BMW Foundation
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NAVIGATING THE PATHWAY
TOWARDS REGENERATION:

APPLYING THE THREE HORIZONS MODEL TO NEW MATERIALS

RESPOND

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THE THREE HORIZONS MODEL

Our current model of conducting business has in recent decades put us on a path of nurturing an accelerated model of 'degenerative economics': one that has led to a point where we are now facing multiple planetary and social crises, including climate breakdown, pollution and biodiversity loss, as well as deep social inequity. It is increasingly clear that this is a model unfit for 10 billion people to thrive on the only planet we call home.

We have to learn how to work with existing systems that are breaking down, while nurturing the conditions and supporting disruptive innovations that will enable and fuel a new, regenerative system to emerge.

These dynamics of breakdown and emergence, as well as the bridge between them, are well presented in the Three Horizons model, which we use as a tool to help us think about the future in a structured way:

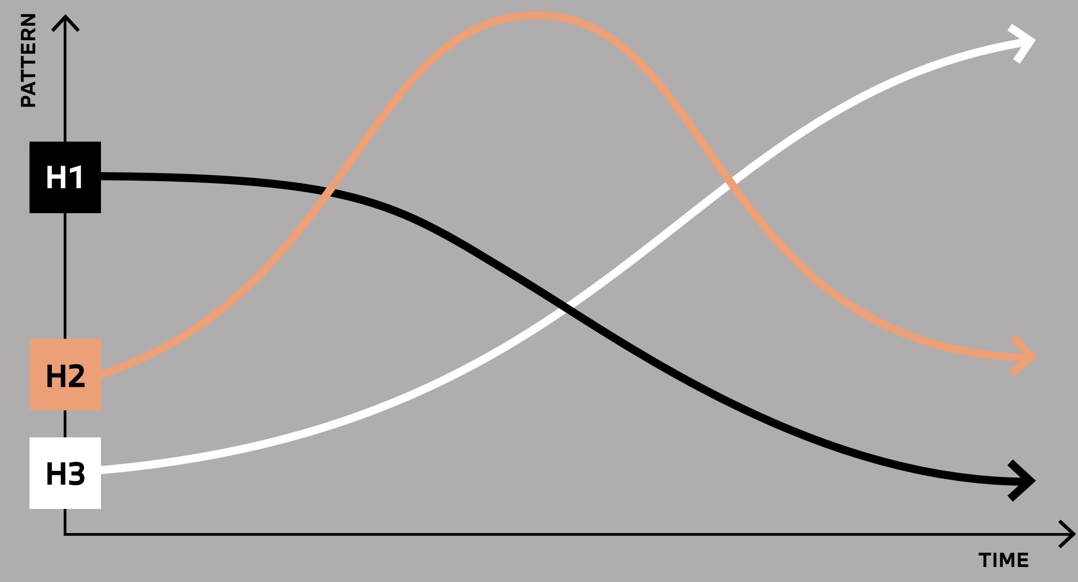
THE FIRST HORIZON – H1
represents the way things are currently done, the prevailing system. When this dominant paradigm starts to show signs of strain and is no longer considered to be fit for purpose, there is a case for change.

THE THIRD HORIZON – H3
shows what a desirable future state may look like.

THE SECOND HORIZON – H2
is an arena of transition where innovations get established to help make our desired future a reality. It points us to what may need to happen in terms of rethinking and (re)inventing new processes, structures, technologies and ways of working in order to create a bridge between the current (H1) and the future (H3) system.[1]

[1] Read more about Three Horizons at International Futures Forum, https://www.iffpraxis.com/three-horizons

THREE HORIZONS



The International Futures Forum (https://www.iffpraxis.com) describes the Three Horizons as follows:

The **first horizon** — H1 — is the dominant system at present. It represents 'business as usual'. We rely on these systems being stable and reliable. But as the world changes, so aspects of 'business as usual' begin to feel out of place or no longer fit for purpose. Eventually 'business as usual' will always be superseded by new patterns of activity.

The **third horizon** — H3 — emerges as the long-term successor to 'business as usual'. It grows from fringe activity in the present that introduces completely new ways of doing things which turn out to be much better fitted to the world that is emerging than the dominant H1 system.

The **second horizon** — H2 — is a pattern of transition activities and innovations, people trying things out in response to the ways in which the landscape is changing. Some of these innovations will be absorbed into the H1 systems to improve them and to prolong their life (we call these innovations 'H2 minus'), while some will pave the way for the emergence of radically different H3 systems (we call those 'H2 plus').

INTRODUCTION TO NEW MATERIALS

Recent crises have reminded us of the intrinsic and intricate links between mankind and the natural environment upon we depend, and how its destruction undermines our own ability to thrive. Moreover, the natural resources this environment provides are fundamental to nearly everything we create or consume.

The world's natural resources have been fueling tremendous economic growth in the past two centuries, commencing with the first industrial revolution. Particularly in the past 50 years, the extraction of raw materials has surged rapidly with currently no outlook of diminishing global demand.[i]

It is clear that the prevailing system of resource production and consumption cannot sustainably carry us into the future.[ii] Although materials innovations that move us toward a more regenerative resource use have been entering markets for decades, the field of modern materials science has advanced tremendously, especially in recent time. This is leading to a revolution in terms of the sheer breadth of new materials entering the market. Advances in, for example, nanotechnology and artificial intelligence (AI) allow us to manipulate materials at the nanoscale, while making it possible to design and optimize them with unprecedented speed and accuracy.[iii]

By incorporating the latest scientific discoveries, the possibilities are in theory almost endless. This includes materials that perform better in terms of weight, strength and durability; materials with unique optical, magnetic or electric properties; self-healing materials; new materials that fully replace harmful non-renewable inputs, or next-gen[2] materials that replace and mimic animal based products, as well as materials that are fully circular and use various biomimicry principles.[iv]

These advances in materials science are fueling radically new designs in products and buildings, and have the potential to significantly lower environmental impacts. Increasingly designers are taking a regenerative approach by incorporating nature's principles[3] and integrating fully biodegradable, emerging materials – such as algae, fungi, and microbes – into new applications.

[i, ii, iii, iv] For general references, please check the References chapter on page 48.

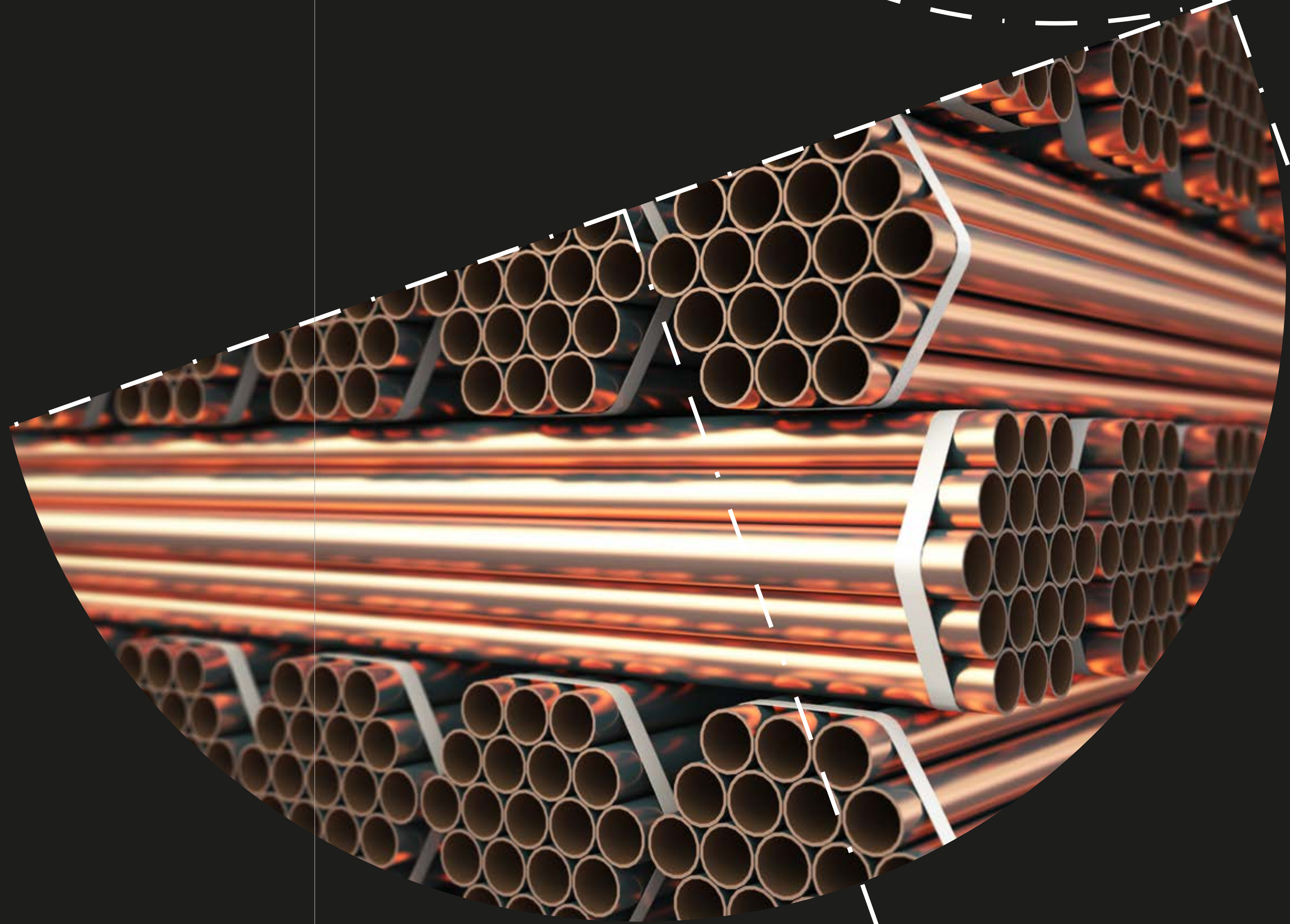
[2] Next-gen materials are novel materials that serve as ethical and sustainable alternatives to conventional animal-based fabrics (such as leather, silk, fur, down, wool, and exotic skins) for use in fashion, home products and more. They use a variety of biomimicry approaches to replicate the aesthetics and performance of their animal-based counterparts.

