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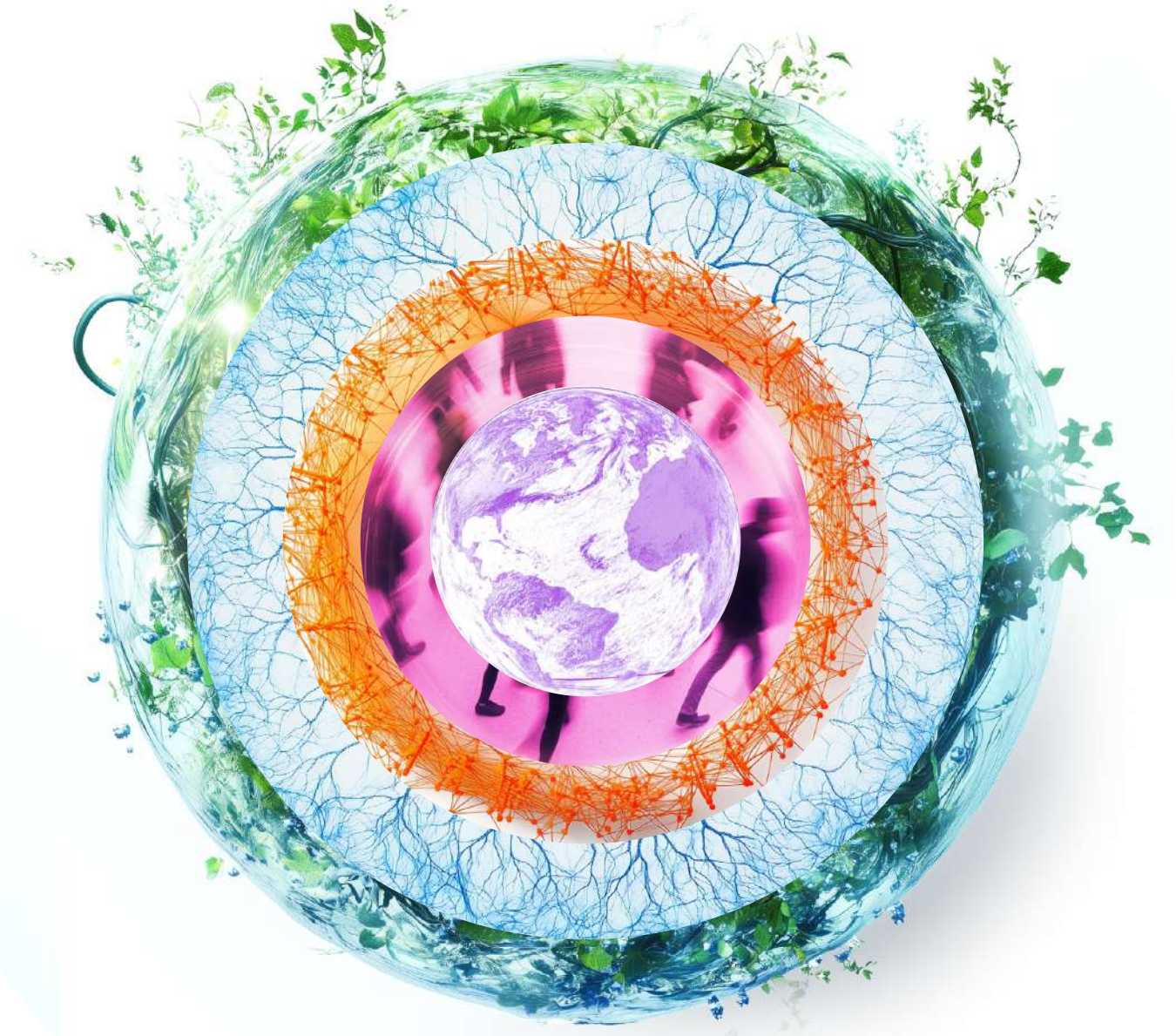

FUTURE OPPORTUNITIES REPORT

THE GLOBAL 50

2025

Cite as: **Dubai Future Foundation (2025) ‘The Global 50’.**
www.dubaifuture.ae/the-global-50

The Future is Designed by Those Who Dare

Mohammad Abdullah Al Gergawi
Vice Chairman of the Board of Trustees & Managing Director,
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Shaping the future is not just a choice – it is a responsibility. Only those bold enough to design tomorrow are the ones who lead today. This has never been more true than in our era of rapid advancement, where evolving realities bring both complex challenges and extraordinary opportunities.

Indeed, the profound economic, social, and environmental shifts our world has witnessed in recent years have redefined the way we perceive progress. These transformations form the foundation of the fourth edition of The Global 50 report, which highlights 50 new opportunities driven by advancements in technology, the digital economy, artificial intelligence, materials science, bioengineering, and other fields that are redrawing the boundaries of possibility. This report serves as a roadmap for leveraging these opportunities, focusing on improving health, restoring natural balance, enhancing sustainability, empowering communities, and driving future innovations.

This report also outlines the 10 megatrends shaping our world today – helping us prepare for what lies ahead and seize the opportunities that emerge from these shifts.

Through this research, we aim to fuel innovation, inspire decision-makers, and drive governments, institutions, and individuals towards a clear vision for a brighter future for humanity. Ultimately, innovation does not happen in isolation; it requires bold leadership, effective partnerships, and agile institutions that can adapt and act swiftly.

When vision meets action, and imagination translates into execution, dreams turn into reality – what were once ambitions become achievements. Indeed, the future belongs to those who create it – and this is an invitation to lead in shaping what comes next.

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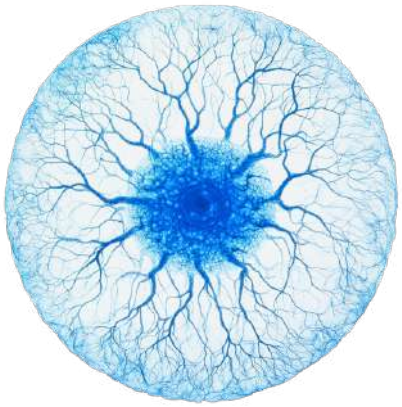

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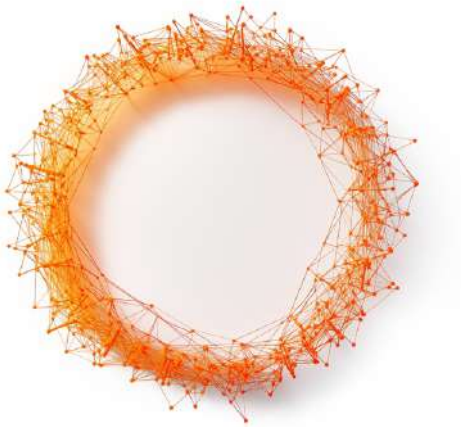

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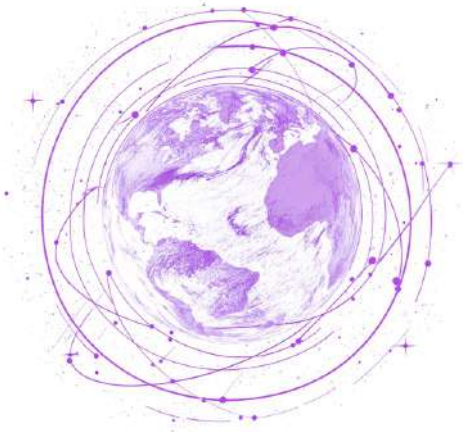


Transformational

Introduction

Our understanding of progress will continue to evolve.

We will need to reflect on and adapt to what we think meaningful progress looks like.[1] However, as the world moves towards more complexity,[2] and in an era of quantum shifts (see Box 1), change happens very quickly,[3] making foresight both increasingly more challenging and more important than ever.

But, this raises an important question. Has it not always been an era of quantum shifts?

BOX 1

The Era of Quantum Shifts[4]

The term **'quantum'** originates from quantum theory, describing the simultaneous and continuous transitions between energy states at the atomic and subatomic levels. It includes the concepts of 'entanglement' and 'superposition' where behaviours of particles can remain correlated and connected even when they are changing and far away from each other.

The Global 50 uses the concept of 'quantum' to represent the rapid, disruptive and dramatic changes that may shape the future of business, communications, culture, government, medicine, technology and other domains. We also use it to acknowledge the intertwined, complex relationships and interconnections that will determine how the future unfolds. The Global 50 also uses 'shifts' to characterise how the same forces can drive societies in opposite directions, and the same innovations may either enable societies to move forward or prevent them from doing so.

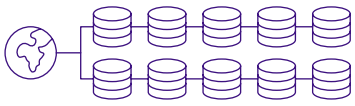
Our era is characterised by such 'quantum shifts'.

We have often heard that **change is the only constant in human history.**[5]

However, there are indicators that technological change is accelerating (see Box 2), pushing the boundaries in many areas of daily work and life, economies and society, sometimes with little or no notice.

BOX 2

In 2014, the number of people using the internet was 2.8 billion (under 40% of the world's population[6]). **By 2024, it was 5.5 billion (two-thirds of the world's population)**.[7]



In 2014, the world generated 12.5 zettabytes of data (approximately 3.1 trillion DVDs[8]). By 2024, this number had grown to **147 zettabytes,**[9] **more than eleven times the amount in 2014**.

Launched in August 2014, Slack grew to have half a million users in six months,[10] whereas ChatGPT, launched in November 2022, **grew to have 100 million users in six months**.[11]

While 229 patents were registered in the first decade after the US patent office was set up (1790–1800), **approximately the same number were registered daily in 2015**[12] and – assuming a 40-hour work week – in just under two hours in 2023.[13]

While it took 121 years for the first million US patents to be registered, at the rate patents were registered in 2023, **it will take 35 months to achieve the next million**, with many of these patents relating to developments in artificial intelligence.[14]

Generative AI alone is expected to add up to more than

$4.4 trillion

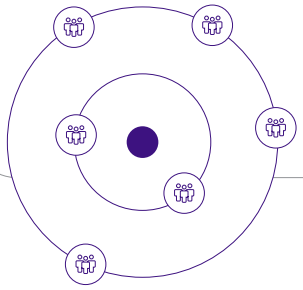
to the global economy

Whereas in our ancient past **we tended to live within communities of**

50–150 people,

4.4 billion

now live in large cities with thousands of neighbours, yet loneliness is a growing global concern.



On a more prominent scale, **artificial intelligence (AI)** and **quantum computing** are expected to reshape and disrupt industries, create new ones, and significantly influence our sense of purpose and understanding of work and income.

Generative AI alone is expected to add up to more than $4.4 trillion to the global economy.[15] According to Accenture's Pulse of Change Index, the rate of change in businesses went up 183% between 2019 and 2024, with a 33% increase in 2023 alone, largely thanks to the technological disruption of generative AI.[16] While quantum computing feels far away, it is advancing rapidly and is expected to enable faster and more precise problem-solving with complex multimodal linkages, resulting in exceptional operational and transactional optimisation and security.[17]

A similar trend is seen in societal outcomes and indicators. The first year of the COVID-19 pandemic pushed the prevalence of depression and anxiety up by 25% globally, adding to the billion people already managing mental health conditions.[18] While these numbers have not been updated, mental health is still a concern with no signs of going down.[19] In more specific examples, between 2000 and 2019, rates of depression, anxiety and stress increased from nearly 56 to 77 per 1,000 person-years in the United Kingdom, more than doubling among youth aged between 16 and 24 years.[20] Similarly, in the United States between 2005 and 2017, the rate of depression in youth aged between 18 and 25 years rose from 8.1%[21] to 21.5%.[22] Mental health conditions account for an average of 10.4% of the total disease burden across Egypt, Jordan, Kuwait, Oman, Qatar and Saudi Arabia, which is just over double the global average.[23]

Whereas in our ancient past we tended to live within communities of 50 to 150 people, 4.4 billion (more than half of the global population) now live in large cities with thousands of neighbours, yet loneliness is a growing global concern.[24] Generation Z (born 1997–2012[25]) are lowering their career goals and delaying home ownership, relationships and starting a family because of the rising cost of living.[26] Together with technological advances, these drivers will influence our thoughts about what a meaningful and good life looks like.

Now in its fourth year, The Global 50 continues to focus on the future through the lens of growth, prosperity and well-being (see Box 3).

BOX 3

Definitions of **Growth, Prosperity, Well-being**

Growth

Today
Increases in the total output of goods and services in an economy over time.

Tomorrow
The definition could go beyond economic factors, accounting for the negative impacts of economic growth (such as deforestation) to create a measure of net-positive growth.

Prosperity

Today
The ability to live with dignity and stability, free from the threats of poverty or harm, including those caused by the environment. This includes access to suitable employment opportunities, sufficient food, and basic services such as water, energy, education and healthcare.

Tomorrow
The definition may evolve to include access to personalised and self-managed services. Beyond employment, it may include varying streams or opportunities for income generation by which people can earn a living. It may encompass broader life choices and a more supportive environment in which to make them.

Well-being

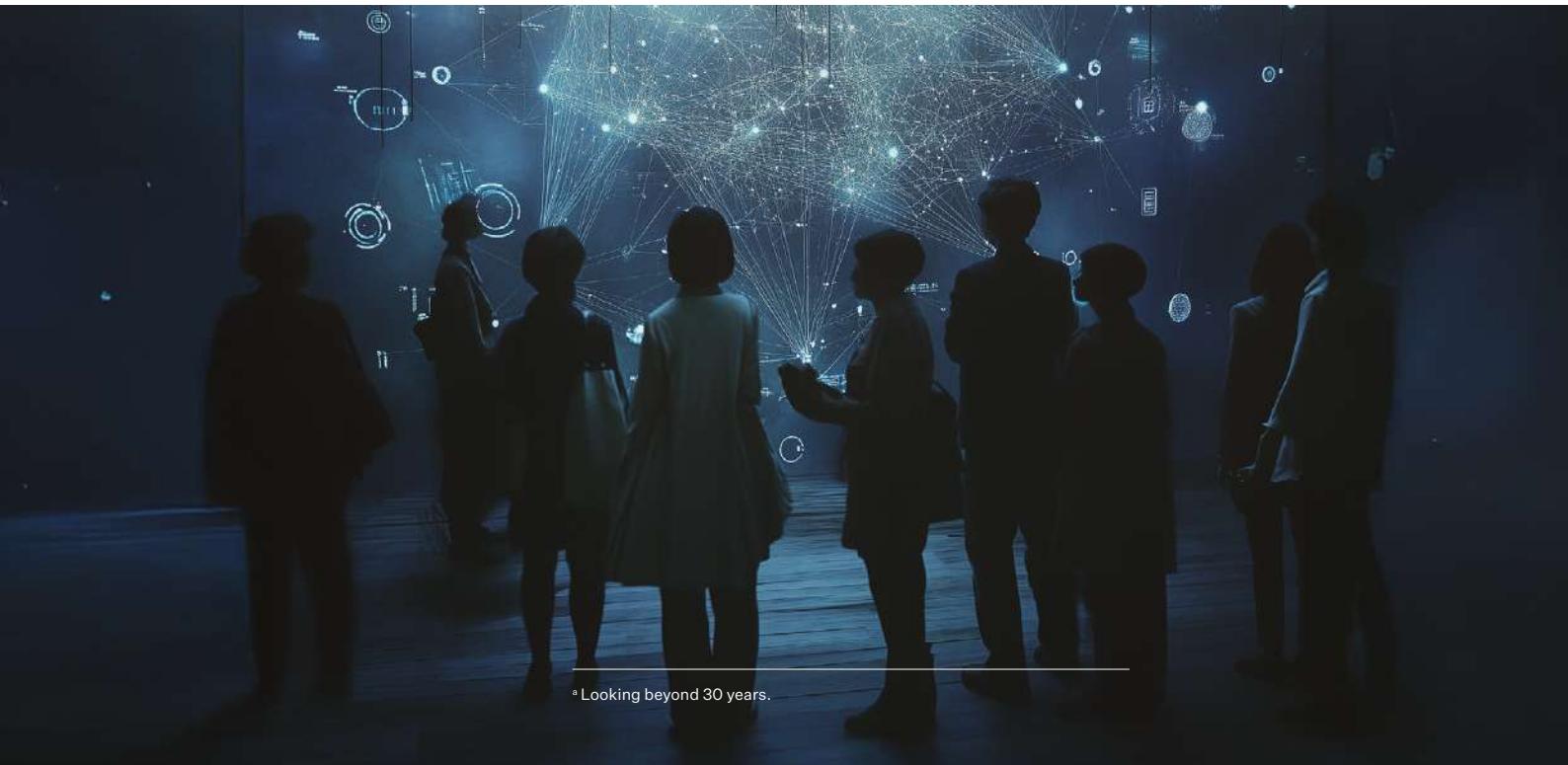
Today
A multifaceted concept centred on a generally good state of mental and physical health and feelings of life satisfaction, based on growth and prosperity along with positive social interactions, a sense of belonging, and positive interactions with the environment.

Tomorrow
The definition may evolve to include heightened feelings of self-realisation, self-esteem and self-confidence, as advances in medicine and technology could lead to the complete removal of (or greater ability to overcome) mental and physical health issues.

In this edition of The Global 50, we again explore the key pillars that make up our view of the future. While the pillars have not changed, we have introduced a new assumption about global interdependencies that we had initially alluded to in our report Navigating the Future for Growth, Prosperity and Well-Being: The Foundation of The Global 50 Report in 2023.[27] In addition, and taking the long view,[a] we used the uncertainties and the research conducted for this edition to explore a set of scenarios that are most likely to impact future growth, prosperity and well-being along with how industries may evolve. Additionally, and noting the dynamic nature of the megatrends, *Saving Ecosystems* has been reworded into *Evolving Ecosystems* to include the renewed or new focus on regeneration in many ecosystems.

In this edition of The Global 50, and to empower action within foresight, we once again share 50 new opportunities as in the previous editions, that cover ways to adapt, disrupt and innovate for future growth, prosperity and well-being. With the 50 opportunities in each of the 2022, 2023 and 2024 editions of The Global 50, readers now have 200 opportunities to consider that could inspire over 1,000 ideas and initiatives, whether economic, legal, societal, technological or a combination of all four.

The next 50 years are set to bring both opportunities and challenges for all generations. By exploring potential futures and imagining new possibilities, we can take proactive steps to navigate uncertainties, benefit from the opportunities, and mitigate the risks.



[a] Looking beyond 30 years.

Our View of the Future

Our view of the future is built upon four pillars: **assumptions**, **uncertainties**, **megatrends** and, by covering how to navigate The Global 50, **action.**

While establishing a view of the future helps achieve future readiness, it is through action that the impacts of foresight are realised.

Thinking about and planning for the future is not straightforward.[28] Our view of the future provides us – and readers – with **a conceptual model for navigating the era of quantum shifts**. It can help find new ways to meet our basic needs and fulfil our desire for self-realisation in the diverse and constantly changing realities that the world faces today and will face tomorrow.[29] The assumptions and uncertainties will be relevant over multiple decades, while the megatrends are relevant only over the next decade or so and are continuously evolving.[30]

While the four pillars of our view of the future are presented in silos, they are interrelated. The role of foresight, strategy or innovation professionals is to translate complex future possibilities into actionable insights, exploring scenarios and narratives that help nations, organisations and individuals prepare for multiple futures while building strategic capabilities.[31]

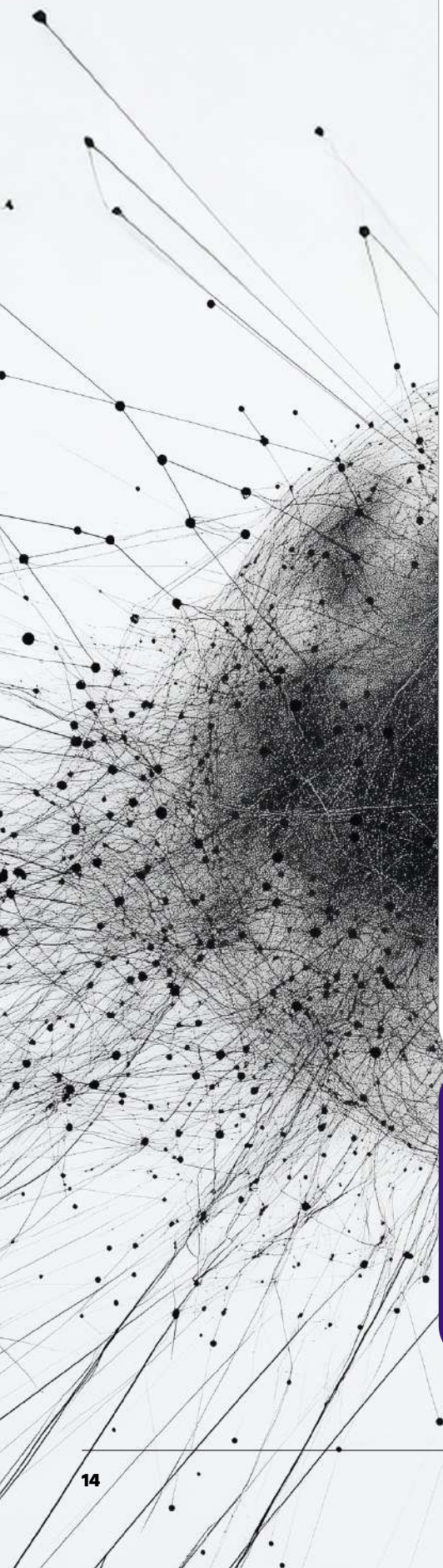
Our View of the Future

Assumptions

As the foundational aspects informing our thinking about the future of growth, prosperity and well-being, assumptions apply over several decades.

Any shifts in the assumptions could substantially change the future scenarios built on them and our ability to realise future opportunities.

As mentioned, this year we have introduced a new assumption (see Box 4), which is based on our earlier work[32] and further supported by the research carried out this year. As we take the long view on assumptions, we recognise that related signals may shift in the short term due to unforeseen events, which may or may not have a lasting impact.



BOX 4

⊕ New Assumption

Global Interdependencies Will Remain

This assumption is linked to two key drivers: increasing technological interdependencies and expanding resource dependencies (i.e. between people, minerals and commodities).[33] Various technologies and infrastructures around the world depend on each other, whether in terms of their hardware, their software or their storage (including energy needs). Economically, trade is not just about manufactured goods – it is also about information, natural resources, agriculture, services, R&D, finance, patents and many others.[34] The cross-border connections are deep and intricate, including societal ones.[35] Even if we see increasing localisation, such as reshoring,[36] this will still happen within a reality of deep interdependencies.

Some implications for growth, prosperity and well-being

- Global approach to challenges and knowledge sharing
- Better business continuity and disaster recovery
- Increased global economic and non-economic opportunities for people and businesses
- Tension between economic and societal goals
- Complex governance and coordination
- Over-reliance on partners and suppliers, reduced resilience

Signals to watch

- Trade flows: goods, people and information
- Market share of multinational companies
- Policy and regulatory synergies
- Memorandums of understanding and collaborative agreements

ASSUMPTION 1

Lives Will Be Longer and Healthier

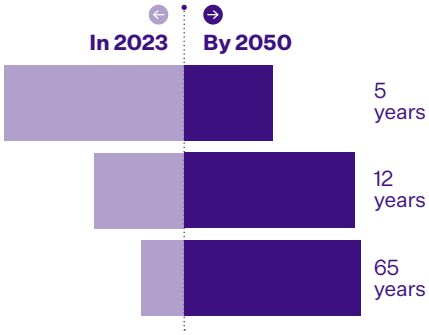
30 years
1800

73.3 years
Now

77.4 years
2054

Average life expectancy around the globe has more than doubled over the past 225 years.

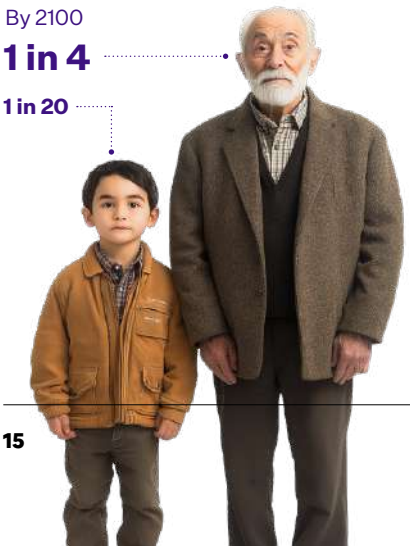
In 1800 it was 30 years,[37] and it has now reached 73.3 years.[38, 39] It dropped marginally during the COVID-19 pandemic, but by 2054 life expectancy is expected to reach an average of 77.4 years worldwide.[40, 41]



A new age distribution is emerging

In 2023, the total number of people aged 65 years or over was approximately half the total number of children under the age of 12 years and a quarter of the number of children under the age of 5 years.[42]

By 2050, the total number of people aged 65 years or over is expected to equal the total number of children under the age of 12 years and to be more than twice the number of children under the age of 5 years.[43]

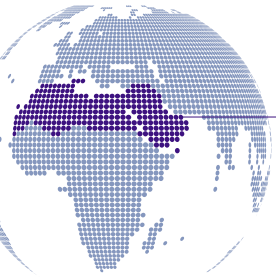


By 2100, one in four of the population will be aged 65 years or over, whereas 1 in 20 will be younger than 5 years.[44]

The percentage of the global population aged 60 years or over is likely to rise from 14.5% in 2024 to 22% in 2050,[45] and the number of people aged 80 or over is expected to triple between 2020 and 2050, reaching 426 million.[46] With healthy ageing, older people will create significant economic opportunities and societal benefit.[47]

ASSUMPTION 2

Climate Change Will Persist

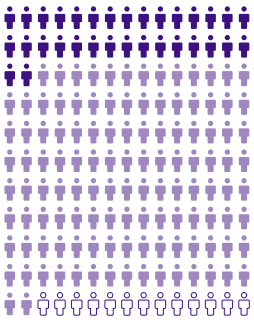


Temperatures expected to rise by **more than twice the global average by 2030**

Global temperatures will continue to rise

Compared with pre-industrial (1850–1900) levels, the average global temperature in 2023 was about 1.45°C higher.[48, 49] The temperatures in the Middle East and North Africa are expected to rise by more than twice the global average by 2030.[50]

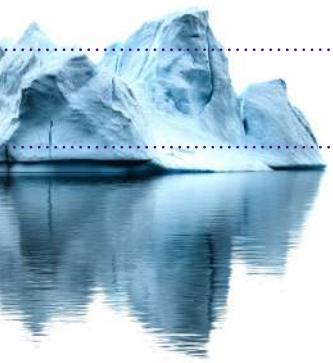
The decade leading up to 2023 was the warmest on record.[51]



By 2030, climate change will have driven **32–132 million people into poverty**

Impoverished countries are more vulnerable to the adverse impacts of climate change.[52]

It is estimated that by 2030, climate change will have driven 32–132 million people into poverty.[53] Climate change is a particular threat to countries in sub-Saharan Africa and South Asia, where impacts are likely to be medium to high in severity, positioning climate change as one of the greatest threats to people and ways of life in these regions.[54]



889 mm per year in 2010s

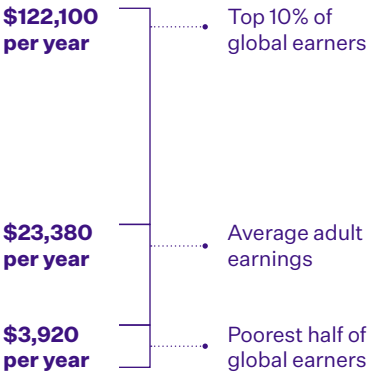
171 mm per year in 1990s

Sea levels will also continue to rise

The rate of glacier loss monitored by the World Glacier Monitoring Service increased from –171 mm (6.7 inches) per year in the 1990s to –889 mm (2.9 feet) per year in the 2010s[55] and accelerated to 4 feet per year between 2021 and 2023.[56] In September 2024, Khalifa University deployed the United Arab Emirates' first Antarctic ice-monitoring instrument, known as Snow Ice Mass Balance (SIMBA). The project is studying sea-ice formation affecting global climate, with Antarctica holding 90% of Earth's freshwater ice.[57]

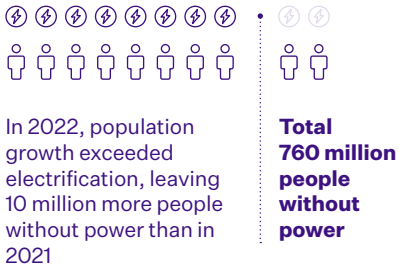
ASSUMPTION 3

Inequalities Will Continue



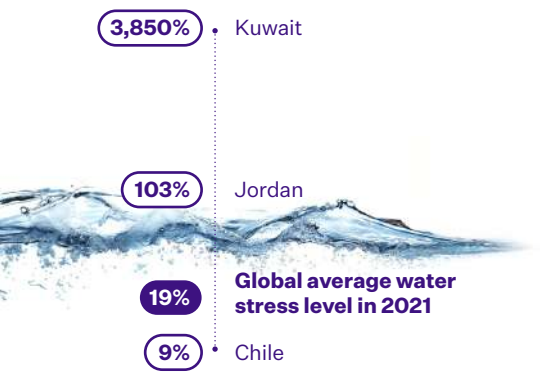
Income gaps persist.

Using the principle of purchasing power parity, the average adult earns $23,380 per year (2021 figures) and has assets valued at $102,600. However, the average adult from the top 10% of global earners takes home $122,100 per year with average assets of $771,300. The average individual from the poorest half of global earners takes home $3,920 per year and has assets valued at $4,100.[58] While the top 10% of global earners now own 53.5% of total national income, representing a modest reduction from their peak of 58.2% in 2000 over the past 25 years.[59]



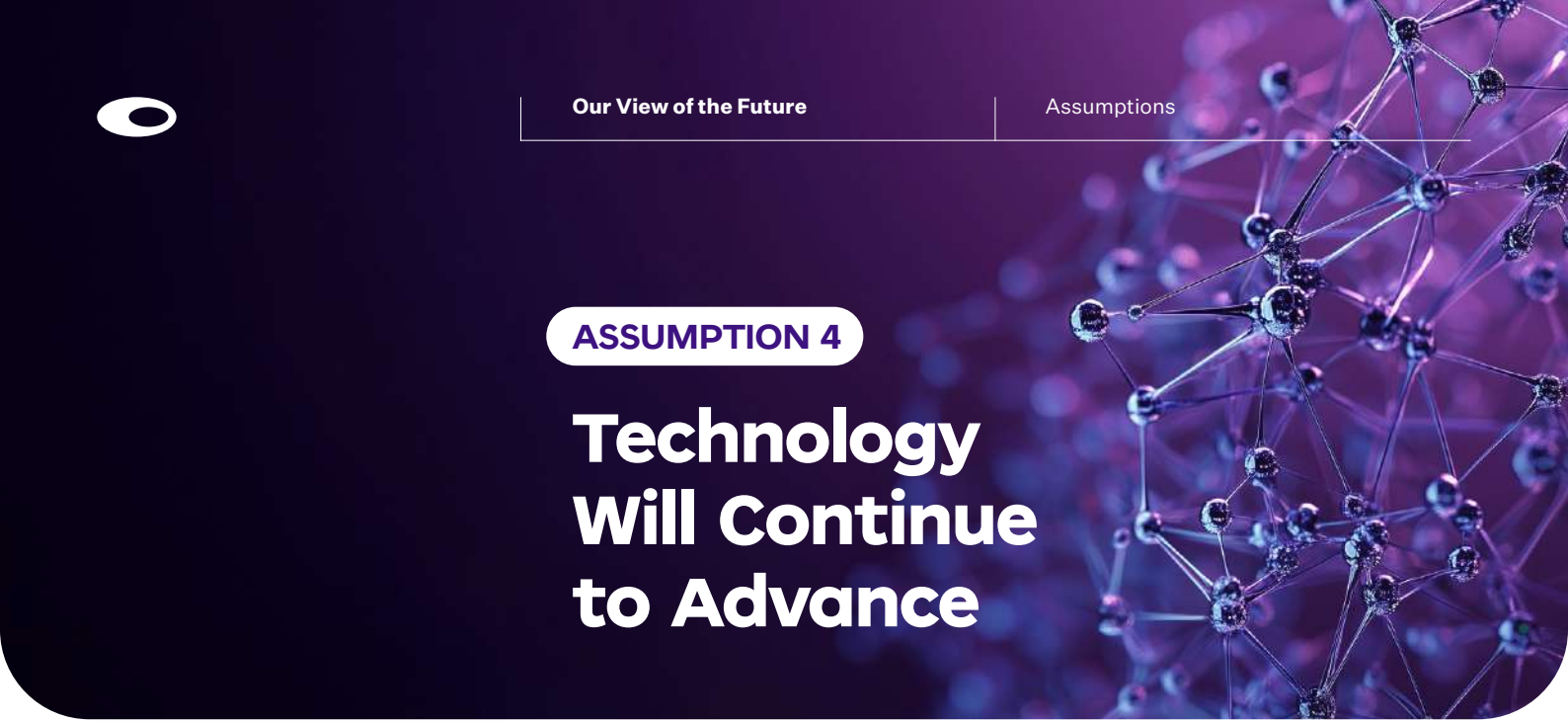
Some people still lack access to electricity.

Global electricity access rose from 73% in 2000 to 91% in 2022. However, 2022 marked a concerning shift – population growth exceeded electrification, leaving 10 million more people without power than in 2021 and resulting in a total of 760 million people around the world without power.[60]



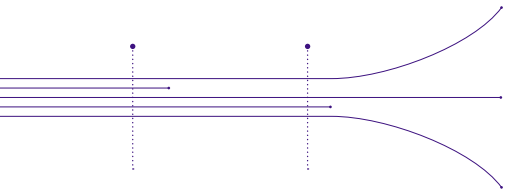
Water stress levels vary greatly around the world.

Globally – and likely to persist – the average water stress level in 2021 was 19%.[61] Measured as fresh water withdrawn as a proportion of available fresh water, regional disparities are significant, ranging from countries that far exceed sustainable limits such as Kuwait (3,850%), Egypt (141%) and Jordan (103%) to those with lower water stress levels such as Japan (36%), the Netherlands (16%) and Chile (9%).[62]



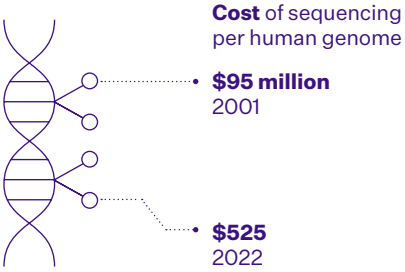
ASSUMPTION 4

Technology Will Continue to Advance



El Capitan is now the fastest supercomputer.

Frontier was the fastest supercomputer until 2023, when El Capitan – based in the Lawrence Livermore National Laboratory in California, United States – carried out operations at 1.742 ExaFLOPS/s.[63] Frontier recorded a new speed of 1.353 ExaFLOPS/s.[64]



DNA sequencing is cheaper.

Technological advancement has enabled a reduction in the cost of sequencing per human genome from just over $95 million in 2001 to $525 in 2022.[65]

Quantum computing will reshape sectors and industries.

By 2035, quantum computing could yield $450–850 billion in net income across sectors such as finance, healthcare and energy. Early adopters may capture 90% of this value by securing talent, intellectual property, and partnerships, gaining substantial competitive advantages.[66]

ASSUMPTION 5

Global Interdependencies Will Remain

DHL's global trade depth

20% 2003

25% 2023

Global trade will continue to expand.

Despite significant trade shifts between China and the United States, and between Russia and the European Union (EU), flows of trade, capital, information and people reached new highs in 2022 and 2023, with DHL's global trade depth – international compared with domestic flows – reaching 25% in 2023 compared with 20% in 2003.[67]

$33 trillion
global trade in 2024

Service trade +7%
Goods +2%

The world will remain connected through global supply chains.

Despite significant challenges, global trade was set to reach $33 trillion by the end of 2024. This growth was driven by increases in service trade (+7%) compared to a mild increase in goods trade (+2%), with growth particularly strong in apparel (+14%), office equipment (+13%) and information and communications technology (ICT) (+13%) sectors.[68]

The market for **critical minerals** such as nickel, lithium and aluminium is expected to

double

within five years

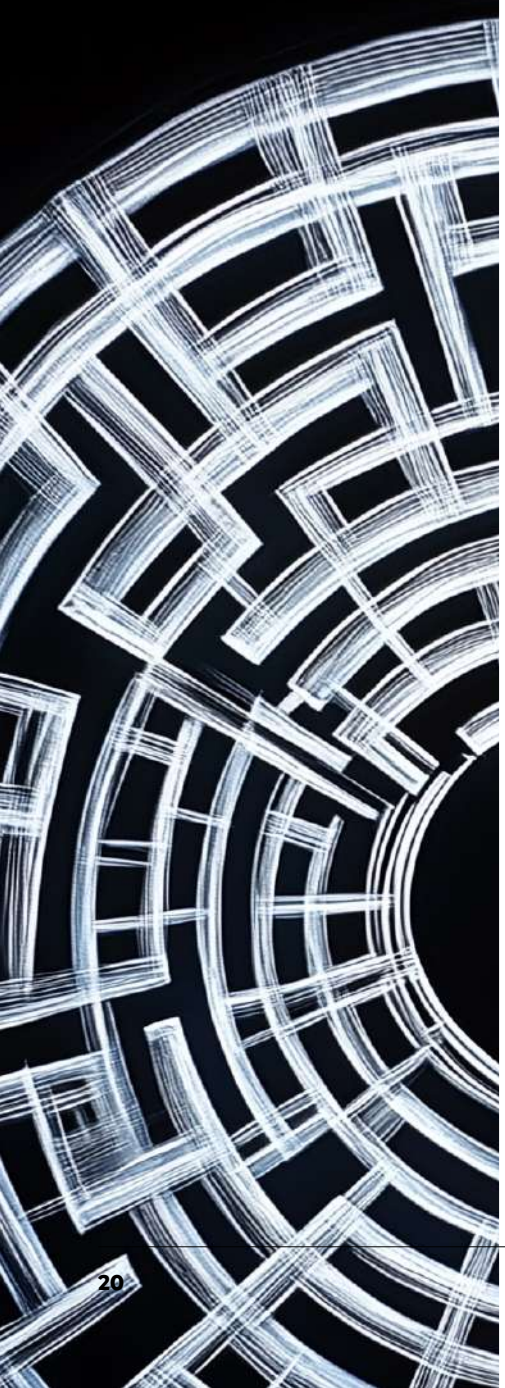
Critical raw materials will remain key especially for the green transition.

Even with the passing of the Critical Raw Materials Act in 2024[69] and the EU plans to increase its domestic production of rare earth elements from none today to 20% by 2030,[70] China still dominates mining (54%) and refining (77%) of rare earth elements.[71] As the market for critical minerals such as nickel, lithium and aluminium is expected to double within five years,[72] global interdependence will play a crucial role in meeting these needs.

Our View of the Future

Uncertainties

The future is uncertain. However, by identifying and navigating the specific ways in which it is uncertain, we can identify potential outcomes that may impact our future growth, prosperity and well-being either positively or negatively. **Like assumptions, uncertainties apply over multiple decades**, and each year for The Global 50 we validate and refine (where needed) the five uncertainties (see Box 5).



BOX 5

Future Uncertainties

On a broad spectrum, where a global community sits – city, country or region – varies by both location and time.

Collaboration

To what extent will governance and international collaboration advance at the global level?

Multilateralism ⟷ **Multipolarity**

Values

To what extent will global communities converge on shared values or become divided by differences?

Universality ⟷ **Uniqueness**

Technology [b]

To what extent will technology serve as a multiplier for productivity and a better quality of life or dictate our lives?

As multiplier ⟷ **As master**

Nature [c]

To what extent will our innovative technologies and efforts help nature restore itself?

Renewal ⟷ **Degradation**

Systems [d]

To what extent will systems evolve greater resilience to meet changing needs?

Resilience ⟷ **Fragility**

[b] Technology is both an uncertainty and an assumption. Refer to the relevant assumption to understand the difference.

[c] Nature is both an uncertainty and an assumption. Refer to the relevant assumption to understand the difference.

[d] As an uncertainty, systems relates to the processes and mechanisms that are used to operationalise global policies, laws, regulations and cross-border transactions.

The uncertainties reflect the vastly divergent socio-economic, political and environmental conditions that global societies may experience.

Although the uncertainties themselves are not novel, they manifest into new challenges within evolving realities. Meeting the expectations of global societies will require a nuanced understanding of the multifaceted uncertainties and landscapes shaping our shared future, which foresight can help address.

Imagining the future is at the heart of foresight and is particularly impactful in times of uncertainty, when clarity is important.[73] It is impactful because it helps us imagine futures in ways that we may not instinctively think of, aiding our creative thinking about opportunities and challenges and helping us to set a strategic direction and take action. Part of imagining the future involves developing scenarios.

Scenarios often fall into three broad types: predictive, exploratory and normative. Whereas predictive scenarios are solely focused on developing outlooks based on information that is available today (e.g. forecasting), exploratory scenarios define possible futures based on a set of assumptions and drivers.[74] In the middle sit normative scenarios, which take into account information today but also goals for tomorrow, with the aim of uncovering pathways to preferable future(s)[75] in a process often referred to as backcasting.

As scenario building can be both a strategic planning tool[76] and a research method,[77] scenarios are used by practitioners, strategy professionals, and even researchers to uncover underlying thoughts and assumptions, improve understanding, and extract insights on a particular topic.

Taking the long view,[e] and in this year's edition of The Global 50, we used the assumptions and uncertainties along with the research carried out to develop exploratory scenarios of future growth, prosperity and well-being. While specific outcomes will vary based on local conditions, these global scenarios are designed to prompt reflection and deeper analysis. These four scenarios are not exhaustive and the Dubai Future Foundation welcomes debate and discussion to refine them further.

Based on our research, **technology and nature will have the greatest impact** on future growth, prosperity and well-being and, hence, are critical uncertainties.

Technology

As multiplier ⟷ As master

Nature

Renewal ⟷ Degradation

[e] Looking beyond 30 years.

Today

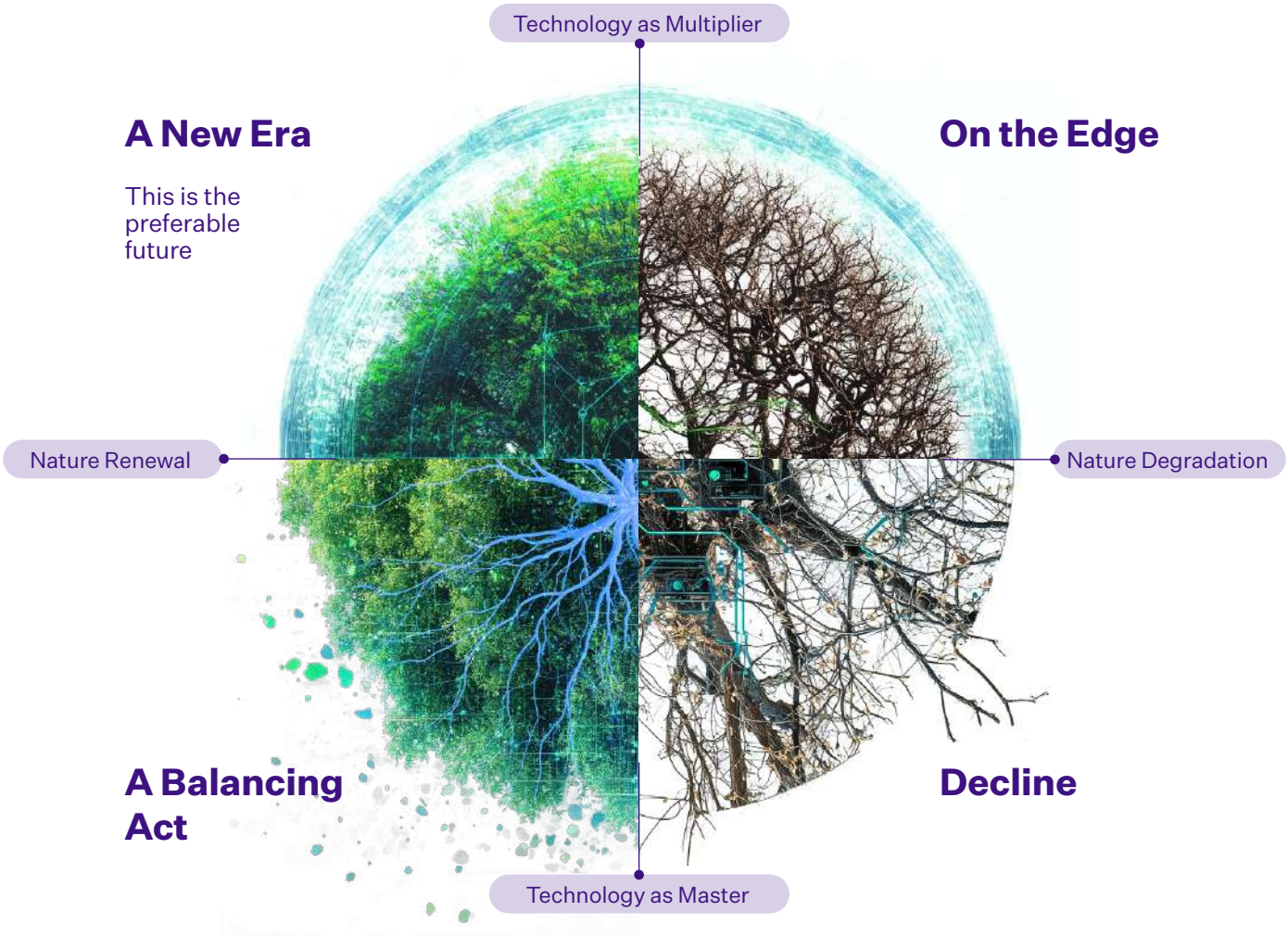
Understanding the present provides context for how each future scenario may unfold. While many signals are discussed throughout this, and previous, editions of The Global 50 report within both the megatrends and opportunities sections, several key themes can be used to characterise the present.

While the global **economy** has maintained stability since the COVID-19 pandemic,[78] a question remains about how we will manage evolving matters, from redefining value and wealth while adapting to new forms of monetary exchange including cryptocurrencies[79] and addressing the financial needs of low- and middle-income countries,[80] to expanding economic metrics beyond gross domestic product (GDP)[81] and the evolving shape of future economic growth.[82] Although many remain optimistic about **technology's** continued role in improving our lives,[83] concerns persist.[84] The development of artificial intelligence (AI) **regulatory** frameworks[85] and collaborative international efforts, such as the United Nations Declaration on Future Generations, the Global Digital Compact, and the Pact for the Future,[86] suggest a commitment to quality of life as a priority. However, challenges remain, including attaining equitable access to advanced connectivity,[87] energy and food and water around the world. While biotechnology holds great promise for improving food systems[88] and healthcare,[89] **societies** continue to deal with issues related to loneliness,[90] mental health,[91] bottlenecks in healthcare systems,[92] food waste and lack of access.[93] Many countries and cities have made **environmental** commitments and signed treaties related to the environment,[94] sea[95] and space,[96] but extreme weather patterns and climate variability continue to be concerning[97] and migration due to climate may be inevitable.[98]

Five questions to consider for a preferable future of growth, prosperity and well-being

1. How can human well-being and quality of life remain central to technological advances and innovation?
2. What technologies and strategies can provide clear visibility in critical raw materials, ecosystem health, and biodiversity?
3. What legal frameworks, governance mechanisms, and progress indicators are needed to ensure global commitment to closing digital, economic, energy, food and health divides?
4. How can innovations remain accessible and affordable for all while adapting to and addressing the impacts of climate shifts?
5. How can investments and funding models be secured to make these goals achievable?

Four Scenarios
for Growth, Prosperity and Well-Being



A New Era

This is the preferable future

In this scenario, technology, innovation and environmental restoration usher in a new era of growth and well-being. People live healthier, fulfilling lives as sustainable technologies enable more equitable access to optimised resources. Ecosystems are responding positively to innovation and science, biodiversity is restored, and climate resilience improves, providing clean air, water and food security. However, inherent challenges like inequality will persist, pushing the need for focused efforts for inclusive progress despite broader societal progress.

Growth
Technology drives sustainable growth beyond GDP metrics, creating a diversified economy that balances environmental and human prosperity.

Prosperity
Technology enables broader access to essential resources, energy and food, although equal distribution remains an ongoing challenge.

Well-being
Advanced technologies improve health, environmental resilience, and access to essentials, elevating overall human well-being to historic levels.

How we got there and signals to watch

Commitment to progress beyond GDP and shifts from traditional GDP metrics

Partnerships, investments in ecosystems, and achievement of environmental targets

Technological and scientific breakthroughs, new education models

International agreements on responsible AI and other technologies

Closing as many divides as possible, although some will persist as per our assumptions

On the Edge

In this scenario, while technology generates uneven economic gains through enhanced productivity, worsening climate impacts intensify environmental stress and societal challenges. Climate change accelerates, straining ecosystems and deepening inequality. Resource shortages and environmental degradation drive increasing climate migration, affecting even prosperous regions. Disparities widen between technology-rich areas and vulnerable communities, creating a striking divide in quality of life.

Growth
Environmental decline and resource scarcity undermine economic gains from technology, destabilising long-term growth.

Prosperity
Technology brings progress to some, while climate impacts and resource shortages disproportionately burden poorer communities.

Well-being
Environmental decline and climate disasters worsen health outcomes, with vulnerable populations bearing the heaviest burden.

How we got there and signals to watch

Commitment to progress beyond GDP but struggling to contain environmental degradation

Technologies improve human well-being and quality of life but only in some contexts

Emerging cooperation on technology focused on human well-being and quality of life

Investment tensions because of immediate environmental crisis management

Accelerating climate impacts and ecosystem decline, increased severity of climate events

Rising inequality as already climate-vulnerable regions deteriorate

A Balancing Act

In this scenario, technological advancement and ecological restoration create mixed outcomes and uneven sectoral growth with first-movers gaining significant advantage. While innovations in renewable energy and ecosystem regeneration drive ecological prosperity, the focus on economic efficiency over societal needs or quality of life creates uneven benefits that lead to deep societal divides and well-being gaps between communities. Nature responds positively to restoration efforts, but tension grows between profit-driven technology deployment and human-centred development.

Growth
Innovation drives sustainable economic growth, while restored ecosystems provide stable natural resources and opportunities.

Prosperity
Technology and ecological health create prosperity, although benefits remain unevenly distributed across communities.

Well-being
Environmental restoration and technological advances improve well-being where available, but access remains inconsistent.

How we got there and signals to watch

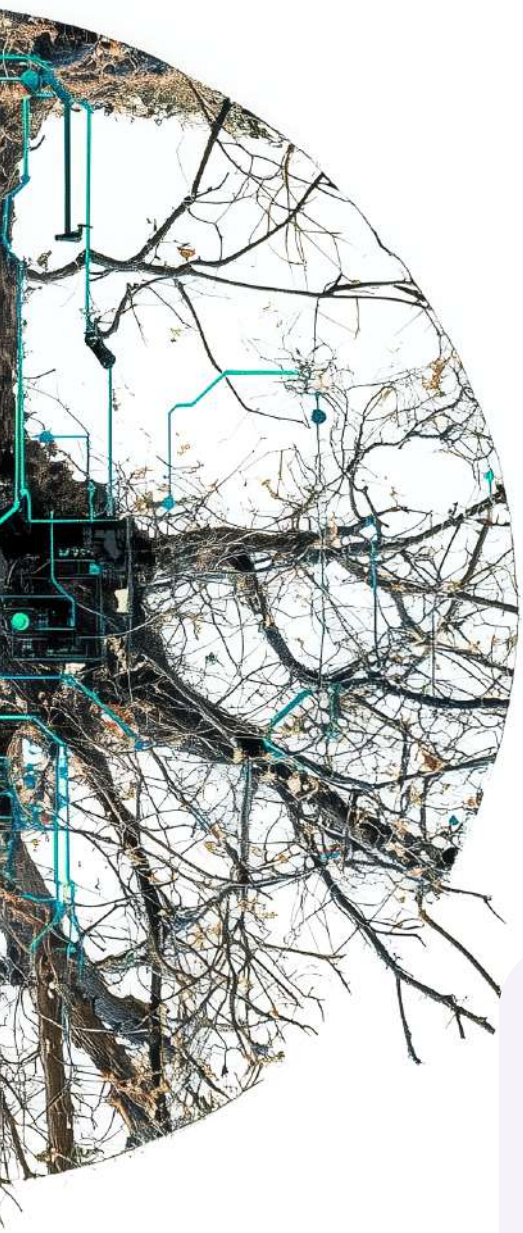
Increasing investments in green technologies and ecosystem restoration

Struggling economies grow and benefit from nature's positive response to efforts

Technologies supporting economies of scale and scope resulting in efficiencies

Growing disconnect between efficiency gains and people-centred development, affecting jobs, income and quality of life

Increasing debate over privacy and autonomy concerns in emerging technologies



Decline

In this scenario, technologies like automated production systems and resource extraction methods prioritise economic efficiency over environment and societal costs. While some regions prosper, environmental degradation and global inequalities deepen. Accelerating climate impacts and natural resource scarcity lead to widespread climate migration and social instability that undermines global cooperation when it is needed most.

