sequestered by 2050 and to reach the safe and just ESB for Functioning Ecosystems 50% of Danish land should be protected nature by 2050. Source: Reduction Roadmap

3.4 Moving Denmark "Beyond the Roadmap"

Building on the status, transition targets, and destination for Denmark, this section applies the Butterfly framework to outline pathways for the country to return within planetary limits. It presents strategies that demonstrate how the framework can guide both policy and strategic decisions, emphasizing that committed actions from governments, policymakers, and companies are essential for meaningful progress.

Strategy 1: Adhering to the 30x30 Framwork
Strategy 2: Adhering to the Paris Agreement
Strategy 3: Adhering to the Safe and Just Earth-System Boundaries

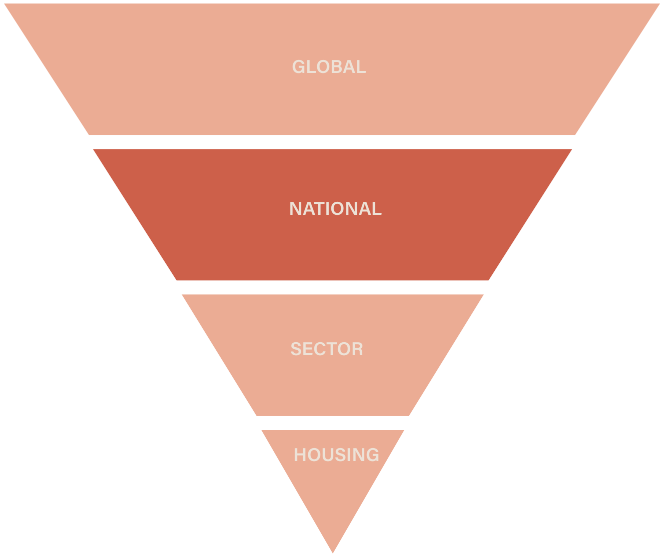


Figure 3.11 - The butterfly is applied at the national level. Source: Reduction Roadmap

Strategy 1: Adhering to the 30x30 Framework

Currently, approximately 10% of Denmark's land is classified as nature, with only about 1,6% designated as protected[26]. To align with the 30x30 Framework, Denmark must designate an additional ~28% of its land as protected nature. This requirement surpasses the current biodiversity strategy, which aims to protect only 20% of natural areas by 2030[27], resulting in a 10% shortfall (Figure 3.13 & 3.14).

In conjunction with the 30x30 Framework, the Danish Biodiversity Council emphasizes the urgent need to expand protected areas to address the ongoing decline in biodiversity. To achieve this, Denmark must establish large, interconnected protected zones that support biodiversity and restore natural processes, especially as human activities such as agriculture, forestry, and fisheries continue to exert pressure on ecosystems[28].

Researchers have already identified key areas that could significantly enhance biodiversity if protected (Figure 3.15). Designating 30% of Denmark's land as protected nature would not only increase biodiversity but also improve vital ecosystem services such as climate regulation, water quality, and flood control. Expanding protected areas would help

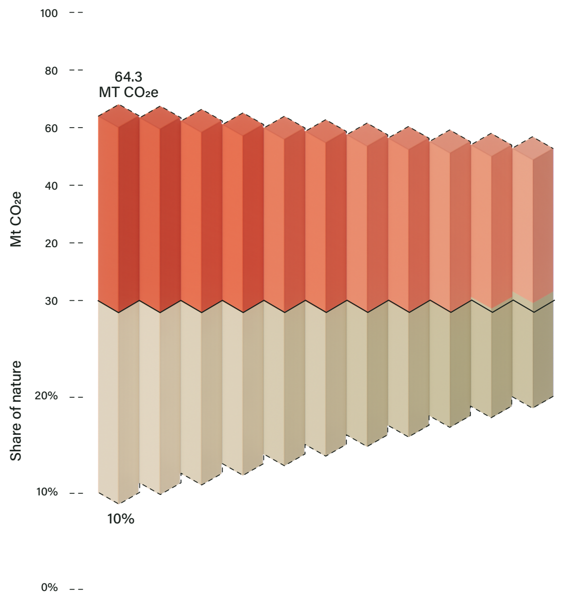


Figure 3.13 - Danish Frozen Policy for CO_2-eq reduction and land-use change.

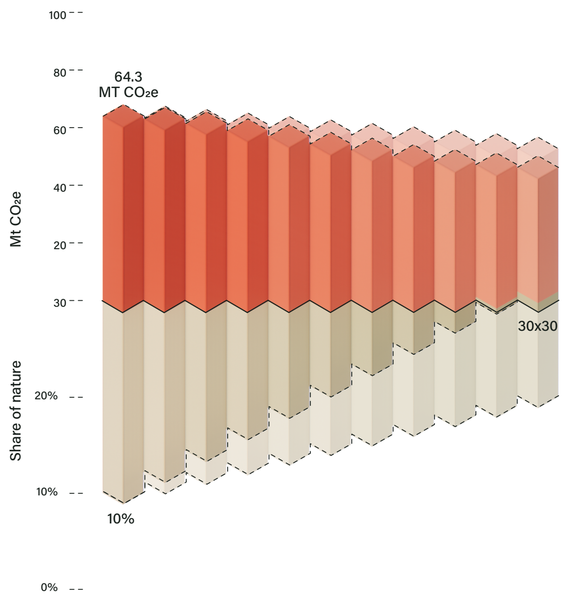


Figure 3.14 Adhering to the 30x30 Framework. If Denmark follows through on the 30x30 commitment not only will Danish protected nature be restored to 30% but the total carbon sequestered over the period would amount to 6 million tons, assuming the land distribution shown in Figure 3.16. Source: Reduction Roadmap

reduce agricultural runoff, enhance coastal ecosystems, mitigate dead zones, and support marine life. These actions would enable Denmark to meet the European Water Framework Directive and promote healthier habitats across both land and water[26 28]. Other benefits are described in Table 3.2.

With the current distribution of land, achieving the 30% target would, however, require conversion of primarily agricultural land, necessitating substantial policy shifts and economic support for the affected sectors. According to experts involved in "Vejen til Biobeseret Byggeri" report[35]: “More space with better quality is needed to halt biodiversity loss and improve ecosystem services.”

Government incentives and compensation will be essential for farmers transitioning away from intensive land use. Shifting agricultural practices to prioritize human food production over animal fodder could help Denmark maintain its protein supply while reducing land use. Achieving this goal would, however, require an annual investment of 2-4 billion DKK [29] (approximately 0.55% of GDP), to cover both lost production and ecosystem management.

"If Denmark is to approach the 30/10% targets at the national level, it will be necessary to take significant areas of agricultural land out of production for the restoration of nature and biodiversity."[30]

The Danish Biodiversity Council highlights the urgent need for economic assessments related to the protection of 30% of Denmark's land . These analyses are essential for understanding the societal gains and costs of conservation, considering nature's immense and potentially infinite value. International studies indicate that investing approximately $140 billion annually until 2030 to protect 30% of the Earth could generate over $250 billion in economic output and $350 billion in enhanced ecosystem services each year, resulting in a cost-benefit ratio of 5 to 1[31]. This underscores the compelling economic case for protecting nature, which offers significant returns on investment. Therefore, investing in nature not only supports biodiversity but also promotes economic resilience and public health benefits.

Furthermore, increased carbon storage can be achieved when open areas, particularly former agricultural fields, are allowed to regenerate into forests or natural areas, and when cultivated forests are left undisturbed to enhance their carbon stock. Consequently, the climate benefits will encompass reduced CO_2 emissions and increased carbon sequestration through natural uptake. By taking out agricultural land from production, CO_2 emissions can be lowered - not only through a general decline in agricultural output but also through the preservation of carbon-rich lowland soils. This illustrates a clear synergy between biodiversity and climate, emphasizing the importance of protecting natural ecosystems[28].

Using estimates from the Danish Climate Council[51] and Klimaskov Fonden[32] regarding the carbon sequestration capacity of various ecosystems[33] - including both new and old untouched forests, wetlands, and grasslands - the average sequestration rate is approximately 11 tons of CO_2eq. per hectare per year for biodiversity forests and 1.5 tons of CO_2eq. per hectare per year for open land with scattered trees or bushes. If Denmark designates 30% of its land as protected areas under the 30x30 Framework, the total carbon sequestered by 2030 would amount to 6 million tons, assuming the land distribution shown in Figure 3.15.

Figure 3.15 - A proposal for land-use change in Denmark to reach the 30x30 target. Denmark's natural areas need to expand from 10% to 30%, with full protection for all designated regions. Source: Vejen til Biobeseret Byggeri (30%)35 Bioversitetsrådet (10%)26

Box 3.3 Land Distribution

To meet the 30/30 goal and establish safe and just boundaries for functioning ecosystems, Denmark must significantly reshape its current land use distribution. Currently, only 10% of the land is designated as nature, with just 2% being protected. This allocation needs to be transformed by 2030 to expand the area of protected nature.

Some existing production forests can be converted into biodiversity forests. However, the majority of the land that needs to be reallocated will come from agricultural areas, which will be designated for biodiversity purposes, including untouched forests, wetlands, and grasslands.

The projected land use distribution for 2030 is based on the initiatives of the "Fra Foder til Føde II[34]" project and the "Veje til biobaseret byggeri[35]" project. The trajectory from 2030 to 2050 is a linear projection aimed at reaching 50% natural land. During this period, the area of production forests is expected to remain stable, and land use for infrastructure is anticipated to remain relatively constant, meaning that the transformation will primarily involve converting agricultural land to natural areas.

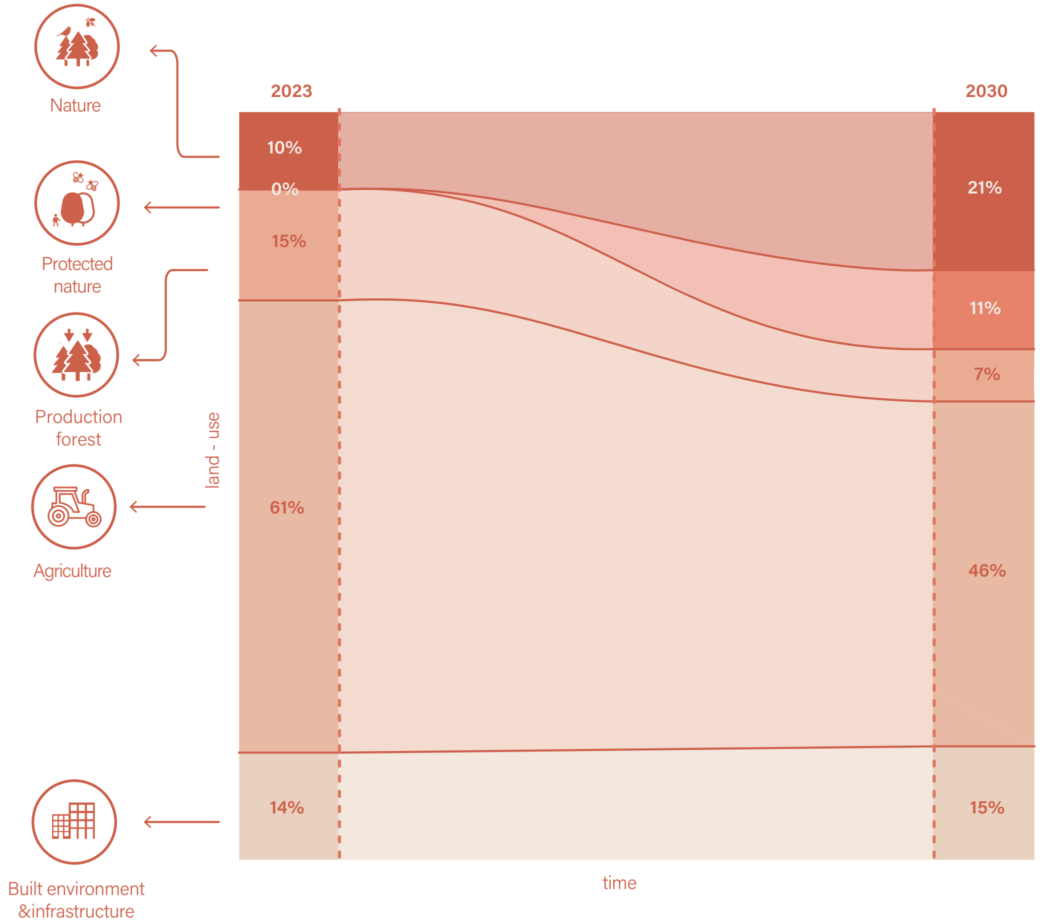


Figure 3.17 Projection of land use in Denmark to achieve 30% nature by 2030. Source: Reduction Roadmap

Strategy 2: Adhering to the Paris Agreement

Denmark is currently not aligned with established climate science directives and is projected to significantly exceed the targets set by international climate agreements. Under the current policy framework, referred to as the "frozen policy," Denmark is expected to surpass its carbon budget for limiting global warming to 1.5°C, as agreed in the Paris Agreement[36].

The Danish Climate Act sets binding targets for territorial greenhouse gas emissions—those emitted within Denmark's national borders. These emissions are mandated to be reduced by 70% by 2030, relative to 1990 levels, with a goal of achieving net-zero emissions by 2050[37]. As described in the Foreword – Relative versus Absolute Reduction Targets section, relative targets are not sufficient to shift development within planetary boundaries. However, this framework does not address emissions associated with Danish consumption, which occur outside national borders due to the production of goods and services consumed in Denmark.

The Danish Council on Climate Change has strongly recommended the establishment of national targets for

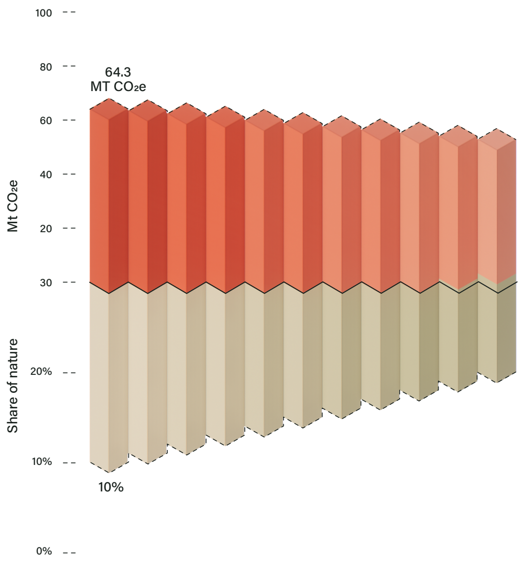


Figure 3.17 - Danish Adherance to the 30x30 Framework. Source: Reduction Roadmap

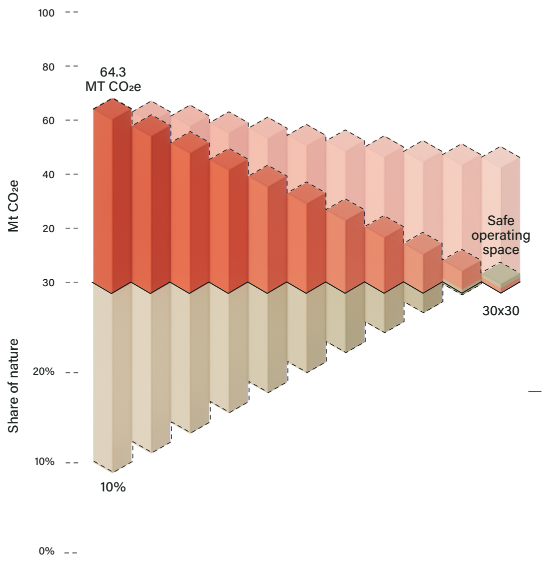


Figure 3.18 Danish adherance across sector to the Paris Agreement 1.5C CO2-eq. reduction targets to get within the safe operating space. Source: Reduction Roadmap

these consumption-based emissions. Given Denmark's high level of economic prosperity, the country should not only take responsibility for its domestically produced emissions but also for the emissions embedded in its global supply chains. Expanding Denmark's climate accountability beyond territorial boundaries is essential for reducing its total climate impact and aligning with global climate equity principles[38].

To reduce Denmark's consumption-based emissions within the remaining 1.5°C greenhouse gas budget allocated to the country, each sector and industry must account for its emissions and align with international climate commitments. The overarching objective is for all sectors to collectively reduce emissions to fit within Denmark's safe operating space, which is defined as 1.7 million tons of CO_2 equivalent per year[39] (Figure 3.11).

Adopting the Butterfly framework could assist sectors like agriculture and energy in identifying key areas for emissions reductions, setting realistic targets, and effectively implementing sustainable practices. This comprehensive, systems-based approach requires transformative changes in resource management, energy use, and sustainability measures across the nation. Collective action is essential if Denmark is to meet its global climate commitments and ensure a sustainable future.

Adopting the Butterfly framework could assist sectors like agriculture and energy in identifying key areas for emissions reductions, setting realistic targets, and effectively implementing sustainable practices. This comprehensive, systems-based approach requires transformative changes in resource management, energy use, and sustainability measures across the nation. Collective action is essential if Denmark is to meet its global climate commitments and ensure a sustainable future.

Strategy 3: Adhering to the Safe and Just Earth-System Boundaries.

To bring Denmark back within the safe and just Earth system boundaries for functioning ecosystems, it is essential to designate minimum 50% of its territory as protected areas[40] - exceeding the targets set by the 30x30 Framework.

Allocating half of Denmark's land to protected nature would significantly benefit biodiversity, climate stabilization, and human well-being. While detailed research on the optimal locations for these protected areas is still developing, the Danish Biodiversity Council's recommendations suggest prioritizing the creation of large, contiguous tracts of land where ecosystems can thrive with minimal human interference[41] as illustrated in Figure 3.19.

If Denmark were to designate 50% of its land as protected natural areas, the total carbon sequestered by 2050 would reach approximately 9 million tons of CO_2 per year, based on the land distribution shown in Figure 3.20 and Figure 3.21and the previously outlined carbon sequestration rate of natural areas. Accumulated over time, this would enable Denmark to sequester 20% of its carbon deficit by 2050. Including carbon sequestration from production forests could raise this figure to 35% of the deficit.

Figure 3.19 - A proposal for land-use change in Denmark to reach the 50x50 target. Denmark's protected nature will need to increase from 30% associated with the 30x30 Framework to 50% by 2050. While there is no clear plan for the addition 20% of protected nature this transition will demand, the cross-sectoral collaboration and systemic thinking should enable the best allocation of land. Source: Vejen til Biobeseret Byggeri55

The Butterfly framework highlights Denmark's transformative potential for achieving true sustainability. By dedicating 50% of its land to thriving ecosystems and reducing CO_2e emissions within safe limits, Denmark could sequester its entire carbon debt and restore biodiversity within 60 years. This ambitious path would bring the country back within safe and just planetary boundaries by 2100, setting a powerful example of regenerative development for the rest of the the world. How this could happen, is described in Box 3.2.

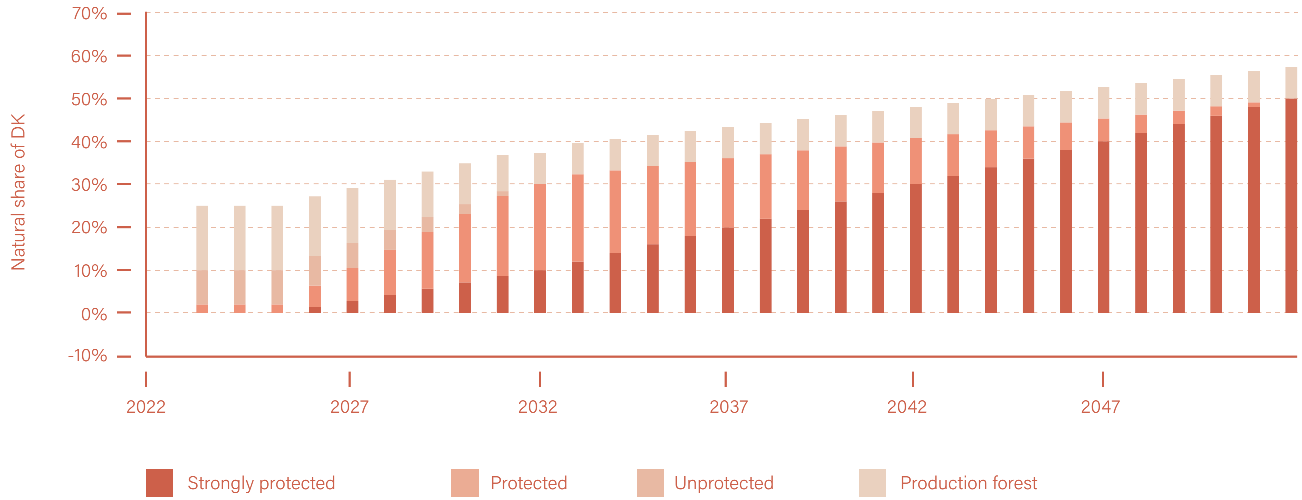


Figure 3.20 Gradual conversion of forests and natural areas to achieve the 30x30 target by 2030, aiming for 50% protected nature by 2050. Source: Reduction Roadmap?

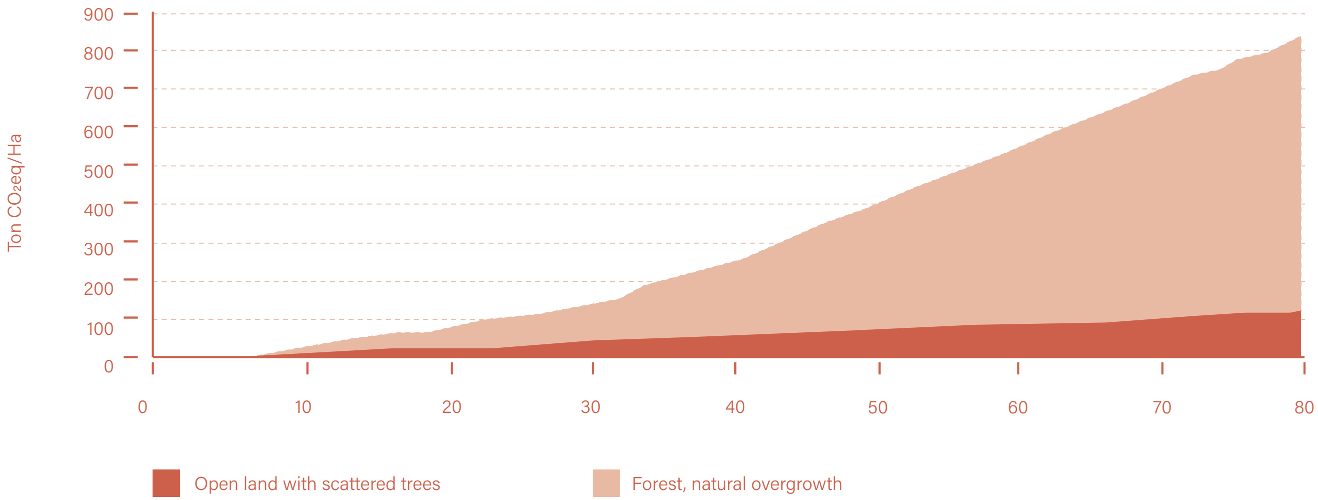


Figure 3.21 Accumulated carbon update from two different models for sequestering carbon on land - biodiversity forests and open natural areas. Source: Artelia

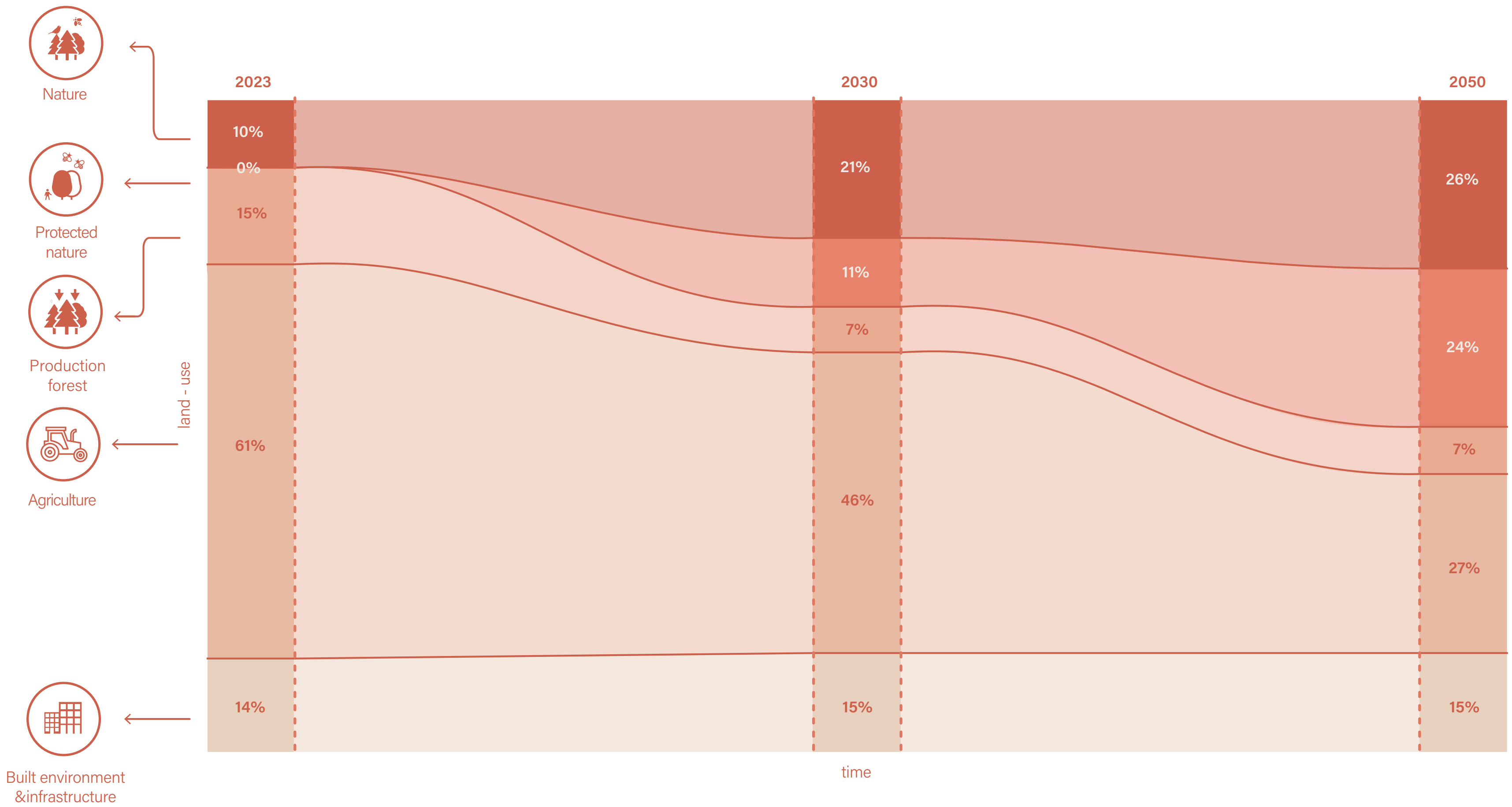


Figure 3.22 Land disribution change from 2030 towards 2050. Source: Reduction Roadmap

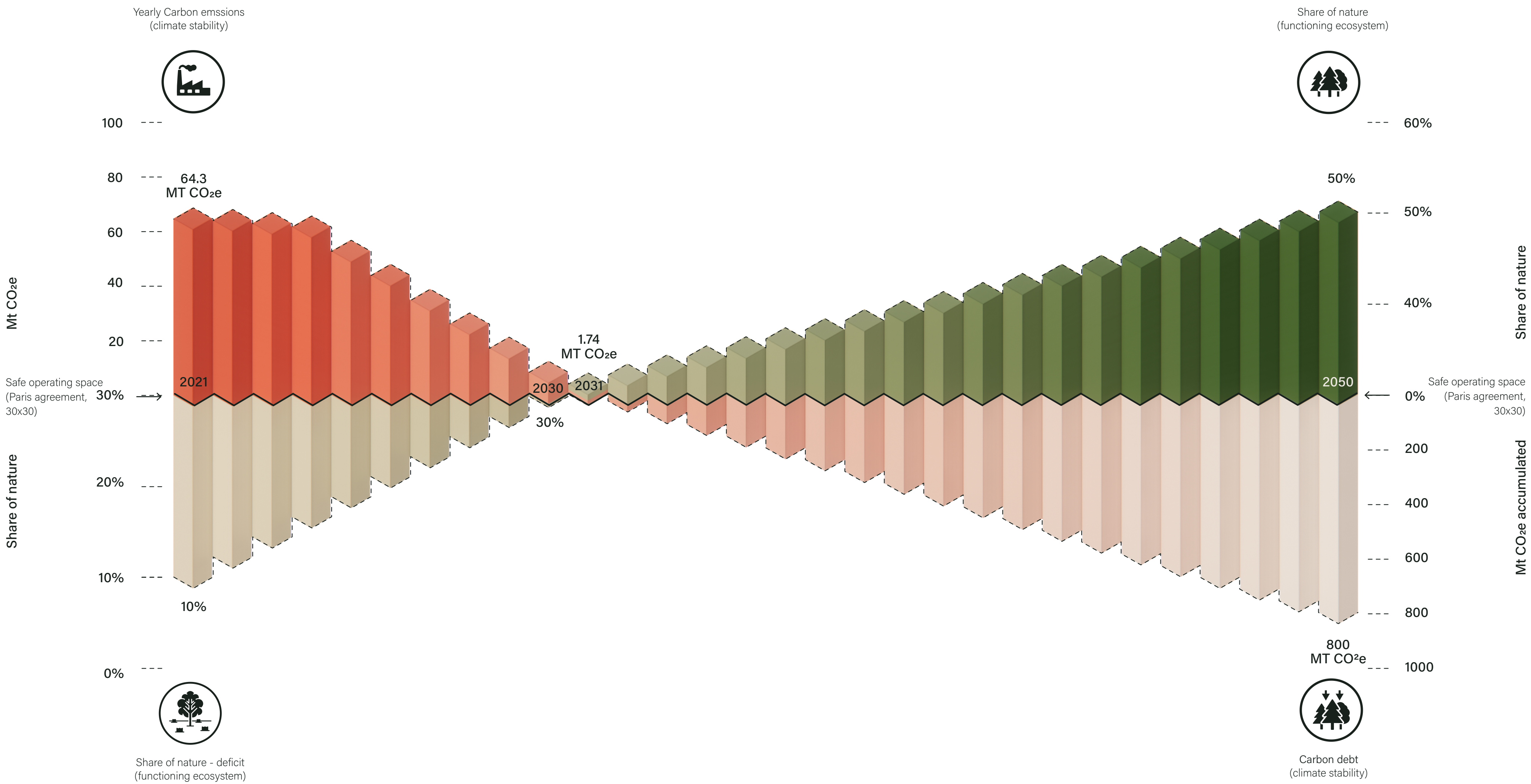


Figure 3.21 - Denmark within the Butterfly Beyond the Roadmap. Source: Reduction Roadmap

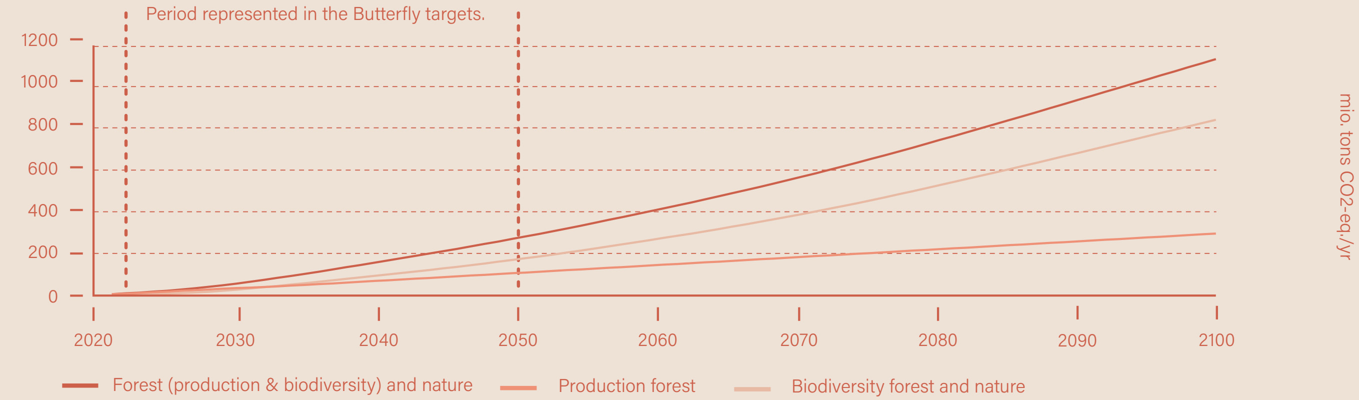
Box 3.2 Getting Dennmark back with safe and just ESB in 60 years.

