Arup Explores: Regenerative Design

Towards living in harmony with nature

Contents

Foreword

As the results of our impacts on the planet become ever more obvious, it would be easy to allow a pervasive sense of inevitability about the future to dominate. However, there is much that we can, and must, do to set humanity on a safer course. The great systems thinker Donella Meadows makes the case in her seminal essay *Leverage Points* that, too often, we try to bring about change by intervening in the less influential points in the system and, to really bring about change, we should strive to change the whole mindset or paradigm that determines how the system works.[1] That is the spirit that lies behind the shift from sustainable to regenerative.

The limits to the framing of sustainability are becoming increasingly clear — we must transcend and include that into a broader paradigm. Whereas, previously, pressure may have come from activists or critics within our professional spheres, now we must face the prospect of the admonishment for inaction coming from closer to home. Drew Dellinger, in his poem *Hieroglyphic Stairway*, raises the uncomfortable reality that many of our children will ask: “What did you do when you knew?”

Ove Arup once observed that he “took up engineering in order to practice philosophy”, and this feels more relevant now than ever. It is clear that our current worldviews which see humans as separate from nature, and nature as an externality to our economic system, need to be fundamentally revised. The shift towards regenerative design will compel us to rethink much that we thought we knew for certain. It will change our notions of success and coax us into defining a deeper purpose for ourselves as individuals and as organisations.

Some of the terms in this document may be unfamiliar and some of the aims may seem daunting, but this can be seen as an opportunity for personal growth. Historically, the evolution of human consciousness has expanded through various stages: from individualistic to tribal to national and international perspectives. Now, we must extend that further to a planetary perspective that sees all life on Earth as connected.

Our urgent challenge is to integrate everything we do as humans into the web of life that supports us so that we can flourish within planetary limits.

This expansion in thinking must also embrace the way we see ourselves as humans. In recent times, we have moved from identifying as subjects, to consumers, to conscious consumers. We must now go further and see ourselves as citizens or ‘possibilists’ actively engaged in shaping a positive future with neither the constraints of pessimism nor the false comforts of optimism. Where we encounter obstacles to regenerative solutions, we may need to expand our spheres of influence to press for change at institutional, national and international levels.

As practitioners in the built environment (including policymakers, designers and engineers), we have far greater agency than many other professions. We have the training in integrative thinking that allows us to develop strategic as well as detailed solutions — and we have the opportunities to implement those ideas at scale. We can lead teams to develop solutions that our clients never dreamed would be possible. We know how to embrace complex situations with multiple opposing constraints and to resolve these creatively. Indeed, some of the greatest opportunities in regenerative design are to be found in the synergies between cycles of food, energy, water and materials. Where previously ‘grey infrastructure’ may have been the default solution, now nature-based solutions can deliver much better outcomes in terms of whole-system benefits — sometimes even at lower costs.

We live in the most extraordinary moment in history. We have all the solutions we need to make rapid progress on addressing the planetary emergency. What could possibly be more fulfilling than leading the world out of the industrial age and into the ecological age?

“What could possibly be more fulfilling than leading the world out of the industrial age and into the ecological age?”

Michael Pawlyn
Architect and systems thinker
Director of Exploration Architecture
& co-author of *Flourish: Design Paradigms for Our Planetary Emergency*

Executive summary

Executive summary

Regenerative design is an approach in which human systems are designed to co-exist and co-evolve with natural systems, ensuring planetary and social health.

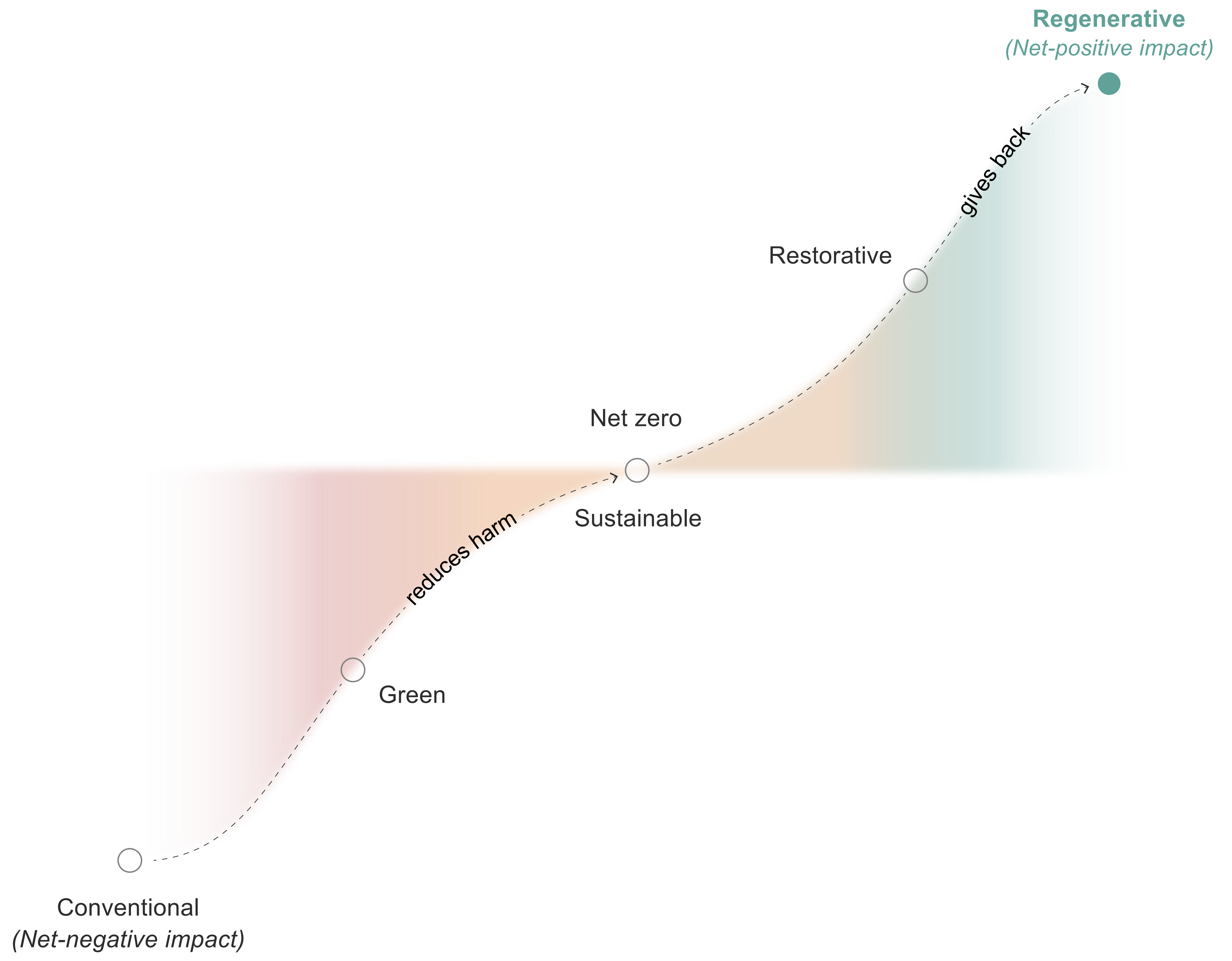
Understanding our place within nature

Humans are part of nature, yet we are most unusual in the natural world. In our brief time on this very old Earth, we've become one of the most influential species in its history with an extraordinary ability to alter our planet's systems irreversibly.[2] Extractive human activities are pushing us beyond the limits of Earth's capacity to regulate against shocks and stresses and to support all life. These are known as the planetary boundaries. As an influential species, we have an ethical and ecological responsibility to leverage our position and to participate in the natural system in a positive, reinforcing way.

What is regenerative design?

Regenerative design is a holistic approach in which human systems are designed to co-exist and co-evolve over time with the natural systems of which we are part, ensuring planetary health. Green design, in contrast, merely focuses on reducing harm while sustainable design is about recovering an equilibrium where human needs no longer exceed planetary resources. To achieve this in perpetuity requires us to go a step further; to restore planetary health and design systems that support human life and repair the damage done to date. This is part of the transition towards a regenerative future.

In the optimal, regenerative state, human systems replenish ecosystems and fully align with the needs and characteristics of thriving natural systems. This means incorporating nature as a key stakeholder and co-creator. Integrating regenerative design into our built systems will require human ingenuity, inspired and supported by life's unique adaptations that are the result of 3.8 billion years of 'natural R&D' (research and development) called evolution.



Transitioning towards regenerative outcomes

Adapted from Reed and Mang (2007)[3]

The guiding principles of regenerative design

This report proposes three complementary design principles that we can adopt to guide our transition toward a regenerative future. They are intended to inspire and equip, and include evidence to demonstrate the art of the possible. Together, the principles serve to catalyse activity that achieves positive outcomes for people and planet. The guiding principles are:

Nature-led: *place-based design that enhances and emulates natural systems*

Regenerative design lets nature shape human-built forms by integrating them with, and leveraging, ecosystem functions and processes. It enables humans to live in harmony with natural cycles; thus ensuring resilience through planetary health.

Systemic: *relationships, exchanges and flows of materials and resources that restore, protect and replenish*

Regenerative design ensures human-made systems participate positively in the wider natural system. It guides us to understand interconnections between systems and helps us identify design interventions to build synergies; thus leading to greater systemic health.

Equitable: *collective change, co-creation and collaboration that ensure inclusivity and social justice*

Regenerative design guides us to nurture a just space for humanity by prioritising the biosphere that supports us all. It maximises harmony and justice through equitable nature, climate and social targets; thus ensuring human health and wellbeing.

Nature-led
place-based design that enhances and emulates natural systems

Life's Principles
Learn from and leverage the design principles embodied by nature's 3.8 billion years of evolution

- Mimic life's unique adaptations
- Utilise living organisms and biological materials
- Partner with nature as infrastructure

Place-based design
Respond to and work with the features of a site to cultivate greater systemic health over time

- Be locally attuned and responsive
- Integrate rather than segregate
- Capture and grow surpluses in the system

Planetary health
Ensure the resilience of human systems by actively reconnecting natural cycles where we disrupt them

- Understand our place in the living system
- Reconnect natural cycles where we disrupt them
- Support the web of life

Systemic
relationships, exchanges and flows of materials and resources that restore, protect and replenish

Systems thinking
Build a deep understanding of resource flows to develop an interconnected ecosystem

- View the city as an ecosystem
- Capture benefits at every exchange
- Break down silos with technology

Nature compatible
Work in harmony with biological cycles through regenerative material cultivation and life-friendly chemistry

- Utilise life's toolbox
- Transition to biological resources
- Design for decomposition

Circular infrastructure
Create a system that enables materials, products and components to be reused and remain in circulation

- Give land back to nature
- Adopt new business models to optimise lifecycle value
- Bioremediate waste and pollution

Equitable
collective change, co-creation and collaboration that ensure inclusivity and social justice

Biosphere economy
Value planetary health over narrow financial gain and inspire collective action within the planetary boundaries

- Value planetary health
- Inform policy and regulations with science-based targets
- Coordinate action globally

Just social foundations
Enable humans to co-evolve with nature through equitable and just foundations which meet the needs of all people

- Cultivate public luxury and the commons
- Co-create healthy and resilient communities
- Address historical inequalities with environmental justice

Contextual stewardship
Prioritise nature as a key stakeholder and co-creator, and shape places led by the local community

- Integrate place-making with land stewardship
- Embed participatory and inclusive democracy
- Partner with Indigenous and traditional ecological stewards

Sowing the seeds for tomorrow

Even though we may not have all the answers today, we can take steps right now across our projects and designs that embed and test regenerative design principles and deliver positive outcomes for the real world. Adopting a regenerative mindset and applying these guiding principles require a fundamental shift in the values and desired outcomes that frame our decisions, investments, policy and planning. Consequentially, the objectives of our economies also need to be reframed.

Governments have responsibility to set the direction of travel and enable the coordinated action that is needed to achieve a regenerative future. They have the power to guide market movements away from ones that are increasingly serving fewer stakeholders, and instead embed them in the web of life. This way, markets can deliver benefits across whole ecosystems.

Meanwhile, practitioners across numerous sectors must keep in mind the long-term trajectory towards regeneration, while setting detailed and specific short-term targets. Which investment, design or procurement criteria can we change *today*? What parts, products or processes can we rethink right *now*?

The final section of this report describes the potential for a shift to regenerative design, with example actions that can be taken immediately. It also presents a theory of change to visually demonstrate how we can achieve a regenerative future in which human systems contribute to planetary health.

From ⟶ towards

From degradation & conventional practices	⟶ Towards regenerative & positive practices
Extractive built systems	Human civilisation co-evolving as part of Earth's cyclic living systems
Being insulated and disconnected from nature's cycles	Expanding nature literacy by increasing touchpoints with nature
Appropriating Earth's finite resources	Responsibly cycling resources within human systems
The 'builder' of uniform systems that control nature	The 'gardener' working in harmony with a place's complexity and variability
Fragmented systems of buildings, infrastructure, spaces	Buildings, infrastructure, spaces that contribute to wider systemic health
Marginalised groups bearing environmental burdens	A just transition that corrects for historical harms and builds equity
Short-term, siloed politics and decision-making	Long-term, progressive politics that meet the needs of future generations
An individualistic mindset	Community and shared prosperity for the greater good
Markets that degrade nature and drive inequalities	Markets embedded in science-based targets for planetary and social health

*** Inspired by Michael Pawlyn & Sarah Ichioka's book *Flourish*, 2021.**

The regenerative context

We are part of nature

In this chapter:

Aim of this report

This report is a prompt. It calls built environment practitioners and decision-makers to rethink their approaches by better understanding the natural world and humans' place in it.

It also serves as inspiration for how, after millennia of human development and its contribution to what are now near-catastrophic levels of nature loss, we can restore and regenerate planetary health through our interactions with the wider landscape and the way we shape buildings, neighbourhoods, cities and economies. We all have a role to play, whether we design spaces, write policies, deliver services or make decisions that shape the world around us — both locally and globally.

Mainstreaming a regenerative mindset and nature literacy — in education, through play and in practice — will ensure that we collectively develop relevant skills and knowledge to enable a transition towards regenerative design and net-positive impacts. This begins with a deeper understanding that we can, and do, detrimentally impact nature.

The report's content strikes a balance between the visionary and the practical. It introduces Life's Principles and opportunities to include them in our processes. The goal is to draw out a new paradigm where design is oriented towards enabling people and nature to co-exist and co-evolve over time. The report cannot provide all the answers nor specific technical solutions. Rather, it offers avenues for exploration, informs the conversation and empowers readers to embrace a regenerative approach in their designs and decision-making.

This report establishes the historical context of humanity's place in nature, before discussing the values that are fundamental to regenerative design and proposing three guiding design principles. It then highlights how we can take action today through a framework we call 'STEP UP': change areas we can leverage in Society, Technology, Economy, Politics, under Uncertainty and through Partnerships. This shapes a transition to a regenerative future.

This document is the result of research, of a wide exploration and of the convening of experts over several years. It builds on the thinking of leaders in this space, and sets out a glossary of key terms which can be referenced. It also includes case studies (by Arup and others) to illustrate pioneering practices that employ these regenerative principles and that implement the fundamental lessons of Life's Principles.

We all have a role to play, whether we design spaces, write policies, deliver services or make decisions that shape the world around us — both locally and globally.

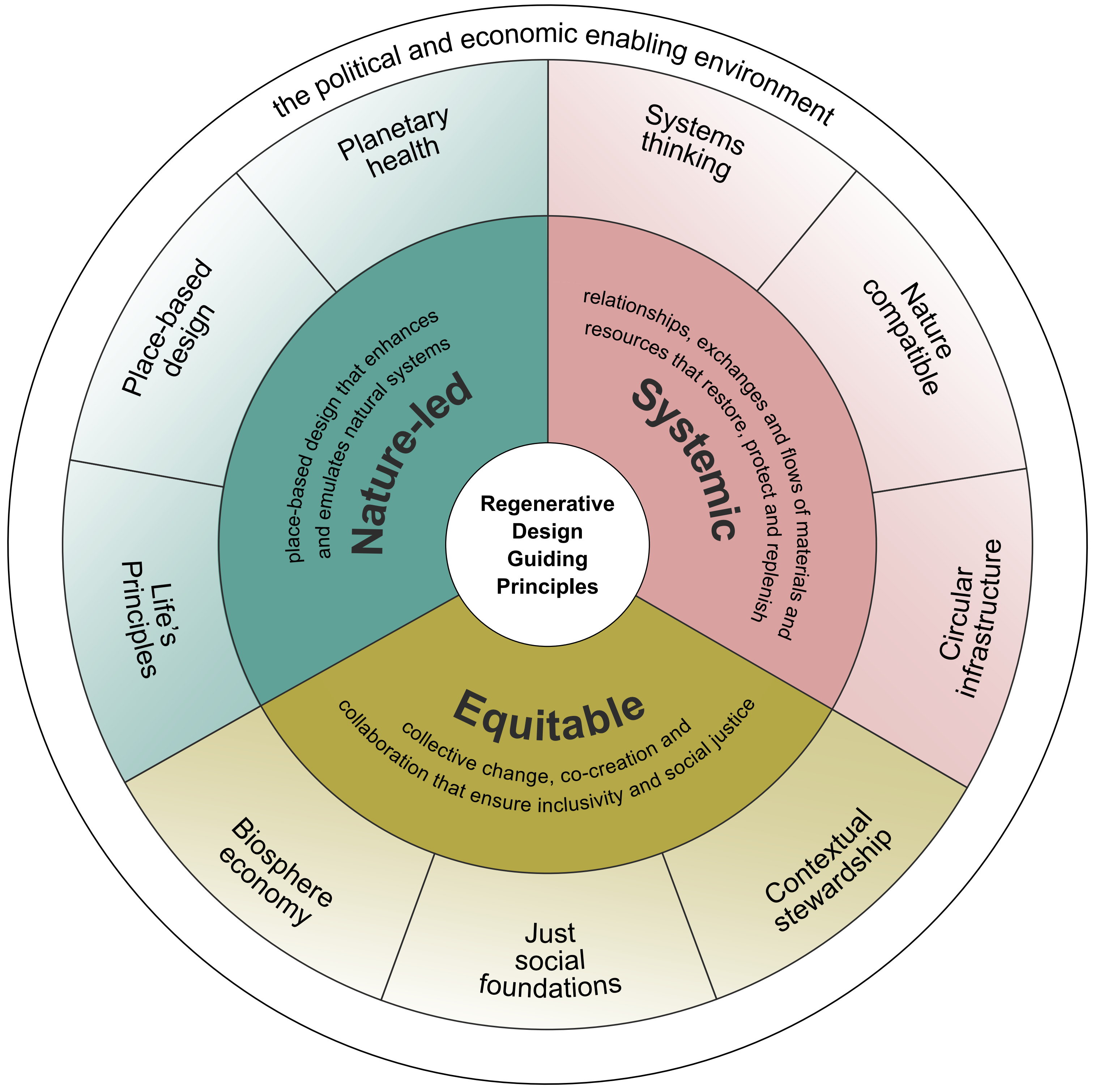


Figure 1: Regenerative Design Guiding Principles
Arup

Humanity's relationship with nature

Understanding our place within nature

The planet we live on today has been 4.6 billion years in the making, with life itself evolving over the last 3.8 billion years. It is the product of a complex co-evolution of living organisms and the non-living chemical and physical parts of the environment. We call these evolving, interconnected systems 'nature'.

History of Earth across a calendar year

Imagine Earth's history as one calendar year. On that scale, life appeared at the end of February. A month later, photosynthesising organisms evolved, reshaping the atmosphere as they soaked up carbon dioxide and exhaled oxygen. Life evolved from single-celled bacteria into multicellular organisms in August. Lifeforms grew increasingly complex through their interaction with each other and their environment, and eventually began to shape rainfall patterns as plants exhaled water vapour. Meanwhile, microbes and fungi unlocked and cycled nutrients. Over time, weather patterns and species distributions evolved to a state that could support human life.[4]

36 minutes to midnight

To understand our place in nature, it is important to grasp the conditions that allowed humanity to thrive. *Homo sapiens* arrived in the last 36 minutes before midnight of the new year, and all of human history since the end of the last ice age occurred in the last 82.2 seconds. Known as the Holocene, this geological epoch of the past 10,000 years or so has been characterised by uniquely stable weather patterns. This allowed *Homo sapiens* to develop place-based agriculture and settlements, which in turn led to a unique ability to grow by leveraging natural processes and extracting stored energy.[5]

That is our place in nature: we are a very recent part of it, wholly dependent on its continuing processes, yet with an unusual ability to unsettle and alter these processes irreversibly. Humans have so profoundly changed and disrupted Earth's natural processes that scientists suggest we have forced the planet into a new geological epoch – the Anthropocene (*anthropos* is Greek for 'human'). As one of the most influential species on the planet, we have a responsibility to better understand and improve our place within nature.

> "Our everyday lives are shaped by processes that vastly predate us, and our habitats will in turn have consequences that will outlast us by generations."
>
> — Marcia Bjornerud, professor of geology and environmental studies[6]

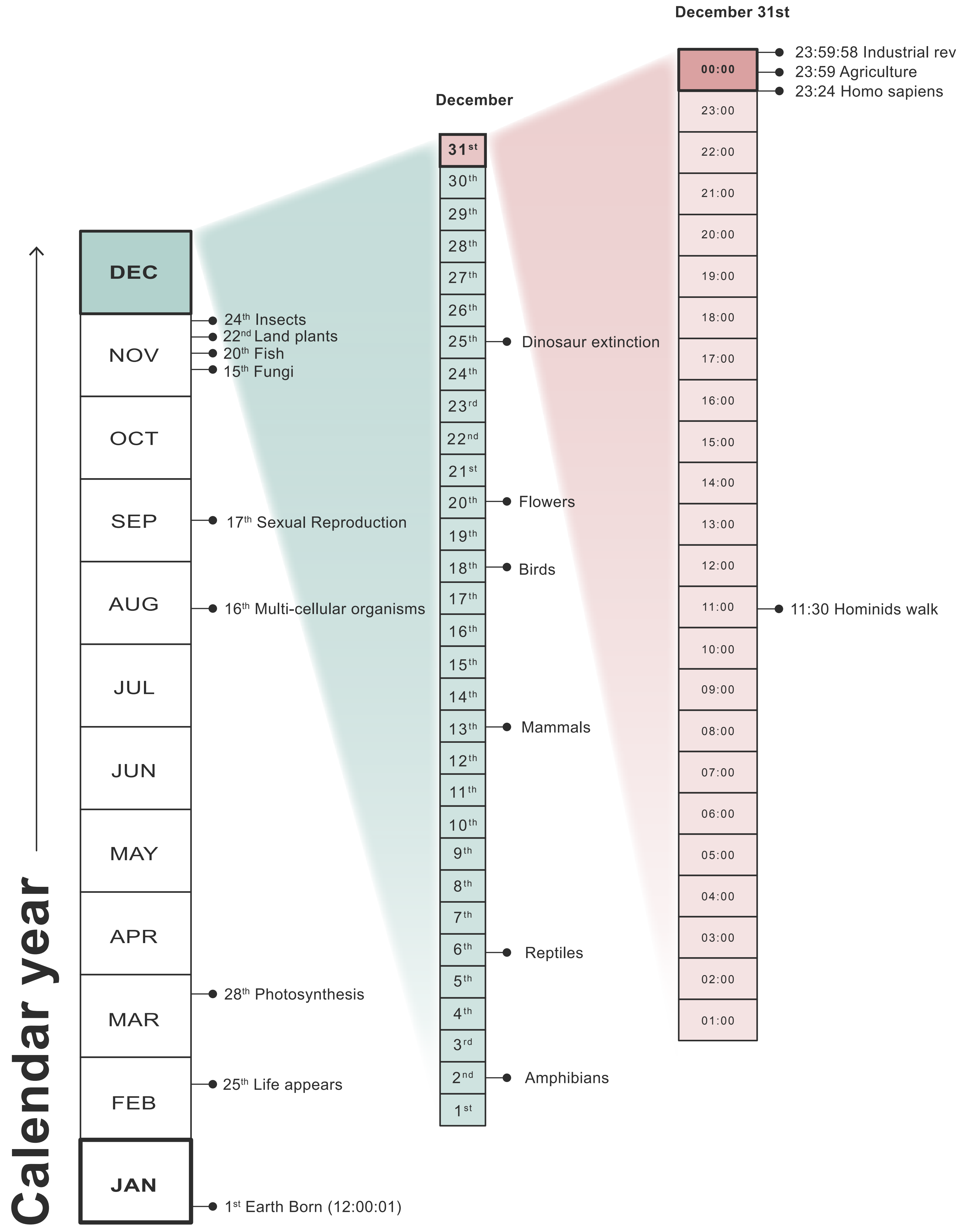


Figure 2: Earth's history in a calendar year

Adapted from Biomimicry 3.8[7]

Starting in Africa, just before midnight on the 31st of December, humans migrated around the world. The pressure that the human population placed on the wider natural systems was immediately obvious: human migration patterns coincide with the extinction of more than 178 of the world's largest mammals, highlighting the unusual ability of humans to quickly shape the natural world around them.[8]

One minute to midnight

At one minute to midnight, humans began to farm, and land became a means of production. Wild forests and plains turned to farmland, which sustained the development of settlements.[9] Technological advances meant metals began to replace stone and wood, and this enabled humans to extract even more resources.

As we established and expanded our cities, human systems were increasingly developed in conflict with, or at the expense of, natural systems. Meanwhile, land, environmental resources, fauna, flora and even humans were increasingly measured by their productive potential alone. The race to expand and exploit new land and resources drove European colonialism, while the expansion of global capitalism has now reached a point where the natural world, and everything in it, is commodified at the cost of its health, diversity and stability.[10]

Today, 75% of the land-based environment and 66% of the marine environment have been significantly altered by human actions.[11]

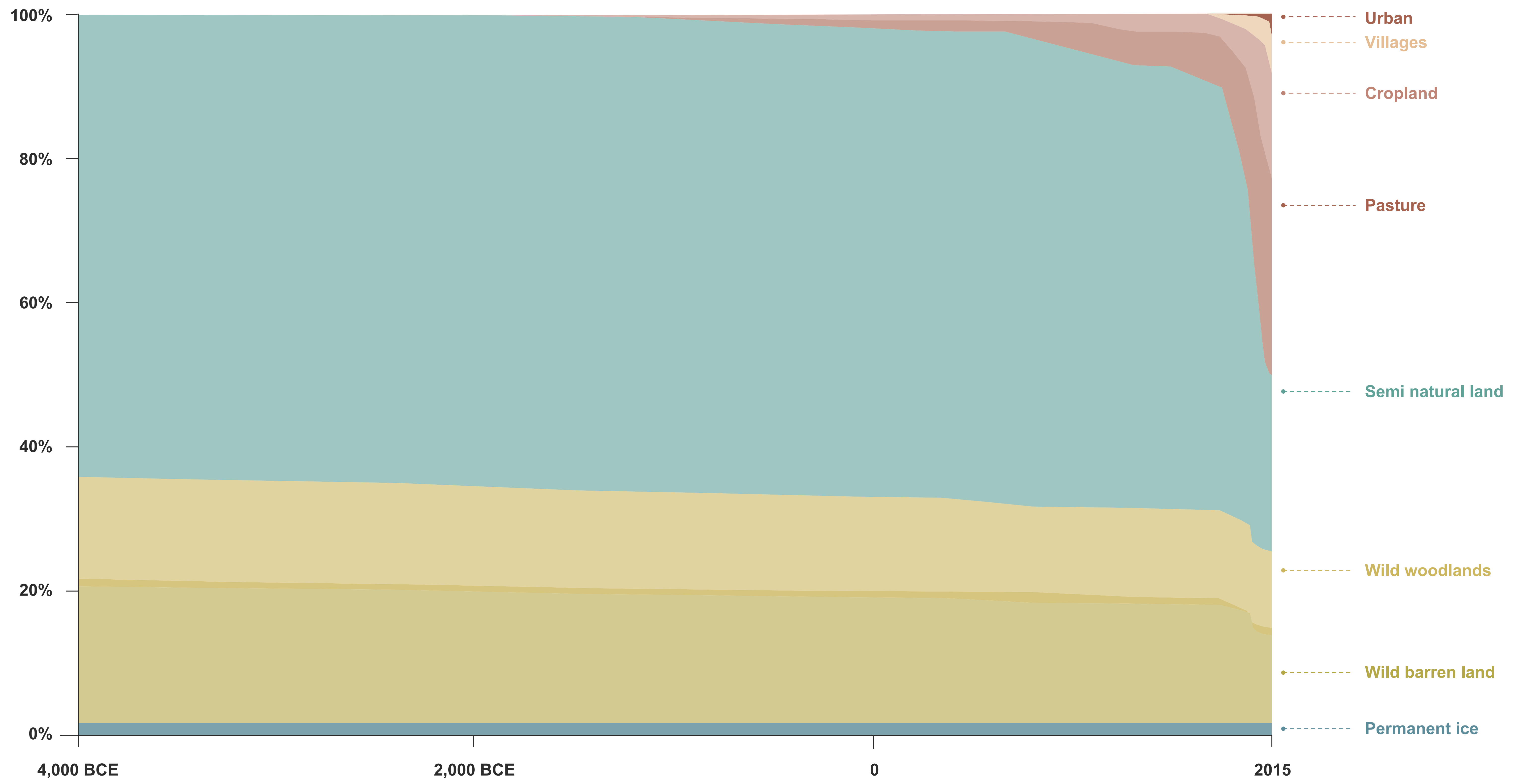


Figure 3: Global land use since 4,000 BCE
Adapted from Our World in Data[12]

Humans have striven for ever more financial and material wealth at the expense of plants and other animal species: some species were considered useful and, therefore, transported and cultivated globally for human prosperity, while others were replaced and dispensed of.[13] Extinction rates in birds, insects, mammals and amphibians have grown to 100 to 1,000 times higher than the natural background extinction rate.[14]

The final seconds

In the final seconds of the calendar year, the human population grew by around 400%.[15] Fossil fuels, such as coal and oil, were the common energy source. Transportation and industrial processes made use of new extractive fuels, accelerating economic growth and increasing atmospheric CO_2 levels. In real time, this corresponds to an increase in atmospheric CO_2 levels of 50% in less than 200 years, altering the climate.[16] Meanwhile, novel materials and inorganic compounds were developed that cannot be reabsorbed in natural processes.