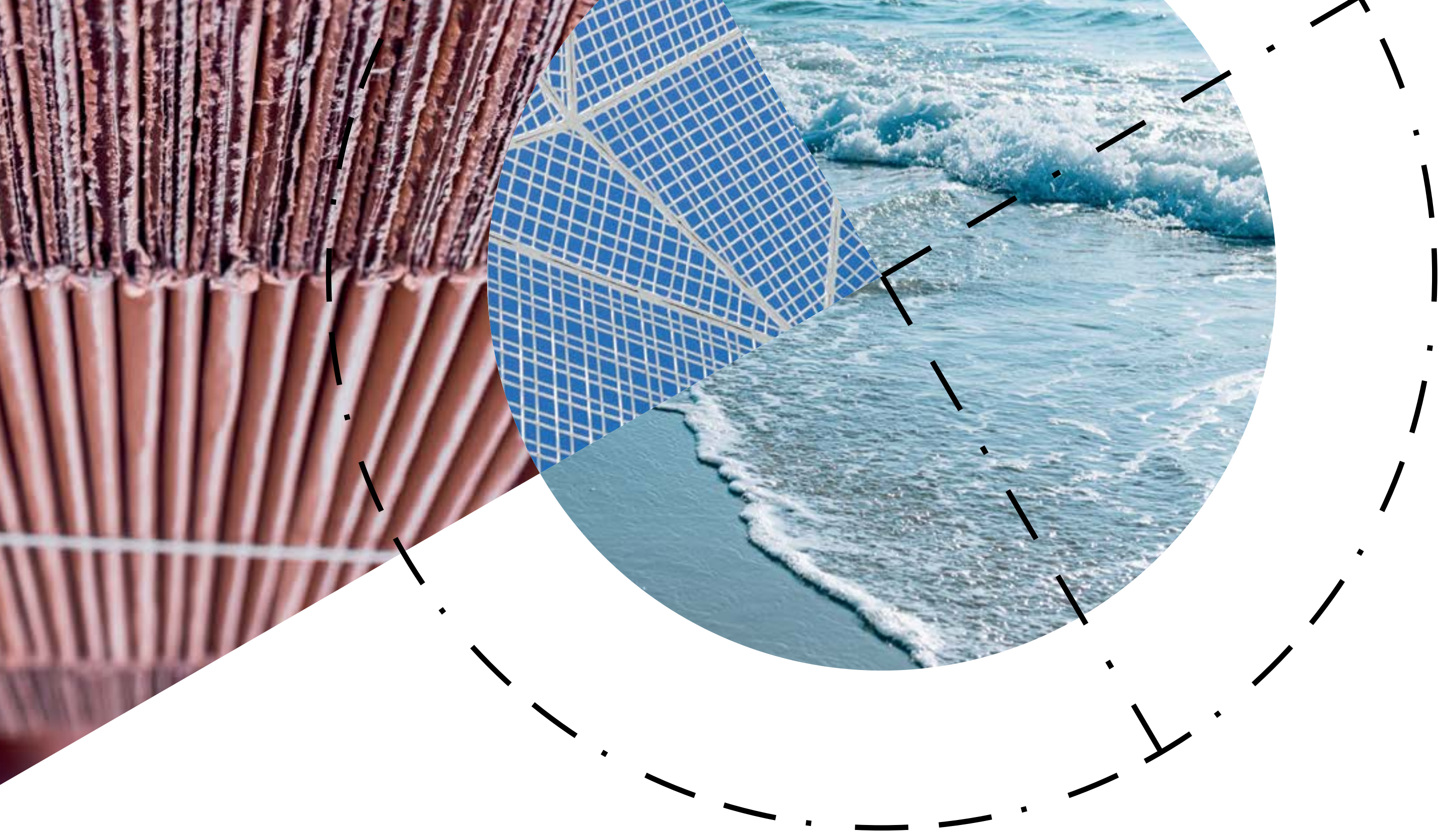
[3] Examples include the use of biomimicry, nature based solutions, and genomics.

The convergence of innovations is set to disrupt and revolutionize the materials market in the coming decades, and will increasingly move us from an extraction to a creation-based system of production. A move which may over time see exponential declines in the cost and equally exponential increases in the efficiency with which we can convert resources into materials and subsequent products.

This could have profound impacts, allowing a considerable part of current resource extraction and agricultural sites to be freed up for alternative uses. It's only up to our imagination as to what can be done with all this land if we have the technologies and the right leadership ready to leverage nature-based solutions at scale to restore biodiversity and drawdown large amounts of CO_2-e from the air.[v] For the first time since the industrial revolution, the new materials market holds the promise to decouple our rampant consumption of resources from its significant environmental footprint.

HORIZON 1
CURRENT PARADIGM





INTRODUCTION

The **first horizon** — H1 — represents the current dominant system: 'business as usual'. We rely on the prevailing system to be stable and reliable, but as the world changes, aspects of this 'business as usual' state start to feel out of place and no longer seem fit for purpose. Eventually the prevailing system will be superseded by new patterns of activity.

This overview provides a snapshot of the key characteristics of the current Horizon 1 for the materials sector, and why this system in its current state is unlikely to keep humanity within the safe and just operating space.[4] As part of the transition to a different future state, it briefly considers which aspects of the current Horizon 1 we should actively aim to hospice (in other words, support their accelerated breakdown); and which aspects we should retain for the time being in order to keep the current system functioning long enough for a new one to emerge and avoid mid-way collapse as a result of rapid breakdown before a new system has come to fruition.

A critical factor will be responsible leadership at both the public and private sector level, which can navigate the dynamics and disruptions that come with systemic change. A type of leadership in tune with an era of transformation. A type of leadership that enables us to frequently recalibrate our compass to keep it firmly pointing towards the third horizon while in the midst of a turbulent process of breakdown and emergence.

[4] The 'safe and just operating space' refers to a situation where the capacity of our planet to provide life-support systems for humanity is not endangered, and the adaptive capacities of human societies is not overburdened, while providing social wellbeing for all.

KEY CHARACTERISTICS OF THE CURRENT DOMINANT SYSTEM (H1)

EXTRACTION-BASED RESOURCE PARADIGM

Our current resource use paradigm is underpinned by an extraction-based model of resource production. Within this model, we have seen exponential growth of global resource use in the past 50 years, with currently no outlook of diminishing global demand. Non-renewable resources represent more than two-thirds of global raw material extraction, and we extensively rely on them for the production of materials such as plastics and chemicals.

LINEAR RESOURCE USE

This growth in resource consumption comes with an exponential increase in global waste generation. More than 90% of current global resource use is linear, from take to make to waste. Once turned into products, materials generally have only one lifetime before being discarded, with few materials returning to the economic system after a product reaches end-of-life.[vi]

DEPLETION OF RESOURCE STOCKS

A growing number of raw materials, some labelled as 'critical' for economic purposes, are at risk of (future) shortages. Excessive extraction of raw materials such as ores increasingly leaves lower-quality or more-difficult-to-extract stocks to harvest for future generations.

ECONOMIC PROSPERITY RELIES ON CONSUMPTION

In the current system, the environmental and social impacts of resource extraction and use are considered externalities, not (fully) priced into the earnings model. We live under a false notion of separation between humans and nature, with nature treated as a 'machine' that can be tweaked to our liking. Countries' economic prosperity is predominantly measured through the Gross Domestic Product (GDP) indicator, which is merely a measure of total consumption. Nearly all countries strive for annual GDP growth, meaning an absolute year-on-year growth in the consumption of goods and services.

TODAY'S DOMINANT SYSTEM: LOSING STRATEGIC FIT AND THEREFORE DOMINANCE OVER TIME

WHY THIS SYSTEM FAILS TO STAY WITHIN PLANETARY BOUNDARIES & MEET SOCIAL FOUNDATIONS

CURRENT RESOURCE USE A MAJOR CAUSE OF ADVERSE IMPACTS

Unsustainable resource production and consumption patterns are a systematic and major cause of negative environmental and social impacts. They're at the heart of the triple crisis of climate change, biodiversity loss and pollution. There is a strong interconnection, for instance, between our resource consumption levels and global warming, the former contributing half of global greenhouse gas emissions.[vii] In addition, over 90% of global biodiversity loss and water stress is attributed to resource production.[viii]

NET ZERO GOALS CAN EXACERBATE RESOURCE DEPLETION

Ambitious 2050 net-zero carbon goals hold the potential to substantially increase resources pressures and environmental impacts due to the tremendous volume of metals and minerals mining required in just a few ddecades to fuel e.g. the renewable energy transition. An estimated 3 billion tons of minerals and metals will be required to deploy wind, solar and geothermal power, as well as energy storage. Recycling will only meet part of this demand. Even at 100% end-of-life recycling rates, 40% of aluminum demand for renewables would still come from mining by 2050.[ix]

CONTINUED ANNUAL GDP GROWTH UNSUSTAINABLE

If developed countries in particular keep aiming for an annual GDP growth, we would double the amount of materials and waste the world generates in about 25 years. If we keep doubling, a century from now we would be using 16 times as much as today. One day we will reach the limits of such growth: when that happens, our GDP-driven economic model will collapse, unemployment will soar, and we might even get into direct conflict over whatever little resources are left.[x]

WHICH PARTS OF THE SYSTEM SHOULD WE ACTIVELY AIM TO HOSPICE?

Some of the components of the current paradigm that we should pro-actively aim to get rid of will likely come as no surprise. Nonetheless, in the absence of widespread availability of sustainable and regenerative alternatives at all levels of society, we will continue to rely on prevailing methods of resource production and consumption for some time to come.

In addition, the research and initial development of certain new materials may rely on aspects of the current Horizon 1 that are difficult to avoid in the near future if we don't want to cut off innovation. An example is the use of certain conventional types of plastics in the production process of some intermediate or end products, where no or few regenerative alternatives are yet available.