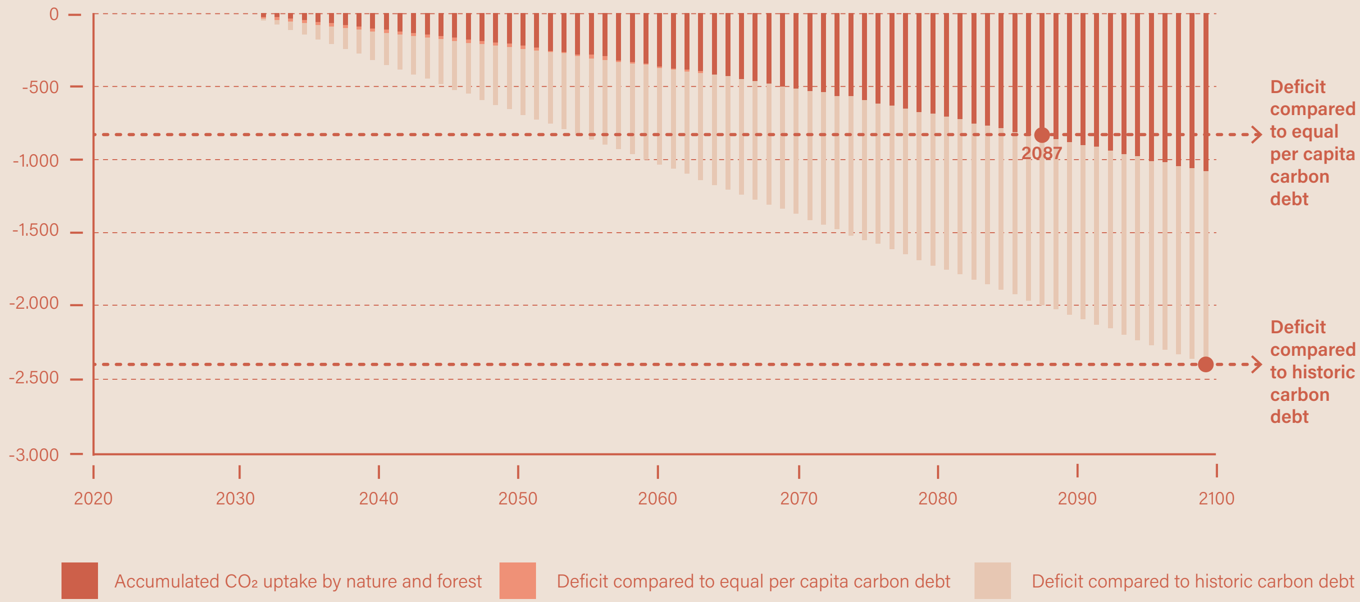
The top figure illustrates Denmark's potential CO_2 sequestration if 50% of its land were protected, applying the specific land distribution outlined above. This visual represents the cumulative CO_2 storage capacity by 2100.

The lower figure displays how much CO_2 the 50% protected areas would sequester and illustrates the portion of Denmark's carbon debt that could be mitigated if Denmark adhered to climate science recommendations. Together, these figures clarify how strategic land protection and optimal land use could contribute to significant carbon reduction.

By dedicating 50% of its land to thriving ecosystems and reducing CO_2-equivalent emissions within safe limits, Denmark could sequester its entire per capita carbon debt and restore biodiversity within 60 years. This implies that by adhering to climate science, Denmark could return within the safe and just limits, ensuring a sustainable future for the next generation. It's important to note that even if we account for the current per capita debt, we would still have a significant amount of carbon to reduce to fully take responsibility for our historic carbon debt.

Sources:






"If we dedicate 50% of our land to thriving ecosystems and reducing CO_2eq emissions within safe limits, Denmark could sequester its entire carbon debt and restore biodiversity within 60 years."
- Reduction Roadmap

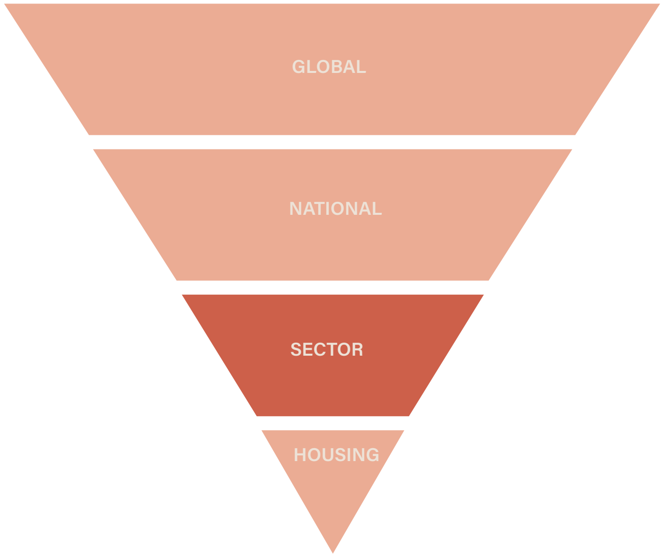


Figure 3.22 - The Butterfly is applied to a sector level. Source: Reduction Roadmap

3.5 Operationalization of the Butterfly in the Building Sector Level

Getting Denmark back within safe and just limits requires all industries to reduce emissions and minimize their impact on biodiversity. No single entity can solve the polycrisis alone; rather, everyone must contribute by focusing on the two core boundaries of the butterfly framework. As previously described, all industries, including individual companies, can adopt the butterfly framework. This section examines how the framework can be applied at building sector level.

The building industry already assesses the climate impact of new constructions through Life Cycle Assessments (LCA). However, the sector must also begin evaluating its impact on biodiversity loss. While strategies exist to lower emissions and move closer to the safe operating space for climate impact, merely reducing harm to biodiversity will not bring us back within safe and just limits. Therefore, the building industry should actively compensate for the biodiversity loss it causes and ensure the regeneration of disrupted ecosystems. This can, for example, be achieved by converting agricultural land into natural areas like forests. Such initiatives can support the necessary land-use transformation for Denmark to achieve 30% protected nature by 2030 and 50% in the long term.

Following the Reduction Roadmap

Having demonstrated how the butterfly framework can be applied at global and national levels, its potential within the Danish building industry is now examined. As such, the potential outcomes if the building industry commits to the Reduction Roadmap have been analysed. This commitment includes following a pathway that reduces current levels of emissions by 97% to reach the safe operating space determined for the building sector.

The Reduction Roadmap deals primarily with Climate Stability (carbon reduction) however, when we reduce pressure on climate stability, we also reduce pressure on Functioning Ecosystems (biodiversity loss). The Reduction Roadmap focuses mainly on Climate Stability through carbon reduction, which can alleviate some pressure on Functioning Ecosystems (biodiversity loss). However, decreasing carbon emissions does not always ensure a reduction in biodiversity loss. As described in Chapter 2, it's possible to mitigate climate change while inadvertently increasing biodiversity loss, underscoring the complexity of these environmental issues.

Reduction Roadmap sets ambitious emissions reduction targets for the building industry but does not dictate specific strategies, allowing flexibility in how the targets are met. To

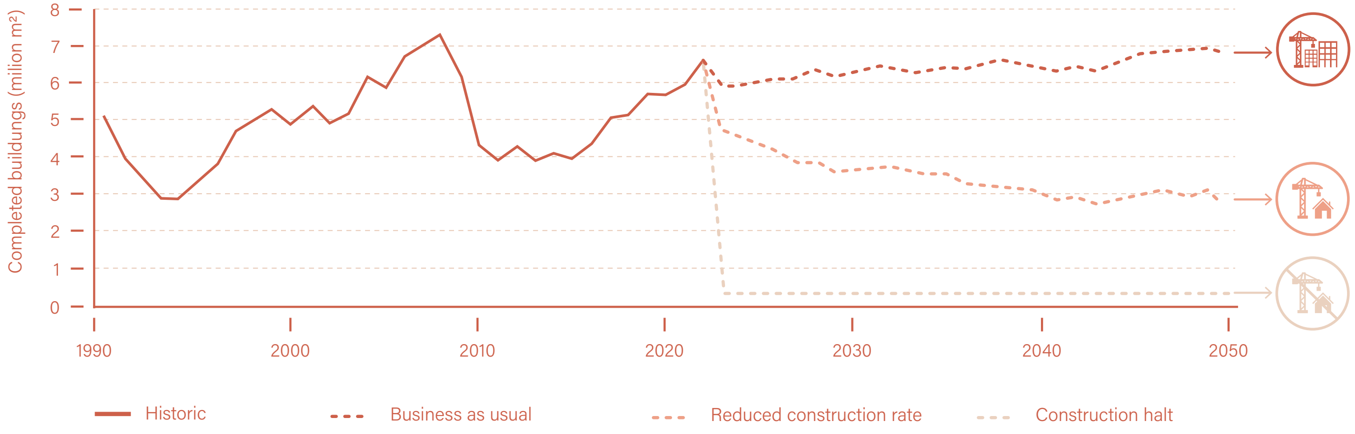


Figure 3.23 -Historic building activity in Denmark based on completed square meters and estimation of future scenarios. This figure illustrates the rate of construction (m²/year), historically (From 1990-2023), following a business-as-usual trajectory, a reduced construction rate (50%) and a building stop. Source: Danish building statistics and Reduction Roadmap

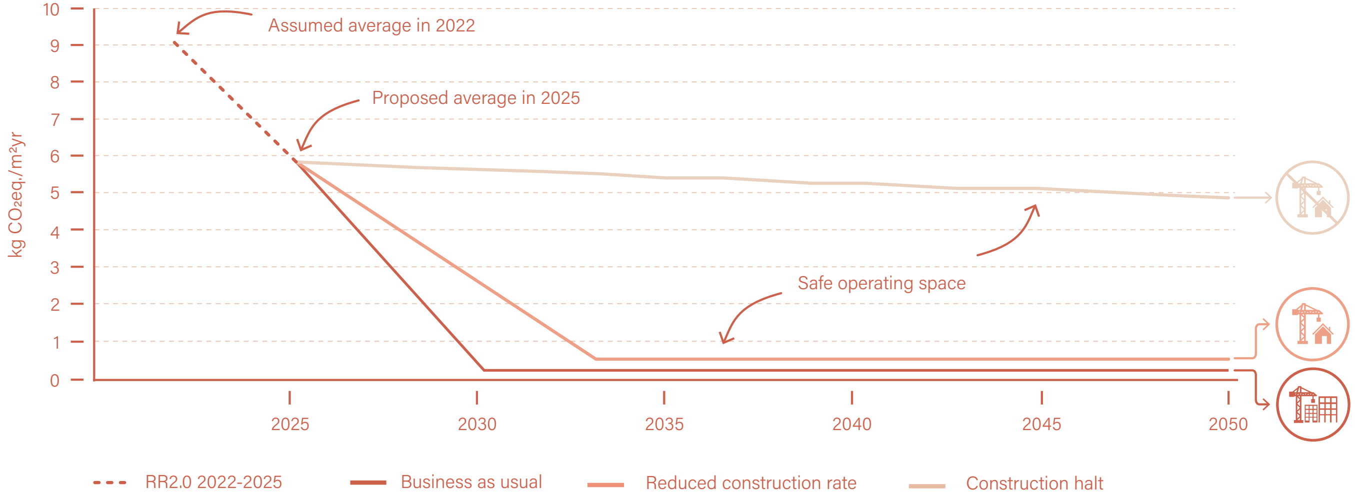


Figure 3.24 - Comparing scenarios for carbon emission levels associated with square meters built in Figure 3.19. Source: Danish building statistics and Reduction Roadmap

facilitate informed discussion, three potential strategies for the Danish building industry are outlined, each presenting its own set of challenges, but all aimed at reducing carbon emissions within the remaining CO_2 budget allocated to the industry.

The strategies are based on a forecasting model developed by the project "Veje til biobaseret byggeri[42]," which analyzes building activity over the past 40 years[43] to estimate future construction rates. In this report, the scenarios "Business as Usual," "Reduced Construction Rate," and "Construction halt" (to new construction) are employed to illustrate how the targets of the Reduction Roadmap can be achieved under varying levels of building activity as illustrated in Figure 3.23 and Figure 3.24.

By implementing the Roadmap, the building industry could directly contribute to an annual reduction of up to 1.5 million tons of CO_2eq. in Danish greenhouse gas emissions, supporting Denmark's commitments under the Paris Agreement. This reduction is based on emissions calculated using the Life Cycle Assessment (LCA) methodology for buildings. However, since the LCA does not account for all building materials or operational energy, the actual reduction potential is likely even higher.

Additionally, stricter carbon limits on new construction could have significant indirect effects on both the renovation market and the industry. Historically, the renovation sector has adopted many of the same solutions used in new builds, and given that renovation projects contribute roughly 75%[19] of the climate impact of new construction, there is substantial potential for further reductions. As climate requirements for buildings become more stringent, the industry is also expected to shift toward producing materials with lower environmental footprints, amplifying the overall impact.

The precise effect of these additional factors lies outside the scope of the Reduction Roadmap to quantify, but they should not be overlooked, as they represent a significant contribution toward meeting Denmark's climate goals.

Strategy 1: Maximizing Efficiency with a Constant Rate of Construction (Figure 3.25)

To maintain the current construction rate of approximately 6-7 million newly built square meters per year under the "Business as Usual" scenario, the Danish building industry must achieve a drastic 97% reduction in emissions, decreasing from 9.2 kg CO_2-eq/m²/year to just 0.3 kg CO_2eq/m²/year at the latest in 2030[44]. Achieving this goal will require transformative changes in materials, construction practices, and the adoption of advanced green technologies. While some projects have successfully reduced their carbon footprints by up to 60%[45], these projects are exceptions rather than the norm. Scaling such practices to industry-wide standards will necessitate rapid innovation and widespread adoption of new methodologies.

However, focusing exclusively on CO_2 reduction risks exacerbating other environmental challenges. CO_2 alone is not a sufficient indicator of environmental health, as 80-90% of biodiversity loss occurs off-site during material production[3 46]. Therefore, reducing CO_2 emissions without simultaneously reducing material usage could worsen biodiversity loss. Given these challenges, the viability of maintaining the current rate of construction must be questioned in terms of sustainability.

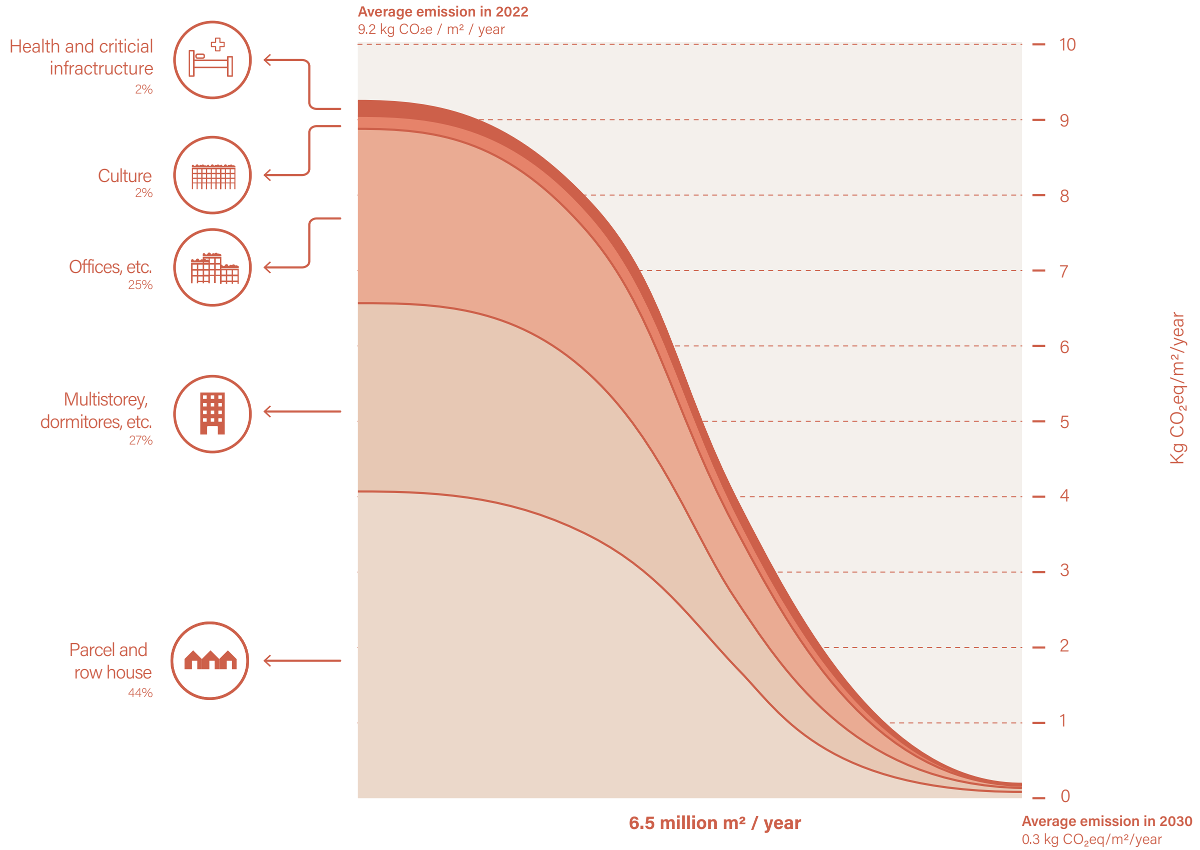


Figure 3.25 - This figure illusrates Strategy 1: Maximizing Efficiency with a Constant Rate of Construction.
Source: Reduction Roadmap

Strategy 2: Reducing Construction Rates to Enable a Higher Target (Figure 3.26)

If the building industry adopts the “Reduced construction rate” scenario and cuts its construction volume in half while maintaining the same mix of building types, this strategy would permit higher emissions per unit area. Although target emissions would still need to decrease significantly - from 9.2 kg CO_2eq/m²/year to 0.6 kg CO_2eq/m²/year - this approach makes it somewhat easier for the industry to meet its targets while providing an additional three years to achieve them. Implementing this strategy would require careful planning of new projects, prioritization of critical infrastructure, and rapid advances in innovation.

Reducing construction by 50% would also cut demand for materials in half, significantly easing pressure on ecosystem health[47]. This decrease in material usage would not only support climate goals but also alleviate stress on other planetary boundaries, offering a more holistic solution to

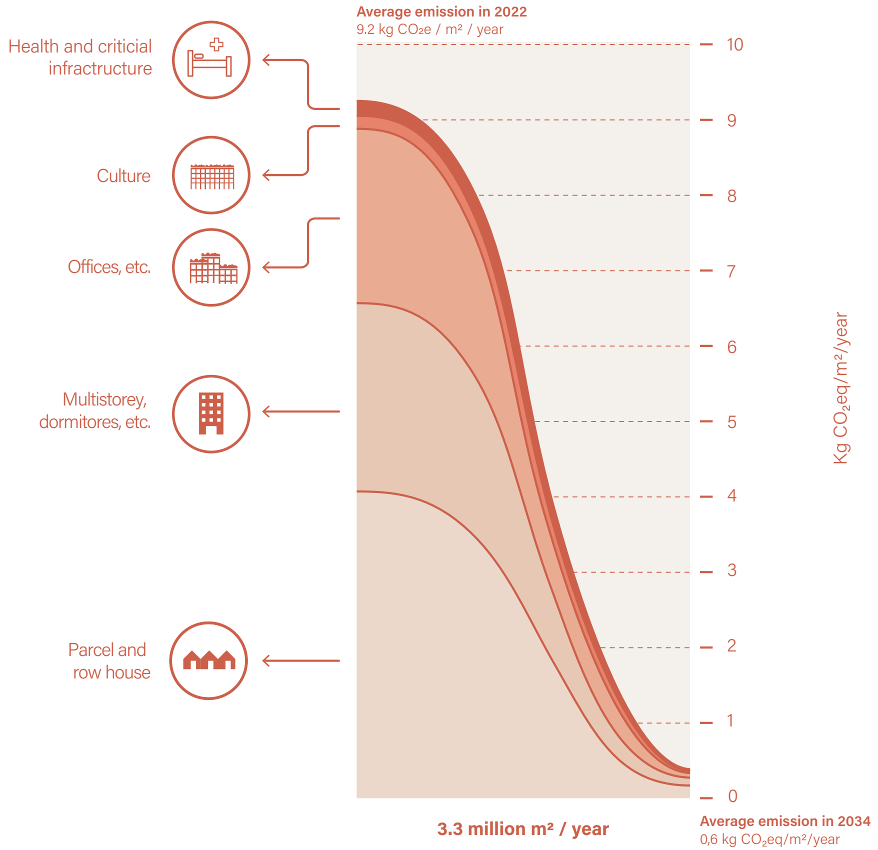


Figure 3.26 - This figure illustrates Strategy 2: Reducing Construction Rates to Enable a Higher Target.
Source: Reduction Roadmap

Strategy 3: Halting Construction (Figure 3.23)

In this strategy, the building industry shifts its focus entirely by halting new construction, except for societally critical buildings, which currently account for approximately 5% of newly built square meters. By concentrating resources on these societally critical structures, the building industry can allow for higher emissions per square meter while reducing the immediate need for advanced technologies and new materials.

Focusing solely on essential buildings, such as hospitals and critical infrastructure, provides a practical pathway to meet societal needs without significantly increasing environmental pressures. This approach allows for a more manageable emissions target per square meter, recognizing that lower overall construction volumes can reduce demand for materials and associated emissions. Consequently, target emissions would only need to decrease gradually, reaching approximately 5 kg CO_2eq./m^2/year by 2050. (assuming an average of 9.2 kg CO_2eq./m^2/year today)

Halting most new construction shifts the focus from extensive development to enhancing existing buildings, fostering a renovation culture that requires fewer materials and generates less waste than new builds. This approach conserves resources while minimizing disruptions to ecosystems and biodiversity. Renovating buildings also reduces operational energy use, improves indoor environments, and lower health costs , aligning with the EU's goal to retrofit 146 million buildings by 2050 to achieve net-zero emissions.

By reducing new construction and repurposing existing buildings, material consumption can be significantly lowered. For example, the French Environment and Energy Management Agency estimates that new construction will consume around 1.3 billion tons of materials, compared to just 74 million tons for renovations. Building a detached house uses approximately 1.2 tons of material per square meter—40 times more than a renovation of the same size. Multi-occupancy buildings or nursing homes consume even more, about 1.6 tons per square meter, nearly 80 times more than renovations. These figures highlight that transforming the existing building stock is crucial for reducing environmental pressures on both the climate and ecosystems.

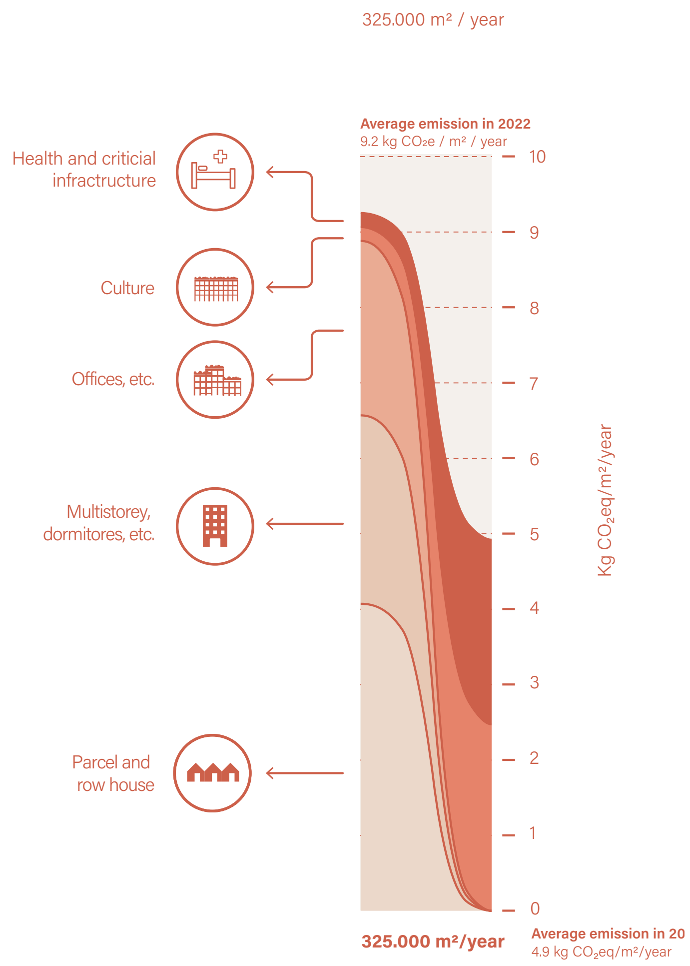


Figure 3.27 - This figure illustrates Strategy 3: Halting Construction. Source: Reduction Roadmap

A new material paradigm

Biogenic materials, derived from biological sources such as plants and marine organisms offer the potential to significantly lower emissions in construction. These renewable materials - ranging from timber and hemp to straw and marine biomass - have a lower environmental footprint than conventional materials like concrete and steel, with the added benefit of storing biogenic carbon. In Denmark, biogenic materials could replace a substantial portion of conventional materials, potentially storing 1.7-1.8 million tons of CO2 equivalent annually by 2032[52].

However, the use of biogenic materials must be carefully managed to avoid negative environmental impacts, as discussed in Chapter 2. Proper oversight is essential to ensure that while reducing emissions, the extraction and production of these materials do not exacerbate other environmental challenges such as biodiversity loss or ecosystem degradation. Just as over-extracting minerals can harm ecosystems, unsustainable material growth can damage biodiversity.

The potential of transitioning from conventional mineral-based building materials to bio-based alternatives has been analyzed in the "Veje til Biobaseret Byggeri" project, which explores three scenarios: a stagnated transition maintaining current building activity, an ambitious transition aiming for 100% bio-based materials by 2050 under the same construction levels, and an ambitious transition paired with a construction halt, reducing activity to just 5% of current levels.

In the stagnated transition, emissions remain relatively constant but increase slightly as construction activity grows from 6 million m^2 to 7 million m^2 annually by 2050. In contrast, the ambitious transition could provide short-term climate benefits through carbon sequestration by bio-based materials. By 2050, this may lead to net carbon sequestration; however, these benefits gradually diminish as the materials approach the end of their life cycle and the stored biogenic carbon is released back into the atmosphere. The construction halt scenario results in the most significant long-term emission reductions, primarily due to the sharp decline in building activity, even with minimal use of bio-based materials (Figure 3.28)

While this analysis does not capture the complete environmental impact of the construction sector, it offers valuable insights into the climate effects of different scenarios over time. The findings underscore the importance of both material innovation and circular practices in achieving long-term sustainability. Effective circular strategies are essential for extending material lifespans and delaying the release of biogenic carbon through reuse and recycling.

As the building industry adopts new techniques, the focus should shift towards maximizing the efficiency of existing resources, embracing "deep circularity" to address consumption without further depleting materials. Following the principles of the Material Pyramid for Sufficiency (Figure 3.29), this approach emphasizes doing significantly more with much less, ensuring that resource use is optimized while minimizing environmental impact.

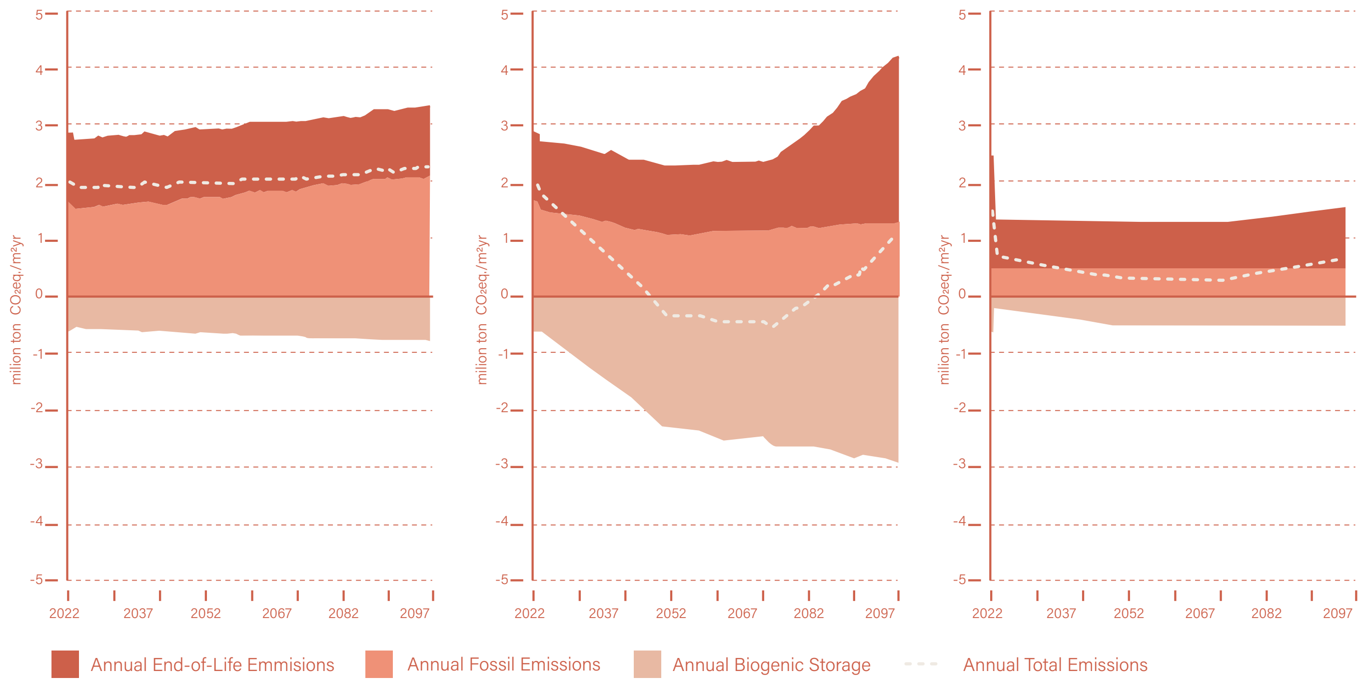
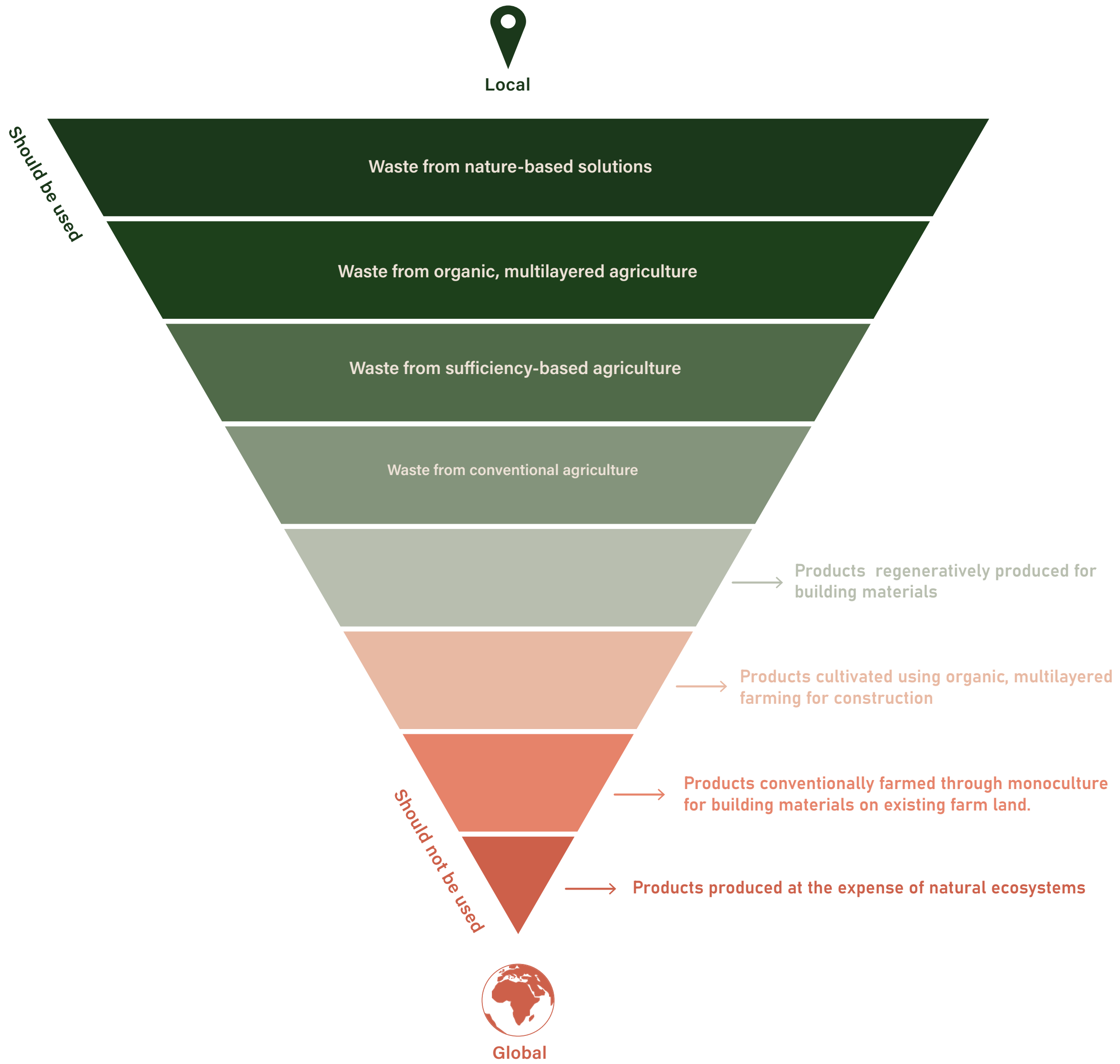


Figure 3.28 - Climate impact predictions from new construction and renovation from 2022 towards 2100. Source: Reduction Roadmap

Figure 3.29 - Material Pyramid for Sufficiency
The Biobased Materials Hierarchy Pyramid advocates a critical philosophy for sustainable construction: avoid repeating past mistakes of monoculture farming, which have contributed significantly to environmental degradation. Instead, the pyramid encourages the use of materials from regenerative, organic, and waste-based sources that support ecological health and biodiversity. By prioritizing these sustainable practices, we ensure that biobased materials contribute positively to the environment, promoting a cycle of renewal rather than depletion. This approach is essential to not only prevent further ecological damage but also to rectify the errors of past resource management strategies. Source: Reduction Roadmap.