A time to regenerate

We are now at a unique point in time where people are starting to understand the complexity of Earth's systems, and how significant of a geophysical force humans have become, while still having the ability to change the trajectory and repair the damage done to date.

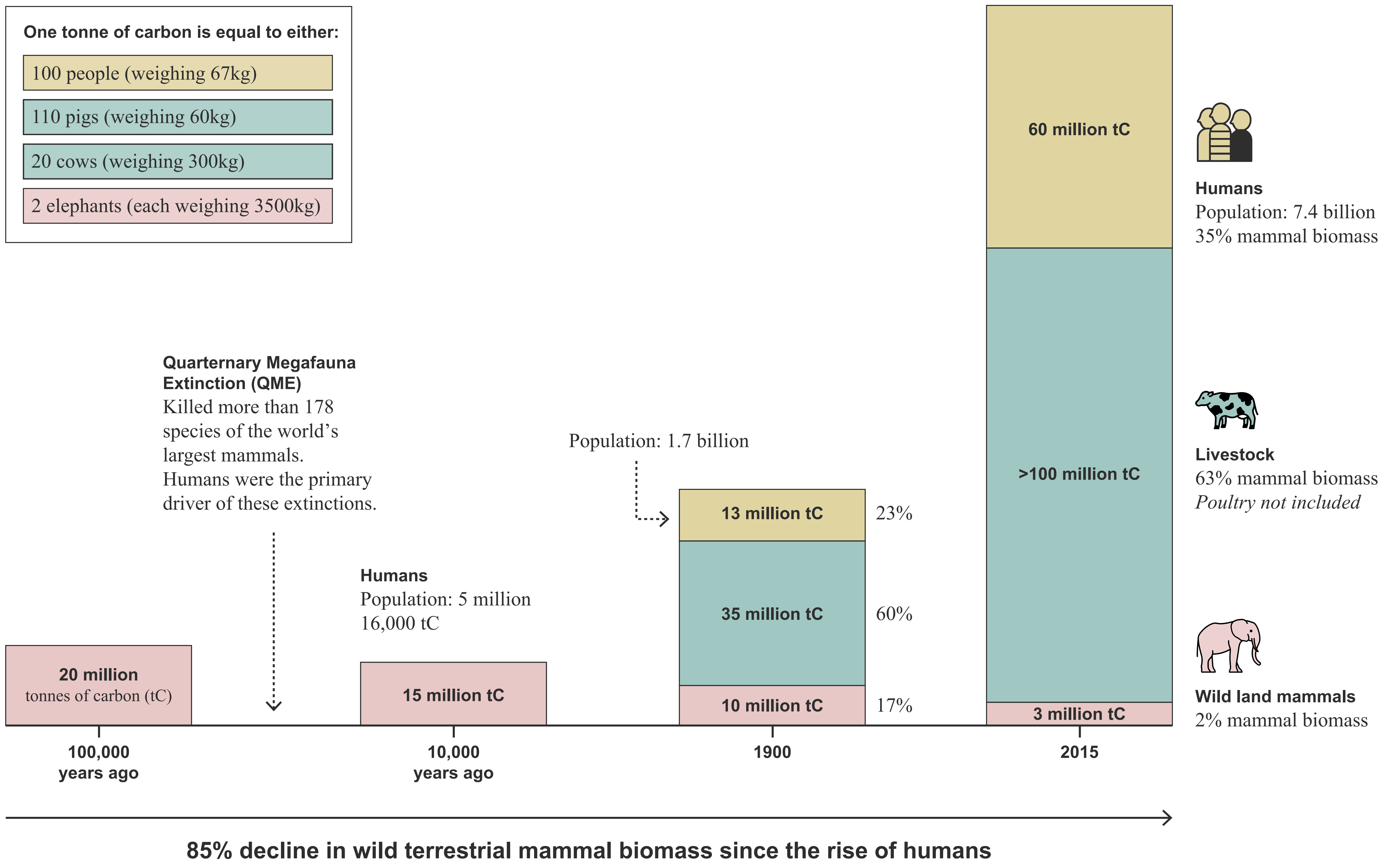


Figure 4: Changing distribution of the world's land mammals
Adapted from Our World in Data[17]

Recognising the planetary boundaries

In 2009, a team of researchers at the Stockholm Resilience Centre identified planetary boundaries to highlight how stable Earth has been over the last 10,000 years and to set limits which cannot be crossed if the planet is to remain a safe operating space.[18] In 2023, the Earth Commission published the first study quantifying safe and just Earth-system boundaries, this time placing human needs at the centre.[19]

This richer and clearer understanding of humanity's place within the planet's systems leaves little doubt: we must begin to restore and regenerate Earth. This requires us, first, to dismantle the artificial divisions between humans, non-humans, and nature that have led to our exploitation and misappropriation of the natural world.

+ Exemplar case study Read more

Planetary boundaries[20]

Location: Global

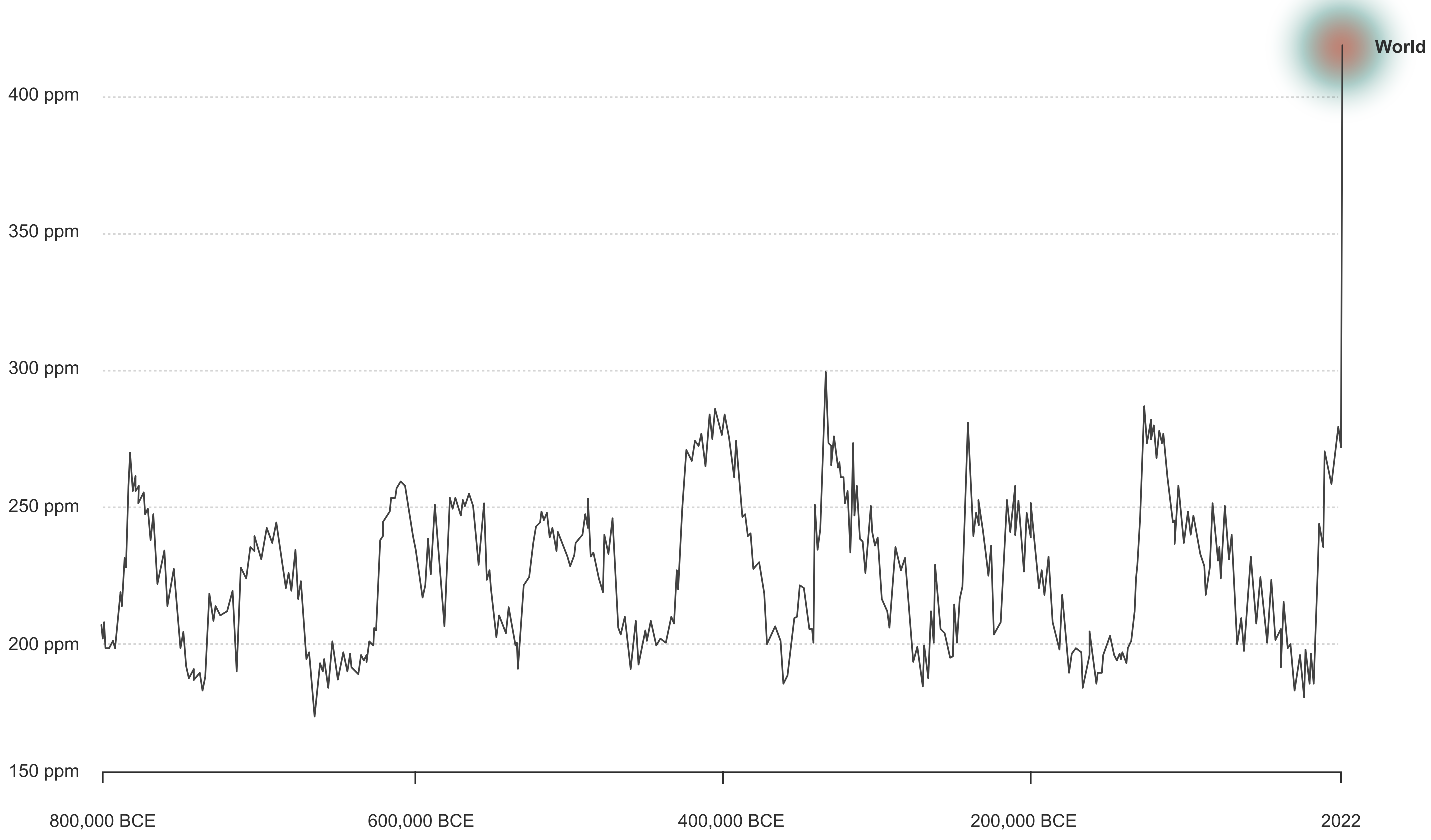


Figure 5: Global atmospheric CO_2 concentrations in parts per million
Adapted from Our World in Data[21]

Recognising Indigenous and traditional wisdom

To design regeneratively, we must heal this artifical divide between human activity and natural cycles. And we must learn from nature.

Land stewardship, where humans care for the land regeneratively rather than exploit it, is not a new concept. Indigenous and traditional ecological knowledge systems have long recognised the interconnectedness of all living beings and, accordingly, have developed practices that foster abundance and biodiversity.[22] Indigenous peoples — distinct cultural groups that share collective ancestral ties to the land and its resources — make up approximately 6% of the global population, yet they are the conservationists looking after 80% of the remaining biodiversity on the planet.[23]

Considered the world's most experienced conservationists, Indigenous cultures contain "thousands of years of observation and trial and error on how to not only promote the regeneration of their native ecosystem but to enhance its properties for their own community's benefit".[24] Their teachings are rooted in ancestral, intergenerational thinking that often views nature as an elder relative, recognising kinship with plants, mountains, lakes and all natural beings.[25]

Indigenous and traditional ecological knowledge systems have long recognised the interconnectedness of all living beings.

Through their close connection to the land, Indigenous and traditional cultures have observed and respected ecological patterns, such as the symbiotic relationships between species and the role of natural disturbances like fire. Indigenous communities around the world have used fire as a tool to shape landscapes and rejuvenate the soil. For example, biochar, a carbon-rich charcoal produced from organic waste, was intentionally introduced by prehistoric Indigenous groups in Western Amazonia to improve soil structure and nutrient retention for greater fertility. Controlled burns and the creation of biochar are evidence of the intentional cultivation of biodiversity and of regenerative practices.[26] Deep Indigenous ecological knowledge has also led to remarkable discoveries, such as the use of natural substances with antimicrobial properties long before the accidental Western discovery of penicillin.

Acknowledging, partnering with, and learning from Indigenous peoples and traditional approaches, creates the opportunity to integrate their regenerative practices and ecological wisdom with modern scientific knowledge and technology. This provides a greater systemic understanding of our natural systems, of how humans disrupt them and of the opportunities we have to regenerate nature at scale and across modern systems. It is our responsibility to care for the Earth, a planet which supports us and underpins all life.

+ Exemplar case study Read more

Chinampas of Mexico[27]
Location: Mexico City, Mexico

The regenerative context

Regenerative design: what and why?

Regenerative design is an approach in which human systems are designed to co-exist and co-evolve with natural systems, ensuring planetary and social health.

Regenerative design is a holistic approach in which human systems are designed to co-exist and co-evolve over time with the natural systems that we are a part of, ensuring planetary health. Such human systems replenish ecosystems and are fully aligned with the needs and characteristics of healthy, thriving natural systems.

Green design, in contrast, merely focuses on reducing harm. Sustainable design is about recovering an equilibrium where human needs no longer exceed planetary resources, but to achieve this in perpetuity requires us to go a step further. With many ecosystems depleted and species and habitats in rapid decline, we must repair the damage done to date. Restorative design is fundamental in the transition towards a regenerative future. In the optimal, regenerative state nature is a key stakeholder and co-creator, able to continuously renew and replenish itself.

In practice, this requires a place-based approach built on an understanding of local conditions and established natural processes. A regenerative approach does not seek to recreate the pre-development ecosystem; but rather to understand how infrastructure, buildings and spaces can co-create with nature to perform the functions supported by those earlier ecosystems. By leveraging natural processes, this requires less energy. From decomposition and the cycling of nutrients to the capture and storage of water: how can our human-built systems participate in and positively contribute to the wider living system?

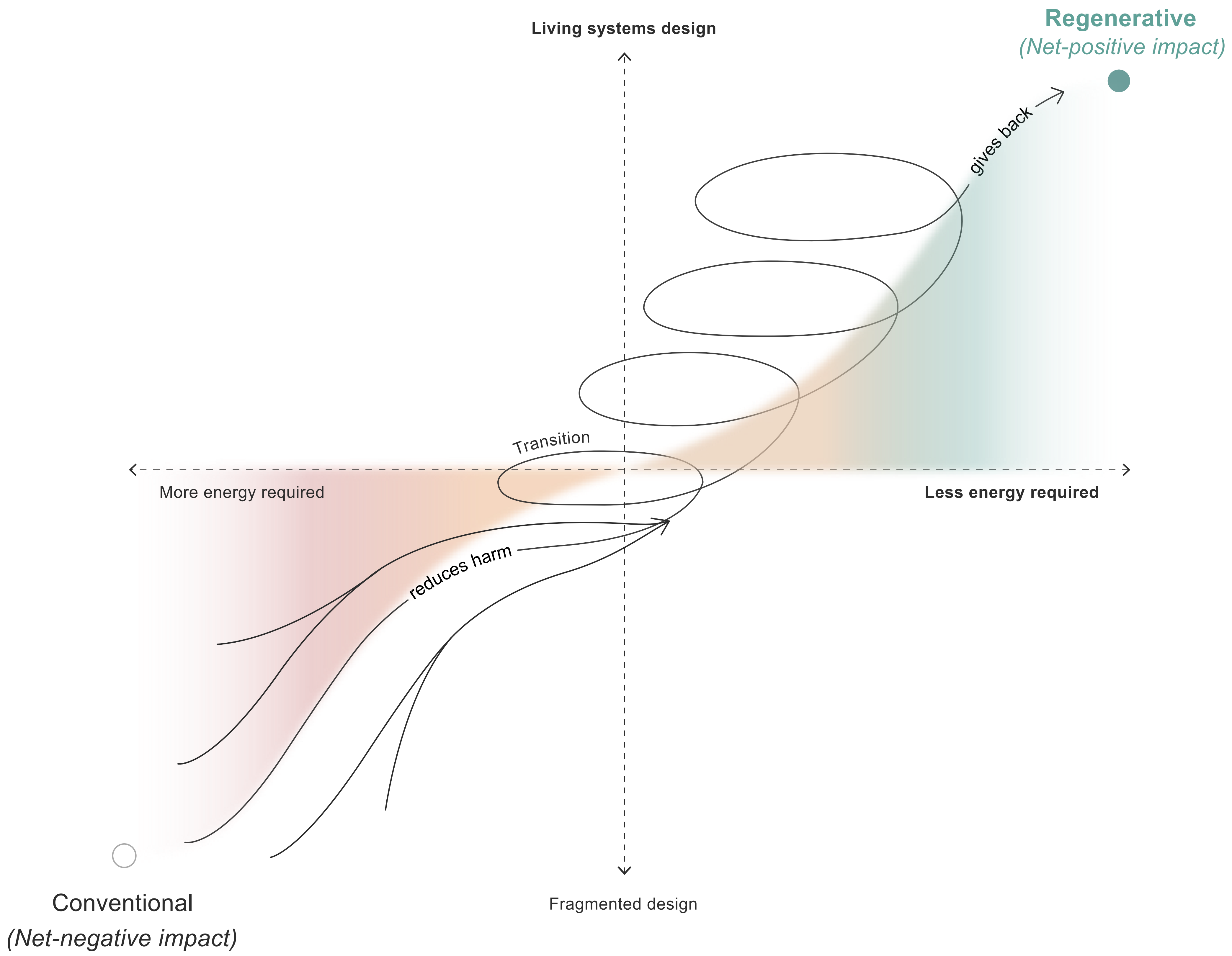


Figure 6: Transitioning towards regenerative outcomes
Adapted from Bill Reed (2007)[28]

The socio-economic case for regenerative design

As one of many species within an ecosystem, our health and survival depends upon planetary and ecosystem health. This is the basic premise of environmentalism. We are subject to the constraints of the natural environment in which our human ancestors evolved.[29] When we damage natural ecosystems and their biodiversity, we dismantle our own support system.

Nevertheless, many consider nature to be a resource from which to extract for human gain, as if we were separate from it. The biologist and naturalist E. O. Wilson, who studied the genetic basis of social behaviour of all animals, called this worldview "exemptionalism".[30] Exemptionalism is the belief that humankind is exempt from the laws of nature, and that we can find a solution to any crisis we face. Far from solving crises, this human-led approach keeps creating them.

The World Economic Forum's Global Risks Report 2024 ranks risks by severity over a 2-year and 10-year period. Environmental risks become increasingly prevalent over time, as seen in the diagram on this page. Climate change and nature loss are not separate crises: they are interlinked and mutually reinforcing. Critical change to Earth systems, biodiversity loss and ecosystem collapse, and natural resource shortages are major risks to people and planet. They cause or aggravate extreme weather events and diminish our ability to buffer against them.[31]

As such, our economies are highly dependent on planetary health: $44 trillion of economic value generation — over half the world's total GDP — is moderately or highly dependent on functioning natural processes, from crop pollination and fisheries to water regulation services.[32]

Yet, many of these processes are on the verge of collapse. The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) estimates that 25% of animal and plant species are threatened with extinction. This amounts to 1 million species over the next few decades.[33] The emphasis on these risks shows us the acute impact of human activity on the natural world, as well as the long-term health of people and the global economy.

Forgetting that we are subject to the laws of nature has made us most unusual. Robin Wall Kimmerer — a scientist, professor, enrolled member of the Citizen Potawatomi Nation, and founder and director of the Center for Native Peoples and the Environment — notes that, "Forces which sacrifice the natural world for so-called economic growth have forgotten that unlimited growth is not an ecological possibility. How strange to be a species that engineers its own demise."[34]

This is not inevitable. Reflecting what Indigenous peoples have long done, Kimmerer also says, "we can be co-creators of biodiversity and abundance when we do it right".[35] In short, we need design that is regenerative. The next chapter proposes three guiding principles to steer us towards a regenerative future.

> "We must understand that everything we do affects everything else, and that we must consider the consequences of our actions."
>
> — Sir Ove Arup[36]

	2 years		10 years
1	Misinformation and disinformation	1	Extreme weather events
2	Extreme weather events	2	Critical change to Earth systems
3	Societal polarisation	3	Biodiversity loss and ecosystem collapse
4	Cyber insecurity	4	Natural resouce shortages
5	Interstate armed conflict	5	Misinformation and disinformation
6	Lack of economic opportunity	6	Adverse outcomes of AI technologies
7	Inflation	7	Involuntary migration
8	Involuntary migration	8	Cyber insecurity
9	Economic downturn	9	Societal polarisation
10	Pollution	10	Pollution

Risk categories: Societal, Technological, Environmental, Economic, Geopolitical

Figure 7: Global risks ranked by severity over the short- and long-term
World Economic Forum Global Risks Perception Survey 2023-2024[37]

The guiding principles

Regenerative design in practice

In this chapter:

- Nature-led
- Systemic
- Equitable

The guiding principles

This section describes three complementary design principles that we can adopt to guide our transition toward a regenerative design practice. They are intended to inspire and equip, and include evidence to demonstrate the art of the possible.

– **Nature-led:** *place-based design that enhances and emulates natural systems*

– Life's Principles

– Place-based design

– Planetary health

– **Systemic**: *relationships, exchanges and flows of materials and resources that restore, protect and replenish*

– Systems thinking

– Nature compatible

– Circular infrastructure

– **Equitable**: *collective change, co-creation and collaboration that ensure inclusivity and social justice*

– Biosphere economy

– Just social foundations

– Contextual stewardship

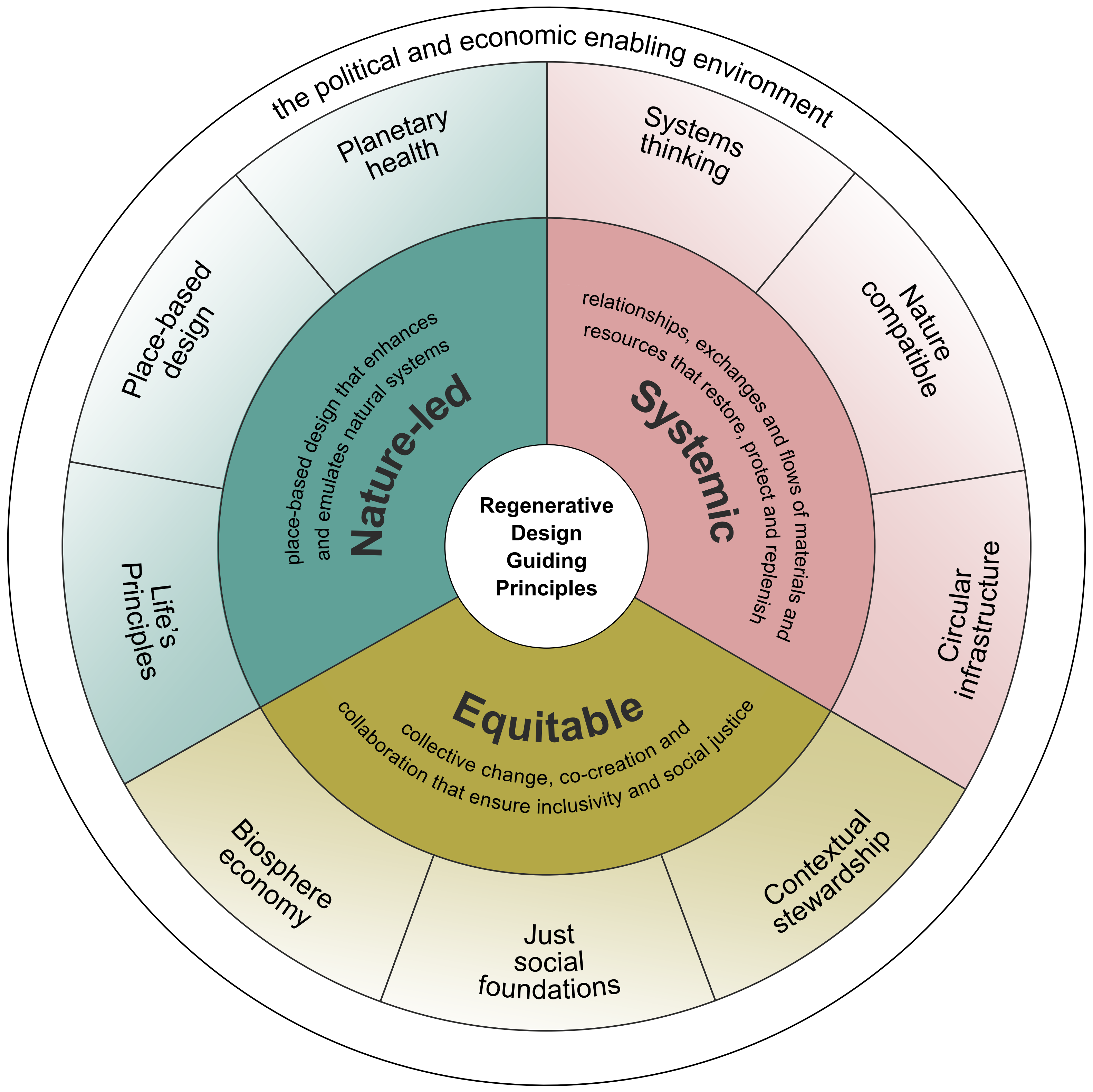
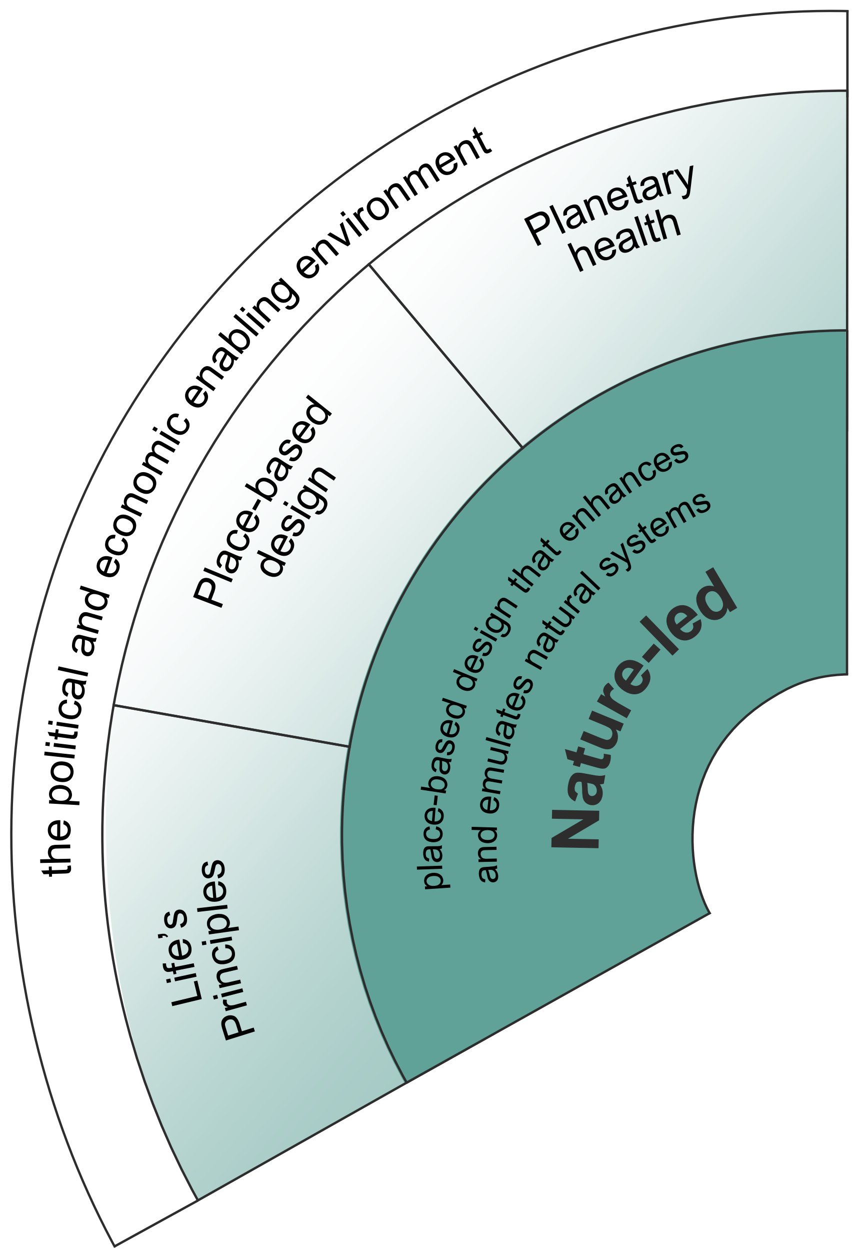


Figure 8: Regenerative Design Guiding Principles
Arup


Nature-led
© Arup

Nature-led



Nature-led
Life's Principles
– Mimic life's unique adaptations
– Utilise living organisms and biological materials
– Partner with nature as infrastructure
Place-based design
– Be locally attuned and responsive
– Integrate rather than segregate
– Capture and grow surpluses in the system
Planetary health
– Understand our place in the living system
– Reconnect natural cycles where we disrupt them
– Support the web of life

We are part of the Earth's living system. To sustain its underlying patterns of health and resilience, regenerative design enables natural systems to lead development by adopting 'Life's Principles' and reconnecting natural cycles where we disrupt them. This means designing *for* nature by giving it space to flourish, and designing *with* nature to leverage the adaptations of 3.8 billion years of evolution.