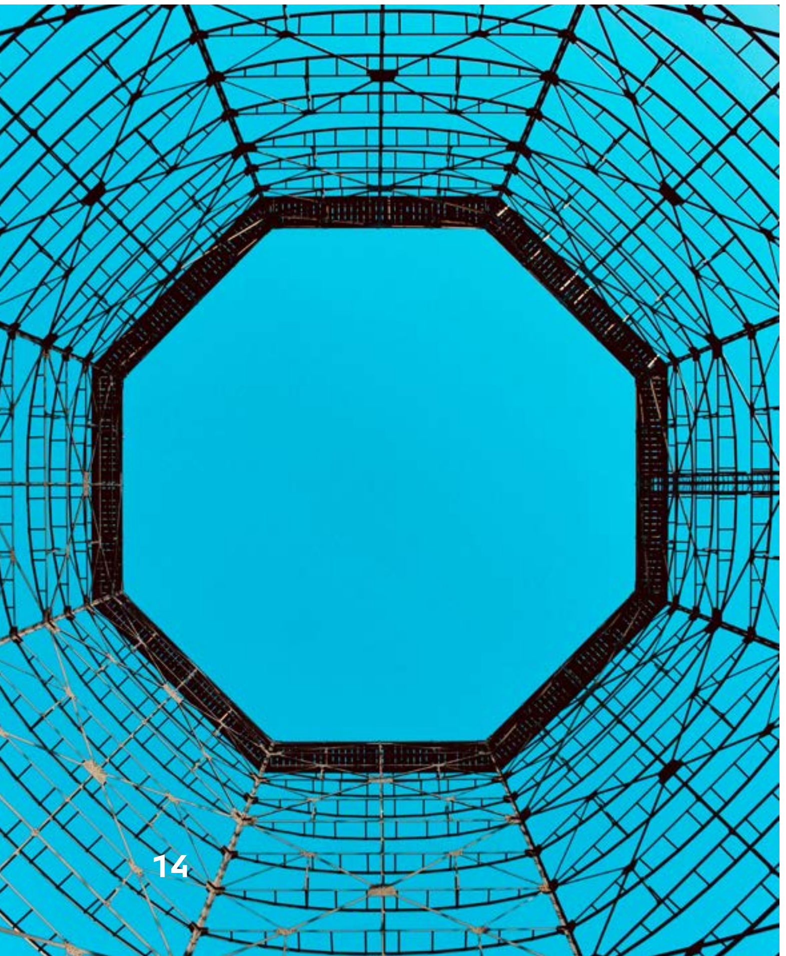
Components to phase out include the:

- Mining of virgin resources
- Use of non-renewable resources for resource production
- Use of non-biodegradable materials with poor or no recyclability
- Use of first-generation biomass where at risk of competing with food/feed crops or from excessive combined demand (e.g. bioplastics)
- Use of persistent chemicals in resource production
- Use of excessive and single-use plastics in resource production or consumption
- Linear product designs, supply chains and business models

WHICH PARTS OF THE CURRENT SYSTEM ARE IMPORTANT TO RETAIN ('THE BRIDGE, KEEPING THE LIGHTS ON')?

While in an ideal world, we would see a rapid transition from an unsustainable to a fully sustainable and regenerative system of resource production and consumption, the reality is that the infrastructure required to achieve such a goal won't be built overnight. The same holds true for dismantling the obsolete infrastructure of the old paradigm. Both processes require considerable levels of investment and planning. In addition, the field of new materials science is very much in flux, and many regenerative alternatives may still be in the research and development phase.

Rather than a big bang in which we clear out the old system before a new one has been able to sufficiently install itself, we have to take a considerate and careful approach in transitioning out of the dominant paradigm of resource production and consumption. This calls for the right leadership in safely steering us out of the current system that is leading us down the wrong road.



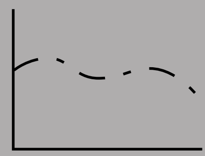
Some of the aspects related to the field of materials and resource production that we may want to retain for the time being include the following (this is by no means an exhaustive list):

- Decarbonization of the steel and cement industry, which both contribute about 8% of global carbon emissions[xi], thus having the highest embodied carbon footprint of all key materials we use. Where relevant the many applications of steel and cement should be replaced with suitable regenerative alternatives, particularly where these materials are being used for structural purposes. Doing so at scale is a major undertaking that will take several decades.
- Existing CAPEX-intensive manufacturing infrastructure and machinery, where this leads to hesitation by corporates to adopt new materials due their early obsolescence. Instead, where possible, it can help to look for opportunities to integrate new materials production into existing processes to help support its uptake and scaling.[xii]
- Certain plastic applications made with plastic types that have high recyclability (such as PET), where alternatives currently don't provide better performance. An example is the use of biobased plastics that require industrial composting to biodegrade. Many countries lack suitable industrial composting facilities, let alone separate recycling collection schemes, that would allow for capturing the end-of-life benefits of such bioplastics.[xiii]
- Current-gen alternatives for animal-based products from the meat industry, such as leather, as long as next-gen materials aren't market-ready yet at scale or are in direct competition with food crops.
- With >750 million people globally working in industry, many of which live in the Global South, a transition away from unsustainable patterns of consumption should happen soon, however at a pace that allows for mitigating its economic and employment impacts.

THE HORIZON 1 CURVE

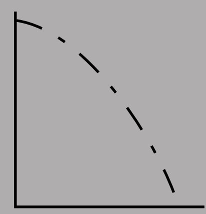
HORIZON 1 IN THE MATERIALS SECTOR

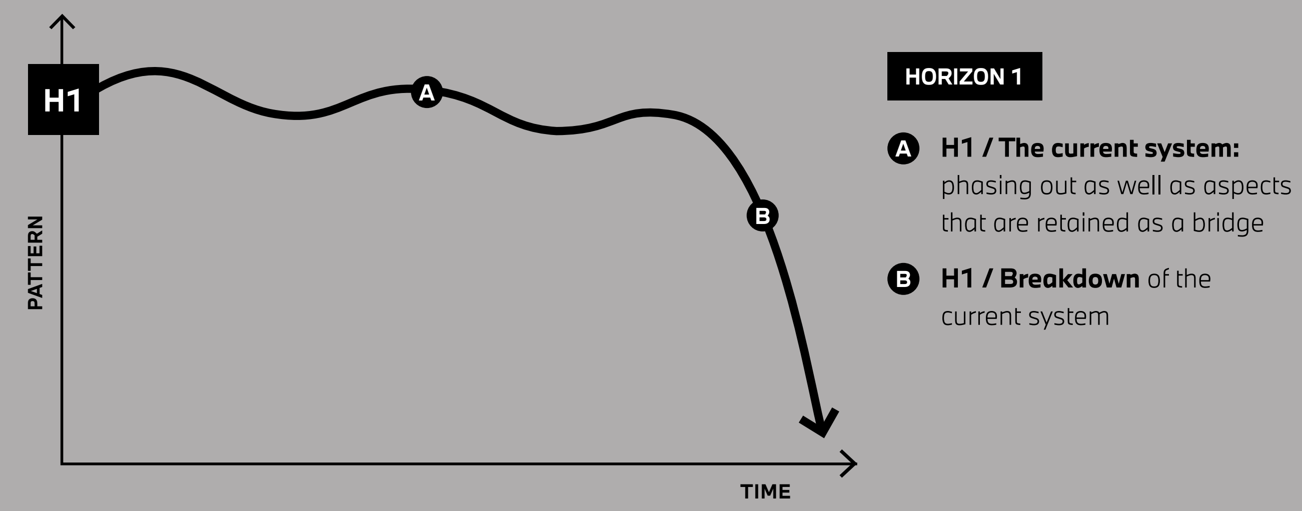
Our prevailing unsustainable paradigm for the production and consumption of physical resources, despite its lack of future-fit, appears at least volume-wise set to remain the dominant system for the time being. Even though there are clear cracks appearing in the system, as its physical, environmental and social footprints continue to expand and a growing number of actors are raising their concerns, the incumbents still hold a very powerful position. They are fueled by the ever growing resource demands of an increasing world population and expanding middle class.



Aspects that keep fueling the current paradigm and help retain its dominance include the relentless promotion of materialistic lifestyles (think, for example, 'fast fashion'), the discovery and exploitation of new resource deposits such as the oil & gas fields being eyed in the melting Arctic, the pursuit of new consumer markets particularly in the Global South, which is where most of the world's population growth is taking place, opportunities to expand existing markets even where others are shrinking and the still favourable policy climate.

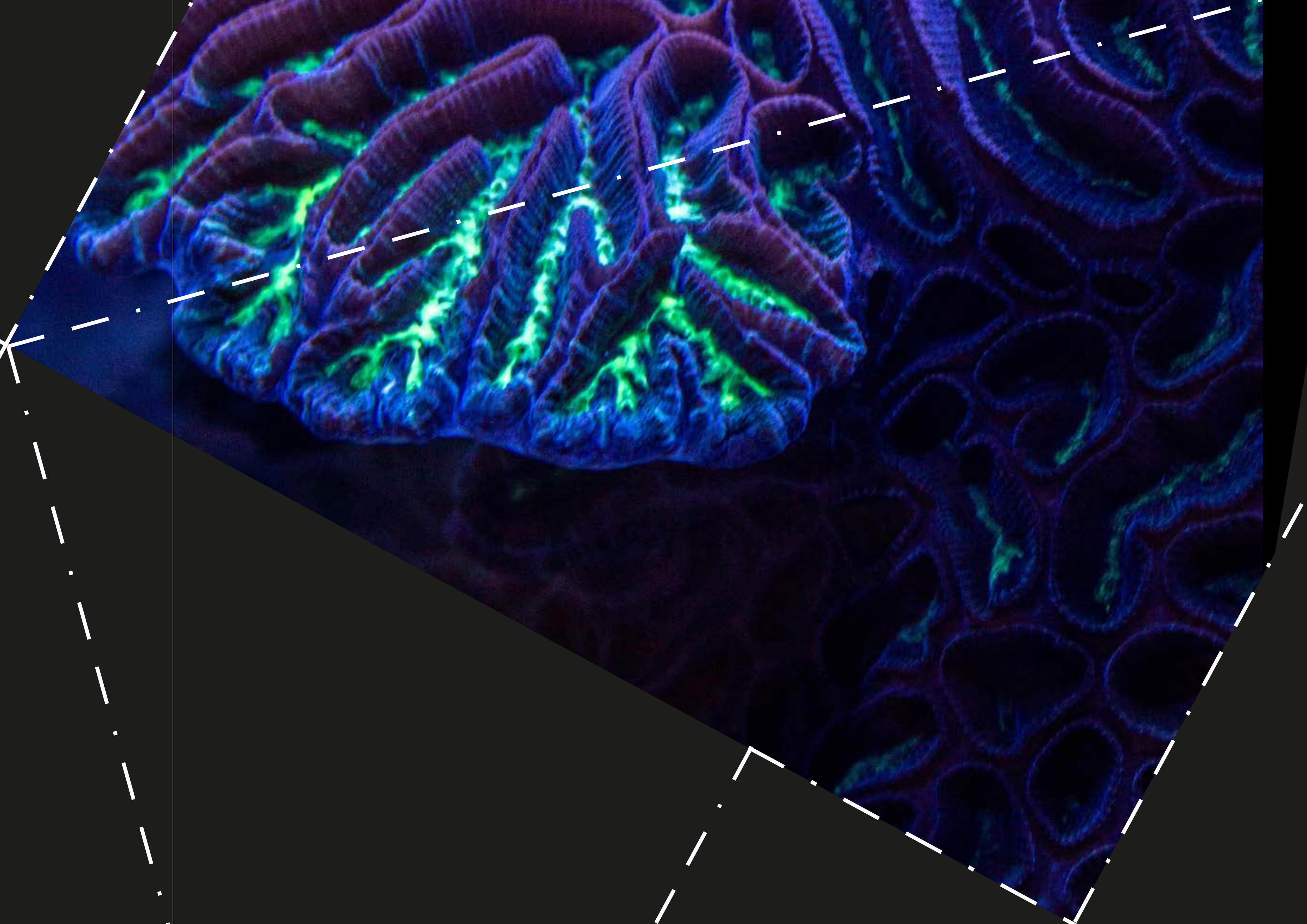
However, once the system truly hits its physical limits – in other words, when we run out of absolute resource availability – it may rapidly collapse. However, with the right leadership and decisive action, we could intentionally bend down the curve of the Horizon 1 faster, although this requires us to adopt a radically different mindset as to how we think about – and thus act on – resources and consumption. This isn't an unsurmountable challenge: the recent Covid-19 pandemic serves as an example of how a large section of the world's population can rapidly come to embrace a completely different paradigm. Nonetheless, this likely won't happen by itself, and it may not suffice for such a change of mind to happen incrementally. Rather, leaders may be wise to look for 'windows of opportunity' that can swiftly shift the Overton window* in order to bring in the new future.