"We can only get back within the safe and just planetary boundaries through net-positive, regenerative action deployed at a sufficient pace and scale."
- Reduction Roadmap

Anne Beim
Head of CINARK and Professor at The Royal Danish Academy - Architecture Design Conservation

Lykke Arnfred
Architect and PhD Fellow at CINARK - The Royal Danish Academy

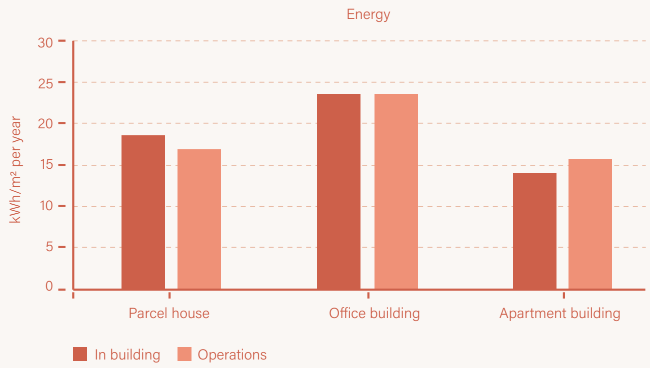
From energy performance and use - to material understanding and the Reduction Roadmap

The building industry, in its current configuration, fails to align with the principles of sustainability, despite holding a significant environmental responsibility that extends across numerous domains. Since the oil crisis in 1973, the Western world has predominantly focused on reducing the energy consumption of buildings. However, contemporary approaches to designing and constructing modern buildings emphasize accommodating a variety of technical solutions alongside a high demand for spatial and comfort-related needs. This approach has not only led to the overconsumption of materials but has also resulted in a substantial negative impact on the environment.

In response, industrialized countries have implemented stricter energy efficiency requirements for both new constructions and refurbishments. This shift, however, has inadvertently fostered a building practice that is both resource and energy-intensive, affecting both the production of building materials and the design of building structures. The environmental burden is particularly evident in the embedded carbon of these constructions. A paradox often emerges, wherein the energy expended in the construction of new, energy-efficient buildings surpasses the energy savings achieved during their operational phases (Figure 1).

The notion that it is possible to maintain current living standards while simultaneously constructing a way out of the climate crisis is fundamentally flawed. There is a pressing need to shift focus towards the development of building technologies and construction typologies that prioritize the use of materials with low carbon footprints throughout the entire value chain.

Throughout historical epochs, the physical aspects of global society, such as buildings and consumer goods, have been shaped by the transformation of materials from one stage to another. The Earth's natural processes continuously generate new raw materials and resources; however, the formation of inorganic materials is a protracted process, spanning many years—resulting in the potential depletion of certain materials like metals, grit, and sand within the foreseeable future. Alternatively, biological materials, which are generated at a much faster rate, are considered renewable resources. These biological materials absorb biogenic carbon from the atmosphere, hence the designation as biogenic materials. Nonetheless, the scarcity of resources often hinges on the demand for specific materials, indicating that renewable resources can also be subject to overexploitation and pressure.



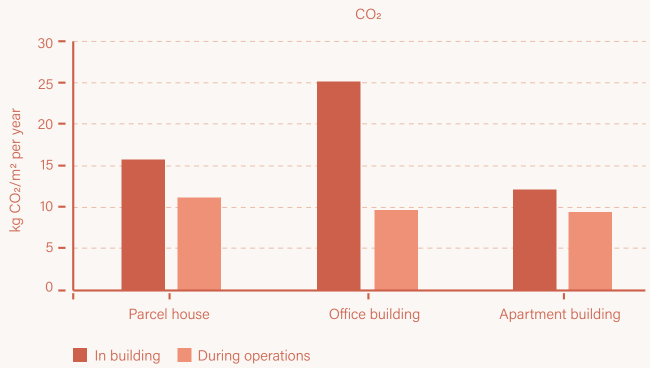


Figure 1 - Energy and CO2 emissions – in operation and embedded in the building constructions such as: One-family housing, office buildings, multi-story housing. (Blue: Construction / Brown: operation) Source: Bygningers indlejrede energi og miljøpåvirkninger, SBi 2017:08 [1]

Therefore, the utilization of biogenic materials must be approached with environmental considerations and a focus on reduction. The increasing emphasis on biogenic materials such as wood, straw, reed, hemp, flax, and seaweed are indicative of a new era that prioritizes the reduction of greenhouse gases, circular thinking, environmental responsibility, and the reconsideration of living standards and energy efficiency. Building with biogenic materials advocates for a purer form of ecological architecture—or rather, a "biogenic architecture"—that is more simply constructed and draws upon the inherent properties of the materials. This biogenic architecture is rooted in a humble and cyclical understanding of nature's resources, wherein the built environment is created – in accordance with the reduction roadmap - with a respect for our shared natural environment, the ecological balance of nature, and an awareness of planetary boundaries.

The availability of biogenic/biobased materials is also influenced by factors such as the location of production, seasonality, and the harvest cycle of the materials. CINARK (Center for Industrial Architecture) has dedicated years to exploring biogenic architecture through various projects that examine biogenic/biobased materials and construction from different perspectives, including building systems, buildability, lifecycle assessment (LCA), CO2 emissions, aesthetics, fire resistance, and moisture management. By presenting a narrative of CINARK's research on biogenic construction from 2020 to 2024, the objective is to establish a visionary foundation for biogenic architecture.

The initial project, titled "**Thatched Facades for the Green Transition of the Building Industry – Carbon Neutral Fire Protection of Vertically Thatched Facades**[2]" was conducted under the MUDP-program[3] from 2020 to 2021. The primary objective of this initiative was to develop and evaluate environmentally sustainable, feasible, and architecturally coherent methods for fire prevention in vertically thatched facades. The research specifically focused on utilizing clay and other similar mineral materials as fire-retardant impregnations. The feasibility of these approaches was assessed through the construction of a full-scale house corner at The Royal Danish Academy, where aspects such as buildability, aesthetics, and the architectural integration of fire-impregnated thatched facades were explored (Figure 3 & 5)

The subsequent research project, a continuation of the MUDP initiative, was presented at the Architecture Triennale Lisbon 2022 under the title "**Prefabricated Thatched Elements.**[4]" This phase concentrated primarily on the buildability and architectural design of the thatched prefabricated elements. The research introduced innovative building principles that proposed new and alternative solutions for thatched facades, rooted in clear guidelines for the development and implementation of prefabricated thatched elements within wooden cassettes. The construction, characterized by lightweight elements and a straightforward system, demonstrated significant potential for efficient buildability and the possibility of future recycling of the elements.

Additionally, the "Reset Materials"[5] (supported by Dreyers Fond and managed by Arkitektforeningen) exhibition at Copenhagen Contemporary featured a project titled "**STRAW; The Burned & Bundled – Unfolding the Will of the Material**," where CINARK (1 of 10) focused on the material properties of straw. This project involved a series of tectonic investigations into the sensory and technical qualities of this biogenic material. The research explored how bundling reed could form a load-bearing arch and how burning could reveal new characteristics of thatched surfaces. The findings highlighted the potential for innovative forms of thatched architecture, offering new conceptions and representations of the material that evoke curiosity and invite further exploration. (Figure 2)

The project "4>1 Planet"[6] Søren Kierkegaards Plads, undertaken in collaboration with Rønnow, LETH & GORI (supported by Realdania and VILLUMFONDEN), focused on the exploration of "**Thatched Brick Blocks**," a novel construction technique that integrates traditional, site-specific materials such as clay and thatched straw. By combining insulating brick blocks, known as 'poroton',

Figure 2: Photo credit: Hampus Berndtson

Figure 3: Photo credit Lykke Arnfred

Figure 4: Photo credit: Anne Beim

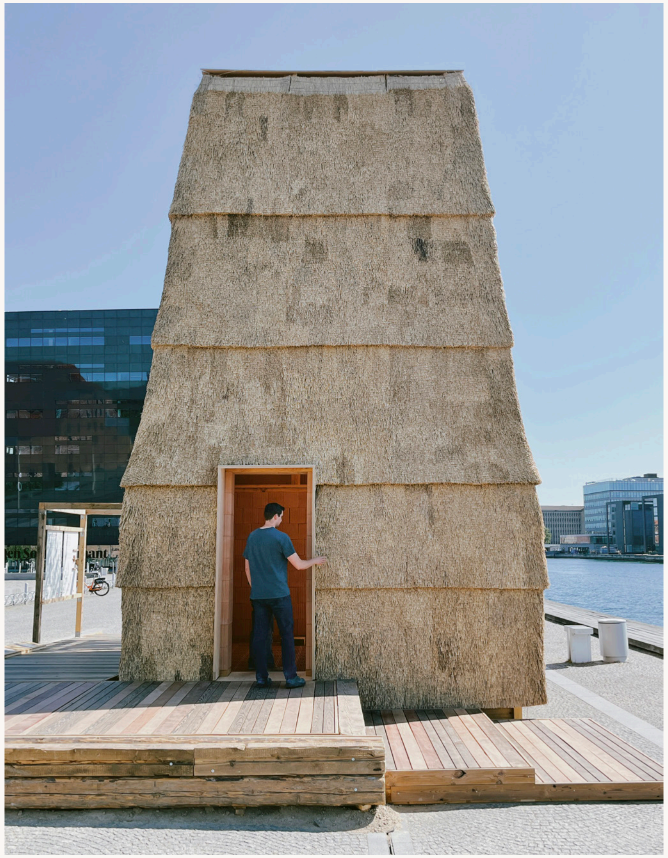


Figure 4: Photo credit: Kim Høltermand

with thatched straw, the project aimed to create a robust and breathable construction system, leveraging the well-established principles of traditional building practices to foster healthy living environments. The project stands on the shoulders of our historic building culture, craftsmanship and construction technical solutions, and reaching into a future where we must build long-term housing to achieve a far smaller CO2 footprint. By developing and demonstrating this building system at full scale, the project provides valuable insights into both the construction technique itself and the spatial and material properties it embodies. Figure 4

The concepts and findings from these projects are currently being further tested and refined through ongoing research initiatives and a PhD program associated with CINARK: “Biogenic Montage Construction – Construction, Fire, Architecture,” and the PhD research titled **“Biogenic Construction in New Buildings and Existing Construction.”**

The objective of the “Biogenic Montage Construction – Construction, Fire, Architecture” project is to establish a visionary foundation for biogenic architecture. The project aims to demonstrate how biogenic building materials such as straw, wood, and reed/thatch can be effectively utilized in prefabricated construction solutions for buildings up to three stories high. The overarching goal is to develop and test biogenic construction methods that can be adapted to industrial montage construction, emphasizing prefabrication and ease of assembly, in alignment with national political objectives to achieve a 70% reduction in CO2 emissions by 2030 and meet the aims of the reduction roadmap. Additionally, the project seeks to ensure that the use of materials is compatible with natural ecosystems, minimizing environmental impact.

Central to the project is the focus on materials such as wood, straw, reed/thatch, and clay as a fire-retardant agent, integrated into composite solutions/products suitable for load-bearing external wall constructions. Through technical, performative, and architectural studies, the project intends to capitalize on and enhance the inherent properties of these materials—such as strength, durability, fire resistance, and aesthetic potential—through their application in the design and construction of prefabricated façade elements. In summary, the project is driven by three key objectives: reducing CO2 emissions, developing construction designs that ensure the effective use of biogenic materials in construction (particularly regarding fire safety and weather resistance), and promoting the prefabrication of biogenic materials, with a specific focus on reed, to expand their application in contemporary construction practices.

The PhD project “Biogenic Constructions in New Buildings and Existing Construction” seeks to contribute to the architectural field by advocating for the increased use of biogenic materials in contemporary construction practices. The study explores the integration and abilities of biogenic materials into both new construction projects and the renovation of existing buildings. The aim is to synthesize these strategies into a comprehensive regenerative material strategy capable of addressing the global climate crisis. The research investigates biogenic construction methodologies through design– and building strategies, including "constructive protection" (focusing on material lifecycles), buildability (considering practical implementation), and the resulting aesthetics. By doing so, it aims to advance the development of a sustainable biogenic building practice. The thesis is structured into two main components: a theoretical analysis and practical experimentation which will result in biobased building instructions following the format of Anvisninger.dk established by SBi (Statens Byggeforskningsinstitut). The theoretical section provides a philosophical, opinion-forming, and operational framework, while the practical component employs drawing as an analytical tool alongside physical construction tests to map, examine, and understand the specific characteristics, particularities, and essential design principles of biogenic materials in architecture.

CINARK will persist in its rigorous exploration of material knowledge, radical tectonics, and building practices. It is imperative to recognize that the use of biogenic and biobased materials in construction should not be viewed merely as a sustainable strategy or an unavoidable necessity for the green transition. Rather as our projects suggest – these materials possess distinct qualities and capabilities that have the potential to foster an architectural environment, aesthetics and finally; a future building practice that surpasses the one we currently inhabit.

The Projects have been realized by:
CINARK – Center for Industrialized Architecture / The Royal Danish Academy: Anne Beim, Line K. Frederiksen, Lykke Arnfred, Henriette Ejstrup, Thorbjørn Lønberg Petersen, Kenneth Hviid Larsen, Pelle Munch-Petersen, Astrid Juul Jørgensen, Joahnnes Schotanus, Jonathan Møller Larsen, Stinus Bertelsen.

DBI/Danish Fire- & Security Institute: Anders Dragsted, Robert Firkic, Mads K. Hohlmann. Craftsmen: Thomas Gerner (Tækkemanden Horneby A/S), Ruud Conijn (Hemmed Tækkefirma A/S), Laura Feline Ebbesen, Thatcher, Lasse Koefoed Nielsen (Egen Vinding & Datter), The Thatchers Information Office: Jørgen Kaarup, Sven Jon Jonsen. Mikael Jackson, Ceramics Workshop and Mads Johnsen, Metal Workshop at The Royal Danish Academy. Linda Hildebrand Aachen University, Daniel Sang-Hoon Lee, The Royal Danish Academy. Britt Gundersen Graphic Designer.

References

1 Ohms, P. & Andersen, C. E. & Nygaard Rasmussen, F. & Ryberg, M. & Hauschild, M. & Birkved, M. & Birgisdottir, H. (2019). "Assessing buildings' absolute environmental sustainability performance using LCA focusing on climate change impacts". IOP Conference Series: Earth and Environmental Science. 352. 012058. 10.1088/1755-1315/352/1/012058.Ibid

2 Beim, A., Ejstrup, H., Munch-Petersen, P., Østerby Arnfred, L., Kaarup, J., Lønberg Petersen, T., Dragsted, A., Larsen, K. H., Hildebrand, L., & Lee, D. S.-H. (2023). Biogenic Costruction: Materials Architecture Tectonics. (1 ed.) Det Kongelige Akademi. https://issuu.com/cinark/docs/til_issuu_23.03.2023_biogenic_construction_bg_fina

3 Beim, A., Ejstrup, H., Østerby Arnfred, L. (red.), Kaarup, J., & Hohlman, M. (2023). Tækkede bygningsfacader til den grønne omstilling: CO2-neutral brandsikring af tækkede lodrette flader. (1 udg.) Miljoeministeriet * Miljoestyrelsen. MUDP Rapport

4 Beim, A., Ejstrup, H., Munch-Petersen, P., Østerby Arnfred, L., Kaarup, J., Lønberg Petersen, T., Dragsted, A., Larsen, K. H., Hildebrand, L., & Lee, D. S.-H. (2023). Biogenic Costruction: Materials Architecture Tectonics. (1 ed.) Det Kongelige Akademi. https://issuu.com/cinark/docs/til_issuu_23.03.2023_biogenic_construction_bg_fina

5 Galaad van Daele, Kathrin Gimmel, Victor Boye Julebæk & Nicolai Bo Andersen, Marianne Krogh, Chrissie Muhr, Amalie Smith. (2023). Reset Materials – Towards sustainable Architecture. (1. Ed.). Arkitektens forlag. København.

6 Beim, A., Leth, U., Gori, C., Østerby Arnfred, L., Lütken, P., Larsen, K. H., Ejstrup, H., & Lønberg Petersen, T. (2022). En lille bolig i tækkede teglblokke. I Smith Innovation (red.), Boligbyggeri fra 4 til 1 planet: Casesamling fra indsatsens to åbne calls "Sustainable Solutions" og "Next Generation Architecture" (1 udg., Bind 1, s. 58-60). Artikel 1 Realdania. https://realdania.dk/publikationer/faglige-publikationer/boligbyggeri-fra-4-til-1-planet

Figure 3.30 Key Criteria for taking truly regenerative actions. Source: Doughnut for Urban Development: A Manual

3.5 The Butterfly in practice

Throughout this chapter, the Butterfly framework has been presented as a guiding tool to help the global community, countries or the industries back within safe and just limits. While the building industry alone cannot directly secure a specific percentage of protected nature, it can play a significant role in accelerating ecosystem restoration and reducing emissions. By taking responsibility for two key system boundaries - climate stability and biodiversity - the industry can become a catalyst for regenerative change.

To implement the Butterfly Framework in practice, the following actions are essential:

1. Adhering to Emission Targets: All projects must meet the Reduction Roadmap targets between 2025–2029, aiming to reduce emissions to 0.3 kg CO_2eq./m^2/year by 2030.

2. Addressing Biodiversity Loss: Every construction project must account for both on-site and off-site biodiversity impacts. This dual focus ensures the building industry addresses both climate stability and ecosystem health.

3. Contributing to Biodiversity: Each project must make a net-positive contribution to nature, regenerating or protecting more biodiversity than it depletes, both on-site and off-site. This approach requires the industry to account for ecological deficits, ensuring that each project goes beyond mitigation to truly support ecosystem health and resilience

Ensuring Regenerative Actions are Truly Regenerative
To guarantee that regenerated nature meets the appropriate standards, regenerative activities must adhere to following key quality criteria that ensure they consistently yield positive impacts. The butterfly framework follows the same principles outlined in Doughnut for Urban Development: A Manual[3] to safeguard against green-washing.

These principles are:

- **Measureability:** Regenerative benefits must be assessable using reliable data and robust methodologies, capturing both direct and indirect impacts.
- **Attentionality:** The environmental benefits must be genuinely additional, meaning they would not have occurred without the specific regenerative intervention. For instance, you cannot claim benefits from preserving a forest if it wasn't under threat of deforestation.
- **Permanence:** Regenerative efforts should focus on long-term benefits that are likely to persist far into the future.
- **Exclusivity:** It's essential to ensure that no other party claims the same environmental benefits, to avoid double-

counting.
• **Positive Impacts:** Regenerative actions should not cause harm to other environmental areas or populations. They should aim for holistic, positive social and environmental outcomes.

By strategically integrating both core system boundaries, the building industry transcends traditional mitigation and adaptation, igniting a transformative shift - actively rebuilding the environment while reducing its footprint. This redefines the industry's role, transforming it from a participant in environmental degradation to a frontrunner in ecological restoration.

"To draw the line, the line that separates before and after. That was then, this is now; and now we act differently. We design and build differently. We imagine different futures." - Daniel Barber

Box 3.3 Biodiversity calculations through LCA

To assess the impact on biodiversity, the "Off-Site Biodiversity Tool," developed for ***Doughnut for Urban Development: A Manual***, is utilized. This tool calculates both on-site biodiversity impacts from local land use and impacts from material usage. Background data is sourced from the Ecoinvent database version 3.10, and the method follows the ReCiPe 2016 framework. Currently, the tool is employed by various stakeholders within the Danish building industry and is freely available, but it relies on third-party data that cannot be publicly disclosed due to licensing restrictions.

The unit used in the tool is "species. Lost," which is converted into the area of land that needs to be restored and protected to regenerate biodiversity. This conversion employs a characterization factor from ReCiPe[53] of 3.26E-07 species.year/m^2, representing the transformation of agricultural land into untouched forest. This conversion provides an actionable indicator compatible with the Butterfly Framework.

Biodiversity Net Gain[54] approach is recommended for on-site biodiversity assessment.

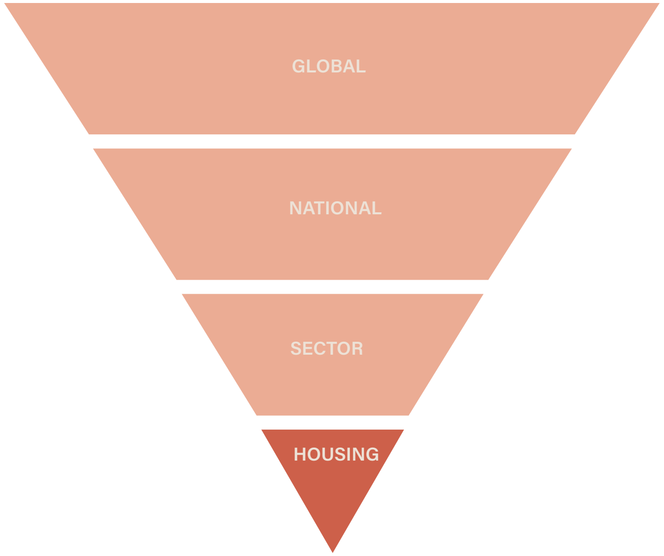


Figure 3.22 - The Butterfly is applied to housing.
Source: Reduction Roadmap

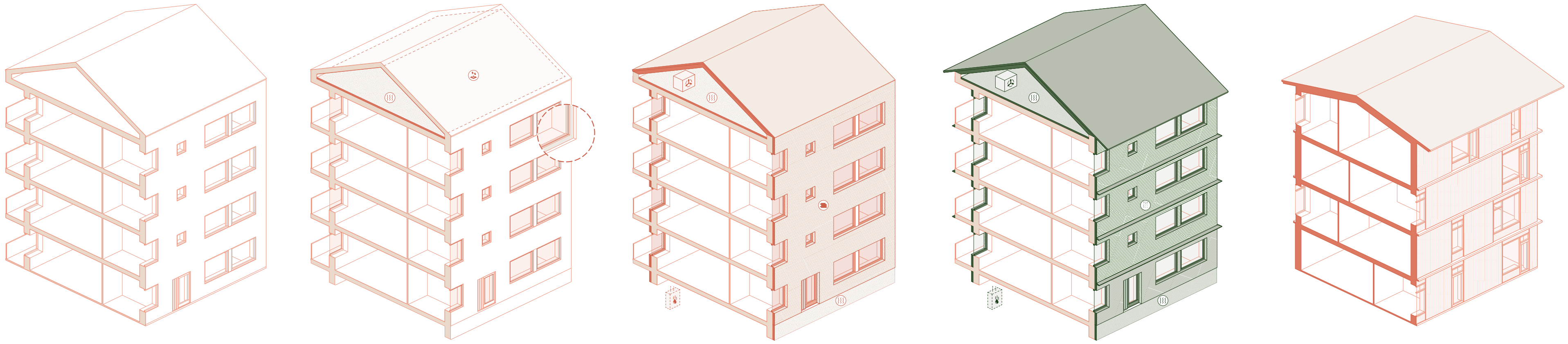
Demonstrating the Butterfly through building cases

To demonstrate how the Butterfly Framework can be operationalized, four scenarios will be explored to illustrate the model's proper application and potential benefits. This approach aims to provide a clear understanding of how the framework can be effectively implemented in practice.

The scenarios focus on different approaches to renovating or rebuilding a multi-story apartment building. In three scenarios, a 1970s-era building is renovated to varying extents, each using different materials. The final scenario involves demolishing the existing structure and constructing a new multi-story apartment building. These renovation scenarios are based on calculations from the "Klimadata for renovering" project, conducted by COWI, Arkitema, BUILD, and the Rådet for Bæredygtigt Byggeri for Realdania[56]. The construction of the new multi-story apartment building is based on the Lisbjerg Bakke project, which is featured in the case library at the Videncenter om Bygningers Klimapåvirkninger[57].

Since the Danish Building Regulations do not yet provide a standardized method for calculating the climate impact of renovation projects or projects involving demolition before new construction, the methodology proposed in the Realdania project has been applied. Further details about the renovation scenarios and methodology can be found in the project report.

For all scenarios, the climate and biodiversity impacts are calculated using LCAbyg and the Life-Cycle Biodiversity Impact tool (Box 3.3), with a study period of 50 years. All scenarios must comply with the Reduction Roadmap 2.0 proposal for differentiated limit values of 6.5 kg CO_2-eq/m^2 /year for multi-storey apartment buildings.



S0 - The Baseline

S1 - The Light Renovation

S2 - The Deep Renovation

S3 - The Deep, Biogenic Renovation

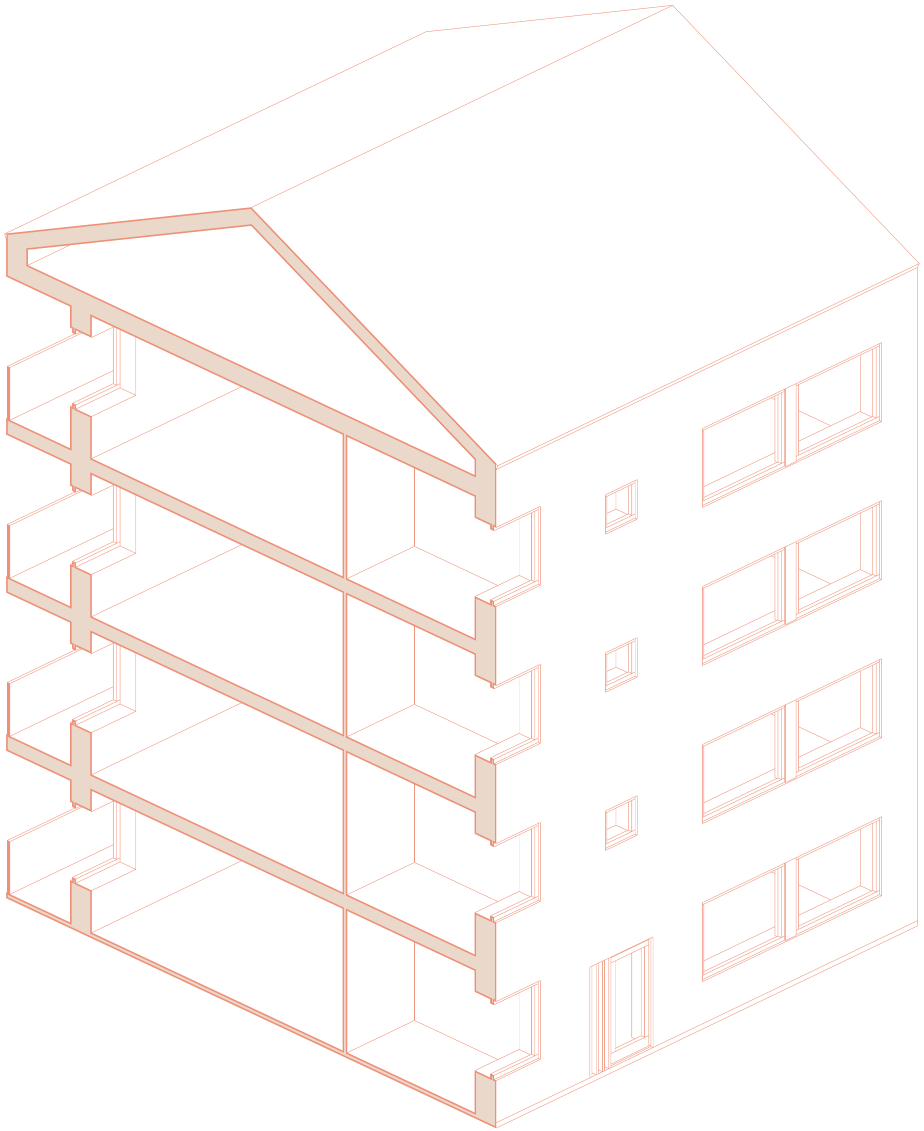
S4 - Demolition and New Construction

Scenario 0: Baseline - an existing 1970's multi-story apartment building

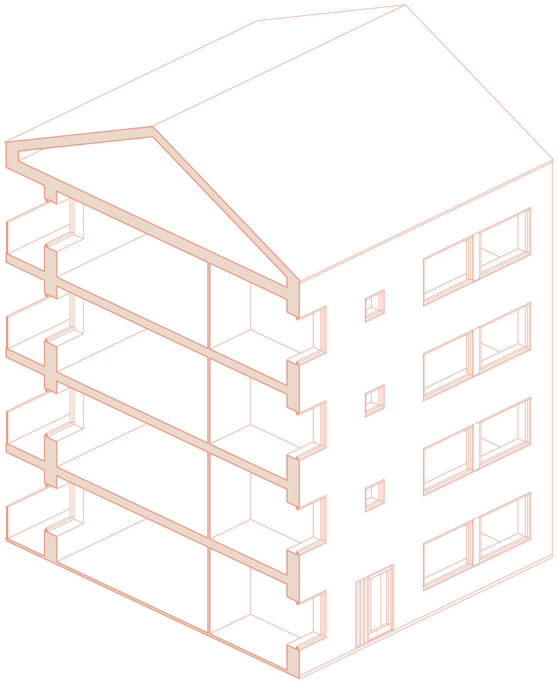
In the baseline scenario, the existing 1970s-era multi-story apartment building, with a total area of 4,230 m², continues to operate without any upgrades to improve energy efficiency. Necessary material replacements are made as components reach the end of their service life, but these replacements are carried out on a one-to-one basis, without improving performance. For example, windows are replaced with similar models rather than more energy-efficient alternatives. No significant renovations are undertaken, and the building remains in its original state throughout the study period.