Rather than imposing human-centric — one size fits all — industrial systems on nature, nature-led design takes root in the local geography and climate. Just as each organism within an ecosystem has a role to play in its wider functioning and health, each component within a human system should give to and receive from its neighbours. This way, it participates in nature's cycles in a positive, reinforcing way.[38]

Because we are a part of the living systems, all human activity — from manufacturing to agriculture and wastewater treatment — will function best, and be more in harmony with ecological processes, when nature is the model and guide. When there is a problem to solve, local species have often already evolved to solve it.

In practice, this means: conserve water like the surrounding flora and fauna; network and communicate with or like mycelial networks; decompose waste with the many organisms evolved to do so; model a circular economy on a flourishing ecosystem.

Regenerative design lets nature shape human-built forms by integrating with, and leveraging, ecosystem functions and processes. It enables humans to live in harmony with natural cycles; thus ensuring resilience through planetary health.

Life’s Principles

“We are still beholden to ecological laws, the same as any other life-form.”

— Janine Benyus, biologist and author of *Biomimicry: Innovation Inspired by Nature*[39]

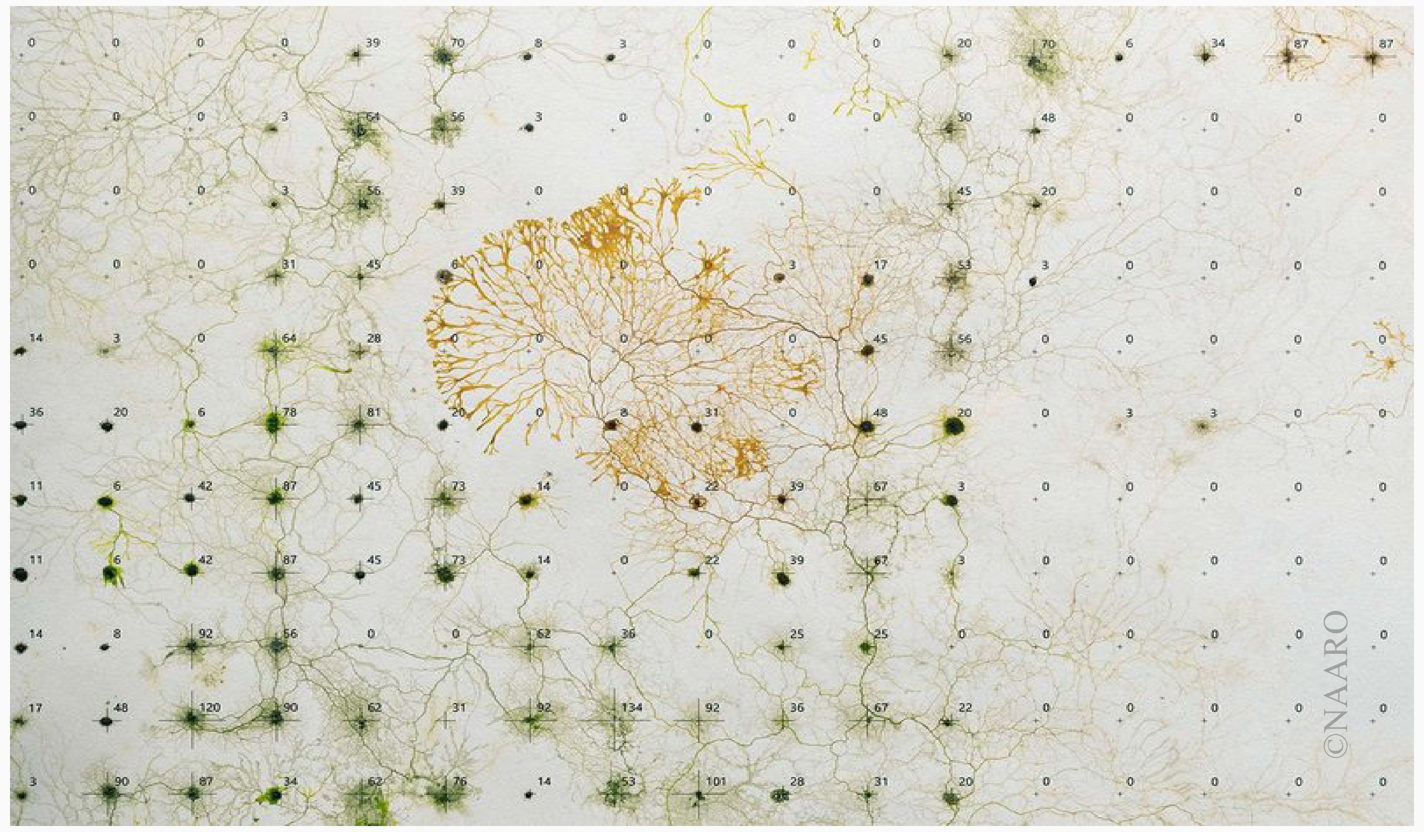
Life’s principles
– Mimic life’s unique adaptations
– Utilise living organisms and biological materials
– Partner with nature as infrastructure

Life’s Principles are design lessons from nature. First articulated by biologist Janine Benyus, they represent the overarching patterns found amongst the species surviving and thriving on Earth.[40] These Principles are rooted in the understanding that life on Earth is interconnected, interdependent and subject to a common set of operating conditions. They encompass design concepts such as using waste as a resource, fitting form to function, optimising rather than maximising, banking on diversity for resilience, and rewarding cooperation to foster symbiotic relationships.

Life has had a head start on human technology. Over the course of 3.8 billion years on Earth, it has been taking part in natural ‘research & development’ as evolution has selected the most efficient and optimal designs and discarded the non-functional ones.[41] Local plants, animals and ecologies have evolved to thrive in the specific climatic conditions and resource constraints.[42] When we learn from and incorporate their unique adaptations, we can design human systems that are well integrated with the local ecosystem. [43]

Life’s Principles reveal how nature overcomes disturbance, adapts to change and prolongs existence on an ever-changing landscape. They are a both a model and a metric, inspiring innovative strategies and enabling us to measure our designs against the tried-and-tested strategies that life has evolved to create and maintain conditions conducive to its continuity.[44] By following them, we can create systems that not only sustainably meet human needs but also contribute positively to the surrounding environment – promoting resilience, efficiency and harmony with the wider natural system.

+ Exemplar case study Read more



Slime mould urban planning[45,46]

Location: London, United Kingdom; Paris, France

– Mimic life's unique adaptations

Biomimicry is a scientific, research-based practice that learns from, and emulates strategies found in nature to solve human design challenges and create more life-compatible technologies. Biomimicry operates on different scales: organism, behaviour and ecosystem.[47] It can take inspiration from the coordination of a hive, the pathfinding of slime mould to optimise complex systems, or even replicating a termite mound's cooling technologies in a building design. The greatest regenerative outcomes are realised when biomimicry is applied at system scale, learning from ecosystems to build in self-regulation in a closed loop system.

In ecosystems, materials and energy are costly, but complex geometry is free. Organisms must be resource efficient, preferring what is freely available and easily accessible — such as sunlight, wind currents, and commonly occurring local minerals — over what is scarce.

Organisms assemble the materials that make up their bodies and habitats at ambient temperature and pressure, using precisely what they need for optimal performance. For example, the distribution of mass in a bone is structurally optimised to bear weight while reducing material need. Life's chemistry is water-based and life-friendly, using a limited subset of materials of only 28 out of 118 elements in the periodic table.[48] Eleven of these are found in all organisms, including four of the most abundant elements in the atmosphere: carbon, hydrogen, nitrogen and oxygen. [49]

– Utilise living organisms and biological materials

Bioutilisation is the process of using biologically derived materials or the services of living organisms in a designed product, process or system.[50] Living organisms have evolved to solve many of the same challenges that we seek to re-engineer with our technologies, within similar contexts and resource constraints. Yet, they do so in an elegant, sustainable manner. Bioutilisation is particularly useful in cases where replicating complex biological machinery or processes in our own technologies is beyond our capabilities, too time-intensive or too energy-intensive to be cost-effective.[51]

Examples of bioutilisation include applying fungi and microbes to treat waste and using fermentation to produce materials, such as spider silk. In the case of spider silk, fermentation produces biodegradable powder at 37°C that can be formed into a fibre, film or gel. The fibre is lightweight with a tensile strength about five times that of steel, similar to that of Kevlar and significantly higher than that of silk, rubber or nylon.[52]

+ Exemplar case study Read more

Riyadh Bioremediation Facility – Wadi Hanifa Wetland[53]
Location: Riyadh, Saudi Arabia

+ Exemplar case study Read more

Abalone shell inspiring high-performance ceramics[54]
Location: Global

– Partner with nature as infrastructure

At landscape scale, the best way to align with Life's Principles is to maximise the intactness of ecosystems. At the urban scale, it is about strategic integration. Nature-based solutions are actions to "protect, sustainably manage, and restore natural and modified ecosystems that address societal challenges effectively and adaptively, simultaneously benefiting people and nature".[55]

For example, incorporating green roofs, permeable surfaces and natural water retention features in urban design can enhance stormwater management, recharge groundwater supplies and reduce the urban heat island effect — all the while providing cultural space that enhances wellbeing. Mangroves, which dissipate storm surges at the same time as they provide habitat for fisheries and a range of cultural services, avert $57 billion in flooding damages in China, India, Mexico, the US and Vietnam every year.[56] Effectively, the objective is to restore the capacity of ecosystems to function at optimal health, for the mutual benefit of both human and non-human life.

+ Exemplar case study Read more

Habitat Royale[57]

Location: Amsterdam, The Netherlands

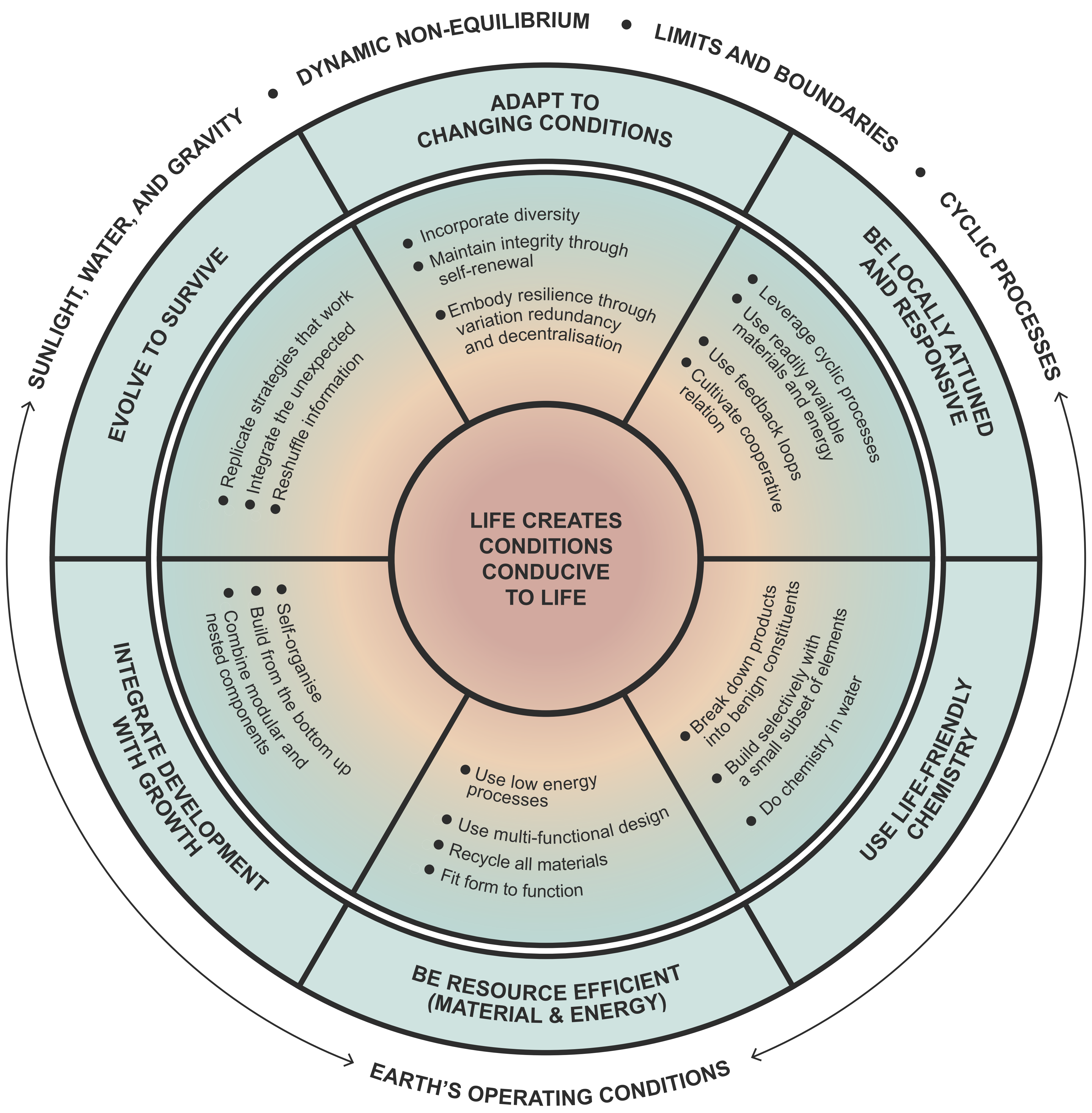


Figure 9: Life's Principles
Adapted from Biomimicry 3.8[58]

Place-based design

"Where nature evolved an ever-varying, endlessly complex network of unique places adapted to local conditions… humans have designed readily manageable uniformity."

— John Tillman Lyle, landscape architect and author of the seminal text *Regenerative Design for Sustainable Development* (1994)[59]

Place-based design
– Be locally attuned and responsive
– Integrate rather than segregate
– Capture and grow surpluses in the system

'Place' is a unique, multi-layered, dynamic network of natural and human systems within a geographic region. Natural systems are characterised by factors including their climate, species composition, mineral and other deposits, soil, water, and geological features. Human systems include cultural norms and values, economic activities, traditions, and physical artefacts such as buildings and infrastructure.

Place, then, is a socio-ecological whole that results from these systems' complex interactions through time. Taking a place-based approach means to work within the local complexity and variability, rather than to impose a universal system that seeks to control the place. It means to be a 'gardener' rather than a 'carpenter': that is, to leverage human interventions and development so as to achieve greater systemic health through time for the place we occupy and depend on.[60]

Permaculture is an example of a place-based approach, derived from a study of the natural world and pre-industrial, sustainable societies. As a design methodology, it is grounded by three core ethics that guide all decisions: care for the Earth, care for people, return the surplus. Place, including natural and human systems, is a key stakeholder in all decisions and a co-creator of designs. Through permaculture, humans co-evolve as part of the local living system, nourishing the land by returning surpluses rather than depleting it, so that it is richer for our presence.

– Be locally attuned and responsive

Regenerative design is informed by the richest possible understanding of the evolution and dynamics of a place. It asks what the local features and forces are that need to be designed for. From the climate, topography, waterways, soils, vegetation, wildlife, and wind through to culture, community, economy, and tradition: regenerative design responds to and embraces the dynamic network of natural and human ecosystems with a geographic region, considering all materials and energies in flow in the ecosystem that affect or are affected by design interventions.

Understanding the dynamics of a place enables interventions that achieve greater systemic health over time as a result of human presence in that place. For example, some environmental conditions change in a cyclic pattern, such as tides, day and night, seasons, and annual floods or fires. A regenerative system dynamically responds to these changes, seeing them as an opportunity rather than a disruption; with good design, a seasonal flood is an opportunity to capture and store water in the landscape and build abundance.

– Integrate rather than segregate

Throughout the living world, from the internal workings of organisms to the dynamic relationships between bacteria, fungi and plants in the soil food web, the interconnections between elements are as vital as the elements themselves. Similarly, to support the self-regulation of our human systems, each element should be designed to serve the needs, and accept the products, of other elements. For example, co-locating biochar production at walnut processing site creates value from the waste stream of shells in the form of energy production and stored carbon, as well as a soil amendment to improve the productivity and resilience of crops. The practice of scaling up this integration in our human systems is often termed industrial symbiosis or industrial ecology (see ‘view the city as an ecosystem’ in the ‘systemic’ section for more).

This holistic perspective recognises that diversity, redundancy, and feedback mechanisms are essential for resilience, enabling systems to adapt to disturbances, maintain stability, and thrive over time. In a resilient system, each element performs multiple functions, and each important function is supported by many elements. More relationships between parts of the system make for more resilience. Built and human systems that are well integrated into natural systems can benefit from the evolved symbiosis and resilience of the ecosystem.

– Capture and grow surpluses in the system

Regenerative design captures flows of renewable, and surpluses of non-renewable energy to re-build ‘capital’ for future needs. This is part of the intergenerational stewardship of a place. For instance, cultivating biomass, which is the result of plants’ turning photons into carbohydrates, stores energy in a landscape. Water can be caught and stored in ponds, reservoirs, and depleted aquifers. Rebuilding healthy soils by returning organic matter retains rainfall and nutrients, stores carbon, and enables the cultivation of food.

This can happen over different time scales. When the sun is shining, excess solar energy can be stored in the form of potential energy by pumping water to elevation. Thermal mass can be leveraged to store the heat of the sun during the day so that it can be slowly re-radiated during cold nights and similarly keep things cool during the day as temperatures rise, serving to average out extremes.. Sustainable forestry practices that balance selective logging with reforestation efforts can maintain or increase forest cover over time. In all contexts, stewardship requires proactive resource management that seeks to reduce extractive pressures build abundance over time.

+ Exemplar case study Read more

Passive cooling like a termite mound[61]

Location: Harare, Zimbabwe, Africa

+ Exemplar case study Read more

Seawater agriculture[62,63,64]

Location: Massawa, Eritrea, Africa

Planetary health

Enabling healthy natural systems means designing for nature, giving it space to flourish and actively intervening to reconnect natural cycles where we disrupt them. By working in harmony with nature as a co-creator and key stakeholder in the planning and design processes, we embrace its complexity and variability rather than trying to control it.

Planetary health
– Understand our place in the living system
– Reconnect natural cycles where we disrupt them
– Support the web of life

Healthy ecosystems naturally provide a range of services that underpin the resilience of our society and economy. Mangroves, coral reefs, seagrass meadows and other coastal habitats, for instance, dissipate wave energy to protect against storm surges, stabilise sediment for erosion control, and provide essential breeding habitats to support fisheries. Inland, thriving ecosystems prevent run-off by slowing down and storing rainfall in healthy, absorbent soils stabilised by deep root systems. This mitigates flooding, erosion and drought, and it improves water quality at the same time.

To ensure that the Earth remains habitable for its current and future residents, we as a species must support the factors that underpin this web of life. This requires, fundamentally, the creation of space for the variety of genetic and functional characteristics within a population. Rich diversity contributes to an ecosystem's long-term capacity to cope with shocks and adapt to change. In practice, this means restoring habitats, with a particular focus on the maintenance of ecosystem functions, and allowing movement between them.

A key mechanism for safeguarding planetary health is including nature as a key stakeholder in planning and design decisions.

+ Exemplar case study Read more

Sponge cities: using AI to measure green and blue space[65]

Location: Auckland; Nairobi; Singapore; Mumbai; New York City; Shanghai; London; Sydney

– Understand our place in the living system

Becoming regenerative at an impactful scale requires a full appreciation of the core services that healthy natural systems provide to human systems, such as the regulation and storage of water in a forested catchment. Ultimately, this means establishing, and designing within, science-based limits to our impact on Earth system processes (such as freshwater flows or nutrient cycles). The planetary boundaries framework is a strong example of this.

It is also essential to understand systemic interdependencies; monitoring and predicting the interaction between natural phenomena and human activities. New technologies such as remote sensing and artificial intelligence (AI) can help us to monitor systems' health. Advanced modelling can simulate the positive socio-economic outcomes of regenerative interventions by integrating data from natural and human-made systems.

– Reconnect natural cycles where we disrupt them

Urban and artificial systems interfere with Earth system processes. This happens locally in the form of habitat destruction from land system change and pollution; urban heat altering rainfall patterns; impermeable paved surfaces that inhibit groundwater recharge; and night-time external illumination that disrupts natural patterns of wildlife. It happens globally, too: the consumption and release of resources and pollutants disrupt the provision of ecosystem services and cycling of energy, nutrients, water and carbon.

Where human development interferes with natural systems, engineered interventions that are co-created and inspired by thriving ecosystems can help reconnect flows and cycles. This might be managed aquifer recharge through constructed wetlands and bioswales, or the recovery and useful application of nutrients in sewage.

The objective of an ecosystems-based approach is not to recreate the pre-development ecosystem, but instead to understand how infrastructure, buildings, and spaces can co-create with nature to perform the functions and processes those earlier ecosystems provided.[66] Just as each organism within an ecosystem has a role to play within the wider functioning and health, each component within a human-built system should give to and receive from its neighbours and participate in nature's cycles (e.g., water, carbon, nutrients) in a reinforcing rather than damaging way.

– Support the web of life

When ecosystems have been degraded, they can regenerate on their own. But it takes time. We can jumpstart biological activity by supporting the factors that underpin the web of life: soil stabilisation, water capture and storage, and decomposition of matter.

Fundamental to building healthy soils is stabilising them against erosion by cultivating deep root systems, as well as the associated mycelial networks and the wider soil food web. Together, they aerate soils and build structure to increase water infiltration and storage. Strategic earthworks such as on-contour swales and ponds also accelerate landscape hydration. By introducing native fungi, microbes, plants, and animals that colonise depleted landscapes and attenuate pollutants, and by returning organic matter to nourish these organisms, we can support life and the ecosystem functions that biodiversity it provides.

Rewilding and the reintroduction of so-called ecosystem engineers can further accelerate the restoration of natural environments.[67] Ecosystem engineers are species, such as beavers, that significantly modify their environment. They create new habitats for themselves or modify existing ones to suit their needs and, in doing so, provide and maintain microhabitats that would not otherwise exist. This allows other species to thrive, too. These 'engineers' participate positively in the wider ecosystem functioning.

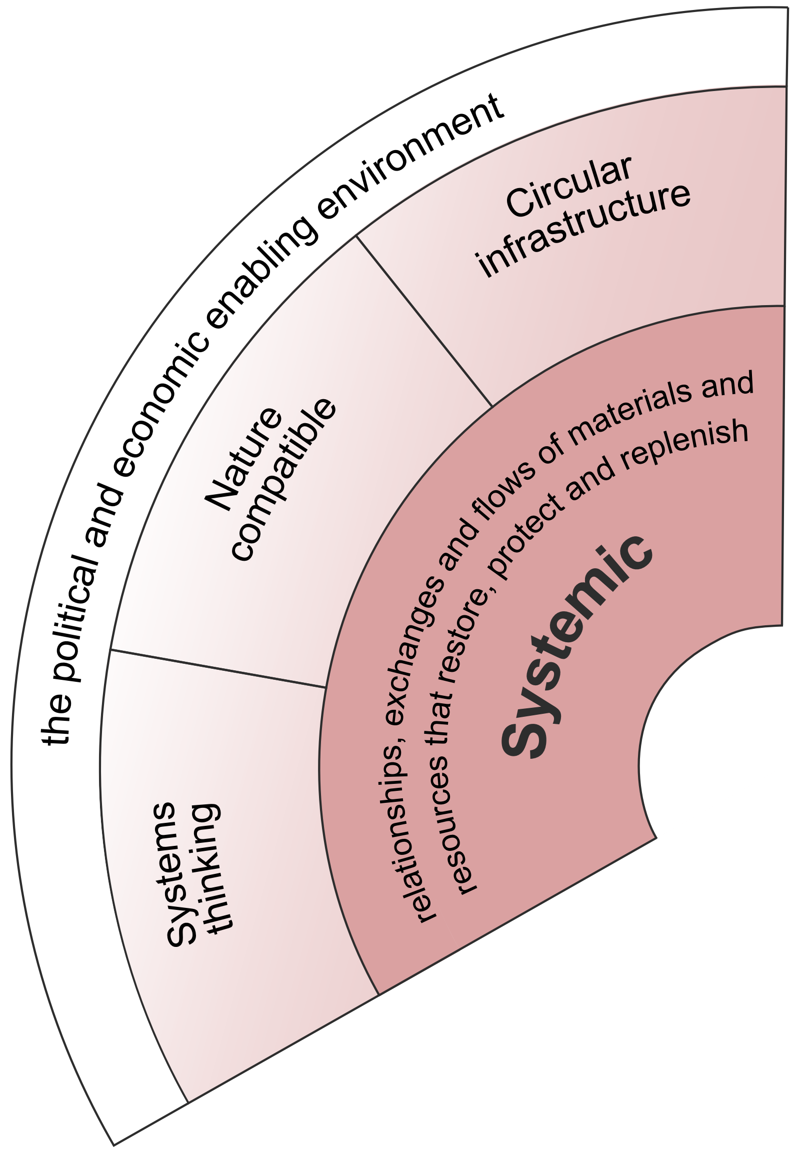
+ Exemplar case study Read more

Reintroduction of beavers, the ecosystem engineers[68,69]

Location: Great Britain

Systemic

Systemic



Systemic
Systems thinking
– View the city as an ecosystem
– Capture benefits at every exchange
– Break down silos with technology
Nature compatible
– Utilise life's toolbox
– Transition to biological resources
– Design for decomposition
Circular infrastructure
– Give land back to nature
– Adopt new business models to optimise lifecycle value
– Bioremediate waste and pollution

The human and natural worlds are arranged in systems of varying scale and complexity. Whether it be the flow of capital in an economy or the relationship between species in an ecosystem, these systems are all interconnected.

Understanding such systems and the dynamics between them is crucial to identifying design interventions that build synergies and create greater systemic health. This interconnected view enables us to think about how decisions made today will ripple through the environment, society and economy over time, thus giving weight to long-term outcomes rather than short-sighted gains. It also involves engaging with multiple stakeholders and perspectives, and co-creating solutions that are inclusive and equitable for all.

Our current human systems are wasteful. More than 100 billion tonnes of resources are extracted globally each year, of which just 7.2% are reused.[70] The losses in our dominant linear 'take, make, waste' economic model are unaccounted for economically; for instance, global GDP is linked to 99% of energy consumption and close to 100% of material use. With current economic forecasts predicted to grow by an average of 2-3% GDP growth per year, our energy and material use will double every 25 years.[71] At the same time, activities that degrade ecosystems are subsidised by an estimated $4-6 trillion per year.[72]

By identifying potential synergies within resource streams, it is possible to develop a system where a material's value is not lost at the end of its perceived life.