Growth
Economic growth declines as environmental degradation lowers productivity, making investments riskier and development uneven.

Prosperity
Resource scarcity and climate impacts deepen economic disparities, with technology failing to counteract environmental decline.

Well-being
Environmental deterioration and insufficient technological solutions worsen health outcomes, while resource competition weakens social cohesion.

How we got there and signals to watch

Prioritising profits in technology deployment over environmental and social impacts

Increasing depletion of critical resources and raw materials

Extreme weather and ecosystem decline and increased severity of climate events

Growing signs of fragmentation in global cooperation, investment and commitment to technology and climate action

Widespread climate migration, global disparities and deteriorating quality of life

BOX 6

A note on industries in the future

Sectors and industries are already transforming their supply chains for future resilience and sustainability.[99] Drawing on lessons from past disruptions such as the COVID-19 pandemic, market volatility, data security breaches,[100] and the growing prevalence in the past decade of misinformation and disinformation,[101] many are putting plans in place to respond to emerging opportunities and challenges.

However, future scenarios for growth, prosperity and well-being will also impact industries. In particular, a focus on a preferable future of growth, prosperity and well-being (i.e. the 'A New Era' scenario) means working towards processes and technologies that improve quality of life and enhance collaboration across sectors while building sustainable, restorative and regenerative ecosystems.[102] Consequently, future industries will need to balance the tensions between local and global interpretations of progress – in areas such as longevity, economic inclusion and opportunity, natural and critical resources, and sustainability – while navigating the need for, and trade-offs between, technologies of scale and scope.[f]

[f] Technologies of scale refer to technologies that are widely adopted across diverse contexts and are generally applicable. Technologies of scope refer to technologies that are tailored to a specific context and targeted opportunity or challenge.

Our View of the Future

Megatrends

Megatrends are research-led thematic paths relevant for a decade or so.[103] Megatrends are interrelated and are shaped by day-to-day signals across all aspects of work and life. They can influence growth, prosperity and well-being positively or negatively.[104]

The nature of megatrends is that they are dynamic and may evolve, especially when they intersect with uncertainties. This year, Megatrend 5, which was previously called 'Saving Ecosystems', has evolved into 'Evolving Ecosystems', reflecting a broad shift to include regeneration,[105] whether through adaptation,[106] restoration[107] or across systems[108, 109, 110,] rather than isolated areas of impact.

Each megatrend includes a brief summary along with keywords readers may use to search for related signals. In addition, for each megatrend we have included three things to look out for in 2025 and three areas of future opportunity that may be relevant over the next decade.

MEGATREND 1

Materials Revolution

KEYWORDS

Biomimetic Materials
Biomimicry
Clean Energy
Critical Minerals
Magnets
Quantum Communication
Quantum Computing
Quantum Materials
Rare Earth Elements
Superconductors

Materials are fundamental to all products, foods, medicines and drinks that we consume on a daily basis. Driven by extensive progress in advanced machine intelligence, nanotechnology and materials science, as well as interdisciplinary research and innovation, new opportunities are arising in the use of materials in almost all industrial, technological and consumer sectors.

THREE THINGS TO LOOK OUT FOR IN 2025

TRANSPARENT WOOD

Biodegradable, natural wood can be processed into a transparent wood composite with a honeycomb structure, which is stronger than glass and plexiglass. Transparent wood insulates five times better than glass, enhancing building efficiency.[111] However, its environmental impact will need to be assessed and improved before widespread adoption.

COOLING CERAMICS

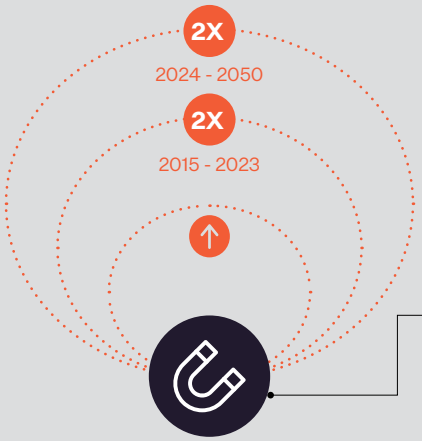
Cooling ceramic is durable and made with an alumina coating that resists ultraviolet degradation and withstands temperatures above 1,000°C.[112] With 99.6% solar reflectivity, it is energy-efficient and offers potential for numerous cooling applications.[113] It could serve as a new type of roof shingle.

BIOFILTRATION

Smart biological filters coated with enzymes have been seen to remove 97% of toxic bisphenol A and 94% of pesticides from water using special proteins that block, trap and break down harmful chemicals.[114] These filters can be reused multiple times and have applications in bioreactors, water treatment, in food processing and as biosensors.

AREAS OF FUTURE OPPORTUNITY

PERMANENT MAGNETS



Permanent magnets – as rare earth elements – contribute to efforts towards the clean energy transition and to reaching net zero.[115] Permanent magnets convert energy from turning wind turbines into electricity.[116] Permanent magnets in electric vehicles convert energy from batteries into torque in motors[117] and can save 20–40% of energy versus non-magnet motors.[118] In fusion energy power plants, strong magnetic fields can regulate plasma at temperatures higher than the Sun's core.[119] Magnets are also used in healthcare (e.g. magnetic resonance imaging (MRI),[120] transcranial magnetic stimulation[121]) and consumer electronics.[122] Eighty-five per cent of magnet mining is concentrated in China.[123]

However, the demand for permanent magnets doubled between 2015 and 2023[124] and is expected to nearly double between 2024 and 2050.[125] To meet this demand, alternative materials will be needed. For example, researchers are exploring rare-earth-free permanent magnets, such as those using iron nitride (FeN), as long as – in the case of electric vehicles – motor performance is maintained.[126] Using artificial intelligence (AI), King's College London has developed an iron-based superconducting magnet, which could be a significant breakthrough in creating cost-effective MRI machines.[127]

BIOMIMETIC MATERIALS

Biomimetic materials are materials that are made by humans but inspired by nature, either in their properties or how they function.[128] Biomimetics is currently contributing to advances in various fields, including science, engineering and medicine.[129] Nature – resilient over billions of years[130] – offers efficient and sustainable approaches to the challenges we face.

From wind turbine blades inspired by the tubercles (bumps) on humpback whale fins, which reduce drag by 32%,[131] to the Namib Desert beetle's hydrophilic shell inspiring materials used in fog harvesting in arid regions,[132,133] innovations inspired by nature can generate considerable economic benefits[134] up to $1.6 trillion by 2030.[135]

QUANTUM MATERIALS

$2 trillion

in global economic value by 2035

Quantum materials have unique properties that are integral to advancing quantum technology.[136] Materials such as superconductors and semiconductor quantum dots (such as those made of silicon and germanium)[137] help stabilise quantum bits (qubits), enhancing quantum computing capabilities.[138] Similarly, materials such as spin qubits and diamond nitrogen-vacancy centres underpin quantum sensing technologies.[139]

Key players, such as Amazon Web Services, IBM and IonQ, are leading advances in this field, achieving significant progress in quantum error correction.[140] Advances in quantum communication are enabling ultra-secure networks resilient to cyber threats.[141]
The potential applications of quantum technologies span multiple sectors, including finance, healthcare and defence. These advances are not only poised to revolutionise industries but could also generate over $2 trillion in global economic value by 2035.[142]

MEGATREND 2

Boundless Multidimensional Data

KEYWORDS

Carbon Emissions
Cross-border Data Flows
Data Analytics
Data Latency
Data Storage
Digital Twins
IoT Connectivity
Multimodal AI
Real-Time Analytics

As technology advances – quantum computing, blockchain, the Internet of Things (IoT), edge computing, automation, digital realities, and more – data will become both more constant and more multidimensional. Data will become more available within, and for, governments, businesses and society, in larger volumes, and at greater speeds. Enhanced by 5G, 6G and uninterrupted connectivity through multiple networks, including satellites, access to real-time analytics and insights will improve. Solutions will be developed to minimise the environmental impacts of data capture, transmission and storage.

THREE THINGS TO LOOK OUT FOR IN 2025

EXPANDING CONNECTIVITY

In 2023, 97 million people accessed the internet for the first time. This brought the total number of people connected to the internet in 2024 to 5.35 billion – 66% of the global population.[143] The continuing roll-out of 5G,[144] efforts to improve the affordability of mobile internet connectivity, and increasing digital inclusion[145] are initiatives to watch.

DATA SOVEREIGNTY

Data sovereignty is evolving as cross-border data flows grow amid differing approaches to artificial intelligence (AI) regulation.[146] Countries and regions continue to evolve their own data protection laws for managing data throughout various stages of the data life cycle. Cloud computing and the IoT will add complexity to data sovereignty, pushing the demand for data localisation and storage,[147] while raising important questions about whether data can truly be sovereign anymore.

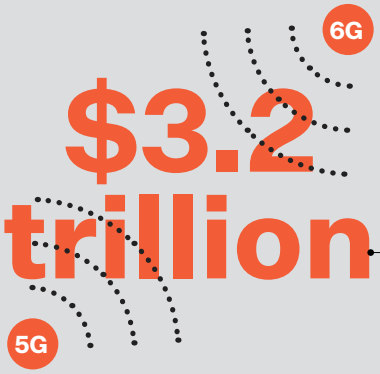
GREEN CONNECTIONS

Organisations that provide services over the internet will continue to take steps to reduce – or be expected to disclose – their environmental impact. For example, as video streaming makes up 65% of global data traffic, and total data traffic contributes 3.7% of global greenhouse gas emissions.[148] Netflix aims to reduce its emissions by half by 2030[9] and is investing in climate solutions to offset its remaining emissions.[149]

[9] From a 2019 baseline.

AREAS OF FUTURE OPPORTUNITY

PREPARING FOR 6G

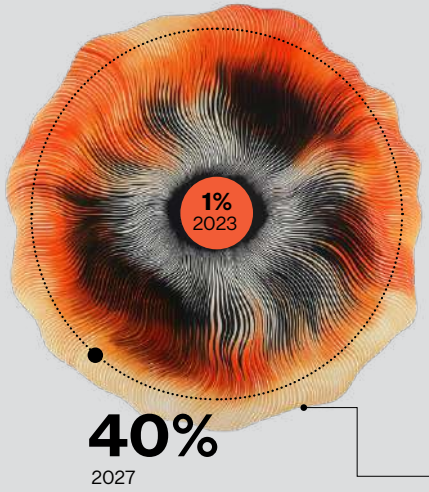


6G will have far-reaching impacts across sectors.[150] From enabling remote surgery and real-time health monitoring[151] to advanced automation and digital twins,[152] 6G will create new market opportunities across telecommunications, manufacturing and transportation.[153]

With low latency (i.e. quick response times),[154] 6G can theoretically increase speeds from 5G's peak data rate of 20 gigabits per second[155] to around a terabit (1,000 gigabits) per second.[156] It is also capable of handling up to 10 times more IoT-connected devices than 5G, with the total number of IoT devices expected to reach 500 billion devices by 2030.[157] 5G- and 6G-enabled activities combined are projected to create $3.2 trillion[h] in global growth by 2030.[158] The development of new optical components and transmission techniques will be critical for achieving the speeds that 6G promises.[159]

From curved light rays and metamaterials[160] to spiral plates that twist and stretch light beams,[161] reconfigurable intelligent surfaces are being developed to enhance signal propagation and networks and actively control electromagnetic waves to improve coverage and reduce energy consumption.[162]

MULTIMODAL EXPLAINABLE ARTIFICIAL INTELLIGENCE



Important decisions in healthcare and finance – for example, relating to diagnoses and treatment[163] and fraud detection[164] – may be made together with AI-based support systems using diverse (i.e. multimodal) data inputs, including text, images, audio and, one day, haptics. Multimodal AI will also impact other industries, including education, media, manufacturing, and consumer packaged goods.[165] Multimodal explainable AI (MXAI) focuses on explaining how, why and what AI delivers,[166] which is important for building trust in AI.[167]

With capabilities ranging from natural language processing and image processing to multi-input analysis and fast processing in real time,[168] MXAI is complex. Its complexity lies not just in its handling of data inputs but also in how those inputs are combined to produce an output. ChatGPT now accepts voice and image prompts,[169] foreshadowing how increasingly multimodal generative AI is likely to look in the future. While around 1% of AI use was multimodal in 2023, by 2027 the figure is expected to be 40%,[170] a significant jump that reflects potential rapid adoption of the technology.

SPORTS ARTIFICIAL INTELLIGENCE

Sports analytics has already had an impact, from improving the identification of talent through statistical modelling and coaching to performance optimisation, fan engagement, and refereeing.[171] Companies such as Catapult[172] and SportVU[173] are reinventing the sports industry with space for more opportunity in the future.[174]

At the 2024 Summer Olympics in Paris, NBC used AI to analyse 5,000 hours of coverage to deliver over 7 million combinations of daily recaps to fans in a personalised way.[175] The Paris Olympics also used AI to track and analyse athletes' performance, safeguard athletes from abuse on social media, provide multilingual and multi-format personalised content for both audiences and athletes, and optimise energy management through the use of digital twins to simulate energy requirements, as well as camera placement needs and accessibility issues.[176]

The value of AI in sports is set to reach nearly $30 billion by 2032, expanding at a compound annual growth rate of 30% from $2.2 billion in 2022.[177]

[h] Based on the EUR:USD exchange rate of 16 November 2024.

MEGATREND 3

Technological Vulnerabilities

KEYWORDS

Cross-border Security
Cyberbiosecurity
Cybercrime
Cyber-physical Threats
Data Breach
Identity Theft
Interoperability
Risk Mitigation
Security Protocols
Threat Detection

Together with technological advances in biotechnology and gene editing, precision agriculture, widespread digitalisation and automation, multimodal artificial intelligence (AI), and the spread of wearables and the Internet of Things (IoT), there inevitably arise new technological vulnerabilities and threats. Some become more severe, frequent and complex, crossing technological, industrial and geographical boundaries, and some, as with biotechnology, also cross biological boundaries. Cybercriminals are more organised, using AI to coordinate and perpetrate crimes. More innovative approaches to identifying, assessing and addressing vulnerabilities will be key.

THREE THINGS TO LOOK OUT FOR IN 2025

CYBERSECURITY A PRIORITY FOR LEADERS

CEOs are increasingly concerned about cybersecurity in the AI era, with nearly half of CEOs surveyed by the Oliver Wyman Forum ranking it as a top risk.[178] Industry data confirm the scale of this challenge. The Commonwealth Bank of Australia detects 85 million potential cyberfraud events daily,[179] with global average data breach costs of $4.88 million.[180]

BORDERLESS MISINFORMATION AND DISINFORMATION

Combating misinformation and disinformation will be a priority.[181] Whereas misinformation is unintentional, disinformation is meant to mislead.[182] Fifty-four per cent of those surveyed in the World Economic Forum Global Risks Perception Survey 2023–2024 said that dealing with misinformation and disinformation will require multistakeholder cooperation.[183] As global cooperation decreases and misinformation and disinformation are AI generated, the risk will only be higher, potentially deepening social and political divides.[184] This would be further complicated by reduced efforts and declining investments in content verification and fact-checking across organisations.[185]

TRUST THROUGH TRANSPARENCY

The demand for consumer protection in the digital economy[186] and in relation to public infrastructure[187] will continue to rise.[188] Robust user protection policies are a critical part of building public trust,[189] particularly in country-run digital systems such as payment platforms and data exchanges, and the millions – if not billions – of public digital records.[190] This will require transparency, public awareness, and public engagement.[191]

AREAS OF FUTURE OPPORTUNITY

INCORPORATING PSYCHOLOGY INTO CYBERSECURITY

Cybercrime significantly impacts victims[192] and their mental health.[193] For example, one survey found that 60% of fraud victims reported mental health struggles, with 55% experiencing anxiety, 48% depression, and 69% sleep problems.[194] In 2023, 349 million people were affected by data breaches, with 2.6 million fraud reports and over 1 million cases of identity theft, demonstrating the vast scale of cybersecurity challenges.[195]

While current barriers include leadership gaps, resource constraints, and the absence of widely accepted principles and standards, incorporating psychology into cybersecurity can deepen our understanding of why cyberattacks occur[196] and improve how we reduce cybersecurity threats. This can also enhance our mitigation strategies, encouraging interdisciplinary approaches and a focus on root behaviours.[197] Addressing these challenges can advance the integration of psychology within cybersecurity strategies.[198]

CYBERBIOSECURITY AWARENESS AND EDUCATION

Besides data privacy risks, there are two major threats unique to cyberbiosecurity. One is cyber-physical (i.e. sabotage of machines and equipment used in biological research, or theft of data) and the other is the creation of dangerous biological materials using digital information.[199] This is particularly relevant in biobanks[200] and other repositories of genetic samples and data where genetic information can be accessed and manipulated digitally, making it possible to create synthetic DNA and even reconstruct dangerous pathogens using published sequences.[201]

Awareness of cyberbiosecurity remains low around the world and some regions are less prepared than others, particularly the countries of Southeast Asia.[202] Irrespective of regulations, it is essential to raise awareness of cyberbiosecurity threats among biotechnology companies, research institutions, and policymakers through education and training, ensuring that researchers and practitioners from all relevant disciplines are involved.[203] One initiative to note is the Biological Security Research Centre at London Metropolitan University,[204] which established the International Biological Security Education Network in 2024.[205]

BALANCING INTEROPERABILITY WITH CYBERSECURITY

Cybersecurity is a global, cross-border challenge, and interoperability (the ability of systems to work together) can be both a challenge for, and a solution to, cybersecurity. As the world becomes more interconnected, particularly when it comes to data flows,[206] innovative approaches to cybersecurity are increasingly needed.

In 2023, the average time to identify and contain a breach was 258 days.[207] This time could be reduced by improving interoperability (often through common security standards and protocols), enhancing overall security and embracing collaborations between entities and nations.[208] For example, on an international scale, Estonia's cross-border electronic governance system X-Road is used in other countries (including several of the Nordics) to deliver security, services and economic benefits,[209] capturing both interoperability and cybersecurity benefits.

MEGATREND 4

Energy Boundaries

KEYWORDS

Carbon Neutrality
Catalysts
Clean Energy Mix
Electrolysers
Energy Storage
Game Theory
Hydrogen Production
Materials
Net Zero
Platinum

Energy has been at the heart of progress for thousands of years,[210] and energy-driven growth has been a major factor in economic progress.[211] Energy is imperative to everyday life. As we move towards new and alternative sources of clean energy, we will also need to focus on the key enablers that will make this possible. From novel materials and advanced machine intelligence to pushing the boundaries of the energy ecosystem between space and Earth, this megatrend is critical to growth, prosperity and well-being.

THREE THINGS TO LOOK OUT FOR IN 2025

FUNDING FOR ENERGY ACCESS

Sustainable Development Goal 7 aims to ensure that everybody has access to affordable and clean energy.[212] The World Bank and the African Development Bank have announced joint plans to bring electricity to 300 million people in Africa by 2030 through $30 billion in public sector investment and $9 billion in private sector investment.[213]

DRIVE FOR ENERGY SELF-SUFFICIENCY

Energy self-sufficiency is becoming even more important as technology advances, increasing the demand for energy.[214] Six Flags Magic Mountain amusement park in California is installing a new solar system that will offset 100% of the park's energy usage.[215] China will have the first onshore commercial small modular reactor (SMR) in 2025,[216] and technology companies Amazon[217] and Google[218] are both supporting their own SMR projects.

OPTIMISING THE BIOFUEL VALUE CHAIN

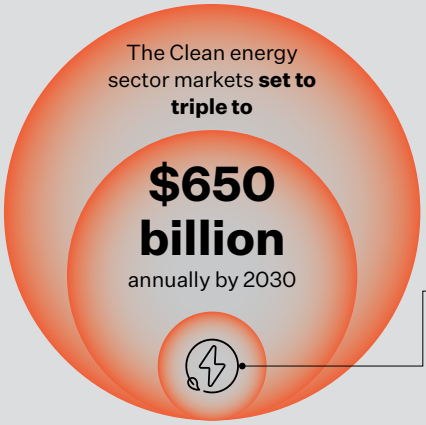
The worldwide biofuel market is expected to double between 2023 and 2033 to $243 billion.[219] While biofuels such as palm oil and sugarcane ethanol generally reduce emissions,[220] biodiesel production using palm oil farms in Indonesia and Malaysia can have 3 to 40 times higher greenhouse gas (GHG) emissions than diesel.[221] Redirection of agricultural products to biofuel production has led to challenges ensuring sufficient sustainable feedstock, leading to indirect environmental impacts.[222]

AREAS OF FUTURE OPPORTUNITY

GAME THEORY FOR THE GLOBAL PATH TO NET ZERO

The global net-zero economy is targeting carbon neutrality by 2050 and it is estimated that this will require approximately $275 trillion in capital spending, with an average annual investment of $9.2 trillion and reaching a peak of 8.8% of global gross domestic product between 2026 and 2030.[223] However, reaching this goal is not straightforward as many aspects come into play.

Game theory is a model for interactive decision-making where the outcomes depend on anticipating the strategies and associated decisions of others.[224] The use of game theory in relation to energy is not new; it has been used to model and optimise interactions between stakeholders within the complex energy system.[225] Applied to net zero, game theory can help – together with climate models – to influence interactions and decisions within multiple scenarios aiming towards net zero.[226]



ONSHORING THE MANUFACTURING OF CLEAN ENERGY TECHNOLOGIES

Clean technologies focus on reducing or eliminating pollutants or waste. From renewable energy, electric vehicles, and biofuels to advanced recycling and waste management systems, these technologies are redefining energy generation and transmission so that they help rather than harm the environment.[227]

Only four countries, along with the European Union (EU), are manufacturing 80–90% of the world's solar photovoltaic panels, wind turbines, batteries, electrolysers and heat pumps.[228] Australia, Chile and China account for more than 90% of global lithium production.[229] Others may start considering onshoring as a viable strategy through the clean energy transition.[230]

The clean energy sector presents an extraordinary growth opportunity, with markets set to triple to $650 billion annually by 2030 as nations fulfil their climate commitments. This expansion is driving strategic diversification of manufacturing capabilities and supply chain resilience across regions.[231] The sector promises to create 8 million new manufacturing jobs globally by 2030.[232]

HYDROGEN AND THE SEARCH FOR A PLATINUM ALTERNATIVE

While not the most significant, hydrogen is part of the future clean energy mix. In 2023, the use of hydrogen in new clean energy applications rose by 40% but still accounted for less than 1% of global hydrogen demand, which is expected to continue growing, driven by new applications in power and transport.[233] At the same time, by 2030, demand for low-emissions hydrogen is expected to reach only 10% of what is needed for net zero by 2050,[234] requiring significant advances in hydrogen fuel cells and infrastructure.[235]

Electrolysers, essential for hydrogen production, rely on materials such as platinum. In 2023, only 22% of installed capacity used the more efficient platinum-based proton exchange membranes,[236] a technology that has the potential to provide 11% of the global carbon dioxide emissions reductions required by the Paris Agreement by 2030.[237] However, platinum is hard to find.[238] While South Africa supplies over 70% of global platinum, its mining sector faces challenges, exacerbating future supply risks.[239] Promising alternative materials that maintain efficient energy conversion and storage capabilities include noble metal alloys, transition metals (e.g. nickel, cobalt), and carbon-based catalysts.[240]

MEGATREND 5

Evolving Ecosystems

KEYWORDS

Acoustics
Biodiversity
Climate Change
Internet of Underwater Things (IoUT)
Marine Conservation
Noise Reduction
Ocean Health
Regeneration
Sustainability
Wildlife

Driven by resource scarcity, climate change, and shifts in social values, environmental impact management will increasingly move towards a focus on ecosystems as opposed to the environmental impact of specific processes, products or services. Approaches will be more interdisciplinary, with a focus on future impact. They will also take into account both societal and environmental factors, with the primary goal of regenerating or conserving biological and ecological services and resources while providing for basic human needs.

THREE THINGS TO LOOK OUT FOR IN 2025

SUSTAINABILITY OF GENERATIVE ARTIFICIAL INTELLIGENCE (GENAI)

By 2026, over 80% of organisations will use GenAI in production settings, compared to less than 5% today.[241] While GenAI enables fast content creation (or recreation) across industries, its environmental impact is a growing concern. ChatGPT is thought to consume the same amount of energy as 33,000 average homes in the United States, and global water demand for cooling data centres used for AI may reach half the annual water consumption of the UK.[242] Mitigating these effects through advanced computer chips for energy-efficiency and the adoption of renewable energy sources will be important.[243]

INCREASED VOLUNTEERISM FOR THE ENVIRONMENT

Globally, 53% of people surveyed for the Peoples' Climate Vote 2024 were more concerned about climate change than they had been in the previous year.[244] In 2022, nearly 15% of people aged 15 and over volunteered at least once per month. As awareness of environmental risks and need for action increases,[245] environmental volunteering (e.g. tree planting, river clean-ups, and habitat restoration) may increase.[246]

CLIMATE TECH START-UPS IN AFRICA

Climate tech start-ups in Africa may be key to driving transformative change. Africa holds great potential for clean energy, responsible mineral extraction, ecosystem restoration, and – through climate tech start-ups – youth engagement.[247] Since 2019, African climate tech start-ups have raised over $3.4 billion, a number expected to rise given the need for $277 billion annually[248] to meet the Paris Agreement climate goals by 2030.[249]

AREAS OF FUTURE OPPORTUNITY

ALL THINGS REGENERATIVE

The concept of regeneration became increasingly popular in the 1990s in urban development as an innovative response to climate change looking beyond making buildings green.[250] Since then, regeneration has become the new sustainability.[251] While sustainability focuses on balancing human needs with environmental protection,[252] regeneration takes efforts further by focusing on restoring natural resources, enhancing biodiversity, and rejuvenating damaged ecosystems.[253]

As a result, the idea of regeneration has spread to other domains.[254] For example, in medicine, there is increasing recognition that the human body can heal itself.[255] In agriculture, farmers are rehabilitating the soil, respecting animal welfare, and building healthier communities while improving their yields.[256] Making efforts to restore and improve ecosystems in day-to-day living,[257] regenerative tourism, long-term community, and environmental enrichment are increasingly prioritised over immediate returns.[258]

ACOUSTIC ARTIFICIAL INTELLIGENCE FOR ECOSYSTEMS

AI with acoustics holds potential in understanding and improving marine, wildlife, urban and other ecosystems. Underwater sound travels further than visual signals or scents and is critical for marine life communication, migration and interaction with the environment.[259] AI has already been successfully used to monitor whale vocalisations, improving species detection and marine conservation strategies.[260]

Recent studies on AI and wildlife have focused on birds (48%) and mammals (22%),[261] but issues include insufficient datasets, high background noise, lack of standardisation, and complex sound classifications. While maintaining wildlife welfare and being aware of potential AI bias, AI may provide valuable real-time insights for conservation.[262]

AI is also helping to optimise room acoustics, urban noise monitoring, studio recordings, and speech clarity in educational environments.[263] From workplaces to healthcare, AI and acoustics can boost productivity and creativity, with Internet of Things (IoT) integration and advanced signal processing enhancing auditory experiences and immersive sound environments.[264]

INTERNET OF UNDERWATER THINGS (IoUT)

In 2021, the **IoT** was expected to unlock up to

$12.6 trillion

in value by 2030

In 2021, it was estimated that the IoT is expected to unlock up to $12.6 trillion in value by 2030 from applications in factories (26%), human health (10–14%), and others.[265] Achieving this will depend on advanced connectivity through 4G and 5G networks, as well as balancing affordability with interoperability, cybersecurity and deployment complexity.[266]

Oceans face critical pressures from climate change and unsustainable use of ocean resources, affecting ecosystems and human societies.[267] The United Nations Decade of Ocean Science for Sustainable Development (2021–2030)[268] promotes interdisciplinary research and global collaboration to improve the health of the oceans.[269] As interest in marine sciences increases and with devices that monitor and support applications underwater, the Internet of Underwater Things (IoUT) provides future opportunities for environmental monitoring, exploration, and disaster prevention.[270,271] Challenges related to harsh water conditions and data collection and transmission will need to be overcome.[272]

MEGATREND 6

Borderless World – Fluid Economies

KEYWORDS

AI Personhood
Cryptocurrency
Digital Assets
Education
Energy
Environment
Regulation
Stablecoin
Tokenisation
Water

Increasingly, unmediated transactions in finance, health, education, trade, services and even space lead to the blurring of jurisdictional boundaries, shifting liabilities and creating increased numbers of cross-border communities and networks. Advances in communications, computing, and advanced machine intelligence will accelerate a borderless world that will change the way we work, live and communicate.

THREE THINGS TO LOOK OUT FOR IN 2025

GLOBAL DATA ACCESS AND USER CONSENT FOR AI TRAINING

Spending on artificial intelligence (AI) is expected to rise to $632 billion by 2028.[273] Existing social media,[274,275] technology,[276] and network[277] platforms, which are global in nature, are turning to user data to train their own AI models. While some companies have denied or expressed no interest in doing this,[278] others are providing their users with updated user terms or the ability to opt out. The need for common global standards for data management and sharing may increase.[279]

CROSS-BORDER PHILANTHROPY FOR GLOBAL CHALLENGES

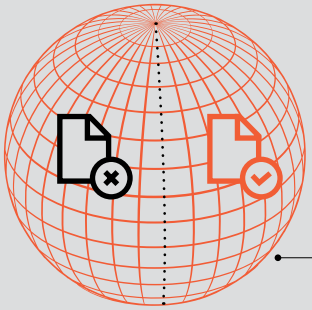
In 2022, 40 private philanthropies reported $11 billion in development support to the Organisation for Economic Co-operation and Development (OECD), although contributions have stagnated since 2021.[280] Reported in the 2023 Global Philanthropy Tracker, global cross-border philanthropy reached $70 billion across 47 high-income countries in 2020, representing 85% of global GDP.[281] While domestic philanthropy grows,[282] cross-border giving remains crucial for addressing natural disasters and global crises such as COVID-19.[283] However, barriers persist, including taxation issues, limited legal recognition for foreign foundations, and misaligned legal protections.[284]

INTELLECTUAL PROPERTY IN A BORDERLESS DIGITAL WORLD

AI, especially large language models and generative AI (GenAI), is trained primarily from public sources, including copyright-protected text, and visual and auditory works.[285] The growing outputs from GenAI will continue to raise questions about its role in the inventive process. The World Intellectual Property Organization runs multiple events and discussion forums on this topic,[286] and the Centre for the Fourth Industrial Revolution in the UAE has published a report touching on intellectual property, AI and the creative industries.[287]

AREAS OF FUTURE OPPORTUNITY

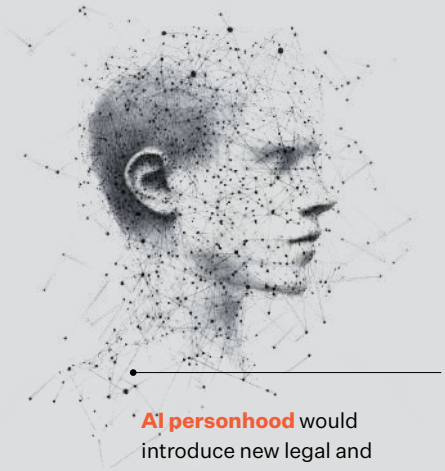
GLOBAL COOPERATION FOR CROSS-BORDER DIGITAL ASSET REGULATION



Overall tokenised market capitalisation, excluding Bitcoin and Tether, could hit approximately $2 trillion by 2030 due to the increased use of these currencies in mutual funds, bonds, exchange-traded notes, loans, securitisation, and alternative funds.[288]

However, digital assets lack a universal definition[289] despite the fact that two-thirds of 86 jurisdictions surveyed by the World Economic Forum already regulate or are planning to regulate digital assets.[290] These differences create regulatory challenges because a digital asset that is legal in one jurisdiction may be illegal in another. The Financial Stability Board[291] and the International Organization of Securities Commissions[292] are working on providing universal definitions,[293] and the Principles of the International Institute for the Unification of Private Law offer a framework connecting digital assets to existing legal structures.[294] However, gaps persist. The UAE is a leader in the Middle East and North Africa region in regulating digital assets. Several organisations have published regulatory frameworks, including Dubai's Virtual Assets Regulatory Authority,[295] Abu Dhabi Global Market,[296] the Dubai International Financial Centre,[297] and the Digital Assets Oasis in Ras Al-Khaimah.[298]

EXPLORING ARTIFICIAL INTELLIGENCE PERSONHOOD FOR LEGAL BOUNDARIES



AI personhood would introduce new legal and **ethical challenges about rights, responsibilities and accountability**

AI has the potential to add as much as $15.7 trillion to the worldwide economy by 2030.[299] As AI becomes ubiquitous, highly autonomous AI systems may eventually warrant legal status like corporate entities, particularly if impacting international decision-making and cross-border interactions.

Granting legal status to non-corporate entities is not a new issue; many have argued for legal rights for nature.[300] However, AI personhood would introduce new legal and ethical challenges about rights, responsibilities and accountability and would require a debate around whether AI entities fit into the existing (or future) legal structures.[301] Considering legal personhood for AI could raise critical questions about moral responsibility, economic efficiency, and legalities, especially as AI's capabilities continue to evolve. Giving AI legal personhood would mean it could face sanctions, fines and deactivation resulting from unlawful actions.[302] However, the perceived accelerated advances in AI make this a challenge,[303] and as an emerging concept it is an area of opportunity for coordination in the larger global context.[304]

TRANSDISCIPLINARY EDUCATION FOR GLOBAL INNOVATION

The next 10 years will see many environmental, societal, technological and economic global risks that cannot be solved by individual countries alone.[305] Between 2030 and 2040, global water and energy demands are expected to rise by 40% and 50%, respectively,[306] impacting food and water systems, economies and supply chain systems, and many other areas of work and life that could lead to increased global tensions.[307] Meanwhile, climate change is affecting global socio-economic systems, such as food, physical assets, infrastructure, natural capital, and migration,[308] triggering an interconnected set of social and environmental risks.[309]

In a borderless, interconnected world, addressing such complex cross-border and cross-sectoral issues requires a transdisciplinary approach. By combining insights from multiple fields, we can develop unique and innovative solutions that address both the technical challenges and the societal implications of emerging and future technologies. Universities and training institutions can promote transdisciplinary education programmes that combine law, technology, ethics, and international relations, encouraging cross-sector understanding and collaboration. These programmes can be co-developed by academic and industry leaders to ensure that they address practical, real-world challenges. Some institutions, such as the University of Twente in the Netherlands,[310] have already set up programmes that focus on transdisciplinary education, but more are needed.

MEGATREND 7

Digital Realities

KEYWORDS

Augmented/Virtual Reality Headsets
Digital Theatre
Immersive Experiences
Life Satisfaction
Performing Arts
Real–Virtual Divide
Self-esteem
Self-expansion
User Acceptance
Virtual Identities

Digital natives – those who have grown up with digital forms of entertainment, education and communications – will naturally usher in increasingly virtual worlds where many 'real-world' tasks and behaviours can be replicated and potentially even improved in 3D and 4D environments. The emergence and spread of 5G and 6G networks will enhance autonomous applications as they offer more reliable, cost-effective and secure high-speed connectivity that enables real-time analytics and decision-making. As quantum technologies, such as quantum computing, communications and sensors, become scalable and reliable, immersive experiences will start to feel like reality.

THREE THINGS TO LOOK OUT FOR IN 2025

METAVERSE CALLS

The metaverse, specifically virtual reality (VR), was expected to replace smartphones by 2035, but its widespread adoption has seen a series of challenges,[311] including the loss of $13.7 billion by Meta's Reality Labs in 2022,[312] cybersickness,[313] mental health problems caused by cyberbullying, identity theft, and financial exploitation,[314] as well as regulatory obstacles, cultural resistance, and security concerns.[315] However, considering the Dubai Metaverse Strategy,[316] South Korea's $177 million investment fund for the metaverse,[317] ongoing efforts by the World Economic Forum,[318] and Mohamed bin Zayed University of Artificial Intelligence's Metaverse Lab,[319] the metaverse may yet be widely adopted.

DIGITAL CONTACTLESS EXPERIENCES

Augmented reality (AR) adoption through smartphones, particularly given the spread of 5G,[320] shows promising growth.[321,322] There are now over 2,000 spatial apps for Apple Vision Pro,[323] and, as generative artificial intelligence (AI) continues to make it quicker and cheaper to build spatial environments and experiences,[324] examples such as IKEA's home visualisation tool, L'Oréal's ModiFace AR tool, and Google Maps Live View[325] may become increasingly common.

ARTIFICIAL INTELLIGENCE POWERING EXTENDED REALITY

AI is expected to contribute nearly $20 trillion (3.5%) of global gross domestic product by 2030.[326] Within extended reality, AI enables personalised interactions and manages data flows, driving user engagement.[327] With results showing 75% improved learning retention and 275% increased confidence in learned topics,[328] extended reality powered by AI may have the potential to increase engagement and collaboration.

AREAS OF FUTURE OPPORTUNITY

GROWING THE DIGITAL THEATRE

The **home entertainment and cinema markets** were worth

$100 billion

in 2023

The home entertainment and cinema markets continue to grow, with an estimated worth of $100 billion in 2023 and an expected increase of 8% annually between 2024 and 2030.[329] The impact of technology has also been transformative in drama and the arts. With technological advances, new forms of theatre have emerged that encourage viewers to actively participate and interact within narratives.[330] Some are calling for technology to be used for analysis of productions to document knowledge for use in drama education in the future.[331]

Many performing arts theatres, some of which had never previously offered digital broadcasts, made their performances available online during the COVID-19 pandemic.[332] For example, National Theatre at Home,[333] launched during the pandemic, attracted over 15 million viewers from 170 countries within just four months of launch.[334] Facing challenges bringing back audiences to pre-COVID levels,[335] digital realities can enhance access and enable distant audiences to attend live performances or feel like they are part of a live performance.

THE VIRTUAL–REAL SELF DIVIDE

The boundary between our real and virtual identities continues to be blurred. People may maintain multiple identities across various platforms, raising philosophical and ethical questions about what it means to be human and what physical existence or being present or conscious means.[336] Key questions include what information can be shared in the virtual self, how to ensure privacy, who is accountable for errors or decisions in the virtual life that may or may not impact real-life experiences, and how to balance regulation to promote both trust and freedom in the virtual world.[337]

How virtual and real identities influence each other remains a crucial area of research,[338] building on previous studies that have focused on the relationship between the actual and idealised self [339] and how they can enhance societal prosperity and well-being. For example, participating in virtual environments can have positive effects when virtual and real identities are aligned. However, it can also create the feeling of being disconnected if the virtual self is seen as superior, negatively impacting self-esteem and life satisfaction.[340]

EVOLVING ACCEPTANCE OF AUGMENTED/ VIRTUAL REALITY HEADSETS

Sales of AR/VR headsets have gone down by

40%

Start-up funding has dropped by

50%

Immersive experiences have expanded across disciplines and domains, mimicking real-life spaces, events and social interactions.[341] From health and climate to gaming and education, digital realities are increasingly enabled by AR/VR. However, despite a jump in popularity during the COVID-19 pandemic,[342] the growth of AR/VR-powered experiences remains uncertain and unpredictable.

While sales of AR/VR headsets have gone down by 40% since 2022, and start-up funding has dropped by 50%,[343] shipments of AR/VR headsets started to grow again in the third quarter of 2024 and are expected to rebound in 2025, with an expected compound annual growth rate (CAGR) of nearly 86% by 2028.[344] However, this optimistic outlook is not universal, as Apple has reduced its production of Apple Vision Pro.[345]

Despite efforts to make devices more user-friendly, AR/VR headsets continue to be considered experimental, with a focus on testing the functionality and viability of the technology.[346] Innovativeness, perceived benefits, and system quality are key to user acceptance, as are user-friendliness and potential societal impacts if more widely adopted.[347] There is an opportunity to develop new acceptance models based on standardisation and validation across applications and environments.[348]

MEGATREND 8

Life with Autonomous Robots and Automation

KEYWORDS

Additive Manufacturing
Biomimicry
Collaborative Robots (Cobots)
Drones
Humanoids
Human–Robot Interaction
Materials
Sea Drones
Soft Robotics
Trust

Driven by advances in mechanical engineering design, materials science, advanced machine intelligence, and advanced communication networks, robots will increasingly expand into other industries beyond the automotive, manufacturing, and supply chain logistics sectors. The use of robots[349] and automation[i] will provide greater opportunities for efficiency and innovation while presenting us with ethical and societal challenges around autonomy, decommissioning, and the future of work. The growing numbers of robot-to-robot, human-to-robot, and human-to-machine interactions will raise questions about intellectual property and robot rights.

THREE THINGS TO LOOK OUT FOR IN 2025

HUMANOID ROBOTS TO DISRUPT ALL ROBOTS

In 2023, there operated around 4.28 million robots in factories worldwide[350] and 4.31 million service robots in other industries, especially consumer service.[351] However, humanoid robots may disrupt both sectors. The global market for humanoid robots, which was $2.43 billion in 2023, is expected to reach $66 billion by 2032,[352] with application particularly in healthcare, manufacturing, and supply chain logistics.[353] RoboFab in Oregon, United States, is the first factory for humanoid robots.[354]

BREAKTHROUGHS IN ROBOT DEXTERITY

Robots are becoming more versatile due to configurational advances,[355] materials science, and sustainable robotics.[356] Generative artificial intelligence is expected to enable better sensing and adaptability in varied environments.[357] For example, Google's ALOHA Unleashed demonstrates advanced dexterity, carrying out complex tasks such as tying shoelaces and repairing other robots, while Google's DemoStart, also dexterous, uses simulation training to improve performance.[358]

DRONE EVOLUTION

The capabilities of commercial drones are expected to expand, with a global sea drone market of nearly $20 billion[j] by 2030[359] and an electric vertical take-off and landing drone market of $160 billion by 2040.[360] China's first global certified air taxi, the EHang EH216-S, can carry two passengers,[361] and Dubai has started building a flying taxi station for up to 170,000 passengers annually.[362]

[i] Includes drones, software, autonomous cars, exoskeletons, unmanned ground vehicles, smart appliances, and so on. While there is no harmonised definition used across organisations, these types are all included in the definitions used by the International Organization for Standardization, the Institute of Electrical and Electronics Engineers, and ASTM International.

[j] Based on EUR:USD exchange rate 17 December 2024.

AREAS OF FUTURE OPPORTUNITY

BIOMIMICRY FOR SOFT ROBOTICS

Biomimicry draws inspiration from nature to enhance quality and functionality across domains and offer innovative solutions to global challenges. Soft robotics, a high-potential application of biomimicry, focuses on the development of adaptable robots made of materials that feel like biological tissue. Bionic multi-legged robots with flexible bodies outperform rigid robots in speed, stability, and terrain navigation,[363] and gecko-inspired robots can achieve an adhesion force of 180N, allowing them to climb and operate in microgravity environments.[364]

The development of bio-inspired soft robots requires several elements to be considered, including materials, actuation mechanisms, and design. Highly interrelated, as they are in biological systems,[365] bio-inspired soft robots are key in medical applications, where precision and reliability can be critical to the preservation of life.[366] Interdisciplinary collaboration between biologists and engineers will drive future innovation, deepening understanding of biological systems while advancing robotics capabilities to produce more sophisticated, versatile and lifelike robotic solutions.

BETTER UNDERSTANDING OF HUMAN–ROBOT INTERACTION

Robots are increasingly used in manufacturing, scientific research, agriculture, and food service. The development of larger numbers of collaborative robots (cobots) and humanoid robots signals a shift towards more adaptable robots that can work alongside humans in varied environments.

Trust in human–robot interaction is not just about reliability.

However, widespread adoption faces several obstacles. Safety concerns, regulatory requirements, the impact on jobs, and resource constraints make scalable adoption challenging.[367] Most importantly, there is the fundamental issue of trust,[368] especially as artificial intelligence (AI) becomes increasingly integrated with robotics.[369] Trust in human–robot interaction is not just about reliability. It is about humans intentionally depending on robots despite the inherent risks and vulnerabilities.[370] This relationship must be founded on positive impacts while acknowledging uncertainties, introducing an emotional dimension beyond technical reliability.[371] As the industry evolves, establishing trust between humans and robots will become crucial for successful integration. This challenge encompasses both technical reliability and the more complex emotional aspects of human–robot collaboration, setting the stage for future developments in the field.

BETTER MANUFACTURING MEASURED THROUGH ROBOT COLLABORATION

Evolving from rapid prototyping, additive manufacturing is distinct from traditional linear manufacturing. Similar to 3D printing, objects are built layer by layer,[372] enabling the manufacture of more complicated designs[373] and without retooling.[374] Materials, including polymers, metals, ceramics, sand and composites,[375] will be critical in scaling additive manufacturing.[376]

Cooperative robots[377] could be the catalyst for widespread adoption of additive manufacturing.[378] They could enhance printing capabilities, assist throughout the printing process, and enable real-time information capture and feedback beyond the limitations of single robotic systems.[379] Their effectiveness would rely on sophisticated planning, collision avoidance technology, and enhancement of the properties of relevant materials, augmented by AI and machine learning technologies.[380] Beyond technical capabilities, the key to success will lie in how the quality of the collaboration is assessed in real time.[381] In this way, the use of cooperative robots in additive manufacturing may reveal a new frontier in manufacturing innovation.

MEGATREND 9

Future Humanity

KEYWORDS

AI Dispute Resolution
Arts Education
Creative Economy
Cross-border Disputes
Digital Media
Generation Z
Legal Aid
Organisational Values
Study Tracks
Talent

With advanced machine intelligence, brain–computer interfaces, technological breakthroughs, advances in science and medicine, and an increasingly borderless world, people's understanding and expectations of self-realisation – including work, education and what it means to thrive – will shift. Personal development, how individuals and communities innovate and communicate, and new definitions of self-esteem, autonomy and stability will bring forth new ideas about parenting, care, love, belonging, inclusion and community. The traditional boundaries between self, society and institutions will evolve.

THREE THINGS TO LOOK OUT FOR IN 2025

WOMEN IN ARTIFICIAL INTELLIGENCE AND DATA SCIENCE

While data varies by source,[382] the share of women in AI engineering increased to approximately 35% in 2024,[383] and several initiatives aim to close this gap. For example, the international Women in Data Science project enables women to be fully represented and empowered in data science.[384] Similarly, Women in AI Benelux (Belgium, Netherlands and Luxembourg) focuses on empowering women to become AI and data experts and leaders,[385] while the UAE's Abdulla Al Ghurair Foundation has launched its own Women in AI programme.[386]

BRIDGING THE TECHNOLOGY-HUMAN GAP IN CUSTOMER SERVICE

In 2025, 85% of customer service leaders are expected to explore or pilot customer-facing conversational generative AI.[387] However, while technology is meant to enhance the customer digital experience, there is a growing disconnect[388] between businesses and customers, as technology alone is not improving customer loyalty.[389] Businesses will need to balance technological advancement[390] with authentic human connection.[391] Companies may look at strategically deploying technology as an enabler while prioritising relevance, genuine customer needs, and customers' ability to control the experience.[392]

ARTIFICIAL INTELLIGENCE AND HUMANITY – AN EVOLVING NARRATIVE

In a cross-disciplinary survey of experts in 68 countries in 2024, 34% expected to see a substantial acceleration in how AI would impact daily life and society within the next year.[393] As people's ways of communicating and connecting continue to change, reshaping relationships and social interactions,[394] AI will evolve to more increasingly reflect what is important to diverse human cultures, ethical frameworks, and region-specific approaches to ensure AI serves society's values and best interests.[395]

AREAS OF FUTURE OPPORTUNITY

The **creative economy** contributed

3.1%

of global GDP
in 2022 and 2023

NEED FOR THE ARTS

Based on UNESCO data in 2022 and 2023, the creative economy generates $2.3 trillion annually, contributing 3.1% of global gross domestic product (GDP) and employing 6.2% of the global workforce.[396] This sector, encompassing both traditional arts and digital media,[397] is projected to reach 10% of global GDP by 2030.[398] Driven by digitalisation, this makes it one of the world's fastest growing sectors.[399] However, funding remains a challenge – heavily depending on traditional fundraising, grants and sponsorship, which are vulnerable to economic downturns – and is often overlooked in policy and investment discussions.[400] Besides funding, dropping enrolments in arts education is also a challenge.

Fundamental to the creative sector, arts education also supports the development of cross-disciplinary skills that can be used to address complex global challenges.[401] It plays an essential role in mental health, education and navigating social change,[402] and can enable a deeper understanding of life,[403] which will be especially valuable as society navigates the challenges of AI and other technological advances.[404]

The **global justice crisis** affects at least

5.1 billion

people

LAB FOR ONLINE DISPUTE RESOLUTION ACROSS LEGAL SYSTEMS

AI-powered dispute resolution shows promising potential for increasing access to justice globally. The global justice crisis affects at least 5.1 billion people around the world.[405] For example, in the United States, low-income Americans receive little to no legal help in 92% of civil cases.[406]

As mediators for dispute resolution,[407] large language models (LLMs) have demonstrated impressive capabilities, outperforming or matching human mediators in the selection of appropriate intervention types (62%) and creation of effective intervention messages (84%).[408] A cross-border online dispute resolution lab could further advance AI-enabled tools for handling disputes across jurisdictions and languages. The University of Cambridge has proposed standards for such an initiative, although there remain challenges related to bias, privacy and worldwide coverage.[409] Several innovative initiatives are already underway to pilot or roll out LLMs for legal aid. Suffolk University Law School and the American Arbitration Association have launched an online innovation clinic for dispute resolution in family law matters.[410] Other examples are the British Columbia Civil Resolution Tribunal, which handles small claims and motor vehicle disputes online,[411] and Queen's University Conflict Analytics Lab, which acts as an incubator for legal technology start-ups.[412]

Gen Z will represent

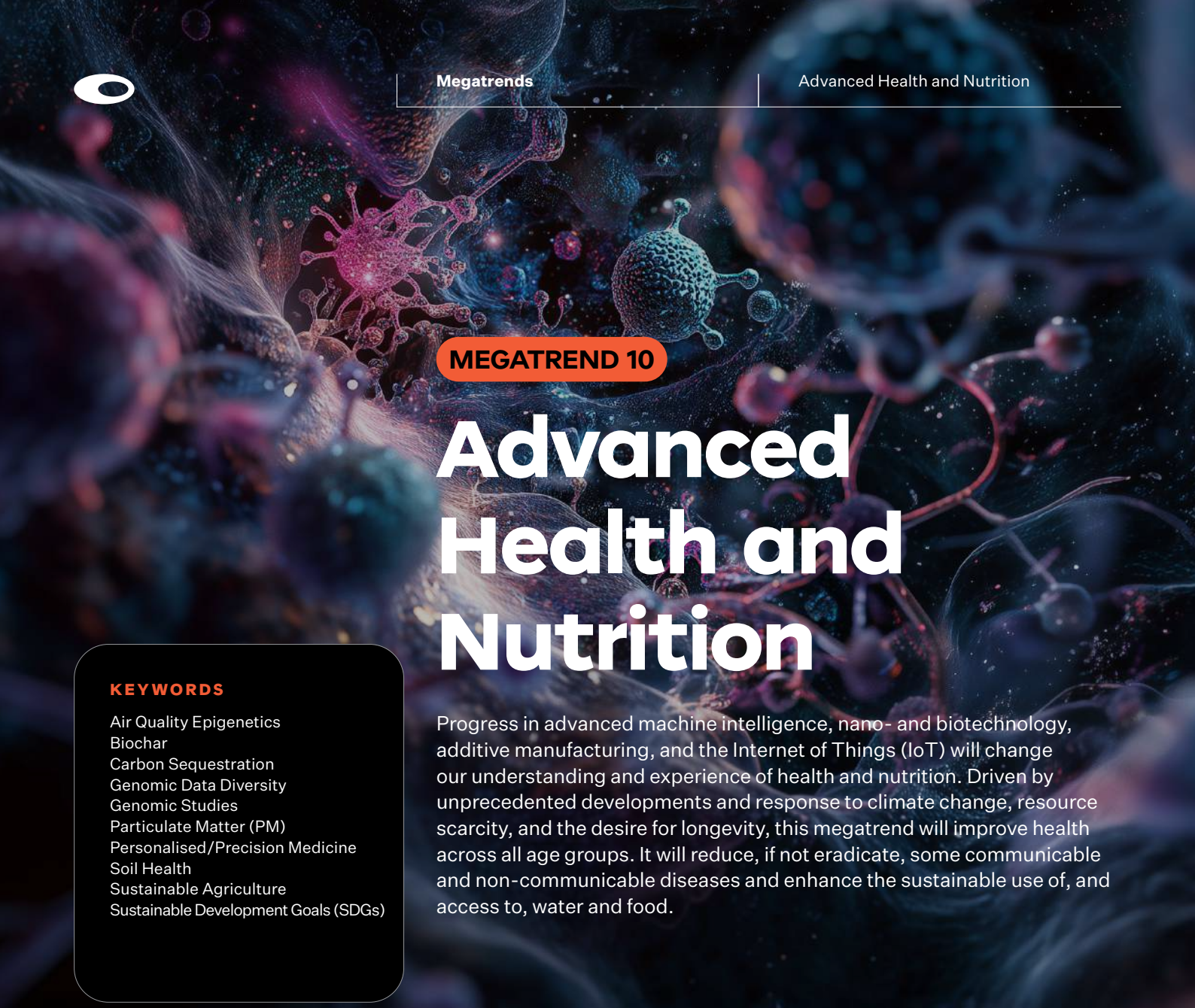
27%

of the workforce in 2025

UNDERSTANDING TALENT RETENTION

Meaningful work and job alignment are important factors in talent retention. However, alignment with organisational values plays a more significant role.[413] This alignment is crucial for Generation Z (Gen Z), who make up 25% of the global population and will represent 27% of the workforce in 2025.[414]

The concerns and preoccupations of this demographic – and others – present unique opportunities for organisations to reimagine workplace culture and retention strategies, particularly as Gen Z prioritise job security over frequent job changes.[415] However, assessing organisational value alignment – including corporate social values[416] – is not easy, particularly if an employee's level of self-knowledge is limited[417] and organisational values are unclear.[418] Along with clear organisational values[419] and ensuring genuine commitment to them,[420] this is best achieved from the hiring decisions that benefit both the organisation and the employee.[421] Organisations can adopt forward-looking strategies that include diverse hiring panels to reduce bias and ensure better cultural fit.[422] Prioritising alignment with values strengthens employee loyalty and positions companies as employers of choice contributing to a more productive workplace culture that meets the demands of an ever-changing job market.