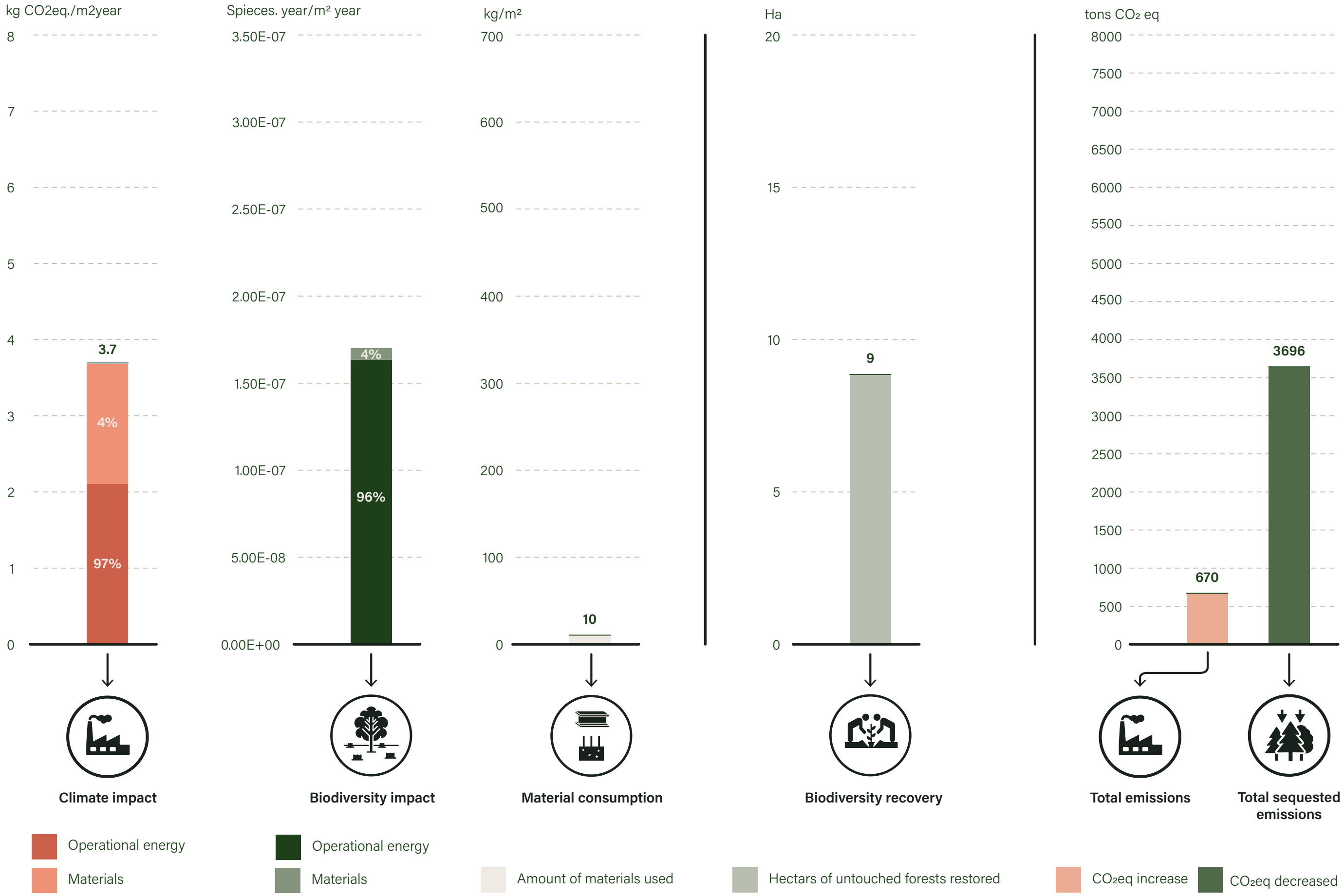
Project Info

Total Mass used of materials (kg/m²)	10
Climate impact total (kg CO_2eq./m²/year)	3,7
Climate impact total (ton CO_2eq.)	670
Biodiversity impact materails (species.year/m²year)	1,70E-07
Regeneration of forest areas (Hectares.)	9
CO2eq uptake from forests (50 years ton $C0_2$eq)	3.696
Net effect (ton CO_2eq)	3.026



Scenario 0: Baseline - an existing 1970's multi-story apartment building





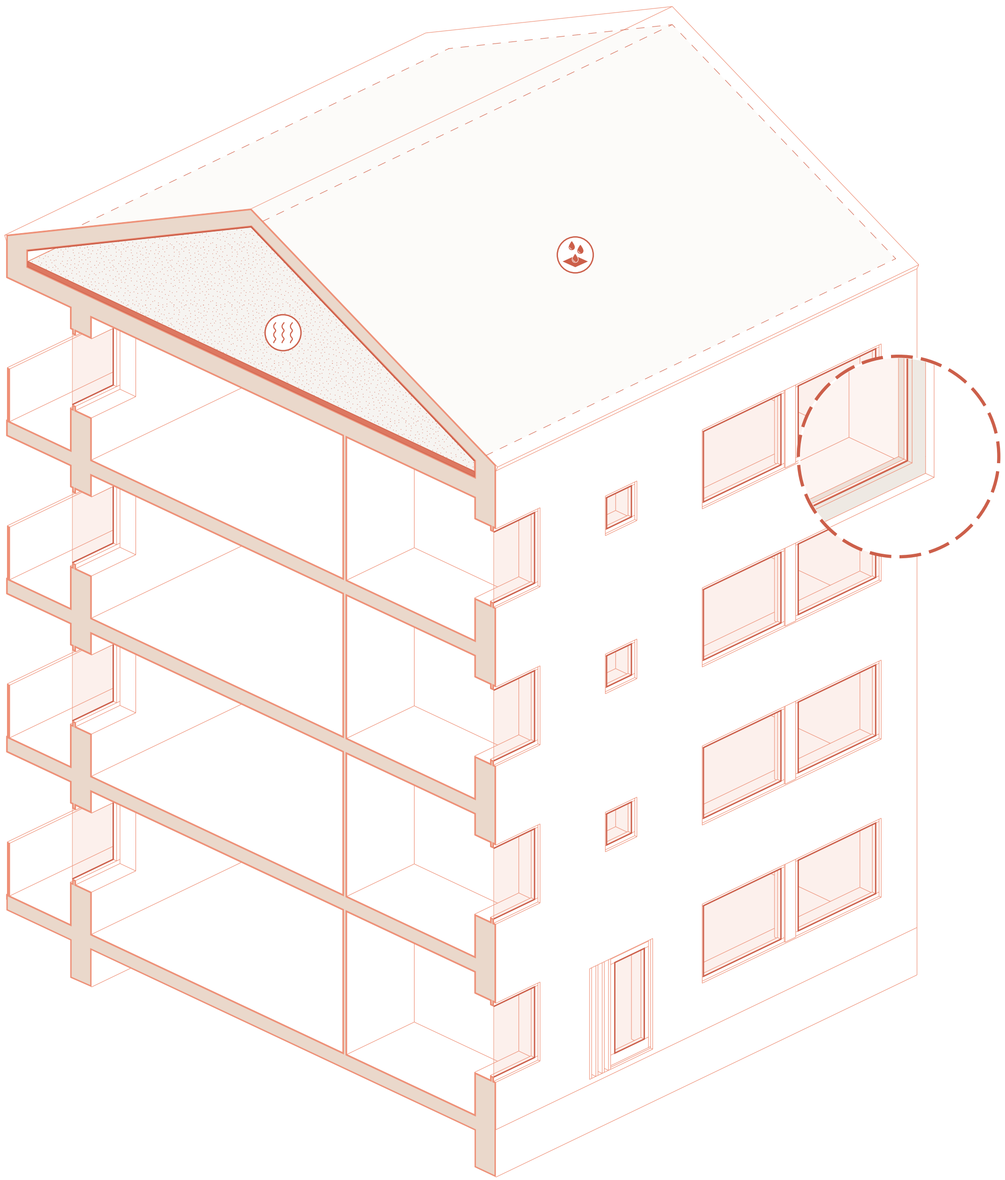
Scenario 1: Light renovation of a 1970's multi-story apartment building

Scenario 1 involves a light renovation of the multi-story apartment building from the 1970s. The primary goal of the renovation is energy optimization, focusing on improvements that extend the building's lifespan without major structural changes.

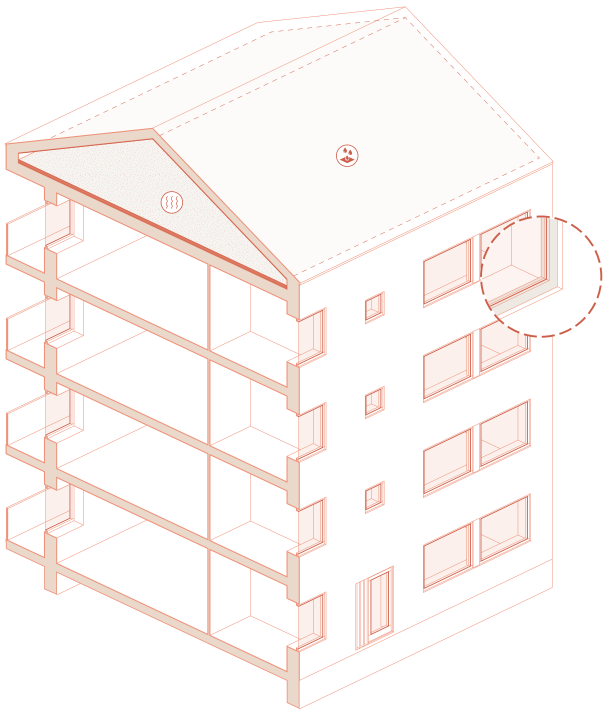
The renovation includes a thorough inspection of the windows, replacing all sealing strips and 10% of the panes and frames to extend their service life. Additionally, materials that have reached the end of their life cycle will be replaced as part of the general maintenance within the 50-year assessment period.

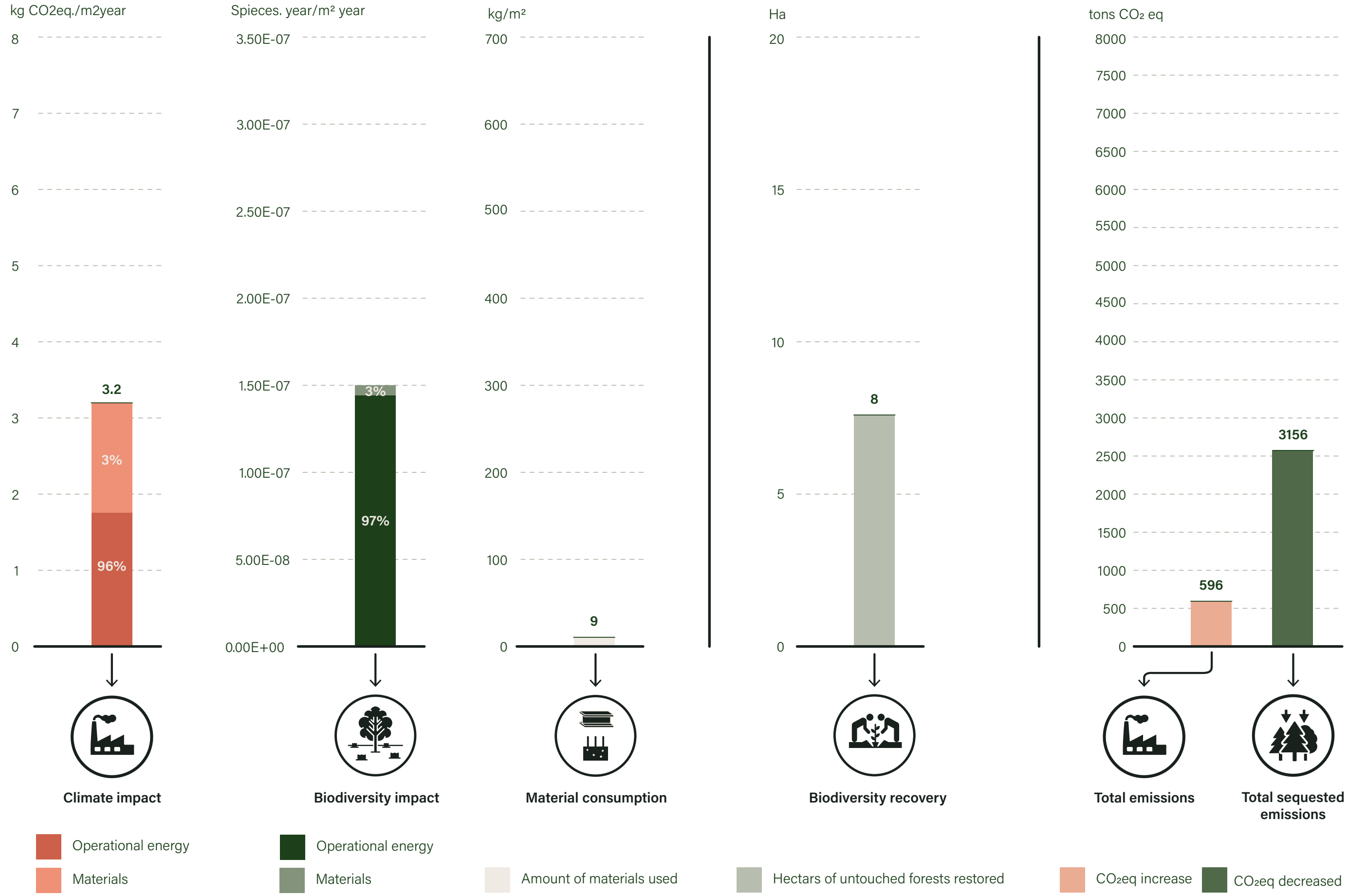
Project Info

Total Mass used of materials (kg/m^2)	9
Climate impact total (kg CO_2eq./m^2/year)	3,2
Climate impact total (ton CO_2eq.)	596
Biodiversity impact materails (species.year/m^{2}year)	1,50E-07
Regeneration of forest areas (Hectares.)	8
CO2eq uptake from forests (50 years ton $C0_2$eq)	3.156
Net effect (ton CO_2eq)	2.559



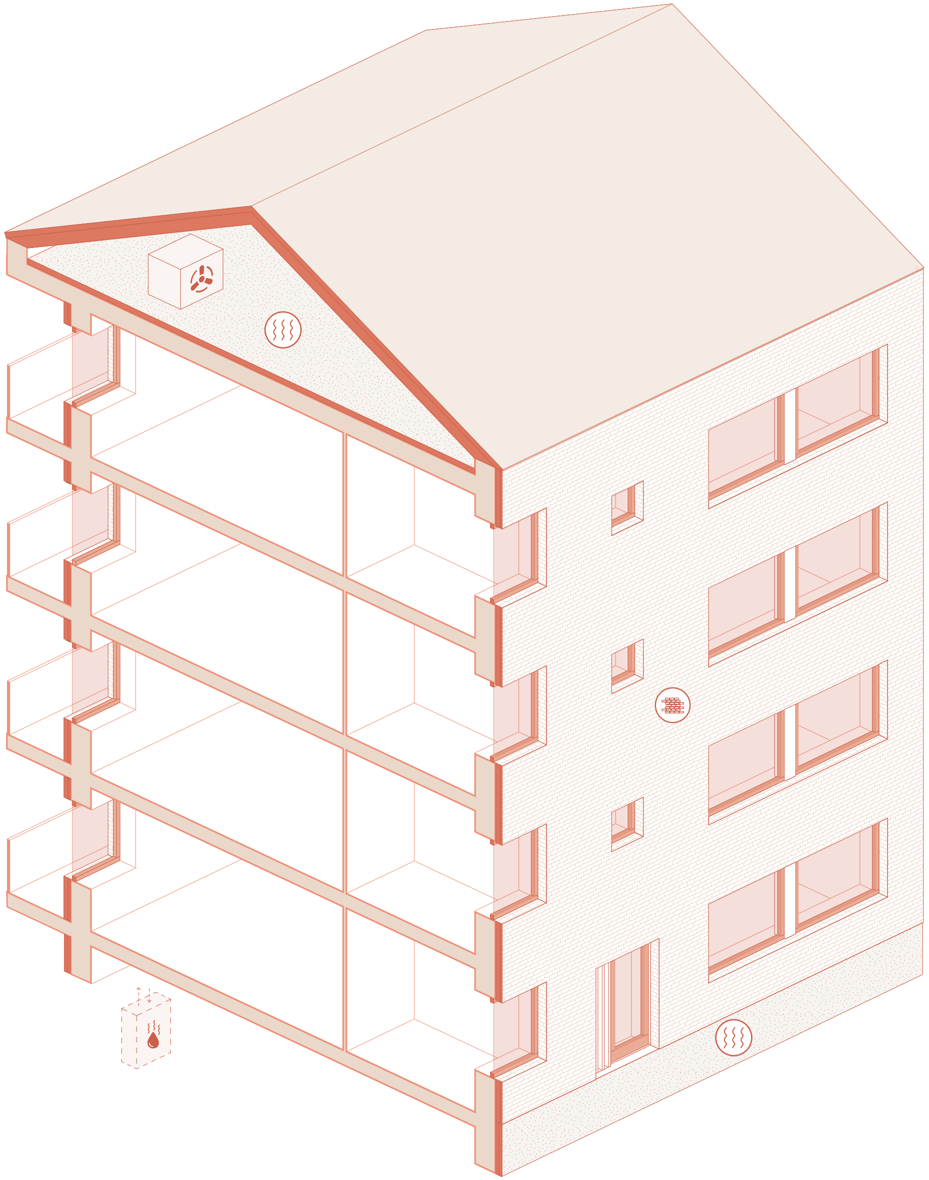
Scenario 1: Light renovation of a 1970's multi-story apartment building





Scenario 2: Deep renovation of a 1970's multi-story apartment building

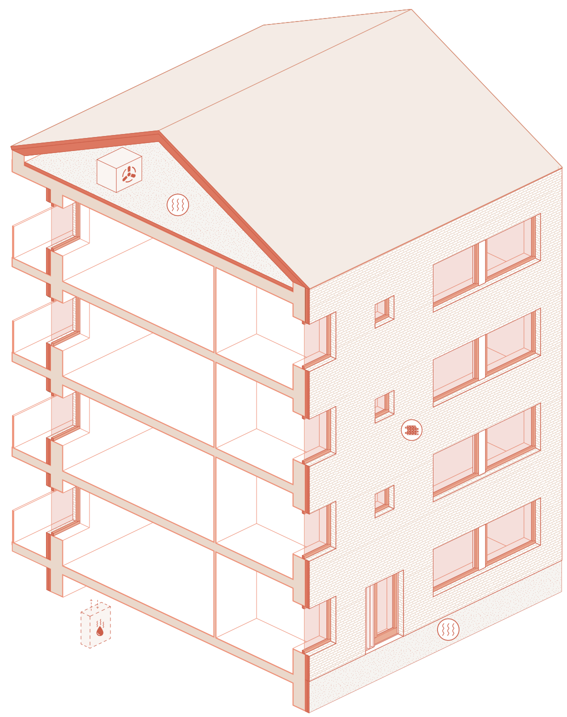
In Scenario 2, a deep renovation is performed on the same 1970s-era multi-story apartment building as in Scenario 1. The renovation is carried out with a focus on energy optimization and extending the building's lifespan. Key measures include replacing windows, roof coverings, and the heating system. Insulation is significantly upgraded for the roof, walls, and foundation, and a mechanical ventilation system with heat recovery is added. Additionally, materials that have reached the end of their service life are replaced to ensure durability over the 50-year study period.

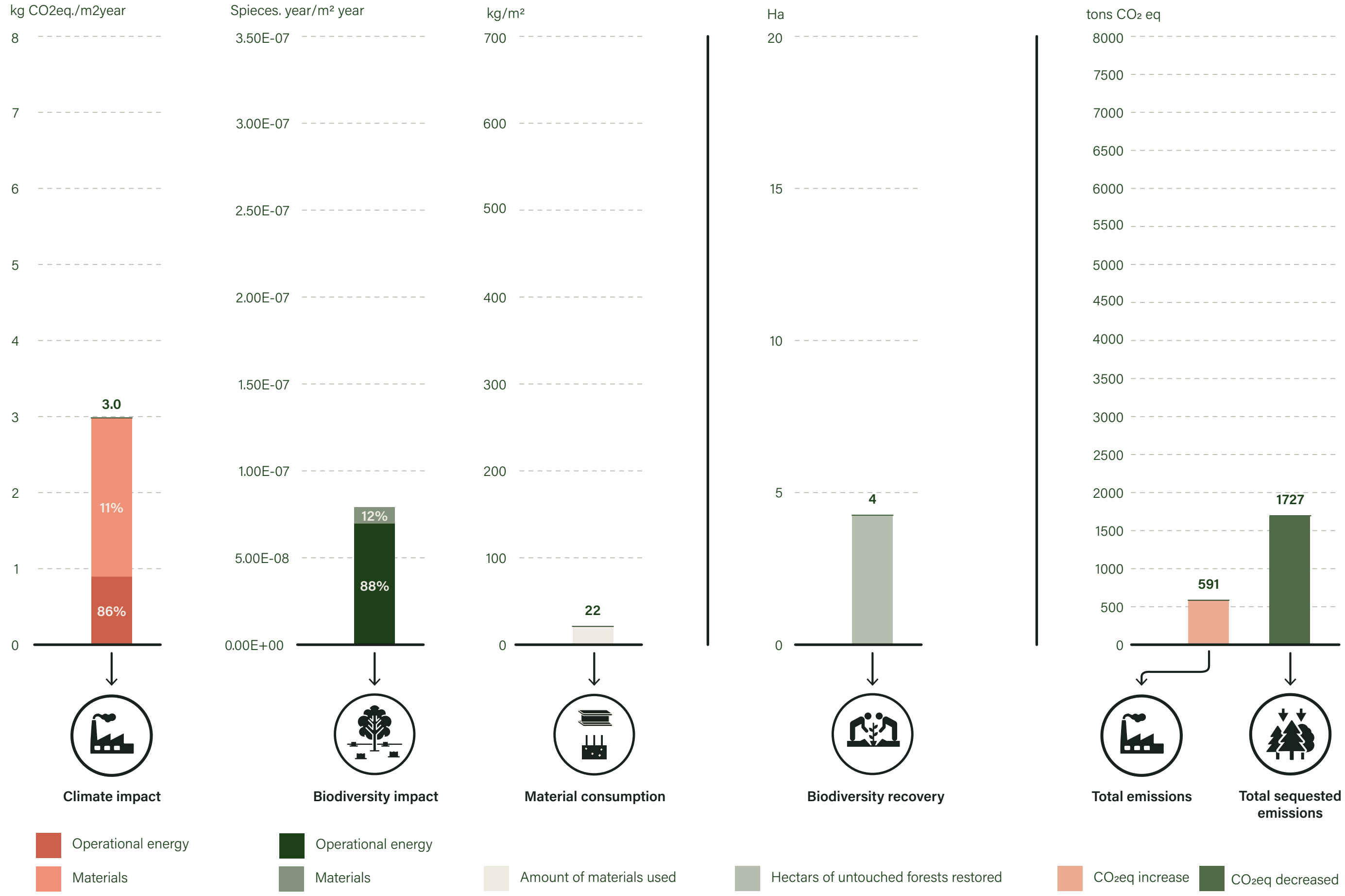


Project Info

Total Mass used of materials (kg/m²)	22
Climate impact total (kg CO_2eq./m²/year)	3,0
Climate impact total (ton CO_2eq.)	591
Biodiversity impact materails (species.year/m²year)	8,00E-07
Regeneration of forest areas (Hectares.)	4
CO2eq uptake from forests (50 years ton $C0_2$eq)	1.727
Net effect (ton CO_2eq)	1.136

Scenario 2: Deep renovation of a 1970’s multi-story apartment building



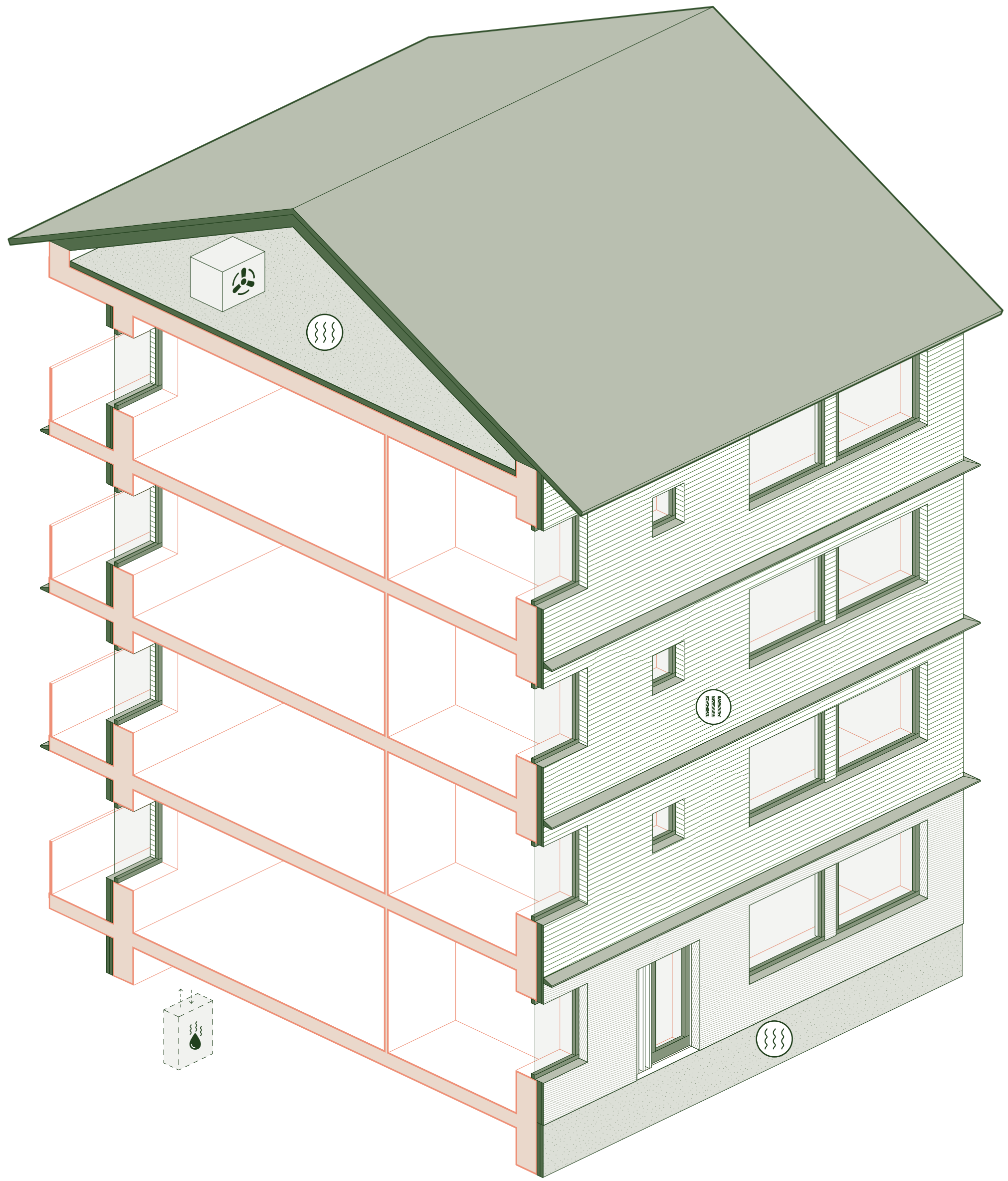


Scenario 3: Deep renovation of a 1970's multi-story apartment building with biogenic materials

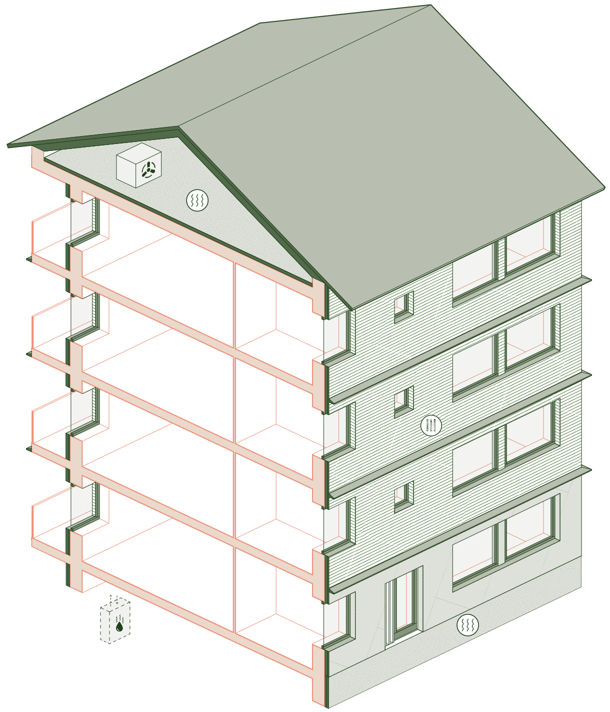
Scenario 3 mirrors the deep renovation approach of Scenario 2, but where possible, mineral-based materials are replaced with biogenic alternatives. Key changes include the use of cellulose insulation (paper wool) instead of mineral wool, biogenic facade materials, and wooden windows instead of wood-aluminum ones. Facades are mounted using a wood-cassette solution, and the roof area is expanded by 5% to provide constructive wood protection through overhangs. These adjustments aim to reduce the building's environmental impact by incorporating more sustainable, renewable materials.

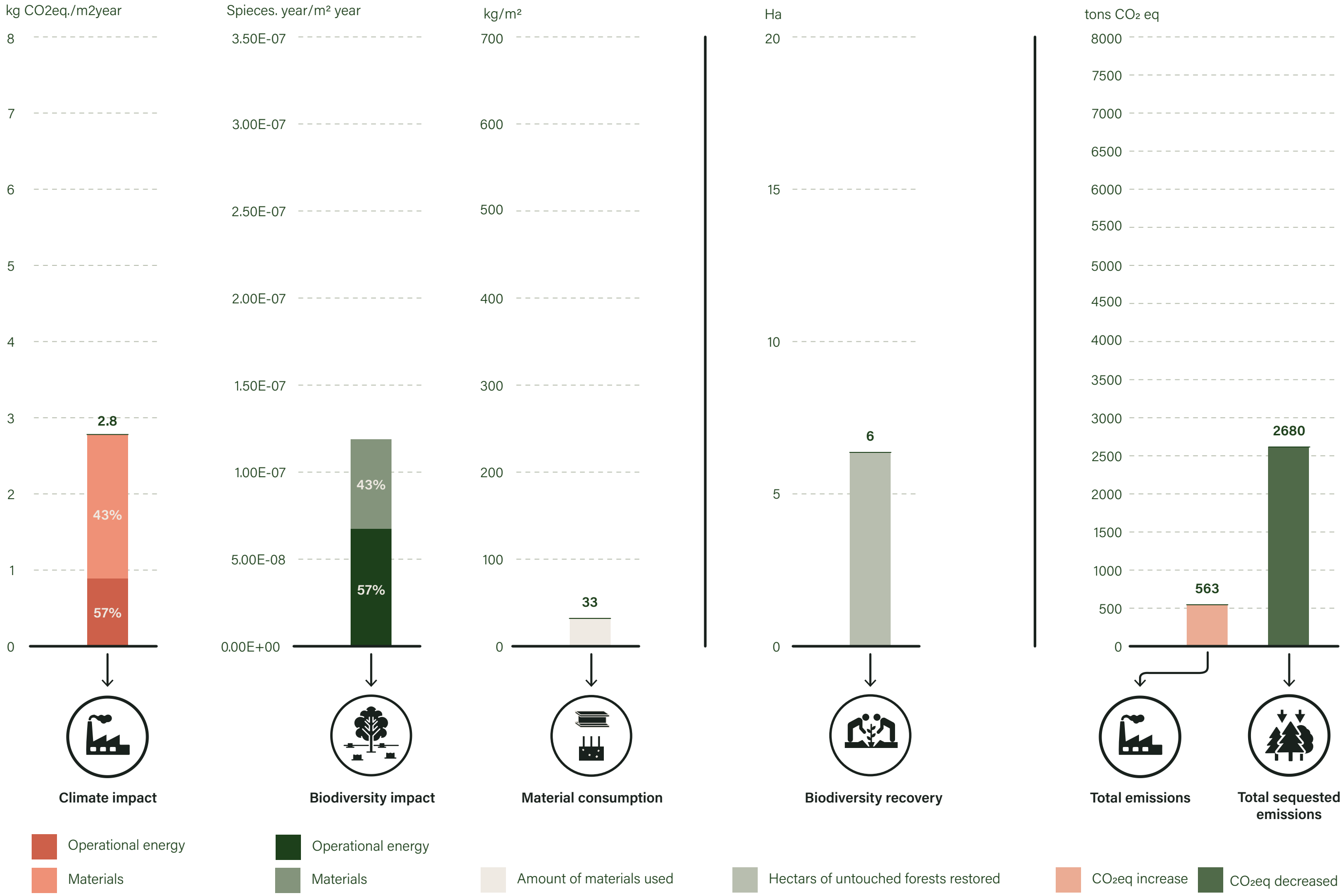
Project Info

Total Mass used of materials (kg/m²)	33
Climate impact total (kg CO_2eq./m²/year)	2,8
Climate impact total (ton CO_2eq.)	563
Biodiversity impact materails (species.year/m²year)	1,20E-07
Regeneration of forest areas (Hectares.)	6
CO2eq uptake from forests (50 years ton $C0_2$eq)	2.680
Net effect (ton CO_2eq)	6.403



Scenario 3: Deep renovation of a 1970's multi-story apartment building with biogenic materials





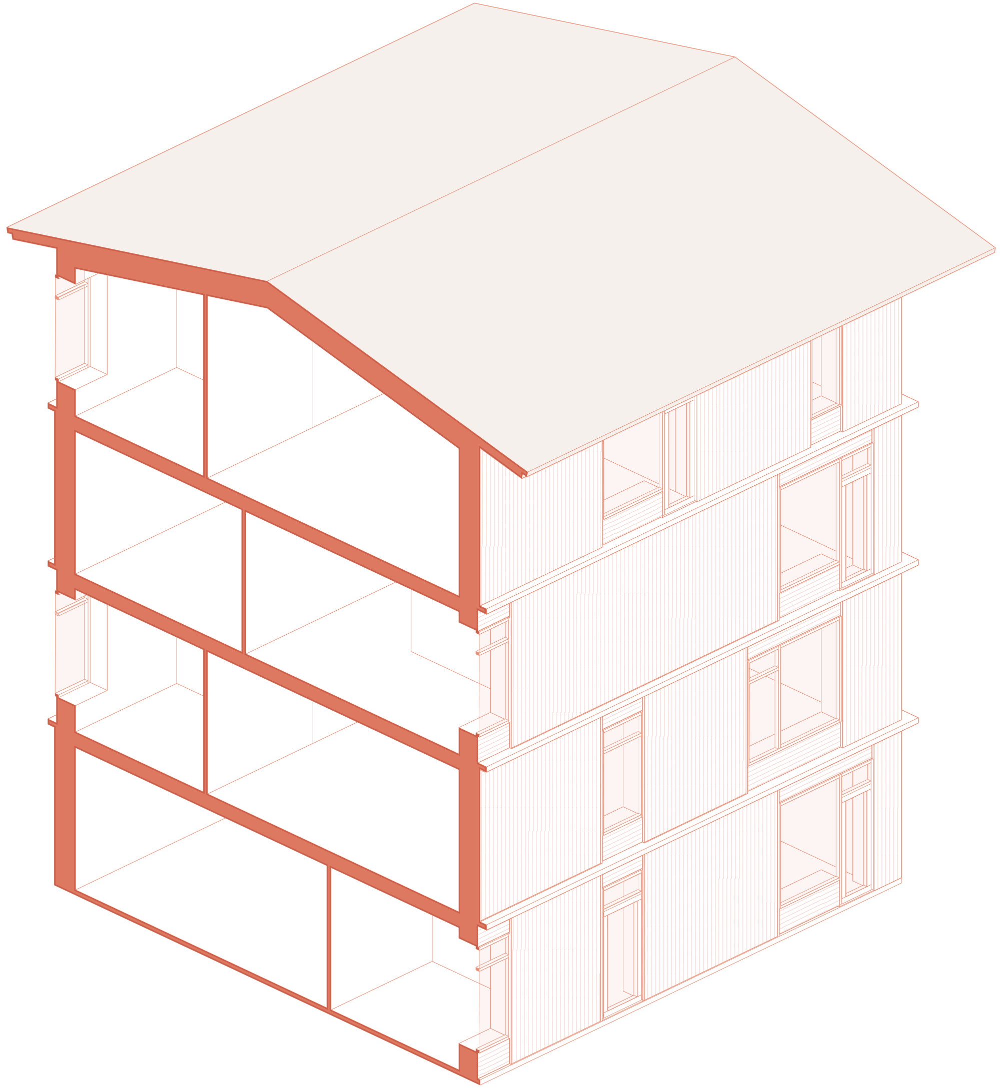
Scenario 4: Demolishing and construction of new multi-story apartment building

This scenario involves the demolition of an existing building and the construction of a new multi-story apartment complex spanning 4,180 m². The project employs a hybrid construction technique that integrates the strengths of timber, concrete, and steel.