Regenerative design ensures human-made systems participate positively in the wider natural system. It guides us to understand interconnections between systems and helps us identify design interventions to build synergies; thus leading to greater systemic health.

Systems thinking

Build on a deep understanding of resource, material and nutrient flows to develop an interconnected ecosystem where 'waste' streams continue to create value and opportunities in a closed loop.

Systems thinking
– View the city as an ecosystem
– Capture benefits at every exchange
– Break down silos with technology

When we design our human systems, such as buildings or cities, we should not view them as isolated entities but as parts of a larger, interconnected whole. A systemic design approach considers how these components interact with and influence each other, and how the human system interacts with the wider natural system.

Energy, nutrients, water, people and more flow through these components, creating a dynamic and complex network. Each component within our human systems must understand its role in the functioning and health of the wider system, and how it can give to and receive from its neighbours in a positive, reinforcing way — just like an ecosystem.

Properly harnessed, urban 'waste' will facilitate growth and new life. The density of agglomeration in towns and cities presents the opportunity to capitalise on interdependencies by redirecting and reallocating existing waste streams, such as nutrients or energy. This complex network relies on technology to connect human and natural systems in creating the possibility of the Earth meeting people's needs and demands, while also remaining within its resource capacity.[73]

+ Exemplar case study Read more

Urban metabolism[74]

Location: Rotterdam, The Netherlands

– View the city as an ecosystem

Our cities only cover 2% of the world's land area but consume over 75% of the planet's material resources and generate 85% of global GDP.[75] Inputs that 'feed' our cities — freshwater, food, building materials, fossil fuels — lead to outputs, such as nutrient-rich wastewater, rubble and heat. The higher the utilisation rate of the inputs, the greater the growth and the smaller the impact a city will have on its surrounding environment. We can learn from ecosystems to optimise this.

This system of biomimetic infrastructure is called 'industrial ecology' or 'industrial symbiosis'.[76] Where networks emulate ecosystems through co-location and resource sharing, they increase the number of useful outputs from the same inputs by adding elements to the system that create more value. For example, rather than treating wastewater from beer, grow spirulina and use that water again for fish farming. The spent grains from brewing can be a substrate to grow mushrooms and, after harvest, fed to animals and used for earthworm rearing to feed chickens. Manure can be anaerobically digested to produce gas for the brewery. That is what the Tunweni Brewery in Namibia did, to produce 12 products instead of just one and seven times as much food, fuel and fertiliser, four times as many jobs, yet a fraction of the waste.[77]

– Capture benefits at every exchange

Every interaction within our human systems is an opportunity to create multiple benefits and shared value for all inhabitants. By diversifying use and cooperating with our neighbours, we can make full use of our urban infrastructure, buildings and spaces.

For example, we can design heat networks that reuse residual heat from industrial processes in housing rather than wasting it to the atmosphere. With an interconnected design view, green infrastructure to manage surface flooding will typically win out over grey infrastructure, because it understands and values the wider benefits for the socio-ecological system, including urban cooling, groundwater recharge, carbon storage, and physical and mental health benefits.

Every time we intervene in a system, we should intentionally design to optimise shared value and net-positive outcomes by incorporating multiple stakeholders and fostering synergistic relationships. This requires us to understand the nature and interdependence of relationships and immaterial abundances, being mindful of how changes can ripple through a system. As such, this calls for a growth in care, sharing, participation and collective intelligence as well as for investment in intangible, immaterial infrastructure that create new pathways of abundance.[78]

+ Exemplar case study Read more

Kalundborg Symbiosis[79]
Location: Kalundborg, Denmark

– Break down silos with technology

Advances in technology can provide a better understanding of our current natural and built systems, but only if data is shared as openly and widely as possible. This requires forward-thinking governance and a sense of collective responsibility for the future, with the aim to increase the value chain throughout the system.

Wider access to data — in the shape of data pooling or decentralised data sets — drives innovation. It develops opportunities to mitigate degradation and cultivate regenerative systems. Earth's most abundant lifeforms transmit a wealth of information — at present, far more than the current technosphere.[80] Improving access to this data would provide greater understanding of the complex biosphere.

For example, digital twins — that is, digital representations of a physical asset ranging from buildings to oceans — help us to understand the damaging effects human processes can have on built and natural systems.[81] These large data sets can also be accessed, processed and manipulated using other technologies, such as artificial intelligence, to observe the health of ecosystems — and to better understand the positive impacts that regenerative interventions have as we create closed-loop systems that grow and replenish nature.

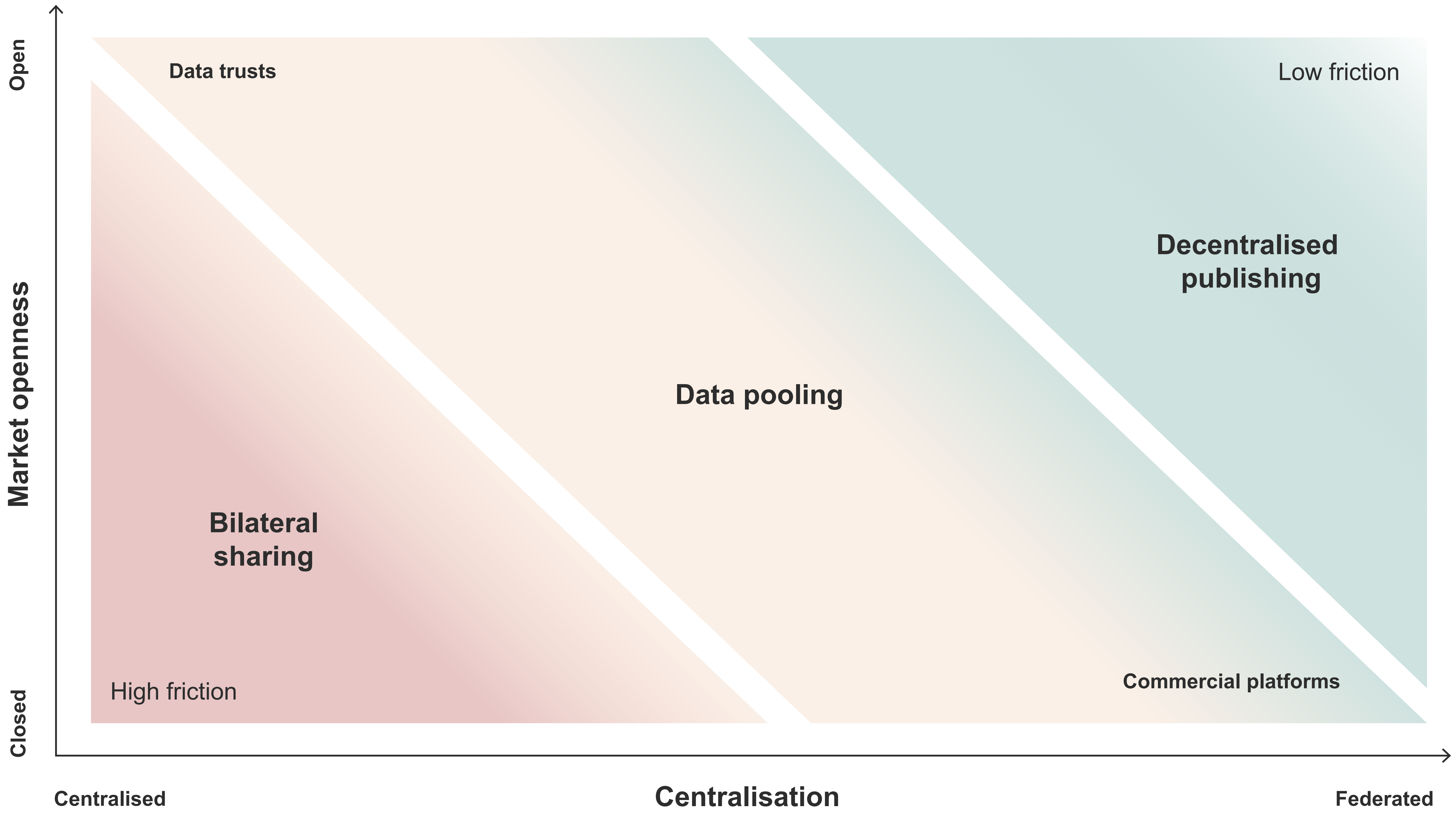


Figure 10: Exploring new approaches for sharing data in the built environment
Open Data Institute for Arup[82]

Systemic

Nature compatible

Working in harmony with biological cycles through regenerative material cultivation and life-friendly chemistry enables organic materials to be returned to natural systems.

Nature compatible
– Utilise life's toolbox
– Transition to biological resources
– Design for decomposition

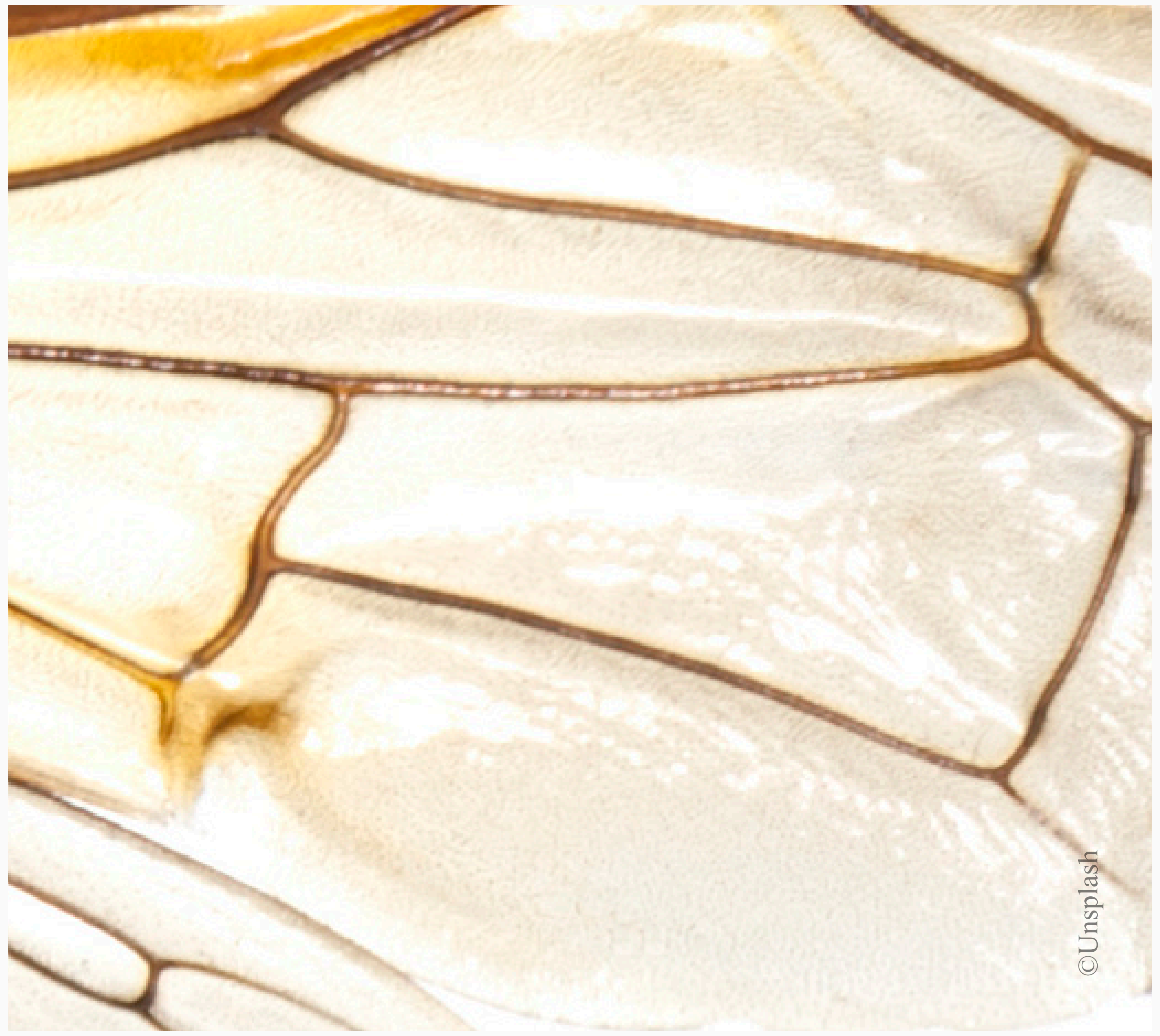
All of human activity — from manufacturing to agriculture and wastewater treatment — will function best, and be more in harmony with ecological processes, when nature is the model and guide (see Life's Principles section).

In 2020, a threshold was crossed. The mass of human-made things exceeded the mass of all living beings and biomass on Earth.[83] In 2023, just over a quarter of all resources extracted globally were organic materials (biomass), with fossil fuels, metal ores and non-metallic minerals making up the rest.[84] Due to our materials selection, manufacturing processes and limited recycling infrastructure, these materials largely cannot safely re-enter the environment or be reused. This is because most industrial chemistry is petroleum-based, happens at high temperature and pressure, and often involves toxins — which makes chemistry highly energy-intensive, dependent on non-renewable resources and hazardous to natural systems at the end of life.

Biological chemistry, on the other hand, is water-based and generally happens at ambient pressure and temperature. However, it is complicated and has been honed over billions of years of evolution that has tended towards increasing complexity. As a result, it has been challenging to understand and replicate. Yet, advances in science such as AI will support this transition by integrating nature as a guide.

If we use the right materials and processes from life's toolbox upfront, we can also leverage life's processes of decomposition and renewal to mitigate the need for landfills and mines.

+ Exemplar case study Read more



Aguahoja, Oxman[85]

Location: New York City, New York, United States

– Utilise life's toolbox

Growing the biological cycle and transitioning to more organic materials will require a mixture of technical innovation, as well as a deep understanding of nature and local contexts.[86] By adopting Life's Principles and toolbox (see Life's Principles section), it is possible to create a cycle that contributes to natural systems, instead of one that sends materials to sit idly or damagingly in landfills.

Engineered materials use a large variety of elements, often sourced from all over the world. They tend to be fabricated at high temperature and pressure and are often toxic to natural ecosystems. This is not only inefficient but also hard to biodegrade into useful constituents at the end of the lifecycle.

However, natural processes can be utilised to help transition away from such materials. Mycelium has the capacity to break down toxic, petroleum-based construction materials and to create low-carbon materials while preventing toxin run-off.[87] Carbon dioxide can be mineralised with a waste concrete substrate, capturing carbon and creating a new construction material. A combination of these innovations, along with the increased utilisation of low-energy materials, will enable a shift to a regenerative circular economy.

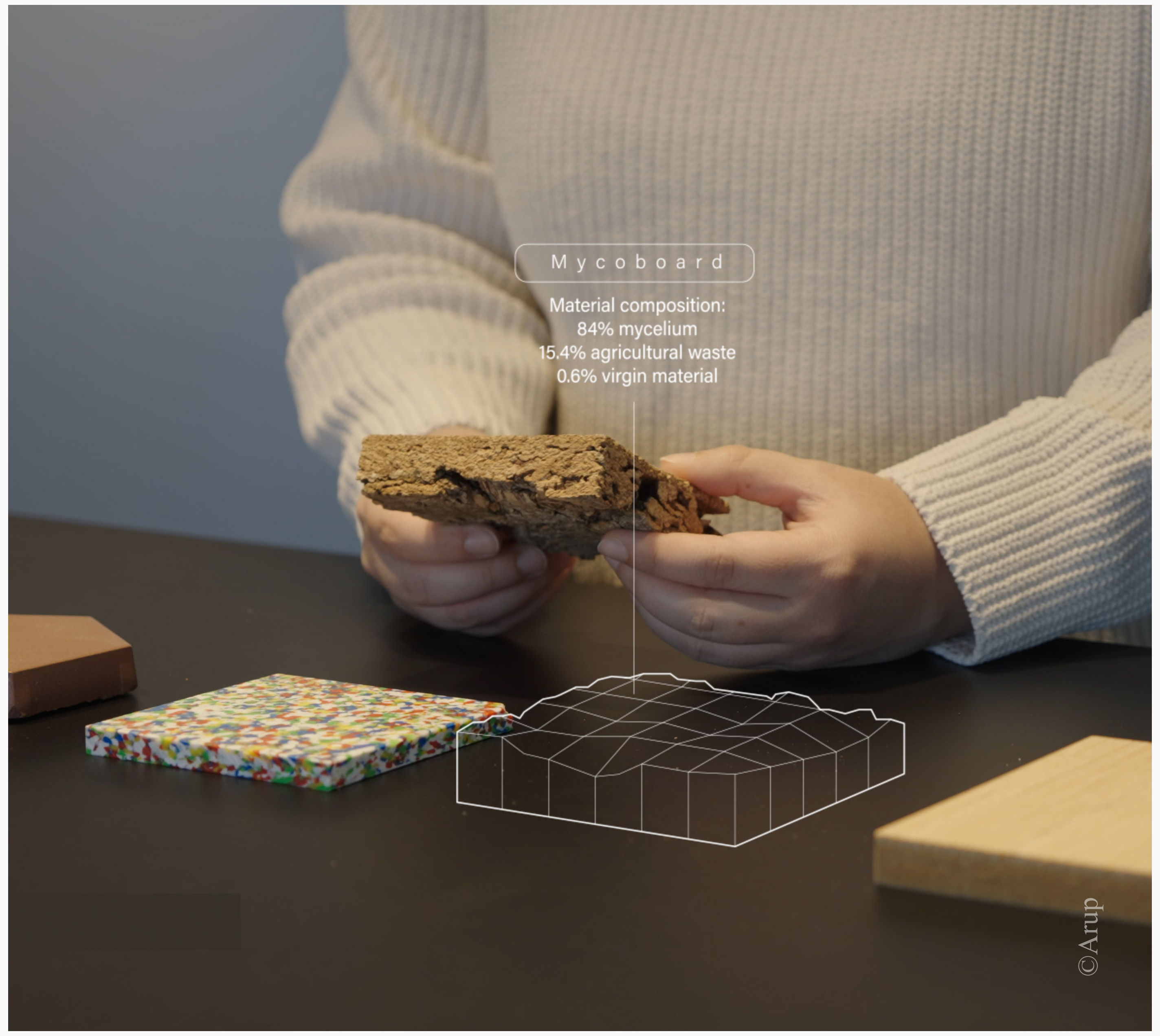
– Transition to biological resources

Organic materials have a significant role to play in a regenerative future. Unlike finite and manufactured materials used in the technical cycle, biological materials can flow in and out of natural and human cycles through processes such as composting and anaerobic digestion. Organic materials can also circulate through the technical cycle, being reused and remade, before rejoining the biological cycle.[88]

Location is key. Each city, town or building project takes place in a bioregion; a location defined by its soil, climate, native plants and animals. If utilised responsibly in the appropriate context, local resource streams can create a connection between the built and natural systems they sit within. Local resource loops avoid the offshoring of negative externalities, which puts pressure on producing nations rather than those consuming.[89]

Through innovation and with a greater understanding of natural processes, the biological cycle can be expanded. Natural alternatives are being developed through both low-tech solutions, such as rediscovering traditional building techniques, and high-tech solutions in synthetic biology and biomanufacturing. It is important that natural alternatives be cultivated in a responsible manner, recognising the local context and integrating regenerative agriculture.[90]

+ Exemplar case study Read more



Materiom[91]

Location: Global

– Design for decomposition

Once the original product or material has been used, as with the technical cycle, it is crucial that its value be recaptured. This will only be made possible through conscious design decisions from the outset. Designing out toxins from a material or product’s creation through to its end-of-life means that the elements can be reabsorbed and broken down naturally, unlocking their regenerative potential.

Artificial compounds, on the other hand, are not designed for end-of-life as they do not break down in the environment. Such ‘forever chemicals’, also known as PFAS, have been found at about 17,000 sites across the UK and Europe[92] and risk harming over 600 species across the globe when exposed.[93] The common methods for getting rid of PFAS may end up leading to further pollution,[94] and unless action is taken, about 4.4 million tonnes of PFAS will end up in the environment over the next 30 years.[95]

When design decisions set the parameters for decomposition, appropriate decomposition technologies can come into play to support the natural system.[96] Anaerobic digestion, for example, is a process that breaks down organic matter in the absence of oxygen. It produces biogas and a digestate which can be used as a nutrient-rich fertiliser.[97]

+ Exemplar case study Read more

Notpla[98,99,100]

Location: London, United Kingdom

Circular infrastructure

Creating a system that keeps products in circulation enables materials and resources to be reused, repaired, remanufactured or recycled. This reduces the need for extraction and enables nature to flourish.

Circular infrastructure
– Give land back to nature
– Adopt new business models to optimise lifecycle value
– Bioremediate waste and pollution

To transition to a regenerative world, we must use materials responsibly; that is, in a manner that reflects the energy required for the Earth to produce them and for people to obtain and process them. This is particularly the case when we appropriate Earth's materials, such as those that are mined, and when we use materials produced at high temperature or pressure. The responsible use of materials reduces the impact on the planet. It frees up degraded land to be regenerated, and it shrinks the energy demand for material processing.

Of the more than 2 billion tonnes of municipal solid waste generated by our human systems, just 19% is recycled or composted with the rest either ending up in an open dump (33%), landfill (37%) or incinerated (11%).[101] The technical cycle deals with materials and products that are not consumed during their use, such as metals and plastic. A regenerative technical cycle keeps products and materials in circulation, much in the same way as nature does. When using finite resources is unavoidable, it is crucial that products be designed such that they can be reused, repaired, remanufactured and recycled, with the necessary infrastructure in place to do so adequately. These processes reduce the need for extraction and thus, allow nature more space to flourish.[102]

Reusing and sharing materials must be prioritised with the remanufacture and recycling of materials considered as secondary alternatives. A product maintains the greatest value when it is whole and not split up into its constituent elements. By remanufacturing or recycling materials, they not only lose value, but the materials' properties are also impacted.[103]

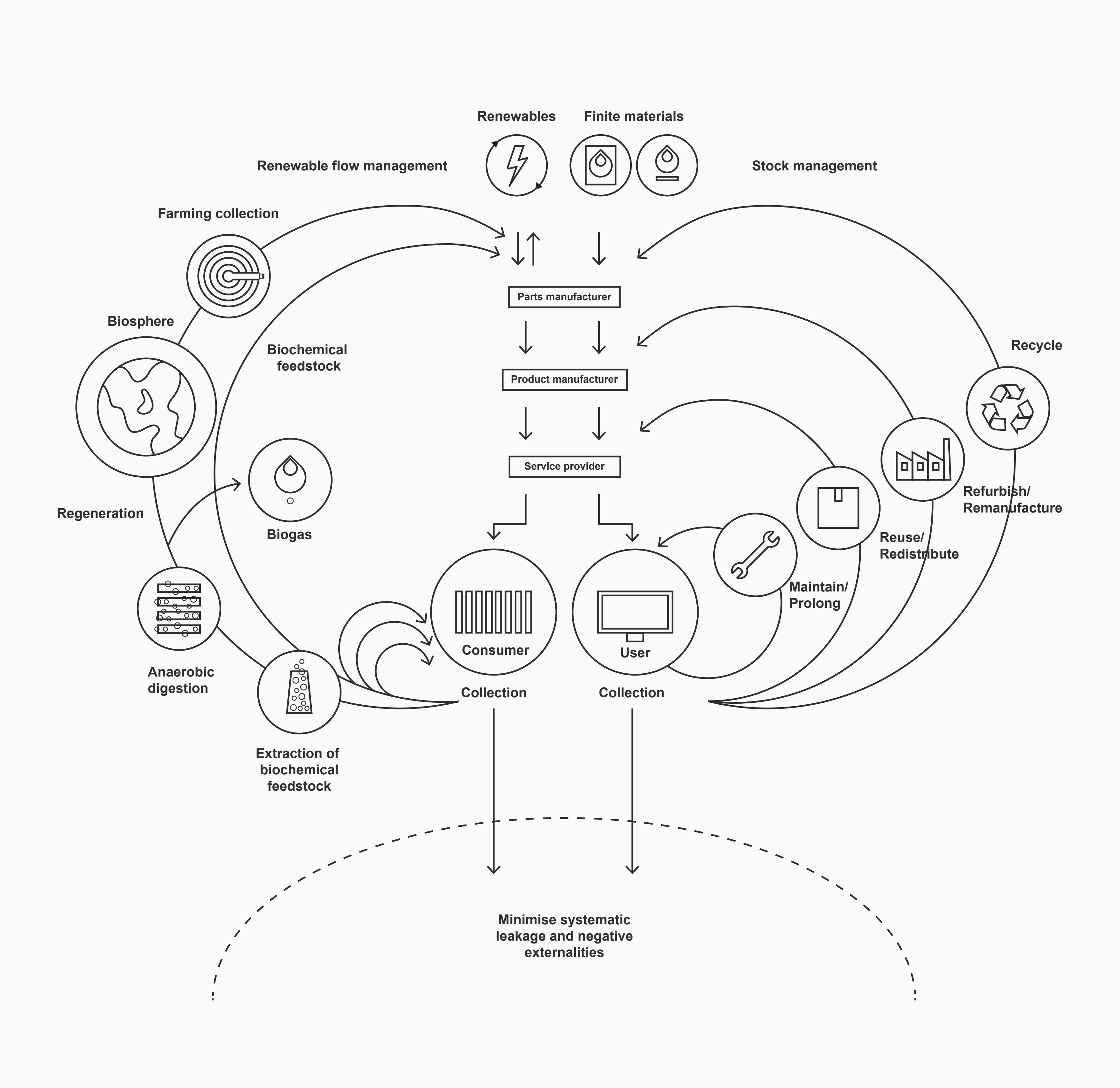


Figure 11: Circular economy systems butterfly diagram
Adapted from the Ellen MacArthur Foundation[104]

– Give land back to nature

Over 6 billion tonnes of waste are produced each year from torn-down buildings.[105] These resources must be harnessed. Developing the infrastructure to recover materials will reduce the demand on new extraction, and space that is otherwise used for extractive processes can be returned to nature.

Mining, for instance, fragments habitats, damages land, pollutes and depletes surrounding waters, and degrades soil.[106] Since 1960, on average, a land area equivalent to twice the size of Germany (720,000km²) has changed in use every year due to human activity.[107] Meanwhile, our oceans and waterways are being littered by materials and products, after a single use. Land use change is estimated to have affected 32% of global land area in just six decades (1960-2019), with about three-quarters of the Earth's land surface being altered by humans within the last millennium.[108] By circulating extracted materials so that they are reused or remade, we can give land back to nature and avoid new destruction. We can also regenerate sites previously used for extraction.

– Adopt new business models to optimise lifecycle value

The way we utilise resources and assets within the technical cycle is driven by our business models, with many privately owned assets currently underutilised. New economic and business models, such as the sharing economy and as-a-service models, increase the utilisation of assets from housing to vehicles, specialist tools and even clothes. At the same time, they build communities by creating new connections and a shared ownership of resources.[109]

Reuse and retrofit are enabled by design for long-term use and disassembly, decisions made at the conception of a product which optimise for durability and allow the constituent elements to be remanufactured. Regulation such as right to repair, and models that capture value from use rather than production, are key to incentivising better design upfront. Up to 90% of a product's environmental impact is influenced by decisions made at the design stage.[110]

New economic and business models must be properly regulated and monitored. If not managed appropriately, the sharing economy risks leading to increased inequality, less sustainable habits and a commodification of everyday life.[111]

+ Exemplar case study Read more

Arup Circular Buildings Toolkit[112]
Location: Global

+ Exemplar case study Read more

Freshkills Park[113,114,115]
Location: New York City, New York, United States

– Bioremediate waste and pollution

Bioremediation harnesses living organisms like fungi, bacteria and plants to treat pollution, including waste and contaminated land, water and air. These organisms absorb, accumulate and degrade pollutants, transforming them into harmless byproducts. The process is cheap, low-energy and scalable, as compared to conventional physicochemical treatment methods.