Horizon 1 – Today's dominant system: losing strategic fit and therefore dominance over time

* The Overton Window refers to the ideas that together define the spectrum of acceptability of policies and practices at any point in time



HORIZON 3
VISION OF THE FUTURE

INTRODUCTION

The **third horizon** — H3 — emerges as the long-term successor to 'business as usual'. It grows from fringe activity in the present that introduces novel and sometimes radically new ways of doing and seeing, which present a better fit for the world that is emerging than the still dominant Horizon 1 system.

This overview provides a snapshot of the key characteristics of a future materials sector, and why this system holds the potential to (better) keep humanity within the safe and just operating space. Whether this system will indeed come about and at what pace depends on a variety of levers, drivers and trends which can help propel us towards or hold us back from reaching this future state. Here, we present some key considerations that may help or hinder the fruition of the third horizon.

KEY CHARACTERISTICS OF THE FUTURE SYSTEM (H3)

CREATION-BASED PRODUCTION

In the new paradigm, materials are to a considerable extent built and shaped 'from the ground up'. This fuels a move to a creation-based production, versus one where materials have to be extracted. Advanced technologies, such as nanotechnology and molecular bioengineering, enable us to manipulate matter at the atomic or molecular scale. AI-driven simulations make it possible to predict the performance of materials in different conditions. On top of this, additive manufacturing techniques such as 3D printing readily allow for turning materials into 3D products.[xiv]

ALTERED SUPPLY CHAINS

The near-shoring of material production has changed the traditional structure of many corporates, with production taking place closer to end consumers. This allows for fewer intermediate steps in terms of supplier tiers, greater horizontal vs. vertical integration and collaboration across supply chains, as well as more regional resource loops.[xvii]

MATERIALS WITH UNIQUE PROPERTIES

Materials can be deliberately created with unique properties not found in nature, including e.g. their strength, weight, durability, degradability and elasticity, but also with optical, electronic and/or magnetic properties. Next-gen materials have replaced conventional animal-based products, using biomimicry and/or synthetic biology approaches to replicate the performance of their animal-based counterparts.[xv] Materials are increasingly smart (able to respond to their environment) and (digitally) connected. This means that rather than product and building design being led by specific material properties and its limitations, materials can be created based on actual design needs. In theory, this generates unlimited potential to innovate entirely new products to serve about any relevant need.[xvi]

THE FUTURE SYSTEM: IN TUNE WITH DEEPER DRIVERS & TRENDS, EVENTUALLY EMERGING AS NEW DOMINANT SYSTEM OVER TIME

WHY THIS SYSTEM IS (BETTER) SUITED TO STAY WITHIN PLANETARY BOUNDARIES & MEET SOCIAL FOUNDATIONS

HYPER-EFFICIENCY IN PRODUCTION

Creation-based production processes enable magnitude improvements in the efficiency of turning resources into products.[5] The hyper-efficiency of creation-based production in terms of inputs including energy eliminates a very significant part of the land, water, emission and pre-consumer waste footprint of resource consumption.

CIRCULAR RESOURCE LOOPS

Creation-based production allows for shorter production chains closer to consumers, significantly reducing the environmental footprint of supply chain logistics. Products can be designed for optimal performance, durability and (energy/material) efficiency. Equally, they can be designed for maximum biodegradability, reusability and/or recyclability, thus supporting circular resource loops.[xviii]

REGENERATIVE DESIGN IN SERVICE OF LIFE

New production techniques permit for materials to be shaped in ways previously not possible or only possible through plastics, allowing for on-demand design and production. This lowers the barriers for materials switching from high- to low-impact materials, and for reducing or eliminating chemicals commonly added to support certain material properties. Equally, it allows for more modular and standardized product design, design for disassembly, as well as the easy printing of replacement parts for products to extend lifetime and support end-of-life recovery.[xix]

[5] Creation-based production holds the potential for hyper-efficiency in resource inputs and for closing the resource loop. However, whether such a state is being achieved also depends on deliberate design for such outcomes. Some of the novel and promising materials that are under development today are energy or resource intensive to produce, requiring deliberate efforts to overcome or eliminate adverse environmental footprints.

KEY LEVERS, DRIVERS AND TRENDS THAT ARE CREATING A SHIFT TOWARDS THIS FUTURE

INCREASED STAKEHOLDER PRESSURE AND AWARENESS

Shifting consumer sentiments as well as (the threat of) increased regulation has companies looking for innovations in material science that result in lower environmental footprints. The risk of price volatility resulting from critical materials scarcity leads to a search for novel materials that can help replace them.

NEW TECHNOLOGIES DRIVE RADICAL MATERIALS INNOVATIONS

The rapid advance of nanotechnology allows for manipulating matter at the atomic or molecular scale, thereby moving us closer to creation-based production methods. Emerging fields such as bioengineering help fuel radically new biobased materials. They also make it possible to increase the efficiency of bioprocesses for the generation of material feedstock. Equally, the rapid advance of AI allows for automating and optimizing the design, production, and testing of new materials.[xx]

SUPPORTING TECHNOLOGIES EASE THE MATERIALS INNOVATION PROCESS

Add to this cloud computing, which supports computing resources to be accessed in a flexible on-demand way, thus enabling greater availability, capacity and affordability of such resources by materials science start-ups for computationally intensive tasks. The Internet of Things (IoT), in combination with big data analysis and cloud computing, provides enhanced process efficiencies and helps fuel data-driven material innovation. Progress in materials science and computation supports a simulation-driven approach to developing new materials, reducing the need for repetitive analysis of physical prototypes. Finally, 3D printing supports (on-demand) design flexibility and can eliminate the need for assembly in various stages of production.[xxi]

SHIFT IN BUSINESS MODELS AND PRODUCT OFFERINGS

The increased acceptance of concepts and business models that provide access over ownership help facilitate more circular materials flows. Moreover, an increase in the customization of products has retailers increasingly switching to agile and customized manufacturing, accelerating uptake and supporting greater open-source design of novel materials. Shifting consumer expectations and enhanced IT capacities also results in increased demand for smart and digitally connected products.[6]

[6] A number of additional trends and innovations are converging that help support the move to a different system of consuming. For example, when it comes to shopping, the so-called 'first moment of truth' (the shelf in a brick & mortar shop) is increasingly being replaced by the 'zero moment of truth' (online). This provides challenges but also real opportunities in terms of resource management. In addition, for the first time in history over half of the world's population resides in urban areas. And with urban populations expected to rise by a further 20%, the higher costs and more complex (reverse) logistics of access over ownership models, such as product sharing and leasing, will benefit from the higher population density and enhanced infrastructure and facilities that are characteristic of urban areas.

KEY LEVERS, DRIVERS OR TRENDS THAT ARE HOLDING US BACK FROM REACHING THIS FUTURE

NEW INNOVATIONS FACE CHALLENGES TO BECOME MARKET-READY

New materials innovations often come with price premiums before economies of scale can be applied to bring cost curves down. They may also face long lead times – a decade is not unusual – before being market-ready due to the need for fundamental materials research and extensive innovation. Once a suitable prototype has been developed, innovations can face scaling issues as a result of the financial (CAPEX) and physical resources required to truly scale production capacity – for example, where large-scale biobased material growth facilities are required (e.g. mycelium), or in cases where one may need to switch from slow, expensive nanofabrication techniques to mass production. Startups and their leaders need more support to bridge the gap from transitioning a new materials technology from pilot or demo scale to the point where they can supply consistent quality and volume at scale.[xxii]

MISMATCH BETWEEN NOVEL INNOVATIONS AND CORPORATE EXPECTATIONS

New materials start-ups regularly struggle with combining materials innovation and its actual production in one hand, as these require very different capabilities. One way to overcome this is to team up with corporate partners. These industrial partners, however, frequently have limited tolerance for high-cost premiums, long lead times to get a novel material to a point of being market-ready, as well as the performance and cost uncertainty associated with early-stage innovations. They may also show limited willingness to shift to new materials where this could render existing machinery and infrastructure obsolete. Add to this that many corporates aren't used to working with small materials innovation start-ups and early-stage technologies, with no supply chain, no ready material, no choice of products etc. This can lead to a chicken-and-egg situation, in which start-ups need brand support to succeed, while brands like to have more certainty up front around the end product.[xxiii]

MECHANISTIC AND REDUCTIONIST MINDSET

In the past 250 years since the onset of the industrial revolution, an increasing number of countries have adopted a mechanistic worldview, which considers humans to be separate from their natural environment. This worldview has also helped fuel a reductionist approach, which refers to the idea that complicated behaviours and phenomena can be explained and solved by breaking them down into small, simple parts – not unlike the assembly line that became popular in industrial production circles. This helps explain why our major environmental crises tend to be treated in relative silos. Although this approach may work well for addressing singular issues and causes, it doesn't lend itself well for addressing complex, interrelated challenges. Unless leadership embraces a more holistic worldview, we're at risk of continuing to underestimate the deep systemic risks of current resource consumption patterns.