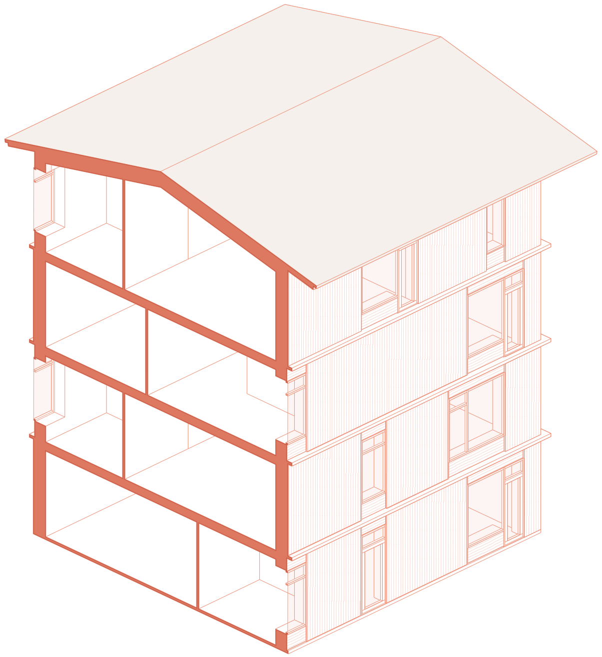
The 4-story residential building utilizes a column-beam framework made of laminated timber, with concrete and steel incorporated where structurally advantageous. This hybrid approach offers significant design flexibility and facilitates future disassembly and material reuse. The project features oversized roof overhangs and water hoods that protect the untreated wooden façade.

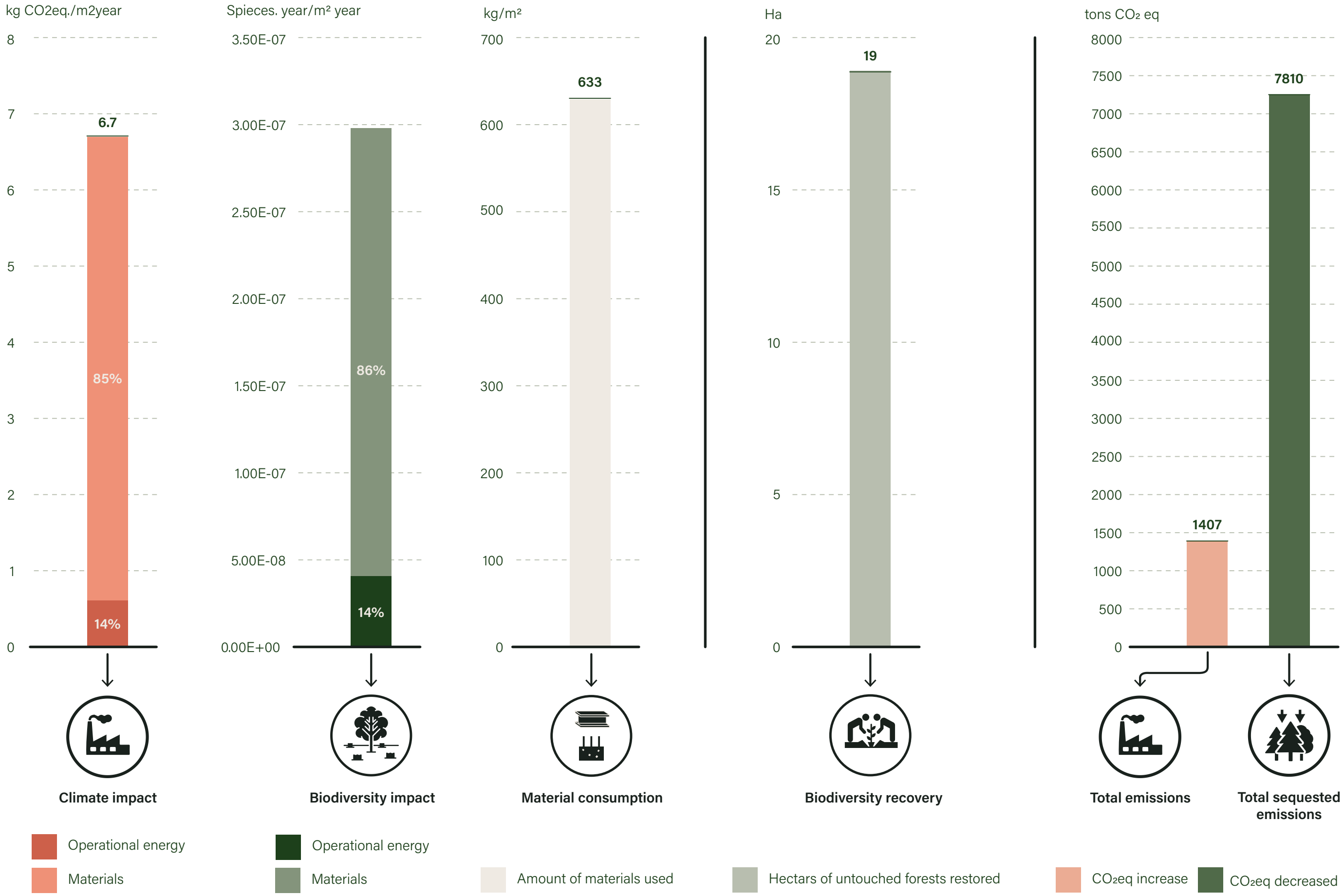
Project Info

Total Mass used of materials (kg/m²)	633
Climate impact total (kg CO_2eq./m²/year)	6,7
Climate impact total (ton CO_2eq.)	1.407
Biodiversity impact materails (species.year/m²year)	3,00E-07
Regeneration of forest areas (Hectares.)	19
CO2eq uptake from forests (50 years ton $C0_2$eq)	7.810
Net effect (ton CO_2eq)	6.403



Scenario 4: Demolishing and construction of new multi-story apartment building





Discussion building case study results

The following section presents the outcomes of the climate and biodiversity impact calculations across all scenarios, emphasizing the significant differences between renovation and new-build approaches. The analysis also examines forest regeneration as a means of addressing biodiversity loss while harnessing carbon uptake, contributing to the overall environmental performance across the scenarios.

Detailed results are documented in Table 3.3.

The results reveal clear trends in material consumption, climate impact, and biodiversity effects across the five studied scenarios. Notably, in the baseline scenario, high energy consumption results in significant impacts on both biodiversity and climate, accounting for 96% of the biodiversity impact and 57% of the climate burden. While light renovation leads to slight reductions in both impacts, these changes are not substantial. In contrast, deep renovation, which employs more materials than light renovation, achieves significant improvements in energy efficiency, making it the most effective solution overall. In this scenario, climate burdens can be reduced to as low as 2.8 kg and 3 kg CO_2/m^2 per year when utilizing biogenic and mineral materials, respectively. However, it is important to note that the biodiversity impact from biogenic renovation is greater than that of conventional deep renovation.

Demolition and new construction incur the highest impacts for both climate and biodiversity. In these scenarios, the contribution from operational consumption drops to around 10% for both indicators. However, the burden associated with new materials is so significant that the total impact is approximately double that of the baseline scenario.

In the baseline scenario, the biodiversity impact is quantified at 1.70E-07 species.year, necessitating the regeneration of 9 hectares of untouched forest to compensate for the biodiversity loss linked to material use. In contrast, light and deep renovation scenarios show improvements, requiring the regeneration of only 4 to 8 hectares of forest.

The new construction scenario, presenting the highest climate impact at 6.7 kg CO_2eq/m^2 per year, also has the greatest biodiversity impact from materials. Although this scenario facilitates the regeneration of 19 hectares of forest, this is primarily necessary to mitigate the substantial biodiversity loss caused by new construction. In this context, regeneration efforts primarily serve to offset damage rather than contribute positively to biodiversity.

When comparing the carbon emissions from the lifecycle assessment (LCA) with the amount of CO_2 captured by the forest, it becomes evident that the sequestered carbon far exceeds the emissions produced throughout the building's life-cycle. It is essential to acknowledge that current LCA methodologies may under report total emissions, as not all phases of the life-cycle are fully accounted for. Nonetheless, the carbon sequestration achieved in these scenarios compensates for emissions, ensuring that biodiversity regeneration contributes significantly to ecosystem recovery and meaningful emissions reductions over the building's operational lifetime.

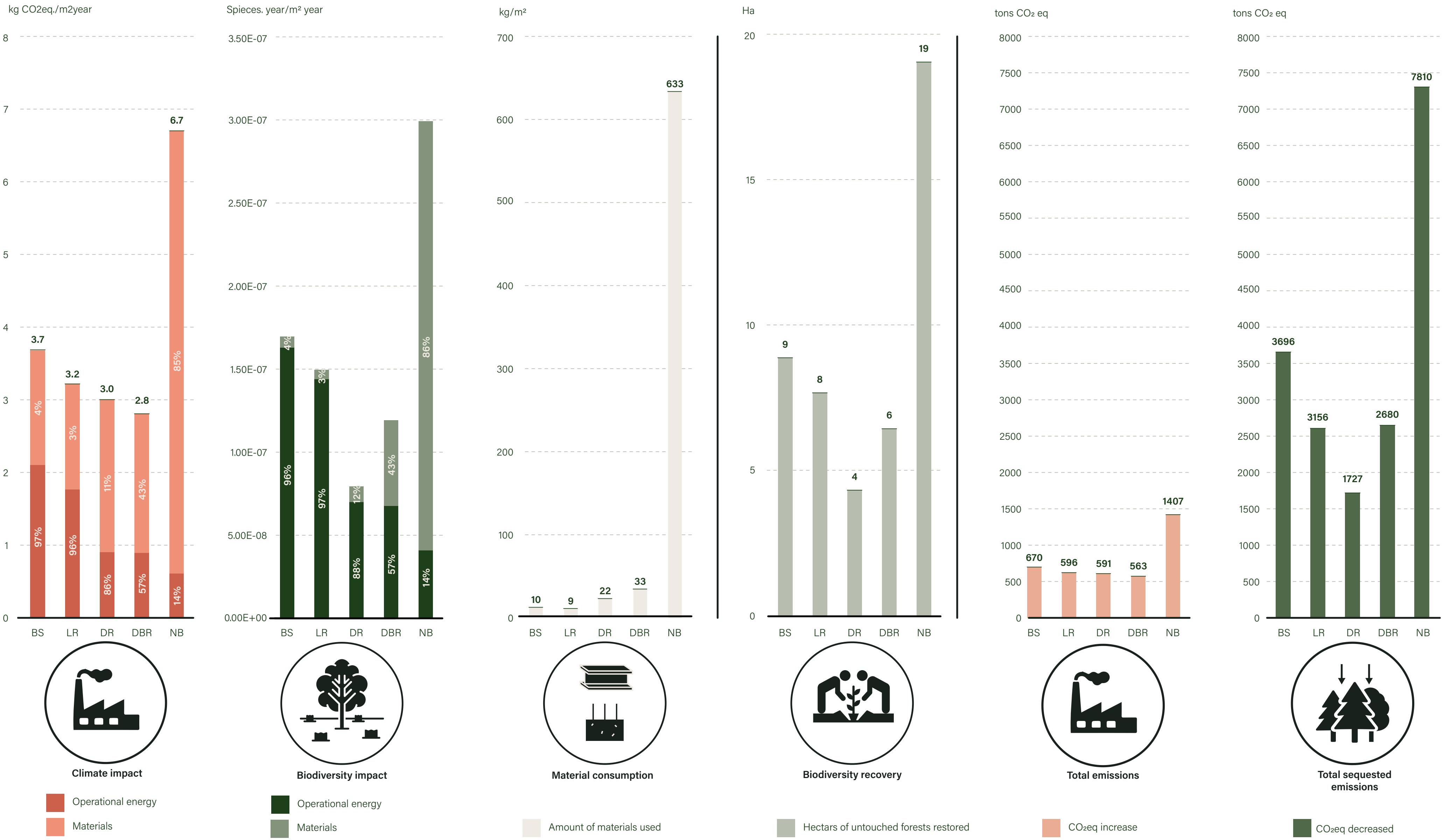
Addressing biodiversity loss within the building industry should not be mistaken for a compensation scheme. Rather, it operates under the "polluter pays" principle. Every construction activity impacts the environment, and it is crucial that the building industry compensates for these impacts. The Butterfly framework mandates that building must a) adhere to Reduction Roadmap CO_2eq targets while b) restoring land to take full responsibility for building activity impact. This dual requirement ensures the Butterfly is not exploited as a loophole to continue business-as-usual. Rather, the Butterfly actively holds the industry accountable for its real environmental impacts.

This approach supports implementing a “polluter pays” principle, ensuring those who contribute to biodiversity loss are financially responsible for mitigating it. According to Danish Statistics land costs approximately 200.000 dkk/hectare, though these figures would adjust with rising land prices.

In summary, deep renovation strategies—particularly those employing biogenic materials—generally result in lower climate impacts and reduced biodiversity effects compared to new construction. However, the extensive forest regeneration required for new construction emphasizes the urgent need to address biodiversity loss linked to material use. Therefore, prioritizing strategies that minimize biodiversity impacts while implementing necessary regeneration efforts is crucial. A balanced approach that reduces operational consumption and material use is essential for achieving both environmental sustainability and climate goals.

Scenario	Total mass of used materials [kg/m²]	Climate impact Total [kg CO_2eq/m²yr]	Climate impact Total [ton CO_2eq.]	Biodiversityt impact Materials [species. year]	Regeneration of forest areas [Ha]	CO2 uptake forest (50 years) ton CO_2eq.
Baseline	10	3.7	670	1.10E-03	8.9	3.696
Light renovation	9	3.2	569	8.50E-04	7.6	3.156
Deep renovation	22	3.0	591	1.60E-03	4.2	1.727
Deep renovation, biogenic	33	2.8	563	9.10E-03	6.5	2.680
Demolishing and new building	633	6.7	1.407	5.30E-02	10.9	7.810

Table 3.3 A detailed overview of analysis results on the building scenarios. Source: Reduction Roadmap


kg CO2eq./m2year
8
7
6
5
4
3
2
1
0
3.7
3.2
3.0
2.8
6.7
4%
97%
3%
96%
11%
86%
43%
57%
85%
14%
BS
LR
DR
DBR
NB
Climate impact
Operational energy
Materials
Spieces. year/m² year
3.50E-07
3.00E-07
2.50E-07
2.00E-07
1.50E-07
1.00E-07
5.00E-08
0.00E+00
4%
96%
3%
97%
12%
88%
43%
57%
86%
14%
BS
LR
DR
DBR
NB
Biodiversity impact
Operational energy
Materials
kg/m²
700
600
500
400
300
200
100
0
10
9
22
33
633
BS
LR
DR
DBR
NB
Material consumption
Amount of materials used
Ha
20
15
10
5
0
9
8
4
6
19
BS
LR
DR
DBR
NB
Biodiversity recovery
Hectars of untouched forests restored
tons CO₂ eq
8000
7500
7000
6500
6000
5500
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
670
596
591
563
1407
BS
LR
DR
DBR
NB
Total emissions
CO₂eq increase
tons CO₂ eq
8000
7500
7000
6500
6000
5500
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
3696
3156
1727
2680
7810
BS
LR
DR
DBR
NB
Total sequested emissions
CO₂eq decreased

Ludwig Engel

House Europe!
The European Citizens' Initiative for the Social-Ecological Transformation of Existing Buildings

Renovate, don't speculate!

Despite being a major contributor to global CO2 emissions, the building sector often goes unnoticed. Today, buildings are seen more as financial assets than as spaces for people to live, leading to the demolition of millions of vacant square meters. This trend denies people their right to a home at the same time as straining the Earth's resources. We are witnessing ongoing environmental destruction in service to profit. Yet, we maintain a system in which buying something new is cheaper than caring about the old. Public awareness, values, and legislation sustain this harmful cycle.

Awareness, Values, Legislation

In the minority world, buildings have become targets for financial speculation. Investors buy land without a prospective tenant primarily in anticipation of financial gains; the construction of spaces for living in is a secondary byproduct of this profit-driven goal ("if you build it, they will come"). This creates a system that favours demolition and new construction, a model that has worked well enough in the past when resources seemed limitless. However, current material and energy shortages reveal the flaws in this approach.

How did we get here?

Reason 1 - Profit Over Community: The prospect of growing profits overrides the undocumented social value of existing structures. Community hubs or affordable housing are routinely demolished to make way for luxury developments in anticipation of higher rents and increasing land value. Urban renewal replaces older structures with developments appealing to wealthier demographics, driving up property values and displacing long-standing communities.

Reason 2 - Perceived Modernity: New construction is perceived as more attractive just by virtue of being new. Developers may appeal to a specific demographic or clientele, driven by the desire to appear contemporary ("keeping up with the Joneses").

Reason 3 - Land vs. Building Value: In dense urban areas, land value often exceeds building value (importantly, this value is derived from the urban location and its liveliness – it is created by the public commons, and not by private property owners). Older, smaller buildings have a lower perceived value than hypothetical replacements, leading to incentives for demolition, to make space for denser and taller buildings.

Reason 4 - Tax Incentives: Some jurisdictions offer tax incentives for new construction, making it financially advantageous for owners to demolish and rebuild.

Reason 5 - Speculative Bubbles: When real estate markets heat up, a herd mentality can take over, where everyone wants a piece of the 'next big thing.' In such environments, even properties that are still functional can become targets for acquisition, demolition, and redevelopment, driven by the speculative belief in potential future profits.

The Demolition Drama

By 2050, Europe will demolish 2 billion square meters of existing space if current trends continue – more than the entire building stock of Paris and Berlin combined. Instead, we will have built billions of square meters of new space as replacement for what was already there. However, there are social, economic and environmental losses that this mass demolition can never replace.

Social Issue = Home Loss:
We are tearing down buildings that could house more than 50 million people. Even when new housing units are built in replacement of what was lost, original occupants are often unable to return due to an astronomic increase of costs, as the assessed property value of a rebuilt plot of land grows.

Economic Issue = Job Loss:
Large, centralized businesses profit from demolition and new construction in the building industry, but small and medium-sized businesses can thrive with renovation. With 92% of architecture offices in Europe having one to five employees, increasing the renovation rate can advantage these smaller practices. Demolishing buildings takes away these bespoke, labour-intensive renovation projects before they even start.

Environmental Issue = Energy Loss:
Our built environment holds a significant embodied energy, representing countless tons of CO_2 that has already been emitted to the atmosphere to build our world. Demolishing buildings wastes all the energy and emissions that have already been used up in their construction.

The Renovation Story

We need a social-ecological transformation of the existing building stock, changing our attitudes and practices by seeing and recognizing the value of existing buildings. The Renovation Wave, initiated by the European Union as part of the European Green Deal can help people to live in much better conditions, and even be economically preferable in the long run. This transformation takes time, but there is a simple roadmap: Preservation, Adaptation, Renovation, Transformation.

We need new cultural narratives: from viewing spaces as commodities to seeing them as necessities.

Preservation - Reuse, don't demolish!
We call for saving existing buildings and the energy invested in them to conserve resources and preserve social and cultural values. Prioritizing reuse over demolition is our first step towards affordable living spaces for all.

Adaptation - Adapt, don't abandon!
We call for repurposing existing structures and underutilized spaces to give Europe's buildings new purpose and value. By adapting buildings that have fallen out of use, we aim to revitalize the potential of existing building stock.

Renovation - Build for the future!
We call for renovating, repairing, and maintaining existing buildings. Our goal is future-proof renovation, focusing on long-lasting construction methods to minimize the need for additional materials and new construction.

Transformation - Shift the Value!
We call for transforming existing structures in a social, environmental, and economic sense. Our aim is to implement policies that ensure equity, resilience, and community-building. We need new cultural narratives: from viewing spaces as commodities to seeing them as necessities. For renovation projects today, banks require insurance rates that are three times higher compared to new construction. This drives up interest rates, compelling people to opt for new construction. It's a vicious cycle we find ourselves in. So, how do we achieve a shift and make a change in reality?

European Citizens' Initiative
HouseEurope! is a citizens' initiative for an EU-legislation that boosts the renovation of existing buildings and stops their demolition for new construction driven by speculation. European Citizens' Initiatives are powerful tools for direct democracy, allowing citizens across the EU to propose new laws or changes to existing ones. If one million EU citizens from at least seven countries support the cause, the European Commission must consider the proposal and allocate a working group.

Together, we aim for an alternative to the current legislation that favours demolition and ground-up new construction over renovation and adaptation. But to make this happen, we need everyone to understand, join in and support the call.

We need each other!
You rent an apartment? You own a building? You care about the environment? You work in the building sector? You can make a difference – put an end to this practice and make a change in reality!

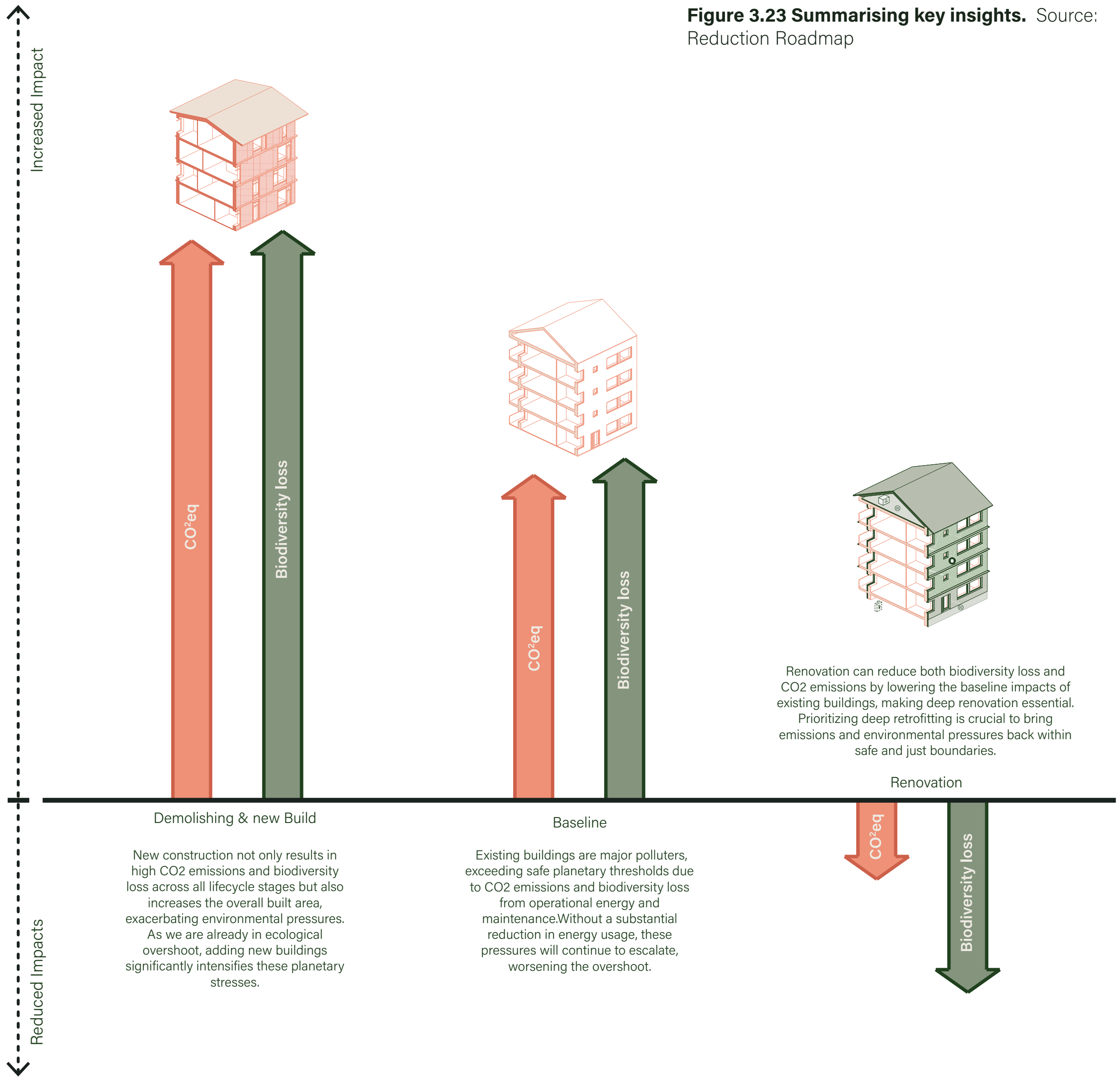
Key insights from the Butterfly Framework and Scenarios

The Butterfly

The Butterfly methodology illustrates that relying solely on CO_2 -eq aas an indicator for planetary health is insufficient, as it allows for climate mitigation while potentially intensifying pressure on other planetary boundaries. In contrast, increasing protected areas not only helps reverse biodiversity loss but also inherently reduces pressure on most planetary boundaries. However, without a reduction in emissions, these efforts alone will not bring the planet back within safe and just limits. True progress requires staying within the boundaries of both core systems.

For Denmark, this truth is even more urgent. Heavily cultivated landscapes leave the nation with a glaring deficit in protected nature, far behind global targets. Despite political agreements like the Climate Act and "Grønne Trepart," Denmark remains misaligned with scientific imperatives, failing to meet international policy commitment and scale development within planetary boundaries. The call for large-scale, transformative action grows louder, demanding that policy and practice realign with the Earth's limits.

Figure 3.23 Summarising key insights. Source: Reduction Roadmap



Yet, within this challenge lies a powerful opportunity. The Butterfly framework not only lays out a clear path for aligning emissions reduction with large-scale nature protection but also encourages a fundamental shift in thinking. It redefines prosperity—not as endless growth, but as living well within Earth's boundaries, fostering resilience and regeneration. This is not about tweaking the system; it's about re-framing our understanding of progress. By addressing environmental and social impacts at their source, rather than outsourcing or deferring responsibility, the framework calls for accountability and creativity.

In doing so, it opens the door to a future where sustainability means more than minimizing harm—it means actively restoring ecosystems, ensuring equity, and designing systems for long-term resilience. For Denmark, and the world, the Butterfly framework offers not just a vision, but a blueprint for a future where thriving is measured by balance, restoration, and justice, not by consumption.

The Building Scenarios

Our analysis of the five building scenarios shows that, new construction results in both the highest biodiversity loss and carbon emissions. While this outcome may be expected, the analysis highlights a critical issue: operational energy demands are one of the biggest contributors to biodiversity loss. This loss is directly linked to the operational energy needs of buildings, which drive habitat destruction, resource extraction for energy production, and contribute to global carbon emissions. There are still uncertainties in the biodiversity loss calculations - as such, these results should be seen as indicative, rather than absolute.

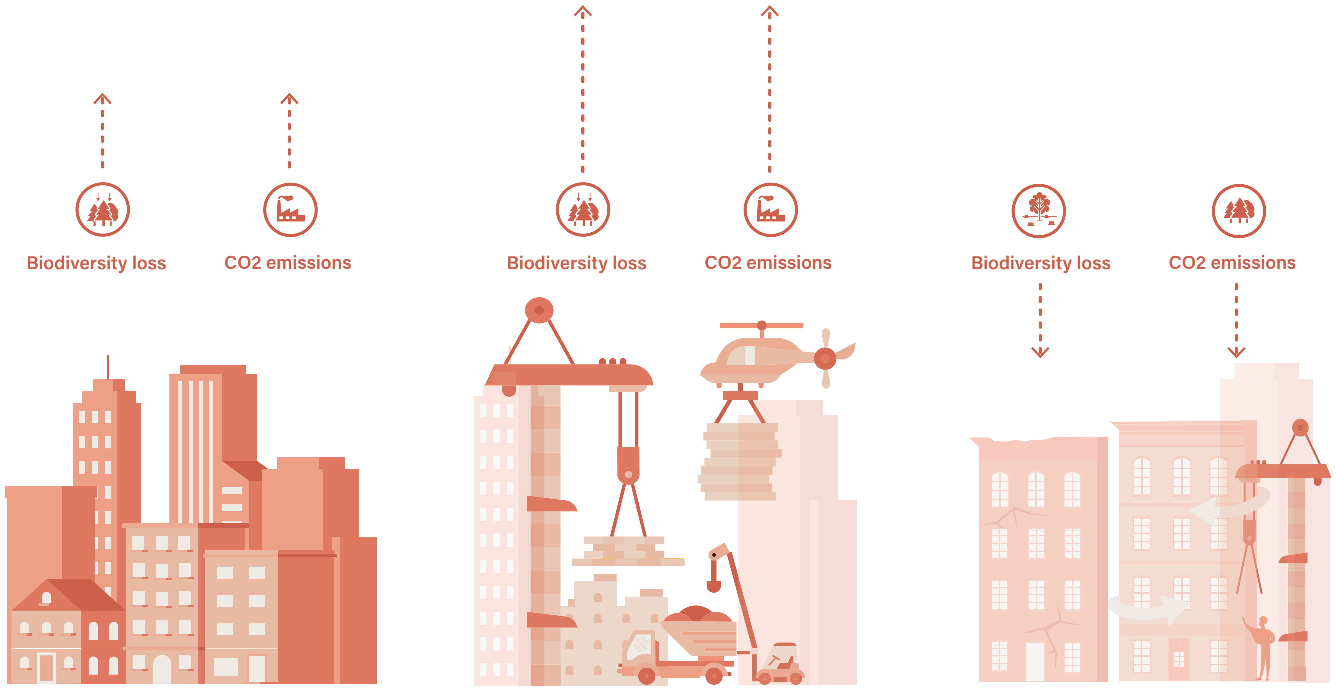
The findings indicate that simply taking a "do nothing" approach with our existing building stock is not a viable option because it increases pressure on climate stability and ecosystem health. As such, it is essential to implement strategies that reduce operational energy, while ensuring sustainable maintenance plans are carried out to extend building lifespans. Whether light or deep, with use of biogenic materials—renovations can significantly decrease the emissions and biodiversity loss. Taking such actions is essential to mitigate current impacts while moving towards a more sustainable future.

Evaluating the environmental impacts of renovation compared to new construction underscores the importance of energy reduction strategies. While both typologies impact biodiversity due through materials use, the crucial distinction lies in their long-term implications: new additive new construction expands the total floor area, leading to increased energy demands - accelerating impact.
In contrast, through light and deep energy renovations

decrease the environmental damage associated with operational energy consumption.

Understanding this distinction is pivotal: new construction inherently adds to biodiversity loss by expanding the built environment, whereas careful renovation acts as a tool for minimizing biodiversity loss. It is not possible to to do the same with new construction. As such, shifting the building industry towards a practice of renovation is essential for creating more stable climates and restoring ecosystem health - to achieve a more sustainable balance between human activities and the planetary health.

The analysis reveals that if the building industry compensates for the biodiversity loss it has caused by establishing protected areas, it can significantly reduce emissions—out weighing the emissions generated by renovation activities. This finding supports the key insight from the Butterfly: Increasing protected areas not only helps reverse biodiversity loss but also inherently reduces pressure on other planetary boundaries. Both core boundaries climate stability and functioning ecosystems—must be addressed in tandem. As such, to reach the safe and just ESB before 2050 requires both increased protected land areas while reducing carbon following Reduction Roadmap targets - thereby transforming the building industry into a powerful driver of regenerative action.



1. Existing City
Existing buildings are significant contributors to biodiversity loss and CO2 emissions, driven by ongoing maintenance, replacement of materials, and high operational energy use. These buildings already exceed safe planetary thresholds, and without substantial improvements in energy efficiency and reduced material consumption, their environmental pressures will continue to worsen.

2. New Construction
New construction leads to high CO2 emissions and biodiversity loss throughout all lifecycle stages, while expanding the built area and intensifying environmental pressures. With ecological overshoot already a reality, adding new buildings further exacerbates planetary stresses.

3. Renovation
The only way to reduce CO2 emissions and biodiversity loss is by renovating the existing building stock, ensuring reduced operational energy. However, renovation only reduces these impacts if the rate of reductions exceeds the emissions and biodiversity loss from new construction. For every new building added, biodiversity loss and CO2 emissions will continue to increase, making it harder and harder to return to the safe and just planetary boundaries.