MEGATREND 10

Advanced Health and Nutrition

KEYWORDS

Air Quality Epigenetics
Biochar
Carbon Sequestration
Genomic Data Diversity
Genomic Studies
Particulate Matter (PM)
Personalised/Precision Medicine
Soil Health
Sustainable Agriculture
Sustainable Development Goals (SDGs)

Progress in advanced machine intelligence, nano- and biotechnology, additive manufacturing, and the Internet of Things (IoT) will change our understanding and experience of health and nutrition. Driven by unprecedented developments and response to climate change, resource scarcity, and the desire for longevity, this megatrend will improve health across all age groups. It will reduce, if not eradicate, some communicable and non-communicable diseases and enhance the sustainable use of, and access to, water and food.

THREE THINGS TO LOOK OUT FOR IN 2025

THE GROWING CLIMATE–HEALTH LINK

Climate change is threatening health worldwide, pushing 132 million people into extreme poverty, including 44 million from the impacts of ill health.[423] In 2023, people experienced 50 more days per year of health-threatening temperatures, and 48% of global land faced extreme drought.[424] Food insecurity affects 151 million more people today compared with the levels seen between 1981 and 2010.[425]

HEALTHCARE SYSTEM BOTTLENECKS AROUND THE WORLD

Healthcare bottlenecks around the world vary from a lack of guidelines, supervision, training and cleanliness for women during childbirth in Pakistan[426] to the cost and voluntary nature of the private insurance system of the United States, which leaves millions of people uninsured.[427] Despite gaps in data,[428] overcrowding and long waiting times in emergency departments are already common in the OECD[429] and around the world,[430] as are access barriers for mental health care.[431]

MEAT TRADE ALONGSIDE REGULATORY, CLIMATE AND DEMOGRAPHIC SHIFTS

By 2033, the global meat trade is expected to grow by 12% driven by rising demand in sub-Saharan Africa and Asia.[432] Exports from North and South America are also expected to grow, accounting for just over half of global meat exports.[433] This is alongside the European Union's ban on food imports linked to deforestation,[434] growing concerns over the impact of meat production on the climate,[435] as well as ageing populations and changing consumer preferences in high-income countries.[436]

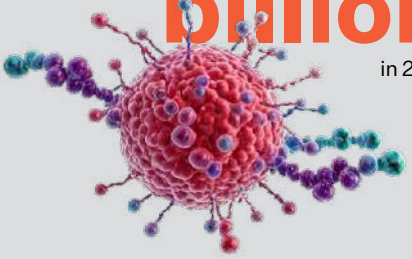
AREAS OF FUTURE OPPORTUNITY

AIR QUALITY EPIGENETICS

The **global epigenetics market** reached a value of

$14.6 billion

in 2023

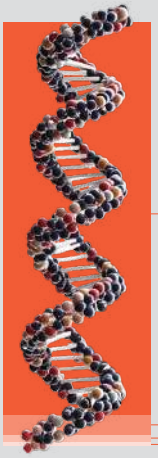


The environment influences epigenetics, which studies the processes that activate or deactivate specific genes, influencing not only individual health but also the health of future generations.[437]

Particulate matter (PM) in the air may include organic and inorganic compounds that have epigenetic effects linked to poor health. Current research on PM's epigenomic impact is limited, with future opportunities to identify biomarkers and develop interventions that could mitigate PM-related health risks, especially in vulnerable populations.[438]

The global epigenetics market reached a value of $14.6 billion in 2023 and is expected to increase by nearly 15% annually up to 2030.[439] Eight epigenetic therapies have been approved by the US Food and Drug Administration (FDA) and are currently on the market, with six being used to treat haematological malignancies and two approved for solid tumours.[440]

EXPANDING PRECISION MEDICINE THROUGH DIVERSE GENOMIC RESEARCH



Current genomic data in genomic studies come from

94.5% European ancestry

4% Asian

0.9% Hispanic and other

0.6% African

Precision/personalised medicine is transforming approaches to genetic diseases.[441] In 2023, precision medicines made up 38% of the FDA's new therapeutic drug approvals and over a quarter of all approvals since 2015.[442] While combined use of magnetic resonance imaging scans with genetic testing has improved diagnostics for neurological disorders such as cerebral palsy[443] and autism,[444] the impact of precision medicine has not been fully realised.[445]

For example, epilepsy affects 50 million people globally, with 80% living in low- or middle-income countries.[446] While 70% of people could be seizure-free with proper treatment – once diagnosed – 50% of cases have unknown causes.[447] Benefiting from personalised medicine in this case requires addressing current limitations, particularly in genomic data presentation. With nearly 94.5% of current genomic data in genomic studies coming from European ancestry, followed by nearly 4% Asian, 0.9% Hispanic and 0.6% African,[448] expanding research to include diverse populations is a future opportunity. From a growing emphasis on data sharing[449] across demographics and geographical regions to efforts to overcome cultural barriers[450] and stigma[451, 452] associated with genetic testing, these steps are crucial for developing more effective, targeted therapies and ensuring broader access to the benefits of precision medicine.

BIOCHAR FOR CROPS

With **biochar**, crop yields can increase by

10%

Biochar, a carbon-rich charcoal, is produced through pyrolysis of biomass at high temperatures (500°C).[453] A by-product of bioenergy production, which currently makes up 55% of global renewable energy and must grow by 8% annually until 2030 if net-zero targets by 2050 are to be met,[454] biochar as a future opportunity powers a circular approach to biomass.

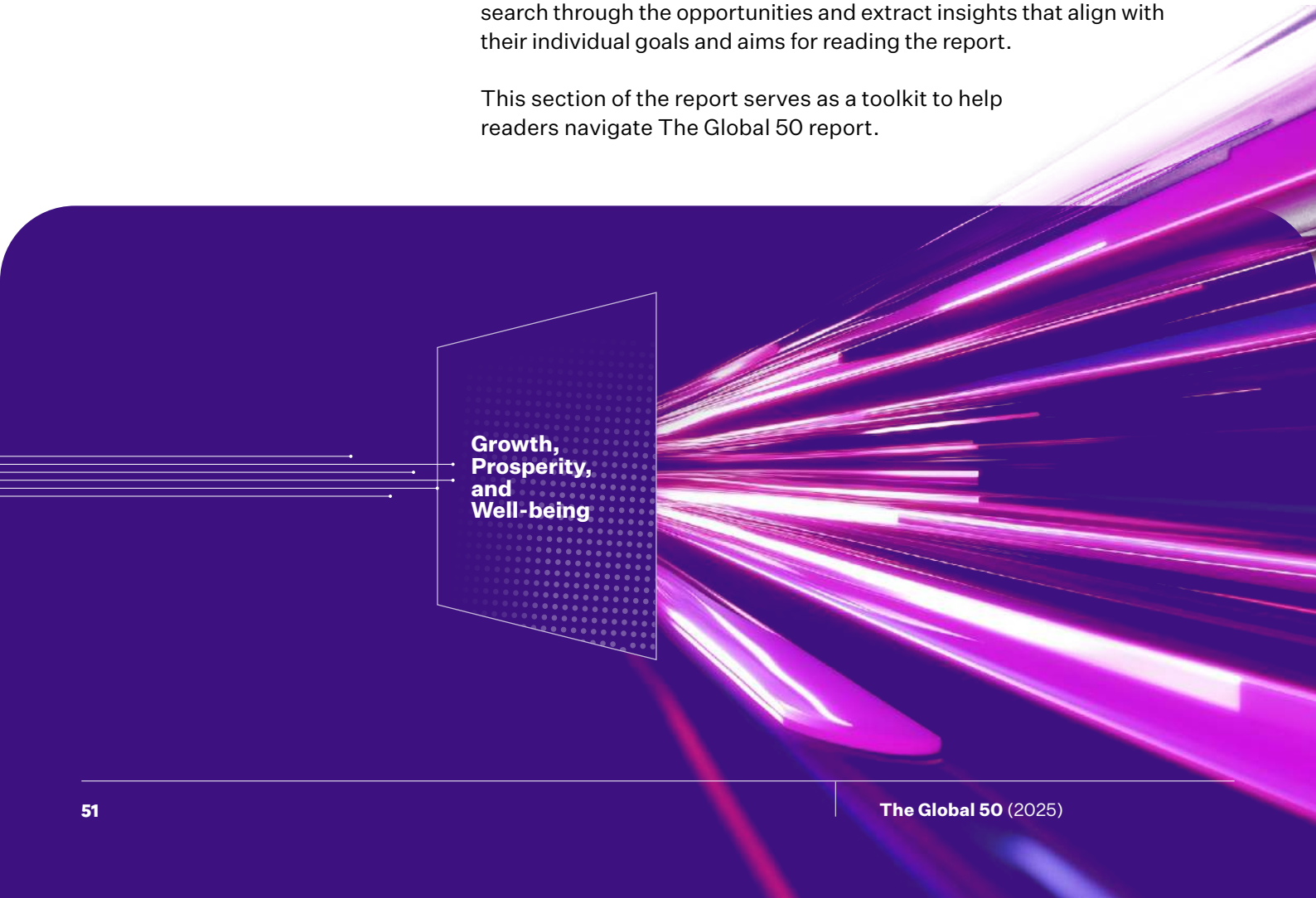
Biochar offers multiple benefits, including enhanced soil health, improved water retention, and carbon sequestration.[455] Biochar can aid composting,[456] water filtration,[457] carbon capture,[458] and agricultural yields,[459] contributing to some of the Sustainable Development Goals (SDGs): SDG 6 (clean water), SDG 13 (carbon capture), and SDG 15 (soil health).[460] Its role in soil health is particularly significant for sustainable agriculture and climate mitigation strategies, as it enhances soil's structure, water retention, and microbial health while reducing acidity.[461] With biochar, crop yields can increase by 10%, as it enhances nutrient absorption and retention, deters pathogens and pests, and makes plants more resilient to environmental impacts.[462]

Navigating The Global 50 Report

We define **foresight as the process of exploring futures** to inform decisions and actions today.

Presented in two parts, the primary aim of The Global 50 is to share the Dubai Future Foundation's view of the future when it comes to growth, prosperity and well-being and some of the ways that this view can be translated into action through 50 future opportunities. This is complemented by a user-friendly web page that allows readers to search through the opportunities and extract insights that align with their individual goals and aims for reading the report.

This section of the report serves as a toolkit to help readers navigate The Global 50 report.



As a Use Case for Foresight Research

Quality is central to research in any domain.[463] With common quality principles, specific quality criteria depend on whether the research is qualitative,[464] quantitative, or mixed methods.[465] Views on what constitutes impactful research are diverse as well,[466] with increasing calls to move beyond criteria focused solely on quantity.[467] Instead, quality of research is increasingly being evaluated – even if informally – through demonstrable value for readers, practical relevance for researchers, practitioners and decision-makers, ability to offer solutions to societal challenges, originality, and theoretical or analytical rigour.[468]

When research includes a futures component, quality considerations expand with particular emphasis on methodology and execution to avoid flawed future scenarios, unreliable projections, or a narrow view of potential futures. High-quality foresight research acknowledges varied and alternative futures, employs methods that align with the researcher's or organisation's research philosophy, regularly reassesses scenarios as circumstances evolve, and considers both near- and long-term futures[469] with extensive reflexivity on underlying assumptions.

Foresight research encompasses various types of futures – from probable, plausible and possible to predicted, projected and preferred.[470] It can incorporate multiple methodologies, including backcasting, case studies, forecasts, interviews, meta-analysis, scenarios, simulations, and trend analysis, among others.

Building on research and analysis carried out since 2021, our approach forming our view of the future uses annual deductive research methods to validate assumptions, uncertainties and megatrends. When it comes to the opportunities, and to ensure trustworthiness,[471] we upheld the principles of **credibility**, through thorough data verification; **transferability**, through detailed contextual description; **dependability**, through consistent methodological processes; **confirmability**, through transparent documentation; and **authenticity**, in representing different perspectives, translating into the following aspects of our research:

Core

- Emphasis on practical value for readers, decision-makers and foresight practitioners
- Focus on growth, prosperity and well-being
- Balance of theoretical rigour with imagination, innovation and practical applicability

Futures

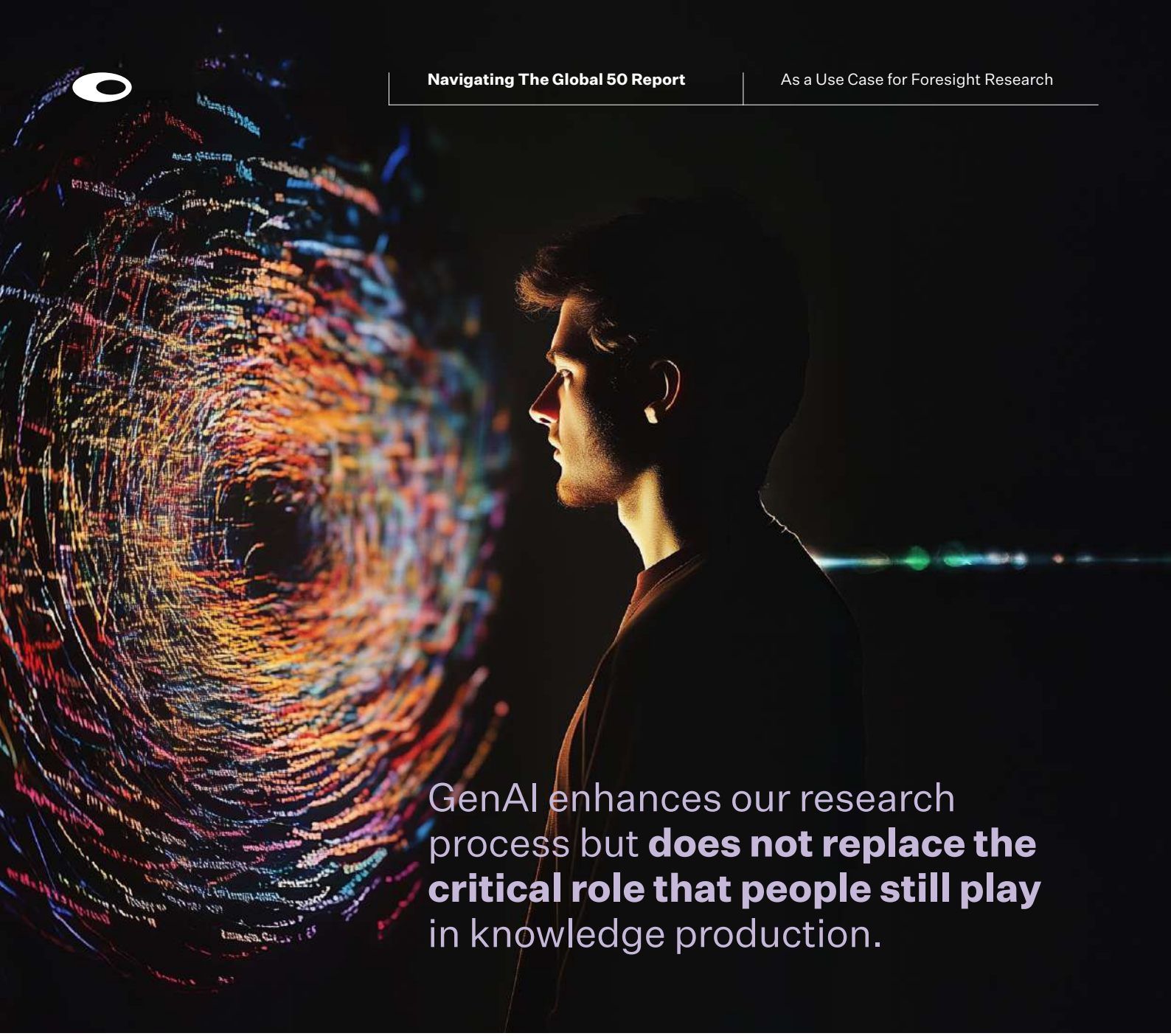
- Consideration of possible futures in benefits and risks
- Consideration of alternative futures
- Factoring in both near- and long-term futures

Process

- Clear research questions, i.e. questions for the future
- Build on existing knowledge through a concise literature review for each opportunity
- Isolate the three most impactful drivers

Findings

- Support opportunities with evidence (why it matters today)
- Connect findings to existing literature (as applicable)



GenAI enhances our research process but **does not replace the critical role that people still play** in knowledge production.

People remain central to improving quality, addressing bias, and generating innovative outputs that, ultimately, refine large language models (LLMs). At their core, LLMs rely on original research and critical thought. As the pursuit of knowledge and research evolves, advances in artificial intelligence (AI) – what we refer to as advanced machine intelligence when taking the long view – will serve humanity. As a branch of that field, **GenAI for research will evolve effectively as long as cognitive health, creativity and out-of-the-box thinking, research quality, and researcher reflexivity remain central to the evolving landscape.**

For Strategic Foresight

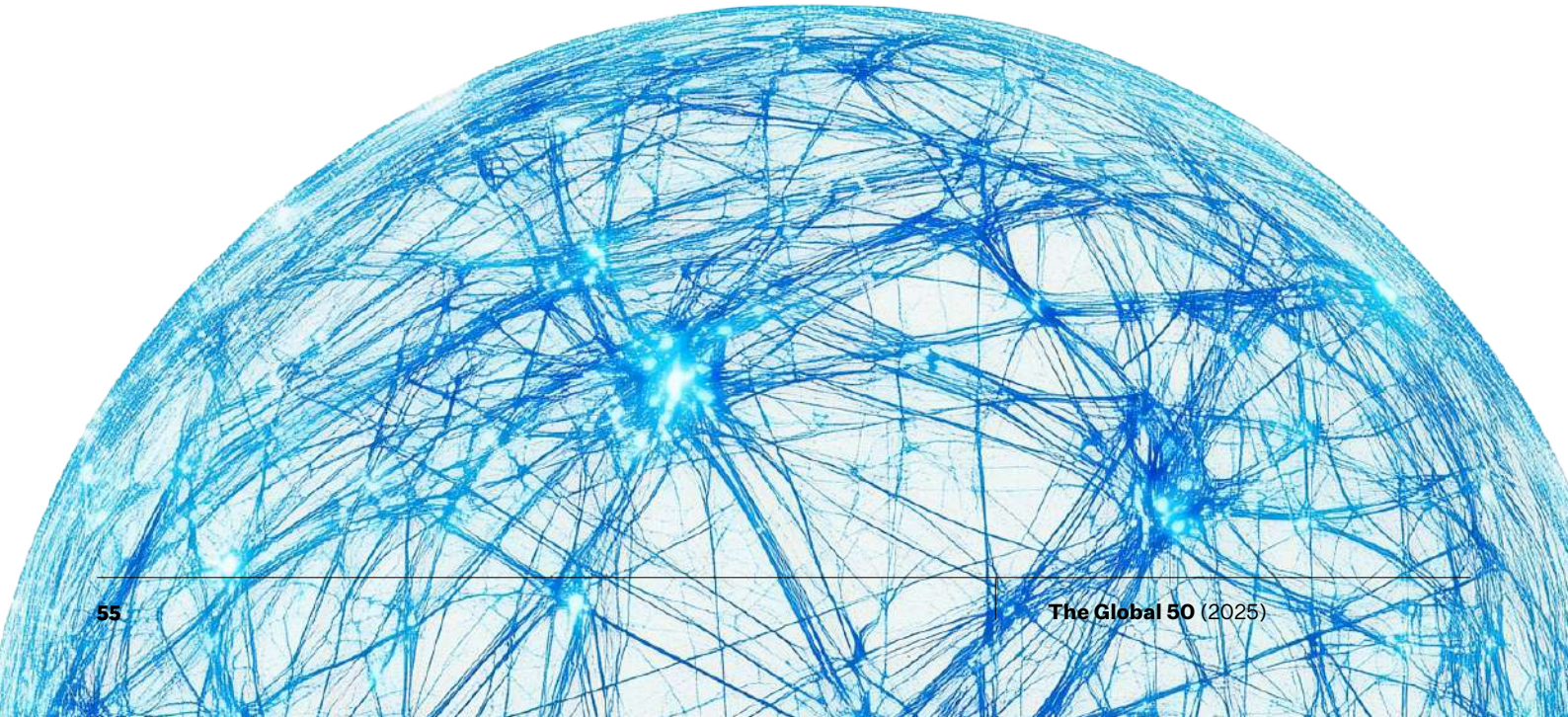
Approaching The Global 50 from a strategic foresight perspective is about **exploring and monitoring signals, trends, disruptions, megatrends and scenarios to extract insights**. It is also about translating these insights into actionable decisions and policies.

The Global 50 (in all four editions) supports both aspects as it presents both a view of the future and future opportunities.

→ **For organisations that do not have an established foresight function**, our view of the future can be used as a blueprint for developing one with a focus on future growth, prosperity and well-being. Using the uncertainties, assumptions and megatrends as the pillars of our view of the future, organisations can establish a starting set of signals or areas of review to scan the environment and explore scenarios relevant to their specific sector, domain or objectives.

→ **For organisations that do have an established foresight function**, The Global 50 offers a perspective from the Middle East and North Africa region both informed by – and contributing to – global insights on the future of growth, prosperity and well-being and can be used to broaden or enhance strategic foresight activities.

In both cases, **the assumptions, uncertainties, and megatrends** can be used to stress-test strategies[472] and support future-oriented impact evaluations.[473] The opportunities can serve as a prompt or inspiration for ideation and innovation.

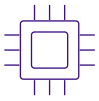


Navigating Our View of the Future

While assumptions and uncertainties shape our long view of the future, the megatrends provide guidance for the near- to medium-term outlook. In navigating our view of the future, we refer back to the Guiding Principles for navigating the era of quantum shifts introduced in 2023.[474]

Guiding Principles for Navigating the Era of Quantum Shifts[475]

1. How are **people's expectations** – globally and in your own context – changing and what new risks and opportunities will they face in their daily lives?



2. Technological progress is hard to predict. However, in addition to drawing on the assumptions in this report, what **technological advances** do you anticipate may play significant roles in your own context's growth and development?

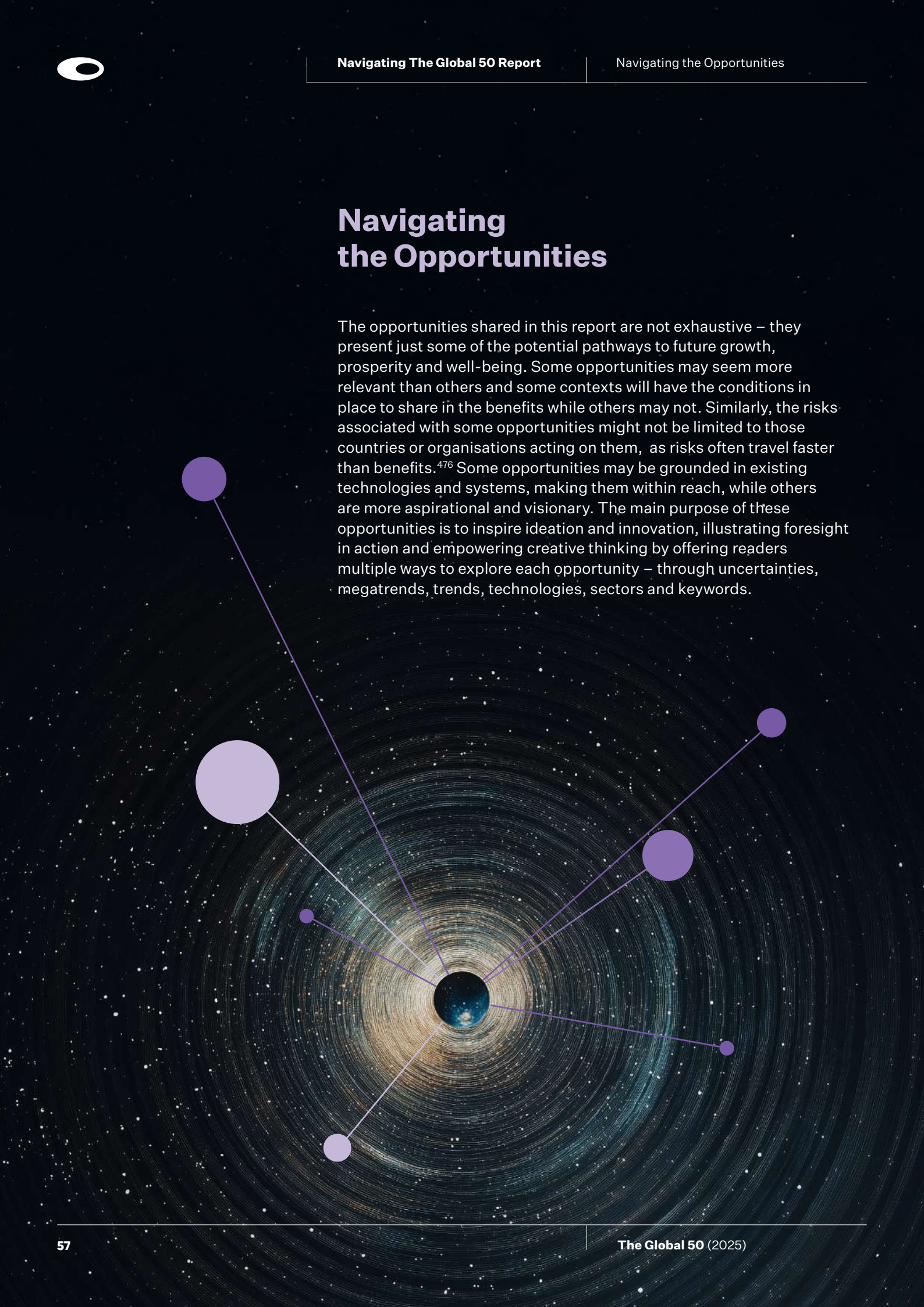
3. Which aspects of the **uncertainties** are you already well equipped to face, and which will require new capacities or fresh solutions? Will the future scenarios and industries of the future enable or hinder your long-term vision?

4. Which **global megatrends** could have the greatest impact on models of work and life in your own domain?

In doing so, readers can develop or inform strategies and initiatives that focus on the future, benefiting from the opportunities and mitigating associated risks relevant to their strategic vision and mission. This can be part of their strategic, operational or risk management plans.

Navigating the Opportunities

The opportunities shared in this report are not exhaustive – they present just some of the potential pathways to future growth, prosperity and well-being. Some opportunities may seem more relevant than others and some contexts will have the conditions in place to share in the benefits while others may not. Similarly, the risks associated with some opportunities might not be limited to those countries or organisations acting on them, as risks often travel faster than benefits.[476] Some opportunities may be grounded in existing technologies and systems, making them within reach, while others are more aspirational and visionary. The main purpose of these opportunities is to inspire ideation and innovation, illustrating foresight in action and empowering creative thinking by offering readers multiple ways to explore each opportunity – through uncertainties, megatrends, trends, technologies, sectors and keywords.



Guidelines on How to Ideate with the Opportunities

Review the opportunities

Examine all the opportunities in The Global 50 from 2022 to 2025 (200 in total) and categorise them into three groups: those that directly relate to your sector, those that relate to linked sectors, such as suppliers, customers, regulators or other stakeholders, and those unrelated to either.

Opportunities within your sector

Assess alignment with your organisation's strategic vision and objectives

- Explore the opportunity's future relevance through research
- Review and develop initiatives that focus on the potential benefits and/or mitigate the risks
- Monitor uncertainties, megatrend signals, trends, technologies and keywords for future action

Opportunities linked to your sector

Assess the benefits and risks

- Assess the impact on your organisation's strategic vision and objectives
- Explore the opportunity's future impact through research
- Review and develop initiatives that focus on the potential benefits and/or mitigate the risks
- Monitor uncertainties, megatrend signals, trends, technologies and keywords for future action

Oppportunities not linked to either

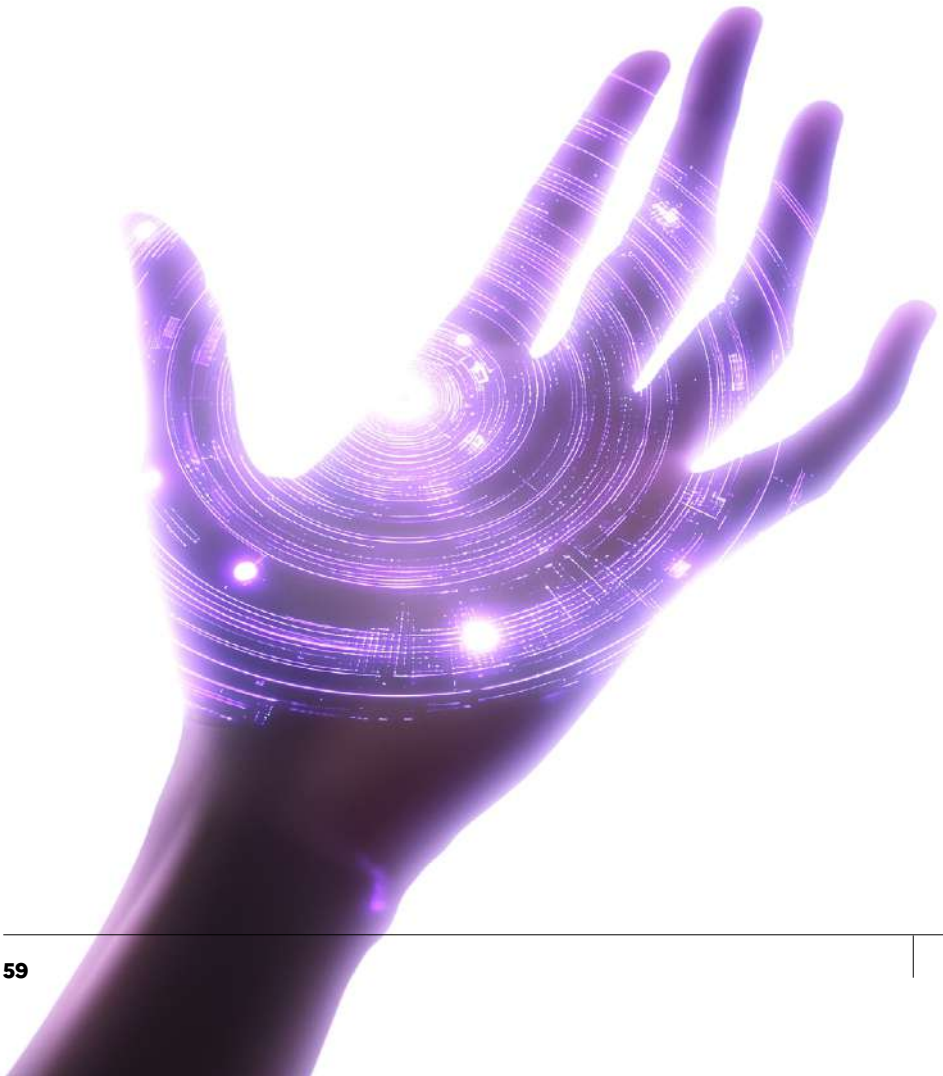
Read the question for the future and the brief description

- Adapt and revise the opportunity to your organisation's sector
- Explore the revised opportunity's future relevance through research
- Review and develop initiatives that focus on the potential benefits and/or mitigate the risks
- Monitor uncertainties, megatrend signals, trends, technologies and keywords for future action

Numerous frameworks, schools of thought, and technologies are available in the fields of ideation and innovative thinking. While we do not favour one approach over another, the approach outlined above is one practical way to reflect on the opportunities and craft strategic responses.

Schematic for the Opportunities

Overall, each opportunity includes **a question for the future** with **a brief description** that succinctly covers the essential aspects of the opportunity. This approach aims to provide enough information to spark curiosity and prompt further questions or thoughts that can assist in decision-making about the opportunity's relevance. Additionally, for each opportunity we include **a scope** that may be 'within reach', i.e. the opportunity is likely to be relevant within two to three years, assuming the necessary conditions, systems and technologies are in place. Where 'transitional' is specified, the opportunity is likely to be relevant within 10 years and is tied to advances in technology, and other conditions and enablers. Where 'visionary' is specified, the opportunity is likely to be relevant beyond 10 years, either because it will depend on technologies that are still in the early stages of development or because it is part of a complex system of drivers and other factors. Finally, each of the opportunities includes a section titled **Why It Matters Today**, which highlights some of the drivers that make the opportunity relevant for consideration today, along with the future **Opportunity** and its associated **Benefits** and **Risks**.

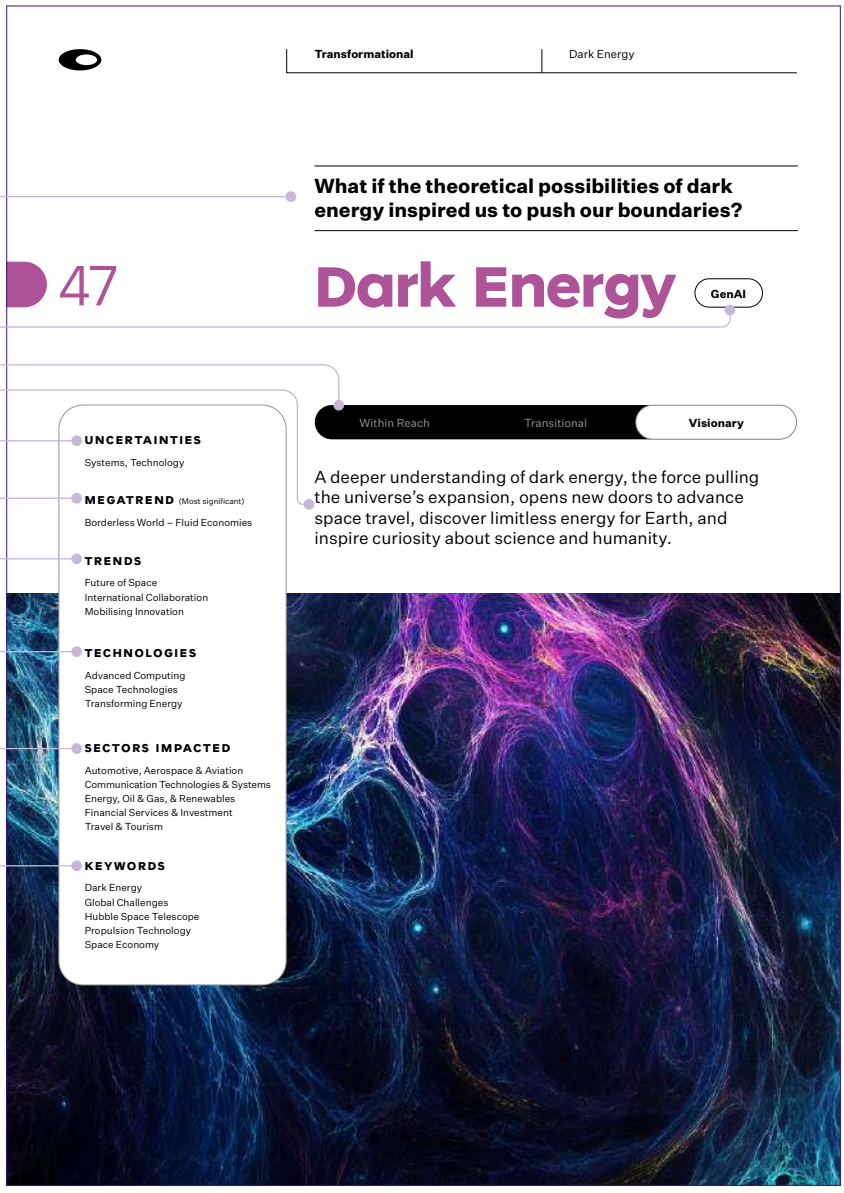


A question for the future

Opportunity inspired by GenAI

Scope

Brief description



Sidebar

Uncertainties most likely to impact the underlying drivers and conditions for the opportunity to materialise

The most significant **megatrend** relevant to the opportunity today (due to the interrelated nature of the megatrends, some may be more prominent than others at different times)

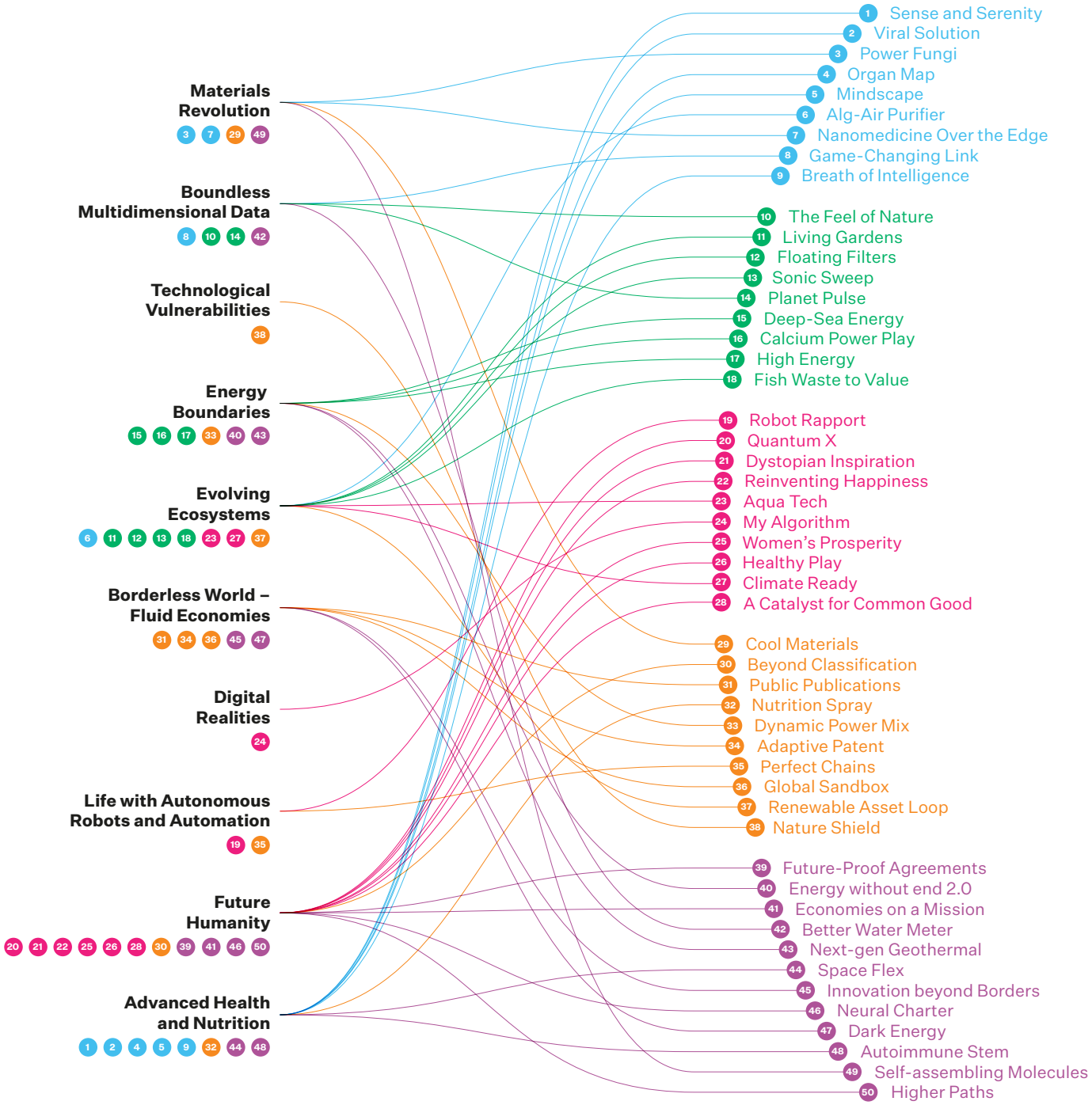
Up to three **technologies** (non-exhaustive, provides readers with what to monitor)

Up to five **trends** (non-exhaustive, provides readers with what to monitor)

Sectors (non-exhaustive) that impact or will be impacted by this opportunity

Relevant **keywords** readers can use as prompts to search for information and conduct further research

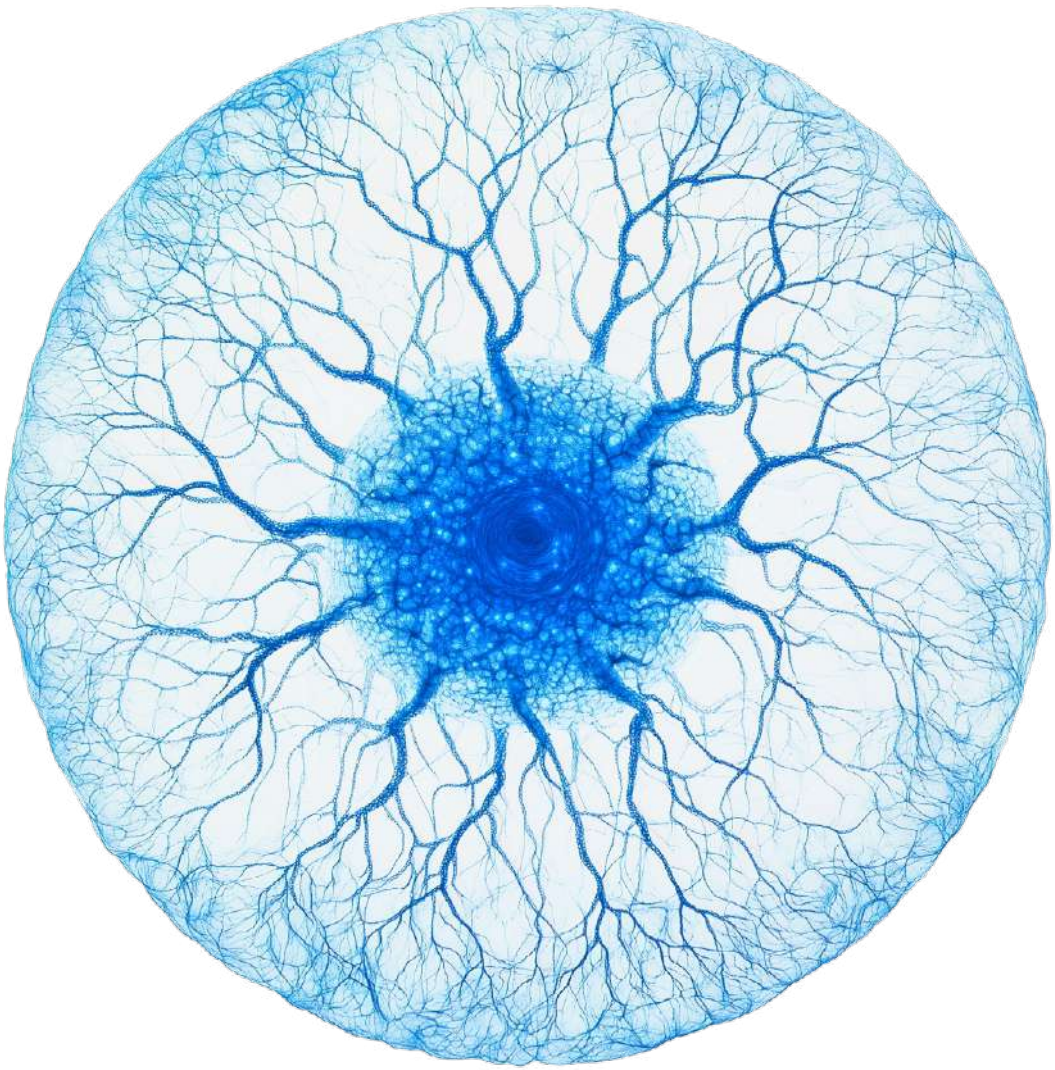
The Global 50 Opportunities



The Global 50 is a global report focused on innovation. Some aspects may be more relevant in some contexts or at different times.

The trends, signals, benefits, risks and data mentioned within each opportunity are non-exhaustive and were based on information available at hand at the time of publication.

Ideas and content within this report are by the DFF. GenAI was used to aid in content analysis, grammar, copyediting, and translation, with human editorial oversight. Where opportunities were inspired by GenAI, these are indicated by an asterisk. All images in this report were created using GenAI with human design oversight based on specific prompts inspired by the report's content. Images do not represent real photographs and are for illustrative purposes only.



Health Reimagined

Redefine mental and physical health, support longer lives, drawing on science, technology and nature for better health and new ways to personalise access for individuals and communities everywhere.

What if personalised sights and sounds offered stress relief and wellness on demand?

01

Sense and Serenity

Within Reach | **Transitional** | Visionary

On-demand sensory experiences activated through brain waves offer immediate anxiety and stress relief tailored to each person's needs, promoting accessible, adaptive mental wellness support.

UNCERTAINTIES

Technology, Values

MEGATREND (Most significant)

Advanced Health and Nutrition

TECHNOLOGIES

Brain–Computer Interfaces (BCI)
HealthTech
Immersive Technologies & Wearables

TRENDS

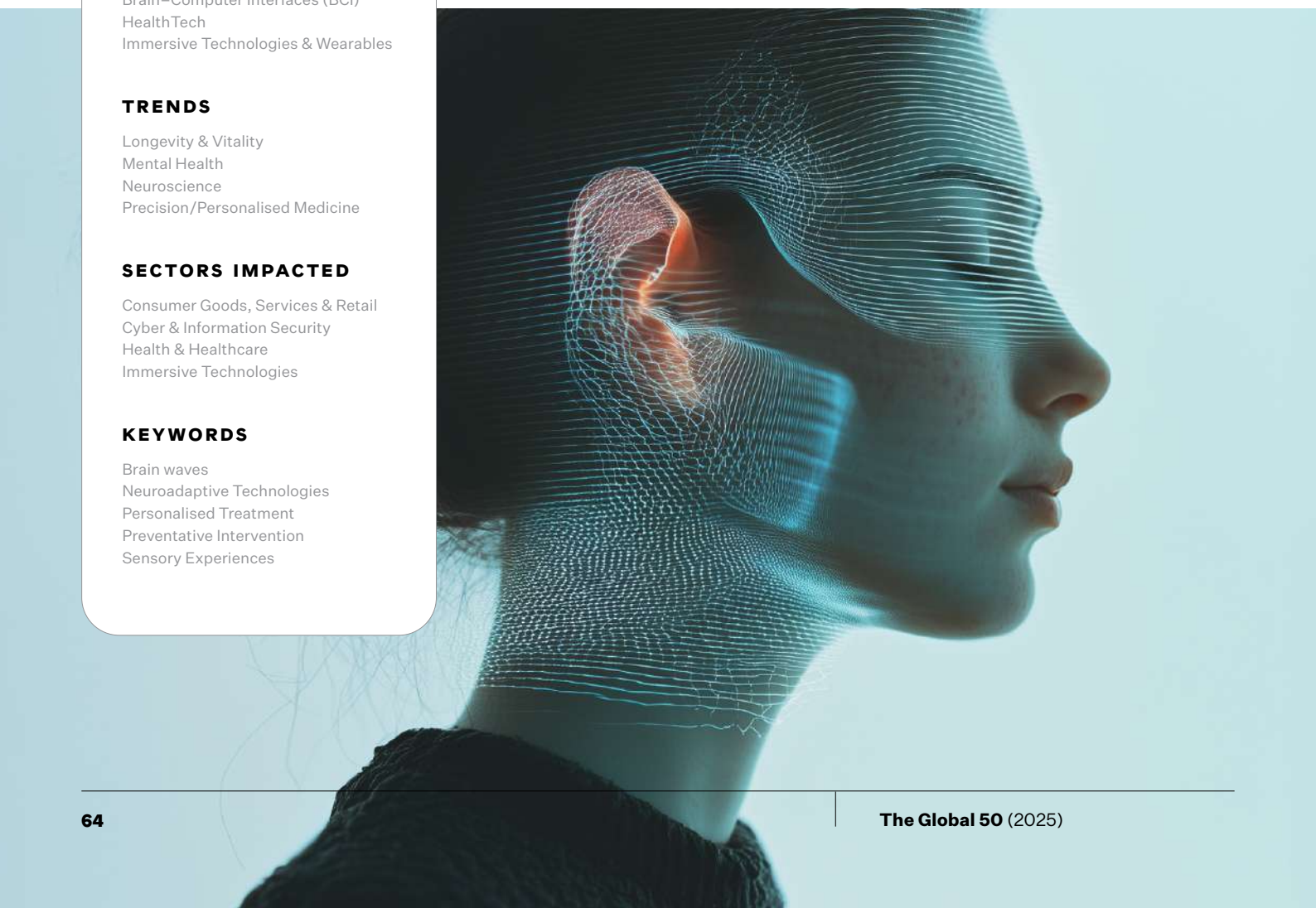
Longevity & Vitality
Mental Health
Neuroscience
Precision/Personalised Medicine

SECTORS IMPACTED

Consumer Goods, Services & Retail
Cyber & Information Security
Health & Healthcare
Immersive Technologies

KEYWORDS

Brain waves
Neuroadaptive Technologies
Personalised Treatment
Preventative Intervention
Sensory Experiences



WHY IT MATTERS TODAY

Mental health outcomes influence people's life prospects both socially and professionally.[477] Those experiencing challenges with their mental health are at greater risk of financial challenges, limited job opportunities, and unstable housing,[478] leading to further decline in mental health. This cycle underscores the importance of supporting mental wellness for stability in various aspects of life.[479]

Mental health conditions affect 15% of youths aged 10–19 years globally, with suicide the third leading cause of death among 15- to 29-year-olds.[480] In 2021, mental and anxiety disorders were the leading causes of death among older youths, followed by violence, which may be sometimes used to cope with emotional challenges.[481]

Among adults, 20% of employees worldwide experience daily loneliness.[482] This can be attributed to several factors, including poor work–life balance, social media exposure, and socio-economic stressors, such as financial insecurity.[483] Adults with severe mental health conditions die 10–20 years earlier than others, facing a higher risk of suicide and significant economic and productivity losses.[484] Mental health conditions affect just under 29% of males and just under 30% of females, with peak onset at age 15 years.[485]

The risk continues into older life as well. By the age of 75 years, half the population will have experienced a mental health condition,[486] and 14% of those over 60 years of age face mental health challenges, most commonly depression or anxiety.[487] The global population aged 60 years or over reached 1 billion in 2020, a number expected to rise to 1.4 billion by 2030 and 2.1 billion by 2050, so mental health will continue to be a priority.[488]

Mental health conditions affect

15%

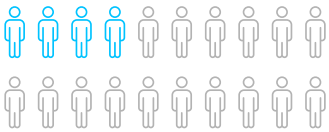
of youths aged 10–19 years globally, with **suicide the third leading cause of death** among 15- to 29-year-olds

14%

of those over 60 years of age face mental health challenges, most commonly depression or anxiety

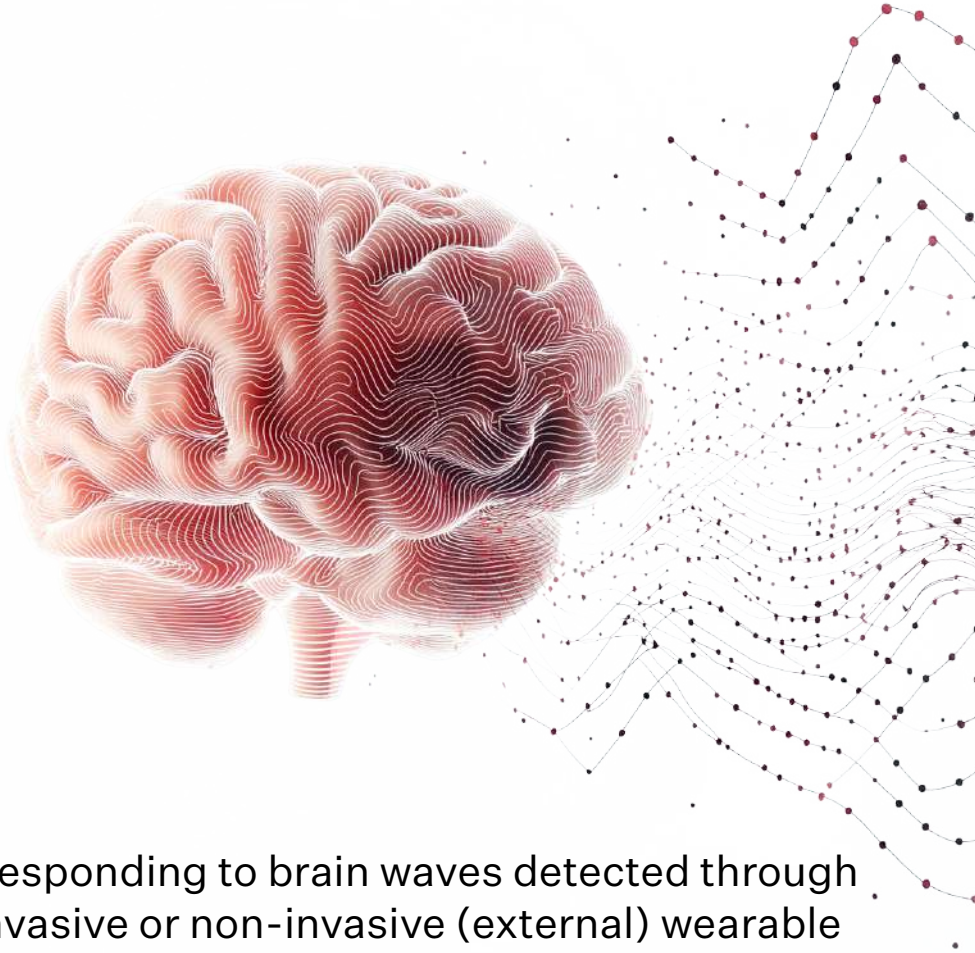
20%

of employees worldwide experience daily loneliness



THE OPPORTUNITY

Seamlessly integrated into daily life, customisable visual and auditory stimuli create environments designed to relieve stress and promote mental wellness on demand.[489] Immersive surroundings provide calming experiences tailored to individual needs. By responding to brain waves[490] detected through invasive or non-invasive (external) wearable or contactless BCI or sensors, surroundings can promptly soothe the nervous system, shifting the body's state from 'fight or flight' to calm.