MATURITY OF THE FIELD

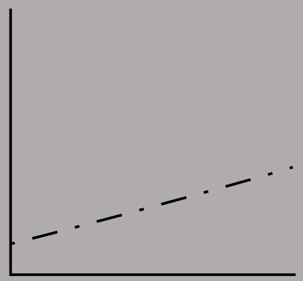
Despite the vibrancy of the field, new materials innovations are sometimes concentrated in just a few materials. For example, the field of next-gen materials innovation overwhelmingly focuses on leather, with much fewer start-ups active in replacing animal-based silk, wool, down and fur. The perception of being on the cusp of a materials revolution can lead to an overestimation in terms of actual maturity and technology readiness level of the new materials start-up field. In reality, new regenerative materials often cannot be that easily sourced. An additional complication is that many new biobased materials compete with non-renewable materials, an area whose supply chains and production processes have been perfected for decades, and may be an ongoing recipient of subsidies helping to keep prices down.[xxiv]

THE HORIZON 3 CURVE

HORIZON 3 IN THE MATERIALS SECTOR

As things stand at the moment, the new system that will replace the prevailing paradigm in the materials sector may be relatively slow to scale. This is in part due to the dominance and ongoing vigour of H1, as well as the various challenges the new materials field faces in gaining ground. Initially this could lead to a fairly modest uptake of many novel, regenerative materials in various markets.

Of course, there will be notable differences in market dominance pending the specific material – from niche markets to mainstream adoption. Nonetheless, with 75% of the world's current raw material footprint being due to non-renewable minerals, fossil fuels and metal ores – with biomass making up the remaining 25% – it is certainly no easy feat to get away from the extractive paradigm.

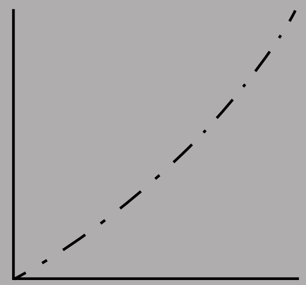


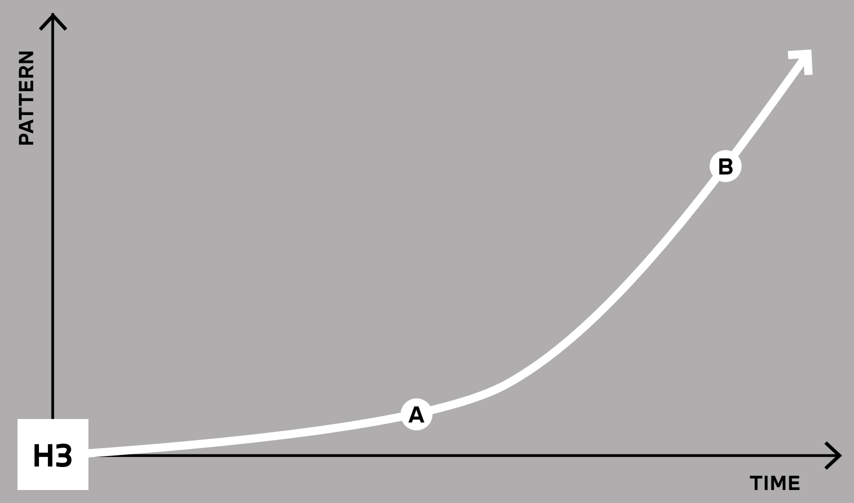
75% of non-renewable minerals, fossil fuels, and metal ores

25% of biomass

Circular Economy (2020), **Global Circularity Gap Report 2020** https://shiftingparadigms.nl/projects/3rd-global-circularity-gap-report/

Nonetheless, once availability and affordability of these new materials hit a tipping point, combined with an increasingly felt urgency to address the flaws and shortcomings of the dominant paradigm, the new materials field is likely to get into sprint mode, thus seeing a rapid uptake after all. At the same time, how quickly and steeply the Horizon 3 curve rises is not set in stone: deliberate interventions – from diverting finance flows H1 to H3, to creating a progressive policy and business environment – can support a more rapid transition from the first to the third horizon. Part of the answer lies in the innovation horizon, Horizon 2, and the vibrancy, maturity and flavour of that innovation field, which will be discussed in the next section.