In mycoremediation, mycelium (the vegetative part of fungi) produces enzymes that break down heavy metals, organic pollutants, textile dyes, petroleum fuels and more. Mycoremediation is typically applied to soil, but Mycocycle is a company that uses the process to transform asphalt roofing tiles into low-carbon raw materials for the built environment.[116] Techniques such as bioventing and biosparging introduce oxygen and nutrients into contaminated soil to promote the growth of native microorganisms, while phytoremediation utilises plants to extract, stabilise, and/or degrade contaminants from soil and groundwater.[117] Bioremediation also plays a role in treating wastewater in degrading organic matter, removing nutrients and filtering contaminants. Living machines, for instance, mimic the natural processes of wetlands to treat wastewater.[118]

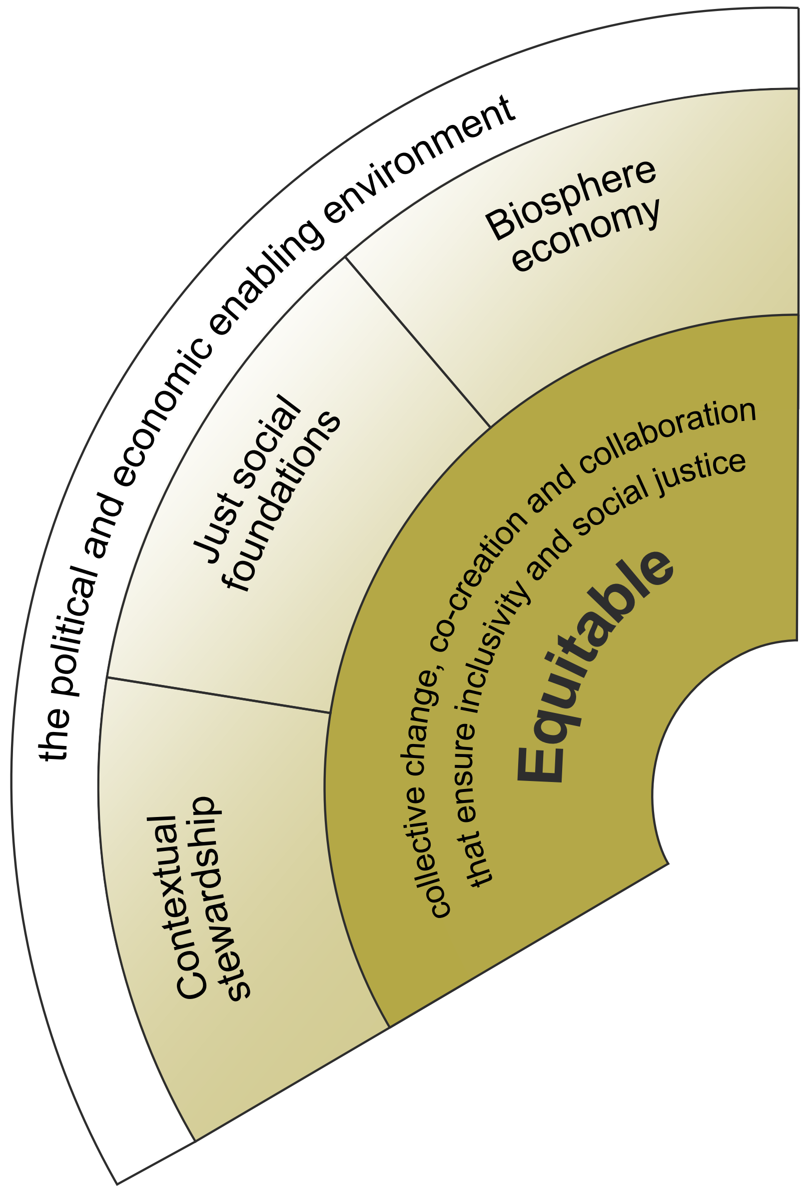
Various organisms can also degrade plastics through enzymatic activities. For instance, *Ideonella sakaiensis* bacteria can break down PET (polyethylene terephthalate) plastic used in bottles,[119] while fungi such as *Aspergillus* and *Penicillium* species degrade different plastic types.[120] Mealworms, beetle larvae, can consume and break down polystyrene foam, while waxworms can do so with polyethylene (used in plastic bags).[121]

+ Exemplar case study Read more

Construction waste in Singapore[122]
Location: Singapore, Asia


Equitable
© Arup

Equitable



Equitable
Biosphere economy
– Value planetary health
– Inform policy and regulations with science-based targets
– Coordinate action globally
Just social foundations
– Cultivate public luxury and the commons
– Co-create healthy and resilient communities
– Address historical inequalities with environmental justice
Contextual stewardship
– Integrate place-making with land stewardship
– Embed participatory and inclusive democracy
– Partner with Indigenous and traditional ecological stewards

The polycrisis — the knot of crises facing humanity — highlights our interconnectedness with each other and with the planet. Geopolitical tensions increasingly threaten our economies. Declines in nature are bringing species to the brink of extinction. Extreme weather events are affecting our food systems. Now more than ever, science-based targets and efficient collaborative efforts are needed to achieve positive systemic outcomes, locally and globally.

Respecting the planetary boundaries is integral to this. Our survival, and that of many other species, depend on our living within the planet's ecological limits. Yet, a successful transition also requires inclusive policies that ensure equitable social foundations. They in turn begin with acknowledging the past so we can address and repair environmental and social inequalities.

Celebrating local stewardship of the land, such as the long-standing practices and traditions of Indigenous peoples, will further ensure that everything we do in the physical environment is in the safe operating space of nature. Nurturing a just space for humanity is how we ensure regenerative outcomes are equitable.[123] This way, both people *and* the planet will thrive.

Regenerative design guides us to nurture a just space for humanity by prioritising the biosphere that supports us all. It maximises harmony and justice through equitable nature, climate and social targets; thus ensuring human health and wellbeing.

Equitable

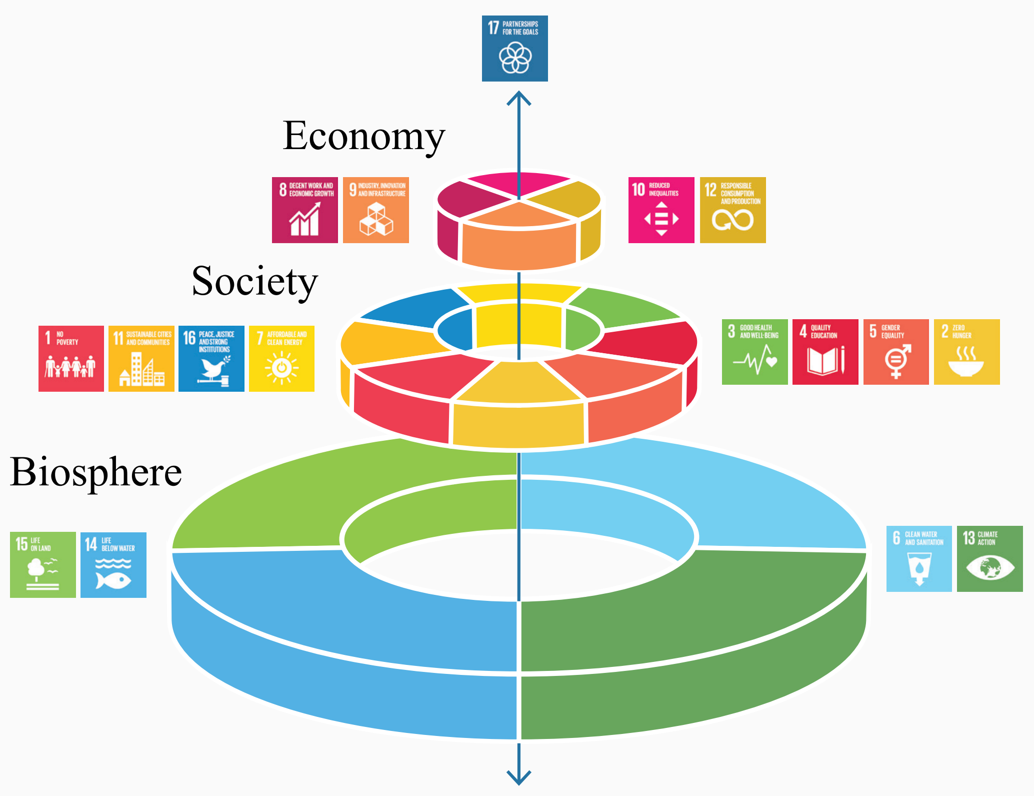
Biosphere economy

"We came all this way to explore the Moon, and the most important thing is that we discovered the Earth."

— Bill Anders, NASA Apollo 8 astronaut and photographer of *Earthrise*[124]

Biosphere economy
– Value planetary health
– Inform policy and regulations with science-based targets
– Coordinate action globally

Rather than seeing social, economic and environmental factors as three distinct fields — as has too often been the case in the debate — there is now a push to view societies and economies as embedded parts of the biosphere.[125] This biocentric perspective encourages humans to reconnect to the life-supporting ecosystems that provide us with a hospitable climate, clean water, food and other goods and services. In turn, this enables us to create societies, economies, targets and policies that enable planetary health.[126] This embeddedness is depicted in the United Nations Sustainable Development Goals (UN SDGs) 'wedding cake' image as seen here.



The SDGs wedding cake

Economy & society as embedded parts of biosphere (Stockholm Resilience Centre)[127]

– Value planetary health

Understanding that people and nature are interdependent socio-ecological systems ensures a shift in perspective that values the health of the planet.[128] To achieve a regenerative future, our social and economic models must transition away from prioritising narrow financial gain towards a model in which nature is always a principal stakeholder. Reframing our approach in this way reflects our responsibility to repair the environmental damage we have caused and to regenerate planetary health.

Practical ways we can value planetary health in our systems can take many forms. Incorporating green and blue infrastructure in all our designs, such as native plants and wetlands, delivers wide-ranging co-benefits for all participants. Prioritising locally grown agriculture and urban farming initiatives creates jobs, increases food supply and generates positive health outcomes for communities. Capitalising on the collateral and long-term value achieved through regenerative design helps move beyond immediate profit and GDP: increased mental and physical health or enhanced urban resilience, for instance, represent not only value in themselves but also future savings.

– Inform policy and regulations with science-based targets

Regenerative design requires us to have a positive impact on all natural systems. To achieve this at scale, new policies and frameworks must incorporate science-based targets that respect the planet's ecological limits. 'Do no significant harm' is not sufficient. Regulation must enable positive outcomes for people, place and planet: revive natural systems, strengthen local communities and ensure the infrastructure and processes that drive the economy are circular and regenerative rather than linear and extractive.[129]

Only long-term thinking that prioritises nature as a stakeholder and includes future generations can hope to be successful. Such policymaking must also learn from traditional and Indigenous peoples, whose knowledge as historical custodians of the land is integral to this. They have thrived alongside nature for millennia.

Some countries are already starting to think in this way. In Wales, the Senedd passed the Well-being of Future Generations (Wales) Act 2015.[130] This act was created to align with the UN SDGs and "requires Welsh public bodies to think about the long-term impacts of their decisions, to work better with people, communities, and each other, and to combat deep-rooted societal problems such as poverty, health inequalities, and climate change".[131]

– Coordinate action globally

The global reach of the nature and climate crises demands that we develop solutions through strong partnerships. An interconnected and coordinated approach is necessary to influence emerging practice and policy, share best practice and catalyse the regenerative transition. This does not preclude adaptation to the specificity of local conditions, but indeed helps guide it.

The UN's 'Our Common Agenda' is an example of this. It is a set of actions to accelerate the implementation of existing agreements including the UN SDGs and the 2030 Agenda.[132] It includes recommendations across four areas: renewed solidarity between peoples and future generations; a new social contract anchored in human rights; better management of critical global commons; and global public goods that deliver equitably and sustainably for all.

Another instance of a science-based, global approach is The Intergovernmental Panel on Climate Change (IPCC)'s Sixth Assessment Report (2022). It assesses the impacts of climate change through an examination of ecosystems, biodiversity and human communities at global and regional levels. The report considers vulnerabilities of nature and the capacity of societies to adapt to climate change.[133] To disseminate this scientific information, the IPCC produced a supporting Summary for Policymakers, which provides a concise narrative on observed and projected impacts and risks, benefits of adaptation, and more, to catalyse political transformation.[134] To support the systems change needed to resolve the worldwide crises we are currently facing, we need a hyper-connected community of governments, corporations, organisations and citizens, all working together to provide regenerative solutions.[135]

+ Exemplar case study Read more

Safe and just Earth system boundaries[136]

Location: Global

Equitable

Just social foundations

"We need to meet the needs of all within the means of the planet. Bring everybody over the social foundation but to do so within the planetary boundaries. To me, that's the 21st-century definition of human progress and it's about creating a thriving balance between those two."

— Kate Raworth, economist and creator of doughnut economics[137]

Just social foundations
– Cultivate public luxury and the commons
– Co-create healthy and resilient communities
– Address historical inequalities with environmental justice

For people truly to thrive, humanity needs to co-evolve as part of nature. This requires a rediscovery of what it means to be a citizen, as we are all inhabitants within the shared living system. A healthy society requires the establishment of equitable social foundations, while the economy shifts from extractive towards regenerative. For this transition to be just, communities must not be left behind and ecologically resilient outcomes should be cultivated for all places.[138]

Collaborative local and global efforts to regenerate the health of the biosphere will result in a renewed common perspective and awareness to the importance of human health. Increasing access to opportunities and shared resources, and creating equity through redressing past harms, will catalyse systemic change to ensure all humans can be well.

Earthrise

Taken by Apollo 8 astronaut Bill Anders during lunar orbit (NASA, 1968)[139]

– Cultivate public luxury and the commons

"Private sufficiency, public luxury" is a phrase used by George Monbiot, a British author known for environmental and political activism.[140] The underlying premise is that, because our resources are limited, we should use space more intelligently and prioritise public amenities, such as transport and goods, to create better conditions and spread resources amongst the many, not an elite few.

The commons is an approach to distribute wealth amongst communities in which all people have open access to a resource. It relates to distributive justice, which focuses on a fair distribution of the burdens and benefits of social cooperation among people with competing needs.[141] Farhan Samanani, an anthropologist and lecturer in social justice at King's College London, advocates for people to move away from only claiming individual rights to space, towards embracing differences and practising trust. Through trust, finding common ground is possible even with a plurality of users' needs.[142]

Together, these concepts promote inclusion and create more communal places in which land and resources are rebalanced for the enjoyment of all. Physical space in cities, for instance, could be redistributed to accommodate active travel, recreation, urban farms and nature reserves to equitably meet the needs of everyone in the community.[143] If we can acknowledge and respect our interdependency, we are better equipped to live in harmony with others.[144]

– Co-create healthy and resilient communities

Health is a human right. Wellbeing should be prioritised in all communities to ensure the resilience of people and of society. Revitalising natural systems increases the health of people, as humanity is intrinsically linked to and depends upon the health of nature.[145,146] Eliminating pollutants that cause environmental harm — by prioritising organic materials in our systems, manufacturing, and buildings — has a direct, positive impact on the wellbeing of people. Reducing air pollution levels through proactive measures such as clean transport, energy efficient homes and circular waste management helps diminish the societal burden of disease from stroke, heart disease, lung cancer, and chronic and acute respiratory diseases.[147]

Design interventions should promote active lifestyles through the equitable provision of appropriate travel routes and natural green corridors, at scale. Spending time in nature is associated with multiple health benefits, including improved attention, cognition, sleep, and stress recovery as well as lower rates of obesity, mental distress, and diabetes.[148,149] This also has economic co-benefits, such as lower healthcare costs, less sick leave taken by employees, and a more resilient and functional labour force.[150] The creation of ample local green networks and spaces increases opportunity to enjoy nature conveniently close to home, allowing everyone to be well, not just those with the time to be. In turn, feeling connected with nature results in happier emotions and pro-environmental behaviours, enabling people and nature to thrive.[151]

– Address historical inequalities with environmental justice

The origin of environmental justice has close ties to the American Civil Rights movement, as low-income groups — particularly People of Colour — disproportionately bear the burden of environmental degradation.[152] Acknowledging the historical context enables us to redress past harms which have impacted some communities more than others. Without correcting disparities that evolve over time, truly regenerative outcomes are impossible. In the United States, low-income and minority areas are typically hotter than wealthy areas due to a lack of green space.[153] American Forests created a Tree Equity Score to demonstrate “how much tree canopy and surface temperature align with income, employment, race, age and health factors”.[154] This science-based approach can help city governments, activists and others to make the case for planting trees and allocating resources to the areas most in need.

Justice can include publicly remediating contaminated land for community use. It can involve providing incentives to farmers who have ‘dead’ soil but wish to be more environmentally conscious.[155] It can also include funding coastal restoration in less developed countries. Negotiations at the 27th United Nations Climate Change conference (COP27) echoed this sentiment. Wealthy nations agreed to create a fund for vulnerable nations who have been hit hard by climate change and disasters, providing vital ‘loss and damage’ support.[156] ‘Loss and damage’ is defined as “the most severe impacts of the climate crisis, too great for countries to adapt to or prepare for”.[157] Addressing such inequalities will create equity and social value, supporting a just transition to a more regenerative future.

+ Exemplar case study Read more

Doughnut economics[158,159,160]
Location: Global

+ Exemplar case study Read more

Research on transforming US urban green infrastructure planning to address inequity[161,162]
Location: United States

Equitable

Contextual stewardship

"We don't inherit the Earth from our ancestors. We borrow it from our children."

— Ancient Native American proverb[163]

Contextual stewardship
– Integrate place-making with land stewardship
– Embed participatory and inclusive democracy
– Partner with Indigenous and traditional ecological stewards

Caring for the land and its natural resources properly requires humans to be deeply rooted in, and knowledgeable about, the local context. It is not about ownership or utilising the land for extractive purposes. Rather, an attitude of stewardship sees nature as a stakeholder and co-creator, seeking to create symbiosis within the local environment.

Adopting such a mindset empowers individuals to participate in decision-making processes and to shape places proactively, integrating native ecosystems and reflecting communities' identity, culture and local traditions. It is regenerative in that it will ensure the planet's future habitability and that humans can co-exist and thrive with nature.

+ Exemplar case study Read more

Whanganui River claims settlement[164]
Location: Aotearoa (New Zealand)

– Integrate place-making with land stewardship

Place-making is the multifaceted process of creating spaces in which people want to live, work and play.[165] This includes the planning, design and management of public spaces. Land stewardship involves managing land in such a way that it can be used in perpetuity, by future generations.[166] Regenerative design integrates thoughtful and conscious place-making practices with land stewardship, enhancing nature to deliver positive places which work for people and planet. To enhance whole ecosystems, this should also include consideration of multi-species, or non-human clients. Rewilding is an example of how we as humans can consider both non-human and local community needs, restoring degraded or abandoned land with native species.[167]

Accountable political leadership is required to ensure that policies and development proposals truly reconnect natural systems and meet community needs. However, every single practitioner can be an advocate for, and work with nature. From the outset of design, only the collaboration of a multitude of stakeholders ensures that the local context is represented accurately in proposed development schemes. Prioritising nature as a stakeholder and co-creator will be key to rethinking and designing healthy places where humans and nature can thrive. This aligns a local approach with planetary outcomes.[168]

– Embed participatory and inclusive democracy

Inclusive design and participatory democracy empower citizens to shape their spaces more actively. Their outcomes address the needs of different user groups and promote equitable access to opportunities. One tangible method to achieve this is structured decision-making (SDM). SDM is an organised approach to devising alternative courses of action with transparency on how they deliver against a group's manifold objectives. It begins by establishing objectives based on the values of all stakeholders, including the non-human, cultural and scientific. Robust data and expert elicitation then seek to quantify each alternative's strengths and weaknesses. This reduces inherent biases and supports decision-making in complex situations.[169] The method is both inclusive and participatory, which increases the overall buy-in from the group.

Proactive use of technology, rather than meeting minimum regulatory standards, can help promote engagement and transparency. This includes methods such as accessible online voting, simple yet engaging web-based platforms to inform the public on proposed development, or urban data models such as Urban Citizen Learning to evaluate and visually simulate public policies and intangible aspects of urban agendas.[170] When decision-making is more inclusive and participatory, it results in more straightforward and efficient resolution of conflicting human-made and natural environment issues. This creates spaces that reflect the communities which inhabit them while also fostering native habitats.

– Partner with Indigenous and traditional ecological stewards

Indigenous and traditional practices have evolved over time, learned and inherited by communities around the world as part of their culture and intergenerational thinking. The basic tenet that underpins Indigenous design is that "spiritual and cultural forces … are more profound than any individual's single intervention."[171] The Seventh Generation Principle encourages everybody "to think of the seventh generation coming after you in your words, work and actions, and to remember the seventh generation who came before you."[172]

A key focus of Indigenous architecture is storytelling. For instance, it might look at a building and see the landscape behind it.[173] A building that contributes to regenerative outcomes does not stand on its own; rather, the space within and around it should come alive and reflect the natural and social environment it is part of. Designer and environmentalist Julia Watson promotes Lo-TEK design philosophy. Lo-TEK — local traditional ecological knowledge — reframes our view of what technology is and what we can do differently to live in symbiosis with natural systems.[174] Canadian Indigenous architect Douglas Cardinal believes "that the Indigenous worldview, which has always sought this balance between nature, culture and technology, is the path that humanity must rediscover and adopt for our future."[175] Partnering with Indigenous and traditional ecological stewards will ensure this essential knowledge and mindset is core to regenerative approaches.

+ Exemplar case study Read more

Living tree bridges[176]

Location: Cherrapunji, India

In conclusion

This section has described three complementary design principles that we can adopt to guide our transition toward a regenerative design practice. They are intended to inspire and equip, and include evidence to demonstrate the art of the possible.

The next section sets out how we can begin to sow the seeds for a better tomorrow by taking positive action today in line with the three principles. It presents a 'theory of change' that maps the wider transition, and a 'From → towards' that contrasts our current paradigm and ways of working with a regenerative future.

Nature-led
place-based design that enhances and emulates natural systems

Life's Principles
Learn from and leverage the design principles embodied by nature's 3.8 billion years of evolution

- Mimic life's unique adaptations
- Utilise living organisms and biological materials
- Partner with nature as infrastructure

Place-based design
Respond to and work with the features of a site to cultivate greater systemic health over time

- Be locally attuned and responsive
- Integrate rather than segregate
- Capture and grow surpluses in the system

Planetary health
Ensure the resilience of human systems by actively reconnecting natural cycles where we disrupt them

- Understand our place in the living system
- Reconnect natural cycles where we disrupt them
- Support the web of life

Systemic
relationships, exchanges and flows of materials and resources that restore, protect and replenish

Systems thinking
Build a deep understanding of resource flows to develop an interconnected ecosystem

- View the city as an ecosystem
- Capture benefits at every exchange
- Break down silos with technology

Nature compatible
Work in harmony with biological cycles through regenerative material cultivation and life-friendly chemistry

- Utilise life's toolbox
- Transition to biological resources
- Design for decomposition

Circular infrastructure
Create a system that enables materials, products and resources to be reused and remain in circulation

- Give land back to nature
- Adopt new business models to optimise lifecycle value
- Bioremediate waste and pollution

Equitable
collective change, co-creation and collaboration that ensure inclusivity and social justice

Biosphere economy
Value planetary health over narrow financial gain and inspire collective action within the planetary boundaries

- Value planetary health
- Inform policy and regulations with science-based targets
- Coordinate action globally

Just social foundations
Enable humans to co-evolve with nature through equitable and just foundations which meet the needs of all people

- Cultivate public luxury and the commons
- Co-create healthy and resilient communities
- Address historical inequalities with environmental justice

Contextual stewardship
Prioritise nature as a key stakeholder and co-creator, and shape places led by the local community

- Integrate place-making with land stewardship
- Embed participatory and inclusive democracy
- Partner with Indigenous and traditional ecological stewards

Sowing the seeds for tomorrow

The transition to regenerative design

In this chapter:

Creating the enabling environment for a regenerative future

Even though we may not have all the answers today, we can take steps right now across our projects and designs that embed and test regenerative design principles and deliver positive outcomes for people and planet. With scientists arguing that Earth's systems are on the edge of collapse,[177] there is no time to wait — designers and practitioners can lead by example.

What matters is that we begin to make choices in accordance with our values and start to invest and drive change now, through prioritising research, projects and actions that will support planetary health and resilience for the long-term; and crucially by letting go of practices that do not.

Built environment practitioners and decision-makers should be integrating regenerative principles and experimenting with their application, sharing results and best practices widely. Policymakers and regulators should develop a coordinated direction-of-travel, which gives confidence to business and industry in regenerative design; and importantly prevents further delays arising from any uncertainty on this being the right way forward. Many solutions and frameworks we need to push already exist, such as science-based targets, multi-species design, planetary boundaries, doughnut economics, circular economy, and many more. What needs to happen now is that they must be amplified, integrated and aligned towards a common aim and set of priority outcomes.

Prioritisation will not be easy; practitioners across numerous sectors must keep in mind the long-term trajectory towards regeneration, whilst also setting detailed and specific short-term targets. Which investment, design or procurement criteria can we change *today*? What parts, products or processes can we rethink right *now*?

To do this, we need to take a holistic approach to transition to a regenerative future; an examination of the wider operating context to avoid blind spots and identify interdependencies or collaboration opportunities. Rather than grouping actions by sector, we can focus on six change areas across 'STEP UP': in Society, Technology, Economy, Politics, under Uncertainty and through Partnerships.

Social ensures people are an integral part of a regenerative future, with Technological covering the tools and practices needed to get us there. Economic and Political, together, ensure the transition includes a shift away from a pure focus on growth, built on long-term thinking and mechanisms as the foundation for change. Uncertainty recognises the need to drive resilience in increasingly uncertain times, with Partnerships setting out the need for broad coalitions and collaboration to collectively achieve a regenerative future.

This section describes the potential for a shift to regenerative design through each of these areas, with example actions that can be taken immediately. It also presents a theory of change to visually demonstrate how we can achieve the aim of a regenerative future, in which human systems contribute to planetary health.

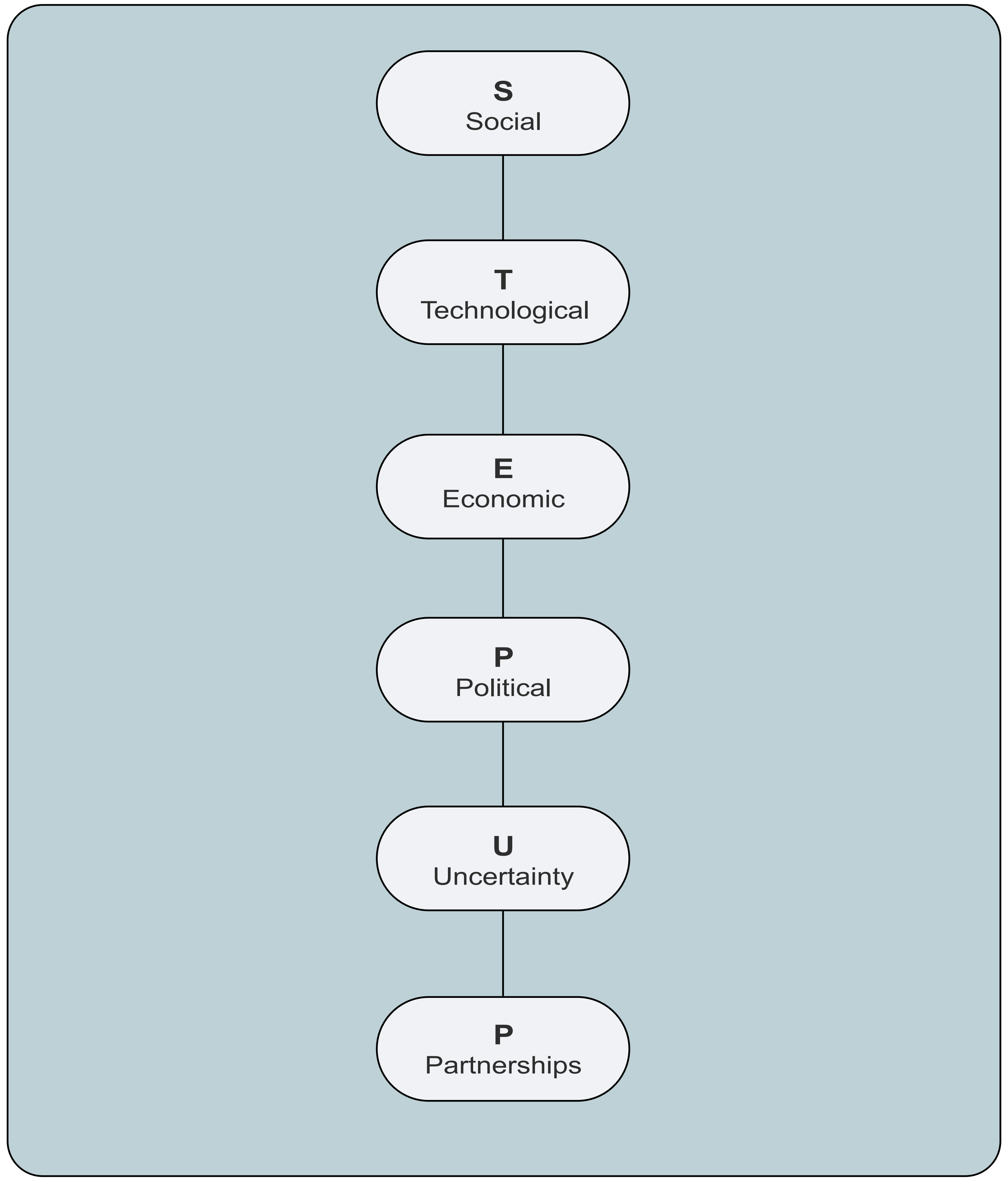


Figure 12: Arup's STEP UP Framework
Theory of change identifying key change areas

Social

The regenerative transition must be driven by a social transformation that prioritises collaboration and co-creation as opposed to extraction and exploitation. It requires strong social foundations, established in communities and shared resources, skills and work. Ecological regeneration can be a tool for conflict resolution and community by building trust and social cohesion, for example community gardens and the Paani foundation (case study, right). As with a natural ecosystem, social systems are strengthened by diversity and interconnectedness, where a rich and diverse social fabric enhances resilience and ensures a range of needs are met.