Figure 3.24 - Summarizing key insights. Source: Reduction Roadmap

3.6 Discussion and Limitations

Throughout Chapter 3, calculations and analyses have been conducted, relying on assumptions that require further discussion to nuance the results and clarify that these calculations are not definitive conclusions. Instead, they show trends and introduce a new methodological approach for the future of construction. The discussion is structured around key themes, exploring the limitations of the methods and assumptions used.

Land Distribution

A central goal of the butterfly model is to achieve 30% protected nature by 2030 and 50% by 2050. Achieving this requires a major reallocation of Danish land, as only 2% is currently protected. Although this transition could occur in various ways, as agriculture covers about 60% of Danish land, there is consensus that the agricultural sector must release land for nature restoration[20]. In the present analysis, the reallocation is based on the scenario “From Feed to Food” in the project “Veje til Biobaseret Byggeri[35]” as well as a similar project, "Fra foder til føde II[34]", developed by several organizations, including the Danish Society for Nature Conservation and the Council for Green Transition. While this scenario provides a comprehensive model to reach the 30% goal by 2030, there are no corresponding analyses or policies outlining how to reach 50% by 2050. This project’s allocation for 2050 is, therefore, based on a linear projection from 2030 to 2050, with agricultural land gradually being converted to nature.

This assumption, naturally, can be debated, but it illustrates that if Denmark is to achieve 50% protected nature while retaining production forests and land for cities and roads, it is necessarily agriculture that will need to yield cultivated areas. Furthermore, it could be debated which areas are best suited for nature and forest, and which are most suitable for agriculture, especially concerning carbon-rich lowland soils[20]. This approach would provide a clearer picture of how much of the protected nature would be allocated as untouched forest and other natural types, such as grasslands and wetlands.

The assumptions made could thus be further refined and validated, for instance, by integrating forest, nature, and agricultural models from the University of Copenhagen, Aarhus University, and the Biodiversity Council. This approach would give a more nuanced understanding of the real impact and significance of reallocating 50% of Denmark’s land to protected nature.

Additionally, the discussion on future land distribution in Denmark raises significant questions, such as how to produce sufficient food and feed for humans and animals on a significantly reduced area. However, addressing this goes beyond the scope of this report.

Carbon Uptake from Natural Areas

In connection with the reallocation of land to protected nature, the potential effect of CO_2 absorption and storage in these areas has been calculated. The analysis includes only two different types of nature, namely untouched forest and open natural areas with scattered vegetation. This calculation is based on data and models from the Danish Climate Council[32] and the Climate Forest Fund[33] and is compared with similar data from the project "Veje til Biobaseret Byggeri[35]." However, nature can take many different forms, and the calculation in this report does not reflect reality but rather provides an illustrative picture of potential effects. Consequently, the calculated CO_2 absorption could be either higher or lower than estimated, which is crucial in terms of how much of the historical carbon debt can be absorbed by natural areas by 2050 and 2100.

As with land allocation, more precise estimates could be obtained by applying forest and nature models from the University of Copenhagen and the Biodiversity Council. This would allow for a more accurate identification of natural areas and vegetation types suited to specific regions and the resulting carbon uptake.

Target Years

The Butterfly method assumes that the "Transition" biodiversity goal will be achieved by 2030 and the "Destination" goal by 2050. These dates align with the international Kunming-Montreal biodiversity agreement[11] and the Danish Climate Act[37], which also supports IPCC's SSP1-1.9 scenario[10], involving net-zero CO_2 emissions by 2050.

The Kunming-Montreal biodiversity agreement specifically refers to 2030 as the target year for reaching 30% protected nature. However, it could be debated whether Denmark should also reach 30% by 2030 or, given its status as an agricultural country with only 2% protected nature, contribute to a lesser extent than other countries, or whether the target year for Denmark could be extended at the expense of other countries' efforts.

Reaching the 2050 target may seem challenging given current policies in Denmark and internationally. Nevertheless, this ambitious goal is set against the pressing climate and biodiversity crises, aiming to reduce the time spent in sone of uncertainty, which in turn reduces the risk of triggering tipping points. However, extending the target to 2100 could provide more time to develop effective

The Butterfly method assumes that the "Transition" biodiversity goal will be achieved by 2030 and the "Destination" goal by 2050. These dates align with the international Kunming-Montreal biodiversity agreement[11] and the Danish Climate Act[37], which also supports IPCC's SSP1-1.9 scenario[10], involving net-zero CO_2 emissions by 2050.

...this LCA methodology provides a useful benchmark for comparing climate performance across buildings and assessing compliance with regulatory limits, the assessed climate impact should not be interpreted as an exact representation of total emissions.

solutions and align with unofficial goals to meet the Paris Agreement's temperature targets by century's end. This would prolong the time spent in the zone of uncertainty, warranting careful consideration.

Assessment of climate impact

The climate impact assessment in this report follows Life Cycle Assessment (LCA) methodologies for buildings as defined in the Danish Building Regulations. This approach captures emissions associated with primary construction materials such as concrete, steel, and insulation but omits several materials, including interior fittings like kitchens, electrical wiring, ventilation fittings, temporary constructions, and materials for outdoor areas[61]. As a result, this exclusion may significantly underestimate the actual climate impact, as these unaccounted-for materials also contribute emissions throughout their lifecycles.

Additionally, the calculation of operational energy consumption uses a standardized model that often does not align with actual energy use in buildings, introducing potential discrepancies. Real energy demands often differ from these estimates due to variations in occupancy, behavior, and maintenance, which can affect total emissions significantly. This is also discussed in the essay of Kirsten Gram Hansen in Chapter 2.

Moreover, the emission factors applied for electricity and heating in the LCA model are based on European Union guidelines, which classify biomass as a carbon-neutral fuel source. This assumption is especially relevant in Denmark, where a considerable portion of energy is derived from imported biomass. Consequently, these factors may not fully represent the emissions released into the atmosphere[62].

Overall, while this LCA methodology provides a useful benchmark for comparing climate performance across buildings and assessing compliance with regulatory limits, the assessed climate impact should not be interpreted as an exact representation of total emissions.

Assessment of Off-Site Biodiversity Impact

When practically applying the butterfly methodology in the building industry, off-site biodiversity impact is assessed using the "Off-Site Biodiversity Tool," developed for Doughnut for Urban Development: A Manual[3]. This tool uses background data from the Ecoinvent database version 3.10 and follows the ReCiPe 2016 methodology[53].

The tool uses only 65 material categories for which Ecoinvent supplies biodiversity impact data, though these data cannot be tailored to specific countries or production methods. Consequently, the data are generalized, based primarily on global and European averages. For example, the tool cannot distinguish between timber products from sustainable forestry and timber products from clear-cut forests. Additionally, the biodiversity impact for electricity and district heating is not projected forward, meaning the same value is assumed for the entire 50-year lifespan of a building LCA, as required by the Danish building regulations. This assumption significantly affects the results and warrants further investigation, given the expected transformations in the energy sector by 2050[63].

Moreover, as the methodology is still under development, the data used carry a degree of uncertainty[60], underscoring the need for cautious interpretation of the results. Future assessments could benefit from newer and more detailed data and improved methods for evaluating off-site biodiversity loss related to material consumption.

Case Analysis

Anvendelsen The butterfly method's application is demonstrated through a single case study, an existing apartment building from the 1970s. This case analysis examines three different renovation scenarios and one scenario involving demolition followed by new construction, comparing the results to a baseline scenario in which the building is maintained but not renovated.

While the results reveal a clear trend regarding climate and biodiversity impacts, they should be viewed as indicative rather than definitive conclusions.

The case was adapted from the Realdania project ”Klimadata for renovering[56]” which also highlights that the climate impact of different renovation types varies depending on building typology and construction date. To draw more general conclusions, additional case studies are needed in which the butterfly methodology is applied and analyzed.

Future assessments could benefit from newer and more detailed data and improved methods for evaluating off-site biodiversity loss related to material consumption.

"It is so few people who really recognize that 30% of the carbon dioxide that we emit from fossil fuel burning, is actually absorbed by intact nature on land. It is thanks to the biodiversity and the intact forest systems in particular, that are buffering this... And if you don't have a healthy planet, that capacity of buffering that stress, is reduced... So, my fear is that we are shooting ourselves in the foot emitting greenhouse gasses and causing the climate crisis and at the same time making the planet in her weakest state to deal with that crisis."

-Professor Johan Rockström

Chapter 3 References

1. Global Footprint Network, "Earth Overshoot Day," accessed October 23, 2024, https://overshoot.footprintnetwork.org/.

2. The Tipping Points of Climate Cange - and Where We Stand with Johan Rockström (Talk Talks, 2024), https://www.ted.com/talks/johan_rockstrom_the_tipping_points_of_climate_change_and_where_we_stand?subtitle=en.

3. H. Birgisdottir et al., Doughnut For Urban Development: A Manual, ed. Dani Hill-Hansen and Kasper Guldager Jensen, 1st ed. (Copenhagen: Danish Architectural Press, 2023), https://www.home.earth/doughnut.

4. Johan Rockström et al., "Safe and Just Earth System Boundaries," Nature 619, no. 7968 (July 2023): 102–11, https://doi.org/10.1038/s41586-023-06083-8.

5. Karl Burkart, "30×30 Is Not a One-Size-Fits-All Biodiversity Target (Commentary)," Mongabay Environmental News, October 15, 2021, https://news.mongabay.com/2021/10/30x30-is-not-a-one-size-fits-all-biodiversity-target-commentary/.

6. Katherine Richardson et al., "Earth beyond Six of Nine Planetary Boundaries," Science Advances 9, no. 37 (September 15, 2023): eadh2458, https://doi.org/10.1126/sciadv.adh2458.

7. United Nations Environment Programme, Emissions Gap Report 2023: Broken Record – Temperatures Hit New Highs, yet World Fails to Cut Emissions (Again) (United Nations Environment Programme, 2023), https://doi.org/10.59117/20.500.11822/43922.

8. UNFCCC, "The Paris Agreement | UNFCCC," 2015, https://unfccc.int/process-and-meetings/the-paris-agreement.

9. Steffen Petersen, Morten W Ryberg, and Morten Birkved, "The Safe Operating Space for Greenhouse Gas Emissions," August 31, 2022

10. IPCC, Climate Change 2022 Mitigation of Climate Change: Working Group III Contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change, 2022, https://www.ipcc.ch/report/ar6/wg3/.

11. United Nations Environment Programme, "Decision Adopted by the Conference of the Parties to the Convention on Biological Diversity: Kunming-Montreal Global Biodiversity Framework" (Montreal, Canada: Conference of the Parties to the Convention on Biological Diversity, December 7, 2022)

12. Joyeeta Gupta et al., "A Just World on a Safe Planet: A Lancet Planetary Health–Earth Commission Report on Earth-System Boundaries, Translations, and Transformations," The Lancet Planetary Health 0, no. 0 (September 11, 2024), https://doi.org/10.1016/S2542-5196(24)00042-1.

13."A 'Global Safety Net' to Reverse Biodiversity Loss and Stabilize Earth's Climate | Science Advances," accessed September 30, 2024, https://www.science.org/doi/10.1126/sciadv.abb2824.

14. UC San Diago Scripps Institution of Oceanography, "The Keeling Curve," Latest CO2 Reading (blog), accessed October 24, 2024, https://keelingcurve.ucsd.edu/.

15. Piers M. Forster et al., "Indicators of Global Climate Change 2023: Annual Update of Large-Scale Indicators of the State of the Climate System and Human Influence," Earth System Science Data 15, no. 6 (2024): 2625–50, https://doi.org/10.5194/essd-15-2295-2023.

16. Statista, "Average Carbon Dioxide (CO_2) Levels in the Atmosphere Worldwide from 1959 to 2023 (in Parts per Million)," n.d., https://www.statista.com/statistics/1091926/atmospheric-concentration-of-co2-historic/.

17. GHG budget is derived from the most recent updated CO_2 budget that reflects a 50% probability scenario of reaching 1.5°C without an overshoot15

18. Amount includes the remaining greenhouse gas budget necessary to meet the 1.5°C target

19. Danmarks globale klimapåvirkning – Global afrapportering 2024, Energistyrelsen, 2024

20. Biodiversitetsrådets Årsrapport 2023: Sammenfatning, april 2024, https://www.biodiversitetsraadet.dk/pdf/2024/04/Sammenfatning-2023-04-11.pdf

21. "Danmark Er Blandt de Allermest Landbrugsintensive i Verden | LandbrugsAvisen," accessed October 2, 2024, https://landbrugsavisen.dk/danmark-er-blandt-de-allermest-landbrugsintensive-i-verden.

22. Based on an equal per capita allocation principle. From 2020 to 2050, the Danish population is expected to represent 0,069% of the global population.

23. Based on an equal per capita allocation principle. From 2020 to 2050, the Danish population is expected to represent 0,069% of the global population.

24. Joachim Tilsted and Anders Bjørn, "Green Frontrunner or Indebted Culprit? Assessing Denmark's Climate Targets in Light of Fair Contributions under the Paris Agreement," Climatic Change 176 (July 20, 2023), https://doi.org/10.1007/s10584-023-03583-4.

25. Jason Hickel, "Quantifying National Responsibility for Climate Breakdown: An Equality-Based Attribution Approach for Carbon Dioxide Emissions in Excess of the Planetary Boundary," The Lancet Planetary Health 4, no. 9 (September 1, 2020): e399–404, https://doi.org/10.1016/S2542-5196(20)30196-0.

26. Biodiversitetsrådet, "Fra tab til Fremgang," November 29, 2022, https://www.biodiversitetsraadet.dk/pdf/2022/12/Biodiversitetsraadet-2022-Fra-tab-til-fremgang-Final-hjemmeside.pdf.

27. Faktaark om skov natur og biodiversitet, Miljøministeriet, 2024

28. Anders Højgård Petersen et al., "Mere, bedre og større natur i Danmark - Hvor, hvordan og hvor meget?" (Center for Makroøkologi, Evolution og Klima, Globe Institute, Københavns Universitet, May 29, 2024), https://macroecology.ku.dk/news/2024/mere-bedre-og-stoerre-natur-i-danmark/.

29. Danmarks Statistik (2024) BNP-fremgang på 0,6 pct. i andet kvartal 2024. Available at: https://www.dst.dk/da/Statistik/nyheder-analyser-publ/nyt/NytHtml?cid=48823 (Accessed: 21 October 2024)

30. Biodiversitetsrådet, "Besykttet natur i Danmark i et internationalt perspektiv."

31. "Protecting 30% of the Planet for Nature: Costs, Benefits and Economic Implications," accessed October 2, 2024, https://www.conservation.cam.ac.uk/files/waldron_report_30_by_30_publish.pdf.

32. "Baggrundsnotat 2 - Modellering Af Bioressourcer Og Drivhusgasudledning Fra Landbrug, Skovbrug Og Arealer.Pdf," accessed October 2, 2024, https://klimaraadet.dk/sites/default/files/node/field_files/Baggrundsnotat%202%20-%20Modellering%20

af%20bioressourcer%20og%20drivhusgasudledning%20fra%20 landbrug%2C%20skovbrug%20og%20arealer.pdf.

33. Klimaskov Fonden, Beregningsmodel for CO2 optag ved skovrejsning version 1.4 sept. 2023

34. Danmarks Naturfredningsforening et al., "Fra Foder Til Føde II," November 2023.

35. Realdania. 2024. Vej til biobeseret byggeri. https://realdania.dk/projekter/veje-til-biobaseret-byggeri

36. Danmarks Klimamål – Hovedkonklusioner, Klimarådet, 2022

37. LOV nr. 2387 af 14/12/2021, Lov om ændring af lov om klima, Klima-, Energi- og Forsyningsministeriet

38. Danmarks globale klimaindsats, Klimarådet, 2023

39. Reduction Roadmap, "Reduction Roadmap: Preconditions and Methodologies," September 27, 2022, https://reductionroadmap.dk/reduction-roadmap.

40. "A 'Global Safety Net' to Reverse Biodiversity Loss and Stabilize Earth's Climate | Science Advances."

41. Working Paper Analysing the Economic Implications of the Proposed 30% Target for Areal Protection in the Draft Post-2020 Global Biodiversity Framework."

42. Scenarier for fremtidens behov for biobaserede byggematerialer, Artelia, 2024

43. Danmarks Statistik, BYGV01 Landstal for den samlede byggeaktivitet (ikke korrigeret for forsinkelser) efter byggefase

44. Reduction Roadmap. 2024. https://reductionroadmap.dk/

45. Velux.2024 Living Places Copenhagen, https://buildforlife.velux.com/en/livingplaces/the-experiment

46. Camilla Ernst Andersen et al., "Assessment of Absolute Environmental Sustainability in the Built Environment," Building and Environment 171 (March 15, 2020): 106633,

47. Zoran J. N. Steinmann et al., "Resource Footprints Are Good Proxies of Environmental Damage," Environmental Science & Technology 51, no. 11 (June 6, 2017): 6360–66, https://doi.org/10.1021/acs.est.7b00698.

48. Helmut Haberl et al., "Contributions of Sociometabolic Research to Sustainability Science," Nature Sustainability 2, no. 3 (March 2019): 173–84, https://doi.org/10.1038/s41893-019-0225-2.

49. Maaike Bouwmeester et al., "l'empreinte matières de l'économie française : une analyse par matière et catégorie de produits" (Ministere de la transition ecologique et solidaire, November 2019).

50. Morten Helveg; VELUX VELUX, "Healthy Homes Barometer 2019" (Rand Europe, 2109).

51. European Academies' Science Advisory Council (EASAC), "With 25% of Europe's Greenhouse Emissions Coming from Buildings, Scientists Suggest Fundamental Policy Changes," easac.eu, n.d., https://easac.eu/media-room/press-releases/details/with-25-of-europes-greenhouse-emissions-coming-from-buildings-scientists-suggest-fundamental-policy-changes.

52. Torben Valdbjørn Rasmussen et al., "Biogene Materialers Anvendelse i Byggeriet," BUILD Rapport (Institut for Byggeri, By og Miljø (BUILD), Aalborg Universitet., 2022), https://vbn.aau.dk/ws/portalfiles/portal/467134787/BUILD_Rapport_2022.09.pdf.

53. M.A.J. Huijbregts et al., "ReCiPe 2016 A Harmonized Life Cycle Impact Assessment Method at Midpoint and Endpoint Level Report I: Characterization" (National Institute for Public Health and the Environment Ministry of Health, Welfare and Sport, 2016).

54. UK government. (2023). Guidance: Biodiversity metric: calculate the biodiversity net gain of a project or development. Department for Environment, Food & Rural Affairs. https://www.gov.uk/guidance/biodiversity-metric-calculate-the-biodiversity-net-gain-of-a-project-or-development

55. Daniel A. Barber, "Drawing the Line," Places Journal, Repair Manual, January 30, 2024, https://placesjournal.org/article/drawing-the-line-architecture-in-the-anthropocene/.

56. Arkitema et al., "Klimadata for Renovering - Et Udviklingsprojekt Om Livscyklusanalyser, Klimabelastning, Økonomi Og Arkitektoniske Perspektiver Ved Renovering." (Realdania, 2024).

57. Videnscenter om bygningers klimapåvirkninger, "Case: Lisbjerg Bakke (Casenr.:EB-02)," Byggeri og Klima, October 24, 2024, https://byggeriogklima.dk/casebibliotek/lisbjerg-bakke-casenr-eb-02/.

58. Nate Hagens, "The Great Simplification - Exceeding Earth's Safe Limits with Johan Rockström | TGS 134," accessed September 23, 2024, https://www.youtube.com/watch?v=JaboF3vAsZs.

59. "Effektivlandbrug.Landbrugnet.Dk," Jordprisen Holder Sig På Cirka 200.000 Kroner Pr. Hektar (blog), June 28, 2024, https://effektivtlandbrug.landbrugnet.dk/artikler/markedsfokus/103282/jordprisen-holder-sig-paa-de-ca-200-000-kr-ha-.aspx.

60. Esther Sanyé-Mengual, "Linking Inventories and Impact Assessment Models for Addressing Biodiversity Impacts: Mapping Rules and Challenges," The International Journal of Life Cycle Assessment, 2022.

61. Bygningsreglementet 2018, Bilag 2: Kapitel 11, Tabel 6 - Bygningsdele til beregning af klimapåvirkning

62. Artelia, Effekten af biobrændslers klimabelastning på el- og fjernvarmesektorens emissionsfaktorer, 2024

63. Energistyrelsen, 'Klimastatus Og -Fremskrivning 2023', April 2023 (ikke refereret i kapitel 3 men som (18) i kapitel 2

Chapter 4
Investing in a livable future

How can business be redesigned to acheive the regenerative potentials of the butterfly?

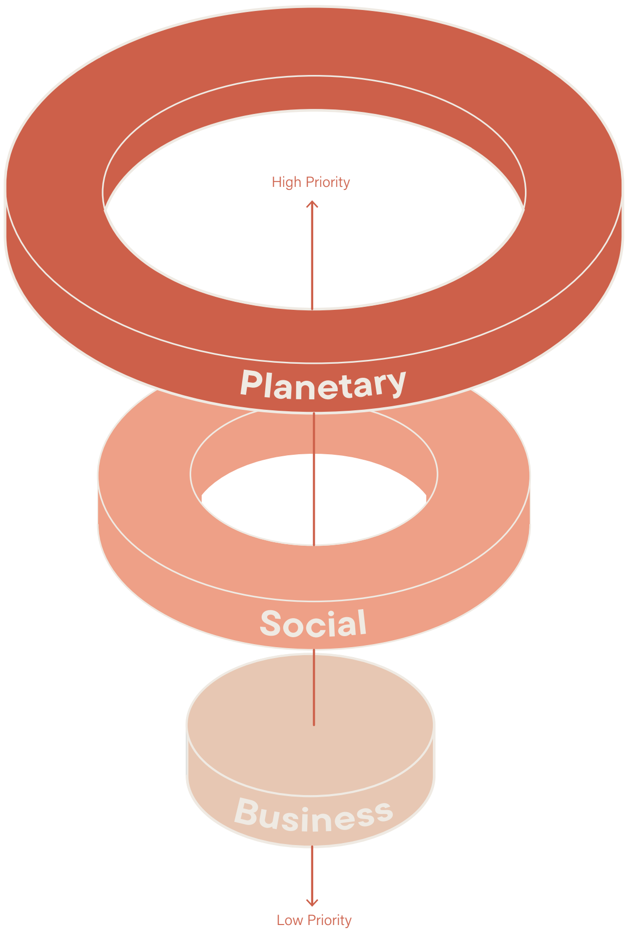


Figure 4.1: Human well-being and socio-economic infrastructure are embedded in planetary health. Socioeconomic goals cannot be achieved without a stable climate and healthy ecosystems. Therefore, society, including businesses, must undergo systemic change to meet these objectives. Source: The Playbook (EFFEKT).

4.1 A starting point

This chapter serves as a foundation for rethinking investment to create a safe and just future. Many of the concepts build on the knowledge, data and analysis presented in the rest of the report. It should be read as a starting point, that opens up to new-economic thinking, not a precise end point.

It asks the question: "How can business be redeisgned to achieve the regenerative potentials of the butterfly?" Drawing on insights from previous chapters, we conclude that socio-economic systems will change—by design or by disaster. We face a pressing need to fundamentally reshape socio-economic systems to respect Earth's finite limits, and thereby counter the Polycrisis. Human well-being and socio-economic infrastructure are embedded in planetary health (Figure 4.1). As such, business must be redefined to serve the purpose of creating climate stability and functioning ecosystems, not as an end goal in itself[6].

Waiting for policy and financial regulations to evolve at the pace of environmental degradation would be a grave error: instead, we must leverage the influence of private and public sectors to lead change[3 10]. To achieve this, we need to reject the growth imperative and redesign business to serve a greater purpose: regenerating the living world[32].

As such, we present the idea of systemic foresight as an approach to making smart investments today - to ensure long-term, stable business in a rapidly changing future. Systemic foresight is the antidote to the "sunk cost fallacy" introduced in Chapter 2.

Additionally, we introduce several known tools and frameworks that can help guide businesses towards their transformative and regenerative potentials.

"There is no business on a dead planet" - David R. Bower

Defining Systemic Foresight

We have a choice

In investment, foresight is essential. In the Polycrisis, systemic thinking is essential. Through systemic foresight - the ability to anticipate and navigate future challenges and opportunities by considering the complex interconnections within systems: environmental, social, and economic – we can create a livable future.

Systemic foresight involves analyzing trends, uncertainties, and potential scenarios in order to anticipate long-term impacts and guide strategic decision-making. Unlike traditional foresight methods that may focus on isolated predictions, systemic foresight aims to understand how various systems influence one another, identifying leverage points to foster resilience, adaptability, and sustainable outcomes in complex, dynamic environments.

As predicted by Limit's to Growth, human socio-economic systems will soon outgrow Earth's limits resulting in collapse. As described in Chapter 1 and Chapter 2, the world is in crisis, perpetuated by the economic growth imperative. As described in Chapter 3 – we may just have a future - if we invest in the regeneration of the living world.

As highlighted through this report, the building industry is material intensive. It is both complicit in the current climate collapse and responsible for charting a reliable path forward. The building industry is dependent on function ecosystems to act as a sink, balancing impact of building activity and a source, to provide resources for future needs.

David R. Brower stated: "There is no business on a dead planet." Also, there is no building industry on a dead planet. This is the reality we must face when confronting the likelihood of a global warming level between 1.5°C – 3°C.

Adopting business strategies and investments plans that regenerate functioning ecosystems, while respecting Earth's biophysical limits is crucial for a just transition in the building industry[1] and a non-negotiable for future business.

Today, investors are in a unique position of knowing what lies ahead with heightened clarity, as the climate science is unequivocally clear. The ecological deficit that we have accrued since the 20th century is modeled to significantly reduce incomes around the world. The global economy is projected to experience a 18% reduction in income by 2049—regardless of which climate pathways we pursue[2]. In fact, GDP could be slashed by up to 50% by 2070 if emissions are not curbed. Research shows that mitigating climate change is six times less expensive than dealing with

Box 4.1: GDP is a poor measure of human development and prosperity

Relying solely on GDP growth as a measure of national well-being is deeply flawed, as it inadequately reflects human development and planetary prosperity. To reach a regenerative future we need new valuation metrics that are more holistic and account for the real impact externalities of human activity on ecosystems systems over a long-term period. GDP has many shortfalls and is a highly critiqued indicator but many[6 7 8 9 10] – summarized below.

1. Exclusion of Social and Environmental Factors: GDP tracks economic output but omits social welfare and environmental costs such as pollution and resource depletion. This creates a misleading view of progress, as GDP growth can coexist with environmental harm and declining quality of life.

2. Growth Over Sustainability: By prioritizing GDP economies pursue unsustainable practices. True progress values sustainable development over endless growth, as focusing on GDP alone drives overconsumption and environmental degradation.

3. Neglect of Inequality: GDP aggregates output without considering wealth distribution, meaning growth can occur alongside rising inequality. This focus can skew political priorities, leading to policies that benefit a select few rather than society.

4. Overlooks Quality and Well-being: Focusing on quantity over quality, GDP does not capture life improvements. For example, healthcare costs raise GDP whether they reflect positive or negative health trends. This limited view fails to reflect actual well-being.

5. Short-term Focus: As a short-term economic snapshot, GDP misses long-term indicators like health, education, and environmental stability - all of which are essential for a balanced view of progress.

These critiques highlight the need for measures that incorporate well-being, equity, and sustainability, providing a fuller view of human and planetary health.

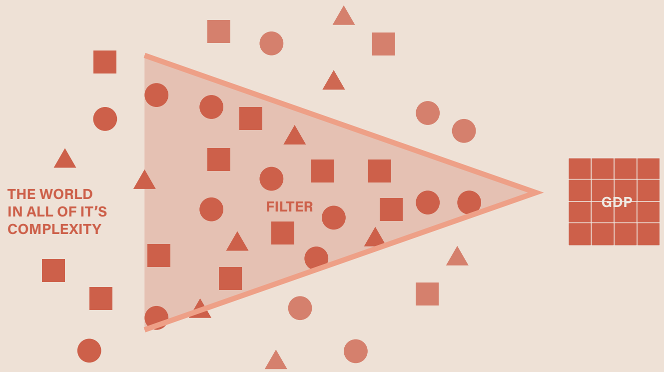


Figure 4.2 -Although GDP was never intented to define what constitutes a good or prosperous action, it has come to be seen that way over time. It is a highly simplified measure that captures only fragments of a complex reality. Source: Economish[36]

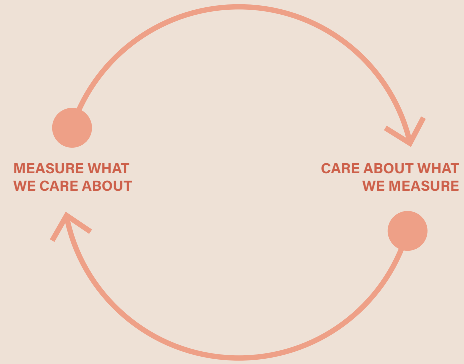


Figure 4.3: "We measure what we care about and care about what we measure". The use of GDP as a measure enforces the importance of GDP as a goal. This loop can potentially be true for measures and goals that enforce regenerative impacts – which is why we need include more "Beyond GDP" indicators in accounting. Source: Economish[36]

the damage it causes[3].

To put this into perspective, the current economy risks slipping into recession when growth slows down below 2%. At the height of the financial crisis in 2009, the United States experienced a GDP contraction rate of -2.5%. During the corona crisis the global economy contracted by -3.3% in 2020 alone[4]. A 18% contraction is unprecedented. Furthermore, existing economic models based on GDP grossly underestimate real impact because GDP is simplistic indicator of well-being and progress. Yet – it is the dominant indicator of progress (Box 4.1).

The current economic forecasts severely underestimate the economic impacts of crossing irreversible ecosystem tipping points[4]. "Economic growth trajectories (which dominate global economic policy) pose even greater risks through destabilisation of the global commons - ie, the biosphere, climate, and cryosphere, and nutrient and water cycles"[5].

Economic growth requires exponential expansion, meaning the global economy must double in a fixed period, doubling in size every 25 years[11]. This drives increased material consumption and environmental degradation[12], highlighting the need for sustainable resource management and socio-economic transformation[13]. The IPCC has made it clear that mitigation and development goals cannot be met through incremental change.[37]

Investors must decide how much farther to impoverish the world beyond the 18% contraction that is locked in. Policymakers must decide who this 18% contraction will hurt, and whether societies will shoulder the burden collectively or continue sacrificing those who are least responsible, yet most vulnerable. Consultants must decide, what projects we will and won't supply.

All is not lost

The good news is that the modern economic system is a man-made construct - designed and maintained by human decisions - and, as such, it can be reconstituted to better serve life on earth. New strategies, which involve the renegotiation of our economic systems are required to bring about a stable, livable future. Through systemic foresight, investors can bravely lead the industry towards a regenerative future.

"Ultimately, what we call 'the economy; is our material relationship with each other and with the rest of the living world. We must ask ourselves: what do we want that relationship to be like? Do we want it to be about domination and extraction? Or do we want it to be about reciprocity and care?" - Jason Hickel

"the economy is our material relationship with each other and with the rest of the living world. We must ask ourselves: What do we want that relationship to be like? Do we want it to be about domination and extraction? Or do we want it to be about reciprocity and care?" - Jason Hickel

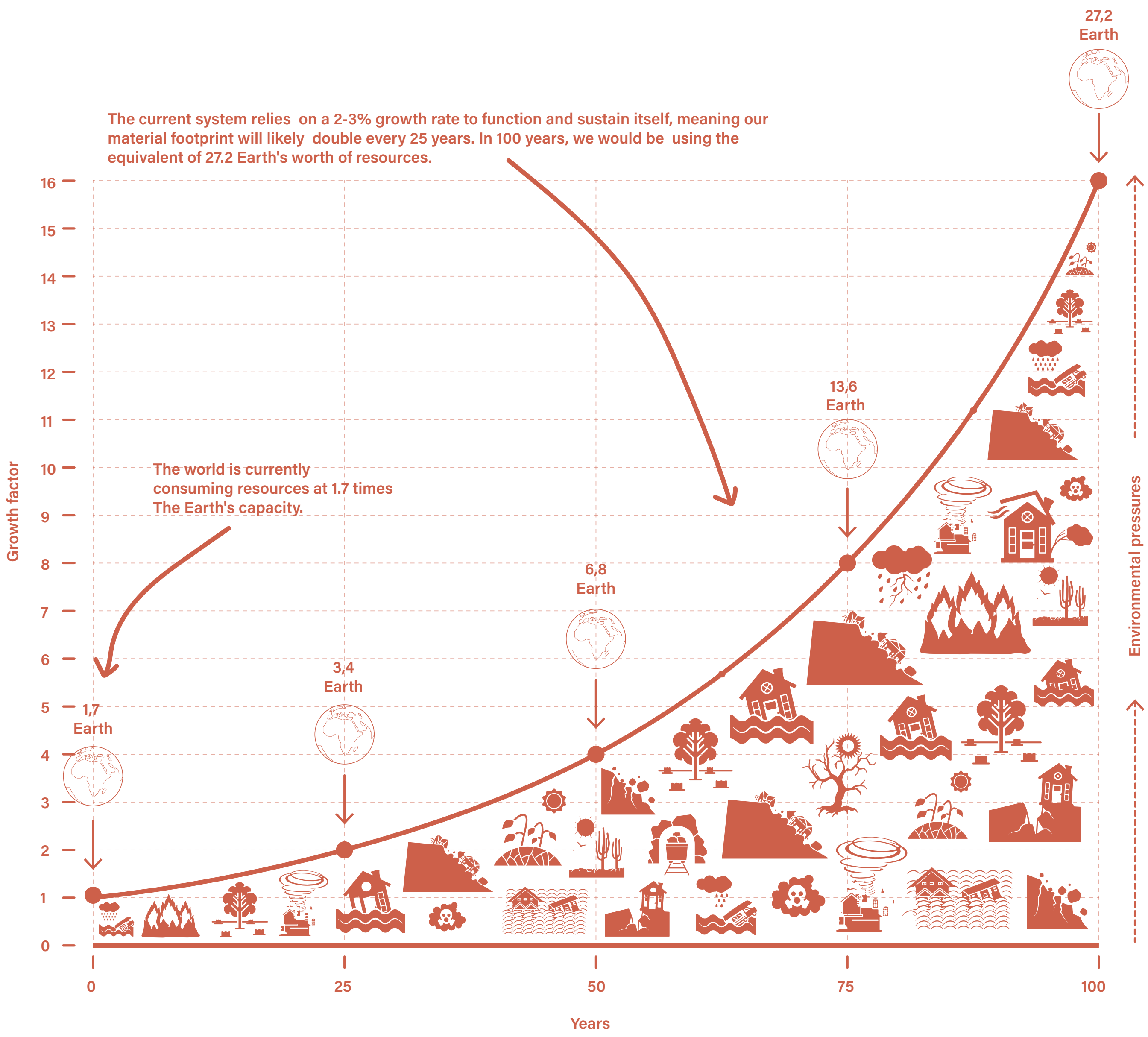


Figure 4.4 - Infinite growth cannot be sustained on a finite planet. Source: Reduction Roadmap

Post-Growth Business

What is a post-growth business?