BENEFITS

Enhanced individual well-being; accessible mental health support; immediate stress management and relief; increased productivity.

RISKS

Potential neglect of underlying root causes of stress and anxiety; over-reliance; unknown long-term effect on neuroplasticity; error reading brain signals; potential misuse; lack of affordability.

Responding to brain waves detected through invasive or non-invasive (external) wearable or contactless brain–computer interfaces (BCI) or sensors, surroundings can promptly **soothe the nervous system, shifting the body's state from 'fight or flight' to calm**

What if viruses eliminated the need for antibiotics?

02

Viral Solution

Within Reach | **Transitional** | Visionary

Bioengineered viruses serve as a form of precision treatment for bacterial infections, eradicating antibiotic-resistant infections and eliminating the need for antibiotics.

UNCERTAINTIES

Technology, Values

MEGATREND (Most significant)

Advanced Health and Nutrition

TRENDS

Communicable & Non-Communicable Diseases
Genomics
Longevity & Vitality
Precision/Personalised Medicine

TECHNOLOGIES

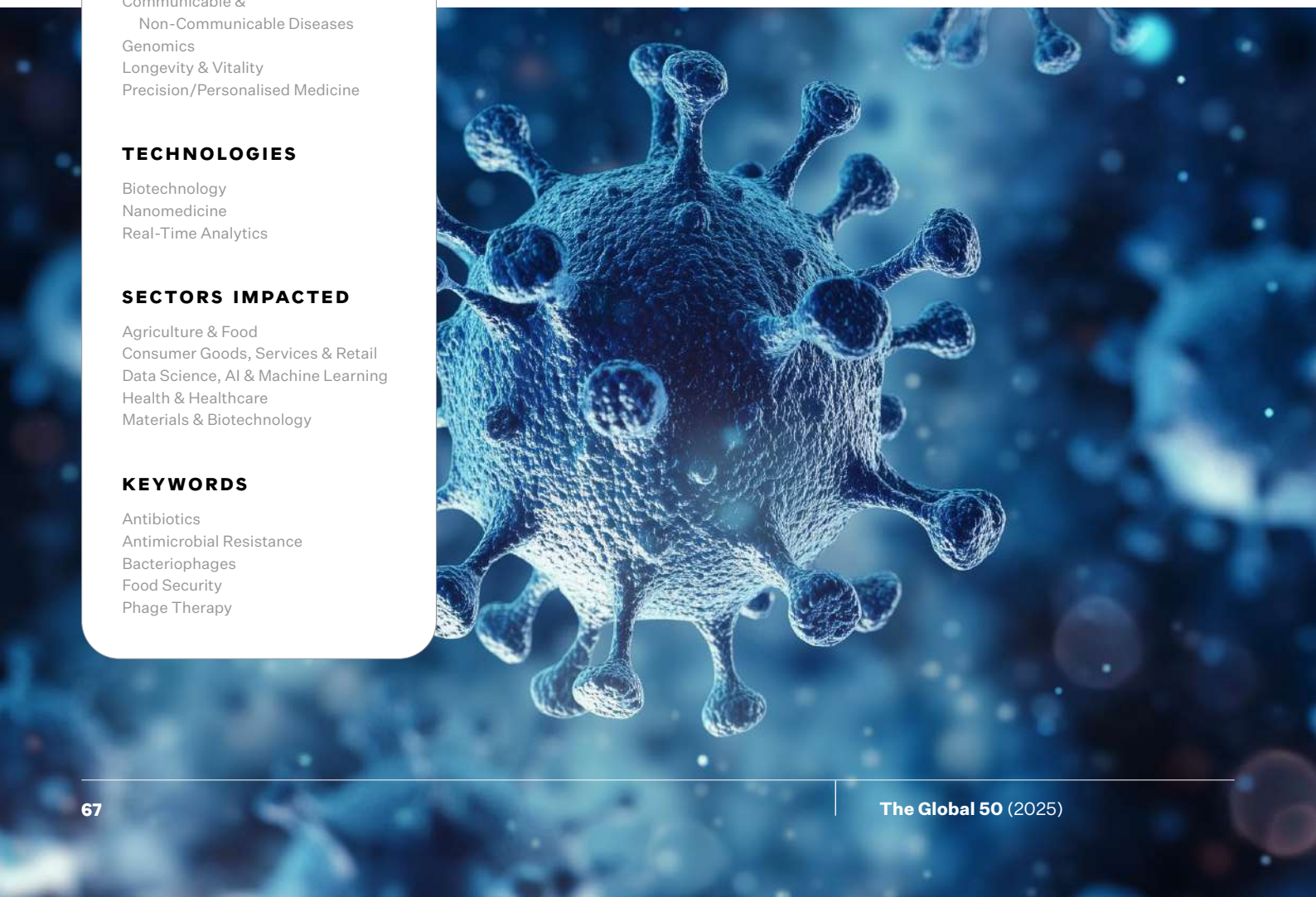
Biotechnology
Nanomedicine
Real-Time Analytics

SECTORS IMPACTED

Agriculture & Food
Consumer Goods, Services & Retail
Data Science, AI & Machine Learning
Health & Healthcare
Materials & Biotechnology

KEYWORDS

Antibiotics
Antimicrobial Resistance
Bacteriophages
Food Security
Phage Therapy



WHY IT MATTERS TODAY

Antimicrobial resistance is projected to cause

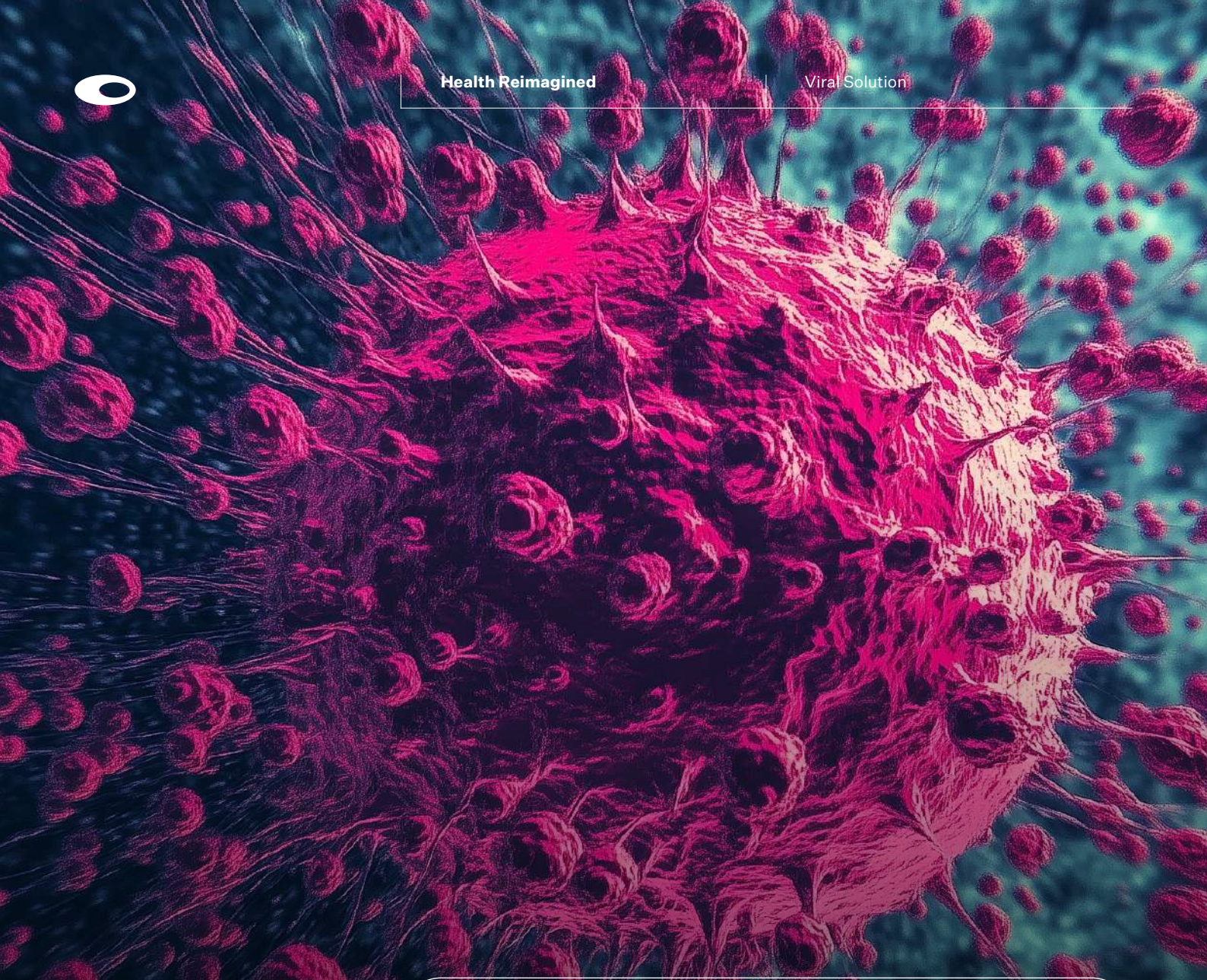
10 million

deaths annually by 2050, sitting just behind cancer – at 10.5 million – as a leading cause of mortality worldwide

Antimicrobial resistance (AMR) is a rapidly accelerating global health crisis that threatens to reverse decades of progress in modern medicine. AMR is projected to cause an average of 8.2 million deaths by 2050,[491] sitting just behind cancer – at 10.5 million – as a leading cause of mortality worldwide.[492] AMR is closely linked to the misuse and overuse of antimicrobials in humans, animals and plants, which has led to the emergence of drug-resistant pathogens.[493] AMR presents a substantial barrier to achieving the Sustainable Development Goals (SDGs), particularly the targets within SDG 3 related to newborn survival and healthy ageing.[494]

AMR also threatens the sustainability of agriculture, where it is primarily driven by the misuse of antimicrobials. This results in reduced animal health and welfare in food production, leading to increased food insecurity, safety concerns, and economic losses for farmers.[495] A new report from the World Organisation for Animal Health estimates that annual livestock production losses due to AMR could equal the consumption needs of 746 million people.[496] In a more pessimistic scenario, this figure could rise to around 2 billion people.[497]

Bacteriophage (also known as phage) therapy is not new. Phages – viruses that infect and replicate within bacterial cells – have proven effective against bacterial infections.[498] Bacteriophages were initially noted by British bacteriologist Ernest Hankin in 1896 after he observed antibacterial effects in river water in India. Frederick Twort and Félix d'Hérelle coined the term 'bacteriophage' following d'Hérelle's pioneering use of phage therapy in 1919.[499]



Bacteriophage therapy is currently limited in clinical application.[500] Phage production began commercially in the 1920s, with companies such as L'Oréal in France and Eli Lilly in the United States creating phage-based treatments for various bacterial infections until antibiotics became mainstream.[501] The George Eliava Institute of Bacteriophages, Microbiology and Virology in Georgia is the world's largest bacteriophage collection: over 1,000 phages and 12,000 bacterial strains.[502] The Phage Therapy Unit at the Hirszfeld Institute of Immunology and Experimental Therapy in Poland provides outpatient phage therapy as an experimental treatment.[503]

THE OPPORTUNITY

Bacteriophages (viruses targeting bacteria) are engineered to destroy or alter bacterial cells,[504] eliminating the need for antibiotic treatment. Nanobots enable the delivery of specific therapies that target bacterial cells, while real-time monitoring allows the identification of bacteriophages tailored to each bacterial profile, optimising treatment efficacy and triggering timely introduction of new phages.[505] This is complemented by the use of advanced machine intelligence to analyse bacterial behaviour and identify strains likely to cause infection.[506]

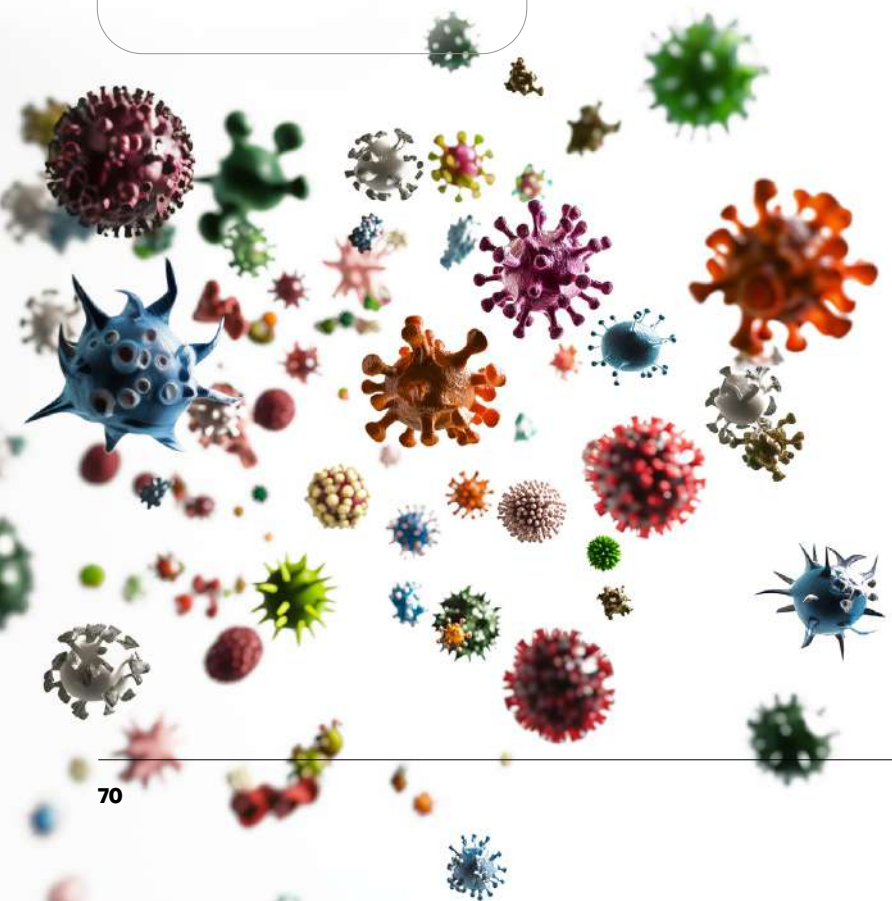
Beyond detecting and targeting bacteria,[507] phages can be used to prevent food contamination[508] and, in veterinary settings, effectively treat infections in livestock, reducing reliance on antibiotics and promoting safer food supply chains.[509]

BENEFITS

Precision treatment of bacterial infections; elimination of antibiotic resistance and even removal of the need for antibiotics; increased food safety; enhanced global health security.

RISKS

Bacterial resistance to phages; regulatory challenges; viral mutations; increased health access inequality as antibiotic production stops; potential misuse; unknown long-term effects on human health; lack of social acceptance.



Bacteriophages (viruses targeting bacteria) are engineered to destroy or alter bacterial cells, **eliminating the need for antibiotic treatment**

What if fungal fuel cells powered medical devices in remote communities?

03 Power Fungi

Within Reach | **Transitional** | Visionary

Bioelectricity generated by fungi powers small medical devices in remote areas, letting doctors check on patients even where there are limited sources of micropower, allowing advanced monitoring capabilities in previously unreachable areas.

UNCERTAINTIES

Nature, Technology

MEGATREND (Most significant)

Materials Revolution

TRENDS

Biomimetics
Communicable & Non-communicable Diseases
Longevity & Vitality
Mobilising Innovation

TECHNOLOGIES

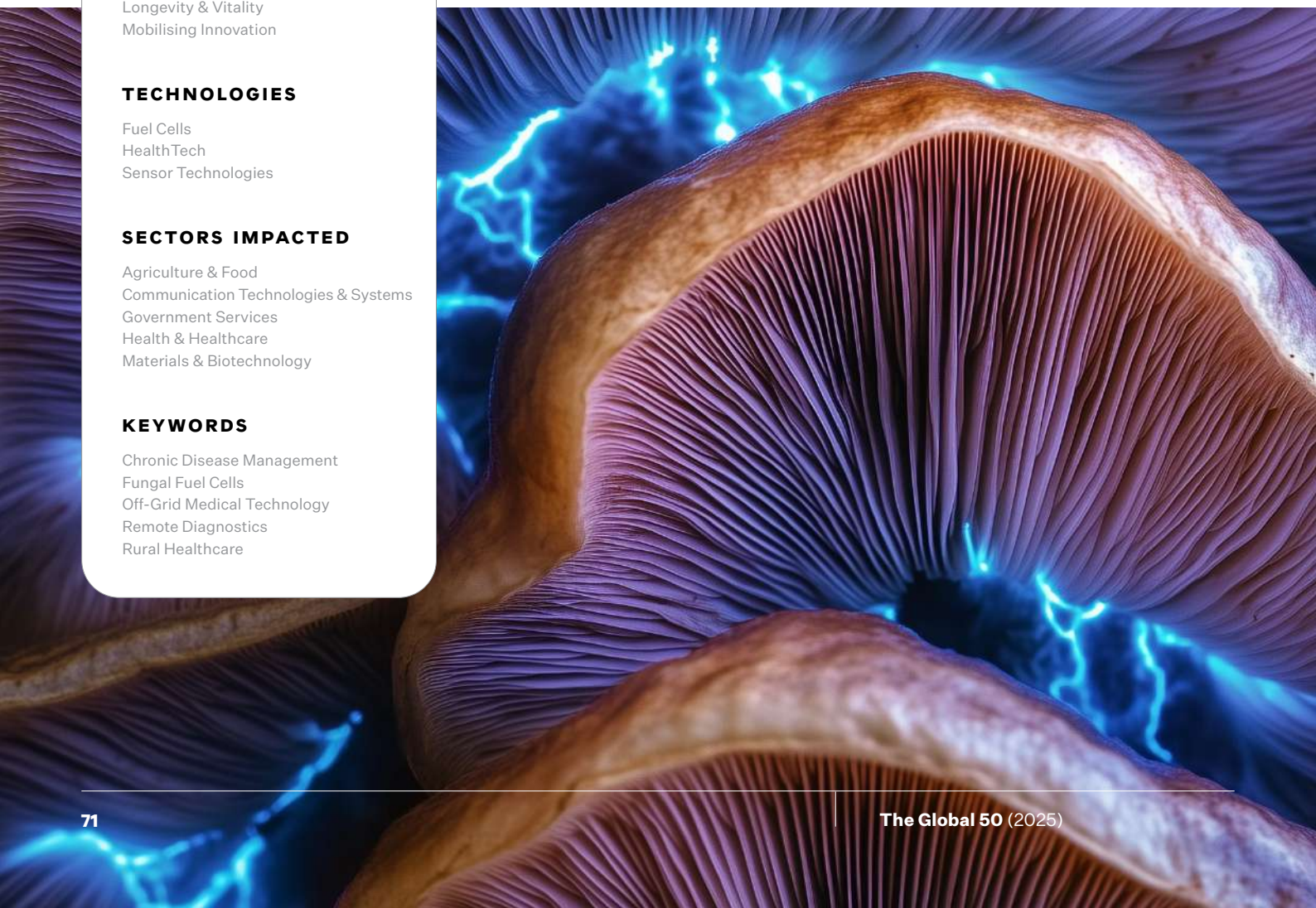
Fuel Cells
HealthTech
Sensor Technologies

SECTORS IMPACTED

Agriculture & Food
Communication Technologies & Systems
Government Services
Health & Healthcare
Materials & Biotechnology

KEYWORDS

Chronic Disease Management
Fungal Fuel Cells
Off-Grid Medical Technology
Remote Diagnostics
Rural Healthcare



WHY IT MATTERS TODAY

While the global rural population today consists of 3.4 billion people, it is projected to decline to 3.1 billion by 2050, with China and India having the largest rural populations.[510] In the Middle East and North Africa, following a period of steady migration, only 37% of the population lived in rural areas in 2023 compared with 66% in 1960.[511] Nevertheless, despite these reductions, the number of people living in rural areas in the future will still be significant.

Rural residents are affected by chronic disease more than people living in urban areas. In a study carried out in China in 2015, rural residents had a higher prevalence of chronic disease than urban residents, at nearly 83% and 80%, respectively.[512] Similarly, in the United States, the 46 million Americans (13.8% of the population)[513] living in rural areas face higher rates of premature death from heart disease, cancer, lung disease, and stroke.[514]

Implementing behavioural interventions for chronic disease prevention in rural areas is often challenging.[515] Due to technological and staffing barriers, rural areas face a shortage of healthcare specialists and primary care providers, and residents have limited access to the network connectivity that could help them seek healthcare remotely.[516] Nearly 70% of people without internet access (2.6 billion globally) live in rural areas.[517]

Rural residents are affected by chronic disease more than people living in urban areas

THE OPPORTUNITY

Mycelium cells within fungi produce bioelectricity through cellular interaction with other living cells.[518] Fungal fuel cells (FFCs) power small medical devices in rural, off-grid locations that do not have consistent micropower sources, such as batteries, enabling remote diagnostics and healthcare monitoring. Using technologies ranging from digital stethoscopes and electrocardiogram monitors to ultrasound probes and implantable medical devices,[519] healthcare providers in community-based healthcare services can remotely assess people and share diagnostic data with other global experts for evaluation.

FFCs generate electricity by breaking down biomass (i.e. organic materials such as wood, leather and paper)[520] using an anode that contains fungi and a cathode that allows proton and oxygen exchange.[521] These cells can provide power as long as biomass or organic waste is available,[522] offering longer operational lifetimes than batteries and supporting the use of portable medical equipment in rural areas, field clinics, and disaster relief efforts.

BENEFITS

Increased access to healthcare; sustainable, low-cost electricity generation from organic waste; support for disaster relief; reduced battery waste.

RISKS

Potential biosafety concerns with fungal species; reduced cell performance over time; potential toxicity and pathogenic infection.

Fungal fuel cells power small medical devices in rural, off-grid locations that do not have consistent micropower sources

What if a small blood sample could predict and prevent organ failure?

04 Organ Map

UNCERTAINTIES

Systems, Technology

MEGATREND (Most significant)

Advanced Health and Nutrition

TRENDS

Communicable & Non-Communicable Diseases
Longevity & Vitality
Precision/Personalised Medicine
Proteomics

TECHNOLOGIES

Analytical Methods & Technologies
Genomics
Open Data

SECTORS IMPACTED

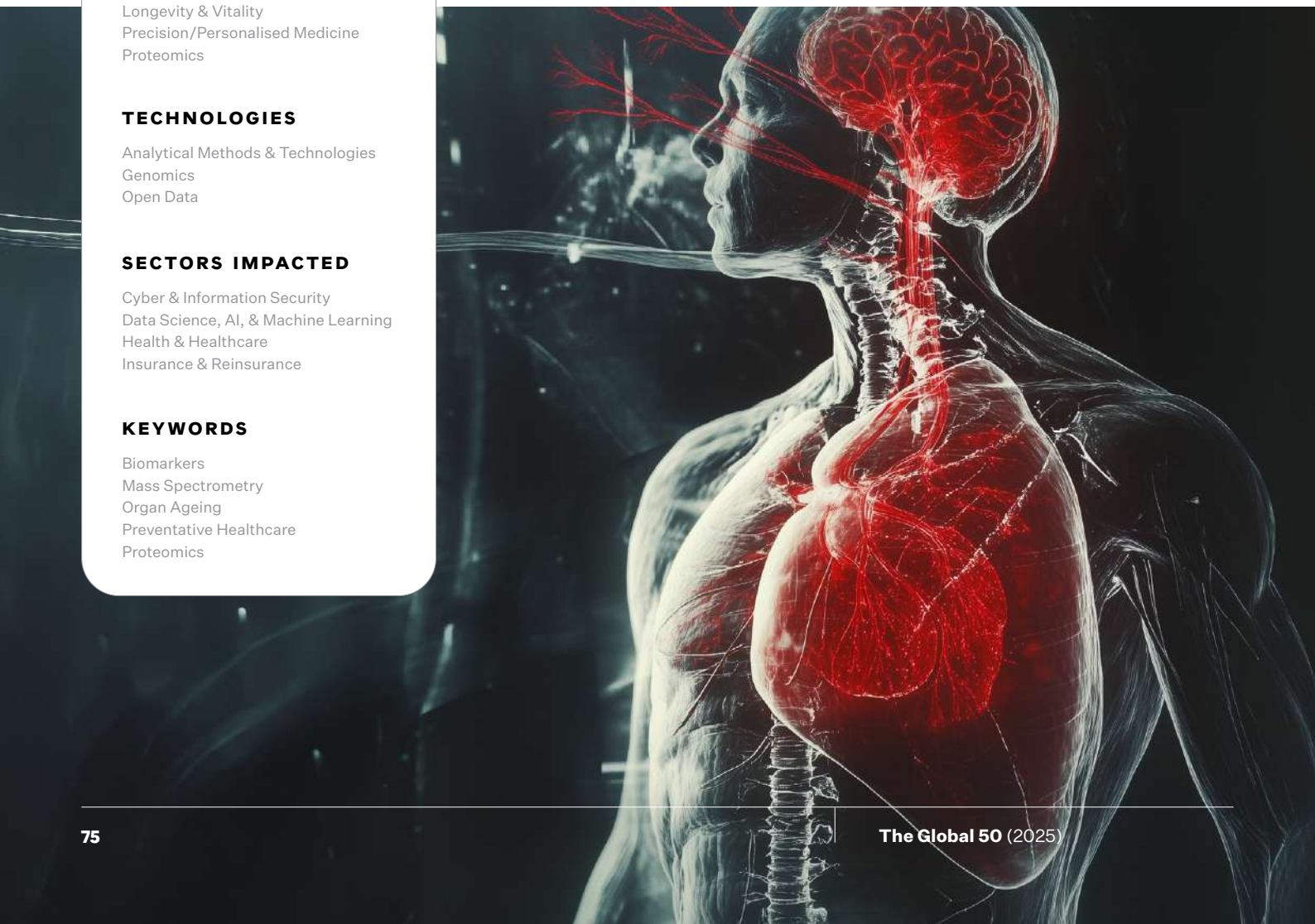
Cyber & Information Security
Data Science, AI, & Machine Learning
Health & Healthcare
Insurance & Reinsurance

KEYWORDS

Biomarkers
Mass Spectrometry
Organ Ageing
Preventative Healthcare
Proteomics

Within Reach | **Transitional** | Visionary

Advances in mass spectrometry and plasma proteomics make it possible to identify – with a small blood sample – organ-specific age, enabling personalised medicine and early health interventions.

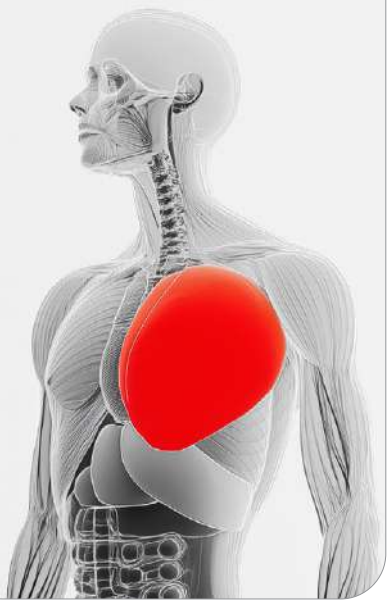


WHY IT MATTERS TODAY

Ageing organs can increase mortality risk by

5.5X → 29X

times, depending on the **number of affected organs**



Global life expectancy has been steadily increasing.[523] As people live longer, the focus is growing on not just extending lifespan but also actively improving healthspan – the period of life spent in good health.[524] The COVID-19 pandemic has increased public awareness of health vulnerabilities, particularly in relation to age.[525,526] This has led to greater interest in preventative healthcare and the role of individual risk factors.[527] In 2022, Ipsos surveyed 1,160 people across the United States to predict how well-being might change in a post-pandemic world. They found that, for 62% of Americans, their health was more important to them than before the pandemic[528] and in 2024, their top concerns are affordability, quality and future pandemics.[529]

Organ ageing rates vary and influence mortality risk, yet methods to assess organ-specific ageing[530] and predicting disease risk remain limited.[531] Two plasma proteomics studies based on 45,000 and 50,000 samples (respectively) from the UK Biobank found that certain proteins have a connection to organ ageing.[532, 533] Ageing organs can increase mortality risk by 5.5 to 29 times, depending on the number of affected organs.[534] In a further study at Stanford University, researchers used machine learning to analyse blood plasma proteins from adults to estimate the biological age of 11 organs and body systems including the arteries, brain, heart, intestines, kidneys, liver and pancreas. It found that almost 20% of the participants showed accelerated ageing in a single organ, while around 2% had multiple ageing organs.[535] People with accelerated heart ageing had more than double the risk of heart failure over the next 15 years. For most other organs, accelerated ageing led to a 15–50% greater risk of death from any cause, while indicators of brain and artery ageing were linked to a higher risk of Alzheimer's disease and cognitive decline.[536]

As people live longer, the focus is shifting

from **lifespan** to **healthspan**

– the period of life spent in good health

THE OPPORTUNITY

Further understanding of proteins enables the use of plasma protein-based biomarkers to assess the biological age of specific organs, creating a personalised organ ageing map. Through a simple blood test, these biomarkers enable targeted therapies. Combined with individual genetic testing, this provides powerful insights,[537] leading to a fully personalised, organ-focused prevention and treatment plan.

Proteins play a critical role in cellular functions and remain important in drug discovery. While large-scale human studies on proteins have so far been limited, new research provides insights into previously unclear protein origins and functions.[538] Advances in mass spectrometry are starting to enable more accurate protein measurements, addressing the current inaccuracy rate of up to one-third in current methods currently used for protein analysis.[539]

BENEFITS

Personalised healthcare and improved preventative medicine; increased longevity; early disease intervention; non-invasive approach to disease identification for many diseases.

RISKS

Psychological stress from health predictions; reduced focus on overall well-being; high potential to widen the inequality gap between countries; errors in testing.

Through a simple blood test, plasma protein-based biomakers help assess the biological age of specific organs, allowing a fully personalised, organ-focused prevention and treatment plan

What if a focus on early brain health provided cognitive health for life?

05 Mindscape

Within Reach | Transitional | Visionary

Early integration of cognitive health in education and youth-focused public policy helps build cognitive reserve for lifelong mental resilience, reduced dementia risk, and cognitive health in later years.

UNCERTAINTIES

Technology, Values

MEGATREND (Most significant)

Advanced Health and Nutrition

TRENDS

Longevity & Vitality
Neuroscience
Precision/Personalised Medicine

TECHNOLOGIES

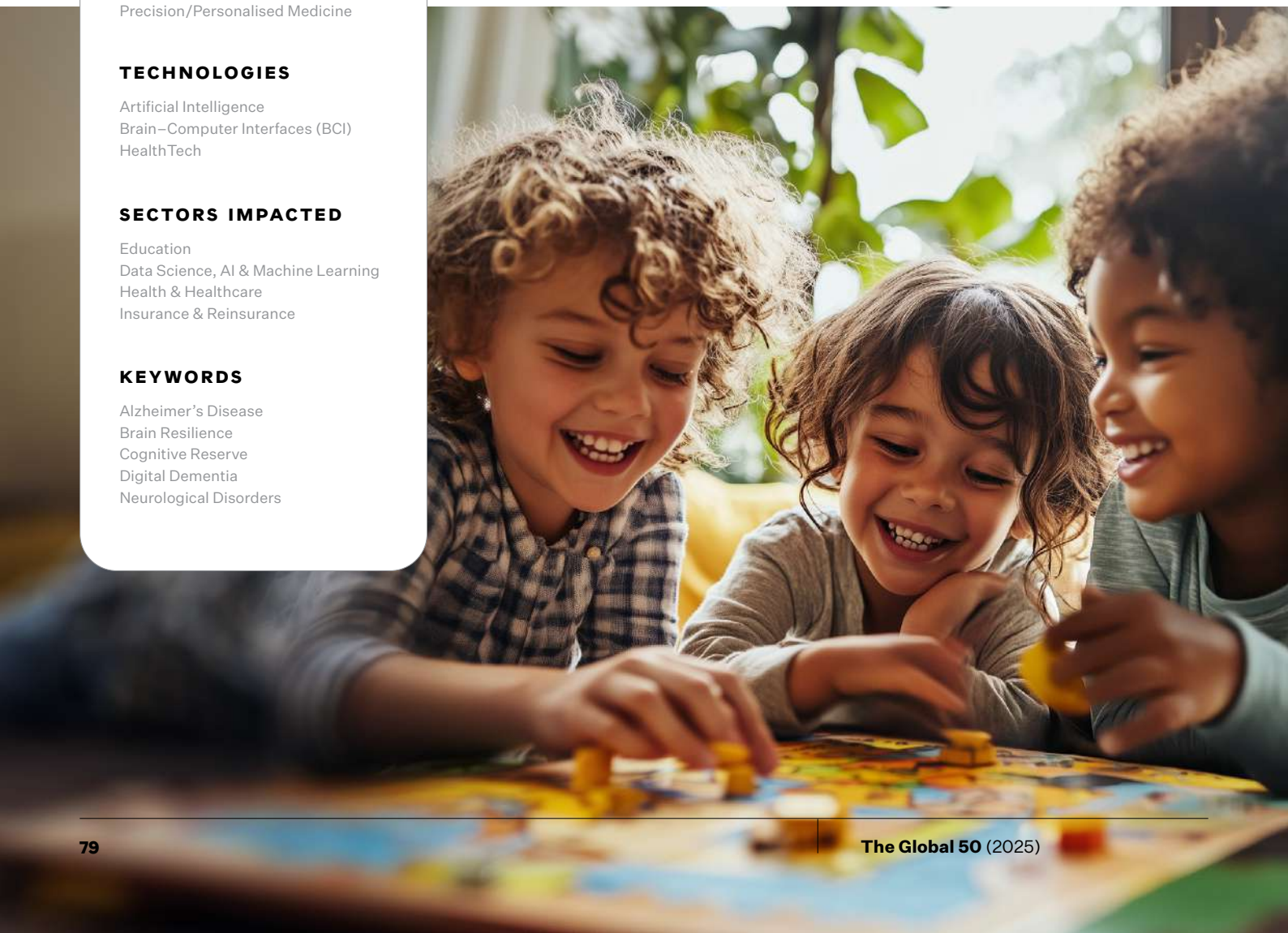
Artificial Intelligence
Brain–Computer Interfaces (BCI)
HealthTech

SECTORS IMPACTED

Education
Data Science, AI & Machine Learning
Health & Healthcare
Insurance & Reinsurance

KEYWORDS

Alzheimer's Disease
Brain Resilience
Cognitive Reserve
Digital Dementia
Neurological Disorders



WHY IT MATTERS TODAY

Dementia is projected to affect

153 million

people by 2050

High cognitive reserve earlier in life lowers dementia risk by

18%

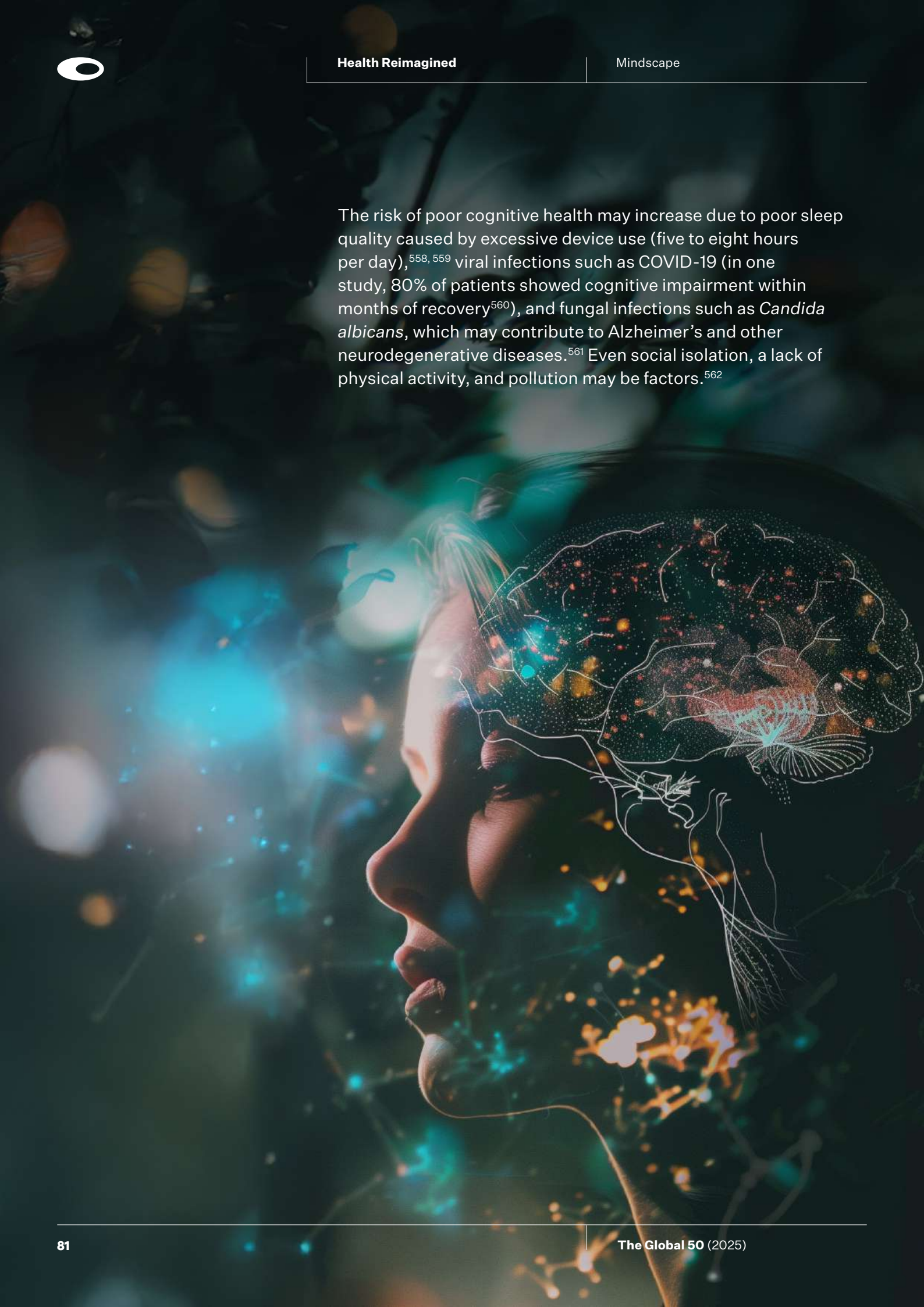
One in three people is affected by neurological conditions.[540] The burden of neurological disorders has increased over the past 25 years because of population growth and ageing,[541] with dementia projected to affect 153 million people by 2050.[542]

Although a family history of Alzheimer's (a type of dementia) increases people's risk, the disease often results from a combination of genetic, lifestyle and environmental factors,[543] and organ ageing.[544] While most studies on dementia focus on later life, having a higher cognitive reserve (CR) throughout life is associated with lower dementia risk later on.[545] CR builds resilience against future cognitive decline through education as well as social, physical and other activities.[546]

High CR earlier in life lowers dementia risk by 18% and dementia risk reduction is greater with education, particularly in primary school.[547] Higher CR in mid-life lowers dementia risk by 9%, with particular benefits coming from job complexity, social interaction, problem-solving, and data analysis.[548] Higher CR in late life lowers dementia risk by 19%, particularly through social connection.[549] Physical activity throughout life shows beneficial effects on cognitive health as well.[550]

While the impact of technology on cognitive health remains understudied, especially as artificial intelligence (AI) reshapes daily work and life,[551] over-reliance on AI risks reduced metacognition and other skill loss.[552] Metacognitive skills – the ability to reflect on how one thinks and completes tasks – are essential for effective human–AI interaction,[553] as deep reliance and dependence on AI may diminish critical thinking and creativity[554] as well as weaken memory and spatial skills, raising concerns about 'digital dementia' and structural brain changes.[555] This is an emerging area of research, but factors thought to promote cognitive health include human oversight of AI instead of relying entirely on AI, metacognitive skills training,[556] and good dietary choices, such as green, leafy vegetables, fatty fish, berries and walnuts.[557]

The risk of poor cognitive health may increase due to poor sleep quality caused by excessive device use (five to eight hours per day),[558, 559] viral infections such as COVID-19 (in one study, 80% of patients showed cognitive impairment within months of recovery[560]), and fungal infections such as *Candida albicans*, which may contribute to Alzheimer's and other neurodegenerative diseases.[561] Even social isolation, a lack of physical activity, and pollution may be factors.[562]



THE OPPORTUNITY

BENEFITS

Reduced risk of future cognitive decline; improved educational outcomes; promotion of healthy ageing.

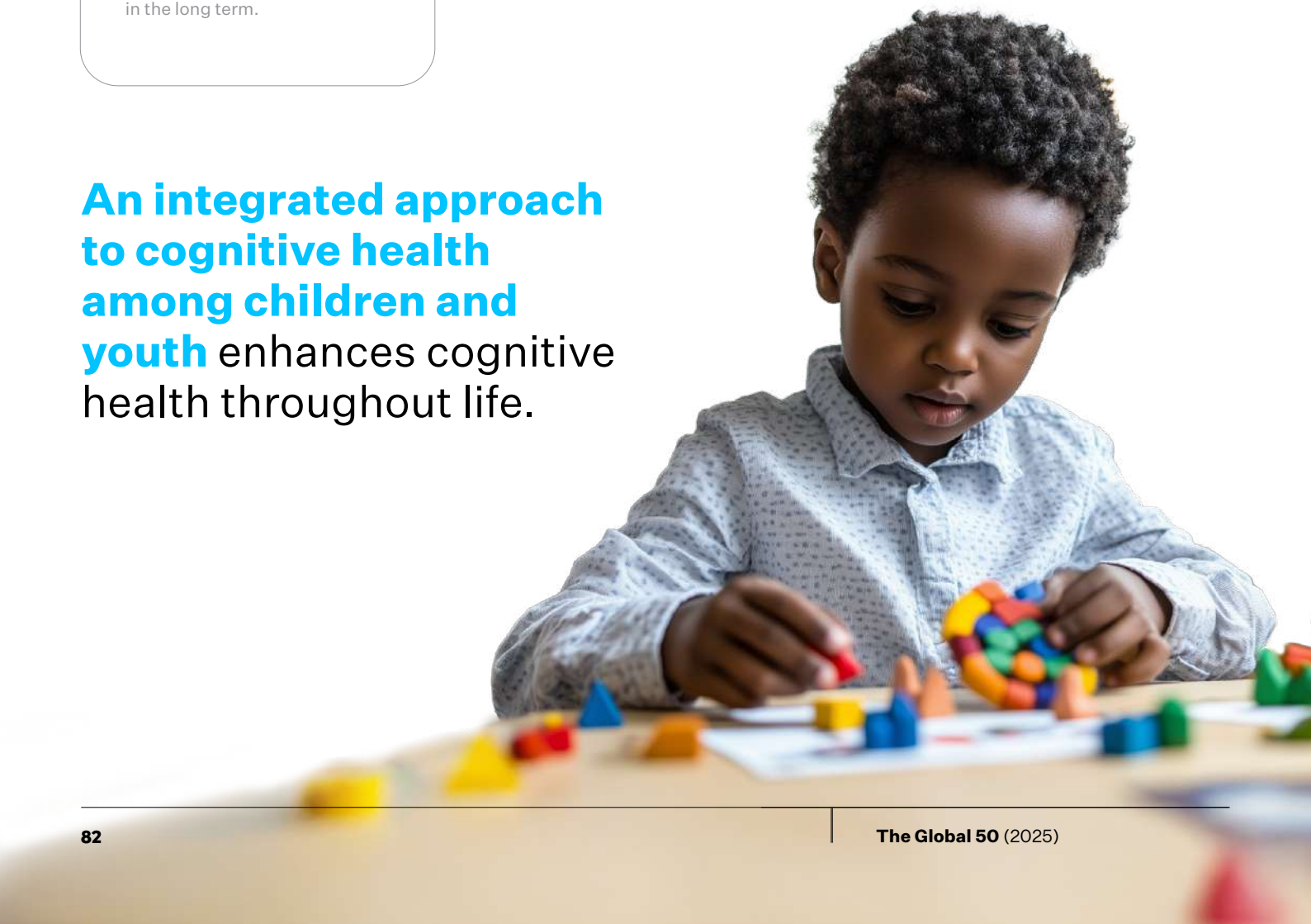
RISKS

Limited evidence; not universally accessible; approach to cognitive health not sustainable in the long term.

A focused and integrated approach to cognitive health among children and youth enhances cognitive health throughout life[563] by building cognitive resilience, neural flexibility, and CR.[564]

Policies focused on cognitive health across sectors – such as health, education and other areas of public policy – can help individuals stay cognitively healthy as they age. By incorporating factors and activities that strengthen cognitive health, and avoiding those that weaken it, targeted interventions can promote optimal cognitive development.[565] Strengthening cognitive skills supports mental health[566] and makes learning more effective,[567] preparing future generations for potential cognitive challenges.

An integrated approach to cognitive health among children and youth enhances cognitive health throughout life.



What if algae-powered air purification made indoor air cleaner and healthier?

06 Alg-Air Purifier

Within Reach | **Transitional** | Visionary

As we spend more of our lives indoors,[k] powered by the Sun's rays or LED lighting, algal bioreactors regulate and purify indoor air, removing microorganisms and reducing respiratory issues.

UNCERTAINTIES

Nature, Technology

MEGATREND (Most significant)

Evolving Ecosystems

TRENDS

Biomaterials
Carbon Capture & Storage
Tackling Air Pollution

TECHNOLOGIES

Biotechnology
Climate Tech
Internet of Things (IoT)

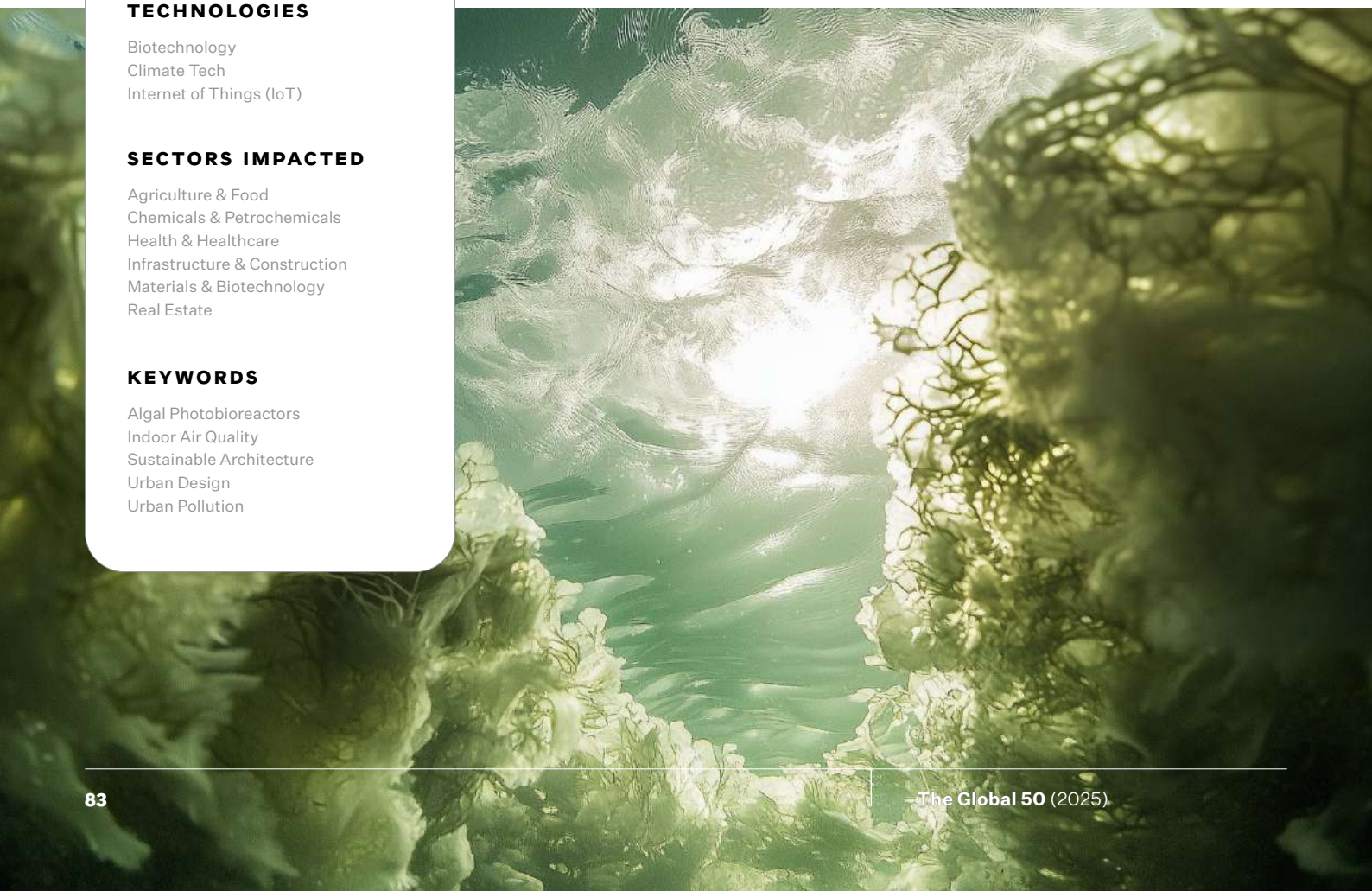
SECTORS IMPACTED

Agriculture & Food
Chemicals & Petrochemicals
Health & Healthcare
Infrastructure & Construction
Materials & Biotechnology
Real Estate

KEYWORDS

Algal Photobioreactors
Indoor Air Quality
Sustainable Architecture
Urban Design
Urban Pollution

[k] The scenario presented here is one of many possible futures and does not advocate for the elimination of outdoor experiences or discount the value of experiences in nature.