Co-design techniques that involve collaboration with diverse stakeholders to integrate cultural perspectives, local knowledge and scientific insights are therefore vital to achieve a regenerative future.[178] More broadly, nature supports, gives richness to, and underpins our health, wellbeing, culture, and society. The hypothesis of ‘biophilia’ describes human’s innate tendancy to seek out connections with nature.[179] Daily connection to nature reinforces the values of respect and care for the environment.[180]

Actions to take now

- Identify key members and groups in the community who can steward the project after completion, delivering long-term impact. They can champion a project as well as ensure that unheard voices are brought to the table.
- Co-design allows you to hand over some authorship of the project to local stakeholders, increasing their engagement and ownership of it. This will make the project more nuanced, impactful and meaningful.
- Start with and maintain a relationship with the history and culture of a place, to ensure the project becomes an intervention that enriches the heritage and social fabric of the local context. This should also include partnering with traditional and Indigenous ecological stewards.

Relevant knowledge and approaches

Social value

Accessible environments

Community engagement

Inclusive cities

+ Exemplar case study

Read more

Paani Foundation: Satyamev Jayate Water Cup[181]

Location: India

Technological

Living in harmony with nature requires a nuanced understanding of how our human systems interact with natural systems to inform regenerative intervention. These systemic interconnections are vast and complex, giving technology an integral role as an enabler of change and desired outcomes. For example, novel modelling technologies using big data and AI can monitor change, predict outcomes and optimise interventions and designs. Monitoring can integrate citizen science, camera trapping, lidar and more.

Technology should work *for* nature in ensuring that we design and live within the science-based targets required for healthy ecosystems; and *with* nature in leveraging 3.8 billion years of nature's innovations (see asknature.org for a catalogue). We should draw inspiration from communities around the world with a wealth of local ecological knowledge and technologies, who have been fostering mutually beneficial relationships between community and place for generations. Indigenous knowledge of, for example, regenerative soil practices is good science, and we must value it as such.

Actions to take now

- Innovate with biomimicry and biophilic solutions before artificial interventions. These are often much more efficient, more resilient and less wasteful than artificial solutions.
- Enrich our understanding of natural systems, material flows and ecologies through emerging data science. Doing this will provide an evidence-led and quantitative approach to developing regenerative solutions that can support natural systems.
- Where possible, draw on Indigenous and traditional practices and technologies, which can lead to more regenerative and effective place-based outcomes. Modern technology is not always appropriate. Indigenous and traditional groups often have much to teach us about the tools, techniques and methods of stewardship they have developed over generations.

Relevant knowledge and approaches

Planetary boundaries

Earth observation

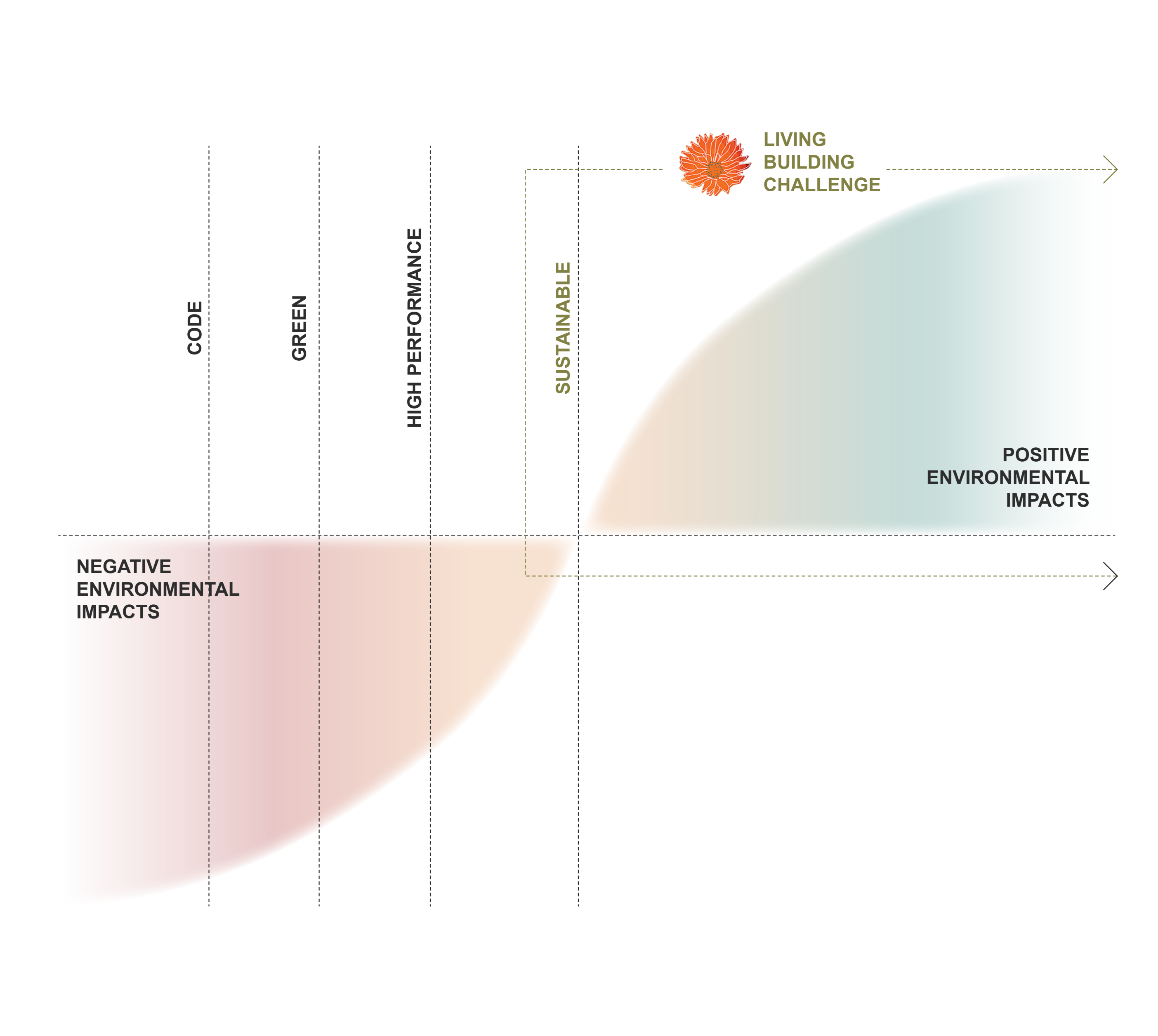
Digital twin

Indigenous knowledge

Circular economy

+ Exemplar case study

Read more



Living Building Challenge[182,183]

Location: Global

Economic

The economist Kate Raworth suggests that a healthy economy is designed to thrive, not grow exponentially. "Our current model of growth is not actually growth", she writes. "The unpriced externalities we are generating are self-terminating us."[184] A shift away from a pure focus on growth can lead to more regenerative, distributed economies that work within the planet's ecological limits.[185] Understanding how we attribute value reveals the tangible economic risks that conventional design approaches have on the natural world. A recalibration will prevent harm caused by short-term and near-sighted economic policy decisions from becoming an irreversible reality.

Representing social values and natural systems in financial valuation — for instance, by pricing in the damage to ecosystems as a cost — is a powerful way to sow the seeds for a better future. Rethinking the way we cost resources and the way we price impacts on ecosystems will drive the transition. It will create a market that reflects our values more accurately.

Actions to take now

- Adopt best practice of factoring lifecycle and economic damage from ecosystem degradation into plans and proposals. This encourages action towards regenerative design.
- Utilise case studies and scenarios that highlight the enormous economic benefit of restorative and regenerative design. For example, how restoring ecosystems restores communities and, therefore, attracts business and investment.
- Adopt a futures mindset. Integrate design interventions in the built environment with long-term economic targets to show how regenerative interventions can support or drive business goals.
- Develop and use ways to better highlight and track the direct and indirect economic value of restorative and regenerative practice.

Relevant knowledge and approaches

Doughnut economics

Total value

+ Exemplar case study

Read more

Mesoamerican Reef: insuring a natural asset for its resilience services[186]

Location: Mexico, Belize, Guatemala, and Honduras

Political

Regulation and policy are the mechanisms that will guide and drive the transition and ensure it is equitable and effective. Governments articulate the long-term vision for communities, societies and international relations. They are responsible for creating the conditions and platforms to enable change through investment in research and innovation, regulation and treaties. Understanding and working with government to build the foundation for change is vital. Businesses need to demonstrate the art of the possible to signal to government what they should set policy for. In this feedback loop, businesses needs to feel confident that their strategies are aligned with the long-term vision, while the governement needs confidence that businesses can deliver.

Policymakers can identify levers of change through health, wellbeing, education and social care that support a quality of life for all — enabling communities to take part in, act on and drive positive change locally. Societies struggling with social and wealth inequality, poor health and education outcomes, and weak infrastructure will lack resilience and deprioritise needed regenerative interventions.

Actions to take now

– Encourage government stakeholders to take joined-up approaches to education, human health and ecosystems that can contribute together to more positive outcomes.

– Include diverse sets of stakeholders from across different political priorities in projects. For example, how can we align the needs of infrastructure providers, educators, community carers and policymakers for long-term benefits?

– Embed projects in the context of long-term policy goals and targets, demonstrating how regenerative approaches to design and planning issues can help policymakers and legislators on the path to achieving these targets.

Relevant knowledge and approaches

Green economy

Inclusive, participatory stakeholder engagement

Nature legislation
(e.g., UK's Environment Act 2021, Australia's Nature Repair Act 2023, EU's proposed Nature Restoration Law)

+ Exemplar case study

Read more

Stormwater retention credit trading programme[187]

Location: Washington, D.C., United States

Uncertainty

We live in a volatile, uncertain, complex and ambiguous (VUCA) world.[188] Increasing geopolitical instability, supply chain crises, divided societies with contested elections, the return of high inflation and extreme weather are just a handful of phenomena driving businesses and governments to risk-averse, short-term planning and strategies. It is the role of regenerative practitioners and designers to show how they can drive resilience in uncertain times.

For example, healthy ecosystems are inherently more resilient. This could help support and quickly recover businesses and sectors affected by extreme weather events. For another example, as climate and geopolitical uncertainty continue to drive accelerating global migration, regenerative design practices build inclusive and well-supported communities, resilient to migratory shocks and stresses. We know that we will be experiencing great change, from species compositions to weather patterns, but we can't be sure about an end state. Thus, the objective is building adaptive, nature-led systems that can co-evolve over time with our ever-changing contexts.

Actions to take now

- Utilise case studies, examples and scenarios to tangibly demonstrate how regenerative design can mitigate shocks and enhance resilience for clients in an increasingly uncertain world.
- Utilise case studies to show how regenerative design's holistic approach to natural systems, society, technology and economies allows stakeholders to manage risk and quickly adapt to rapidly changing social, technological or climatic conditions.
- Seek to provide adaptability for uncertainty. As part of a project, designers should understand potential futures for an area, community or ecosystem, and build them into the project. For instance, what might the area's future climate look like? Its future demographics? Its future economy? How can communities and users be empowered to adapt a design as circumstances change?

Relevant knowledge and approaches

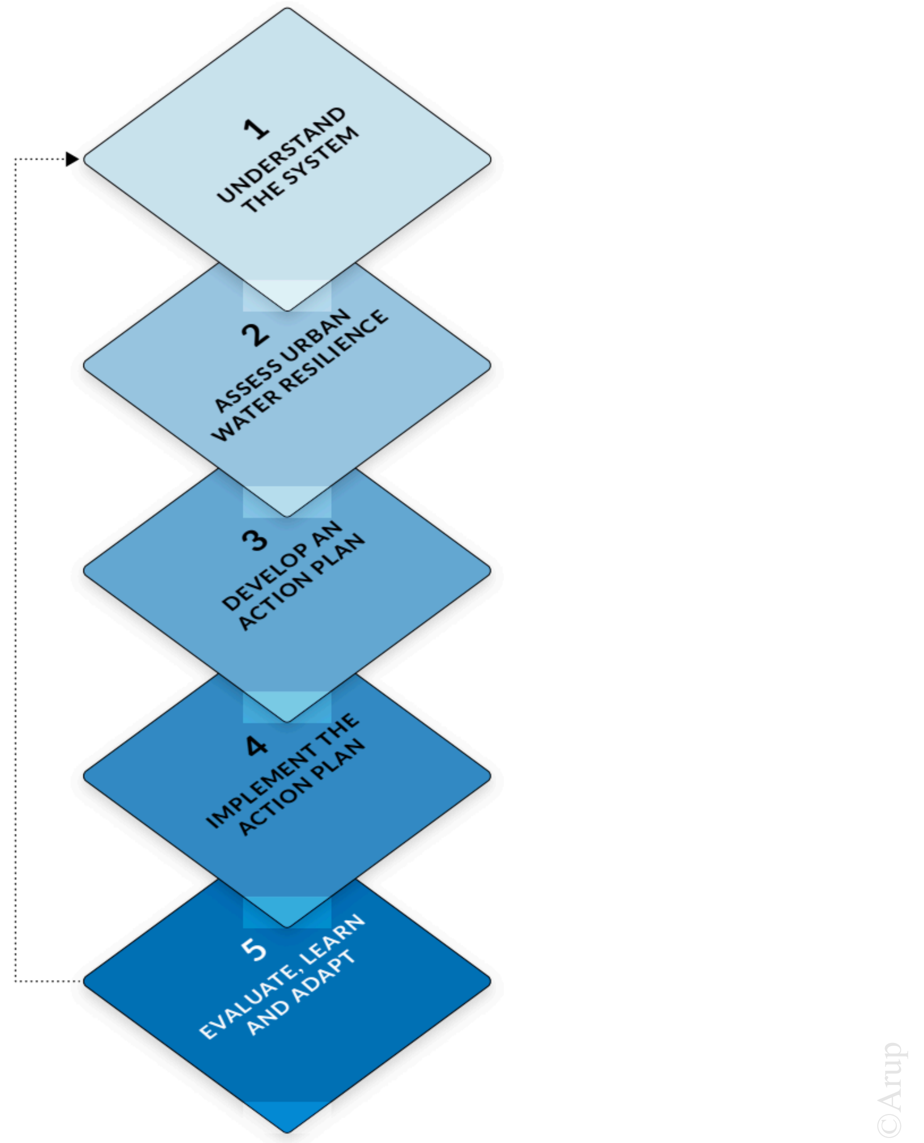
Climate change adaptation

Urban resilience

Foresight advisory

+ Exemplar case study

Read more



City Water Resilience Approach[189,190]

Location: Global

Partnerships

Regenerative design cannot scale or be effective without the participation and mutual interest of broad coalitions who can contribute and benefit collectively across global and local levels. These partnerships can take a variety of shapes, such as formalised knowledge exchange between industry and academic research, collaborative development projects, or more informal methods of co-design and participation.

Partnerships, coalitions, and collaborations should be flexible enough to benefit the different needs of different organisations, institutions, communities and individuals while being framed around ambitious outcomes for a regenerative future. These partnerships can be strengthened and enabled by new approaches, such as mission-oriented innovation, and new technologies of decentralisation and open data.[191]

The key partnership that we need to rebuild is with nature. Nature is our ultimate, universal stakeholder and we must re-learn how to co-create and co-design with it rather than seeking to control and contain it.

Actions to take now

– Focus on ambitious goals for projects through new systems like mission-oriented innovation. This frees up space to be innovative and experimental by focusing on outcomes rather than the process of design.

– Engage partners beyond your comfort zone to ensure longevity and lasting change. For example, you can partner with local organisations for political support, scientific institutions for rigorous evidence, tech companies for data, or schools for education.

– Explore new forms of collaboration through decentralised networks, open data and open science. These new types of networks can provide easier ways to drive more ambitious, interconnected outcomes.

Relevant knowledge and approaches

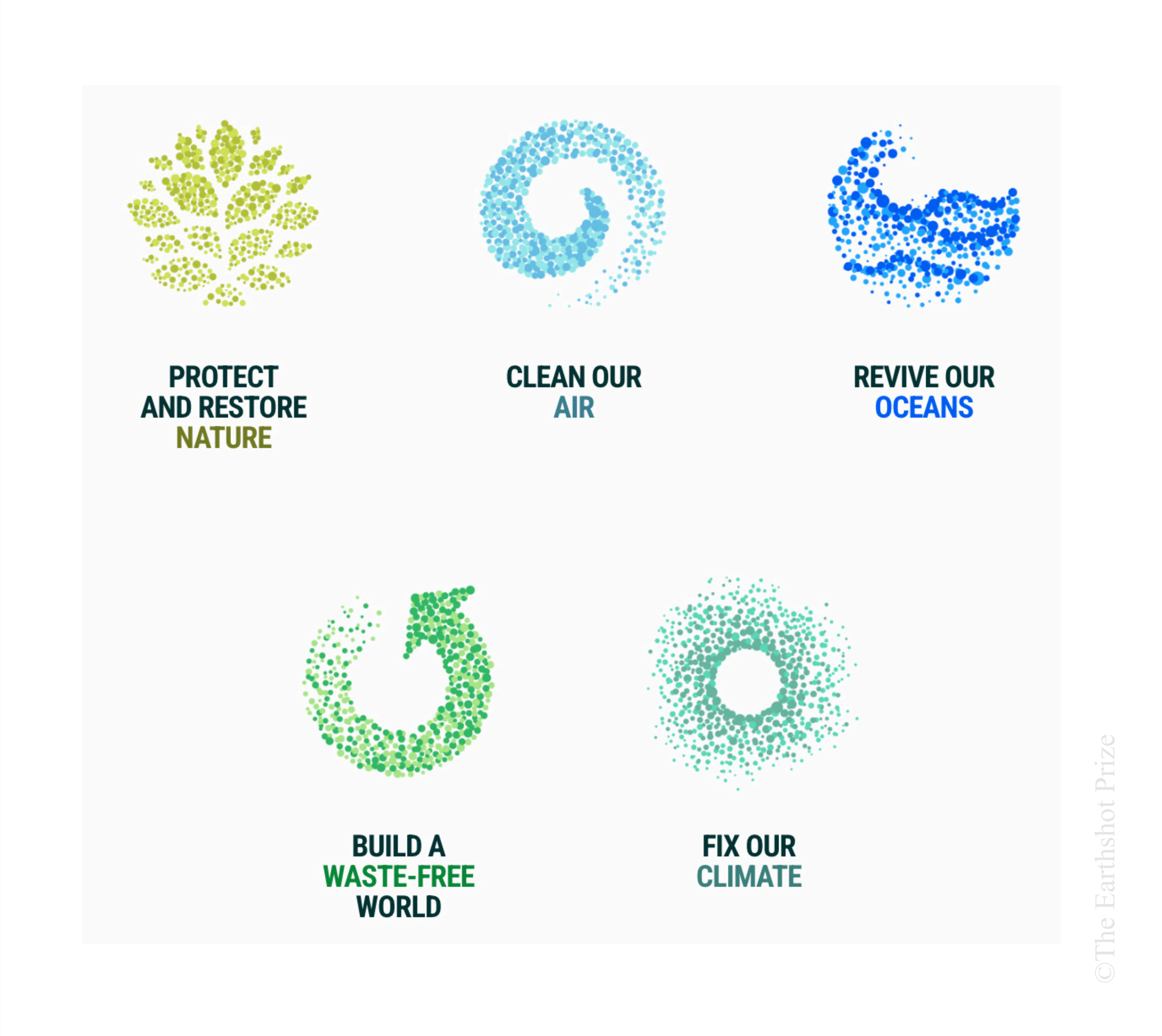
Strategic partnerships

Regenerative land management

Open data

+ Exemplar case study

Read more



The Earthshot Prize[192,193,194]

Location: Global

Theory of change

Figure 13: Theory of change
Arup

Why

$44 trillion of economic value generation – over half the world's GDP – is moderately or highly dependent on nature

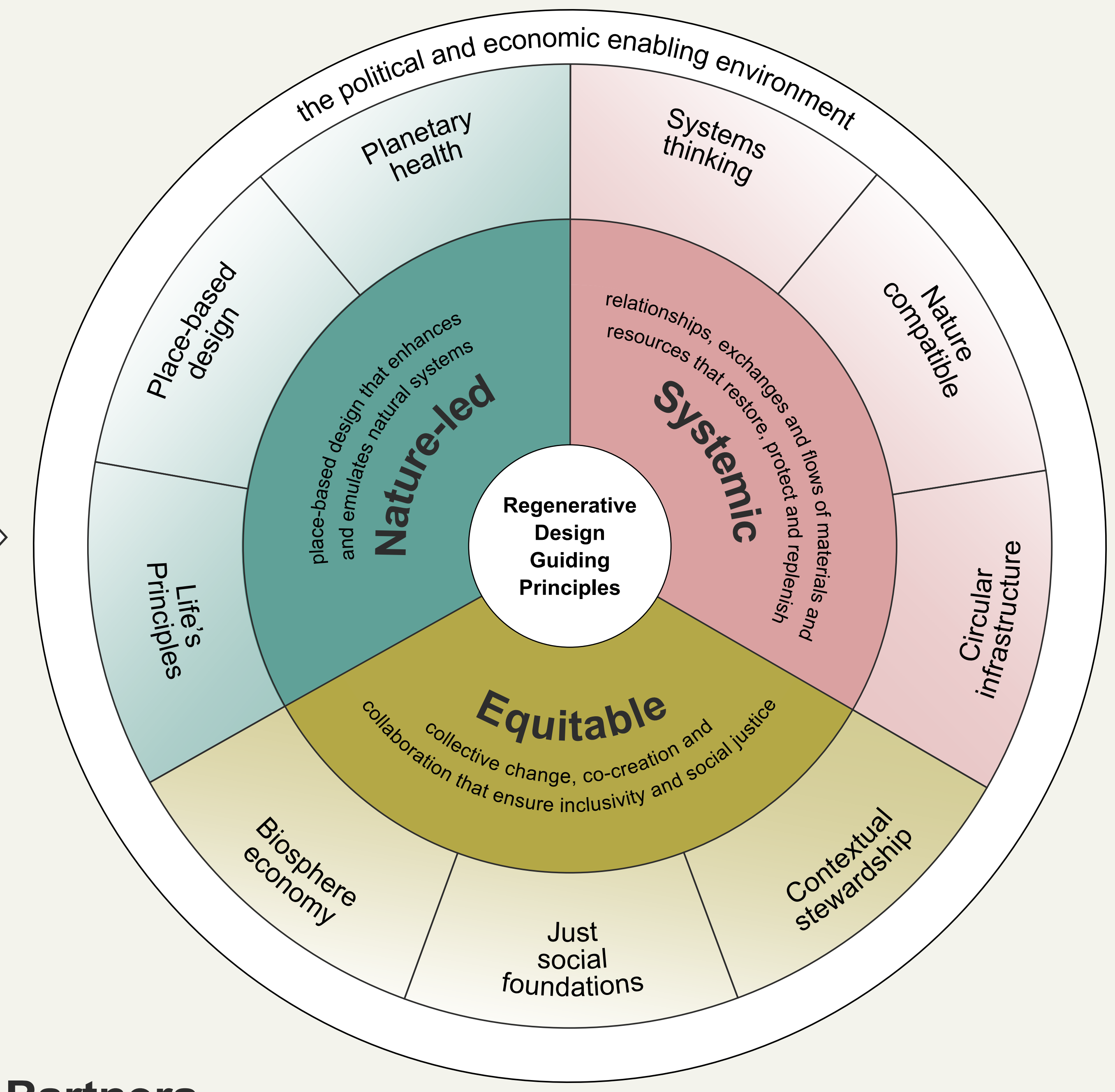
We have exceeded six of the nine planetary boundaries, which define limits of acceptable alteration to Earth systems

25% of animal and plant species are threatened with extinction, amounting to 1 million species over the next few decades

Environmental risks are increasing in prevalence, causing extreme weather events and ecosystem collapse, in turn diminishing our ability to adapt and increasing risks to human health

Stakeholders

Nature • Insurers • Investors • Institutions • Practitioners & designers
Asset owners & developers • City & regional government • Regulators



Partners

Nature • Land owners • Traditional & Indigenous ecological stewards
Innovators • Local communities & groups • Professional bodies
Educators • Market-focused partners • Communities of practice

Change areas

S Social

T Technological

E Economic

P Political

U Uncertainty

P Partnerships

Outcomes

Economy and infrastructure that value healthy natural and social systems

Nature inspires research and development for life-compatible solutions

Systems thinking which views people and place as part of nature

Local communities and species have a voice in co-design processes

Environmental justice addresses spatial inequalities and remediates land

Long-term accountability to future generations is prioritised

Impacts

2030
Nature is a stakeholder and co-creator in design and decision-making, contributing to reversing nature loss

2040
The built environment corrects for historical harms and restores natural systems

2050
Human systems co-evolve with and regenerate nature, achieving continuous ecosystem health

Aim

A regenerative future: human systems contribute to planetary health

From ⟶ towards

From degradation & conventional practices	Towards regenerative & positive practices
Extractive built systems	Human civilisation co-evolving as part of Earth's cyclic living systems
Being insulated and disconnected from nature's cycles	Expanding nature literacy by increasing touchpoints with nature
Appropriating Earth's finite resources	Responsibly cycling resources within human systems
The 'builder' of uniform systems that control nature	The 'gardener' working in harmony with a place's complexity and variability
Fragmented systems of buildings, infrastructure, spaces	Buildings, infrastructure, spaces that contribute to wider systemic health
Marginalised groups bearing environmental burdens	A just transition that corrects for historical harms and builds equity
Short-term, siloed politics and decision-making	Long-term, progressive politics that meet the needs of future generations
An individualistic mindset	Community and shared prosperity for the greater good
Markets that degrade nature and drive inequalities	Markets embedded in science-based targets for planetary and social health

*** Inspired by Michael Pawlyn & Sarah Ichioka's book *Flourish*, 2021.**

Glossary

Abiotic: Non-living parts of the ecosystem, such as water, light, temperature, wind, soil composition and pollution. The composition of these factors shape a variety of different ecosystems. Abiotic can be translated to without (a) life (bio). In comparison, biotic factors are the living parts of an ecosystem.[195]

Anaerobic digestion: Anaerobic digestion is a process through which bacteria break down organic matter in the absence of oxygen. An anaerobic digester is a sealed tank that works without oxygen to break down the organic matter and produce biofuels and biofertiliser from the leftover matter.[196]

Anthropocene: Earth's history has been divided into times or epochs. Officially, our current epoch is referred to as the Holocene, which started after the last major ice age. However, as human activity is currently believed to have a major impact on the Earth's climate and ecosystems, since around the 2000s, the current epoch is unofficially described as the Anthropocene — deriving from man (anthropos) and new (cene).[197]

Biodiversity: The term biodiversity encompasses all living species on Earth. This includes plants, bacteria, fungi, animals and humans. It is estimated that around 8.7 million plant and animal species exist on Earth.[198]

Biomimicry: Biomimicry, meaning 'imitation of the living', is an approach that learns from and emulates the strategies found in nature to solve human design challenges. It leverages the efficient and optimal designs selected by evolution over 3.8 billion years of 'natural R&D.' Local plants, animals and ecologies have evolved to thrive in the specific climatic conditions and resource constraints, and we can learn from their adaptation. Biomimicry-based designs include aspects such as resource efficiency, self-healing or aerodynamic designs.[199]

Biophilia: The biophilia hypothesis suggests that humans possess an innate tendency to seek connections with nature and other forms of life. Edward O. Wilson introduced and popularized the hypothesis in his book, Biophilia (1984). He defines biophilia as "the urge to affiliate with other forms of life".[200]

Biosphere: The biosphere represents the sphere of our planet where life exists — this includes the solid layer (ground), the atmosphere (air) and the hydrosphere (water). It consists of all natural and living organisms on Earth, and provides us with habitable climatic conditions, air, water, food and other goods that support life on Earth.[201, 202]

Bioutilisation: Bioutilisation refers to the use of living organism services, such as microorganisms for fermentation or synthesis, or biologically-derived materials, such as the harvest of wood or plants, in the design process. As opposed to biomimicry, bioutilisation directly utilises nature's services.[203]

Blue-green infrastructure: Blue-green infrastructure (BGI) refers to natural and strategically planned networks of natural and semi-natural areas that deliver a wide range of ecosystem services, including air/water/biodiversity enhancement, climate mitigation and adaptation, as well as spaces for recreation. It consists of a combination of green and blue infrastructure elements wherein blue infrastructure refers to elements such as ponds, lakes, streams, rivers, wetlands and floodplains, and green infrastructure refers to elements including forests, trees, parks and agricultural areas.[204, 205]

Built systems: Built systems refer to the totality of man-made structures that form the backdrop of human activity. They include everything from buildings and parks to cities, infrastructure, transport, water and energy systems.[206]

Circular economy: Circular economy, or circularity, refers to a resource use model that moves away from the linear process of taking materials to manufacture products and eventually disposing them, to a circular process that manufactures products and resources in a circular way, based on the principles of reduce, reuse, recycle — or in a closed-loop system. The circular economy aims to create an economic system based on circularity around three principles: eliminate waste and pollution; circulate products and materials; regenerate nature.[207, 208]

Co-create/co-creation: Co-creation refers to the action of creating something jointly with others, or by working with others.[209]

Co-evolution: In biology, co-evolution refers to the reciprocal evolutionary change in a set of interacting populations over time resulting from the interactions between those populations. The term is used metaphorically, similarly to 'evolution', to refer to the reciprocal change within systems resulting from their interaction.