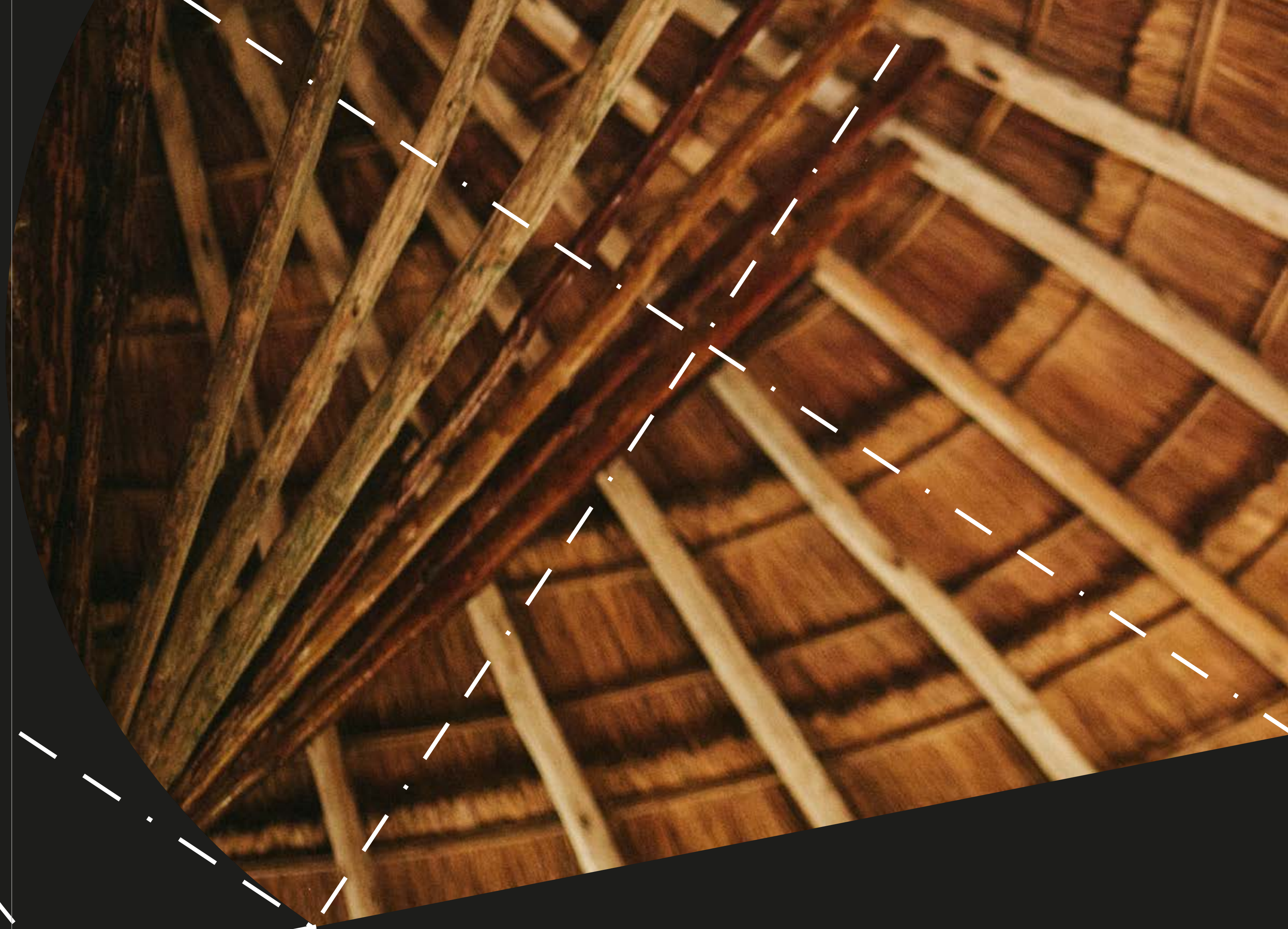
HORIZON 3

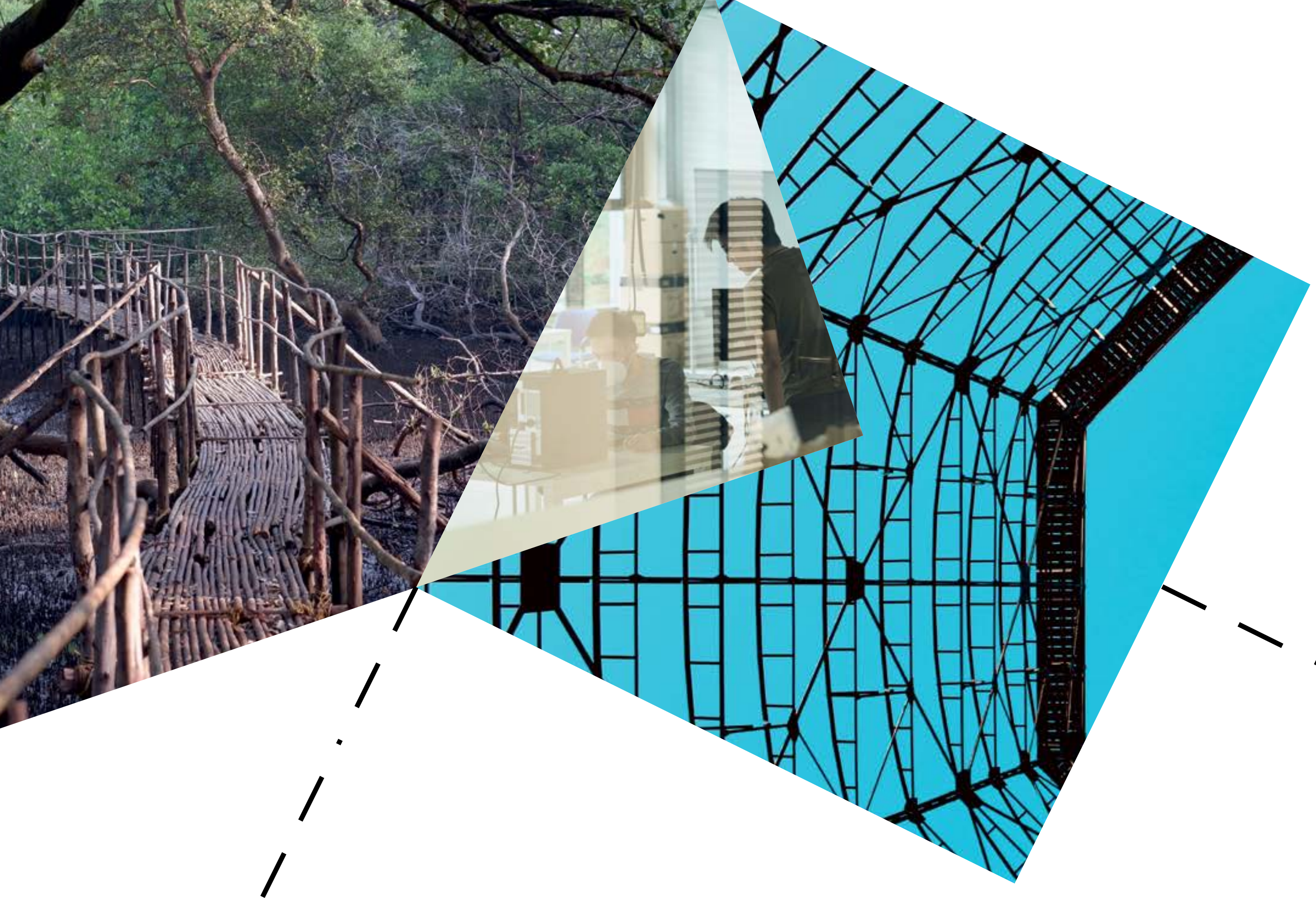
A **H3 / Weak signals of the future:** glimpses of the new system emerging

B **H3 / Breakthrough of the new system:** creation-based & circular materials production

Horizon 3 – The future system: in tune with deeper drivers & trends, eventually emerging as new dominant system over time

HORIZON 2
INNOVATION HORIZON





INTRODUCTION

The **second horizon** — H2 — is a pattern of transition activities and innovations, with innovators trying things out in response to the ways in which the landscape is changing. Within this second horizon, we can look at the field of innovations as spanning a spectrum that runs from the first (H1) to the third horizon (H3). In other words, we distinguish between innovations:

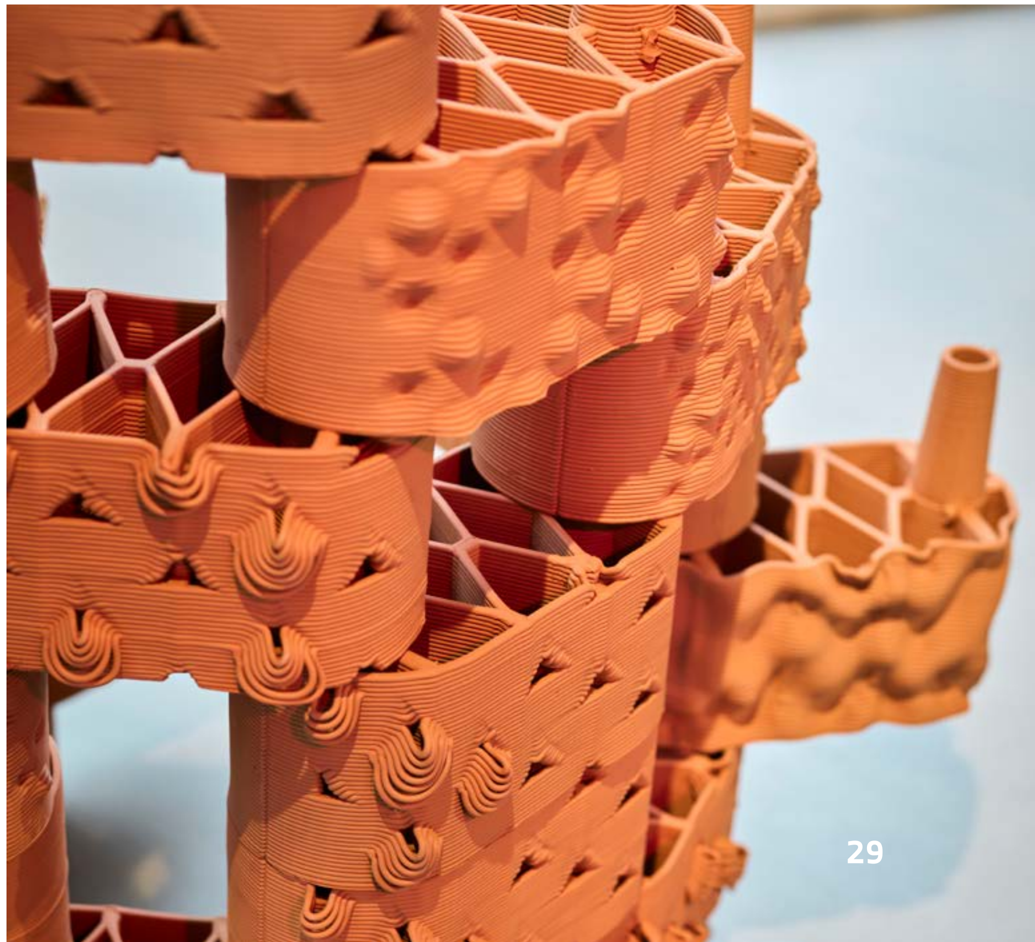
H2− which, even if helpful in the short term, are unlikely to bring about the deep change we're after and are mainly improvements on the current ways of working, thereby continuing to prop up Horizon 1 (we call these 'H2 minus' innovations),

H2+ which can be considered truly transformative innovations, disrupting current patterns and helping to bring forth the new vision in the third horizon (we call these 'H2 plus' innovations).

WHAT IS BEING DISRUPTED?

The innovation in the new materials science field that's taking place in the innovation Horizon 2 has the potential to significantly disrupt the current status quo of resource production and creation. Aspects of the current system that are likely to be fundamentally disrupted by the emergence of the new system include:

- The way materials are produced: from extraction- to creation-based;
- The raw materials they're derived from: increasingly from renewable and biodegradable sources;
- The way they can be returned into the economic system after end-of-life, or alternatively be safely returned to the natural environment: from linear to circular;
- The performance that the materials provide: with unique properties not found in nature;
- The purposes for which these materials can be used: serving about any relevant need;
- The environmental footprint these materials leave behind: hyper-efficient and closed-loop production methods, which manipulate matter at the molecular scale, and increasingly decouple resource production and consumption from its environmental impacts.



TRANSITION ZONE: LOOKING TO CAPTURE THE OPPORTUNITIES EMERGING IN A CHANGING WORLD

STATE OF INNOVATION IN THE SECOND HORIZON

Radically new materials innovations are set to disrupt and revolutionize the materials market in the coming decades[xxv], increasingly moving us from an extraction- to a creation-based system of production. At the same time, we still have some way to go to ensure that the feedstock, production process, operational performance and end-of-life options of novel materials all support regenerative outcomes across the entire materials and product lifecycle.

Nonetheless, it's not always as clear-cut as to what can be considered an innovation that supports the emerging Horizon 3 and its promise to stay within planetary boundaries, and one that rather helps prolong the dominant and unsustainable Horizon 1.

Many of the promising new biobased materials, for instance, still partially operate under the premises of Horizon 1. This may be a direct result of the limitations given by pushing the boundaries of materials science while still operating within the old paradigm. For example, the many different type of plastics already on the market provide a wide range of functionalities, some of which are difficult to mimic but are important for the performance of the end product. Although sustainable alternatives are starting to appear, developing such replacements takes considerable time and effort and also requires sufficient demand, with the latter building slowly in recent years.

Outcomes that could be considered unsustainable if scaled up and sustained over time can also be the (temporary) result of the development phase novel materials are in: innovators may use first- and second-generation biomass for their prototypes, aiming to switch out to third-generation biomass over time; energy and space requirements of new materials may fall over time as production processes become more refined and efficient. Although this can make such practices sit on the H2 minus side of the innovation spectrum, it does not automatically mean that these materials should be considered H2 minus innovations. Rather, deliberate and conscious design efforts that keep the third horizon as the ultimate north star will allow for further improving all aspects of the lifecycle and supply chain of novel materials to ensure a genuine move to a regenerative paradigm.

Having said that, the reality is as well that there are new materials entering the market which, although providing clear environmental benefits, have not been designed for truly sustainable outcomes and keep prolonging some of the harms that the current first horizon has become known for. An example is the increase in new materials that are amalgamations of multiple materials. Those materials may provide real advantages in terms of e.g. weight and strength; however, by converging different material classes, this can also easily lead to materials that are very difficult and cost-ineffective to recycle or repurpose.

This goes to show that new materials may still sit within the linear take-make-waste paradigm despite their potential benefits. Environmental benefits in a material's use phase do not automatically translate into that material actually fitting the regenerative paradigm. For that to hold true, the full lifecycle has to be designed in service of regenerative performance.[xxvi]

The next two sections thus point more towards practices and potentials in the manufacturing and use of new materials that lead to H2 minus or H2 plus outcomes rather than classifying the entire materials innovation as sitting squarely on the H2 minus or plus side of the spectrum. After all, the field is highly emergent and many innovations have not yet reached their (commercial and at-scale) end state.