We spend

90%

of our time indoors, where the **levels of pollutants can be up to**

5x

higher than outdoors

WHY IT MATTERS TODAY

Indoor air quality has become increasingly important as green spaces are not always available or accessible, particularly in urban areas, and as activities increasingly take place indoors. In high-income countries, people spend up to 90% of their time indoors,[568] where the levels of pollutants can be up to five times higher than outdoors.[569] Rising temperatures, humidity and rainfall due to global warming are expected to increase fungal (e.g. mould) and bacterial growth,[570] with inadequate ventilation and poor maintenance making the problem worse.[571] In addition, rising indoor temperatures increase pollutant emissions from building materials themselves.[572]

Poor indoor air quality can negatively impact physical health, cognitive performance, and productivity. Indoor pollution can trigger various health concerns, from asthma[573] to heart disease and cancer.[574] Research published in 2020 shows that reducing carbon dioxide (CO_2) inside classrooms by more than half can lead to students working faster (12%) and learning better (5%).[575]

Various regulatory frameworks and green building certification programmes, such as LEED (Leadership in Energy and Environmental Design) and BREEAM (Building Research Establishment Environmental Assessment Method) set out robust standards for indoor air quality.[576] In addition, the World Health Organization has guidelines for indoor air quality,[577] Sustainable Development Goal Indicator 7.1.2 calls for reliance on clean fuel,[578] and the American Lung Association is one example of an organisation that is running a campaign to improve indoor air quality.[579] The National Air Quality Agenda 2031 in the United Arab Emirates provides a framework for the government and private sector to improve air quality.[580]

THE OPPORTUNITY

Algal bioreactors work through algae's ability to absorb CO_2 and other pollutants through photosynthesis.[581] Integrated algal systems could reduce levels of CO_2 by 13% in 200-person buildings, capturing 16 kg of CO_2 daily.[582] Integrated into architectural elements, such as façades, artificial trees, and amenities,[583] a distributed network of algal air purifiers can be adapted and scaled to meet specific building and urban city needs.[584] These living façades create dynamic exteriors and healthier indoor environments.[585]

Powered by the Sun's rays or LED lighting for optimal algal growth,[586] these systems are self-sustaining and environmentally friendly. Through urban-wide analytics and monitoring in smart cities, high-pollution areas can be identified and provided with algal bioreactor units. Units can also be installed as part of building HVAC (heating, ventilation and air conditioning) systems to absorb pollutants and provide clean air indoors.[587]

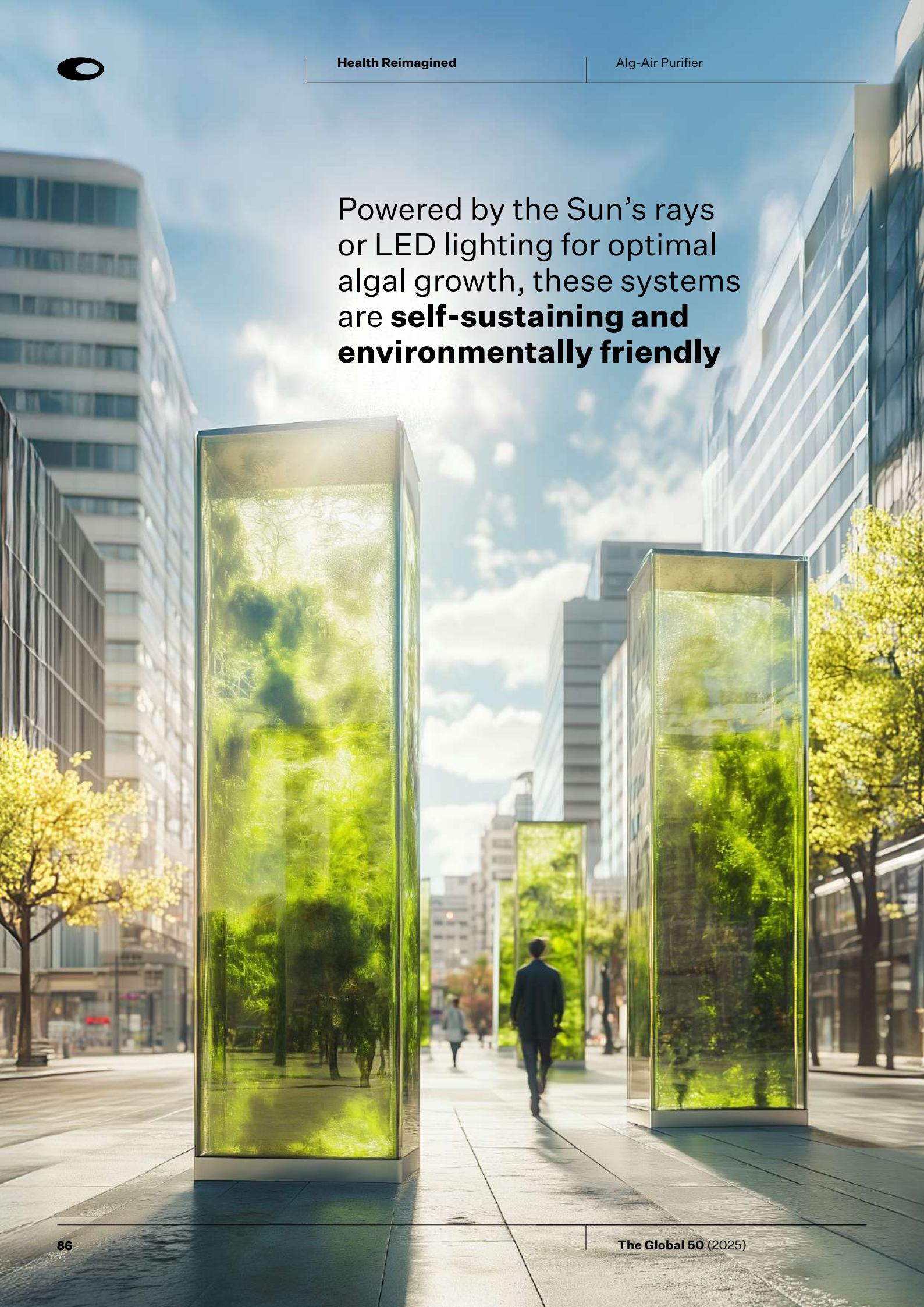
BENEFITS

Better indoor air quality; fewer respiratory issues; nature-based solution; sustainable solution that meets indoor green building certification requirements.

RISKS

Inadequate conditions (light, temperature and nutrient management) to ensure optimal algal growth; improper maintenance leading to suboptimal performance; algal contamination and biological hazards; potential toxicity and pathogenic infection.

Integrated algal systems could **reduce levels of CO_2 by 13% in 200-person buildings, capturing 16 kg of CO2 daily**



Powered by the Sun's rays or LED lighting for optimal algal growth, these systems are **self-sustaining and environmentally friendly**

What if nanomedicine made the leap from potential to reality?

07

Nanomedicine Over the Edge

Within Reach | **Transitional** | Visionary

Advanced machine intelligence, open data, and genomic research unlock nanomedicine's potential by solving critical toxicity challenges, enabling advances in precision medicine.

UNCERTAINTIES

Technology, Values

MEGATREND (Most significant)

Materials Revolution

TRENDS

Bioinformatics
Biotechnology
Longevity & Vitality
Open Data
Precision/Personalised Medicine

TECHNOLOGIES

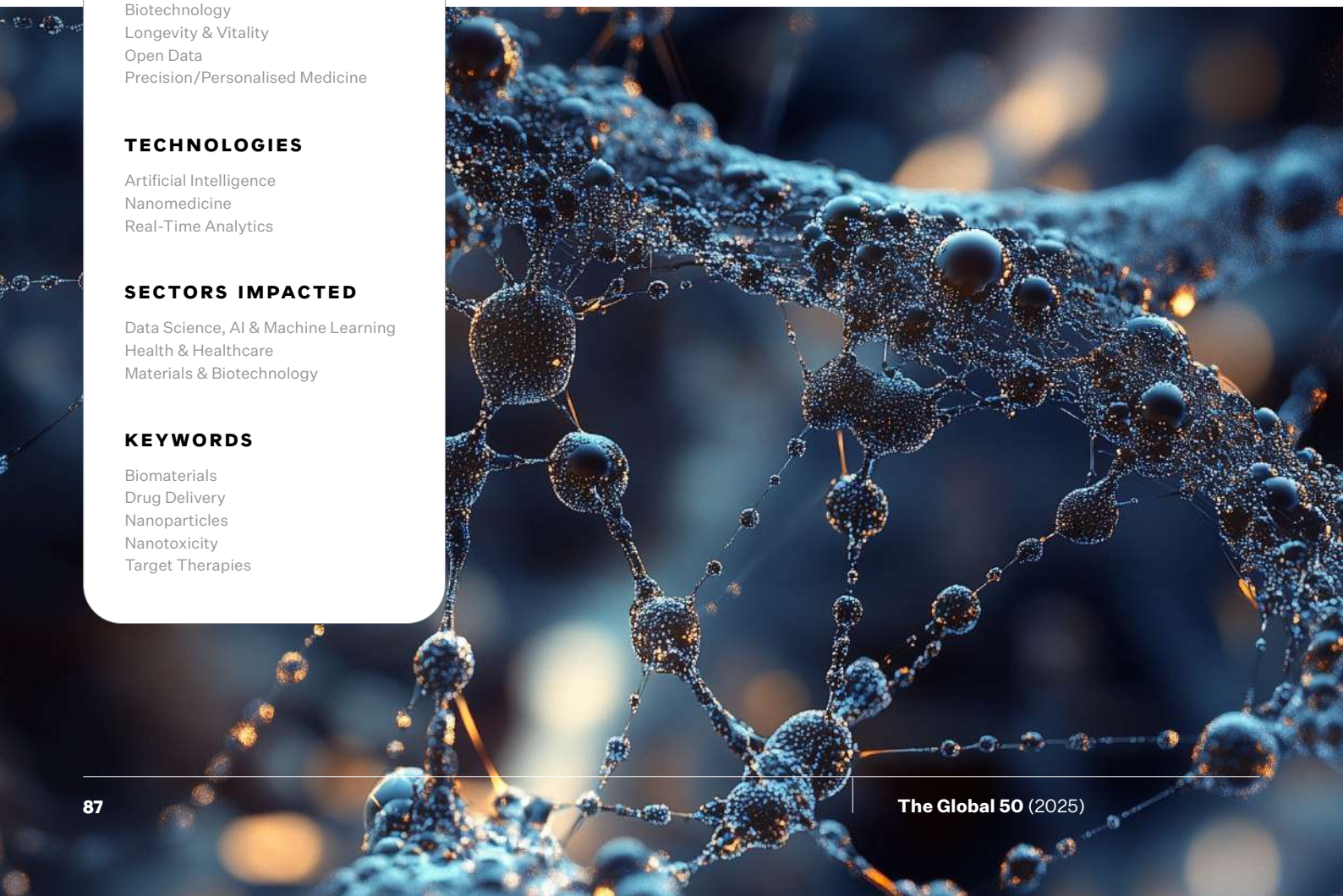
Artificial Intelligence
Nanomedicine
Real-Time Analytics

SECTORS IMPACTED

Data Science, AI & Machine Learning
Health & Healthcare
Materials & Biotechnology

KEYWORDS

Biomaterials
Drug Delivery
Nanoparticles
Nanotoxicity
Target Therapies



WHY IT MATTERS TODAY

In 2023, nearly half

47%

of healthcare providers around the world **report worsening access to healthcare**

The limitations of a one-size-fits-all approach to healthcare underscore the growing need for personalised medicine.[588] Unlike standardised treatments applied broadly, personalised medicine seeks to tailor therapies. This innovative strategy focuses on the unique genetic, environmental and lifestyle factors of each patient, enabling healthcare providers to deliver targeted therapies that are more effective and have fewer side effects. Using advanced diagnostic tools and molecular profiling, personalised medicine allows earlier disease detection and intervention, ultimately leading to improved health outcomes.[589]

At a time when healthcare facilities are under strain around the world,[590] nanotechnology can help to build a more resilient healthcare model.[591] In 2023, nearly half (47%) of healthcare providers around the world reported worsening access to healthcare. The industry is facing increased hospital costs and rising labour costs (driven in part by staffing shortages), and people have lower disposable incomes, making it harder for them to cover unexpected medical costs.[592]

Rapid advancements in biotechnology and bioinformatics are paving the way for the further development of nanomedicine. At a scale of one-billionth of a metre, nanobiotechnology can improve disease detection (e.g. ovarian cancer), and diabetes management through biosensors, targeted drug delivery, enhanced imaging quality, and wound healing.[593] While successful applications exist in bone regeneration,[594] breast cancer treatment,[595] genetic disorders,[596] and glaucoma treatment,[597] challenges remain with long-term toxicity and stability of nanomaterials.[598]

THE OPPORTUNITY

BENEFITS

Early disease detection; enhanced preventative care; targeted drug delivery; autonomous medicine; reduced burden on healthcare; advances in understanding environmental toxicity.

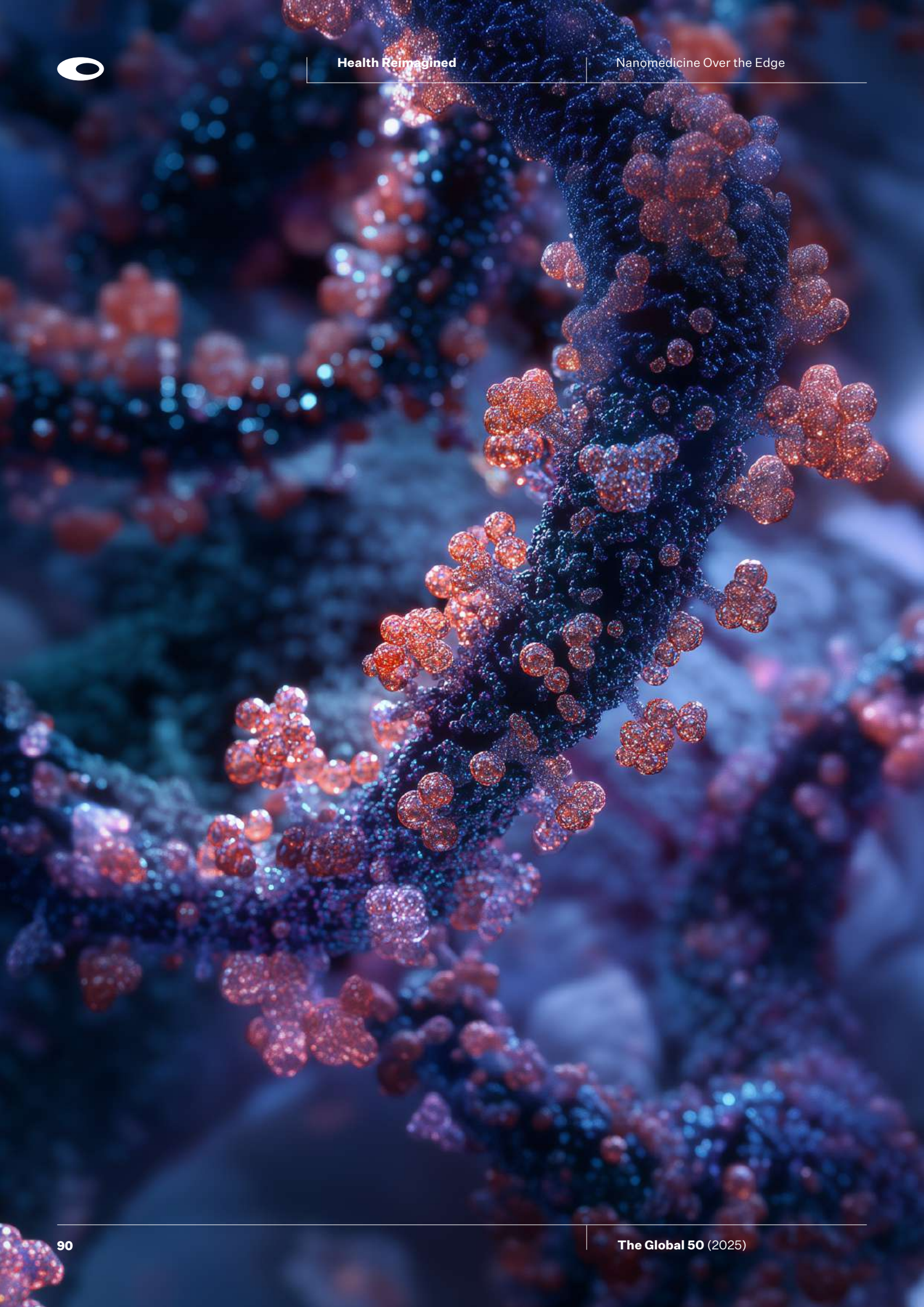
RISKS

Misdiagnosis and treatment; unknown side effects caused by biomaterials; unknown long-term effects or toxicity; regulatory challenges; potential job displacement in healthcare.

A comprehensive approach combining advanced machine intelligence, open data,[599] and genomics helps overcome the challenge of nanotoxicity in nanomedicine. This approach provides a deeper understanding of how nanoparticles may affect our bodies and our genes,[600] including their potential role in epigenetics – the way our genes respond to external factors – and can help turn clinical successes into reality.[601]

Nanomedicine holds great potential to dramatically improve the accuracy, efficiency and sensitivity of diagnostic testing and treatment, but nanotoxicity remains a critical barrier to widespread adoption.[602] From nanotubes, nanorods and nanofibres, to nanowires, nanoplates and nanoparticles, nanomaterials can enter the body through breathing, ingestion, injection or skin contact, with each method carrying its own risks.[603] While breathing carries the greatest risk, nanotoxicit
health risks related to long-

Advanced machine intelligence, open data, and genomics can help overcome **nanotoxicity challenges, turning clinical successes in nanomedicine into reality**



What if sports analytics improved public health?

08 Game-Changing Link

Within Reach | **Transitional** | Visionary

Sports analytics integrates with public health through a secure data sharing platform, revealing links between fitness trends, injuries, physical activity patterns and health outcomes, while enabling breakthroughs in public health policy and targeted health interventions.

UNCERTAINTIES

Systems, Technology

MEGATREND (Most significant)

Boundless Multidimensional Data

TRENDS

Big Data
Cross-Sectoral Partnerships
Longevity & Vitality
Open Data
Precision/Personalised Medicine

TECHNOLOGIES

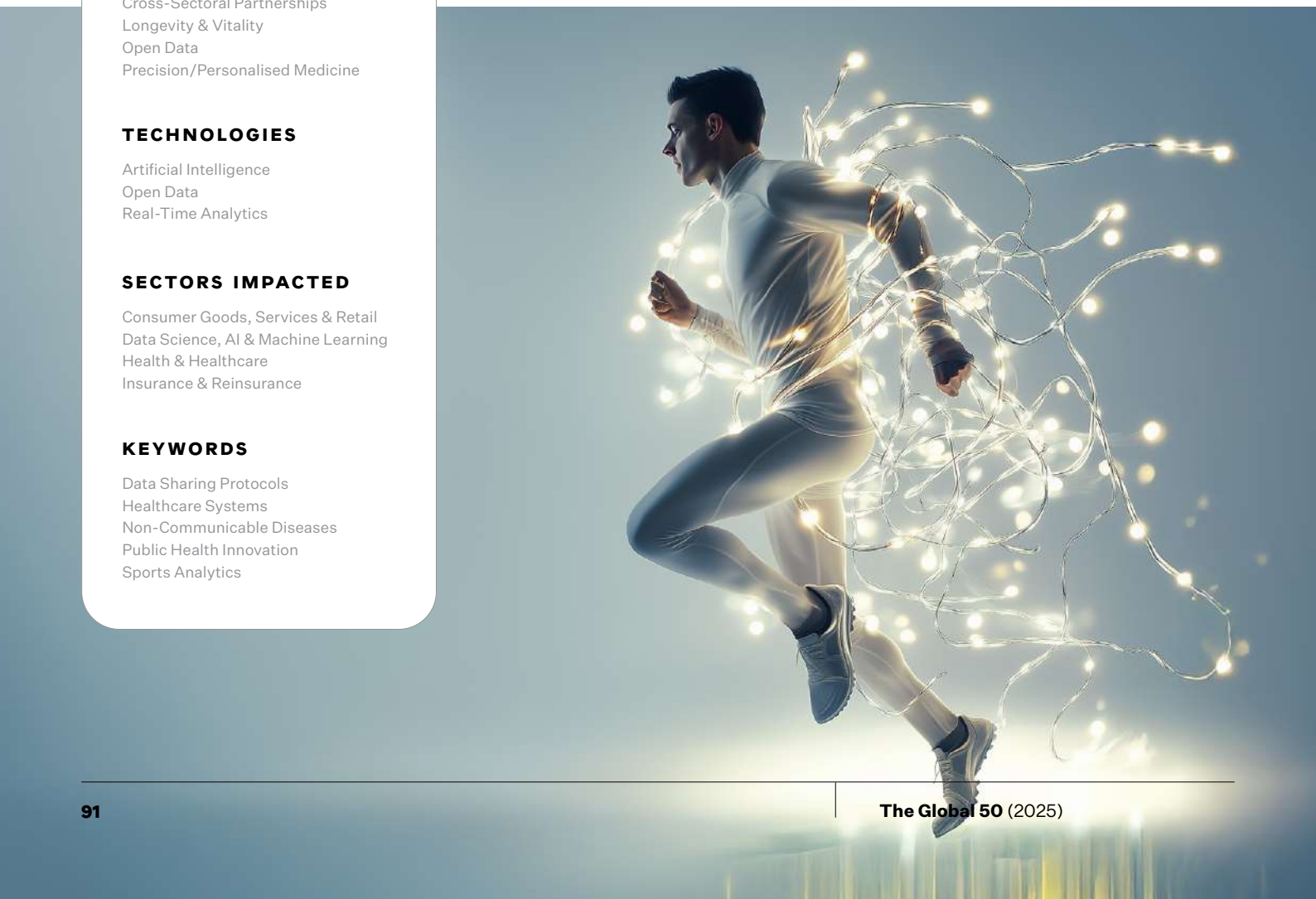
Artificial Intelligence
Open Data
Real-Time Analytics

SECTORS IMPACTED

Consumer Goods, Services & Retail
Data Science, AI & Machine Learning
Health & Healthcare
Insurance & Reinsurance

KEYWORDS

Data Sharing Protocols
Healthcare Systems
Non-Communicable Diseases
Public Health Innovation
Sports Analytics



WHY IT MATTERS TODAY

According to the most recent WHO data (2019, **non-communicable diseases accounted for**

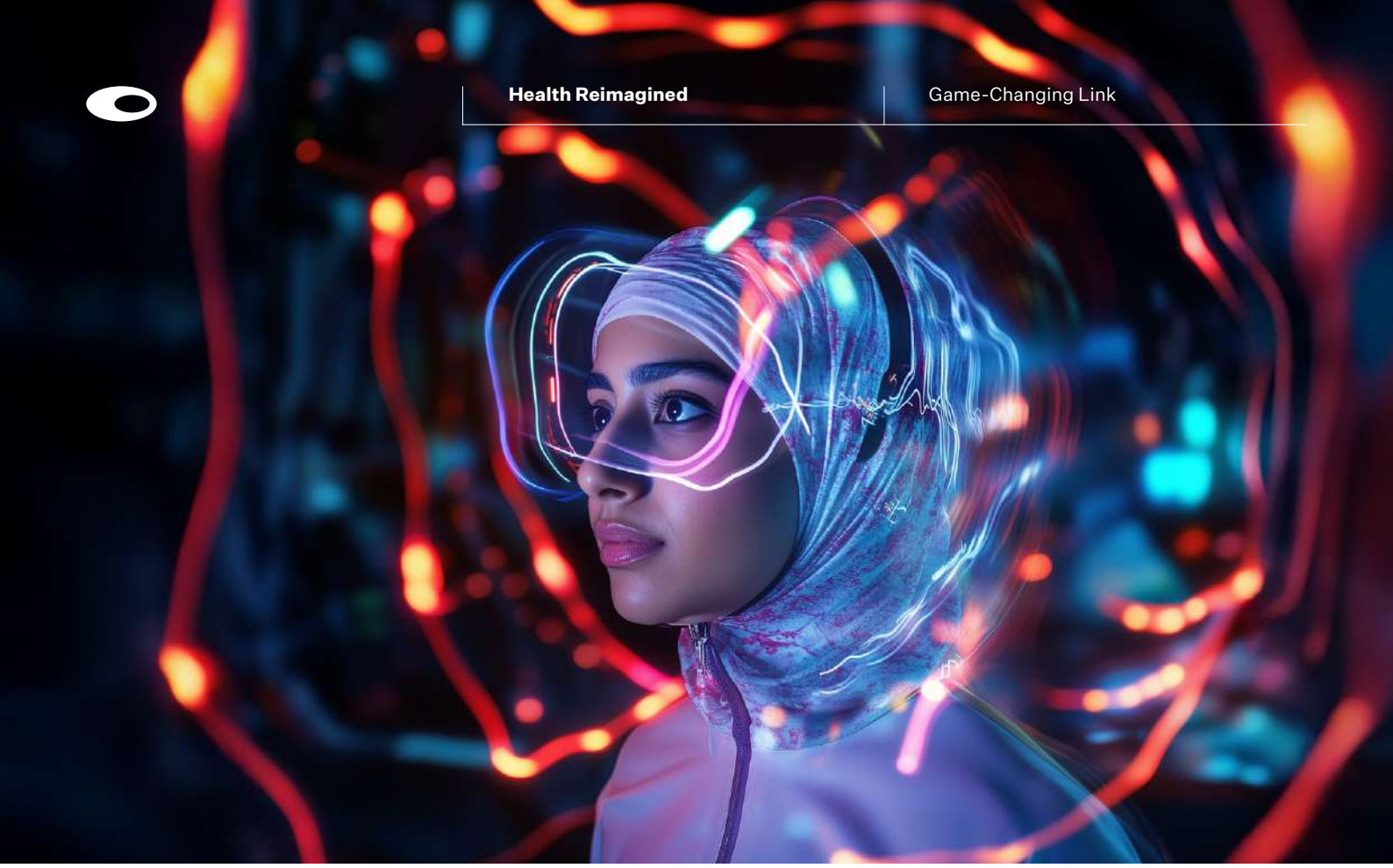
74%

of all deaths globally

Healthcare systems are currently overwhelmed. Global life expectancy is projected to increase from 73.6 years in 2022 to 78.2 years by 2050,[605] and this may be accompanied by a rise in disability-adjusted life years.[606] While better public health data collection is an ongoing need,[607] the World Health Organization projects a shortfall of 10 million health workers by 2030, with the majority of this gap affecting low- and lower-middle-income countries.[608]

According to the most recent WHO data (2019), non-communicable diseases (NCDs) account for 74% of all deaths globally.[609] NCDs cause 41 million people each year, with cardiovascular diseases, cancer, chronic respiratory conditions and diabetes, making up 80% of premature NCD deaths.[610] The Sustainable Development Goals aim to reduce premature mortality from NCDs by one-third by 2030.[611]

Sports analytics and big data have transformed sports medicine. Biosensors, artificial intelligence (AI),[612] and wearable technologies,[613] among others, are enhancing athlete monitoring and injury prevention.[614] The Podium Institute for Sports Medicine and Technology, a partnership between Podium Analytics and the Institute of Biomedical Engineering at the University of Oxford, focuses on evidence-based innovations for sports injuries suitable for practical adoption within five years.[615] The global sports analytics market is expected to reach a value of $4.81 billion in 2024 and $32.31 billion by 2032, with a compound annual growth rate of 26.9%.[616]



THE OPPORTUNITY

Sports analytics platforms are connected to public health data through secure, standardised data sharing protocols, creating a shift in public health and health innovation. Advanced machine intelligence reveals correlations between fitness trends, injuries, physical activity patterns, and health outcomes, accelerating the development of targeted interventions and personalised medicine approaches, particularly for NCDs.

Advanced data exchange protocols, such as blockchain and quantum-secured systems, allow these platforms to share anonymised performance metrics, injury patterns, and recovery data with public health agencies while maintaining strict privacy controls. With multi-partner access, the use of integrated data unlocks unprecedented opportunities for medical breakthroughs and health innovation as researchers analyse patterns across sports performance, recovery, and long-term health outcomes, with findings leading to new insights into injury prevention, treatment protocols, and public health.

BENEFITS

Better understanding of public health; health innovation breakthroughs; evidence-based policymaking.

RISKS

Misinterpretation of health data; data privacy and security concerns; increased health disparities due to unequal access.

Sports analytics platforms are connected to public health data through secure, standardised data sharing protocols, creating a shift in public health and health innovation

What if a single breath diagnosed communicable diseases and automatically triggered treatment?

09

Breath of Intelligence

Within Reach | **Transitional** | Visionary

Autonomous nanobiomaterial-based breath diagnostics enable rapid and precise detection of communicable diseases, automatically initiating personalised treatment.

UNCERTAINTIES

Systems, Technology

MEGATREND (Most significant)

Advanced Health and Nutrition

TRENDS

Bioinformatics
Biomaterials
Mobilising Innovation
Neuroscience
Precision/Personalised Medicine

TECHNOLOGIES

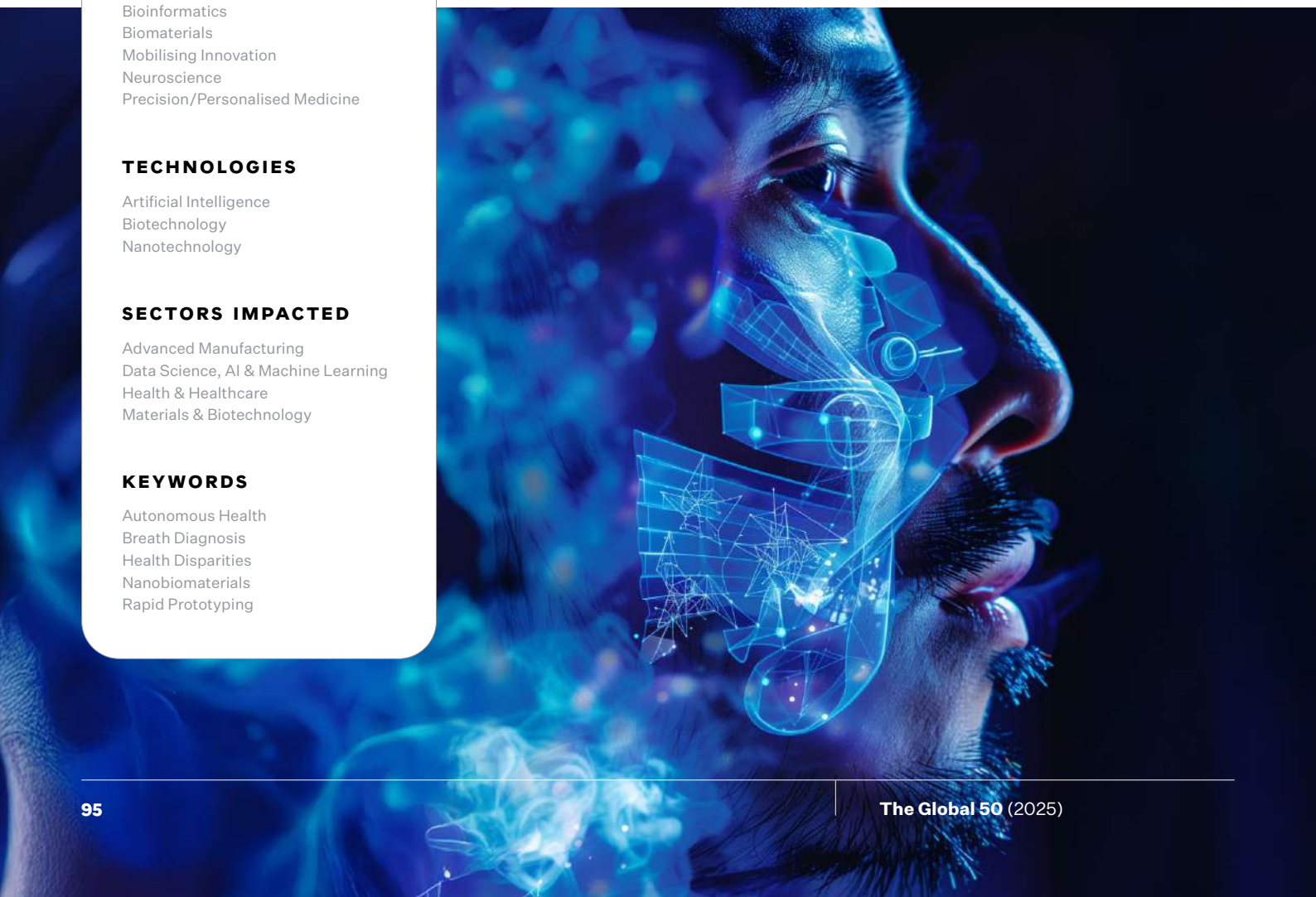
Artificial Intelligence
Biotechnology
Nanotechnology

SECTORS IMPACTED

Advanced Manufacturing
Data Science, AI & Machine Learning
Health & Healthcare
Materials & Biotechnology

KEYWORDS

Autonomous Health
Breath Diagnosis
Health Disparities
Nanobiomaterials
Rapid Prototyping



WHY IT MATTERS TODAY

GenAI achieved

90%

accuracy in diagnosing medical conditions, while doctors using **conventional medical diagnosis scored**

74%

Global health disparities remain significant across regions, with many populations facing barriers to accessing quality healthcare services. Global life expectancy variations are stark, with up to 30-year differences between countries such as Japan and Nigeria.[617] Even within single cities, life expectancy can vary by up to 20 years between neighbourhoods.[618] These disparities often stem from socio-economic, geographical and cultural factors, leading to unequal health outcomes and a widening gap in health equity.

Diagnostic errors contribute significantly to patient mortality and morbidity. In the United States, an estimated 371,000 deaths and 424,000 permanent disabilities each year because of diagnostic errors.[619] Many diseases present with non-specific symptoms, such as weight loss, fatigue, pain, and loss of appetite, or have complex secondary effects, making them challenging to diagnose using traditional methods.[620]

Artificial intelligence (AI) systems demonstrate superior diagnostic accuracy compared with conventional medical diagnosis. In one study covering emergency medicine, family medicine, and internal medicine,GenAI alone performed better than doctors at diagnosing medical conditions, achieving 90% accuracy, while physicians using conventional methods scored 74%.[621] Even when physicians had access to AI assistance, their performance only marginally improved, to 76%.[622]

Using breath for diagnosis is not new. The technique has been tested with tuberculosis,[623] COVID-19,[624] influenza,[625] fungal infections,[626] malaria[627] and some bacterial infections,[628] especially in the gut.[629] For example, highly sensitive nanomaterial-based sensors can detect pathogen-specific volatile compounds in exhaled breath.[630]

THE OPPORTUNITY

Nanobiomaterials (i.e. nanostructured materials for biomedical applications[631]) enable autonomous diagnosis and treatment initiation through a person's breath.[632] As diagnostic sensors, nanobiomaterials can be incorporated into handheld devices[633] and wearables[634] or they can be integrated into homes or healthcare spaces.

While rigorous clinical trials remain essential, advanced machine intelligence enhances both diagnosis[635] and materials design.[636] Training on vast datasets of breath profiles from both healthy individuals and those with various disease profiles enables accurate diagnosis, predicts disease progression,[637,638] and triggers treatment protocols.[639] Additionally, 3D printing could accelerate the development and deployment of devices[640] and enable customisation based on local disease patterns across geographies.[641]

BENEFITS

Accessible health; improved disease outbreak prevention; enhanced treatment; improved health outcomes.

RISKS

Misdiagnosis; bias in training data; poor detection due to weakening sensor materials over time; despite diagnosis, treatment remains inaccessible.

Nature Restored

Minimise environmental risks and harness nature's capacity to restore itself or have a positive impact on crucial environmental ecosystems and habitats, creating a more stable, healthier planet for all.

What if we truly connected with nature?

10

The Feel of Nature

Within Reach | **Transitional** | Visionary

Touchless haptic technology uses ultrasonic waves and smart sensors to convert environmental data into mid-air sensations, creating immersive, real-time and tangible connections that enhance awareness of nature.

UNCERTAINTIES

Nature, Technology

MEGATREND (Most significant)

Boundless
Multidimensional Data

TRENDS

Community-Based Solutions
Human–Machine
New Materials
Air Pollution

TECHNOLOGIES

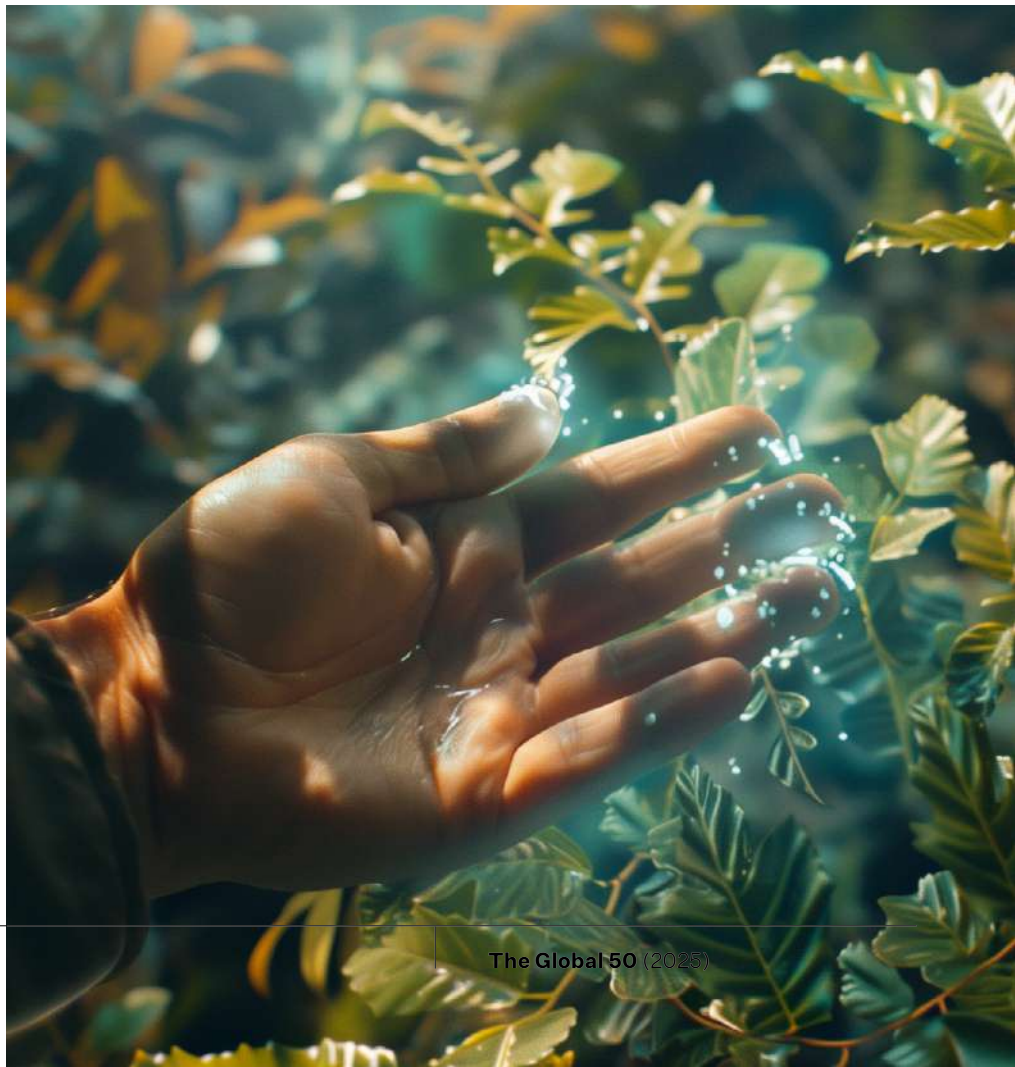
Edge Computing
Immersive Technologies & Wearables
Internet of Things (IoT)

SECTORS IMPACTED

Art, Media, Sports & Entertainment
Communication Technologies & Systems
Consumer Goods, Services & Retail
Data Science, AI & Machine Learning
Education
Health & Healthcare
Immersive Technologies
Insurance & Reinsurance
Materials & Biotechnology

KEYWORDS

Behavioural Change
Environmental Sensing
Sensory Experience
Touchless Haptics
Ultrasonic Technology



WHY IT MATTERS TODAY

People in modern industrial societies spend

90%

of their time indoors in artificial, temperature-controlled environments

Tactile feedback expands the boundaries of sensory experience. The potential of haptic technology extends far beyond assistive applications, offering immersive experiences that were previously unimaginable. By converting sensory information into tactile feedback, this technology allows individuals to experience music, virtual environments, and complex interactions in entirely new ways.

Climate change and environmental degradation are urgent global issues but often feel far from individuals. The expanding urban population, in particular, often lose touch with nature and the health of their surroundings.[642] People in modern industrial societies spend 90% of their time indoors[643] in artificial, temperature-controlled environments. Their lives are often cut off from natural cycles and devoid of birdsong, rivers and streams, and fresh air. Even people living in rural areas are not immune to the disconnecting effects of increasingly technology-mediated, busy modern life.[644]

There is a growing emphasis on experiential learning and sensory engagement, which can be key contributors to behavioural change. King's College London used a device developed by Dyson as part of the Breathe London initiative. The aim of this study, which involved 250 children, was to understand the effects of daily exposure to pollutants, including $PM_{2.5}$ and nitrogen dioxide, on the school run.[645] As a result of the study, 31% of children changed the way they travelled to and from school to reduce their exposure to air pollution.[646]

Climate change and environmental degradation are urgent global issues but **often feel far from individuals**

THE OPPORTUNITY

Using ultrasonic waves,[647] mid-air sensations allow people to experience – and feel – nature. By adjusting airborne ultrasonic waves and using acoustic levitation (the use of sound waves to hold particles in the air),[648] data and sounds are converted into haptic sensations. Users can experience virtual textures and forces with unprecedented spatial precision and responsiveness.[649]

Ultrasonic transducers[650] and the Internet of Things (IoT)[651] enable touchless interactions and a wide range of sensations, from light pressure to more complex tactile experiences,[652] enabling more natural and immersive experiences across environments.[653] A distributed nanoscale sensor network embedded in nature[654] monitors environmental conditions, such as air quality ($PM_{2.5}$), soil moisture, temperature and pollutants. Edge computing simultaneously processes these data to deliver real-time physical sensations.

BENEFITS

Increased awareness of nature; enhanced environmental education; data-driven ecosystem management; accessible experiences for the visually impaired; enhanced immersive experiences.

RISKS

Increased eco-anxiety; data manipulation; reliance on training to understand how haptics relate to given environmental conditions; less authentic nature experiences; sensory overload; wear and tear of sensors.

By adjusting airborne ultrasonic waves and using acoustic levitation (the use of sound waves to hold particles in the air) **data and sounds are converted into haptic sensations**

What if self-evolving microhabitats restored biodiversity in urban spaces while adapting to changing needs?

11 Living Gardens

Within Reach | **Transitional** | Visionary

4D-printed microhabitats in gardens dynamically respond to environmental and biodiversity changes, creating ideal conditions for plants, insects and microorganisms to grow together naturally.

UNCERTAINTIES

Nature, Technology

MEGATREND (Most significant)

Evolving Ecosystems

TRENDS

Biomimicry
New Materials
Restoration

TECHNOLOGIES

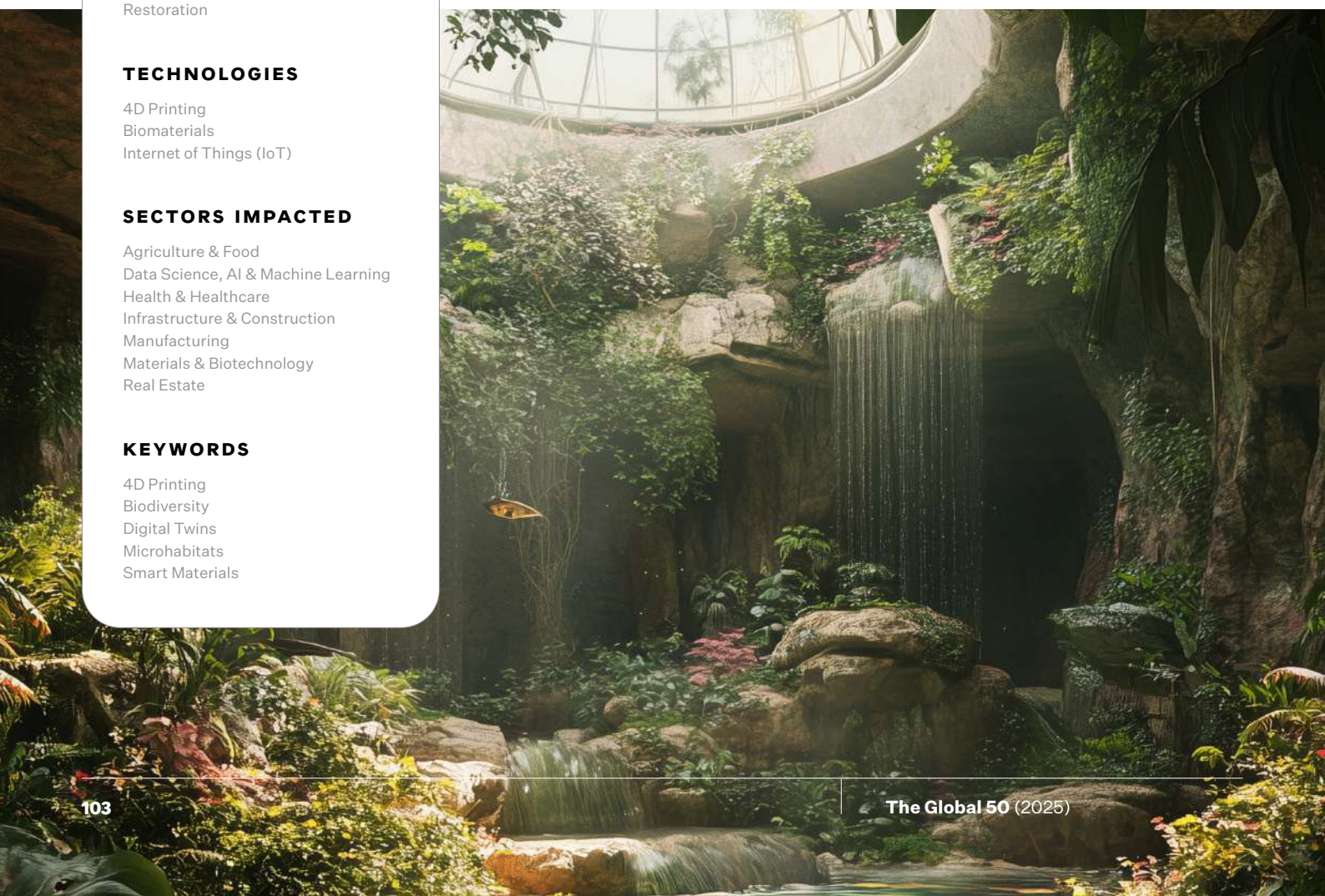
4D Printing
Biomaterials
Internet of Things (IoT)

SECTORS IMPACTED

Agriculture & Food
Data Science, AI & Machine Learning
Health & Healthcare
Infrastructure & Construction
Manufacturing
Materials & Biotechnology
Real Estate

KEYWORDS

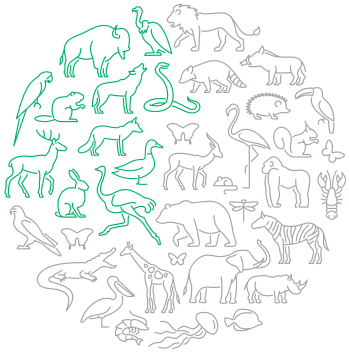
4D Printing
Biodiversity
Digital Twins
Microhabitats
Smart Materials



WHY IT MATTERS TODAY

69%

average decline in terrestrial wildlife populations since 1970, marking biodiversity loss as a pressing environmental crisis alongside climate change



Biodiversity loss is a critical global issue. It is accelerating at an unprecedented rate, with profound implications for ecosystem stability and human well-being. Around 1 million species are currently threatened with extinction, with the number rising over time.[655] Recent data from the Living Planet Report show a 69% average decline in terrestrial wildlife populations since 1970, marking biodiversity loss as a pressing environmental crisis alongside climate change.[656] Among environmental risks in the next ten years, biodiversity loss ranks as the second most severe threats.[657]

Declining urban green spaces are further contributing to biodiversity loss. Currently, over 56% of the world's population live in urban areas,[658] which is contributing to a significant decline in urban green cover.[659] Urbanisation is impacting biodiversity conservation, the connection between humans and nature, and the health and well-being of both wildlife and people. The restoration of urban green spaces, which is crucial for strengthening ecosystems, has never been more urgent. With each degree of global warming, the risk of species extinction grows larger.[660] The relationship between biodiversity and climate change is reciprocal: if one suffers harm, so does the other.

4D printing – that is, 3D printing that incorporates smart materials that respond to stimuli and cause the 3D object to change over time – emerged in 2013.[661] Key applications of 4D printing include soft robotics, toys and microtubes, and contexts that require bending, twisting, lengthening and moving in wave-like patterns as a result of environmental changes.[662] Future applications include self-healing bridges and expandable infrastructure, self-tailored clothing and adaptive shoes, on-demand prosthetics and smart implants, and even bone and tissue growth in regenerative medicine.[663] As a precursor to 4D printing, the global 3D-printing market was valued at $20 billion in 2023 and is expected to expand at a compound annual growth rate of 23.3% to $88 billion by 2030.[664]

THE OPPORTUNITY

4D-printed microhabitats[665] enhance urban and rural gardens, creating thriving natural ecosystems.[666] These microhabitats use the Internet of Things (IoT) sensors and edge computing to monitor the environment and adapt in real time to changing conditions.[667] Inspired by biomimicry, these microhabitats respond to environmental triggers such as light, heat and pH (acidity) levels.[668] Over time, these microhabitats integrate with the existing garden environments, helping to spread healthy ecosystems naturally.

Constructed using 3D printing from smart materials such as shape-memory polymers,[669] these structures – designed to mimic natural elements such as plants, rocks and stones – can alter their form and characteristics in response to their surroundings, enabling them to dynamically adapt to shifting conditions,[670] making them 4D. The microhabitats also capture and store carbon dioxide,[671] collect rainwater to hydrate soil, and regulate temperature for microorganisms through shading.[672] In addition to microorganisms, the microhabitats support pollinators, which together with microorganisms are crucial for supporting local food systems. The microhabitats also play a role in combating deforestation and restoring biodiversity.

BENEFITS

Enhanced biodiversity; increased ecosystem resilience; enhanced air quality; ecological restoration.

RISKS

Dependence on technology for ecosystem conservation; unintended consequences for microorganisms; cyberbiosecurity; cost.

What if floating ecosystems naturally cleaned polluted waters?

12

Floating Filters

Within Reach | Transitional | Visionary

As an effective nature-based solution, floating wetlands are optimally designed using advanced machine intelligence for various water networks and locations, naturally filtering polluted water networks and making them clean and safe.