'Do no (significant) harm': This term refers to an aspect of sustainability in which no (significant) harm to the environment or an environmental objective should be caused by undertaken actions and activities.[210]

Doughnut economics: Doughnut economics refers an economic mindset that defines goals which meet the needs of all of humanity withing the means, or limits, of the planet. It consists of two rings, the ecological ceiling and the social foundation which form the doughnut. It argues that the space between these rings represents an ecologically safe and socially just space for humanity.[211]

Earth systems: Earth systems refer to the five systems of Earth, and their interaction and interconnection, which create our environment. The five systems are referred to as the geosphere (interior and surface of Earth), the biosphere (the sphere where life exists), the cryosphere (ice), the hydrosphere (water), and the atmosphere (envelope of gas providing oxygen and carbon dioxide).[212]

Ecosystem: An ecosystem refers to an area — large or small — in which a dynamic complex of biotic factors (plants, animals, micro-organisms) as well as abiotic factors (water, light, temperature, humidity, rocks) form a functional unit and depend on each other. The term ecosystem usually refers to natural ecosystems. Those are naturally occurring systems that don't rely on human intervention. On the other hand, human-made or artificial ecosystems refer to the adjustment of an ecosystem by humans or the creation of an ecosystem that mimics natural conditions. The ecosystems usually rely on constant attention.[213, 214]

Ecosystem functions: Ecosystem functions — also referred to as ecosystem processes — describe flows of materials and energy through the ecosystem, such as decomposition, biomass production, the cycling of nutrients, etc. These functions are the biological, geochemical and physical processes that occur within an ecosystem.[215 216]

Environmental justice: Environmental justice is concerned with equal access for all people to decision-making processes around environmental and health concerns with regards to their living and working environment. In addition, it refers to equal protection for all people from health and environmental hazards, and actively correcting for past injustices and their ongoing consequences.[217]

Global commons: The global commons refers to the Earth's resources which humanity shares and relies on. They include the atmosphere and land, the ocean and freshwater, a stable climate and abundant biodiversity.[218]

Habitat: Habitat refers to the home or natural environment of an organism. In a habitat, all environmental conditions needed for survival of an organism are met.[219]

Holocene: A period of time which is the current geological epoch that started approximately 10,000 years ago.[220] (See Anthropocene.)

Living system: Living systems are described as open and self-organising systems that hold characteristics of life and an interaction with their environment. The term stems from the Living Systems Theory that is concerned with the way living systems work, maintain, develop and change themselves.[221]

Nature: The evolving, interconnected systems of life and non-living things occurring naturally on Earth. This comprises the interaction of all living species (including humans), climate and weather, and natural resources.[222]

Nature literacy: The ability to understand the natural systems that make life on Earth possible, including the principles of the organisation of ecosystems and the flows of energy and matter within them (such as photosynthesis and decomposition), and applying those principles to inform design and decision making. Nature literacy is cultivated principally through practical, hands on experience (such as surveying, farming, and land restoration), but also through formal education in ecology, and informal education in daily life by noticing nature's principles all around us.[223]

Permaculture: Permaculture (from 'permanent [agri]culture') is a land management and settlement design informed by arrangements observed in flourishing natural ecosystems. It includes a set of design principles derived from the study of the natural world and pre-industrial sustainable societies. It seeks to leverage synergies with whole systems thinking.[224]

Physical environment: The built and natural environment including geographic features, the climate and urban systems.

Planetary boundaries: A framework that characterises the limits of acceptable alteration to nine key Earth systems: biosphere integrity, climate change, novel entities, stratospheric ozone depletion, atmosphere aerosol loading, ocean acidification, biogeochemical flows, freshwater use, and land-system change.[225]

Planetary health: The health of the planet as a system. This health is maintained by staying within the planetary boundaries.[226]

Public good: Public goods are defined as a commodity or a service that benefits, and can be accessed or used, by everyone. These can include access to drinking water and clean air, but also governmental services.[227]

Regenerate/regenerative: Regenerative design takes a holistic approach in which built and natural systems are designed to co-exist and co-evolve over time, delivering positive environmental and social outcomes and ensuring both human and planetary health.

Resilience: The capacity of social, economic and environmental systems to cope with a hazardous event or trend or disturbance, responding or reorganising in ways that maintain their essential function, identity and structure while also maintaining the capacity for adaptation, learning and transformation.[228]

Restorative design: Restorative design refers to design strategies that reverse damage done to places and spaces by humans or nature.[229]

Rewilding: An approach to nature restoration that focuses on the re-instatement of ecological processes (often termed 'natural processes'), such as seasonal flooding, habitat succession and naturalistic grazing. Rewilding can be characterised as being nature-led but human-enabled, with no predetermined end point.[230]

Safe operating space: The concept of a safe operating space is closely linked to the planetary boundaries that characterise the limits of acceptable alteration to nine key Earth systems. The safe operating space refers to the space within these planetary boundaries in which it is expected that humanity can develop and thrive.[231]

Social value: Social value goes beyond measuring value in economic terms, and is instead concerned with the positive value businesses and decisions create for the economy, communities and society.[232]

Sustainable/Sustainability: Sustainability is defined as "meeting the needs of the present without compromising the ability of future generations to meet their own needs".[233]

Urban metabolism: Urban metabolism conceptualises a city as an organism. Inputs that 'feed' our cities — such as freshwater, food, building materials, fossil fuels — lead to outputs, such as nutrient rich wastewater, rubble and heat. It looks at how resources are being imported into the cities and utilised to produce useful outputs.[234]

Core research team

Credits

About Arup

Dedicated to sustainable development, Arup is a collective of designers, consultants, and experts working globally. Founded to be humane and excellent, we collaborate with our clients and partners using imagination, technology, and rigour to shape a better world.

About Arup University

Arup University is the firm's global excellence programme of directed learning, expert skills development, collaborative research, foresight, and knowledge and information management. Arup's Foresight team analyse the major trends shaping the future of the built environment.

Get in touch
Arup's Foresight team
e: foresight@arup.com
arup.com

Programme leader
Katelyn Nagle

Lead researchers & authors
Katelyn Nagle
Lola Bushnell
Freddie Oxland

Lead designer
Lauren Davies

Researchers & authors
Lucy Henriques
Stephanie Schemel

Designers
Emily Clements
Malina Dabrowska
Eleanor Tomlinson
Marie Walker-Smith

Marketing & communications
Essi Maikola
Annabel Elliott-Browning
Eleanor Davis

Copy editor
Julien Clin

Editorial & review
Josef Hargrave
Tobias Revell

Business sponsors
Barbara Lane
Jo da Silva
Paula Kirk

Steering group
Florence Lam
Ian Carradice
Joseph Correnza
Malcolm Smith
Mark Fletcher
Nille Juul-Sorensen

Key contributors
Amy Leitch
Andrew Chalmers
Arlind Neziri
Becci Taylor
Devni Acharya
Dima Zogheib
Eike Sindlinger
Fiona Patterson
Frances Yang
Francesca Galeazzi
Franki Chiu
Graham Dodd
Isobel Vernon-Avery
Jan Wurm
Jessica Watts
Kate Jackson
Laetitia Lucy
Lillian O'Mahony
Linda Toth
Liz Crump
Martin Pauli
Mathew Vola
Mel Allwood
Melanie Grills
Mona Ivinskis
Neil Harwood
Rainer Zimmann
Sarah Gillhespy
Stuart Smith
Tom Butterworth
Tom Norton
Zoe Webb

Other contributors
Arup global & region reviewers, interviewees, & workshop participants
Global survey respondents
Joanna Choukeir, *The RSA*
Michael Pawlyn, *Exploration Architecture Limited*
Nick Jeffries, *Ellen MacArthur Foundation*
Sarah Clement, *The Australian National University*

References

1. Meadows, D. (1999). Leverage points. Places to Intervene in a System, 19, 28.
2. Earth's calendar year. (n.d.). Biomimicry 3.8. Retrieved August 15, 2023, from https://biomimicry.net/earths-calendar-year/
3. Earth's calendar year. (n.d.). Biomimicry 3.8. Retrieved August 15, 2023, from https://biomimicry.net/earths-calendar-year/
4. Bowles, S., & Choi, J. K. (2013). Coevolution of farming and private property during the early Holocene. Proceedings of the National Academy of Sciences, 110(22), 8830-8835.
5. Bjornerud, M. (2018). Timefulness. In Timefulness. Princeton University Press.
6. Earth's calendar year. (n.d.). Biomimicry 3.8. Retrieved August 15, 2023, from https://biomimicry.net/earths-calendar-year/
7. Ritchie, H., Spooner, F., & Roser, M. (2022). Biodiversity. Our World in Data. https://ourworldindata.org/biodiversity
8. Global land use since 10,000 BCE. (n.d.). Our World in Data. Retrieved August 15, 2023, from https://ourworldindata.org/grapher/global-land-use-since-10000bc
9. How colonialism spawned and continues to exacerbate the climate crisis. (2022, September 21). State of the Planet. https://news.climate.columbia.edu/2022/09/21/how-colonialism-spawned-and-continues-to-exacerbate-the-climate-crisis/
10. IPBES (2019). Global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. E. S. Brondizio, J. Settele, S. Díaz, and H.T. Ngo (editors). IPBES secretariat, Bonn, Germany. https://doi.org/10.5281/zenodo.3831673.
11. Global land use since 10,000 BCE. (n.d.). Our World in Data. Retrieved August 15, 2023, from https://ourworldindata.org/grapher/global-land-use-since-10000bc
12. Syvitski, J., Waters, C. N., Day, J., Milliman, J. D., Summerhayes, C., Steffen, W., ... & Williams, M. (2020). Extraordinary human energy consumption and resultant geological impacts beginning around 1950 CE initiated the proposed Anthropocene Epoch. Communications Earth & Environment, 1(1), 32.
13. IPBES (2019). Global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. E. S. Brondizio, J. Settele, S. Díaz, and H.T. Ngo (editors). IPBES secretariat, Bonn, Germany. https://doi.org/10.5281/zenodo.3831673.
14. Syvitski, J., Waters, C. N., Day, J., Milliman, J. D., Summerhayes, C., Steffen, W., ... & Williams, M. (2020). Extraordinary human energy consumption and resultant geological impacts beginning around 1950 CE initiated the proposed Anthropocene Epoch. Communications Earth & Environment, 1(1), 32.
15. NASA. (2023). Carbon Dioxide Concentration | NASA Global Climate Change. Climate Change: Vital Signs of the Planet; NASA. https://climate.nasa.gov/vital-signs/carbon-dioxide/
16. Ritchie, H., Spooner, F., & Roser, M. (2022). Biodiversity. Our World in Data. https://ourworldindata.org/biodiversity
17. Rockström, J., Steffen, W., Noone, K. et. al. (2009). Planetary boundaries: exploring the safe operating space for humanity. Ecology and society, 14(2).
18. Rockström, J., Gupta, J., Qin, D. et. al. (2023). Safe and just Earth system boundaries. Nature, 1-10.
19. NASA. (2023). Carbon Dioxide Concentration | NASA Global Climate Change. Climate Change: Vital Signs of the Planet; NASA. https://climate.nasa.gov/vital-signs/carbon-dioxide/
20. Rockström, J., Steffen, W., Noone, K. et. al. (2009). Planetary boundaries: exploring the safe operating space for humanity. Ecology and society, 14(2).
21. Indigenous peoples and the nature they protect. (2020, June 8). UNEP. http://www.unep.org/news-and-stories/story/indigenous-peoples-and-nature-they-protect
22. Indigenous peoples. (2023, April 6). World Bank. https://www.worldbank.org/en/topic/indigenouspeoples
23. Indigenous peoples and the nature they protect. (2020, June 8). UNEP. http://www.unep.org/news-and-stories/story/indigenous-peoples-and-nature-they-protect
24. Kimmerer, R. W. (2020). Braiding sweetgrass: Indigenous wisdom, scientific knowledge and the teachings of plants. Penguin Books.
25. Allohverdi, T., Mohanty, A. K., Roy, P., & Misra, M. (2021). A review on current status of biochar uses in agriculture. Molecules, 26(18), 5584.
26. Millison, A. (2022, April 15). Chinampas of Mexico: Most productive agriculture ever? https://www.youtube.com/watch?v=86gyW0vUmVs
27. Reed, B., Mang, P. (2007), Regenerative Development and Design 2nd edition. Iregenisis group
28. Dalrymple, S. (2022, June 1). Are humans separate from nature? British Ecological Society. https://www.britishecologicalsociety.org/are-humans-separate-from-nature/.
29. E. O. Wilson | biography, facts, & writings | britannica. (2023, July 14). https://www.britannica.com/biography/Edward-O-Wilson
30. World Economic Forum (2024). Global Risks Report 2024. https://www.weforum.org/reports/global-risks-report-2024/.
31. World Economic Forum with PwC (2020). Nature Risk Rising: Why the Crisis Engulfing Nature Matters for Business and the Economy. https://www3.weforum.org/docs/WEF_New_Nature_Economy_Report_2020.pdf.
32. IPBES (2019). Global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. E. S.
33. Kimmerer, R. W. (2020). Braiding sweetgrass: Indigenous wisdom, scientific knowledge and the teachings of plants. Penguin Books.
34. Kimmerer, R. W. (2020). Braiding sweetgrass: Indigenous wisdom, scientific knowledge and the teachings of plants. Penguin Books.

35. Arup, O. The Built Environment (1972), Philosophy of Design, p.189

36. World Economic Forum (2024). Global Risks Report 2024. https://www.weforum.org/reports/global-risks-report-2024/.

37. Zari, M. P. (2015). Ecosystem services analysis: Mimicking ecosystem services for regenerative urban design. International journal of sustainable built environment, 4(1), 145-157.

38. Benyus, J. M. (1997) Biomimicry: Innovation Inspired by Nature.

39. Benyus, J. M. (1997) Biomimicry: Innovation Inspired by Nature.

40. Pawlyn, M. (2019). Biomimicry in architecture. Routledge.

41. Haggard B, Reed B, Mang P (2006) Regenerative development. Revitalization, Mar/Apr 2006

42. Pawlyn, M. (2019). Biomimicry in architecture. Routledge.

43. What is biomimicry? (n.d.). Biomimicry Institute. Retrieved October 12, 2023, from https://biomimicry.org/what-is-biomimicry/

44. Pawlyn, M. (2019). Biomimicry in architecture. Routledge.

45. Fratzl, P., & Weinkamer, R. (2007). Nature's hierarchical materials. Progress in Materials Science, 52(8), 1263–1334. https://doi.org/10.1016/j.pmatsci.2007.06.001

46. Fratzl, P., & Weinkamer, R. (2007). Nature's hierarchical materials. Progress in Materials Science, 52(8), 1263–1334. https://doi.org/10.1016/j.pmatsci.2007.06.001

47. Zari, M. P. (2018). Regenerative urban design and ecosystem biomimicry. Routledge.

48. Bioutilization—Asknature. (n.d.). Retrieved October 12, 2023, from https://asknature.org/term/bioutilization/

49. Gu, Y., Yu, L., Mou, J., Wu, D., Zhou, P., & Xu, M. (2020). Mechanical properties and application analysis of spider silk bionic material. e-Polymers, 20(1), 443-457.

50. Nature-based solutions | iucn. (n.d.). Retrieved February 7, 2024, from https://www.iucn.org/our-work/nature-based-solutions

51. Nature-based solutions | iucn. (n.d.). Retrieved February 7, 2024, from https://www.iucn.org/our-work/nature-based-solutions

52. Designlens: Life's Principles. (n.d.). Retrieved September 12, 2023, from https://biomimicry.net/the-buzz/resources/designlens-lifes-principles.

53. Buxton, P. (2022, March 23). Slime and the city: Can a mysterious mould aid urban planning? RIBA Journal. https://www.ribaj.com/culture/reseaux-mondes-centre-pompidou-paris-ecologicstudio-slime-mould.

54. Kay, R., Mattacchione, A., Katrycz, C., & Hatton, B. D. (2022). Stepwise slime mould growth as a template for urban design. Scientific Reports, 12(1), 1322. https://doi.org/10.1038/s41598-022-05439-w.

55. Riyadh bioremediation facility | landscape performance series. (2015, October 15). https://www.landscapeperformance.org/case-study-briefs/riyadh-bioremediation-facility

56. Zhao, H., Yang, Z., & Guo, L. (2018). Nacre-inspired composites with different macroscopic dimensions: Strategies for improved mechanical performance and applications. NPG Asia Materials, 10(4), 1–22. https://doi.org/10.1038/s41427-018-0009-6

57. Habitat Royale. (n.d.). Zuidas. Retrieved September 12, 2023, from https://zuidas.nl/en/project/habitat-royale/.

58. Lyle, J. T. (1996). Regenerative design for sustainable development. John Wiley & Sons.

59. Auber, A., Waldock, C., Maire, A., Goberville, E., Albouy, C., Algar, A. C., ... & Mouillot, D. (2022). A functional vulnerability framework for biodiversity conservation. Nature Communications, 13(1), 4774.

60. How nature can inspire us to create more resilient buildings – Arup. (n.d.) Retrieved September 12, 2023, from https://www.arup.com/projects/eastgate.

61. Subasinghe, R., Soto, D., & Jia, J. (2009). Global aquaculture and its role in sustainable development. Reviews in aquaculture, 1(1), 2-9.

62. Bailis, R., & Yu, E. (2012). Environmental and social implications of integrated seawater agriculture systems producing Salicornia bigelovii for biofuel. Biofuels, 3(5), 555-574.

63. Hranjski, H. (2001, January 6). U. S. Biologists use red sea to turn eritrean desert into shrimp farm. Los Angeles Times. https://www.latimes.com/archives/la-xpm-2001-jan-06-mn-9169-story.html

64. Zari, M. P. (2015). Ecosystem services analysis: Mimicking ecosystem services for regenerative urban design. International journal of sustainable built environment, 4(1), 145-157.

65. Byers, J. E., Cuddington, K., Jones, C. G., et. al. (2006). Using ecosystem engineers to restore ecological systems. Trends in ecology & evolution, 21(9), 493-500.

66. Global sponge cities snapshot—Arup. (n.d.). Retrieved February 7, 2024, from https://www.arup.com/en/perspectives/publications/research/section/global-sponge-cities-snapshot.

67. Merino, D., & El-Hadi, N. (2023, January 26). Beavers and oysters are helping restore lost ecosystems with their engineering skills – podcast. The Conversation. http://theconversation.com/beavers-and-oysters-are-helping-restore-lost-ecosystems-with-their-engineering-skills-podcast-198573.

68. Beavers | the wildlife trusts. (n.d.). Retrieved September 12, 2023, from https://www.wildlifetrusts.org/on-land/beavers.

69. Circle economy foundation. (2024). Circularity gap report 2024. https://www.circularity-gap.world/2024

70. Designing our futures. (2023). New European Bauhause Economy. https://www.irresistiblecircularsociety.eu/assets/uploads/20230707-New-European-Bauhaus-Economy_Digital-version_DML.pdf

71. UNEP. (2021). Ecosystem restoration for people, nature and climate becoming #generationrestoration. United Nations 2021. https://wedocs.unep.org/bitstream/handle/20.500.11822/36251/ERPNC.pdf

72. Desing, H., Brunner, D., Takacs, F., Nahrath, S., Frankenberger, K., & Hischier, R. (2020). A circular economy within the planetary boundaries: Towards a resource-based, systemic approach. Resources, Conservation and Recycling, 155, 104673.

73. Owen-Burge, C. (2022, April 28). Visualizing the material impact of global urbanization. Climate Champions. https://climatechampions.unfccc.int/visualizing-the-material-impact-of-global-urbanization/

74. Chertow, M. R. (2000). Industrial symbiosis: literature and taxonomy. Annual review of energy and the environment, 25(1), 313-337.

75. Pawlyn, M. (2019). Biomimicry in architecture. Routledge.

76. Designing our futures. (2023). New European Bauhause Economy. https://www.irresistiblecircularsociety.eu/assets/uploads/20230707-New-European-Bauhaus-Economy_Digital-version_DML.pdf

77. Lingam, M., Frank, A., & Balbi, A. (2023). Planetary scale information transmission in the biosphere and technosphere: Limits and evolution. Life, 13(9), 1850. https://doi.org/10.3390/life13091850

78. A tale of two oceans: Scientists are building digital twins of the ocean | Research and Innovation. (2022, February 11). https://ec.europa.eu/research-and-innovation/en/horizon-magazine/tale-two-oceans-scientists-are-building-digital-twins-ocean

79. Arup and the Open Data Institute. (2021). Exploring new approaches for sharing data in the built environment. https://www.arup.com/en/perspectives/publications/research/section/exploring-new-approaches-for-sharing-data-in-the-built-environment

80. Gemeente Rotterdam, IBAR, FABRIC, JCFO, & TNO. (2014). Urban Metabolism : sustainable development of Rotterdam. Internationale Architectuur.

81. Kalundborg Symbiosis - The world's leading industrial symbiosis. (n.d.). Retrieved May, 2023, from https://www.symbiosis.dk/en/

82. Elhacham, E., Ben-Uri, L., Grozovski, J., Bar-On, Y. M., & Milo, R. (2020). Global human-made mass exceeds all living biomass. Nature, 588(7838), 442–444. https://doi.org/10.1038/s41586-020-3010-5

83. UNEP International Resource Panel. (2024). Global material flows database [dataset]. https://www.resourcepanel.org/global-material-flows-database

84. Ichioka, S., & Pawlyn, M. (2022). Flourish: Design paradigms for our planetary emergency. Triarchy Press.

85. Home—Mycocycle. (2023, August 14). https://mycocycle.com/

86. The butterfly diagram: Visualising the circular economy. (n.d.). Retrieved September 13, 2023, from https://ellenmacarthurfoundation.org/circular-economy-diagram

87. Luthe, T., Fitzpatrick, H., & Wahl, D. C. (2022, October). Designing a "bioregional regenerative economy": How could that work, realistically. In Relating Systems Thinking and Design 2022 Symposium. University of Brighton Brighton, UK.

88. Ichioka, S., & Pawlyn, M. (2022). Flourish: Design paradigms for our planetary emergency. Triarchy Press.

89. Salvidge, R., & Hosea, L. (2023, February 23). Revealed: Scale of 'forever chemical' pollution across UK and Europe. The Guardian. https://www.theguardian.com/environment/2023/feb/23/revealed-scale-of-forever-chemical-pollution-across-uk-and-europe

90. EWG. (2023, September). Global danger: Threatened and endangered species at risk from PFAS exposure. http://www.ewg.org/interactive-maps/pfas_in_wildlife/map/

91. Stoiber, T., Evans, S., & Naidenko, O. V. (2020). Disposal of products and materials containing per- and polyfluoroalkyl substances (Pfas): A cyclical problem. Chemosphere, 260, 127659. https://doi.org/10.1016/j.chemosphere.2020.127659

92. European chemical agency. (2023, April). ECHA publishes PFAS restriction proposal. https://echa.europa.eu/-/echa-publishes-pfas-restriction-proposal

93. Biomimicry Institute. (2021). The Nature of Fashion: Design for Decomposition. https://d4d.biomimicry.org/

94. DEFRA. (n.d.). Anaerobic Digestion Strategy and Action Plan. Retrieved September 22, 2023, from https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/69400/anaerobic-digestion-strat-action-plan.pdf

95. Materiom: Home. (n.d.). Retrieved February 8, 2024, from https://materiom.org/

96. Natural Resources Defence Council. Single-use plastics 101 (January 2020). https://www.nrdc.org/stories/single-use-plastics-101#what

97. Home – Notpla (2024, February 9). https://www.notpla.com/

98. P.Paslier. (2018, January 19) As shops ditch plastic packaging, seaweed will take over. Wired Magazine. https://www.wired.co.uk/article/post-plastic-future-seaweed-packaging-wired-world-2018

99. The World Bank Group. (n.d.). What a waste 2.0: A Global Snapshot of Solid Waste Management to 2050. https://documents1.worldbank.org/curated/en/697271544470229584/pdf/What-a-Waste-2-0-A-Global-Snapshot-of-Solid-Waste-Management-to-2050.pdf

100. The butterfly diagram: Visualising the circular economy. (n.d.). Retrieved September 13, 2023, from https://ellenmacarthurfoundation.org/circular-economy-diagram

101. Desing, H., Brunner, D., Takacs, F., et. al. (2020). A circular economy within the planetary boundaries: Towards a resource-based, systemic approach. Resources, Conservation and Recycling, 155, 104673.

102. Ellen MacArthur Foundation. Circular economy systems diagram (February 2019). www.ellenmacarthurfoundation.org. Drawing based on Braungart & McDonough, Cradle to Cradle (C2C).