A post growth business stays within ecological and social limits, moving away from the traditional growth-driven business models that currently dominate how businesses are run. One of the core principles of such a business is to be growth-independent. In other words, to create value, offer decent jobs, and survive without relying on infinite growth, aligning with the planet's limited resources. In this way of seeing a business, after reaching a steady state, it focuses on development (increase in quality), not growth (increase in quantity). It doesn't focus on increasing production but on improving social equity and restoring the environment. Instead of blindly pursuing continuous growth, a post growth business navigates after a level of resilience and stability that allows it to choose regeneration consistently. The concept of "limits to growth" is fundamental to the definition of a post growth business. A post-growth business is often structured as a not-for-profit business that generates revenue by selling a product or service but where profits are redistributed towards social and ecological goals instead of going exclusively to shareholders. And that's a legally binding arrangement. By moving away from a model that seeks to only maximize profit, a post growth business can reduce the need for short-sighted continuous growth, making long-term goals a business reality. A more equitable power distribution also prevents unchecked growth driven by personal wealth or influence.

What can post-growth businesses do?

Post growth businesses can, for many years to come, grow revenue streams within the sectors needed if we want to transition into an economy where we operate within planetary boundaries—while noting that even the new required sectors will have to "grow up" at some point and reach a steady-state where focus again will be on development, not growth. Understanding these categories is crucial for investors who want to contribute to a future where we stay within the planetary boundaries. The majority of capital needs to be diverted into these areas. These sectors represent the industries that will sustain us within ecological limits and those that actively contribute to regenerating our ecosystems while serving fundamental human needs. With their long-term investments, pension funds are particularly well-suited to lead this shift. By reallocating capital from new construction to renovation and other post-growth-aligned sectors, they can protect their portfolios from climate-related risks while contributing to broader societal goals of regeneration and equity.

Mads Oscar Haumann

Marcus Feldthus

Co-Founders
Post-Growth Guide

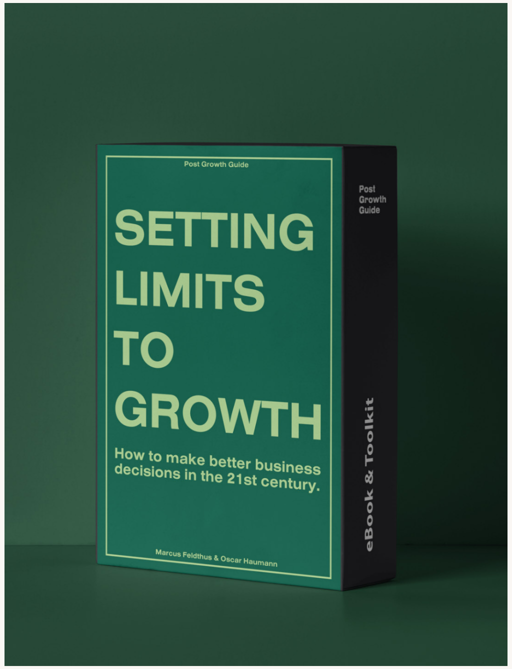


Figure 4.5 - Setting Limits to Growth - How to make better business decisions in the 21st century. Available at: https://www.postgrowthguide.com/handbook

For the building industry, this includes areas like retrofitting and upgrading existing buildings that focus on adaptive reuse projects, emphasizing low-impact, and biogenic materials like straw and hemp. Companies that work with local materials are equally suited to ensure eco-friendly practices in construction and can, to a higher degree, ensure that all materials are sourced free from exploitative labor practices. Ultimately it is about creating affordable and cooperative housing that meets social needs with community-based solutions.

Besides working with products or services that are sufficient, regenerative, and equitable, businesses must embrace structural shifts that ensure long-term resilience. One of these mechanisms is establishing wage caps to help limit personal incentives, prioritizing business goals over meaningful long-term social and environmental value. Wage caps are, therefore, a simple mechanism to direct focus toward long-term viability instead of company growth.

How can post-growth businesses adapt?

In addition to these limits, a post growth business must be able to stay stable in a volatile market with increasing crises and political turmoil. Establishing economic buffers is a way to absorb fluctuations in the market and the environment. With reasonable resource reserves, companies are more likely to make good decisions, prioritizing ecological and social commitments while navigating unforeseen challenges.

An economic buffer ensures leaders are not pressured to make short-term decisions. Buffers are, therefore, essential for a post growth business to maintain stability, ensuring that it not only survives but thrives while staying within planetary boundaries.

Scenario planning will become an essential tool for leaders in a post growth business as it will help them create relevant strategies and the best way to use buffers that can ensure resilience, even in the hardest times

Key advantages of post-growth businesses

Hyper-growth often leads to bad decisions with significant ecological and social costs. It is, therefore, critical for a post growth business to slow down, allowing time to make thoughtful and informed decisions. Accounting for delays and feedback loops will force the business to slow down and adjust to the market and environmental conditions. Corrective feedback loops ensure that the company adjusts the operations to avoid exceeding resource limits. These corrective measures should, therefore, be implemented in the day-to-day business operations.

We can't produce our way out of the crisis. To scale impact, a post-growth business can use donations and investments in local communities or open-source parts of its solution. This way, growth can be linked to community projects or regenerative practices that create long-term ecological and social value instead of relying on material resources. To make these decisions, a post growth business needs transparent information. Ensuring that decision-makers have the right information to make sufficient and timely responses is essential. Accurate information is not only a nice-to for compliance reasons; it is the very foundation that ensures a business can be held accountable and adjust actions accordingly.

Rules and governance structures must also change to support the new objectives, prioritizing ecological and social well-being over profit maximization. This means fundamental changes to the company policies with mechanisms to keep them in place. Governance structures should support a culture that is centered around decentralization and self-organization. A lot of attention, time, and resources should be spent on encouraging employees to participate in decision-making, strengthening the company's ecological and social commitments beyond a few select.

Finally, the fundamental goals within the business must be changed or at least updated. Short-term revenue goals and KPIs must be replaced with long-term goals centered around regeneration and equity. Otherwise, individual behavior won't follow. By replacing growth with development, a business can not only survive but thrive within the planetary boundaries.

We need to rethink growth, embrace the natural limits, and adopt regenerative practices that are sufficient and equitable. It's a business model that creates a financially stable business that, through sufficient, regenerative, and equitable strategies, can adapt to the needs of the 21st century.

We need to rethink growth, embrace the natural limits, and adopt regenerative practices that are sufficient and equitable. It's a business model that creates a financially stable business that, through sufficient, regenerative, and equitable strategies, can adapt to the 21st century.

We have a choice – either we can change our socio-economic structures by design or we will be forced to change them by disaster.

New economic thinking for a living world

The science is clear. Current economic growth is tied to finite resources, making a shift toward a post-growth economy inevitable[15].

We have a choice – either we can change our socio-economic structures by design or we will be forced to change them by disaster.[16]

This includes the ways we finance, design, procure, assemble, sell, buy, rent, operate, maintain, and demolish buildings. Change by design, enabled by systemic foresight is preferable and possible. For a group of professionals working in the building industry, who pride ourselves on creativity and innovation in service of the public good - are well-positioned to enact.

"Either we democratically plan a downscaling of production and consumption to reduce ecological footprints while securing wellbeing for everyone, or we keep pushing planetary boundaries until nature imposes sufficiency upon us through a lethal mix of resource shortages and climate catastrophes."[17]

The good news is that a safe and just life for all within planetary boundaries is possible[18], but it requires a profound shift towards sufficiency. Sufficiency - meaning "enough" - is not merely a strategy but a revolutionary concept that can counteract ecological overshoot and address unmet human needs. The concept of sufficiency aligns with Degrowth, advocating for meeting human needs within ecological limits rather than pursuing endless economic expansion[7 8 19 21].

Degrowth is not about shrinking the entire economy[19]. Rather, degrowth focuses on scaling back sectors that are both environmentally harmful and are socially unproductive - particularly those driven by speculative construction and financial interests - while scaling-up activities that enhance the well-being of the living world[7]. Degrowth by disaster, manifesting as decay and destruction, leads to economic and financial system collapse. In contrast, degrowth by design – based on principles of sufficiency offers a path that transcends the growth versus no-growth dualism, offering a vision of societal transformation that balances ecological sustainability with human well-being. In the simplest form, sufficiency means enough[8] (Figure 4.7).

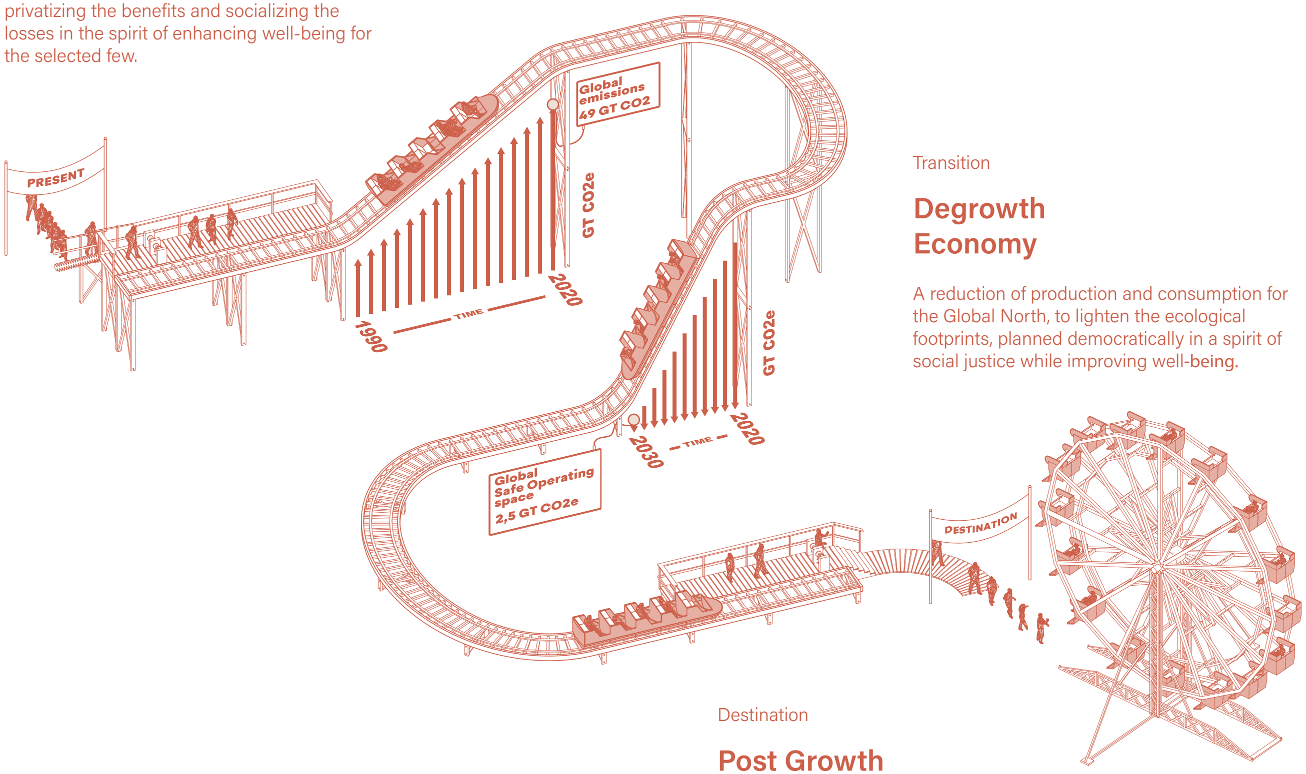
Embracing sufficiency is essential for addressing the Polycrisis and must be democratically planned and rooted in justice, offering a framework for reducing destructive activities to direct financial resources toward necessary

Figure 4.6 - By embracing Degrowth by design, we can enable a pathway towards a regenerative society. As illustrated we must move from a growth economy, through a transitional period towards a post-growth society. Source: Kasper Benjamin Reimer Bjørksov and Reduction Roadmap with written description from Timothee Parrique.

Present

A Growth Economy

Based on increasing production and consumption to grow profit for private owners by privatizing the benefits and socializing the losses in the spirit of enhancing well-being for the selected few.



Transition

Degrowth Economy

A reduction of production and consumption for the Global North, to lighten the ecological footprints, planned democratically in a spirit of social justice while improving well-being.

Destination

Post Growth Economy

A steady-state economy in harmony with nature where decisions are taken together and where wealth is equitably shared in order to prosper without growth.

sustainable development[18]. Such an approach provides a basis for rethinking economic priorities and advancing more equitable and environmentally responsible financial strategies.

For people living in poverty, “enough” can also mean “more.”

As described in Chapter 1, Global justice requires sufficiency to end unequal exchange between the richest and poorest. This shift involves curbing excessive demand for energy, materials, land, and water, reducing geopolitical tensions, resource conflicts, and militarization risks. This shift demands that those of us in the majority world – whom have what we need must learn to do a lot more, with less.

The key distinction between a growth-based and a sufficiency-based economy lies in their principles regarding production, consumption, and resource management. In essence, the growth-based paradigm of today is dependent on “more”, whereas sufficiency seeks to define “enough” [20,21,22]. Understanding these differences (Figure 4.7) is crucial for shaping a future that prioritizes ecological and social well-being over the pursuit of endless economic growth.

Characteristic	Current Economic System (Growth)	Degrowth / Sufficiency	Growth to Sufficiency
Definition of Prosperity	Equates prosperity with economic growth, typically measured by rising GDP and increased consumption.	Focuses on well-being, quality of life, and ecological balance rather than material wealth.	
Resource Use	Encourages high levels of resource extraction and consumption, often exceeding ecological limits.	Utilizes resources within the constraints of ecological boundaries, striving for sustainable levels of consumption.	
Economic Goal	Maximizes GDP and economic expansion, viewing growth as essential to societal advancement.	Prioritizes meeting basic needs equitably and sustainably rather than maximizing GDP.	
Environmental Impact	Views nature as an infinite resource for societal advancement, disregarding environmental impacts.	Affluent countries must adopt low-impact lifestyles to adhere to safe and just planetary boundaries by minimizing energy and resource consumption.	
Supply Chains	Relies on global supply chains sustained by cheap labour and resources, propelled by imperialist appropriation.	Emphasizes localization & bioregionalism to break away from dependency on global supply chains. Seeks to end unequal exchange and imperialist appropriation.	
Social Responsibility	Focuses on privatizing gains while socializing losses, with minimal emphasis on equitable resource distribution.	Considers resource allocation a collective duty, striving for social equity and ecological integrity for everyone.	
Focus on Profit	Prioritizes short-term profit and productivity, often at the expense of long-term sustainability.	Aims for long-term sustainability with the objective of returning within safe and just planetary boundaries while enhancing well-being for all.	
Growth Mindset	Emphasizes continuous expansion and “more is better,” viewing growth as a primary goal regardless of ecological costs.	Advocates for “enough” rather than “more”, aiming for a balanced, sustainable society that operates within social and planetary boundaries.	

Figure 4.7 From the current economic system defined by growth towards Degrowth defined by sufficiency. Key characteristics of each system are described for comparative analysis. Source: Reduction Roadmap

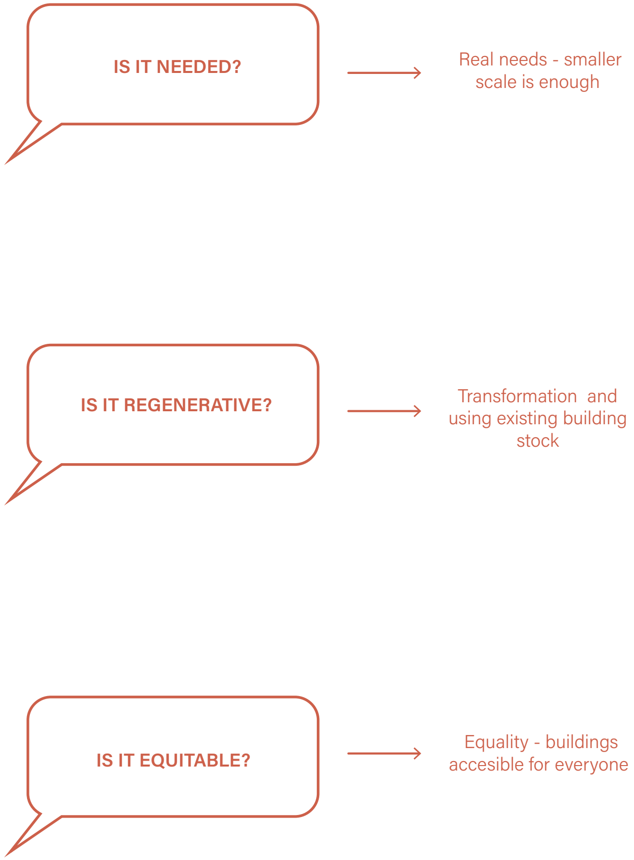


Figure 4.8 Preconditions for Investment based on sufficiency Source: Reduction Roadmap

Preconditions for investment

To shift from a growth-dependent business to sufficient-based business is not a walk in the park and cannot be done overnight. Though challenging and unprecedented, this shift is inevitable.

For every investment, we ask:

•Is it needed – does this investment align with sufficiency?
•Is it regenerative – does this reduce climate instability at the same time as restoring biosphere integrity?
•Is it equitable – does this investment distribute benefits and burdens in a way that is just and fair?

To establish regenerative investment in the building industry, it's essential to evaluate potential projects based on three key preconditions that ensure alignment with sufficiency, ecological regeneration, and equity:

1. Is it needed? — Does this investment align with sufficiency?

In line with sufficiency, this approach prioritizes essential housing, infrastructure, and community facilities that genuinely support well-being, without overburdening resources. Moving away from the financialization of the housing sector and speculative construction means focusing on investments that truly serve societal and ecological needs rather than fuelling unnecessary consumption or economic growth.

Projects should aim to minimize material and energy inputs while maximizing functionality and durability, ensuring that buildings contribute to local resilience and respond to real needs, rather than promoting excess or luxury. Sufficiency-centered investments also emphasize smaller-scale, adaptable buildings that evolve with community needs, ensuring that development is focused on what is "enough" for sustainable living rather than expansion for its own sake. This shift refocuses housing on its core purpose—providing for communities sustainably—rather than as a speculative asset.

2. Is it regenerative? — Does this reduce climate instability while restoring biosphere integrity?
Regenerative investments go beyond merely avoiding harm; they actively contribute to ecosystem health, biodiversity, and carbon sequestration. This strategy is about mitigating carbon emissions aligned with the Reduction Roadmap targets, while at the same time regenerating more nature along the supply-chain than is consumed by a company or building project. This shift necessitates minimizing the

development of new construction towards using the existing building stock for transformation projects and as a material bank. It may also mean investing in the regeneration of nature for the sake of nature.

3. Is it equitable? — Does this investment distribute benefits and burdens in a way that is safe and just?

Equitable investment in the building industry is essential to achieving sustainable transition. This requires that the benefits of development - such as housing, green spaces, and improved infrastructure - are fairly distributed across all socioeconomic groups, locally and globally, and do not disproportionately burden vulnerable communities. Rather than creating enclaves of wealth or contributing to gentrification that displaces lower-income residents, equitable investment fosters inclusive communities where resources and opportunities are accessible to everyone. Furthermore, such investments must consider the entire supply chain, ensuring fair labour practices, responsible sourcing, and fair wages for all workers involved. By preventing exploitative practices, equitable investments distribute benefits and burden in a safe and just way. Together, these preconditions provide a framework for a building industry rooted in sustainability, resilience, and fairness, steering investments toward projects that serve as foundations for thriving, inclusive communities in harmony with the planet.

Figure 4.9 From chaos to clarity through systemic foresight (Previous page) Source: Reduction Roadmap

Applying Systemic Foresight

The shift presented in the preconditions is simple: away from growth towards sufficiency. There is plenty of work to be done. The building industry isn't looking at a halt in activity, but a shift towards applying economic power, embedded knowledge and technical know-how within a new problem-solving context.

Several examples of innovative economic thinking and a 'regenerative' blue ocean awaiting regenerative business include:

• The European Commission's estimation that approximately 35 million buildings in Europe will require renovation to meet energy efficiency and sustainability targets over the next decade. This strategic shift from constructing new buildings to renovating existing ones is anticipated to generate up to 160,000 additional green jobs in the construction sector, exemplifying practical degrowth[23].

•Similarly, in a recent Forbes article, Willem Ferwerda, founder of Commonland, presents a persuasive economic case for the restoration industry. Economic analyses reveal that the financial returns from restoration efforts are 8 to 10 times higher than the initial investment costs across various ecosystems. For instance, in Europe, restoring 10% of biodiversity-rich land is projected to cost $167 billion but is estimated to yield benefits exceeding $2 trillion,[24] illustrating practical regeneration.

• Food forests offer a promising alternative to convention farming: Storing around 43.22 t CO_2 per hectare, [25 26] supporting biodiversity and producing food more efficiently than monoculture. A food forests in Coldstream, Scotland, yields 5.2 million calories per hectare, far surpassing conventional livestock which yield between 84,000-86,000 calories per hectare[27]. Converting 20% of Denmark's agricultural land to food forests could sequester about 20.75 million metric tons of CO_2, potentially feeding 1.13 million people, enhancing food security, and contributing to climate and biodiversity goals[28]. Food forests include economic benefits: by boosting food production per hectare, lowering input costs after initial investments, diversifying income, and creating new employment opportunities in sustainable agriculture.

Applying systemic foresight during the polycrisis—allows businesses to identify and adapt to complex, interconnected risks before they escalate. This approach goes beyond traditional, short-term planning to anticipate how global challenges like climate change, resource scarcity, and social inequity can affect business stability and growth. By

Applying systemic foresight during the polycrisis—allows businesses to identify and adapt to complex, interconnected risks before they escalate.

mapping interconnected risks, businesses can proactively design resilient strategies that are less vulnerable to shocks, such as supply chain disruptions or regulatory shifts, which are becoming more common in today's environment.

Implementing systemic foresight to redesign businesses around principles of sufficiency creates a strategic advantage through future preparedness - designing for limitations before they are imposed on business activities through economic and climate collapse.

Examples of this strategic advantage are:

• **Aligning with Emerging Paradigms:** Moving from growth-centric to sufficiency-based, planetary-centered models enables businesses to operate within ecological limits. This proactive alignment helps avoiding future constraints and supports long-term stability, positioning companies as pioneers of sustainability-driven innovation.

• **Building Resilience to Systemic Risks:** By adopting sufficiency-based resilience strategies, businesses can mitigate risks associated with interconnected global crises. Research into regenerative models provides new metrics that prioritize sustainability, preparing businesses to navigate disruptions with agility and adaptability.

• **Enhancing Responsiveness to Stakeholder Expectations:** As stakeholders increasingly prioritize Environmental, Social, and Governance (ESG) factors, businesses adopting sufficiency principles can strengthen their corporate responsibility standing. This responsiveness builds a positive reputation, meets regulatory demands, and ensures long-term stakeholder loyalty.

• **Anticipating Regulatory Compliance and Influence:** Proactively engaging in sufficiency allows companies to stay ahead of evolving regulations, such as the EU Taxonomy and CSRD, while also positioning them to influence sustainable industry standards. This foresight gives businesses a voice in regulatory landscapes, shaping standards that support ecological balance.

• **Enhanced agility in turbulent times:** Proactively redesigning business based on principles of sufficiency creates independence from financial growth in turbulent economic times. Rather than focusing on growth, companies should begin prioritizing strategies for resiliency and adaptability in the Polycrisis.

• **Driving Innovation and Leadership:** Applying Degrowth and sufficiency-oriented models fosters a workforce skilled in systems thinking and sustainability. Such investment in leadership and innovation enables businesses to shape future markets, providing a competitive edge as consumer and regulatory landscapes rapidly transform toward

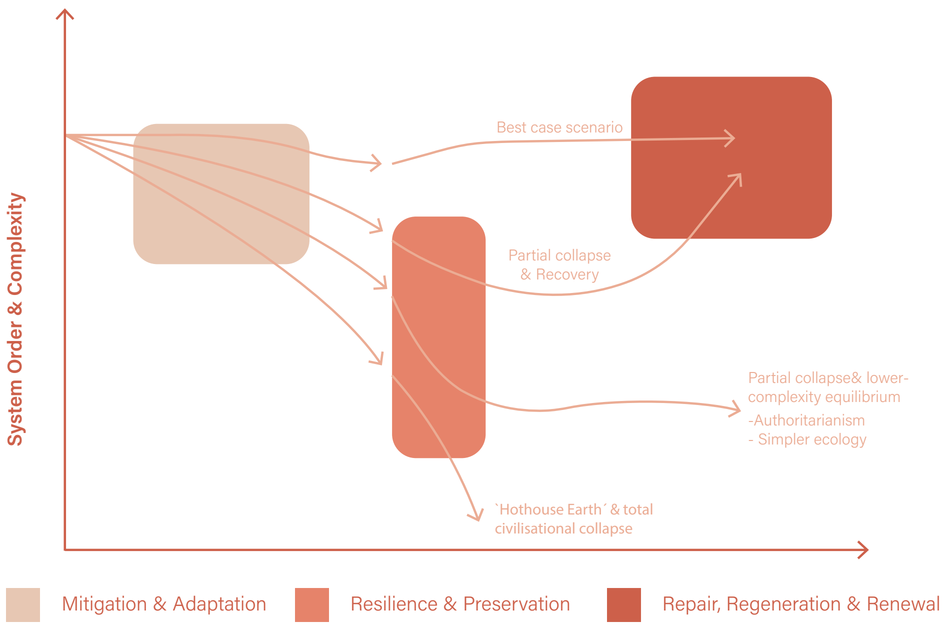


Figure 4.10 - Fields of Action for Society Resilience in the Polycrisis. Source: Jamie Bristow and Rosie Bell, "Between Optimism and Despair: The Messy Middle Paths Through Climate Breakdown", DeSmog.

sustainability.

By shifting focus now, businesses can leverage systemic foresight to create robust, responsible models that thrive within constrained limits of the planet. Businesses can focus on different types of actions to support societal resilience.

As Jamie Bristow describes (Figure 4.10) – there are different fields of action: 1) Immediate mitigation and adaptation to avoid the worst of climate impacts, 2) Actions that create resilience and preparedness to future shocks and 3) Foundations for future renewal such a mindset and practice shifts that are inherently regenerative. These three types of action are mutually reinforcing, creating virtuous cycles that support overall resilience. Investing in these areas fosters public awareness, shifts mindsets toward interconnectedness, and builds stronger community bonds essential for facing crises with both realism and optimism. While our responses must adapt to complex, unpredictable realities, a focus on these integrated efforts increases chances of minimizing harm and fostering a resilient, hopeful future[29].

With these "Preconditions for investment", action types and strategic advantages in mind, the next section introduces several strategies and frameworks that enable a shift towards regenerating the living world on a business and innovation level.

A purpose-driven business evaluates success based on its social and environmental impact rather than growth metrics alone.

4.3 Frameworks for investing in a livable future

Deep Design for Business

Redefining the purpose of business is essential for systemic change, emphasizing a transformation from growth-focused models to those grounded in regeneration and distribution. By incorporating five foundational "deep design" principles defined by Marjorie Kelly[30] - purpose, networks, governance, ownership, and finance - businesses can shift toward a sustainable, regenerative and distributive approach that aligns with the goal of moving towards safe and just planetary boundaries.

Collectively, these principles help businesses transform their practice to prioritize well-being over profit-driven growth (Figure 4.11). y. These principles are outlined in chapter 5 of 'Doughnut for Urban Development: A Manual' [31] and the Doughnut Design for Business[32] tool by Doughnut Economic Action Lab. Below is an in-depth look at each principle:

1. Purpose: This principle reorients the core mission of a business to focus on contributing positively to society and the environment. Instead of aiming solely for-profit maximization, businesses are encouraged to define a purpose that supports sustainable practices, equity, and regeneration. A purpose-driven business evaluates success based on its social and environmental impact rather than growth metrics alone.

2. Networks: This aspect highlights the importance of forming collaborative and transparent relationships across industries, communities, and ecosystems. Businesses are encouraged to engage in partnerships that advance collective well-being, share resources responsibly, and foster resilience. Networks grounded in mutual benefit and shared value help reduce over-extractive practices and promote equitable resource distribution.

3. Governance: Governance in deep design emphasizes inclusive, transparent decision-making that considers diverse stakeholder perspectives, particularly those impacted by business operations. This approach contrasts with traditional top-down governance structures, where decisions are often driven by shareholder interests. A governance model aligned with deep design supports accountability, stakeholder engagement, and social responsibility.

4. Ownership: Rethinking ownership structures is crucial in fostering distributive practices. In traditional ownership models, wealth and decision-making power are often concentrated among a few. Deep design advocates for ownership models that are inclusive and community-oriented, such as cooperatives, employee ownership, or community stakeholder ownership, which help share value and benefits more broadly.

5. Finance: Finance in deep design focuses on funding and investment practices that support long-term sustainability and social equity, rather than maximizing short-term returns. This includes reinvesting profits into regenerative initiatives, adopting sustainable finance practices, and prioritizing funding sources that align with the businesses' purpose-driven mission. Alternative financial models like patient capital or impact investing are encouraged to support regenerative outcomes.