UNCERTAINTIES

Nature, Technology

MEGATREND (Most significant)

Evolving Ecosystems

TRENDS

Community-Based Solutions
New Materials
Sustainable Waste Management

TECHNOLOGIES

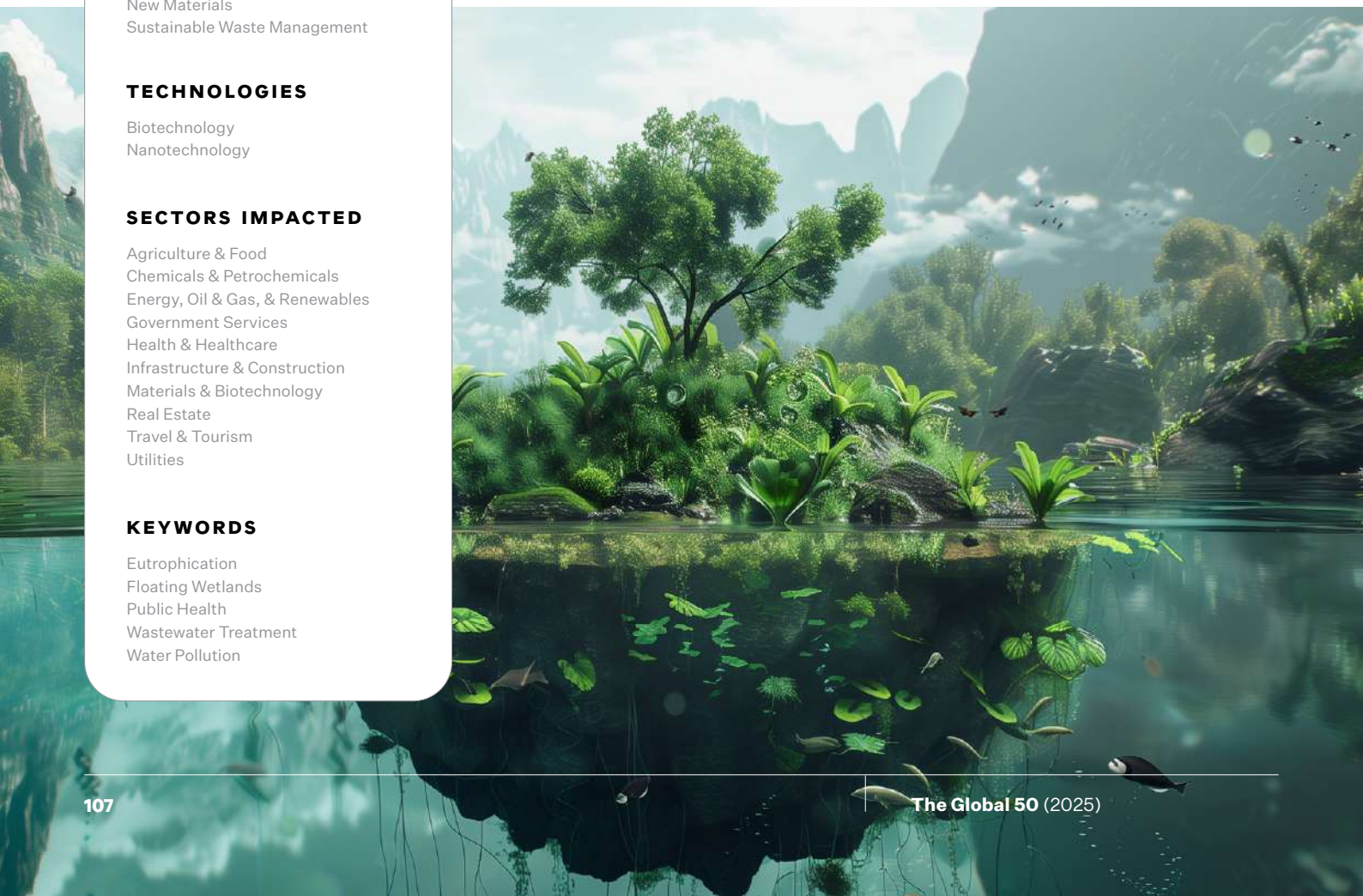
Biotechnology
Nanotechnology

SECTORS IMPACTED

Agriculture & Food
Chemicals & Petrochemicals
Energy, Oil & Gas, & Renewables
Government Services
Health & Healthcare
Infrastructure & Construction
Materials & Biotechnology
Real Estate
Travel & Tourism
Utilities

KEYWORDS

Eutrophication
Floating Wetlands
Public Health
Wastewater Treatment
Water Pollution



WHY IT MATTERS TODAY

Globally, about

80%

of industrial and domestic wastewater is **released back into ecosystems untreated**, severely impacting both human health and aquatic ecosystems

Globally, about 80% of industrial and domestic wastewater is released back into ecosystems untreated.[673] This percentage is often higher in low-income countries, which lack wastewater management systems,[674] and in areas experiencing rapid increases in population and economic growth.[675]

Contaminated water negatively affects human health. For example, excess nitrogen in drinking water is associated with colorectal cancer, thyroid disease, and neural tube defects,[676] and the association between water nitrate concentrations and methaemoglobinaemia – a blood condition that primarily affects infants – is well established.[677] Additionally, algal blooms – caused by an excess of nitrogen and phosphorus – produce toxins that can cause rashes, liver and kidney problems, respiratory conditions, and neurological issues.[678] People are exposed to the blooms through eating contaminated fish, swimming in or drinking the affected water, or breathing contaminated air.[679]

Contaminated water negatively impacts ecosystems as well. Excessive nutrients, and the algal blooms they create, deplete the level of oxygen in the water, leading to eutrophication and its characteristic dead (hypoxic) zones, where aquatic life cannot survive.[680] More than 97% of the Baltic Sea area has been affected by eutrophication due to past or current disproportionate inputs of phosphorus and nitrogen.[681] Floating wetlands can remove up to 91.7% of total nitrogen and 98.4% of total phosphorus.[682] They have the ability to increase sulphate-reducing bacteria by 30%[683] and, in some designs, remove over 70% of sediment.[684]

Small floating wetlands offer a natural solution for water purification and filtration, using advanced machine intelligence, biotechnology, and plant genetic information to optimise designs for specific climates and water qualities

THE OPPORTUNITY

Besides beautifying urban areas and attracting wildlife,[685] small floating wetlands offer a natural solution for water purification and filtration. Using advanced machine intelligence, biotechnology, and genetic plant information, optimal designs and plant species are selected for specific natural ecosystems, water qualities and climates. Built-in, self-powered sensors provide performance feedback and alerts during maintenance and when disposal is needed.

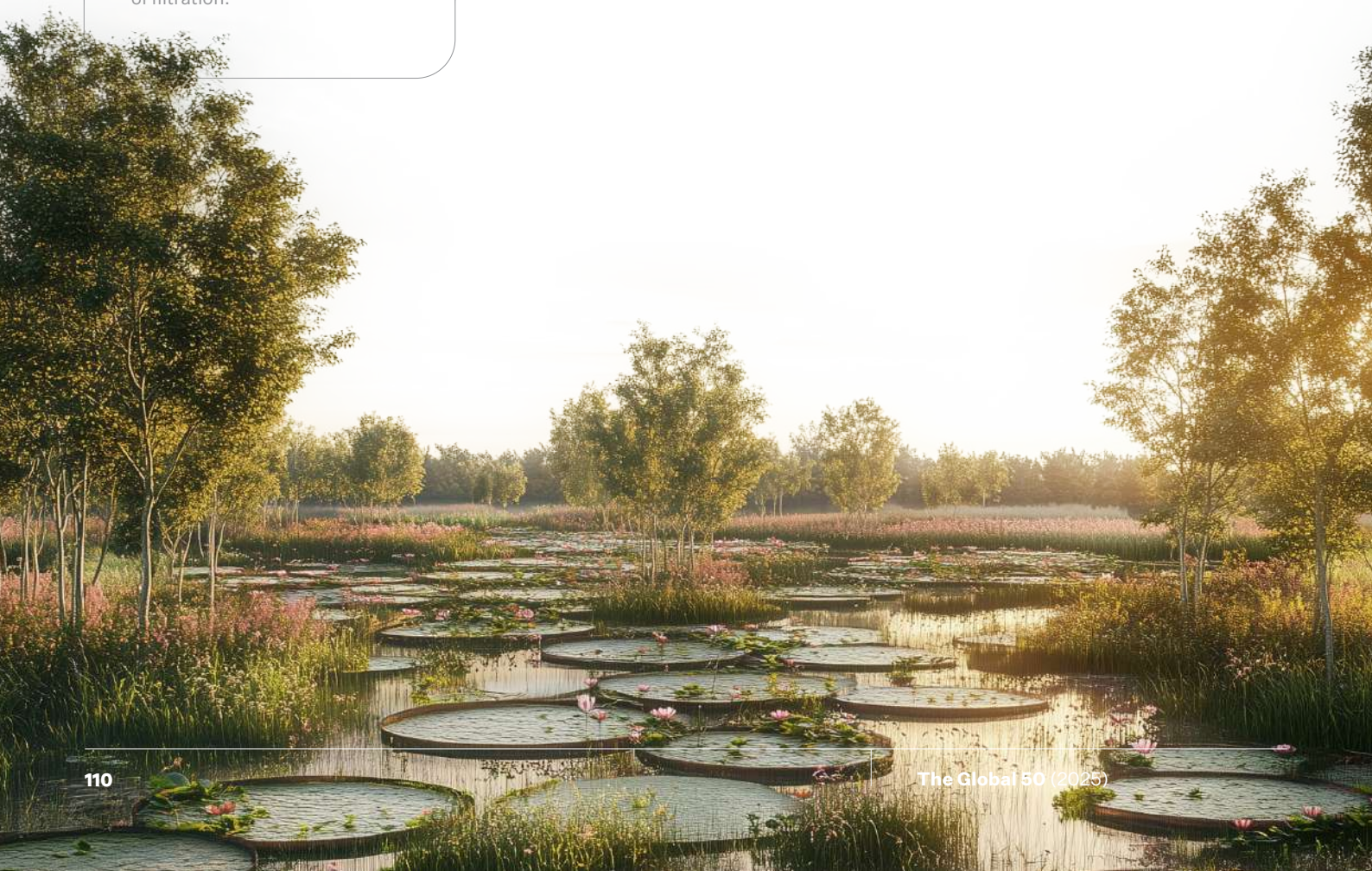
With roots that grow into the water, wetland islands improve water quality by trapping sediments[686] and filtering pollutants. At the same time, the roots absorb nutrients from the water which microbes convert into other compounds that help purify the water.[687, 688] As a self-contained ecosystem, each island acts as a moving filter that requires minimal maintenance. Guided by simulations or digital twins, multiple islands form a networked system that collaboratively optimises water purification.

BENEFITS

Improved water quality; enhanced biodiversity; increased carbon sequestration; eco-friendly wastewater treatment; lower costs; enhanced urban aesthetics.

RISKS

Long-term maintenance and disposal costs and challenges; potential for invasive species or other ecosystem imbalances to be introduced; potential for rate of pollution to exceed rate of filtration.



What if ultrasound eliminated microplastics from oceans and lakes?

13

Sonic Sweep

Within Reach | **Transitional** | Visionary

A chemical-free and scalable solution, ultrasonic waves remove microplastics from water, creating cleaner oceans and safer drinking water globally.

UNCERTAINTIES

Nature, Technology

MEGATREND (Most significant)

Evolving Ecosystems

TRENDS

Cross-Sectoral Partnerships
Food–Water–Energy Nexus
Mobilising Innovation
New Materials
Sustainable Waste Management

TECHNOLOGIES

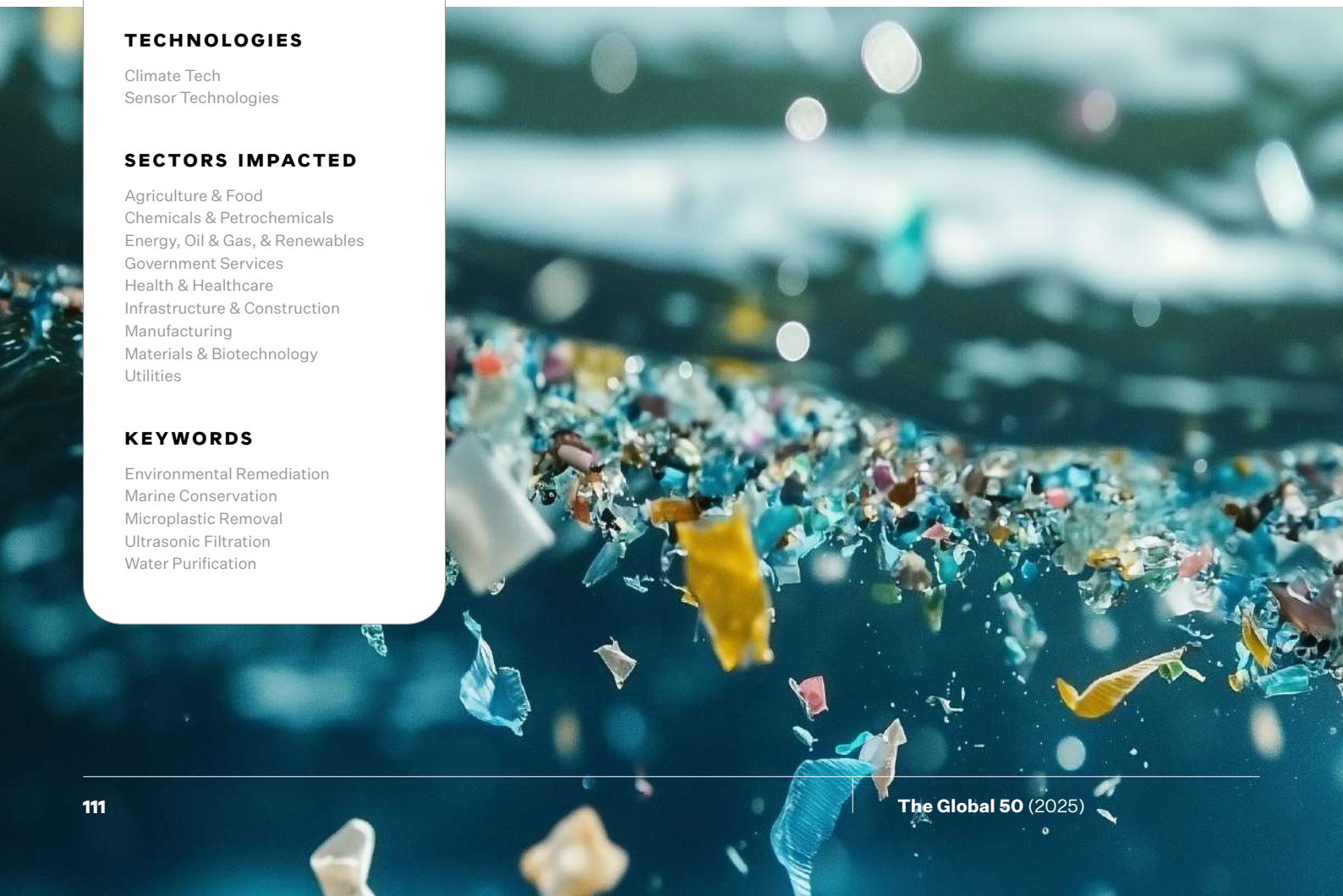
Climate Tech
Sensor Technologies

SECTORS IMPACTED

Agriculture & Food
Chemicals & Petrochemicals
Energy, Oil & Gas, & Renewables
Government Services
Health & Healthcare
Infrastructure & Construction
Manufacturing
Materials & Biotechnology
Utilities

KEYWORDS

Environmental Remediation
Marine Conservation
Microplastic Removal
Ultrasonic Filtration
Water Purification



WHY IT MATTERS TODAY

There are an estimated 50 to 75 trillion pieces[689] of plastic waste currently in our oceans, with up to 10 billion kg of plastic being added each year,[690] with up to 81% of ocean microplastics coming from their breakdown (secondary microplastics).[691] Irrespective of the route, by 2040, the amount of microplastics being released into the environment each year could more than double[692] – all amid rising concerns about their effects.[693]

From an environmental perspective, microplastics pose a dual threat as they leach chemicals into the ocean[694] and serve as magnets for heavy metals and organic pollutants.[695] These properties have detrimental impacts on marine habitats and marine organisms' behaviour.[696] Additionally, microplastics ingested by fish have been linked to gastrointestinal obstruction, enlarged colon, and impaired growth and health due to dietary disruption.[697] Plastic pollution impacts 267 marine species – harming 86% of sea turtles, 44% of seabirds, and 43% of marine mammals.[698]

Microplastic particles pose significant risks to human health through their interference with metabolic and physiological equilibrium,[699] particularly as it is thought that people consume between approximately 78,000 and 211,000 microplastic particles annually through food, drink and air.[700] These particles alter our oxidative balance, hormone regulation, cell growth, and inflammation markers, leading to diverse conditions.[701] Furthermore, microplastics serve as carriers for various environmental contaminants, potentially amplifying their detrimental health effects.[702]

People ingest between approximately

78,000 and 211,000

microplastic particles annually through food, drink and air

THE OPPORTUNITY

Ultrasound technology removes microplastics (10 to 1,000 micrometres) from water, offering a practical chemical-free solution for water purification systems, wastewater treatment plants, and industrial facilities.[703] Integrated at pollution hotspots, such as treatment plant outlets, ultrasonic wave generators[704] provide advanced filtration of various particle sizes,[705] directing microplastics to collection zones for analysis and removal.[706]

Early prototypes have shown promising results, removing up to 82% of microplastics[707] from up to 800 litres of water per hour in the laboratory.[708] This chemical-free, low maintenance approach[709] offers a scalable and sustainable path forward in addressing microplastic contamination on a global scale.

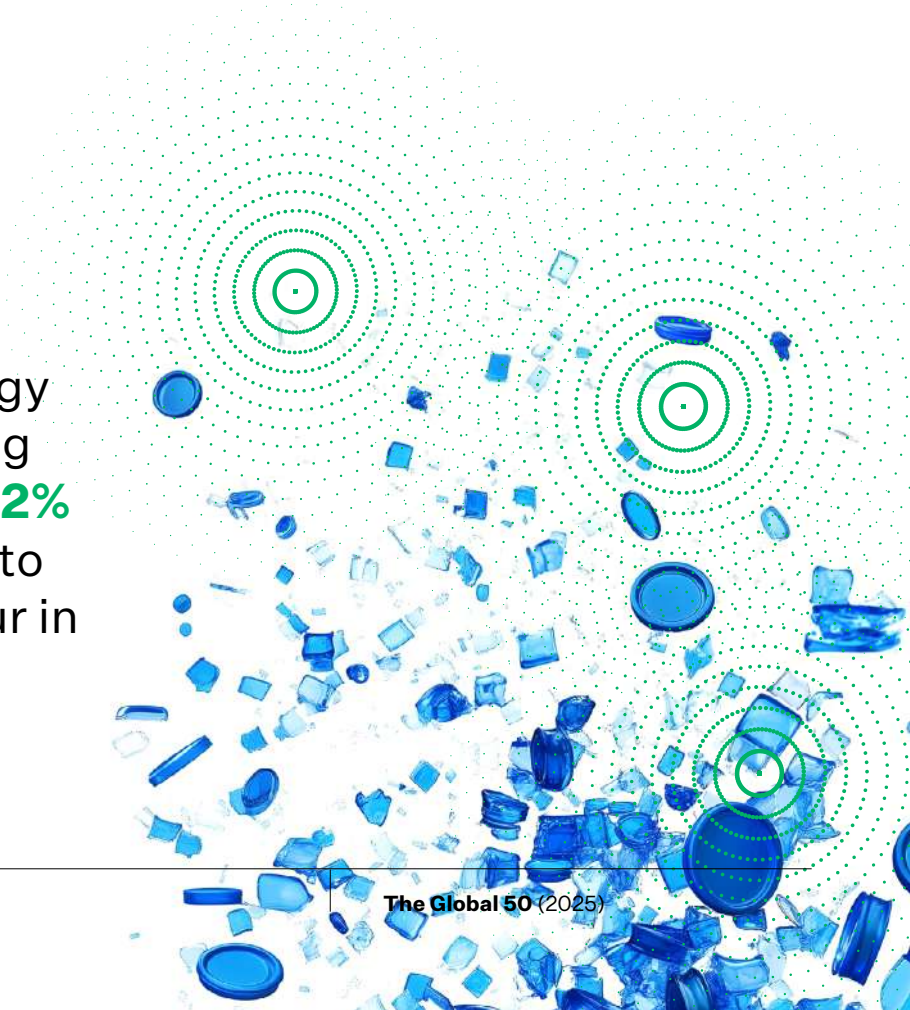
BENEFITS

Eco-friendly solution to microplastic water contamination; cleaner water; reduced use of chemicals; improved public health.

RISKS

Energy-intensive implementation; limited impact; scalability challenges; high costs due to subsequent waste removal.

Early ultrasound technology prototypes show promising results, **removing up to 82% of microplastics** from up to 800 litres of water per hour in the laboratory



What if quantum sensors predicted disasters and protected lives?

14 Planet Pulse

Within Reach | Transitional | **Visionary**

A global quantum sensor network monitors air, land and sea environments in real time, providing instant environmental data analysis and disaster prediction enabled by advanced machine intelligence and international collaboration.

UNCERTAINTIES

Nature, Technology

MEGATREND (Most significant)

Boundless
Multidimensional Data

TRENDS

Cross-Sectoral Partnerships
ESG & Beyond GDP
International Collaboration
New Materials
Open Data

TECHNOLOGIES

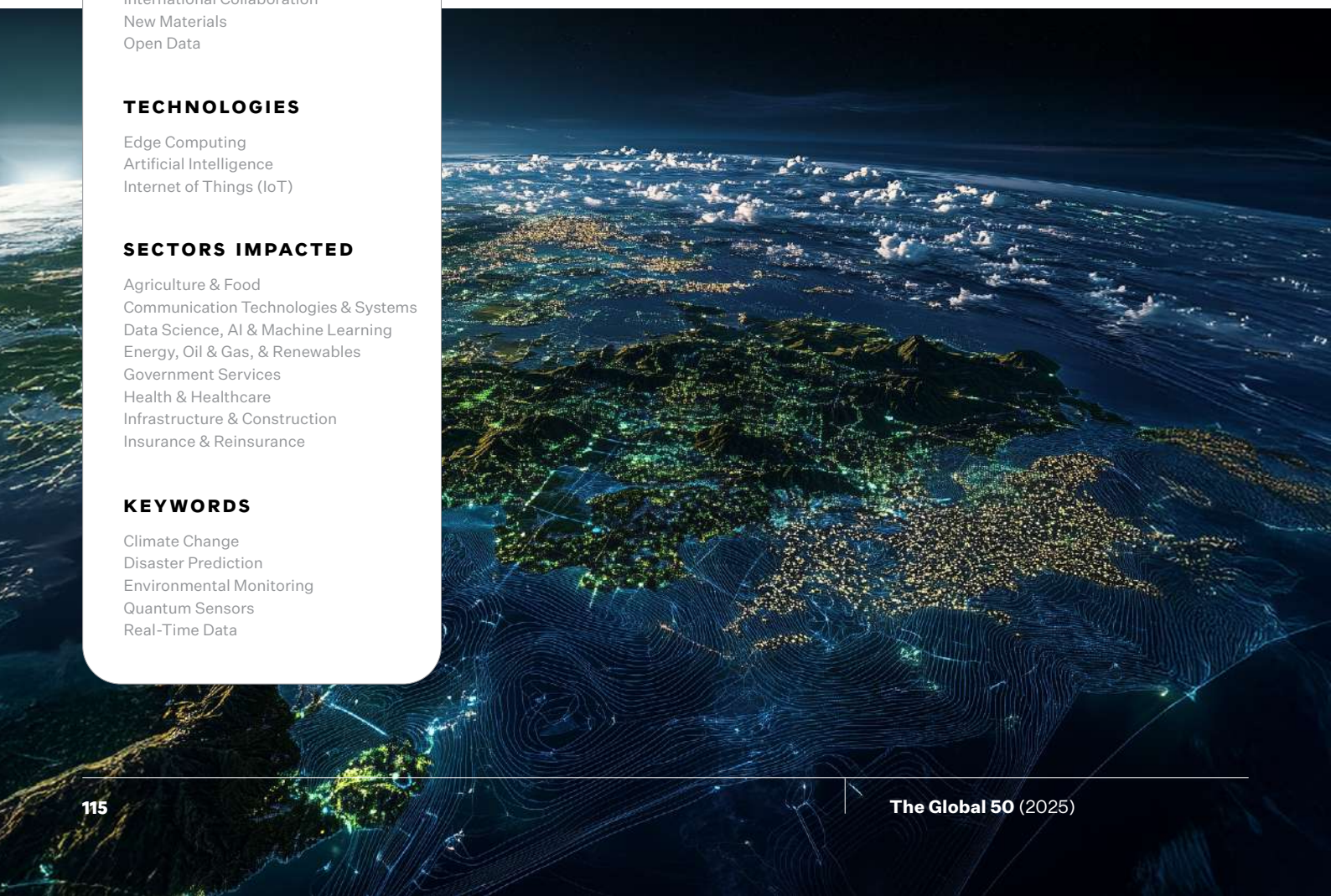
Edge Computing
Artificial Intelligence
Internet of Things (IoT)

SECTORS IMPACTED

Agriculture & Food
Communication Technologies & Systems
Data Science, AI & Machine Learning
Energy, Oil & Gas, & Renewables
Government Services
Health & Healthcare
Infrastructure & Construction
Insurance & Reinsurance

KEYWORDS

Climate Change
Disaster Prediction
Environmental Monitoring
Quantum Sensors
Real-Time Data



WHY IT MATTERS TODAY

Climate change is intensifying extreme weather events, **making accurate prediction more crucial than ever**, as the frequency and severity of disasters such as hurricanes, floods and wildfires are expected to rise

Climate change is intensifying extreme weather events, making accurate prediction more crucial than ever. According to the insurance company Swiss Re, in 2022, natural disasters had nearly 102 million victims and caused 10,500 fatalities globally, and economic losses from natural disasters increased to $275 billion.[710] As the global climate continues to warm, it is expected that the frequency and severity of natural disasters, such as hurricanes, floods and wildfires, will increase.[711] Comprehensive environmental data can help governments and businesses make more informed decisions, reducing the risks associated with climate change and environmental degradation.[712]

Public awareness and concern about climate change and natural disasters are increasing. The Peoples' Climate Vote is the world's largest standalone public opinion survey on climate change. In the 2024 survey, covering 77 countries and representing 87% of the world's population, 80% of the respondents wanted stronger climate action and over half (53%) said that they were more worried about climate change than they had been in 2023.[713] Environmental monitoring is emerging as a powerful tool for diplomatic collaboration.[714]

Quantum technologies are expected to disrupt applications across sectors, such as finance, healthcare and defence. With the potential to generate economic value surpassing $2 trillion by 2035,[715] quantum sensing could reach $2.7 billion by 2035.[716] Quantum sensors that use nitrogen-vacancy centres in diamond can measure numerous properties, including magnetic or electric fields,[717] temperature and rotational motion, with preciseion.[718,719] While many quantum sensors are at the proof-of-concept stage, some are commercially available for various purposes, including leak detection in underground pipes and volcano monitoring.[720]

THE OPPORTUNITY

A real-time environmental monitoring system built on a multilayered, globally distributed quantum sensor network improves environmental monitoring, weather forecasting accuracy, and disaster prediction. The network includes atmospheric sensors (e.g. in high-altitude weather stations, satellite-based remote sensing platforms, mountain observatories, and polar research stations),[721,722] ground sensors (e.g. in forest stations, agricultural research centres, national parks, urban environmental nodes, and geological research sites),[723,724] and oceanic sensors (e.g. in deep-sea sensor networks, coastal stations, marine research vessels, underwater sensor arrays, and coral reef monitoring points).[725,726,727]

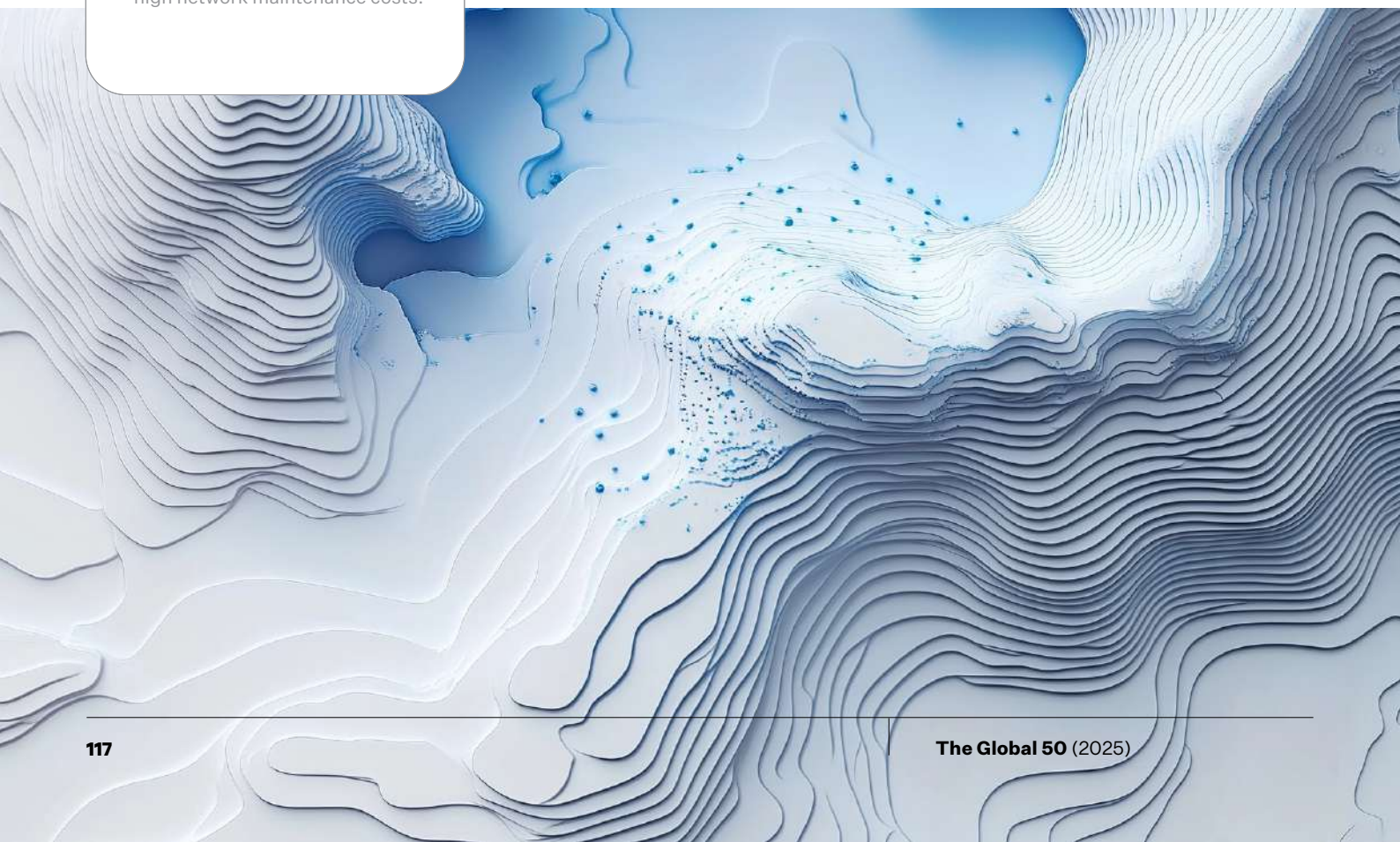
Advanced machine intelligence optimises sensor placement in critical environmental zones, including seismically active regions, mountain ranges, coastal areas, urban centres, and agricultural areas. Self-contained sensor nodes, powered by solar or advanced battery micropower systems and edge computing,[728] provide real-time data analysis and sharing.

BENEFITS

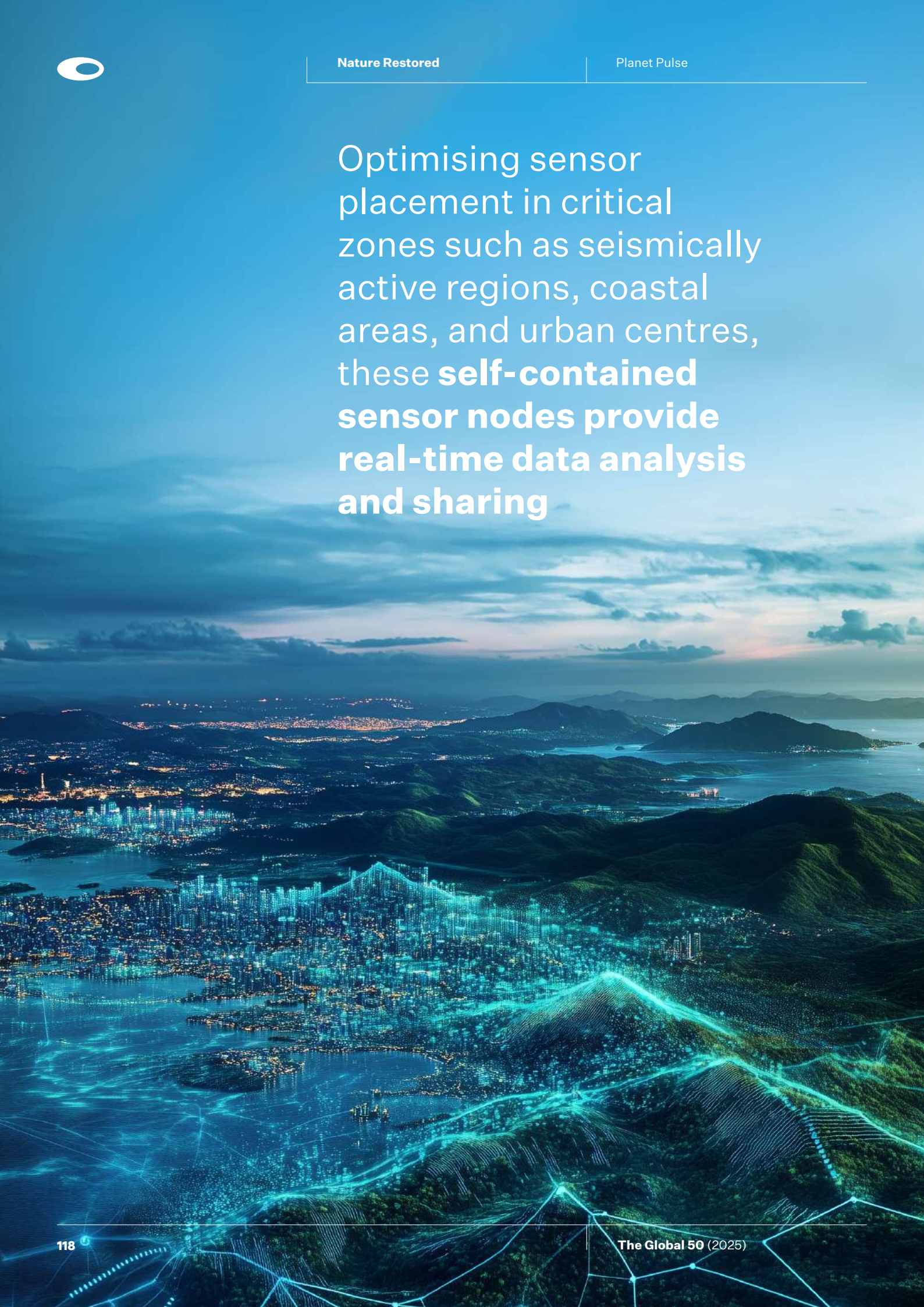
Better forecasting and climate decision-making from live data on oceans, marine life, and forests; open data for research; unprecedented precision in environmental monitoring and action; proactive measures to protect people from natural disasters.

RISKS

Unequal access to data; data manipulation; inconsistent measurement methodologies; wear and tear of sensor network; high network maintenance costs.



Optimising sensor placement in critical zones such as seismically active regions, coastal areas, and urban centres, these **self-contained sensor nodes provide real-time data analysis and sharing**



What if ships generated their own energy and helped reduce emissions at sea?

15

Deep-Sea Energy

Within Reach | Transitional | **Visionary**

Ocean-powered ships use temperature differences between surface and deep seawater to generate their own renewable energy while autonomously identifying and following optimal routes, contributing to a more sustainable future for marine transport.

UNCERTAINTIES

Systems, Technology

MEGATREND (Most significant)

Energy Boundaries

TRENDS

Ideation, IP & Entrepreneurship
Net Zero
Transforming Energy
Transforming Logistics

TECHNOLOGIES

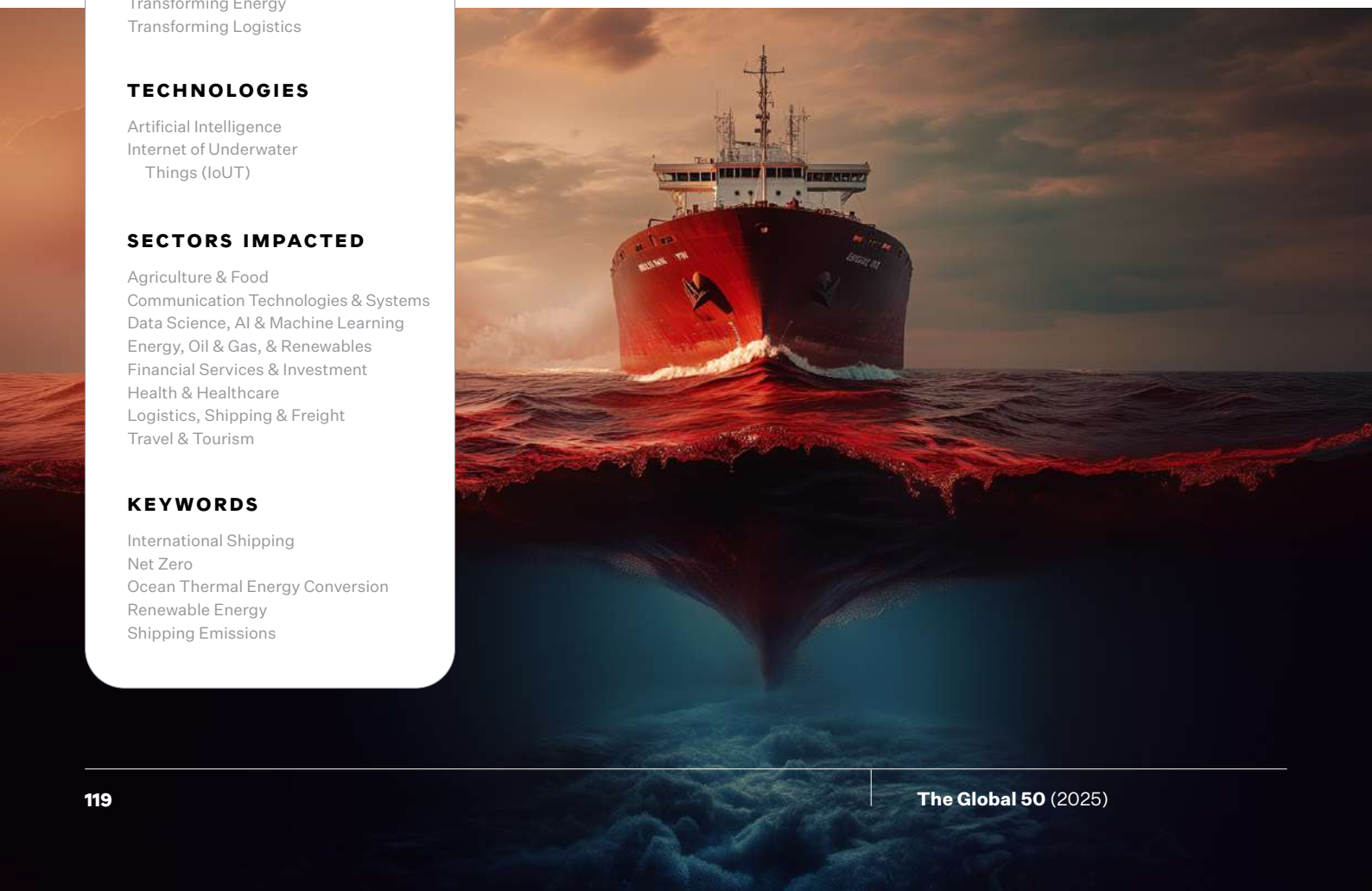
Artificial Intelligence
Internet of Underwater Things (IoUT)

SECTORS IMPACTED

Agriculture & Food
Communication Technologies & Systems
Data Science, AI & Machine Learning
Energy, Oil & Gas, & Renewables
Financial Services & Investment
Health & Healthcare
Logistics, Shipping & Freight
Travel & Tourism

KEYWORDS

International Shipping
Net Zero
Ocean Thermal Energy Conversion
Renewable Energy
Shipping Emissions



WHY IT MATTERS TODAY

Marine transport supports up to

90%

of global trade, and **greenhouse gas** emissions will increase by

50% to **250%**

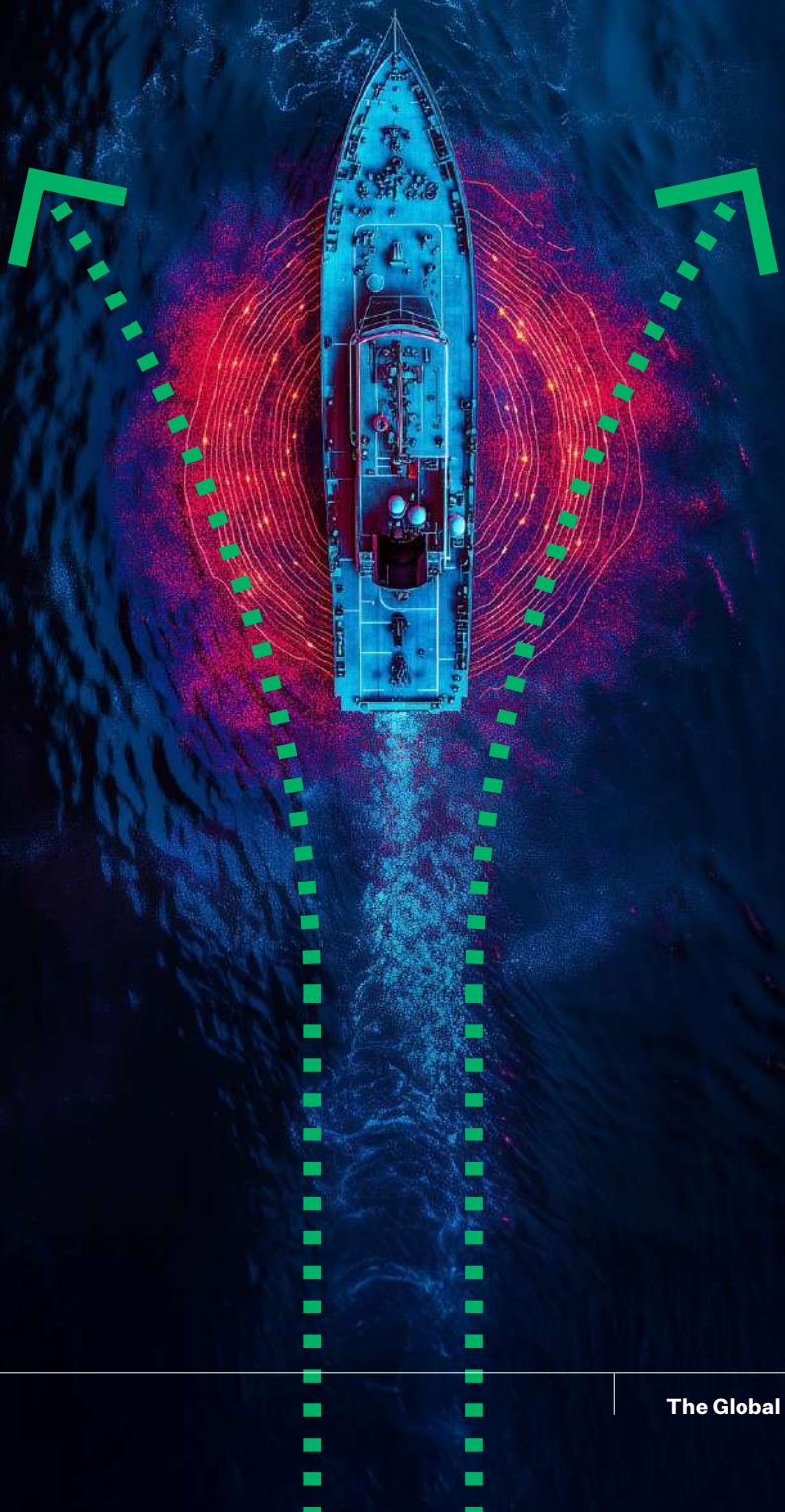
by 2050 **if no action is taken**

Up to 90% of global trade depends on international shipping.[729] The International Maritime Organization projects that maritime trade will increase by 40–115% by 2050 compared to 2020.[730] If no action is taken, greenhouse gas emissions from the shipping industry could rise by 50–250%.[731]

Marine transport impacts human health. Ship emissions are contributing to deteriorating air quality on land, despite being released at sea, as these pollutants can drift hundreds of kilometres.[732] While these numbers can fluctuate, marine transport is responsible for approximately 13% of nitrogen oxide and 12% of sulphur oxide emissions, both of which pose significant risks to human health.[733] Additionally, such pollution accelerates ocean acidification, threatening marine food chains and the human food supply chain.[734]

Air pollution from shipping disproportionately impacts certain communities and regions. Populations living near major shipping routes experience the highest concentrations of shipping-related air pollution, making them more at risk of adverse health effects and economic strain.[735] Achieving net-zero emissions in shipping by 2050 will require both advances in renewable technologies and design improvements for energy efficiency.[736]

Smart routing systems help vessels identify routes with sufficient temperature differentials



THE OPPORTUNITY

Ships are equipped with modular ocean thermal energy conversion (OTEC) systems, optimised and integrated into the vessel's design to generate electricity while at sea. Using satellite data[737] and deep-sea temperatures measured by the Internet of Underwater Things (IoUT),[738] the system activates when it detects a temperature difference of at least 20°C between the warm surface seawater and cold deep seawater,[739] driving turbines to generate electricity.[740]

While technically challenging, integrating OTEC systems into marine vessels offers a promising pathway towards renewable energy generation[741] and offers a more sustainable future for marine transport.[742] Smart routing systems help vessels identify routes with sufficient temperature differentials. With advanced energy storage solutions and next-generation battery technologies, vessels can store surplus power to meet their energy needs in areas that do not have sufficient temperature differentials or that have only limited energy access.

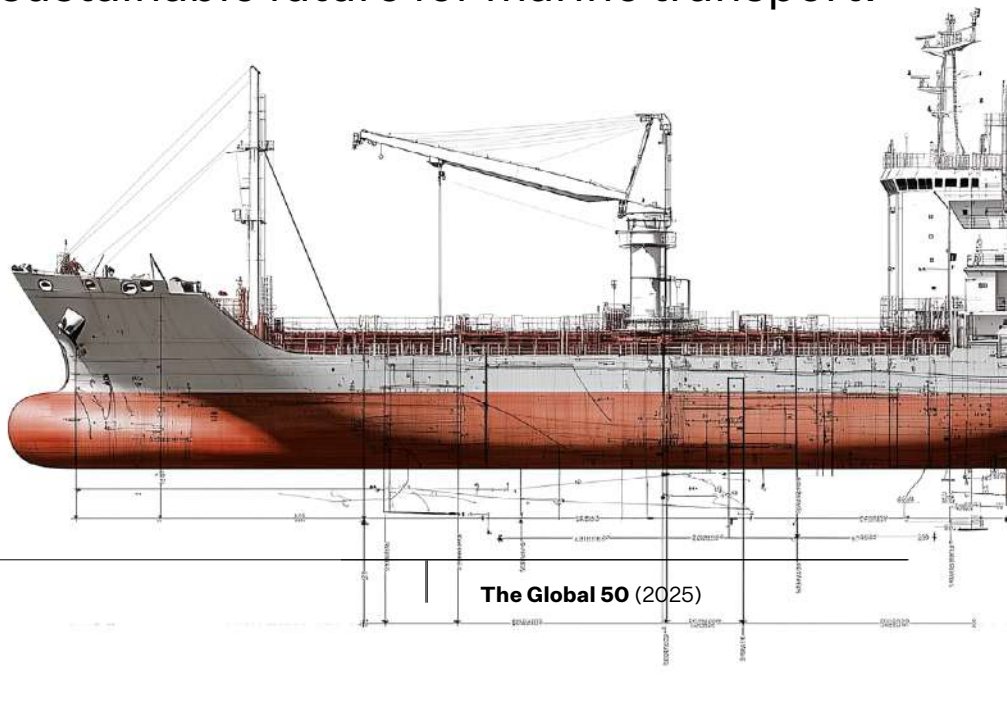
BENEFITS

Clean energy in marine transportation; reduced environmental impact; energy transfer to land-based communities; removal of the need for refuelling.

RISKS

Higher offshore maintenance costs; significant upfront capital investment; significant engineering challenges; shipping delays.

An engineering opportunity and challenge, integrating ocean thermal energy conversion (OTEC) into marine vessels offers a more sustainable future for marine transport.



What if calcium became the new lithium?

16

Calcium Power Play

Within Reach | **Transitional** | Visionary

Calcium batteries outperform lithium-ion to address energy storage needs through advances in design and materials for reliable performance across temperatures and cycles.

UNCERTAINTIES

Systems, Technology

MEGATREND (Most significant)

Energy Boundaries

TRENDS

ESG & Beyond GDP
Future of Raw Materials
Mobilising Innovation
New Materials

TECHNOLOGIES

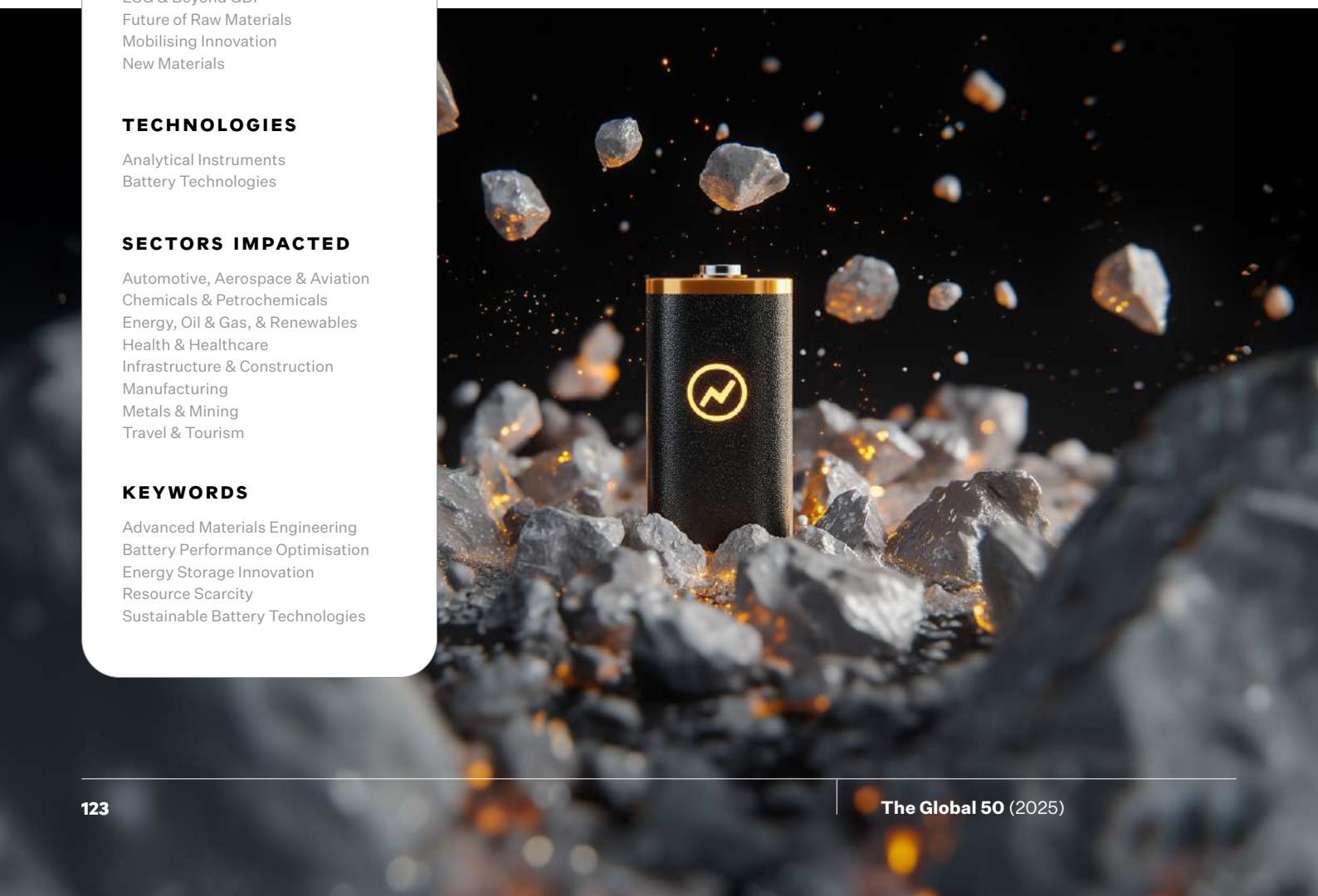
Analytical Instruments
Battery Technologies

SECTORS IMPACTED

Automotive, Aerospace & Aviation
Chemicals & Petrochemicals
Energy, Oil & Gas, & Renewables
Health & Healthcare
Infrastructure & Construction
Manufacturing
Metals & Mining
Travel & Tourism

KEYWORDS

Advanced Materials Engineering
Battery Performance Optimisation
Energy Storage Innovation
Resource Scarcity
Sustainable Battery Technologies



WHY IT MATTERS TODAY

Lithium demand surged by

30%

in 2023, partially driven by nearly

14 million

electric vehicle sales, yet anticipated **mine supplies will meet only 50% of requirements by 2035**

Because of their high energy, power density, and long cycle life,[743] lithium-ion batteries are the most used battery technology in portable electronic devices and vehicles.[744] However, as lithium demand rises rapidly,[745] there is an urgent need to find alternatives to address issues related to sustainability, resource scarcity, safety and cost.[746] The demand for lithium increased by 30% in 2023, with electric vehicle (EV) sales reaching almost 14 million, a 35% year-on-year increase.[747] With EV batteries lasting only five to eight years,[748] the anticipated mine supply of lithium will meet only 50% of requirements by 2035.[749]

Environmental and safety concerns are also significant. The manufacturing of lithium-ion batteries requires cobalt, lithium, magnesium and nickel – materials associated with health risks.[750] Moreover, only 5% of lithium-ion batteries are recycled globally[751] though exact numbers are unclear. In addition, these batteries pose significant fire risks, causing an estimated 48% of waste fires in the United Kingdom and costing £158 million annually.[752, 753]

Emerging alternatives include sodium-ion batteries, with car manufacturers, including those in China, planning EV rollouts by 2025.[754] Sodium, magnesium, calcium and potassium offer greener, scalable battery technologies,[755] with calcium offering the highest energy capacity.[756]

THE OPPORTUNITY

A new generation of calcium-based batteries outperform lithium-ion batteries[757] by overcoming longstanding barriers in calcium battery development.[758]

Calcium, one of the most abundant metals on Earth,[759] surpasses other battery metals (aluminium, lithium, magnesium, potassium, sodium and zinc) in both melting point and electrical conductivity.[760] Its higher melting point reduces fire risk compared with lithium batteries. Advanced machine intelligence, combined with novel materials, aids optimal battery design with suitable electrolytes and cathode components, ensuring consistent and reliable storage across different temperatures and over multiple charge cycles.[761]

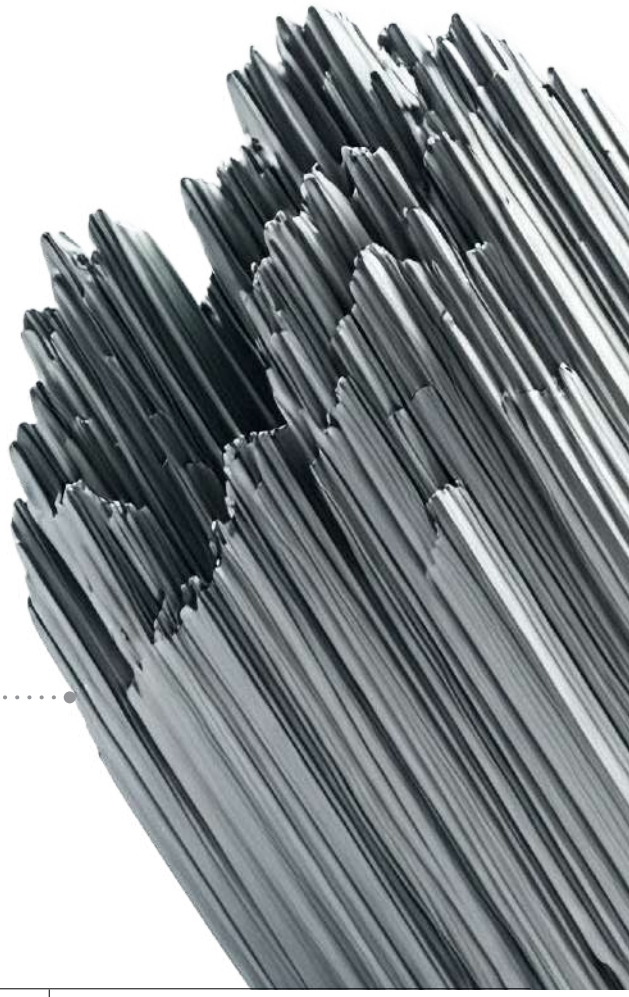
BENEFITS

Affordable clean energy storage; reduced environmental impact; increased energy independence; global access to sustainable technologies; job creation in new industries; improved safety.