103. Earth Overshoot Day 2022: Circular businesses are reversing overshoot. (2022, July). Earth Overshoot Day. https://www.overshootday.org/newsroom/press-release-circular-businesses-reversing-overshoot-english/

104. Encore (ENCORE (Exploring Natural Capital Opportunities, Risks and Exposure)). (2024). [dataset]. https://encorenature.org/en

105. Winkler, K., Fuchs, R., Rounsevell, M., & Herold, M. (2021). Global land use changes are four times greater than previously estimated. Nature Communications, 12(1), 2501. https://doi.org/10.1038/s41467-021-22702-2

106. Winkler, K., Fuchs, R., Rounsevell, M., & Herold, M. (2021). Global land use changes are four times greater than previously estimated. Nature Communications, 12(1), 2501. https://doi.org/10.1038/s41467-021-22702-2

107. What exactly is the sharing economy? (2017, December 13). World Economic Forum. https://www.weforum.org/agenda/2017/12/when-is-sharing-not-really-sharing/

108. An introduction to circular design. (2022, June 7). https://www.ellenmacarthurfoundation.org/news/an-introduction-to-circular-design

109. UN department of economic and social affairs. (2020, February 18). Frontier technology quarterly: Does the sharing economy share or concentrate? https://www.un.org/development/desa/dpad/publication/frontier-technology-quarterly-does-the-sharing-economy-share-or-concentrate/

110. Home—Mycocycle. (2023, August 14). https://mycocycle.com/

111. Sharma, I. (2020). Bioremediation techniques for polluted environment: concept, advantages, limitations, and prospects. In Trace metals in the environment-new approaches and recent advances. IntechOpen.

112. The Living Machine: An ecological approach to poo. (2010, June 8). https://theecologist.org/2010/jun/08/living-machine-ecological-approach-poo

113. Tournier, V., Topham, C. M., Gilles, A., David, B., Folgoas, C., Moya-Leclair, E., ... & Marty, A. (2020). An engineered PET depolymerase to break down and recycle plastic bottles. Nature, 580(7802), 216-219.

114. Srikanth, M., Sandeep, T. S. R. S., Sucharitha, K., & Godi, S. (2022). Biodegradation of plastic polymers by fungi: a brief review. Bioresources and Bioprocessing, 9(1), 42.

115. Peng, B. Y., Li, Y., Fan, R., Chen, Z., Chen, J., Brandon, A. M., ... & Wu, W. M. (2020). Biodegradation of low-density polyethylene and polystyrene in superworms, larvae of Zophobas atratus (Coleoptera: Tenebrionidae): Broad and limited extent depolymerization. Environmental Pollution, 266, 115206.

116. How do we manage waste sustainably? (n.d.). Retrieved September 13, 2023, from https://www.towardszerowaste.sg/zero-waste-masterplan/chapter2/managing-waste-sustainably/

117. Arup. Circular Buildings Toolkit. Retrieved September 13, 2023 from https://ce-toolkit.dhub.arup.com/.

118. Sullivan, R., & Doskow, J. (2020, August 14). How the world's largest garbage dump evolved into a green oasis. The New York Times. https://www.nytimes.com/2020/08/14/nyregion/freshkills-garbage-dump-nyc.html

119. Smithsonian. (2012, October 15). The transformation of freshkills park from landfill to landscape. Smithsonian Magazine. https://www.smithsonianmag.com/arts-culture/the-transformation-of-freshkills-park-from-landfill-to-landscape-75931143/

120. Freshkills park. (n.d.). Freshkills Park. Retrieved February 9, 2024, from https://freshkillspark.org/

121. Smithsonian. (2012, October 15). The transformation of freshkills park from landfill to landscape. Smithsonian Magazine. https://www.smithsonianmag.com/arts-culture/the-transformation-of-freshkills-park-from-landfill-to-landscape-75931143/

122. Rockström, J., Steffen, W., Noone, K. et. al. (2009). Planetary boundaries: exploring the safe operating space for humanity. Ecology and society, 14(2).

123. Earth from the moon | american experience | pbs. (n.d.). Retrieved September 14, 2023, from https://www.pbs.org/wgbh/americanexperience/features/moon-earth-moon/

124. The SDGs wedding cake. (2016, June 14). https://www.stockholmresilience.org/research/research-news/2016-06-14-the-sdgs-wedding-cake.html

125. Reconnect to the biosphere. (2015, February 19). https://www.stockholmresilience.org/research/research-news/2015-02-19-reconnect-to-the-biosphere.html

126. The SDGs wedding cake. (2016, June 14). https://www.stockholmresilience.org/research/research-news/2016-06-14-the-sdgs-wedding-cake.html

127. The SDGs wedding cake. (2016, June 14). https://www.stockholmresilience.org/research/research-news/2016-06-14-the-sdgs-wedding-cake.html

128. UKGBC. (2023). System Enablers for a Circular Economy. https://ukgbc.org/resources/system-enablers-for-a-circular-economy/

129. Well-being of future generations (Wales) act 2015 – the future generations commissioner for wales. (n.d.). Retrieved September 14, 2023, from https://www.futuregenerations.wales/about-us/future-generations-act/

130. Hub, I. S. K. (2022, March 31). Guest article: Future perfect: integrating long-term thinking into public policy | sdg knowledge hub | iisd. https://sdg.iisd.org:443/commentary/guest-articles/future-perfect-integrating-long-term-thinking-into-public-policy/

131. Nationen, V. (2021). Our Common Agenda-Report of the Secretary-General. UN. https://www.un.org/en/content/common-agenda-report/

132. Pörtner, H.-O., Roberts, D. C., Tignor, M. M. B., et. al. (2022). Climate change 2022: Impacts, adaptation and vulnerability. Contribution of working group ii to the sixth assessment report of the intergovernmental panel on climate change. https://www.ipcc.ch/report/ar6/wg2/

133. WGII summary for policymakers headline statements. (2022, February 28). https://www.ipcc.ch/report/ar6/wg2/resources/spm-headline-statements/

134. How collaboration is key to solving the global climate crisis | common purpose | Retrieved June 12, 2023, from https://commonpurpose.org/blog/archive/how-collaboration-is-key-to-solving-the-global-climate-crisis/

135. Rockström, J., Gupta, J., Qin, D. et al. Safe and just Earth system boundaries. Nature 619, 102–111 (2023). https://doi.org/10.1038/s41586-023-06083-8

136. Episode 2: Kate Raworth on "doughnut economics." (2017, August 23). TheNextSystem.Org. https://thenextsystem.org/learn/stories/episode-2-kate-raworth-doughnut-economics?mc_cid=ec024a8f47&mc_eid=88ee59640c

137. Just transition—Climate justice alliance. (n.d.). Retrieved September 21, 2023, from https://climatejusticealliance.org/just-transition/

138. Monbiot, G. (2017, May 31). Public luxury for all or private luxury for some: This is the choice we face. The Guardian. https://www.theguardian.com/commentisfree/2017/may/31/private-wealth-labour-common-space

139. Distributive justice—An overview | sciencedirect topics. (2021). Retrieved September 21, 2023, from https://www.sciencedirect.com/topics/social-sciences/distributive-justice

140. What's the best way to find common ground in public spaces? | Aeon Essays. (n.d.). Aeon. Retrieved September 21, 2023, from https://aeon.co/essays/whats-the-best-way-to-find-common-ground-in-public-spaces

141. Monbiot, G. (2017, May 31). Public luxury for all or private luxury for some: This is the choice we face. The Guardian. https://www.theguardian.com/commentisfree/2017/may/31/private-wealth-labour-common-space

142. What's the best way to find common ground in public spaces? | Aeon Essays. (n.d.). Aeon. Retrieved September 21, 2023, from https://aeon.co/essays/whats-the-best-way-to-find-common-ground-in-public-spaces

143. NASA. (2015, February 23). Earthrise. NASA. http://www.nasa.gov/multimedia/imagegallery/image_feature_1249.html

144. Whitmee, S., Haines, A., Beyrer, C. et. al. (2015). Safeguarding human health in the Anthropocene epoch: report of The Rockefeller Foundation–Lancet Commission on planetary health. The lancet, 386(10007), 1973-2028.

145. Peralta, J. (2015, July 16). Planetary health: A new discipline in global health. The Rockefeller Foundation. https://www.rockefellerfoundation.org/blog/planetary-health-a-new-discipline-in-global-health/

146. Ambient (Outdoor) air pollution. (2022, December 19). https://www.who.int/news-room/fact-sheets/detail/ambient-(outdoor)-air-quality-and-health

147. Franklin, N. (2020, February 3). Mental health benefits of time in nature valued at £4.5 trillion globally. Workplace Insight. https://workplaceinsight.net/mental-health-benefits-of-time-in-nature-valued-at-4-5-trillion-globally

148. White, M.P., Alcock, I., Grellier, J. et al. Spending at least 120 minutes a week in nature is associated with good health and wellbeing. Sci Rep 9, 7730 (2019). https://doi.org/10.1038/s41598-019-44097-3

149. Business in the community. (2021). The power of nature for employee wellbeing. The Prince's responsible business network. https://www.bitc.org.uk/wp-content/uploads/2021/05/bitc-toolkit-environment-ignition-thepowerofnature-may21.pdf

150. Lackey, N. Q., Tysor, D. A., McNay, G. D., Joyner, L., Baker, K. H., & Hodge, C. (2021). Mental health benefits of nature-based recreation: a systematic review. Annals of Leisure Research, 24(3), 379-393.

151. Thomson, S. (n.d.). Exploring Environmental Racism and the Environmental Justice Movement. Oxford African American Studies Center. https://oxfordaasc.com/page/2977

152. Hoffman, J. S., Shandas, V., & Pendleton, N. (2020). The effects of historical housing policies on resident exposure to intra-urban heat: a study of 108 US urban areas. Climate, 8(1), 12.

153. Tree Equity Score. (n.d.). About Tree Equity Score. https://www.treeequityscore.org/about

154. Sustainable farming incentive guidance. (2023, August 10). GOV.UK. https://www.gov.uk/government/collections/sustainable-farming-incentive-guidance

155. COP27 Reaches Breakthrough Agreement on New "Loss and Damage" Fund for Vulnerable Countries. (2022, November 20). UNFCCC. https://unfccc.int/news/cop27-reaches-breakthrough-agreement-on-new-loss-and-damage-fund-for-vulnerable-countries

156. Harvey, F., Lakhani, N., & Gayle, D. (2022, November 18). Cop27: Is it right to talk of 'reparations'? The Guardian. https://www.theguardian.com/environment/2022/nov/18/cop27-is-it-right-to-talk-of-reparations

157. Amsterdam Donut Coalition. (n.d.). Amsterdam city doughnut | deal. Doughnut economic action lab. Retrieved September 21, 2023, from https://doughnuteconomics.org/stories/1

158. C40 Cities. (n.d.) Thriving Cities Initiative. Retrieved September 21, 2023, from https://www.c40.org/what-we-do/raising-climate-ambition/inclusive-thriving-cities/thriving-cities/

159. The Melbourne doughnut. (2023, March 12). Regen Melbourne. https://www.regen.melbourne/news/melbdoughnut

160. Grabowski, Z. J., McPhearson, T., & Pickett, S. T. A. (2023). Transforming US urban green infrastructure planning to address equity. Landscape and Urban Planning, 229, 104591. https://doi.org/10.1016/j.landurbplan.2022.104591

161. Harshbarger, D., & Perry , A. M. (2019, October 14). America's formerly redlined neighborhoods have changed, and so must solutions to rectify them. Brookings; Brookings Institution. https://www.brookings.edu/articles/americas-formerly-redlines-areas-changed-so-must-solutions/

162. Rodriguez, J. C. (2022, February 14). 20 inspiring indigenous quotes that remind us to protect mother earth. Circular Disruption. https://medium.com/circular-disruption/20-inspiring-indigenous-quotes-that-remind-us-to-protect-mother-earth-d4a1e672aedc

163. Staff, C. N. U. (2014, October 10). Four types of placemaking. CNU. https://www.cnu.org/publicsquare/four-types-placemaking

164. Land stewardship policy. (n.d.). Scottish Wildlife Trust. Retrieved September 21, 2023, from https://scottishwildlifetrust.org.uk/our-work/our-advocacy/policies-and-positions/land-stewardship-policy/

165. Roudavski, S. (2020) Multispecies Cohabitation and Future Design, in Boess, S., Cheung, M. and Cain, R. (eds.), Synergy - DRS International Conference 2020, 11-14 August, Held online. https://doi.org/10.21606/drs.2020.402

166. What is Regenerative Place-making? (2022, March 28). The RSA. https://www.thersa.org/fellowship/news/what-is-regenerative-place-making

167. Gregory, R., Failing, L., Harstone, M., Long, G., McDaniels, T., & Ohlson, D. (2012). Structured decision making: a practical guide to environmental management choices. John Wiley & Sons.

168. Urban citizen learning. (n.d.). 300.000 Km/s. Retrieved September 21, 2023, from https://300000kms.net/case_study/urban-citizen-learning/

169. The people are beautiful already: Indigenous design and planning | cooper hewitt, smithsonian design museum. (2017, February 16). https://www.cooperhewitt.org/2017/02/16/the-people-are-beautiful-already-indigenous-design-and-planning/

170. The seventh generation principle 7 the seventh generation. (2021, September 26). https://theseventhgeneration.org/blog-the-seventh-generation-principle/

171. Kassam, A. (2018, May 31). Canada's indigenous architecture Biennale exhibit weaves nature, culture and technology. The Guardian. https://www.theguardian.com/world/2018/may/31/venice-architecture-biennale-canada-indigenous-exhibit

172. Watson, J., & Davis, W. (2019). Lo-TEK: Design by radical indigenism. Taschen.

173. Kassam, A. (2018, May 31). Canada's indigenous architecture Biennale exhibit weaves nature, culture and technology. The Guardian. https://www.theguardian.com/world/2018/may/31/venice-architecture-biennale-canada-indigenous-exhibit

174. Te awa tupua—Whanganui river settlement. (n.d.). Retrieved September 21, 2023, from https://www.whanganui.govt.nz/About-Whanganui/Our-District/Te-Awa-Tupua-Whanganui-River-Settlement

175. Salopek, P. (2019, November 11). Living tree bridges in India stand strong for hundreds of years. History. https://www.nationalgeographic.com/history/article/india-living-tree-bridges-stand-hundreds-years

176. United Nations Environment Programme (2021). Becoming #GenerationRestoration: Ecosystem restoration for people, nature and climate. Nairobi https://wedocs.unep.org/bitstream/handle/20.500.11822/36251/ERPNC.pdf

177. BioScience, Volume 73, Issue 12, December 2023, Pages 841–850, https://doi.org/10.1093/biosci/biad080

178. Wilson, E. O. (1986). Biophilia. Harvard university press.

179. Heerwagen, J. (2009). Biophilia, health, and well-being. Restorative commons: Creating health and well-being through urban landscapes, 39-57.

180. Sustainability 2023, 15(4), 3783; https://doi.org/10.3390/su15043783

181. Arup. (n.d.). Social value and equity. https://www.arup.com/services/climate-and-sustainability-services/social-value-and-equity

182. Arup. (n.d.). Accessible and inclusive environments. https://www.arup.com/services/buildings/accessible-environments

183. Arup. (n.d.). Community engagement. https://www.arup.com/our-firm/community-engagement

184. Arup. (n.d.). Inclusive cities. https://www.arup.com/markets/cities/inclusive-cities

185. Arup. (2021). Designing for planetary boundary cities. https://www.arup.com/perspectives/publications/research/section/planetary-boundaries

186. Arup. (n.d.). Terrain. https://www.arup.com/services/tools/terrain

187. Arup. (2019). Digital twin: towards a meaningful framework. https://www.arup.com/perspectives/publications/research/section/digital-twin-towards-a-meaningful-framework

188. Arup. (n.d.). Arup's Reconciliation Action Plan in Canada. https://www.arup.com/perspectives/publications/promotional-materials/section/arups-reconciliation-action-plan-in-canada

189. Arup. (n.d.) What is the circular economy? https://www.arup.com/perspectives/what-is-the-circular-economy

190. A healthy economy should be designed to thrive, not grow | Kate Raworth. (2018, June 5). https://www.youtube.com/watch?v=Rhcrbcg8HBw

191. A healthy economy should be designed to thrive, not grow | Kate Raworth. (2018, June 5). https://www.youtube.com/watch?v=Rhcrbcg8HBw

192. Doughnut Economics Action Lab. (n.d.). About Doughnut Economics. https://doughnuteconomics.org/about-doughnut-economics

193. Arup. (n.d.) Making the Total Value Case for Investment in Infrastructure and the Built Environment. https://www.arup.com/perspectives/publications/research/section/making-the-total-value-case-for-investment-in-infrastructure-and-the-built-environment

194. McConnell, P. and Carfrae, T. (n.d.) Engaging everyone: virtual design and consultation come of age. Arup. https://www.arup.com/perspectives/engaging-everyone-virtual-design-and-consultation-come-of-age

195. Environment Act 2021, c. 30. Available at: https://www.legislation.gov.uk/ukpga/2021/30/contents

196. Nature Repair Act 2023. Available at: https://www.legislation.gov.au/C2023A00121/asmade/text

197. European Commission. (n.d.). Nature restoration law. https://environment.ec.europa.eu/topics/nature-and-biodiversity/nature-restoration-law_en

198. Richard, B. (n.d.) Shaping the landscape: governments' role in the green economy. Arup. https://www.arup.com/perspectives/shaping-the-landscape-governments-role-in-the-green-economy

199. Bennett, N. and Lemoine, G. James. (2014). What VUCA Really Means for You. Harvard Business Review. https://hbr.org/2014/01/what-vuca-really-means-for-you

200. da Silva, J. (n.d.). Climate change: resilience and adaptability – Promoting open dialogue and best practice on climate change. Arup. https://www.arup.com/perspectives/climate-change-resilience-and-adaptability

201. Arup. (n.d.). City Resilience Index. https://www.arup.com/perspectives/publications/research/section/city-resilience-index

202. Arup. (n.d.). Foresight Advisory. https://www.arup.com/perspectives/publications/promotional-materials/section/foresight-advisory

203. Mazzucato, M. (2017). Mission-Oriented Innovation Policy. The RSA and UCL. https://www.thersa.org/globalassets/pdfs/reports/mission-oriented-policy-innovation-report.pdf

204. Arup. (n.d.). Partnerships. https://www.arup.com/our-firm/arup-partnerships

205. Arup. (n.d.). Regenerative land management. https://www.arup.com/services/planning/regenerative-land-management

206. Open Data Institute for Arup. (2021). Exploring new approaches for sharing data in the built environment. https://www.arup.com/perspectives/publications/research/section/exploring-new-approaches-for-sharing-data-in-the-built-environment

207. Satyamev jayate water cup: Overview, impact and success stories | paani foundation. (n.d.). Https://Www.Paanifoundation.In/. Retrieved September 21, 2023, from https://www.paanifoundation.in/watercup/

208. International Living Future Institute. (n.d.). Living Building Challenge. https://living-future.org/lbc/

209. Arup's sustainable office fit out restores optimises wellbeing. (n.d.). Retrieved September 21, 2023, from https://www.arup.com/en/projects/living-arup-auckland-office-aotearoa-new-zealand

210. Quintana roo reef protection(Parametric insurance). (n.d.). Retrieved September 21, 2023, from https://www.greenfinanceinstitute.co.uk/gfihive/case-studies/quintana-roo-reef-protection-parametric-insurance

211. DC stormwater retention credit trading programme. (n.d.). Retrieved September 21, 2023, from https://www.greenfinanceinstitute.co.uk/gfihive/case-studies/stormwater-retention-credit-trading-programme

212. Arup. (n.d.). City Water Resilience Approach. https://www.arup.com/perspectives/publications/research/section/the-city-water-resilience-approach

213. Shouler, M. (n.d.). From flood risk to safe supply: cities tackle water resilience. Arup. https://www.arup.com/perspectives/publications/research/section/the-city-water-resilience-approach

214. Adlington, K. (2021). Arup brings built environment expertise to winners of the Earthshot Prize. Arup. https://www.arup.com/news-and-events/arup-brings-built-environment-expertise-to-winners-of-the-earthshot-prize

215. The Earthshot Prize. (n.d.). Urgency + Optimism = Action. Our Vision & Mission. https://earthshotprize.org/our-vision-mission/

216. The Earthshot Prize. (n.d.). How We Scale Impact. https://earthshotprize.org/our-vision-mission/

217. Katy, M. (2016, October 19). Abiotic factors—The definitive guide. Biology Dictionary. https://biologydictionary.net/abiotic-factors/

218. Anaerobic digestion—An overview | sciencedirect topics. (n.d.). Retrieved October 12, 2023, from https://www.sciencedirect.com/topics/earth-and-planetary-sciences/anaerobic-digestion

219. Anthropocene. (n.d.). Retrieved October 12, 2023, from https://education.nationalgeographic.org/resource/anthropocene

220. Biodiversity. (n.d.). Retrieved October 12, 2023, from https://education.nationalgeographic.org/resource/biodiversity

221. Wilson, E. O. (1986). Biophilia. Harvard university press

222. What is biomimicry? (n.d.). Biomimicry Institute. Retrieved October 12, 2023, from https://biomimicry.org/what-is-biomimicry/

223. Bioutilization—Asknature. (n.d.). Retrieved October 12, 2023, from https://asknature.org/term/bioutilization/

224. Bioutilization—Asknature. (n.d.). Retrieved October 12, 2023, from https://asknature.org/term/bioutilization/

225. Biosphere. (n.d.). Retrieved October 12, 2023, from https://education.nationalgeographic.org/resource/biosphere

226. Reconnect to the biosphere. (2015, February 19). https://www.stockholmresilience.org/research/research-news/2015-02-19-reconnect-to-the-biosphere.html

227. Ghofrani, Z., Sposito, V., & Faggian, R. (2017). A comprehensive review of blue-green infrastructure concepts. International Journal of Environment and Sustainability, 6(1).

228. 5 lessons learned from blue-green infrastructure delivery | Institution of Civil Engineers (ICE). Retrieved October 12,2023, from https://www.ice.org.uk/news-and-insight/the-civil-engineer/july-2021/theory-and-practice-of-blue-green-infrastructure

229. What is built environment | RICS school of built environment. (n.d.). Retrieved October 12, 2023, from https://www.ricssbe.org/special-pages/understanding-built-environment/

230. What is a circular economy? | Ellen MacArthur Foundation. (n.d.) Retrieved October 12, 2023, from https://ellenmacarthurfoundation.org/topics/circular-economy-introduction/overview

231. Ekins, P., Domenech Aparisi, T., Drummond, P., Bleischwitz, R., Hughes, N., & Lotti, L. (2020). The circular economy: What, why, how and where.

232. Definition of cocreate. (n.d.). Retrieved October 12, 2023, from https://www.merriam-webster.com/dictionary/cocreate

233. Do no significant harm | knowledge for policy. (n.d.). Retrieved October 12, 2023, from https://knowledge4policy.ec.europa.eu/glossary-item/do-no-significant-harm_en

234. About doughnut economics | deal. (n.d.). Retrieved October 12, 2023, from https://doughnuteconomics.org/about-doughnut-economics

235. Earth's Systems. (n.d.). Retrieved October 12, 2023, from https://education.nationalgeographic.org/resource/earths-systems

236. Ecosystem. (n.d.). Retrieved October 12, 2023, from https://education.nationalgeographic.org/resource/ecosystem

237. Ecosystem | definition, components, examples, structure, & facts | britannica. (2023, August 17). https://www.britannica.com/science/ecosystem

238. IPBES. (2019). Global assessment report on biodiversity and ecosystem services of the intergovernmental science-policy platform on biodiversity and ecosystem services. Zenodo. https://doi.org/10.5281/ZENODO.3831673

239. Schulze, E. D., & Mooney, H. A. (Eds.). (2012). Biodiversity and ecosystem function. Springer Science & Business Media.

240. US EPA. (2023, September 6). Environmental justice. https://www.epa.gov/environmentaljustice

241. Global commons. (n.d.). Global Commons Alliance. Retrieved October 19, 2023, from https://globalcommonsalliance.org/global-commons/

242. Habitat. (n.d.). Retrieved October 19, 2023, from https://education.nationalgeographic.org/resource/habitat

243. Holocene—An overview | sciencedirect topics. (n.d.). Retrieved October 19, 2023, from https://www.sciencedirect.com/topics/earth-and-planetary-sciences/holocene

244. Swanson, G. A., & Miller, J. G. (2009). Living systems theory. Systems Science and Cybernetics: Synergetics, 1(System Theories), 136-148.

245. Nature definition & meaning | britannica dictionary. (n.d.). Retrieved October 19, 2023, from https://www.britannica.com/dictionary/nature

246. Nature literacy: Rethinking how we teach about nature in secondary school science. (2021, June 29). Www.Ase.Org.Uk. https://www.ase.org.uk/resources/school-science-review/issue-381/nature-literacy-rethinking-how-we-teach-about-nature-in

247. What is permaculture? | permaculture education center. (n.d.). Https://Permacultureeducation.Org/. Retrieved October 19, 2023, from https://permacultureeducation.org/what-is-permaculture/

248. Arup. (2020) Designing for planetary boundary cities.

249. Horton, R., & Lo, S. (2015). Planetary health: A new science for exceptional action. The Lancet, 386(10007), 1921–1922. https://doi.org/10.1016/S0140-6736(15)61038-8

250. What are public goods? Definition, how they work, and example. (n.d.). Investopedia. Retrieved October 19, 2023, from https://www.investopedia.com/terms/p/public-good.asp

251. Arup. (2024). Knepp Wildland Carbon project. https://www.arup.com/perspectives/publications/research/section/knepp-wildland-carbon-project

252. Glossary—Global warming of 1. 5 oc. (n.d.). Retrieved October 19, 2023, from https://www.ipcc.ch/sr15/chapter/glossary/

253. Lyle, J. T. (1996). Regenerative design for sustainable development. John Wiley & Sons.

254. Rockström, J., Steffen, W., Noone, K., Persson, Å., Chapin III, F. S., Lambin, E., ... & Foley, J. (2009). Planetary boundaries: exploring the safe operating space for humanity. Ecology and society, 14(2).

255. The Portal | Measure and manage social value online. (n.d.). Social Value Portal. Retrieved October 19, 2023, from https://socialvalueportal.com/the-portal/

256. Nations, U. (n.d.). Sustainability. United Nations. Retrieved October 19, 2023, from https://www.un.org/en/academic-impact/sustainability

257. Ferrão, P., & Fernández, J. E. (2013). Sustainable urban metabolism. The MIT Press. https://doi.org/10.7551/mitpress/8617.001.0001

Image credits

In order of appearance.
Michael Pawlyn Headshot, © Michael Pawlyn
Chinampas of Mexico, © Rafael Carlos Gaviria Santos
Chinampas of Mexico, © Rafael Carlos Gaviria Santos
Nature-led Visual, © Arup
Slime Mould Urban Planning, ©NAARO
Slime Mould Urban Planning, ©NAARO
Riyadh Bioremediation Facility, © Moriyama & Teshima Planners
Abalone shell, © Unsplash
Habitat Royale, © Wax
Eastgate Building, Harare, Zimbabwe © Carlos Takudzwa Kankhungwa
Salicornia, © Barmalini
Beaver, © Unsplash
City on River, © Unsplash
Beaver, © Unsplash
Systemic Principle Visual, © Arup
Urban Metabolism, © FABRICations
Adapted Kalundborg Symbiosis, © NORDREGIO
Bee wing close up, © Unsplash
Materials Library, © Arup
Notpla seaweed packaging, ©Notpla
Bee wing close up, © Unsplash
Materials Library, © Arup
Notpla seaweed packaging, ©Notpla
Construction Waste Singapore, © Arup
Circular Buildings Toolkit, © Arup
Freashkills Park, © Freshkills Park Alliance
Construction Waste Singapore, © Arup
Equitable Principle Visual, © Arup
Adapted Earth System Boundaries, © Earth Commission
The SDGs Wedding Cake, ©
Earthrise, © NASA
Adapted Doughnut Economics, © Kate Raworth
Portland River, © Unsplash
Whanganui River, © Rumboalla
Living Tree Bridge, © Debjit
Satyamev Jayate Water Cup, © Paani Foundation
The Living Building Challenge, © International Living Future Institute
Mesoamerican Reef, © iStock
US Capitol, © Shutterstock
City Water Resilience Approach, © Arup
The Earthshot Prize Principles, © Earthshot Prize
Satyamev Jayate Water Cup, © Paani Foundation
The Living Building Challenge, © International Living Future Institute
Mesoamerican Reef, © iStock
US Capitol, © Shutterstock
City Water Resilience Approach, © Arup
The Earthshot Prize Principles, © Earthshot Prize