These five principles collectively reshape business structures, aligning it with regenerative and distributive values. This design enables organizations to foster social equity and environmental health, supporting the goals of creating a thriving, sustainable societ

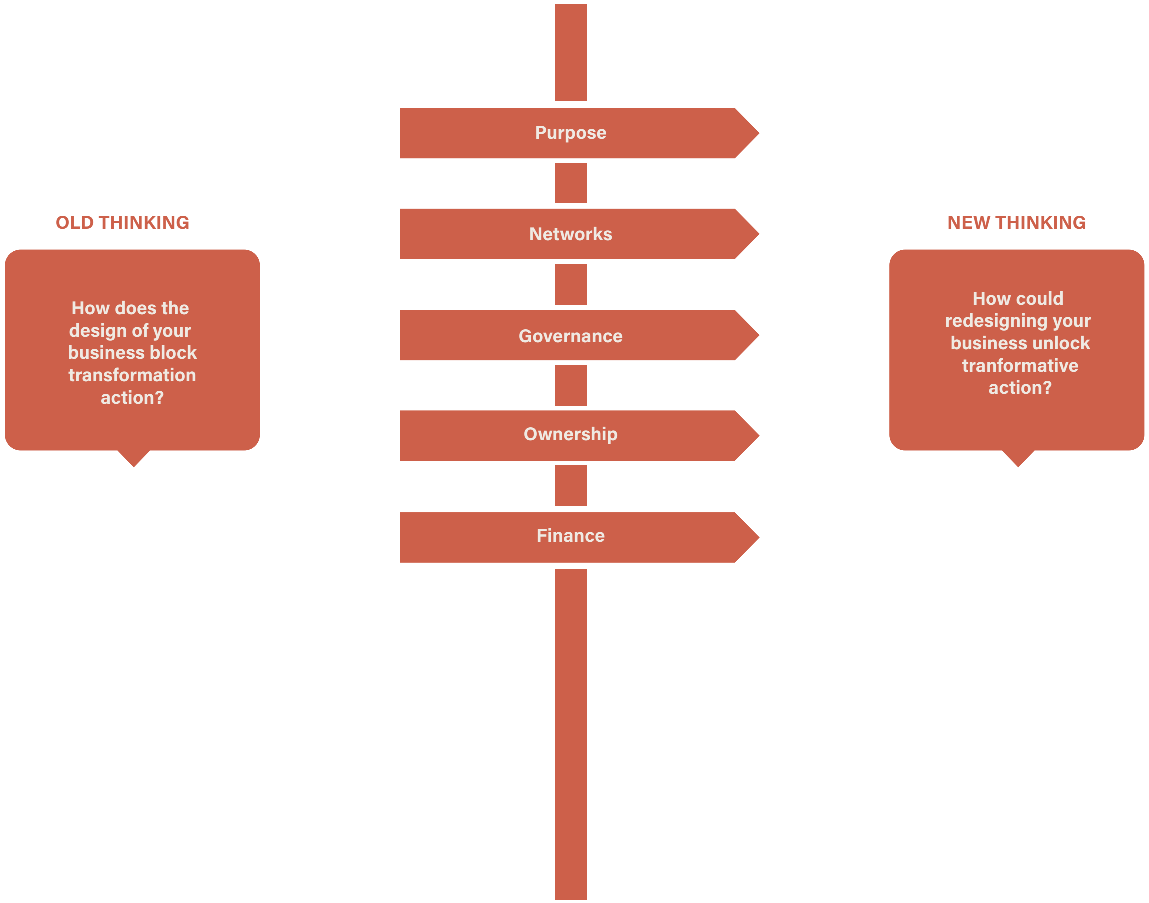


Figure 4.11- Deep design for Business - from old thinking to new thinking for transformative action.
Source: Doughnut for Urban Development: A Manual (2023) Danish Architectural Press

Three Horizons Framework

Bill Sharpe and his colleagues introduced the Three Horizons Framework (3H) in Ecology and Society in 2016 as a strategic tool for transformative thinking in uncertain times[33]. The framework, originally based on an adapted model from McKinsey & Company's "three horizons of growth," was developed to help organizations address complex problems by structuring future-oriented thinking around three overlapping time horizons.

The "first horizon – H1" reflects business-as-usual practices focused on stability; the "second horizon – H2" identifies emerging changes and tensions challenging these practices; and the "third horizon – H3" imagines a visionary future shaped by innovation and transformation. H3 can either be co-opted by business-as-usual (H1) and used to perpetuate practices as they are, or it can be of service to an emerging future (H2) and lead toward regenerative practice.

The core understanding of the 3H framework is that change unfolds as an interaction between these horizons, enabling organizations to recognize which elements of their current practices may need to evolve or be replaced. This approach supports businesses in making strategic shifts, balancing immediate needs with long-term goals, and fostering resilience amid uncertain times.

The framework emphasizes "future consciousness" - an awareness of emerging possibilities within the present - providing a structured dialogue for understanding, managing, and acting on systemic changes over time. This makes it especially useful in navigating today's global Polycrisis by helping organizations envision and work towards transformative futures rather than merely adapting reactively.

The 3H framework differs from other business design tools in its focus on managing transformational change through a structured approach that addresses short-term needs, medium-term transitions, and long-term visionary goals. Unlike tools that often center around incremental improvements or isolated strategic adjustments (e.g. SWOT analysis or PESTLE analysis), the 3H framework enables organizations to address deeper, systemic shifts by considering how current practices (H1) might be replaced by innovative alternatives (H2) and ultimately transformed by future paradigms (H3).

In essence, the 3H is an incredible tool to harness the power of systemic foresight. Box 4.2 illustrates the key idea and questions you can use to understand and apply the framework in a business setting[34 35].

The framework emphasizes "future consciousness"—an awareness of emerging possibilities within the present—providing a structured dialogue for understanding, managing, and acting on systemic changes over time.

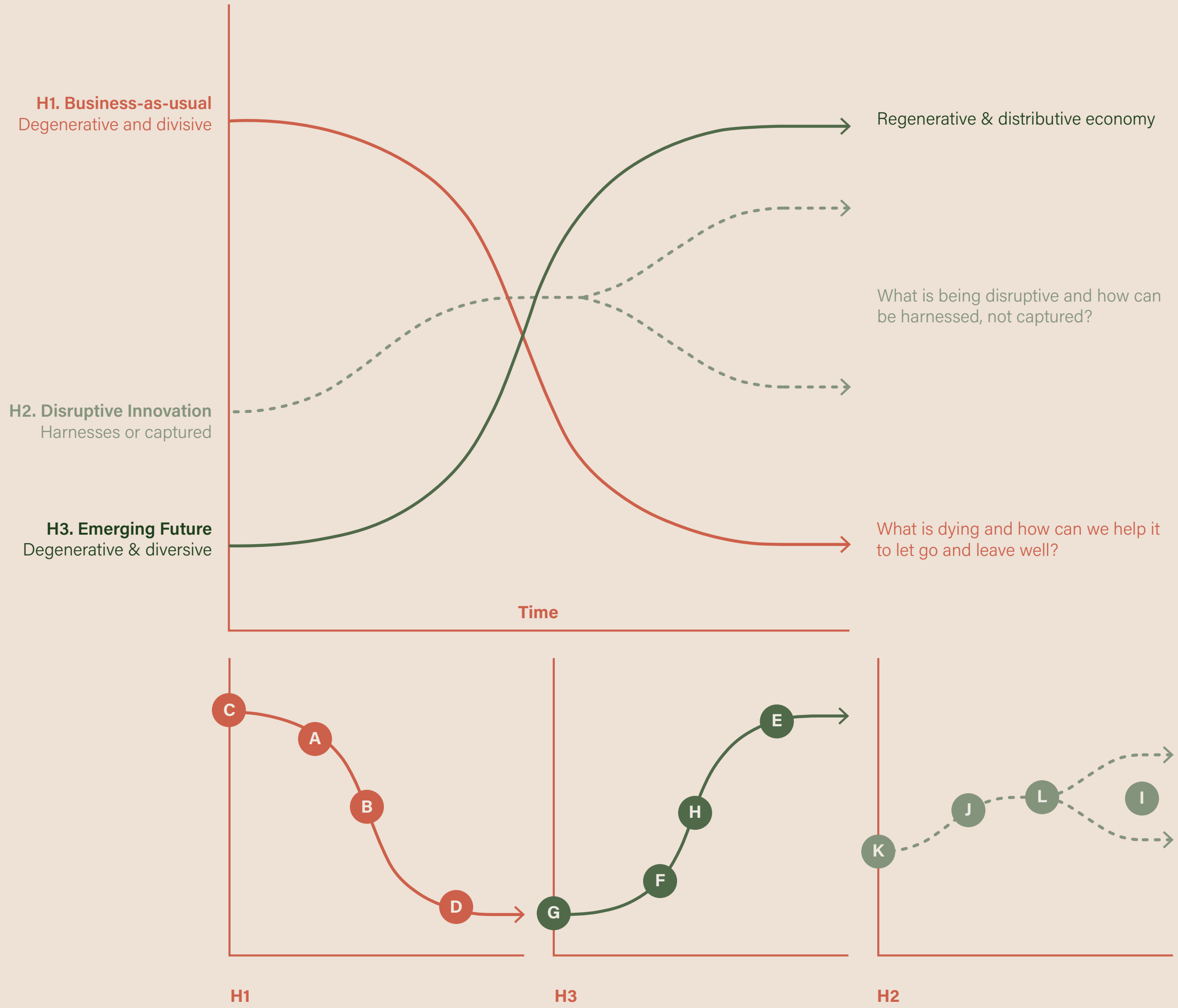
Box 4.2: Three Horizon Framework

The questions below are meant to guide businesses to explore the Three Horizons Framework in a workshop setting. Source: Bill Sharpe (2016) "Three horizons: A pathways practice for transformation" in Ecology and Society and Doughnut Economic Action Lab Youtube channel.

H1: Business-as-usual (BAU)
A: What is our BAU? And what are the key characteristics of the pervasive, BAU system? **B:** Look back: How did we get here? - Which values, cultures, laws, events led to our current business model? **C:** Why do you believe it's not fit for purpose and is failing? How fast do we want to see BAU practices decline? (Collapse benefits no-one) **D:** Is there anything valuable about the old system we should maintain rather than lose? (Such as infrastructure).

H2: Emerging Future
E: What is the future we want to bring about? What are its key characteristics? What would it look like and feel like to be there? **F:** What are seeds of that future visible in the present? **G:** Looking back — whose work are these present possibilities built on? What history, values and culture are embedded within them? **H:** How could these "seeds of that future" be scaled and spread? Give examples of actors who are already working on this. **I:**What are competing visions of the future being pursued by others? Could we collaborate with them because we share enough core elements, or are theirs inherently competing visions? If so how do we prevent their vision from derailing ours?

H3: Disruptive Innovation
J: What is being disrupted? Think of many different types of factors — economic, technological, political, ecological, social, cultural disruptions? **K:** What are the roots of those disruptions? For each one identified what would it look like to be captured H2– or harnessed H2+? What can be done strategically to ensure that it is harnessed? Give examples of disruptions of things that you believe have been captured or harnessed, and in each case, why did it happen and what made it possible? **L:** If you are a disruptive actor (a social movement, a tech innovator, or a new form of finance) what kind of guidance can you set for yourself to help influence whether your disruption is captured to extend the life of H1, or harnessed to bring about H3? What allies will you seek? What action will you take? How will you work with others so that H2+ disruption scales and spreads?



Dan Hill

Director and Professor
Melbourne School of Design at the University of Melbourne

Reduction without being reductive

In Australia, we often find ourselves moving in multiple directions at once, but the climate-positive ones least of all. Recent research by Climate Analytics finds that Australian fossil fuel exports rank second only to Russia for climate damage, with 'no plan' for reduction . In 2024, the Australian Government approved the expansion of three enormous mines and issued nine permits for further gas exploration. Meanwhile, Australia has the largest amount of domestic rooftop solar globally, per capita . Yet we also build the largest houses in the world, on average, double the size of 1960s equivalents whilst our household size has halved since then. We have an affordable housing crisis in all our major cities, not least because our housing sector is dominated by 'financialisation'; houses as financial assets rather than houses as homes. As Mariana Mazzucato and I wrote recently , it is not housing demand that drives unaffordable and unsustainable housing, but financialisation.

As this publication makes clear, advocating for new houses, when driven by financial markets rather than peoples' housing needs, will not only reproduce inequality but also vast and unnecessary amounts of embodied carbon. Yet there appears to be no connection between housing policy and climate policy, despite the fact that both are 'pointing at' the same depleted materials, ultimately.
Indeed, the rhetoric in Australian politics is of constant, continued and apparently endless unsustainable growth. No politician here would dare suggest a reduction in building. In fact, increasing housing supply, irrespective of emissions, is more or less the only policy agenda that unifies major political parties.

In this light, a meaningful Australian Reduction Roadmap seems almost impossible.

Yet we are working on precisely this, bringing together our Melbourne School of Design (MSD) research community around embodied carbon with architects like the Australian/Danish practice Terroir. As with Denmark's roadmap, early work on a draft for Australia indicates a complete transformation of practices is required, and rapidly. As with equivalent UK-based research , our early calculations suggest that Australian housing targets would effectively use up the country's Paris Agreement-defined carbon budget.

Our researchers Rob Crawford, James Helal and André Stephan have produced a suite of digital tools that allow us to better understand our material stocks and flows, as they are drawn up into the built environment sector and transformed into emissions. Yet we also know that models of emissions alone do not capture the truly destructive impact of the built environment sector. Careless design and construction also creates biodiversity degradation, habitat and landscape destruction, loss of livelihood and culture—and at planetary scale. The majority of contemporary buildings create global footprints, usually dispersed across what the Australian philosopher Val Plumwood called "shadow places".

These shadow places are obliged to host the extractive practices that make up a building, such as dredging sand to make concrete, destabilising seabeds in order to extract nickel for steel, denuding hillsides via logging. The construction of even a very standard mainstream house creates distributed destruction. Having largely depleted its material reserves, the Global North is, in effect, largely being constructed from the shadow places of the Global South.

Yet it is not enough to simply trace these flows. As Donella Meadows implored, we must test models on reality in support of producing alternate realities via alternate practices that produce change, rather than simply refining better models.

Alternate practices

Material cultures: Such alternate practices can be glimpsed in the work of London-based Material Cultures. The group moves from research—exploring how Brandenburg's wetland farming might create renewable, carbon-capturing construction materials from regenerated peatland—to practice, such as their Growing Places project at Pasteur Gardens in North London . Here, as part of a platform co-funded by Copenhagen-based re:arc, Material Cultures are creating participatory tools, cultures and systems that enable locals to transform agricultural by-products into communal building materials, and in turn into community buildings.

As their name suggests, the work embodies the connection between materiality—and thus agriculture—and cultural practices, like architecture, making and growing. This clear-sighted link—architecture and agriculture are intrinsically linked, just as the words culture and cultivation are—is a very powerful circuit-breaker, but Material Cultures are playing out these new patterns humbly, carefully and creatively.

Dookie: Back at MSD, Simulaa's André Bonnice is reorienting some of our Master of Architecture studios around similar material practices. Students in Bonnice's studio relocate up to our Dookie campus, a 2440 hectare farm two hours of north of Melbourne. Dookie is traditionally used for agricultural research, and has never been used by our students from our faculty. But over the last year, Bonnice and students have been exploring the farm's potential for a systemic reframing of agriculture and

Figure 4.12: Cattails - Material samples from Material Cultures: Wetlands and Construction:An opportunity for Berlin-Brandenburg. Photo credit: Zara Pfeifer

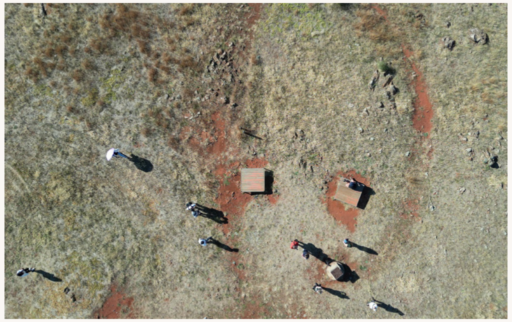


Figure 4.13: Photos from a field strip to Dookie campus. Photo credit: Dan Hill

architecture, through both craft practices and technologies old and new, both Indigenous Australian and 'Western'. These include the purposeful cultivation of straw, hemp and timber, or redirecting the numerous by-products of existing agricultural production— capturing methane from livestock for biodigesters, working with algae from the farm's ponds, making soil bricks from simple presses, or reconstituting the vast amounts of plastic wrapping used in harvesting, diverting them from landfill. This hands-on, place-based research is complemented by students' use of digital tech, for both systems analysis and speculative visualisation. Such a large and diverse farm is an extraordinary resource for a contemporary architecture school to have access to. We hope to be able to reorient our resources around this shared exploration, re-aligning and regenerating agriculture and architecture.

Kagoshima: Related patterns are emerging in some contemporary Japanese towns and cities but for different reasons, not least climate crisis x declining birth rates. (Nomura Research Institute estimates that 30% of all Japanese households could be empty by 2033.)
Some Japanese architects are loosely aligning around these new Japanese dynamics, acutely aware of systems fragility in the wake of the 2011 Tōhuko earthquake, tsunami and meltdown. I've been interviewing practices like Nori Architects, Tsubame Architects and VUILD, and all seem to draw, in different ways, from previous eras of environmentally-concerned thinkers, such as Ivan Illich and Victor Papanek, yet newly enabled by buildings science and digital fabrication technologies.

From well outside of formal design, there are hints that different everyday practices may be emerging in regions like Kagoshima, where community leaders are cultivating forms of resourcefulness and circularity precisely because property is 'de-financialising' as population declines . In Hioki, local people are renovating vacant houses whilst building new community centres from cork and timber. In Kirishima, previously empty elementary schools are being renovated, re-opened and connected to local farmers— agriculture, cooking, learning, and food waste woven together in tight local loops. In Satsumasendai, the design agency Re:public has opened a makerspace in an empty storefront, linking bamboo-based fabrication to the care of the surrounding forests. In Minamikyushu, another empty school has been renovated as a community arts centre, threading new wooden structures throughout the forest it sits in. Technologies like mobile payment systems, wifi, microgrids and crowdfunding make these places work as much as traditional craft practices and local materials, which in turn reveals the transdisciplinary approach required to work in new ways.

Alternate values:

Scholars like Kohei Saito indicate the potential for Japan to describe a new kind of 'slow down' and based around super-local regenerative resource-sharing practices, like commoning and sufficiency . We must understand how to embrace this transformation creatively and equitably, as it could powerfully frame any more broadly accepted reduction roadmap at planetary scale, enabling a swing towards the careful retrofit of existing places build.

Population dynamics won't 'do this for us' by themselves, as a slew of researchers make clear. They all see a "hard landing", in Saito's words, if slowdown conditions are not reoriented around a necessary economic, social and political reimagination, consciously moving beyond the modes of extractive capitalism that have defined our recent history. Equally, it is clear that the handful of rich Global North countries responsible for 92% of all climate breakdown, according to Eswatini anthropologist Jason Hickel , must work harder than others. We must shift building practices in the Global North, working locally at bioregional scale and reducing its impact on the Global South, shedding light rather than darkness onto shadow places.

Shadow places no more

"Architecture roots us in the world ... Meaningful architecture relates us with the landscape, culture, the continuum of history and time, human ideas and institutions, as well as with other individuals."—Juhani Pallasmaa

The actual viability of a bioregional approach was questioned by Plumwood, who could see little evidence of it emerging. Yet perhaps in these loosely-joined small examples—a community garden in London; an agricultural research centre in Victoria; the software models underpinning an Australian roadmap; the renovated schoolhouses of Kagoshima—we might perceive pinpricks of light, possible to throw into shadows.

It is clear that this has huge implications for the various practices implicated in the built and living environment, not least architecture and design. As Pallasmaa describes, the imperative must be a return of architecture to its *"tactile and multi-sensory essence"*, connecting this beautifully to materiality, and halting its multi-decade decline into a *"secondary techno-economic service profession"*—in service only to a materialist consumer culture, a wholly-financialised built environment.

Interestingly, a poetic and ethical reawakening within architecture and its materiality could help enrich its

Figure 4.14: Photos from a field strip to Kagoshima. Photo credit: Dan Hill

We hope to be able to reorient our resources around this shared exploration, re-aligning and regenerating agriculture and architecture. -Dan Hill

necessary reorientation, such that it coherently pays attention to its technical and pragmatic concerns without falling into the trap of 'bean-counting'. That trap would, ironically, be an overly reductive approach to reduction. We must find a way of making this *'make do with now'* emphasis on sufficiency into a richly diverse and open array of dignified, meaningful practices for a common good.

In the tactility of the small examples above, there may also be the seeds of a transformed practice: this opportunity of reconnecting to landscape, to a grounded materiality both old and new, to a diverse and rich reframing of sufficiency, to the joyous rediscovery of aligning agriculture and architecture, cultivation and culture. And thus to the making of meaningful places rather than shadow places.

References:

1 Climate Analytics. 2023. Australia's global carbon footprint https://ca1-clm.edcdn.com/publications/Aust_fossilcarbon_footprint.pdf?v=1723409920

2 Hill, D. and Mazzucato, M. 2024. Modern housing An environmental common good, Council on Urban Intiatitves, https://councilonurbaninitiatives.com/resources/modern-housing-an-environmental-common-good

3 Morton, A. 2023. 'Go hard and go big': How Australia got solar panels onto one in every three houses. The Guardian, 2 November 2023. https://www.theguardian.com/environment/2023/nov/01/how-generous-subsidies-helped-australia-to-become-a-leader-in-solar-power

4 zu Ermgassen, S. et al. 2022. A home for all within planetary boundaries: Pathways for meeting England's housing needs without transgressing national climate and biodiversity goals. Ecological Economics, Volume 201, 107562.

5 Plumwood, V. 2008. Shadow Places and the Politics of Dwelling. Ecological Humanities, Issue 44, March 2008.

6 https://materialcultures.org/growing-place/

7 https://simulaa.com/

8 Hill, D. 2024. Reading Saito in Kagoshima. Future Observatory Journal 1, April 2024. https://fojournal.org/review/reading-saito-in-kagoshima/

9 Saito, K. 2024. Slow down: The degrowth manifesto. Penguin Random House

10 Hickel, J. 2021. Less is More: How degrowth will save the world. Penguin Random House

11 Pallasmaa, J. 2023. The Ethical Dimension in Architecture. Speech at Paimio Sanatorium Spirit of Paimio conference, 16 October 2023

Chapter 4 References

1. Hauke Schlesier, Malte Schäfer, and Harald Desing, 'Measuring the Doughnut: A Good Life for All Is Possible within Planetary Boundaries,' Journal of Cleaner Production 448 (5 April 2024): 141447, https://doi.org/10.1016/j.jclepro.2024.141447; Cédric Durand, Elena Hofferberth, and Matthias Schmelzer, 'Planning beyond Growth: The Case for Economic Democracy within Ecological Limits,' Journal of Cleaner Production 437 (15 January 2024): 140351, https://doi.org/10.1016/j.jclepro.2023.140351.

2. Maximilian Kotz, Anders Levermann, and Leonie Wenz, 'The Economic Commitment of Climate Change,' Nature 628, no. 8008 (April 2024): 551–57, https://doi.org/10.1038/s41586-024-07219-0; Swiss Re Institute, 'The Economics of Climate Change: No Action Not an Option' (Swiss Re, April 2021), https://www.swissre.com/dam/jcr:e73ee7c3-7f83-4c17-a2b8-8ef23a8d3312/swiss-re-institute-expertise-publication-economics-of-climate-change.pdf.

3. Kotz, Levermann, and Wenz, 'The Economic Commitment of Climate Change.'

4. International Monetary Fund, World Economic Outlook, April 2021: Managing Divergent Recoveries, World Economic Outlook (Washington, D.C: International Monetary Fund, 2021), https://doi.org/10.5089/9781513575025.081.

5. Joyeeta Gupta et al., 'A Just World on a Safe Planet: A Lancet Planetary Health–Earth Commission Report on Earth-System Boundaries, Translations, and Transformations,' The Lancet Planetary Health 0, no. 0 (11 September 2024), https://doi.org/10.1016/S2542-5196(24)00042-1.

6. Kate Raworth, Doughnut Economics: Seven Ways to Think Like a 21st-Century Economist (White River Junction, Vermont: Chelsea Green Publishing, 2017), https://books.google.dk/books/about/Doughnut_Economics.html?id=7A4lDgAAQBAJ&redir_esc=y.

7. Jason Hickel, Less Is More: How Degrowth Will Save the World, 1st edition (Cornerstone Digital, 2020).

8. Timothée Parrique, "The Political Economy of Degrowth", 16. december 2019, https://doi.org/10.13140/RG.2.2.33452.82568.

9. Olivier E. Malay, "Do Beyond GDP Indicators Initiated by Powerful Stakeholders Have a Transformative Potential?", Ecological Economics 162 (august 2019): 100–107, https://doi.org/10.1016/j.ecolecon.2019.04.023.

10. Jennifer Hinton, "Five Key Dimensions of Post-Growth Business: Putting the Pieces Together", Futures 131 (august 2021): 102761, https://doi.org/10.1016/j.futures.2021.102761.

11. Anil Ari, Gabor Pula, and Liyang Sun, 'Structural Reforms and Economic Growth: A Machine Learning Approach,' IMF Working Papers 2022, no. 184 (September 2022): 1, https://doi.org/10.5089/9798400219955.001; Zoran J. N. Steinmann et al., 'Resource Footprints Are Good Proxies of Environmental Damage,' Environmental Science & Technology 51, no. 11 (6 June 2017): 6360–66, https://doi.org/10.1021/acs.est.7b00698.

12. Thomas O. Wiedmann et al., 'The Material Footprint of Nations,' Proceedings of the National Academy of Sciences 112, no. 20 (19 May 2015): 6271–76, https://doi.org/10.1073/pnas.1220362110.

13. Gupta et al., 'A Just World on a Safe Planet.'

14. Dark Matter Labs, "Life-Ennobling Economics", 7. marts 2024.

15. Extreme Climate Risks: What Are the Worst-Case Scenarios?, 2021, https://www.youtube.com/watch?v=dkDbCpn0_9I.

16. Arjuna Nebel et al., 'Recalibration of Limits to Growth: An Update of the World3 Model,' Journal of Industrial Ecology 28, no. 1 (February 2024): 87–99, https://doi.org/10.1111/jiec.13442; Jason Hickel and Giorgos Kallis, 'Is Green Growth Possible?,' New Political Economy 25, no. 4 (6 June 2020): 469–86, https://doi.org/10.1080/13563467.2019.1598964; Peter A. Victor, Managing Without Growth: Slower by Design, Not Disaster (Cheltenham, UK ; Northampton, MA: Edward Elgar Publishing, 2008), https://link.springer.com/article/10.1007/s10669-010-9290-9.

17.Timothée Parrique, 'A Response to Daniel Driscoll: Another Slice of Degrowth Bashing,' 29 February 2024, https://timotheeparrique.com/a-response-to-daniel-driscoll-another-slice-of-degrowth-bashing/.

18. Daniel W. O'Neill et al., 'A Good Life for All within Planetary Boundaries,' Nature Sustainability 1, no. 2 (February 2018): 88–95, https://doi.org/10.1038/s41893-018-0021-4.

19. Jason Hickel et al., 'Degrowth Can Work — Here's How Science Can Help,' Nature 612, no. 7940 (December 2022): 400–403, https://doi.org/10.1038/d41586-022-04412-x.

20. Parrique, "The Political Economy of Degrowth".

21. Anja Bierwirth og Stefan Thomas, "Almost best friends: sufficiency and efficiency. Can sufficiency maximise efficiency gains in buildings?", i ECEEE 2015 Summer Study - First Fuel Now, 2015, https://www.eceee.org/library/conference_proceedings/eceee_Summer_Studies/2015/1-foundations-of-future-energy-policy/almost-best-friends-sufficiency-and-efficiency-can-sufficiency-maximise-efficiency-gains-in-buildings/.

22. Iana Nesterova, "Degrowth Perspective for Sustainability in Built Environments", Encyclopedia 2, nr. 1 (marts 2022): 466–72, https://doi.org/10.3390/encyclopedia2010029.

23. European Commission, 'Renovation Wave: Doubling the Renovation Rate to Cut Emissions, Boost Recovery and Reduce Energy Poverty,' Press Release (European Commission, 14 December 2020), https://ec.europa.eu/commission/presscorner/detail/en/ip_20_1835.

24. Forbes EQ, 'The Trillion-Dollar Promise of a Landscape Restoration Industry,' Forbes, 1 March 2021, https://www.forbes.com/sites/forbeseq/2024/03/01/the-trillion-dollar-promise-of-a-landscape-restoration-industry/.

25. Lehmann et al., "Quantification of the Understorey Contribution to Carbon Storage in a Peri-Urban Temperate Food Forest."

26. Schafer, Lysák, and Henriksen, "Tree Layer Carbon Stock Quantification in a Temperate Food Forest."

27. Nytofte and Henriksen, "Sustainable Food Production in a Temperate Climate – a Case Study Analysis of the Nutritional Yield in a Peri-Urban Food Forest."

28. Crawford, "Comparative Semi-Stratified Invertebrate Diversity Study of the Agroforestry Research Trust Forest Garden and Schumacher Nativ."

29. Jamie Bristow og Rosie Bell, "Between Optimism and Despair: The Messy Middle Paths Through Climate Breakdown", DeSmog (blog), 14. oktober 2010, https://www.desmog.com/2024/08/06/between-optimism-and-despair-the-messy-middle-paths-through-climate-breakdown/.

30. Marjorie Kelly and Ted Howard, The Making of a Democratic Economy: Build Prosperity for the Many, Not the Few (Berrett Koehler, 2019), https://www.moralmarkets.org/book/the-making-of-a-democratic-economy/.

31. H. Birgisdottir et al., Doughnut For Urban Development: A Manual, ed. Dani Hill-Hansen and Kasper Guldager Jensen, 1st ed. (Copenhagen: Danish Architectural Press, 2023), https://www.home.earth/doughnut.

32. Doughnut Economic Action Lab, "Doughnut Design for Business - Core Tool", Doughnut Design for Business - Core Tool (blog), set 17. oktober 2024, https://doughnuteconomics.org/tools/doughnut-design-for-business-core-tool.

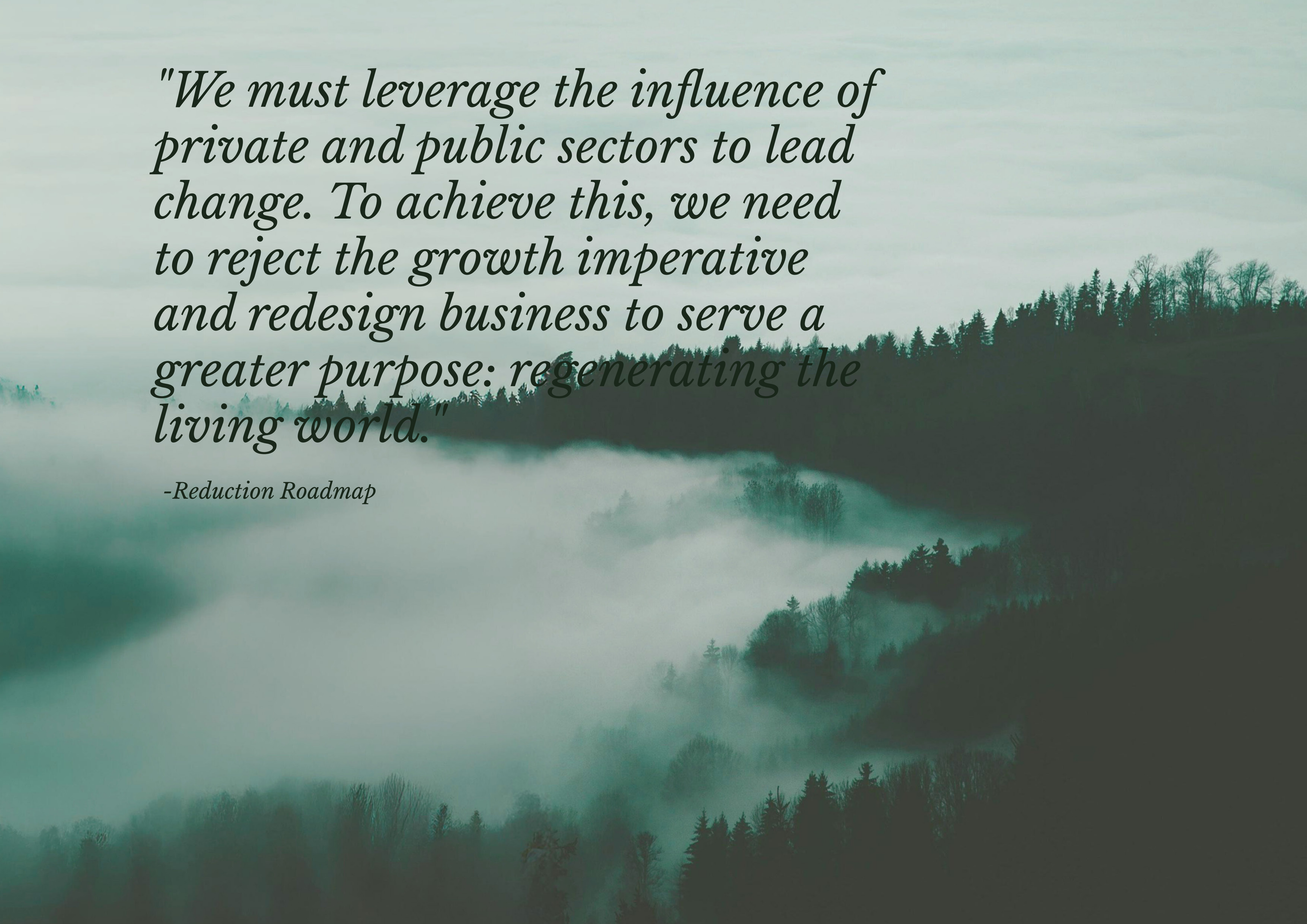
33. Bill Sharpe et al., "Three horizons: a pathways practice for transformation", Ecology and Society 21, nr. 2 (june 2016): 15, https://doi.org/10.5751/ES-08388-210247

34. Three Horizons Framework - A Quick Introduction, Youtube, 2018, https://www.youtube.com/watch?v=_5KfRQJqpPU&t=5s.

35. International Futures Forum, 'Three Horizons,' n.d., https://www.iffpraxis.com/3h-approach.

36. Dani Hill-Hansen et al., "Economish" (Aalborg University, Sustainable Design Egineering, June 6, 2020).

37. IPCC, Climate Change 2022 Mitigation of Climate Change: Working Group III Contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change, 2022, https://www.ipcc.ch/report/ar6/wg3/.


"We must leverage the influence of private and public sectors to lead change. To achieve this, we need to reject the growth imperative and redesign business to serve a greater purpose: regenerating the living world."
-Reduction Roadmap

To reference this report: Reduction Roadmap (2024) *Beyond the Roadmap: A transition plan for the Danish building industry* Version 1. 29. October, 2024. www.reductionroadmap.dk

Beyond the **Roadmap**