RISKS

Job losses in traditional lithium-focused industries; environmental risks from gathering new resources; technological uncertainties; disruption of established economies that rely on lithium.

Calcium, **one of the most abundant metals on Earth**, surpasses other battery metals in both melting point and electrical conductivity



What if airborne wind farms became a widespread reality?

17

High Energy

UNCERTAINTIES

Systems, Technology

MEGATREND (Most significant)

Energy Boundaries

TRENDS

Cross-Sectoral Partnerships
Net Zero
New Materials

TECHNOLOGIES

Advanced Connectivity
Energy Transformation
Internet of Things (IoT)

SECTORS IMPACTED

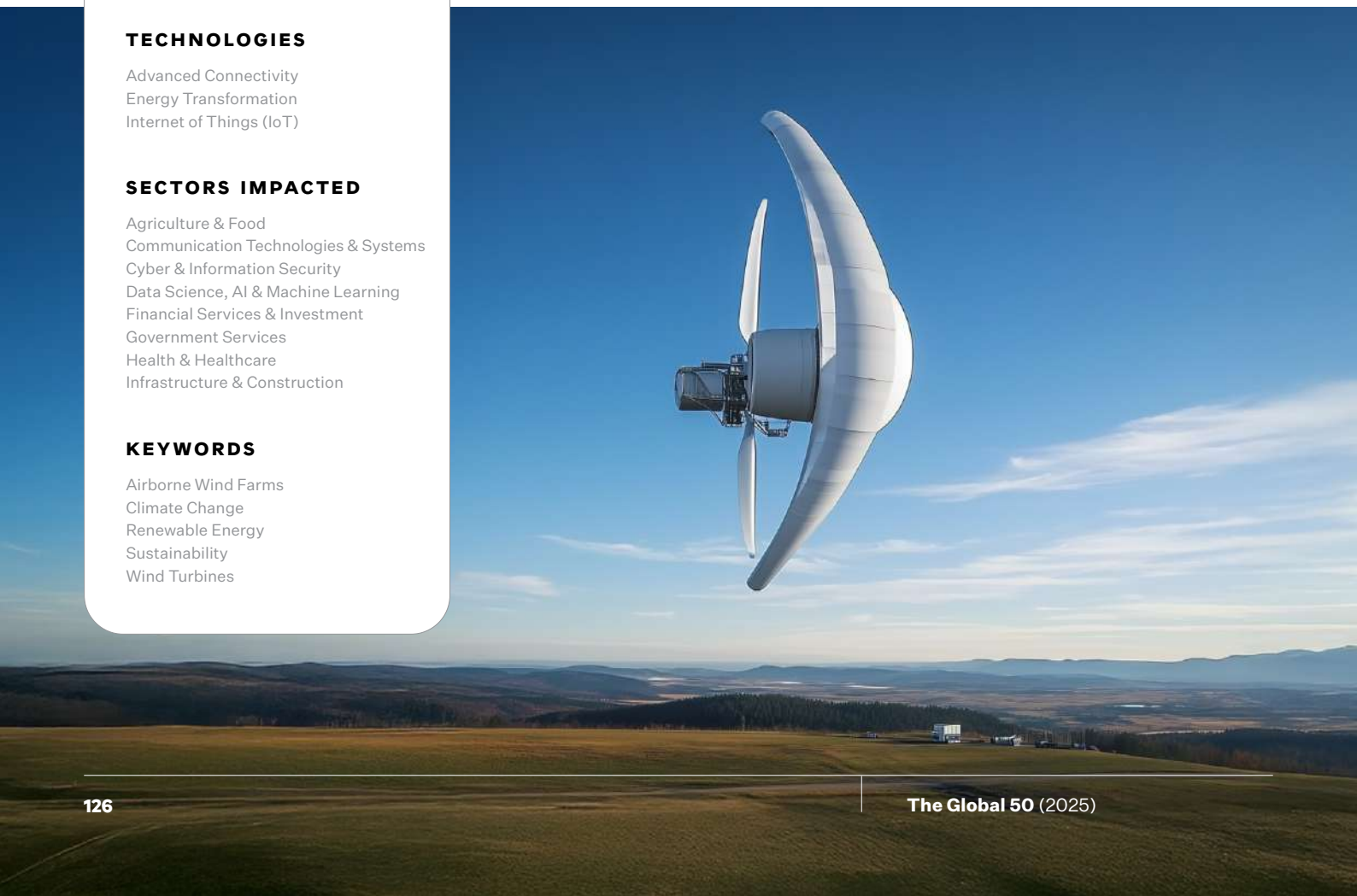
Agriculture & Food
Communication Technologies & Systems
Cyber & Information Security
Data Science, AI & Machine Learning
Financial Services & Investment
Government Services
Health & Healthcare
Infrastructure & Construction

KEYWORDS

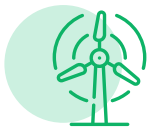
Airborne Wind Farms
Climate Change
Renewable Energy
Sustainability
Wind Turbines

Within Reach | **Transitional** | Visionary

Next-generation airborne wind turbines, durable and resilient to high winds, provide a new form of urban and remote energy generation by capturing energy from high-altitude winds to power future cities.



WHY IT MATTERS TODAY



Technological advances in wind turbine design and 3D printing offer solutions to unlock

80%

more wind energy potential, addressing **challenges posed by shifting weather patterns and urbanisation**

There are increasing global demands for renewable energy, but global renewable energy growth is not expected to meet the 28th United Nations Climate Change Conference (COP28) goal of tripling global renewable energy capacity by 2030.[762] Electricity generation from wind grew by 265 TWh (14%) in 2022, reaching 2,100 TWh.[763] To meet the goal of multiplying this capacity by three and a half times by 2030, consistent annual capacity additions of 14-17% will be required.[764]

Shifting weather patterns are changing the viability of wind energy. Currently, 93% of global wind capacity is onshore,[765] but an expected decline in wind resources in the northern hemisphere – due to climate shifts[766] – is pushing certain regions that had invested in onshore wind farms to reassess their sustainability and viability.[767] Technological advances (e.g. in blade design, materials, and system optimisation) and advanced manufacturing (including 3D printing) are expected to unlock an estimated 80% more wind energy potential this decade[768] and to increase the energy capture per turbine.[769]

Rapid urbanisation and limited acceptance are reducing options for traditional wind turbines onshore. Roughly 56% of the world's population (4.4 billion people) currently live in cities, and this number is expected to more than double by 2050, with almost 70% living in cities.[770] Traditional wind turbines are not suitable for urban environments, as urban areas do not have enough space for these large structures and people often mount strong resistance because of concerns regarding noise and appearance.[771] Moreover, urban environments do not provide the winds required for efficient energy harvesting.[772] Integrating wind turbines into high-rise buildings – as has been done, for example, in the 240-metre-high Bahrain World Trade Center, where turbines are designed to provide 11–15% of the tower's energy needs[773,774] – allows the capture of stronger winds at higher altitudes within the urban environment.

Roughly

56%

of the world's population (4.4 billion people) **currently live in cities, and this number is expected to more than double by 2050,** with almost

70%

living in cities

THE OPPORTUNITY

BENEFITS

Energy capture from stronger, more consistent winds; provision of energy in remote and urban areas.

RISKS

Dependence on consistent wind conditions; bird strikes; interruptions to air traffic; high cost to build and maintain.

Breakthroughs in engineering, materials science, and nature-inspired designs enable a new generation of airborne wind turbines that are durable and more resilient to high winds. These advanced designs capture energy from stronger, steadier winds at altitudes between 300 and 10,000 m[775] in remote, off-grid,[776] challenging terrain,[777] and even urban environments.

As systems, airborne wind farms convert wind energy into electricity either at ground level or in the air.[778] Biomimetics inspires innovations that enhance turbine blades, while advanced machine intelligence enables more efficient, safer designs that reduce bird strikes and prevent damage or safety incidents from malfunctions,[779] potentially scaling the system to more than 1 MW.[780]

Towers such as Burj Khalifa in Dubai (828 m),[781] Merdeka 118 in Kuala Lumpur (679 m),[782] and the One World Trade Center in New York (541 m)[783] could integrate these wind turbines into their structural designs, bringing wind energy generation into urban environments.

Biomimetics inspires innovations that enhance turbine blades, while **advanced machine intelligence enables more efficient**, safer designs that reduce bird strikes and prevent damage or safety incidents from malfunctions

What if fish waste became a great source of value?

18

Fish Waste to Value

Within Reach | **Transitional** | Visionary

Advanced technologies and biotechnology turn fish waste collected during capture, processing and consumption, into valuable bio-based products such as fertiliser and wound-healing and cosmetic agents, enhancing efficiency in these industries and supporting sustainable fishing practices.

UNCERTAINTIES

Nature, Systems

MEGATREND (Most significant)

Evolving Ecosystems

TRENDS

Bioeconomy
Blue Economy
Food–Water–Energy Nexus
Sustainable Waste Management

TECHNOLOGIES

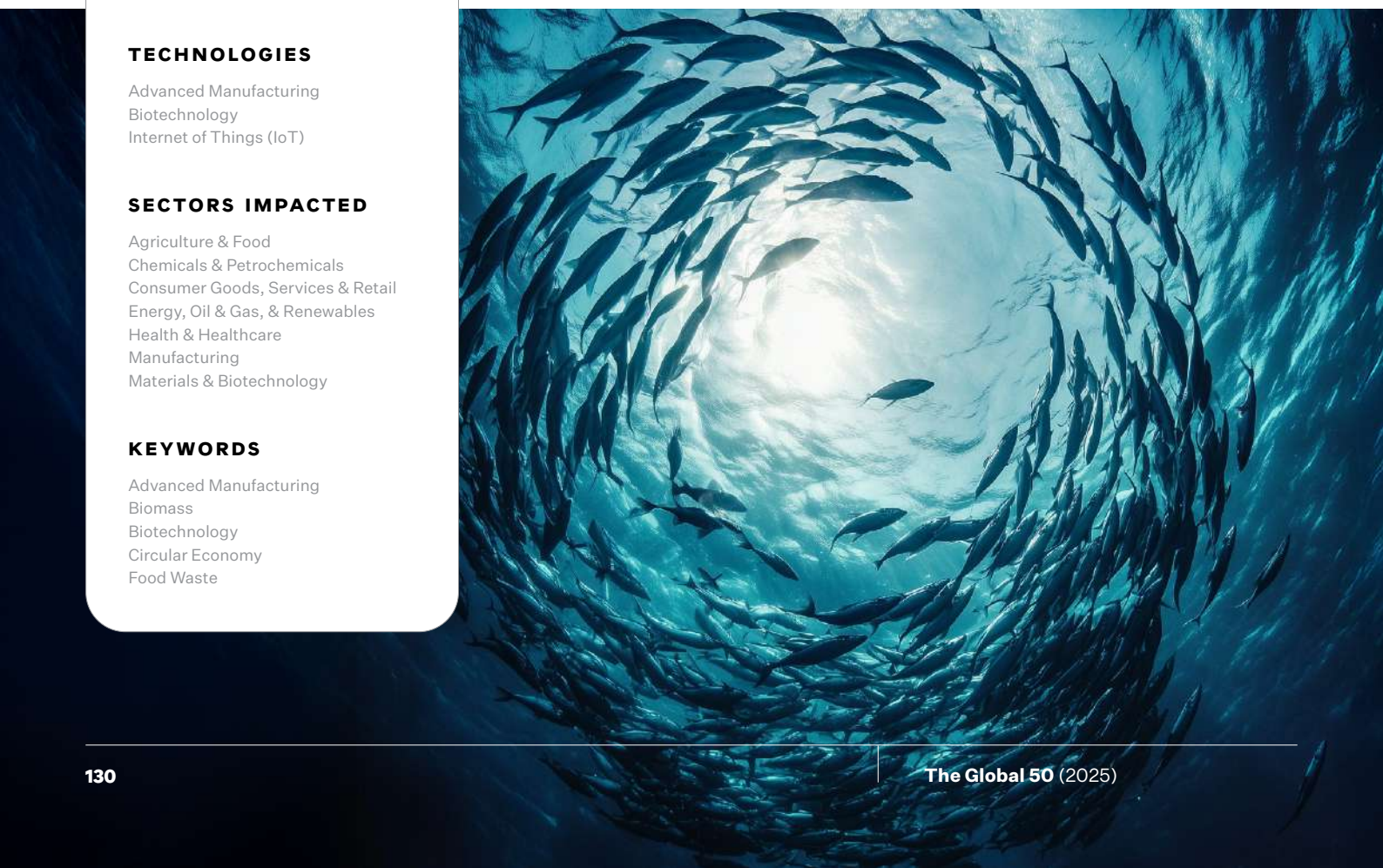
Advanced Manufacturing
Biotechnology
Internet of Things (IoT)

SECTORS IMPACTED

Agriculture & Food
Chemicals & Petrochemicals
Consumer Goods, Services & Retail
Energy, Oil & Gas, & Renewables
Health & Healthcare
Manufacturing
Materials & Biotechnology

KEYWORDS

Advanced Manufacturing
Biomass
Biotechnology
Circular Economy
Food Waste



WHY IT MATTERS TODAY

Aquatic food, a vital source of protein for

3.3 billion

people, faces significant losses during capture, processing and consumption, **highlighting the need for improved handling and infrastructure.**

Agri-food systems are responsible for approximately one-third of global greenhouse gas emissions, making them a central aspect of climate change.[784] Agri-food systems include goods that originate from agriculture, forestry and fisheries. Their emissions primarily stem from crop and livestock production, on-farm energy consumption, land use and land-use changes, domestic food transportation, and food waste disposal.[785]

A significant source of protein for 3.3 billion people around the world,[786] aquatic food makes up nearly one-third of global protein production, 158 million tonnes annually,[787] which is expected to increase by 15%, to 181 million tonnes, by 2030.[788] While the data are varied, significant losses – just over 75% – occur during capture, processing and consumption, driven by discards, spoilage, poor handling, and infrastructure gaps.[789]

There is substantial projected growth for bio-based products, with the global market for bio-based food, products and energy expected to reach $12.8 trillion by 2030.[790] The consumption of bio-based food and feed alone is anticipated to grow at an annual rate of 3.3%, reaching $5 trillion by 2030.[791] Bio-based food includes food produced from renewable sources using fermentation, recycling, and regenerative agriculture.[792]

THE OPPORTUNITY

Advanced manufacturing, advanced machine intelligence, and biotechnology enable innovative extraction and processing of fish waste as part of broader government policies and efforts to support sustainable fishing practices.[793] While better data collection improves tracking of fish capture, production and waste processing, enabling more efficient fish waste management,[794] these technologies efficiently transform fish waste into valuable bio-based products for agriculture (e.g. fertilisers),[795] cosmetics (e.g. collagen)[796] and healthcare (e.g. wound healing).[797]

Advanced extraction methods, such as supercritical fluid extraction and pulsed electric fields, provide sustainable, efficient solutions for extracting high-value components – including proteins, fatty acids and pigments – from fish waste.[798] These extraction methods, when combined with biotechnology such as fermentation, enhance the conversion efficiency.[799]

BENEFITS

Less fish waste in landfill; improved resource efficiency; improvements to the circular economy; support for the Sustainable Development Goals 9 and 12; facilitation of technological advances in biomass processing more generally.

RISKS

Promotion of overfishing because of economic gains further down the supply chain; limited efforts to reduce waste across the supply chain.

Advanced manufacturing, advanced machine intelligence, and biotechnology efficiently transform fish waste into **valuable bio-based products for agriculture (e.g. fertilisers), cosmetics (e.g. collagen) and healthcare (e.g. wound healing)**

Societies Empowered

Empower societies by offering solutions to humanity's most complex and universal needs, optimising systems they rely on, safeguarding risks that could make societies more fragile in the face of crises, and extending individual and collective potential for growth and development.

What if humans trusted robots in the workplace?

19

Robot Rapport

Within Reach | Transitional | Visionary

An international, cross-disciplinary research working group establishes a new model and global standards for human–robot interactions, focusing on building trust by addressing emotional responses and workplace dynamics.

UNCERTAINTIES

Technology, Values

MEGATREND (Most significant)

Life with Autonomous Robots and Automation

TRENDS

Cross-Sectoral Partnerships
Digital Communities
Human–Robot Interactions
International Collaboration
Mobilising Innovation

TECHNOLOGIES

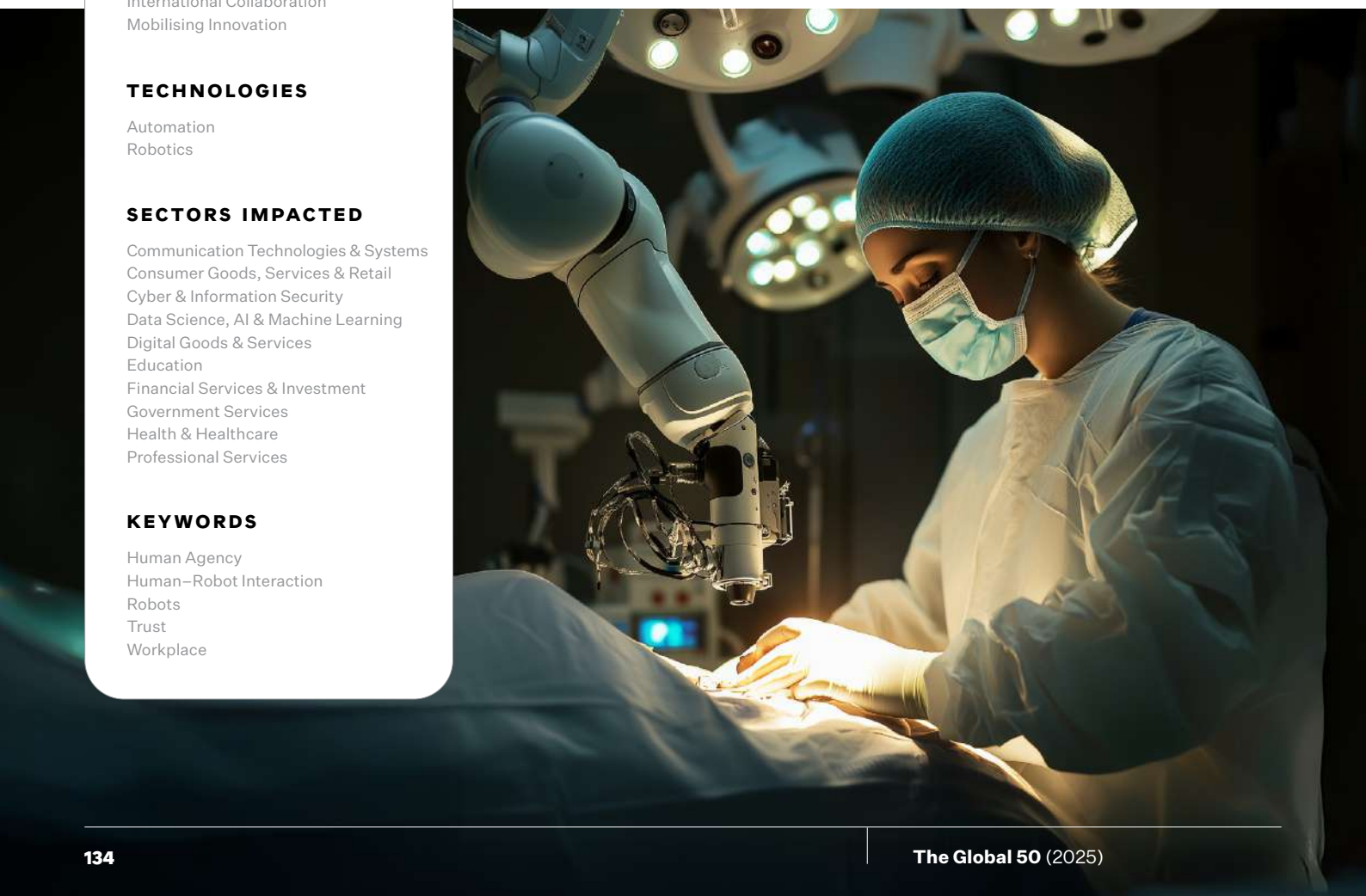
Automation
Robotics

SECTORS IMPACTED

Communication Technologies & Systems
Consumer Goods, Services & Retail
Cyber & Information Security
Data Science, AI & Machine Learning
Digital Goods & Services
Education
Financial Services & Investment
Government Services
Health & Healthcare
Professional Services

KEYWORDS

Human Agency
Human–Robot Interaction
Robots
Trust
Workplace



WHY IT MATTERS TODAY

The global population of industrial robots is

4 million

and between 2024 and 2027 the number of industrial robots is expected to increase by 4% per year in Asia, Australia and the Americas and by 3% in Europe

Despite growing reliance on AI in robotics,

71%

of people believe that AI regulation is required, highlighting concerns around **privacy, safety and the societal impact of AI technologies**

Robots are here. The population of industrial robots around the world is 4 million, with the automotive sector seeing a 25% increase in robot installations in 2023, followed by the electronics sector at 23% and the metal and machinery industry at 14%.[800] In large part because of growing labour shortages in high-income countries, between 2024 and 2027 the number of industrial robots is expected to increase by 4% per year in Asia, Australia and the Americas and by 3% in Europe.[801] The majority of professional service robots are used in transportation and logistics, followed by hospitality, agriculture, professional cleaning, and medicine.[802] This raises public concerns about job losses, bias, widening socio-economic disparities, and the impact on human interaction.[803]

Alongside robotics, artificial intelligence (AI) raises a mixed response. Across 17 countries, 71% believe that AI regulation is required, while less than one in five people (17%) believe that AI regulation is not needed, and the remaining 12% are unsure.[804] In the 2024 Edelman Trust Barometer, only 30% of global respondents embraced AI, while 35% rejected it, with key concerns including privacy, human value, societal impact, and insufficient testing.[805] Nevertheless, the extent to which robots and AI will replace people remains uncertain, despite earlier predictions about their integration into daily life and work.[806]

The human–robot relationship is complex. While ethical and safety standards (e.g. those of the International Organization for Standardization, the British Standards Institution, and the US National Institute of Standards and Technology) provide important guidelines, further development is needed to address evolving challenges of integrating robots into the workplace[807] and other social contexts. Beyond technical and safety concerns, the human–robot relationship extends to broader emotional, ethical and social landscapes.

Beyond technical and safety concerns, **the human–robot relationship extends to broader emotional, ethical and social landscapes**

THE OPPORTUNITY

BENEFITS

Evidence-based integration of robots; global synergies; faster adoption of robots as a result of increased acceptance; increased human agency and sense of purpose in human–robot collaboration.

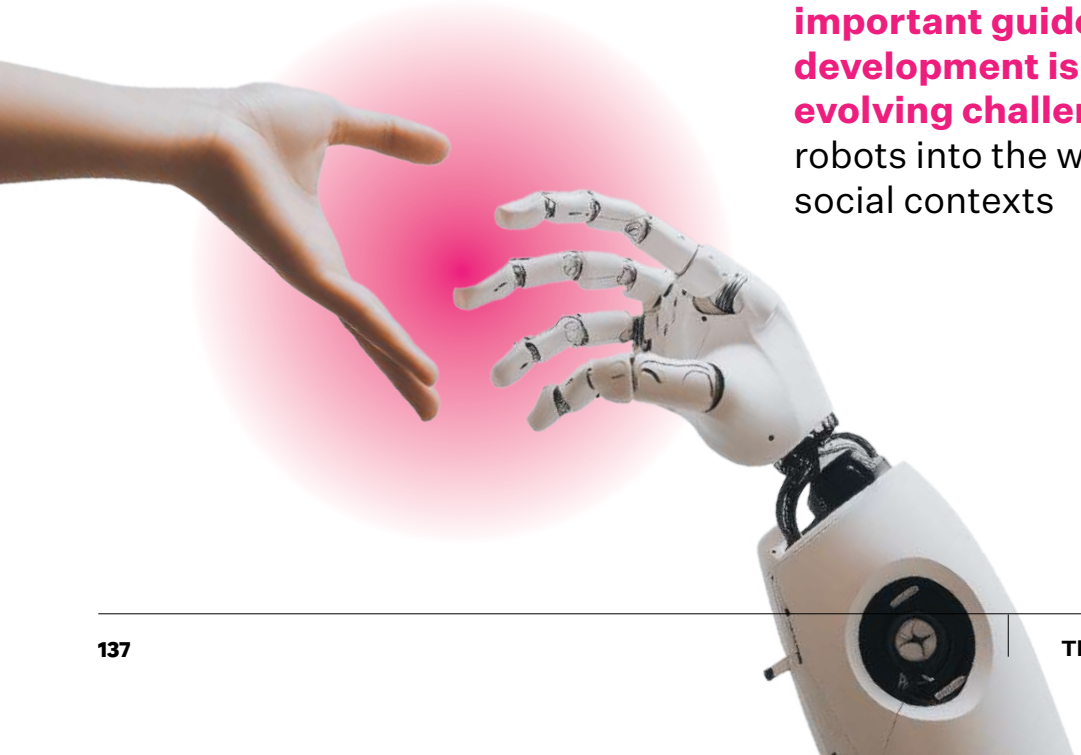
RISKS

Failure to reduce resistance; complex cross-cultural synergies; complex interdisciplinary coordination.

An international working group of researchers representing diverse disciplines – from anthropology, behavioural sciences, communications, engineering, neuroscience and psychology – developed a new model and related standards for human–robot interactions, particularly in the workplace. This model represents a paradigm shift in integrating robots into society for the long-term benefit and trust of humans.

In addition to consolidating existing research, the group builds a repository of longitudinal and real-world case studies and data to enhance research across cultural and situational contexts. The model explores why and how humans respond emotionally to various robots, focusing on theories such as social identity and emotional contagion.[808] This serves as a foundation for a robust human–robot ecosystem in which innovation thrives without sacrificing human agency or societal values, enabling faster and more confident adoption across sectors while establishing a sense of purpose for society.

The human–robot relationship is complex and **while existing ethical and safety standards provide important guidelines, further development is needed to address evolving challenges** of integrating robots into the workplace and other social contexts



What if quantum theory inspired innovative solutions to global challenges?

20

Quantum X

UNCERTAINTIES

Systems, Technology

MEGATREND (Most significant)

Future Humanity

TRENDS

Cross-Sectoral Partnerships
Future of Purpose & Work
Mobilising Innovation

TECHNOLOGIES

Artificial Intelligence
Quantum Technologies

SECTORS IMPACTED

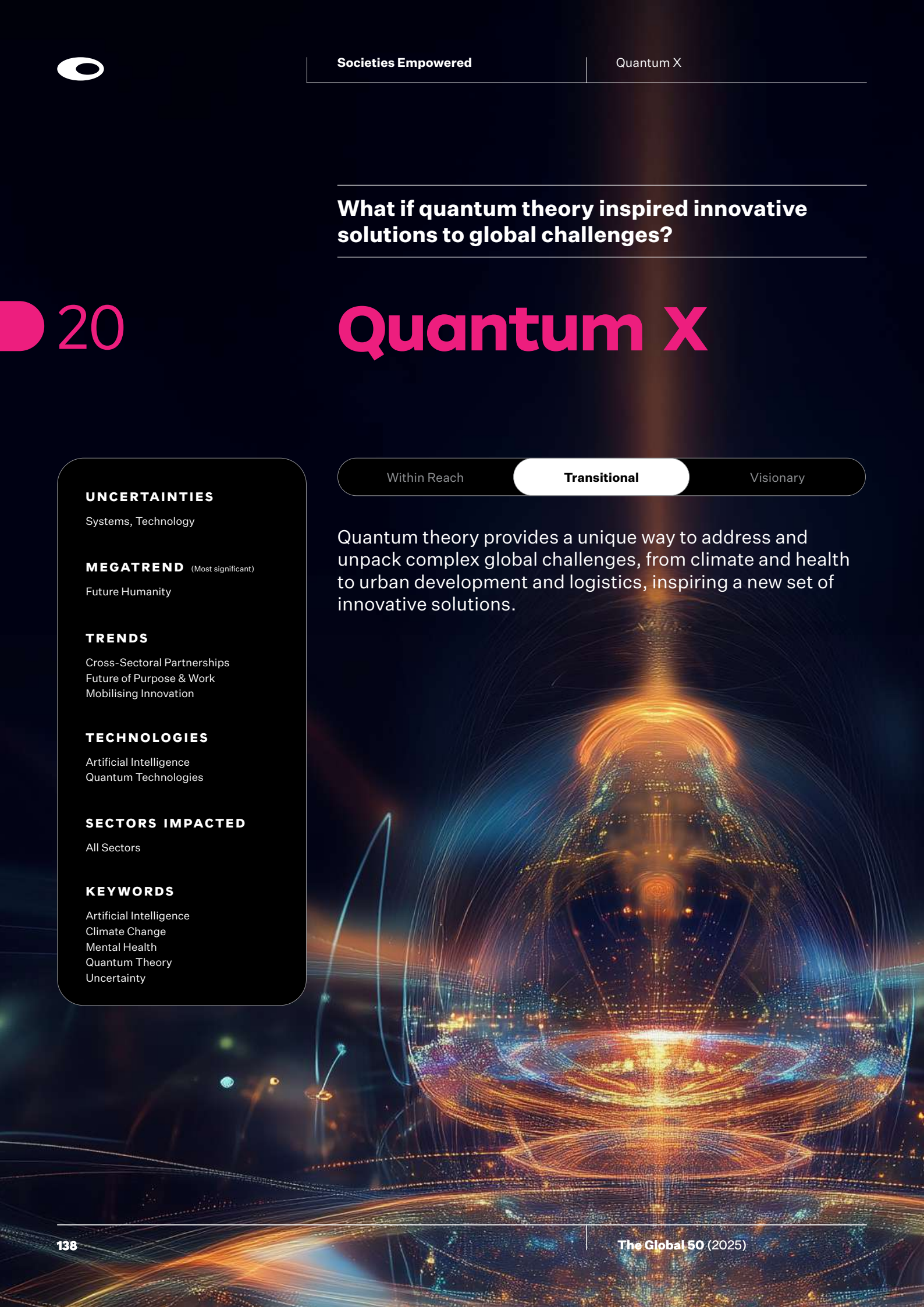
All Sectors

KEYWORDS

Artificial Intelligence
Climate Change
Mental Health
Quantum Theory
Uncertainty

Within Reach | **Transitional** | Visionary

Quantum theory provides a unique way to address and unpack complex global challenges, from climate and health to urban development and logistics, inspiring a new set of innovative solutions.



WHY IT MATTERS TODAY

Climate change is accelerating, with global temperatures rising over

1°C

annually, threatening species and exacerbating health issues

The need for innovative solutions to global challenges is pressing. Increasingly borderless, the information and communications technology sector grew by an average of 6.3% between 2013 and 2023, three times faster than the economies of 27 out of 38 countries in the Organisation for Economic Co-operation and Development.[809] Challenges in this increasingly digital world include security, digital literacy, misinformation, disinformation, polarisation and cyberattacks.[810]

The way that AI is both complementing and replacing jobs is also creating a sense of generalised uncertainty. Investment in generative artificial intelligence (GenAI) grew from $1.3 billion in 2022 to $17.8 billion in 2023,[811] and there has been a parallel 53-fold increase in cyber incidents and hazards related to GenAI since late 2022.[812] AI is expected to affect 40% of global jobs – up to 60% in high-income economies compared with 26% in low-income countries.[813] Although the actual impact of AI on jobs is not clear, there is a risk that AI may increase problems relating to income and wealth inequalities.[814]

Other global challenges include both mental health and climate change. Approximately 14% of children and adolescents aged 10 to 19 years experience mental health conditions,[815] and across 31 countries, mental health is people's top health concern.[816] In terms of the climate, global temperatures are increasing more than 1°C annually on average and are expected to surpass 1.5–2°C target in the next two decades.[817] A million species are at risk of extinction,[818] and infectious diseases, deforestation and pollution are expected to continue to proliferate.[819] Nonlinear and deeply interconnected, complicated multiscale models are key to understanding the impacts and developing potential solutions.[820]

Quantum theory and related concepts help unpack how communities evolve in different ways within different contexts and spheres, **offering new ways of thinking and creative ways to disentangle increasingly complex challenges**

THE OPPORTUNITY

BENEFITS

Application of creative thinking across domains; innovative breakthroughs.

RISKS

Misapplication of quantum principles because of their complexity.

While quantum theory is a branch of physics, related concepts such as entanglement[821] and superposition[822] serve as metaphors for an era of rapid shifts, interconnected change, and complex societal challenges. As a result, quantum theory offers a unique lens to explore how communities evolve in different ways within different contexts and spheres providing new ways of thinking to solve increasingly complex challenges.

Quantum theory has been explored in various domains, from philosophy[823] and international relations[824] to explaining cognitive processes[825] and mental health.[826] For example, superposition reflects how human traits exist on a spectrum, shaped through intentional effort and deliberate choices.[827] From climate change and healthcare to urban development and logistics, quantum theory helps integrate diverse perspectives, balancing technical, social, environmental and economic factors for robust, sustainable policies and solutions. Beyond quantum technologies,[828] quantum principles could guide the redesign of physical and digital working spaces to facilitate collaboration and creativity.[829] Quantum theory could offer a deeper understanding of climate patterns and the complex connections between climate mitigation, adaptation and resilience as well as providing insights into emissions for improved carbon accounting.

What if experiencing dystopian futures inspired purposeful action towards a better future?

21

Dystopian Inspiration

Within Reach | Transitional | **Visionary**

Multisensory simulations of dystopian scenarios immerse decision-makers in possible futures, inspiring purposeful and collective action that shapes policies to enhance preparedness and adaptation to evolving challenges.

UNCERTAINTIES

Systems, Values

MEGATREND (Most significant)

Future Humanity

TRENDS

Cross-Sectoral Partnerships
ESG & Beyond GDP
Government Agility
International Collaboration
Open Data

TECHNOLOGIES

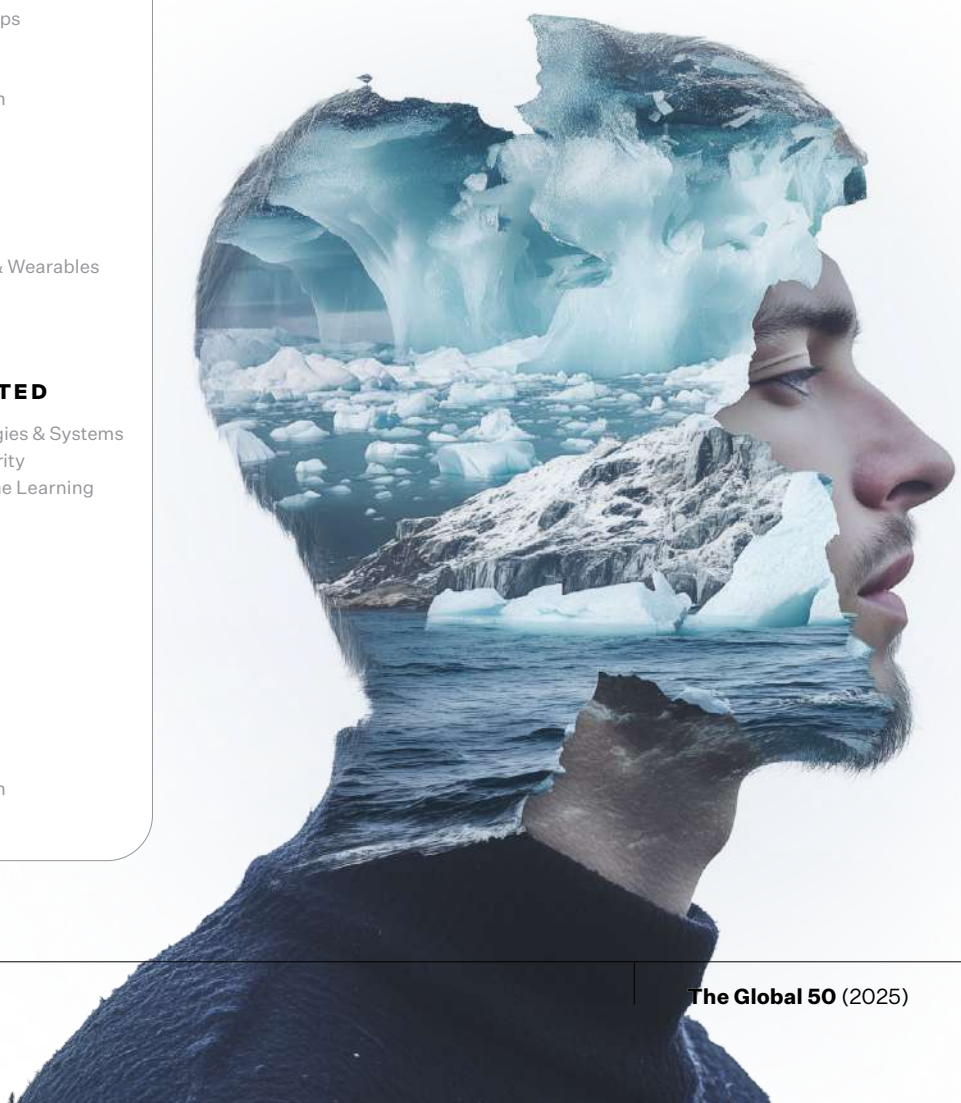
Artificial Intelligence
Immersive Technologies & Wearables
Real-Time Analytics

SECTORS IMPACTED

Communication Technologies & Systems
Cyber & Information Security
Data Science, AI & Machine Learning
Education
Government Services
Immersive Technologies

KEYWORDS

Climate Threats
Cybersecurity Threats
Extended Reality
Haptics
International Collaboration



WHY IT MATTERS TODAY

The global economy may face a

19%

income reduction within the next 26 years because of climate change (likely range 11–29%)

Traditional policymaking may be insufficient in the face of increasing global instability. Fifty-four per cent of global experts anticipate significant instability and a moderate risk of global catastrophes in the next two years, while 63% predict a 'stormy' or 'turbulent' world order by 2034.[830] Climate change, technological disruption, cybersecurity threats, and pandemics are just a few of the complex issues that threaten our future.

Nearly 90% of respondents in a United Nations survey acknowledge that international collaboration is essential to addressing contemporary challenges.[831] These interconnected problems require a new paradigm of international cooperation that goes beyond conventional diplomatic channels and isolated national solutions. Effective responses now demand multistakeholder approaches involving governments, international organisations, private sector entities, civil society groups, and scientific communities imagining the future together to enable aligned decisions that have more impact.

There is a need for intelligent resource allocation in an era of limited resources. The global economy may face a 19% income reduction within the next 26 years because of climate change (likely range 11–29%).[832] Regional impacts will be severe; for example, North America and Europe are expected to see an income reduction of approximately 11%, and South Asia and Africa approximately 22%.[833] Similarly, the economic output gap between high-income and low-income countries is already 25% larger because of the effects of climate change.[834] Bold policy action is needed given that global natural resource consumption is forecast to rise by 60% by 2060 compared with 2020 levels.[835]

Bold policy action is needed given that global natural resource consumption is forecast to rise by

60%

by 2060 compared with 2020 levels

THE OPPORTUNITY

BENEFITS

Improved preparedness for global challenges; enhanced long-term planning and resilience; potential basis for global collaboration; accessibility; enhanced policymaking.

RISKS

Increased anxiety and pessimism; misallocation of resources to unlikely scenarios; failure to prevent the worst-case scenario; potential misuse; high cost to build and maintain.

Combined, haptics, extended reality, advanced machine intelligence, and predictive analytics produce multisensory experiences of dystopian futures for decision-makers, enabling governments and organisations to model and respond proactively to potential crises. By simulating worst-case scenarios, such as climate disasters, technological disruptions, mass displacement, cyberattacks, and food system collapses, this approach transforms abstract threats into actionable insights. It helps decision-makers and policymakers to allocate resources and establish emergency funds more effectively and create robust response mechanisms that can adapt to evolving challenges.

Advanced machine intelligence plays a pivotal role in generating increasingly sophisticated yet realistic simulations, integrating vast datasets from historical events and existing signals. Real-time analytics track emerging patterns across global markets, social movements, and environmental indicators to ensure that the scenarios generated are based on the latest socio-economic conditions. With international collaboration and cross-sector partnerships for open data, these simulations can inspire global collective action.

Advanced machine intelligence generates realistic simulations, integrating vast datasets and real-time analytics, enabling decision-makers to allocate resources more effectively and create adaptable response mechanisms for evolving global challenges

What if living meaningful lives became the new well-being?

22

Reinventing Happiness

Within Reach | **Transitional** | Visionary

As the world shifts towards a possible future of self-sufficient communities, eudaemonic well-being – emphasising personal growth, meaningful relationships, and collective purpose – shapes policies and institutional frameworks around a more fulfilling concept of human development.

UNCERTAINTIES

Systems, Values

MEGATREND (Most significant)

Future Humanity

TRENDS

ESG & Beyond GDP
Future of Education
Future of Purpose & Work
Longevity & Vitality
Mental Health

TECHNOLOGIES

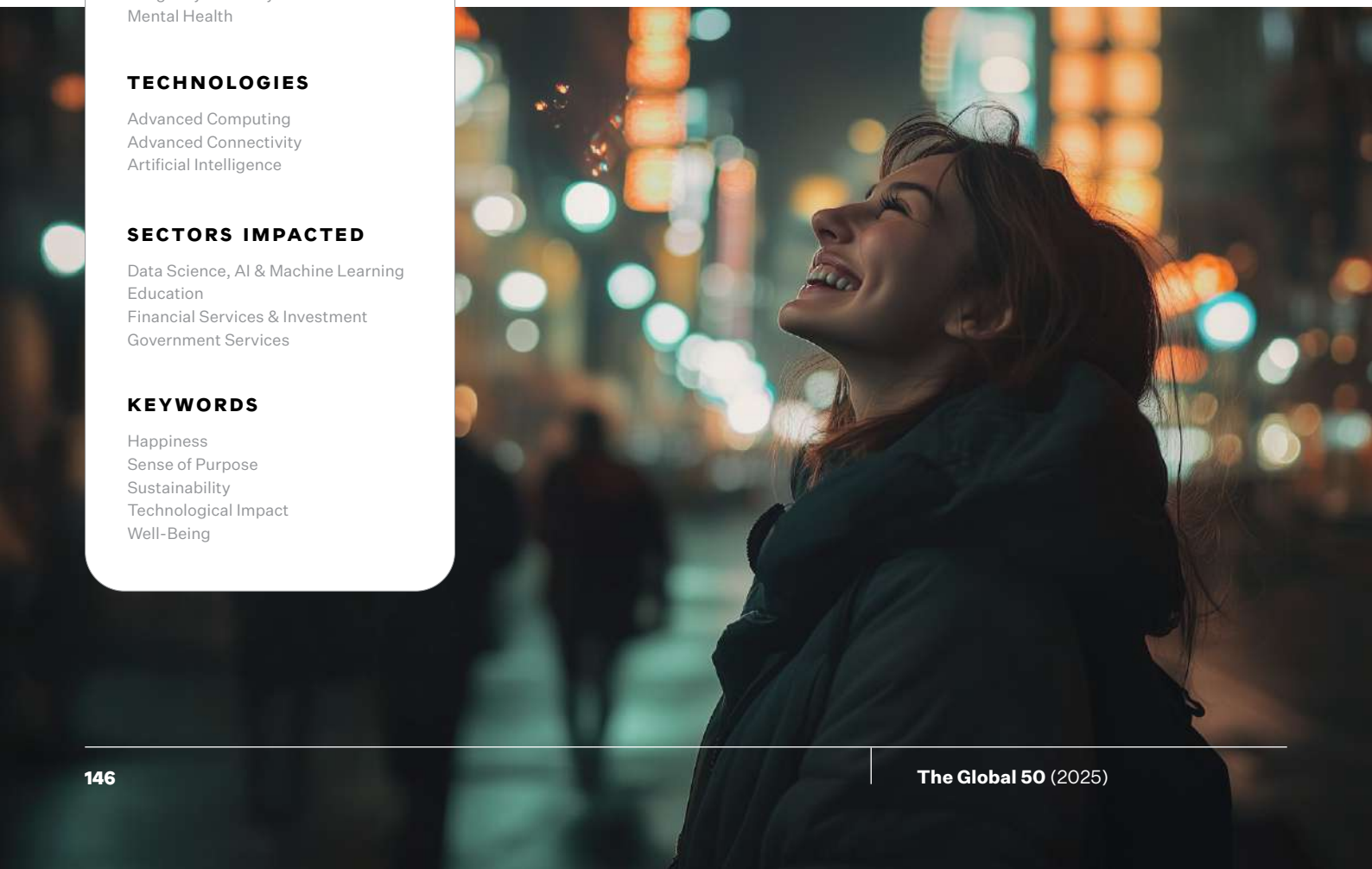
Advanced Computing
Advanced Connectivity
Artificial Intelligence

SECTORS IMPACTED

Data Science, AI & Machine Learning
Education
Financial Services & Investment
Government Services

KEYWORDS

Happiness
Sense of Purpose
Sustainability
Technological Impact
Well-Being



WHY IT MATTERS TODAY

More than

70%

of people in 30 countries **described themselves as happy in 2024, a jump from**

63%

in 2020 but **below the 77% high in 2011**

In the future, through advanced technologies, the circular economy, and government policies, communities become independent and self-sufficient

The way the global community views success is shifting. Gross domestic product (GDP) is increasingly noted as an inadequate metric for modern life.[836] Global GDP has grown to over $100 trillion and median income has increased by 150% since 1985, but persistent inequalities and rising environmental pressures threaten the well-being of current and future generations.[837] Adopted at the 2024 UN Summit of the Future, the United Nations Pact for the Future emphasises well-being and sustainability.[838] Countries including Finland, Iceland, Scotland and Wales are redefining success through frameworks that prioritise human and planetary well-being over material growth.[839]

Globally, happiness is a mixed bag with generational differences. More than 70% of people in 30 countries described themselves as happy in 2024, a jump from 63% in 2020 but below the 77% high in 2011.[840] Despite workforce challenges, 73% of people are satisfied with their jobs.[841] Yet, global happiness inequality has increased by more than 20% in the past 12 years, highlighting disparities in life satisfaction across demographics.[842] Well-being in ageing populations is linked to factors such as social support and health,[843] and Generation Z (born 1997–2012[844]) want to work for companies that prioritise diversity, social responsibility, environmental impact, and mental health.[845]

While there is some anxiety,[846] technology has enhanced our lives. Advances in food availability, clean water, healthcare, and living conditions have significantly extended lifespans.[847] Although technology raises concerns about addiction, reduced attention spans, and social isolation, it also has potential benefits around enhancing connections.[848] In 2014, 2.77 billion people had access to the internet, whereas today the number is 5.52 billion,[849] and this is opening up opportunities for work and income. Renewable energy, carbon-capture technologies, and sustainable meat and dairy alternatives have become a reality, helping us combat climate change.[850]

Advances in food availability, clean water, healthcare, and living conditions have significantly extended lifespans

THE OPPORTUNITY

BENEFITS

Increased life satisfaction; enhanced personal development; improved physical and mental health; resilient and stronger societies; sustainable growth; meaningful innovation.

RISKS

Cultural clashes over definitions of fulfilment; neglect of traditional economic metrics; other societies and communities left behind.

As self-sufficient societies emerge in parts of the world, eudaemonic well-being – where people reach their full potential and living meaningful lives[851,852] – redefines what societal progress means. In this new paradigm, personal growth, meaningful relationships, and collective purpose take precedence. Emotional intelligence and self-actualisation shape policies and institutional frameworks around a more fulfilling concept of human development.

In the future, advanced technologies, the circular economy, and various government policies, enable people around the world to manage their own energy, water, food and health, and even print their own medicines. Traditional definitions of work will no longer be needed to meet daily needs, as economic activity evolves to support a self-sufficient society.

Schooling shifts to flexible, interest-driven paradigms with communities organised around dynamic groups pursuing shared interests and goals and designing solutions to shared challenges.[853,854,855] While this may initially lead to a loss of purpose and an identity crisis for many, it eventually evolves into a newfound sense of purpose centred around these new meanings.

Eudaemonic well-being – the idea of people reaching their full potential and living meaningful lives – redefines what success and societal progress mean

What if sustainable desalination could provide drinking water for everyone?

23 Aqua Tech

GenAI

Within Reach | **Transitional** | Visionary

Smart, renewable desalination systems combine renewable energy and novel materials to turn seawater or groundwater into freshwater in water-scare regions.