IN SUPPORT OF H2 MINUS	IN SUPPORT OF H2 PLUS[7]
Extraction-based	Creation-based
Uses non-renewable inputs	Uses renewable inputs
Relies on virgin feedstock and/or feedstock with very high levels of purity	Works with recycled or repurposed feedstock
Is wasteful and/or energy-intensive in the manufacturing process	Is hyper resource & energy efficient during the manufacturing process
Designed in service of use/consumption, with little or insufficient consideration for its footprint	Designed in service of life, e.g. benign, modular, durable, flexible, mimics or takes inspiration from nature
Designed to serve non-essential and/or wasteful needs	Designed with unique properties, servicing essential as well as previously underserved needs
Relies strongly on a vertically integrated supply chain	Relies much more on a horizontally integrated supply chain
Helps perpetuate hyper / wasteful consumption patterns	Incentivizes efficient / lower / circular consumption patterns
Becomes waste at end-of-life	Is returned to the economic or biological system

Overview of characteristics that make an innovation sit on the H2 minus or H2 plus side of the innovation horizon

[7] Not each material has to meet all these conditions. For instance, it is unlikely that all materials in the future will be fully renewable, nor will that be necessary as long as they can be returned to the economic system again and again without significant leakage such as a major loss of quality.

H2– PREVALENCE OF H2 MINUS INNOVATIONS

NEW MATERIALS INNOVATIONS DON'T ALWAYS SUPPORT OPTIMAL END-OF-LIFE TREATMENT

The new materials space shows increased convergence of materials classes, with innovators creating amalgamations of two or more materials (e.g. carbon-fibre-reinforced plastics). This can hinder their recyclability and biodegradability.[xxvii] Moreover, advanced manufacturing techniques such as 3D printing currently require high-purity materials that hamper the ability to use recycled feedstock.

BIOBASED DOESN'T NECESSARILY MEAN SUSTAINABLE

Many new biobased materials currently rely on first- or (preferably) second-generation biomass. This may cause competition with food/feed crops. In addition, there is a risk that competing future demands for such biomass outstrip supply (e.g. bioplastics).[xxviii] Some of the novel biobased materials are currently also energy- and space-intensive to produce, an example being mycelium. And even biobased materials can be a cause for sustainability concerns. Cellulosics, for example, a type of bioplastics with many applications, are primarily produced from wood pulp derived from virgin trees as a raw input.[xxix]

CONVENTIONAL PLASTICS AND CHEMICALS STILL SHOW UP IN NEW MATERIALS INNOVATIONS

Plastics continue to find their way into many biobased materials applications. Examples are polyester, a plastic that is energy-intensive to produce and with most recycled polyester coming from PET bottles rather than other applications such as fabrics. The same with polyurethane (PU), a plastic often used as coating. For the time being, biobased PU is partially petroleum-based. Many next-gen materials still incorporate synthetic dyes and finishes to support performance features. These additives may result in materials with less than optimal recyclability or biodegradability as a result of toxic and/or persistent chemicals.[xxx]

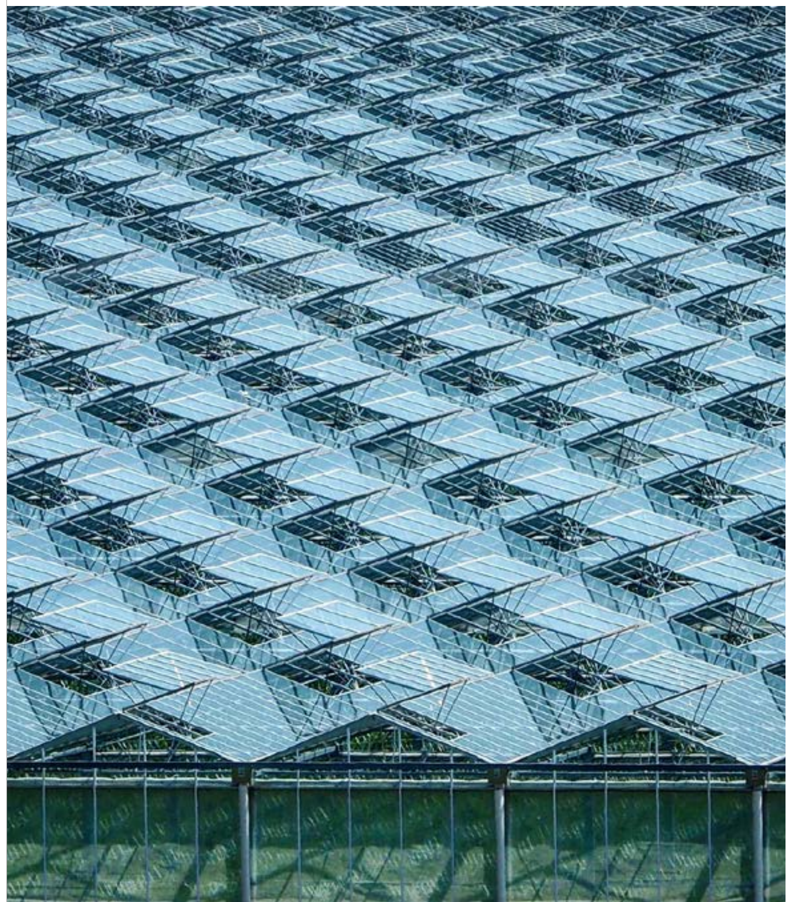
BIODEGRADABLE HAS ITS LIMITATIONS

Many new biodegradable materials can only be composted in industrial composting facilities where materials are exposed to elevated heat levels for a period of time. Such facilities are often rare or even non-existent, plus there is the need for separate collection of these waste streams. If landfilled, these materials may generate more emissions than their non-biodegradable counterparts.

H2+ PREVALENCE OF H2 PLUS INNOVATIONS

The new materials field is brimming with exciting and promising innovations that hold the promise for radically lower adverse or even (net) positive environmental footprints. The overview below provides a non-exhaustive list of innovations that hold true potential to help bring about the next horizon, Horizon 3. Whether they will deliver on this in the decades to come eventually depends on the ongoing design and re-design of the entire materials and product lifecycle to ensure we move from extractive- to creation-based, from degenerative to regenerative in the production and consumption of vital resources.[xxxi]

- The use of greenhouse gases (GHGs), particularly methane and carbon oxide, as feedstock for next-gen materials
- Graphene applications that allow for very energy-efficient, lightweight materials usable across sectors, from solar cells to transport
- Eco-efficient concrete, which uses (partial) replacements for carbon-intensive cement and may even absorb CO_2 as it hardens
- Designer carbon, a nanotechnology-inspired material that makes carbon capture & sequestration, energy storage devices and solar devices more powerful and efficient
- Super-insulating materials that can improve the energy efficiency of buildings
- Solar sprays, which can provide solar cell capability to vehicle and building coverings
- Solar-cell coatings that can potentially double the efficiency of solar cells
- Heat-reducing materials, such as coatings that reduce heat absorption from the sun, lowering air-conditioning needs
- Nanotechnology in fuel cells to provide better fuel cell performance and durability
- Living materials that create a new class of materials which combines the structural properties of traditional building materials with attributes of living systems
- Next-gen materials that use third-generation biobased materials to replace animal-based products providing similar properties and performance

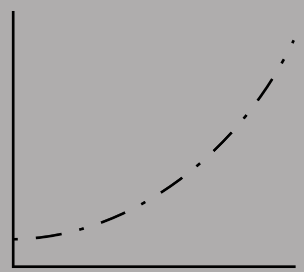


THE HORIZON 2 CURVE

HORIZON 2 IN THE MATERIALS SECTOR

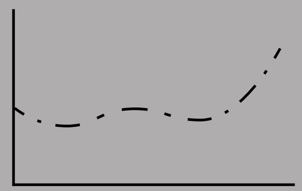
There is a high level of innovation taking place in the new materials field. The sector is vibrant and full of potential. Nonetheless, some of these innovations are at risk of being 'captured' by the prevailing system, thereby helping to perpetuate its dominance (H2-). Others may not be able to break through due to the continued dominance of H1 and the advantages it has in terms of existing production infrastructure, CAPEX, economies of scale, market share, and generally low price points, which are in part the result of not having to account for externalities.

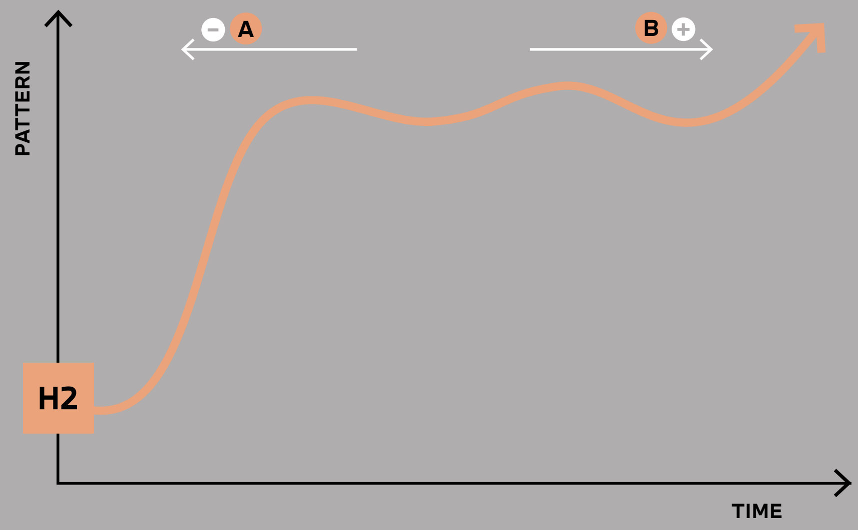
While H1 is still the dominant system in power, thus requiring H2 innovations to 'play by its rules', this may dampen initial levels of innovation vibrancy. Once H1 starts to weaken, however, previously sufficient countries, for example, introduce tough and comprehensive carbon pricing schemes, phase out harmful subsidies. Similarly, once critical material scarcities start hampering economic prosperity, combined with more and more H2+ innovations reaching commercially attractive levels of market presence, the innovation horizon will get a real boost again with larger volumes of finance shifting to these 'next horizon' innovations.



The adoption rate of the collective suite of innovations in new materials is therefore non-linear and initially follows a typical S-curve pattern: slow at first, then rapidly rising before flattening out again as market saturation is being reached. Market saturation is in this case a function of how much market the new entrants are able to capture amidst a field of incumbents.

Although moving from an extractive to a regenerative paradigm is obviously challenging and may at times feel like scaling a mountain, the challenge is certainly not unsurmountable. Pro-active support for the innovation horizon that allows these innovations to gain more traction can help overcome the plateauing of the innovation curve, and push it upwards again more rapidly than the graph suggests, thereby accelerating the emergence of the new future, H3.





Horizon 2: transition zone, looking to capture the opportunities emerging in a changing world

BRINGING IT TOGETHER FOR THE FIELD OF NEW MATERIALS

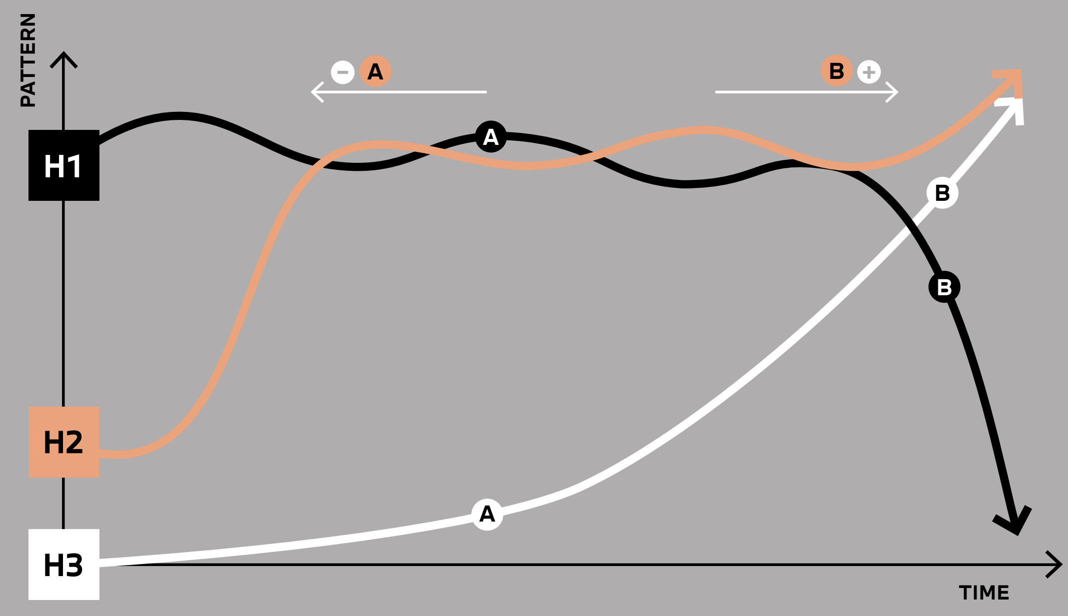
STATE OF THE TRANSITION

The materials field is in flux. On the one hand we are dealing with the incumbent system of resource production and consumption, which is a major driver behind the increasingly exacerbating environmental crises of climate change, biodiversity loss and pollution that humanity is facing today. On top of these existing challenges, the global growth in resource consumption is not showing any signs of slowing down. Rather the opposite: demand for resources continues to increase.

On the other hand, we see a new future emerging: one in which materials are increasingly built from the ground up, leading to a creation-based system of production. This will provide immense opportunities for flexibility of feedstock (input) and its eventual product outputs; for creating continuous resource loops as materials can be broken down to the molecular level at end-of-life; and for incorporating hyper-efficiency in the production process, thereby slashing a considerable part of the system's current environmental and land footprint. We are truly at the cusp of a movement that is set to disrupt and revolutionize the materials market in the decades to come.

Having said that, the prevailing system holds considerable power and under current trends may well retain its dominance for longer than is desirable, delaying the time span that new regenerative materials need to become the majority player in the markets they serve. Even though the innovation field is vibrant, innovation alone won't suffice to bring in the new future. A favourable policy and business climate and much greater levels of finance are some of the aspects that will help fuel these innovations towards market dominance, and help break down the old system.

For that to happen, we need the right type of responsible leadership and the adoption of radically different mindsets by actors across the system, such that our thoughts and actions truly start to align in order to rapidly drive forward the transition to a regenerative future.



Bringing it together – where we stand today in terms of transitioning to a new materials future

HORIZON 1

A **H1 / The current system:** phasing out as well as aspects that are retained as a bridge

B **H1 / Breakdown** of the current system

HORIZON 2

A **H2- innovations:** improve & prolong the life of H1

B **H2+ innovations:** pave the way for the emergence of H3

HORIZON 3

A **H3 / Weak signals of the future:** glimpses of the new system emerging

B **H3 / Breakthrough of the new system:** creation-based & circular materials production

SUMMARY OF THE THREE HORIZONS

HORIZON 1

- The prevailing unsustainable paradigm for the production and consumption of physical resources will at least volume-wise remain the dominant system for for the time, unless decisive action is taken.
- Despite concerns, its physical, environmental and social footprints continue to expand.
- The incumbents hold a powerful position fueled by the growing resource demands of an increasing world population and expanding middle class.
- A variety of direct and indirect drivers keep fueling the current paradigm and help it retain its dominance.
- Once the system truly hits its physical limits, e.g. when critical materials start to become scarce or run out, it may collapse rapidly.
- Equally, embracing the right type of leadership will allow us to bend down the curve faster, although this requires us to adopt a radically different mindset.
- A profound change of mindset likely won't happen by itself; rather, leaders may be wise to look for 'windows of opportunity' that can swiftly help shift the Overton window in order to bring in the new future.

HORIZON 2

- There currently is a vibrant innovation climate in the new materials field.
- Many of these innovations are transformative and can help pave the way for the emergence of a new system (H2+ innovations).
- Some of them may be at risk of being 'captured' by the prevailing system (H1), thereby helping to perpetuate its dominance (H2- innovations).
- Others may not be able to break through due to the continued dominance of H1 and the advantages this provides to the parties acting within the current paradigm.
- While H1 is still the dominant system and holds considerable power, it may dampen initial levels of innovation vibrancy.
- As H1 starts to weaken, combined with more H2+ innovations reaching commercially attractive levels of market presence, finance will shift to 'next horizon' innovations giving them a much-needed boost to break through.
- Nonetheless, pro-active finance, policy and market support for the innovation horizon that allows H2+ innovations to gain more traction can help overcome a prolonged plateauing of the curve, and push it upwards again more rapidly to accelerate the emergence of the new future, H3.

HORIZON 3

- As things stand right now, the new system H3 that will replace the prevailing paradigm in the materials sector, may well be relatively slow to scale due to the dominance and ongoing power of the incumbent system H1.
- Challenges of the new materials space to capture market share may initially see modest uptake of H2+ innovations in various markets, although there will be notable differences in market dominance depending on the the specific material.
- Once we have a combination of factors that start to strengthen each other – such as availability and affordability hitting a tipping point, more consumers starting to demand such materials, and a sense of urgency finally leading to decisive action being taken at policy and business levels – the new materials field is expected to see rapid uptake, becoming the new dominant system.
- Deliberate interventions – from diverting finance flows from H1 to H3, to creating a progressive policy and business environment – can support a more rapid transition from the first to the third horizon.
- This requires decisive and future-proof leadership, as well as a change of mindset among actors across the broader materials ecosystem.

CONCLUSIONS AND RECOMMENDATIONS

The materials sector is ruled by an unsustainable paradigm (Horizon 1) that under current trends is likely to retain its dominance for longer than is desirable. The prevailing system is challenged on many fronts by innovators of new materials who radically reinvent the way we produce and consume resources (Horizon 2). At the same time, these innovators face very real barriers on the path to commercialization and gaining market share amidst a field of powerful incumbents. Under a 'business as usual' scenario, the emergence of the successor (Horizon 3) to the current paradigm will probably be initially characterized by persistence rather than by rapid take-over.

It doesn't have to be this way. In order to deliver different outcomes that would see an accelerated emergence and adoption of a new, regenerative materials paradigm, we need to nourish the right type of responsible leadership and foster radically different and deeply regenerative mindsets across the system. Actions speak louder than words, but the first step on the path to regeneration is not a change of techniques but a change of mindset, to one that acknowledges that humans are inseparable from the natural world and its living systems. Once our thoughts and actions truly start to align, we will no longer be looking for ways to try and make it work; rather, we will be finding ways to make it work. Only this or the threat of rapid breakdown will likely spur us on to swiftly drive forward the transition to a regenerative materials future.

An important role for those seeking to accelerate the adoption of H3 mindsets and the expansion of H2 plus innovations, such as are promoted by the BMW Foundation's RESPOND program, lies with supporting innovators in the new materials field to navigate and challenge the incumbent system; to level the playing field; and to overcome the practical hurdles they face by starting out from a position on the edge of the system. This also includes understanding how to best work with the current paradigm to accelerate the 'demolition' of undesirable practices while finding entries to create a bridge to its successor.

In doing so, we have to be innovative ourselves. That means coming up with novel and creative solutions to divert capital away from propping up the incumbent system. And it means identifying finance instruments that can help support new materials innovators through all development and maturation phases of their journey, even where these may come with relatively long lead times.

We have to advocate for the design of policies that can accomplish win-wins for those helping to bring about the third horizon, as well as for those who have to transition as their first-horizon jobs may fall away. It also means spending time and effort on developing and experimenting with new models of collaborations and value-chain configurations to overcome the various struggles start-ups may face, for example when combining the R&D of materials innovation and its actual production in one hand.

Perhaps this could even lead to supporting (pools of) corporates, other industrial partners and financers in their journey to join hands with start-ups. After all, their often-limited tolerance for cost premiums, long lead times, and the performance and cost uncertainty associated with early-stage innovations may push start-up innovators to pursue mainly the low-hanging fruits of the new materials science: e.g. innovations with a greater certainty of commercialization, which can lead to a concentration of R&D in areas with the shortest route to market and/or highest potential for rapidly reaching scale. However, these material choices don't necessarily align with the materials where there is the highest carbon or other pollution mitigation potential, if regenerative alternatives were to become available.

In addition, it is necessary to support innovators in getting their entire materials and product lifecycle firmly on the H2 plus side of the spectrum. Many promising innovations still rely in part on what we would consider H2 minus practices. And considering that we're aiming for fully regenerative outcomes for materials innovation, while still operating within a system that is anything but regenerative, this presents some real challenges.

Finally, increasing and diversifying the pool of research, including academic research, may help reduce the lead time for promising alternative materials to be identified and developed to the point of market-readiness. It's only when new materials actually start entering markets that we can truly take on the challenge of replacing the first horizon with a new paradigm. For this to happen, we not only need a shift in the materials paradigm, we also need a shift in the leadership paradigm, to one in which leaders unequivocally base their decisions on a regenerative approach in service of life.

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traceless

Biotic

Resortecs, Recycling made Easy.

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GOT BAG.

Concular

STRAWCTURE ECO
EMPOWERING SUSTAINABLE CONSTRUCTION

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