UNCERTAINTIES

Systems, Technology

MEGATREND (Most significant)

Evolving Ecosystems

TRENDS

Biomimicry
Cross-Sectoral Partnerships
Food–Water–Energy Nexus
International Collaboration
New Materials

TECHNOLOGIES

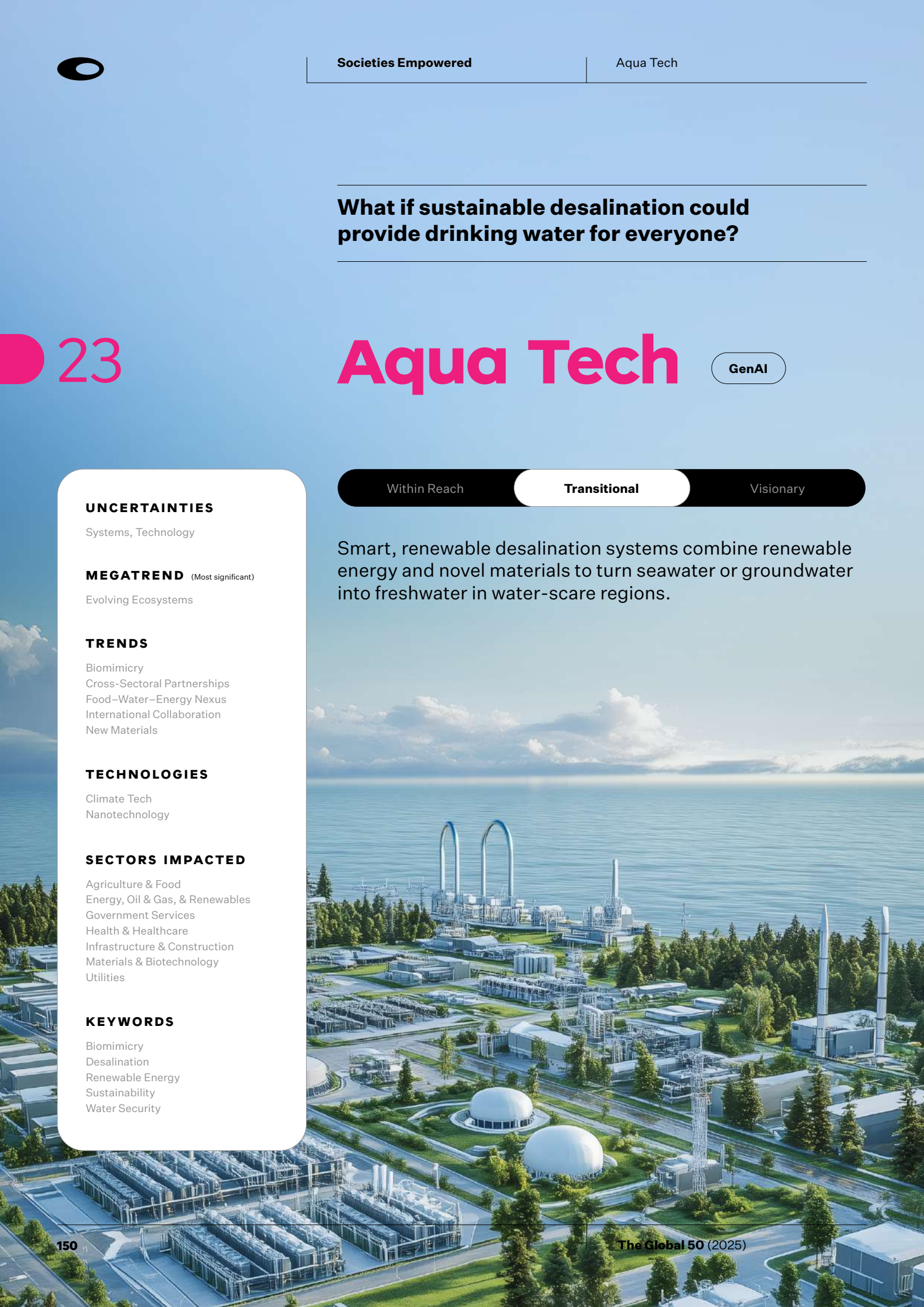
Climate Tech
Nanotechnology

SECTORS IMPACTED

Agriculture & Food
Energy, Oil & Gas, & Renewables
Government Services
Health & Healthcare
Infrastructure & Construction
Materials & Biotechnology
Utilities

KEYWORDS

Biomimicry
Desalination
Renewable Energy
Sustainability
Water Security



WHY IT MATTERS TODAY

2 billion

people lack access to safe drinking water, and global water stress is expected to impact

4 billion

people by 2030

Freshwater is a critical resource globally. Nearly 70% of the Earth's surface is water, of which roughly 97.5% is salty.[856] Of the Earth's freshwater, approximately 69% is in the ice caps and glaciers and 30% is in the ground, leaving only 1% readily accessible for human use – for example, in ice, snow, lakes and rivers.[857] It is estimated that 2 billion people currently lack access to a managed source of safe drinking water,[858] and global water stress is projected to impact 4 billion people by 2030.[859] In addition to the effect of a growing global population,[860] global water stress will be exacerbated by climate change, as rising sea levels increase the salinity of groundwater, and floods and droughts increase water pollution.[861]

A lack of clean water has significant impacts on human health and hygiene. Each year, around a million people are estimated to die from diarrhoea because of unsafe drinking water and sanitation, and in 2021 over 251 million people required treatment for schistosomiasis, caused by parasites in infested water.[862] Increasing water salinity is limiting crop production[863] and contributing to soil erosion,[864] reducing global agricultural production by 124 trillion kilocalories annually, equivalent to feeding 170 million people per year.[865]

The global capacity for desalination has grown by 7% annually since 2010, reaching 99 million m^3/day in 2022, with the Middle East and North Africa (MENA) contributing 70%.[866] Reverse osmosis dominates in the European Union, accounting for 88.5% of capacity, while the MENA region favours thermal processes.[867] Besides the carbon emissions of desalination technologies,[868] desalination also produces over 150 million m^3/day of brine globally, harming marine ecosystems, reducing oxygen, and killing aquatic life.[869]

THE OPPORTUNITY

BENEFITS

Water security; reduced emissions; reduced brine output; improved health through increased access to clean and safe water; improved agriculture and more robust agricultural economy.

RISKS

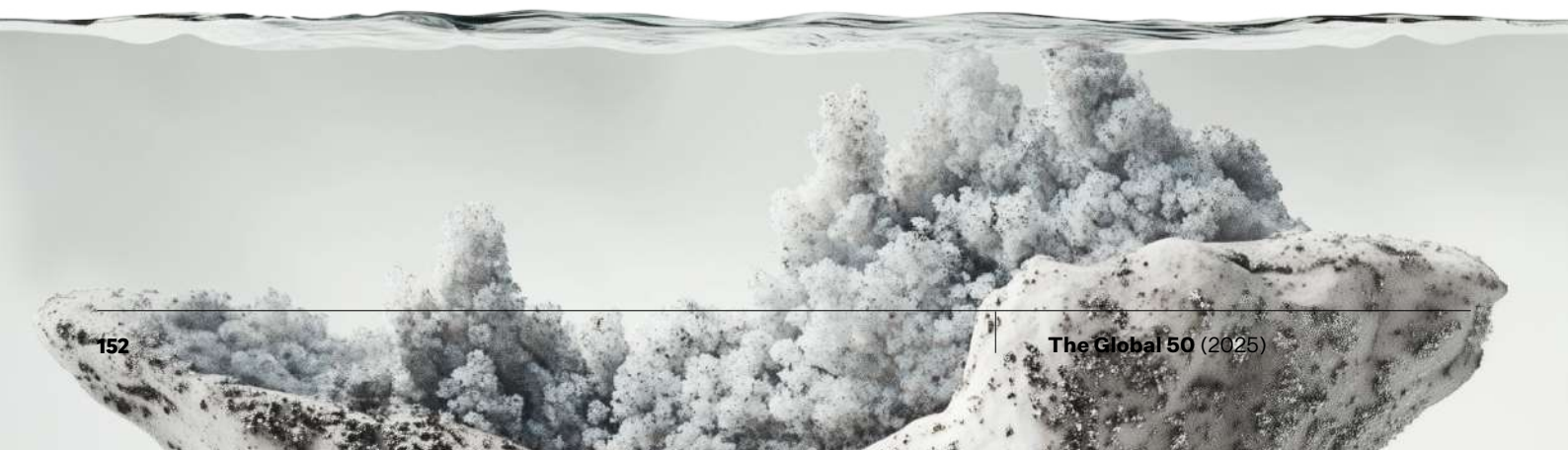
Durability of the materials; cost and complexity of maintaining and managing multiple clean energy technologies.

Advanced machine intelligence, the Internet of Things (IoT), edge computing, and real-time analytics are combined with hybrid solar[870] and wind power[871] systems in single or multiple units designed[872] to autonomously produce clean, cost-effective and safe[873] freshwater from seawater or groundwater[874] at scale. This integration is significant for water-scarce regions,[875] as solar desalination has been limited by lower yields and higher costs and intermittency compared with traditional desalination.[876]

Innovative materials[877] enhance desalination. For example, 2D nanomaterials, including graphene and other highly permeable materials, enable efficient filtering membranes,[878] while 3D-printed porous structures with tree-like topologies[879] improve water transport through capillaries that significantly reduce, or even eliminate, brine as a by-product.[880]

Minimum and zero liquid discharge desalination methods[881] present further opportunities for innovation, with biomimicry possibly enhancing efficiency and reducing costs. For example, researchers at Khalifa University recently explored an all-encompassing solar desalination solution that mimics mangrove processes, using brine crystallisation to eliminate the production of brine as waste.[882]

Khalifa University recently explored an all-encompassing solar desalination solution that **mimics mangrove processes, using brine crystallisation to eliminate the production of brine as waste**



Innovative materials enhance desalination.

What if personal algorithms let us control our digital experiences?

24 My Algorithm

UNCERTAINTIES

Systems, Technology

MEGATREND (Most significant)

Digital Realities

TRENDS

Advanced Connectivity
Cross-Sectoral Partnerships
Cybersecurity
Digital Economy
Interoperability

TECHNOLOGIES

Artificial Intelligence
Quantum Technologies

SECTORS IMPACTED

Art, Media, Sports & Entertainment
Communication Technologies & Systems
Consumer Goods, Services & Retail
Cyber & Information Security
Data Science, AI & Machine Learning
Digital Goods & Services
Education
Immersive Technologies

KEYWORDS

Algorithms
Avatar
Encryption
Privacy
Quantum Computing

Within Reach | **Transitional** | Visionary

A personal quantum-secured algorithm empowers individuals to selectively activate or deactivate data exchange across platforms, enabling transparent and regulated digital experiences around the world and changing the way we manage our data and engage in the digital economy.

WHY IT MATTERS TODAY

Concerns about data privacy are increasingly varied. When shopping online, at least half of consumers are concerned about security, and nearly one in four report that they have been targeted by a scam.[883] In addition, 94% of organisations say their customers will not buy from them if data are not properly protected.[884] Nevertheless, awareness of algorithms influencing behaviour (algorithmic persuasion) does not lead to better privacy protection. A study in the Netherlands found that while just under 40% of social media users are aware of algorithmic persuasion but are not critical of it, 18% have very little awareness and coping ability.[885] Additionally, approximately 28% of users feel they can't do anything about it.[886] Empowered consumers – those who are both aware and critical of algorithmic persuasion – make up the smallest group (just under 15%).[887]

There is a growing demand for personalisation.[888] The preference for personalisation is higher among consumers aged 35–44 years (87%) and 45–54 years (87%).[889] However, 41% of Generation Z (born 1997–2012[890]) users would sacrifice privacy or leave a website if it does not anticipate their needs or preferences.[891] Sixty-four per cent of this generation believe that in five years the internet will be so predictive that it will determine their daily activities,[892] and 66% believe that all websites will eventually communicate with one another, resulting in a personalised experience throughout the web as well as across applications and appliances.[893]

In 2023, nearly 46% of breaches involved sensitive personally identifiable information, including tax IDs, emails, and addresses.[894] The cost of public cloud breaches averaged $5.17 million each – a 13% rise since 2022.[895] Beyond their financial impact, such breaches cause significant stress for victims.[896] As advanced machine intelligence and associated algorithms become widespread, opting in or out of data sharing or training may become impractical.

In 2023, nearly

46%

of breaches involved **sensitive personally identifiable information**, including tax IDs, emails, and addresses

64%

of Generation Z (born 1997–2012) believe that in five years the internet will be so predictive that it will determine their daily activities

A personal algorithm enables **secure and transparent interactions with personalised preferences across platforms**

THE OPPORTUNITY

Drawing parallels with Estonia's X-Road Initiative[897] designed for individuals, a personal algorithm, secured by quantum computing, functions as an algorithm-to-algorithm communication layer, seamlessly managing interactions across platforms. Encrypting all exchanges and maintaining detailed access logs, it provides users with complete visibility into how, where and which part of their data are used as well as which algorithmic systems are active at any given time.

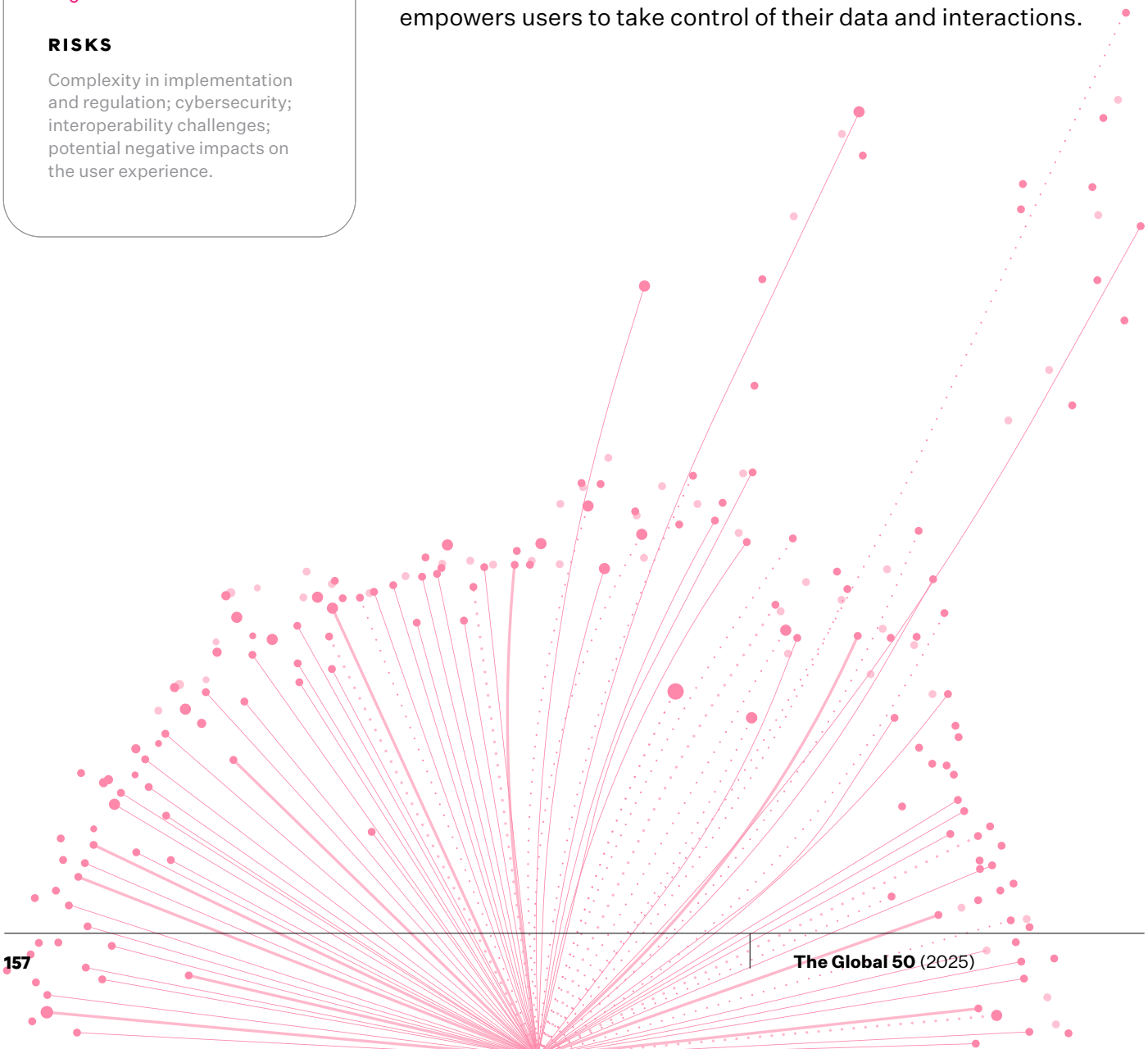
Interfacing seamlessly with other systems, the personal algorithm enables secure and transparent interactions with personalised preferences across platforms. Supported by an interoperability framework regulated across jurisdictions, a personal algorithm empowers users to take control of their data and interactions.

BENEFITS

Secure, transparent and user-centric digital future; personal agency in data and digital experiences; aligning of algorithm regulatory requirements across jurisdictions.

RISKS

Complexity in implementation and regulation; cybersecurity; interoperability challenges; potential negative impacts on the user experience.



What if women attained their expectations for prosperity and well-being?

25

Women's Prosperity

Within Reach | **Transitional** | Visionary

A futures-focused women's prosperity and well-being agenda bridges gaps in subjective well-being, aligning aspirations with realities through multidimensional, data-driven approaches informed by global experiences, ushering in a new era for women and creating positive spillover effects that benefit everyone.

UNCERTAINTIES

Collaboration, Values

MEGATREND (Most significant)

Future Humanity

TRENDS

ESG & Beyond GDP
Future of Education
Future of Purpose & Work
International Collaboration
Mobilising Innovation

TECHNOLOGIES

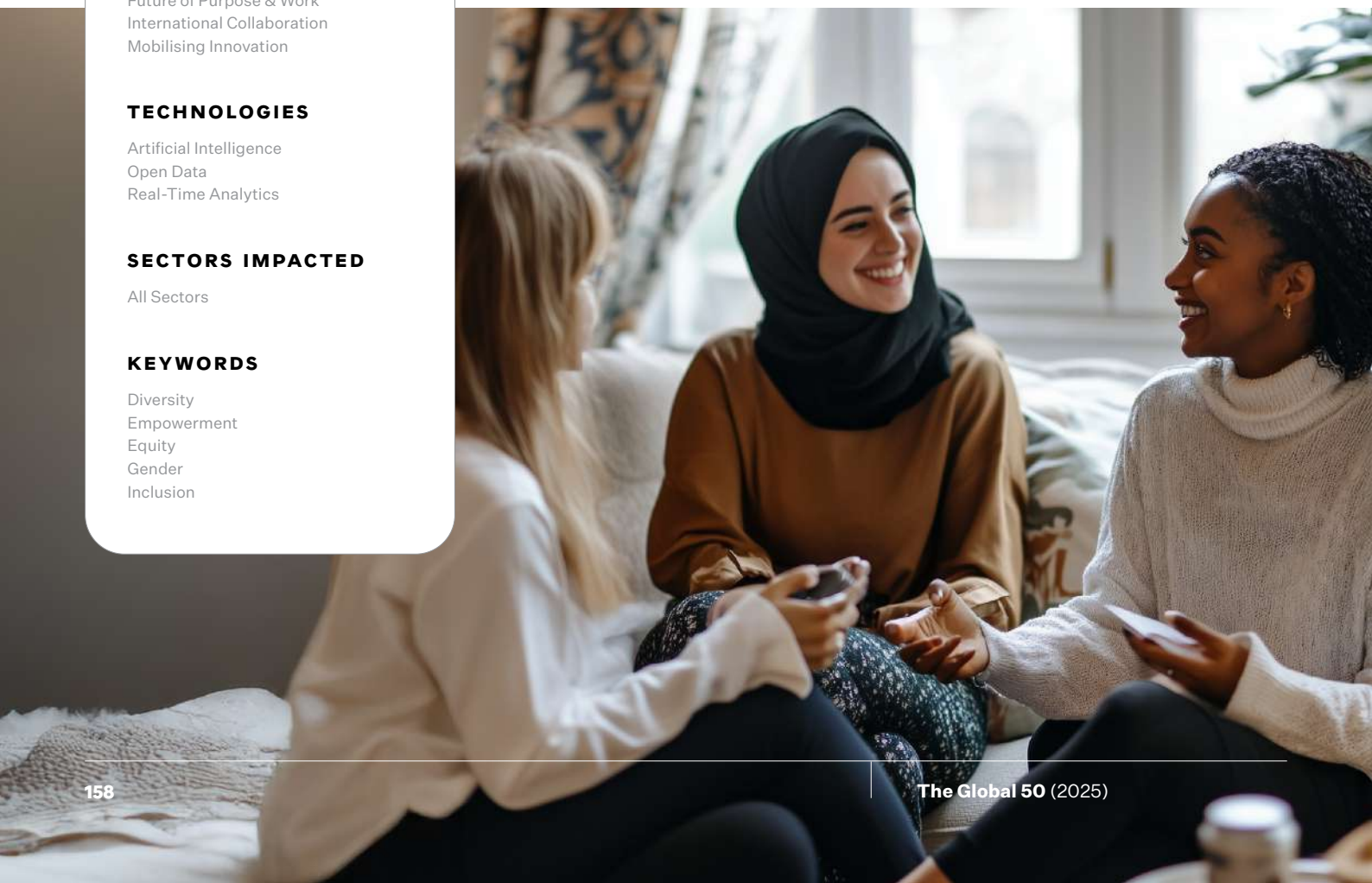
Artificial Intelligence
Open Data
Real-Time Analytics

SECTORS IMPACTED

All Sectors

KEYWORDS

Diversity
Empowerment
Equity
Gender
Inclusion



WHY IT MATTERS TODAY

Diverse teams are more productive, with direct impacts on the bottom line. A lack of diversity can stifle creativity and limit a company's ability to solve complex problems. Economically, closing the gender gap could add an estimated $12 trillion to global gross domestic product (GDP) by 2025.[898] Companies in the top quartile for gender diversity and racial/ethnic diversity are, respectively, 15% and 35% more likely to have financial returns above their industry's national median.[899,900] In addition, greater gender diversity in boards of directors is correlated with increased social trust,[901] increased corporate social responsibility,[902] and a reduction in the number of environmental, social and governance (ESG) controversies, particularly when there are three or more female directors.[903]

Economically, closing the gender gap could add an estimated

$12 trillion

to global GDP by 2025

Science, technology, engineering and mathematics (STEM) and information and communications technology (ICT) fields are facing a shortage of skills.[904] Concerns about growing skill gaps have been raised worldwide;[905] yet, girls and women face various barriers in pursuing STEM and ICT fields throughout their educational journey.[906] Women make up only 34% of the STEM workforce in the United States and 29% in the United Kingdom,[907] with fields such as computer science, and engineering and technology, being as low as 23% and 21%, respectively.[908] Globally, women make up only 35% of STEM graduates, with no progress made over the past 10 years.[909]

Gender disparities persist, with differing insights across different dimensions, resulting in a paradox.[910] Between 1990 and 2022, the United Nations Development Programme's Gender Inequality Index for the world improved 20% thanks to improvements in education and maternal health.[911] Women make up nearly half of leaders in non-governmental organisations and the, education and health sectors[912] but only 5% of CEOs globally and received only 2% of venture investments in 2021.[913] Gender parity has shifted from 100 years in 2020 (pre-pandemic) to 134 years in 2024.[914] While women tend to report higher levels of overall well-being and life satisfaction than men,[915] they consistently report higher rates of depression, anxiety and loneliness, score lower on metrics related to subjective well-being,[916] spend a quarter of their lives in poor health, and are diagnosed later than men.[917] Only 15.4% of the Sustainable Development Goal (SDG) 5 targets on gender equality are on track.[918]

THE OPPORTUNITY

Beyond closing existing main gaps in gender inequality, such as economic empowerment, education, and health, a futures-focused women's prosperity and well-being agenda bridges gaps in subjective well-being, including physical and mental health and their underlying drivers. By aligning women's expectations of a good life with their lived experiences worldwide, this multidimensional approach emphasises gender-specific priorities informed by data and by lessons learned from existing commitments led by the World Economic Forum, the United Nations, the Organisation for Economic Co-operation and Development (OECD) and research institutions focusing on women's research.

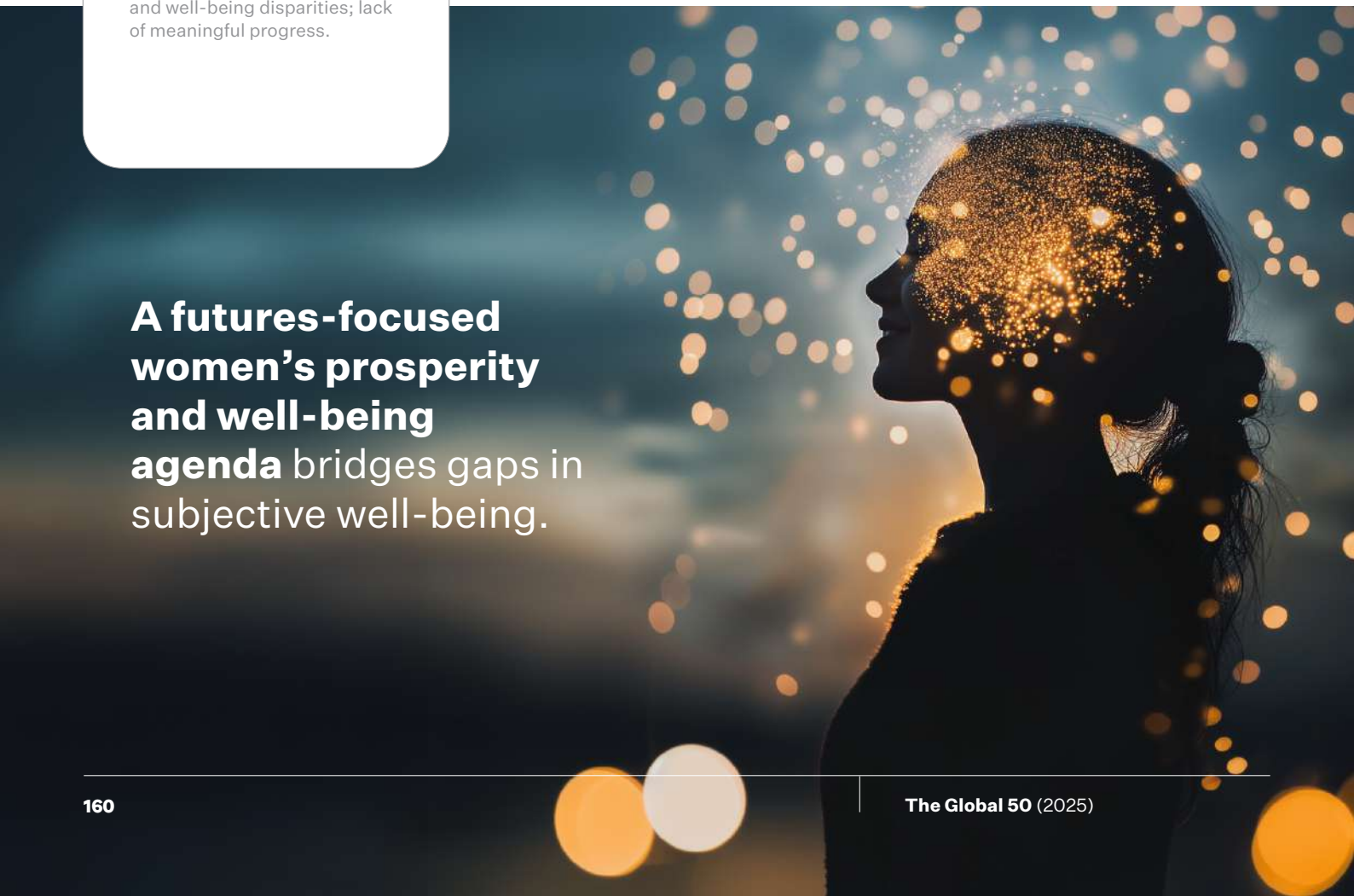
A futures-focused women's prosperity and well-being agenda ushers in a new era that creates positive spillover effects that enhance prosperity and well-being for men as well.[919]

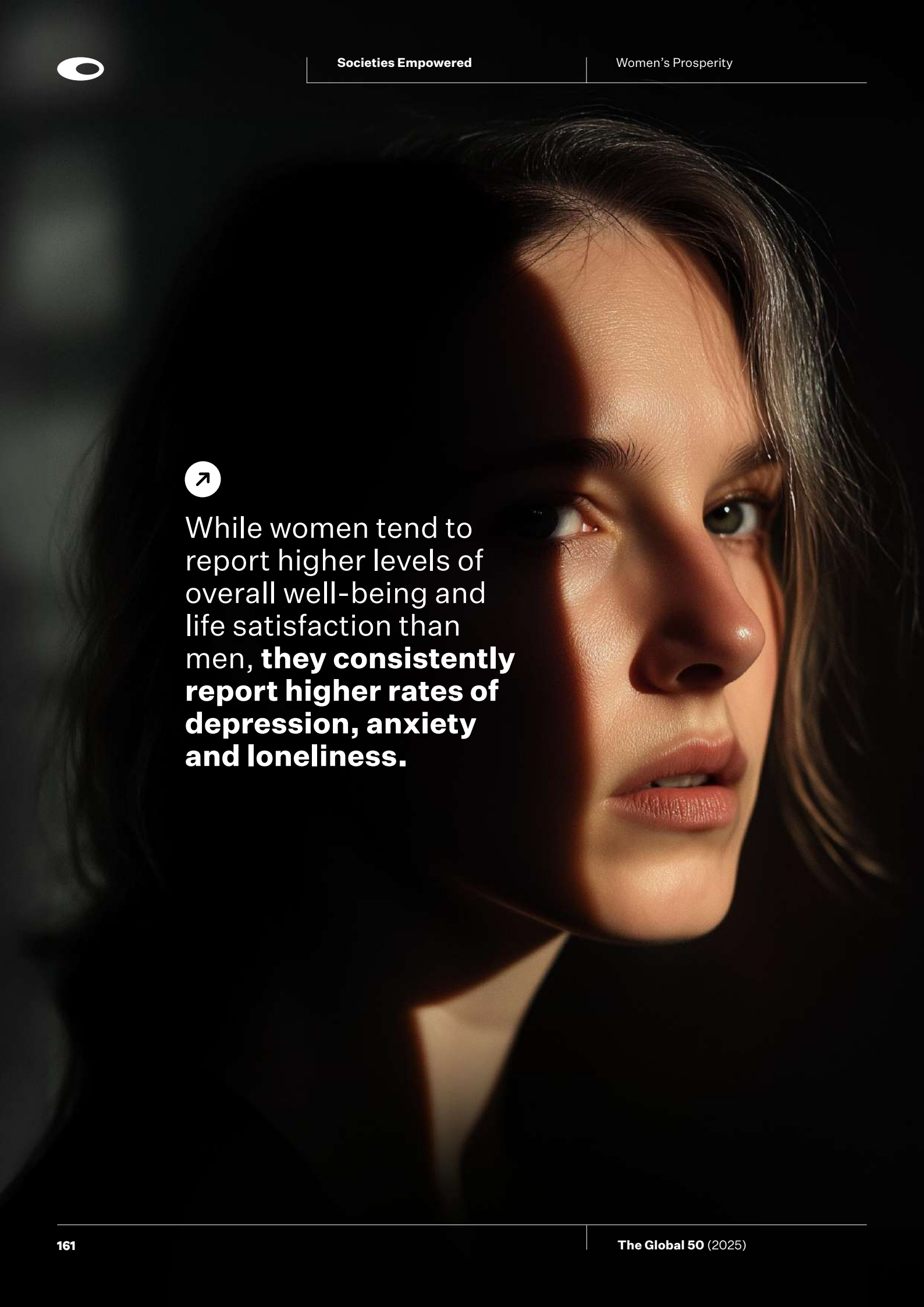
BENEFITS

Women's prosperity; increased innovation through diversity; gender parity; accelerated progress towards SDG 5; opportunities for women in the ICT and STEM fields.

RISKS

Gender-based gaps persist; unintended workplace disruptions; global prosperity and well-being disparities; lack of meaningful progress.





While women tend to report higher levels of overall well-being and life satisfaction than men, **they consistently report higher rates of depression, anxiety and loneliness.**

What if video games improved mental and physical health?

26 Healthy Play

UNCERTAINTIES

Technology, Values

MEGATREND (Most significant)

Future Humanity

TRENDS

Digital Art & Design
Digital Therapeutics
Gaming & Entertainment
Mental Health
Neuroscience

TECHNOLOGIES

Artificial Intelligence
Data Protection & Privacy
Immersive Technologies & Wearables

SECTORS IMPACTED

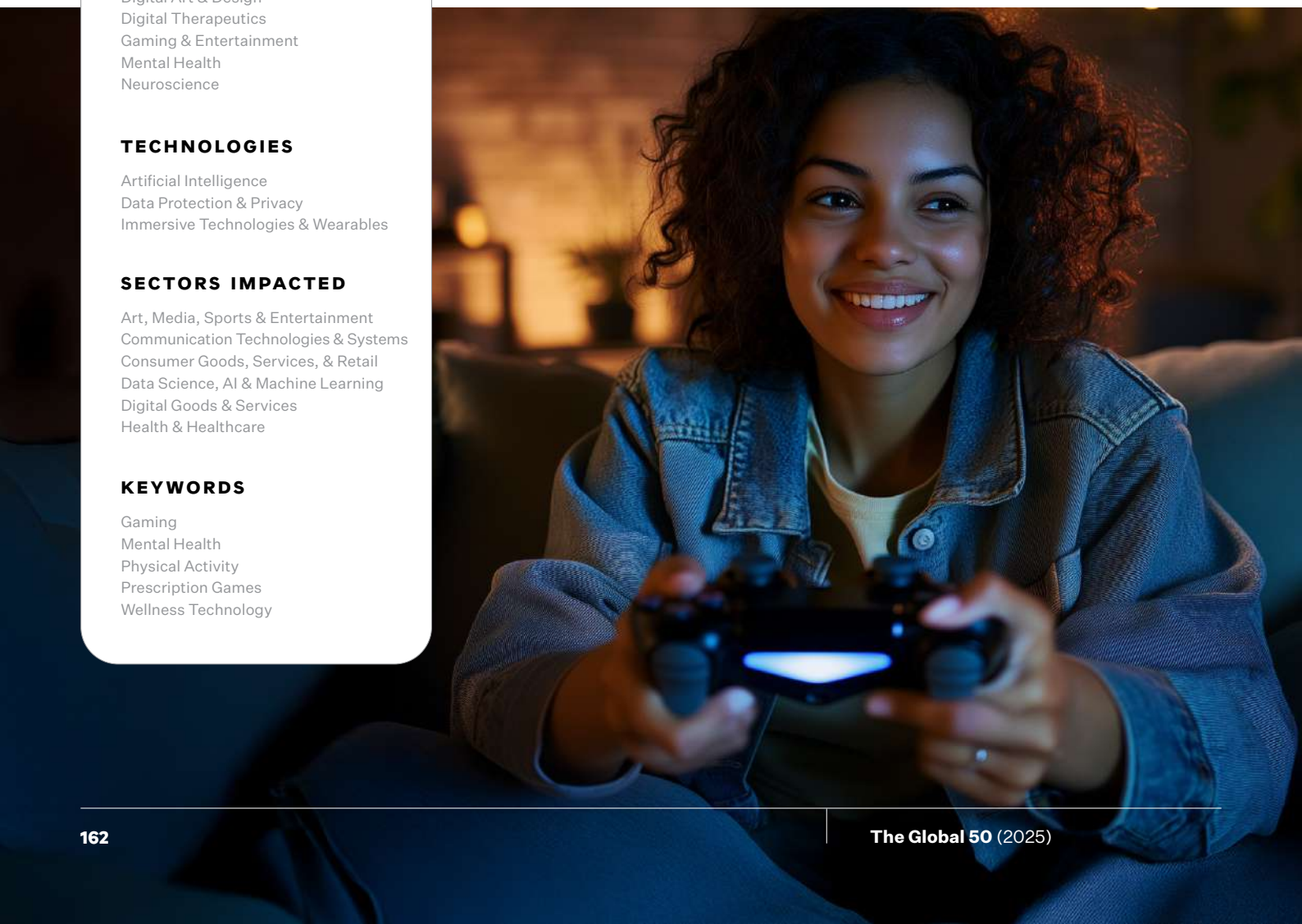
Art, Media, Sports & Entertainment
Communication Technologies & Systems
Consumer Goods, Services, & Retail
Data Science, AI & Machine Learning
Digital Goods & Services
Health & Healthcare

KEYWORDS

Gaming
Mental Health
Physical Activity
Prescription Games
Wellness Technology

Within Reach | **Transitional** | Visionary

Physical and mental well-being become the core of the video gaming ecosystem, unlocking gaming's potential to uplift society through research-backed insights that address well-being and support better health.



WHY IT MATTERS TODAY

Mental health issues have reached critical levels globally, with depressive and anxiety disorders affecting more than

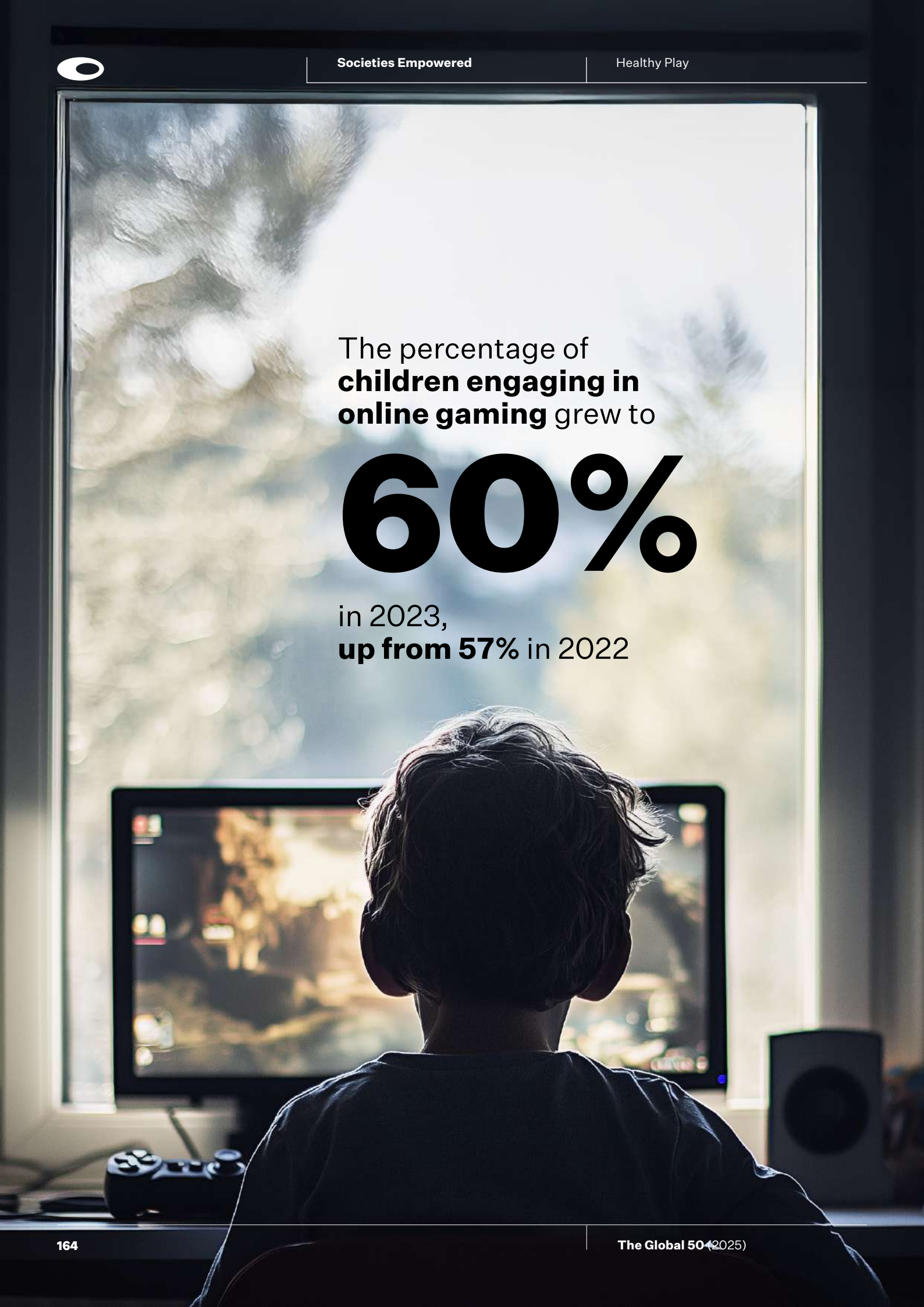
970 million

individuals worldwide

Video games have become deeply integrated into daily life for millions of people worldwide, with gaming covering all generations and age groups.[920] The percentage of children engaging in online gaming grew to 60% in 2023, compared to 57% in 2022.[921] This trend is particularly noticeable among children aged 3–4 years, whose participation rose from 18% to 23%; children aged 5–7 years, rising from 34% to 41%; and teenagers aged 16–17 years, rising from 72% to 79%.[922]

Mental health challenges require innovative solutions amid rising concern. Mental health issues have reached critical levels globally, with depressive and anxiety disorders affecting more than 970 million individuals worldwide.[923] This mental health crisis disproportionately impacts socio-economically disadvantaged populations, while access to traditional mental health services remains limited for many.[924] There is a need for innovative approaches to improve the delivery of mental health support.[925] A promising option, which is especially valuable given the current worldwide shortage of mental health professionals,[926] is game-based interventions, which can be effective in improving individuals' mental health.[927] In a study involving almost 13,000 players across 12 countries, players considered that video games relieved stress (71%), helped them face everyday challenges (64%), and helped them combat isolation (55%).[928] Among the European countries surveyed, the respective values were 68%, 67% and 53%.[929]

Physical inactivity is a concern. Regular physical activity reduces rates of heart disease, stroke, diabetes, depression, dementia and certain cancers, potentially preventing up to 5 million deaths annually.[930] Yet one in four adults and four in five adolescents are insufficiently active, with women, girls, older adults, and those with disabilities disproportionately affected.[931] In high-income countries, the inactivity rate can reach 70%.[932]



The percentage of **children engaging in online gaming** grew to

60%

in 2023, **up from 57%** in 2022

THE OPPORTUNITY

BENEFITS

New approach to personalised wellness, mental health support, and rehabilitation therapy; improved public health; innovative breakthroughs and growth in gaming.

RISKS

Increased addiction; regulatory and ethical challenges; high development costs; accessibility issues; unintended consequences such as misdiagnosis or reduced human interaction.

Physical and mental well-being become core to the video gaming ecosystem.[933] While collaboration with health experts addresses issues such as gaming addiction and physical strain, new games shift gaming from a passive leisure activity to an active health intervention[934,935] and a tool for personalised individual well-being.[936,937] Prescription games are clinically tested and prescribed by healthcare providers targeting specific conditions such as anxiety, depression and cognitive decline.

A comprehensive rating system evaluate video games based on their physical and mental health impacts, with rating boards such as the Entertainment Software Rating Board and other research institutions focused on gaming providing research-backed insights about a game's potential health benefits, such as its cognitive training potential and stress reduction capabilities.[938] Game design, through robust community standards, purposefully enhances inclusivity and positive social interactions. Developers integrate features that promote healthy gaming habits, such as playing limits, breaks and age-appropriate content, in parallel with transparent data practices and secure environments that further build trust.

Physical and mental well-being become core to the gaming ecosystem, **from a passive leisure activity to an active health intervention**

What if our survival depended on smart, climate-resilient households?

27 Climate Ready

Within Reach | Transitional | Visionary

Individuals and households actively adapt to climate shifts, safeguarding their well-being and assets through tailored resilience and disaster preparedness plans informed by real-time data and advanced machine intelligence, enhancing climate resilience and contributing to community-wide climate adaptation.

UNCERTAINTIES

Nature, Technology

MEGATREND (Most significant)

Evolving Ecosystems

TRENDS

Community-Based Solutions
Government Agility
Mobilising Innovation
Open Data

TECHNOLOGIES

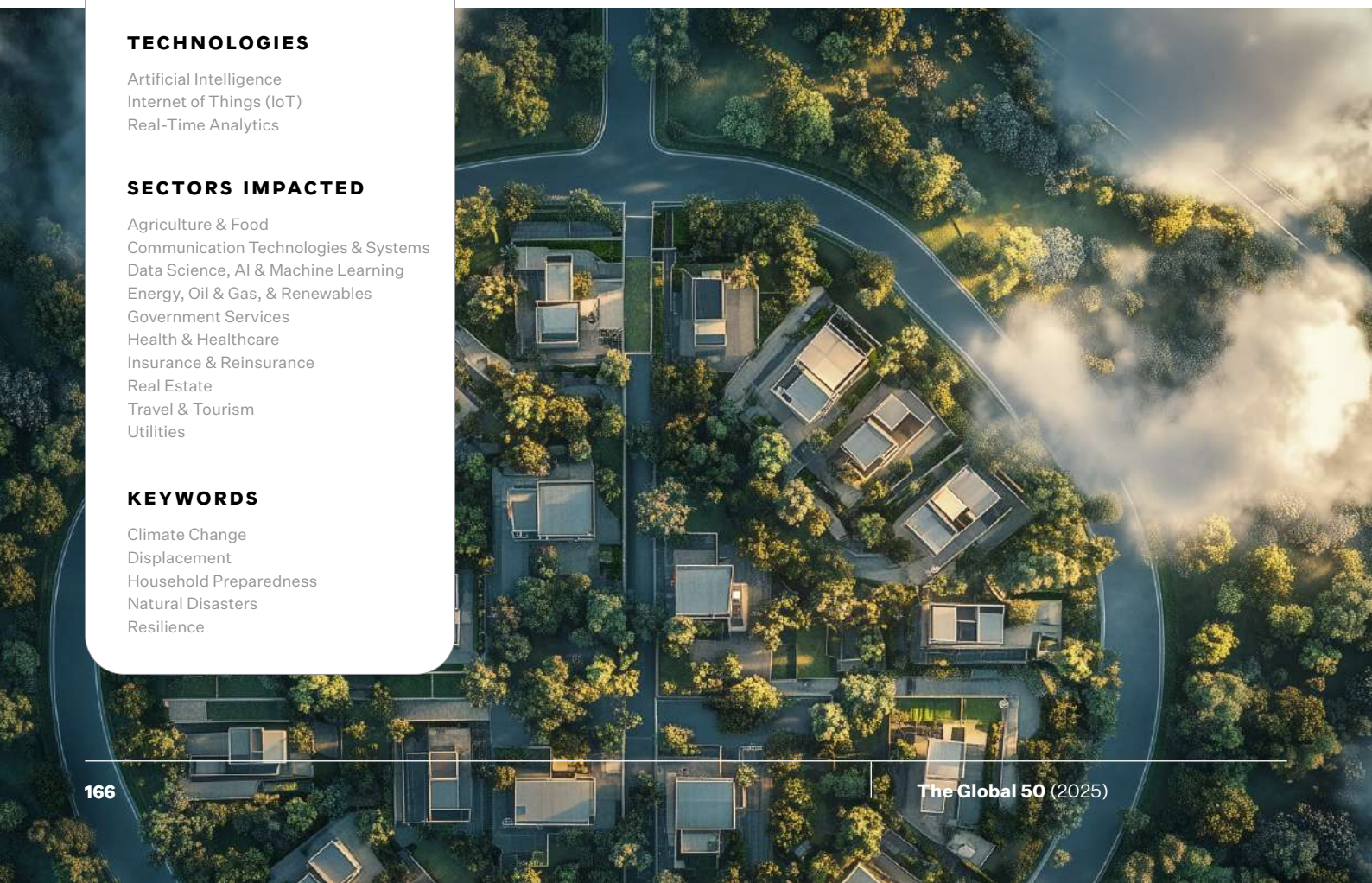
Artificial Intelligence
Internet of Things (IoT)
Real-Time Analytics

SECTORS IMPACTED

Agriculture & Food
Communication Technologies & Systems
Data Science, AI & Machine Learning
Energy, Oil & Gas, & Renewables
Government Services
Health & Healthcare
Insurance & Reinsurance
Real Estate
Travel & Tourism
Utilities

KEYWORDS

Climate Change
Displacement
Household Preparedness
Natural Disasters
Resilience



WHY IT MATTERS TODAY

By 2050, climate change and natural disasters **could displace**

1.2 billion

people, with **216 million forced to relocate within their countries**

The number of weather-related disasters has

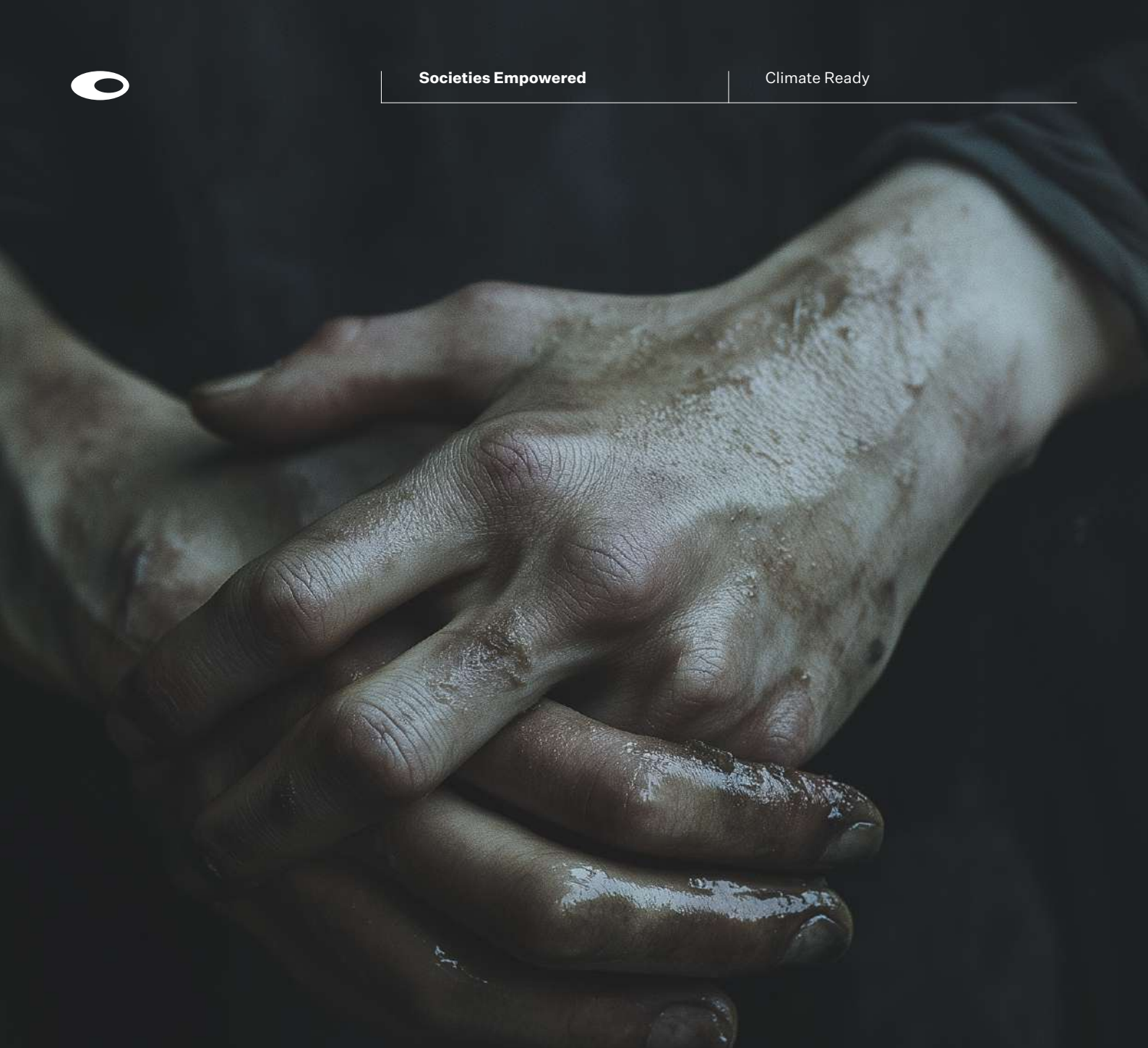
nearly tripled

over the past 40 years

Around 1.2 billion people could be displaced by 2050 due to natural disasters and climate change,[939] and 216 million will have to relocate within their countries by 2050 due to climate change.[940] Weather-related disasters have caused approximately 21 million displacements annually since 2008 and the annual number of weather-related disasters has almost tripled in the past 40 years.[941] Even if global warming is limited to 1.5°C and degraded ecosystems are restored starting in 2030, communities will still face rising sea levels, more frequent natural disasters, extreme weather events, and biodiversity loss.[942]

Between 2030 and 2050, climate change could impact global health, leading to 250,000 additional deaths per year due to undernutrition, malaria, diarrhoea and heat stress.[943] By the 2070s, and in the scenario with the highest likely temperature rises, the United Kingdom could see 21,000 additional heat-related deaths annually.[944]

Climate preparedness pays off both psychologically and economically. Up to 50% of disaster survivors may experience mental distress, including post-traumatic stress disorder (PTSD), depression and anxiety, with 5–10% requiring clinical care.[945] The global cost of natural disasters exceeded $360 billion in 2022, with over 40 events causing more than $1 billion in damages each.[946] In the United States, every $1 invested in disaster preparation saves $13 ($6 on damage and clean-up costs and $7 on economic costs).[947]



Between 2030 and 2050, climate change could cause an additional

250,000 deaths per year

from undernutrition, malaria, diarrhoea, and heat stress alone.

THE OPPORTUNITY

Individuals and households proactively adapt to climate shifts, safeguarding both their well-being and assets, through an integrated society-wide platform powered by advanced machine intelligence that enables individuals to personalise their climate resilience strategies. This platform provides actionable, tailored recommendations based on publicly available data (such as weather forecasts and air quality indices) and real-time household data.

Building on smart home technology, the platform prepares households and provides tailored advice for extreme weather events such as heatwaves and flooding. Tailored disaster preparedness and specific lifestyle and climate proofing guidance enables families and their homes to withstand climate impacts, reduce risks, and potentially lower insurance costs. Integrated with broader community systems, such a platform could enable collective preparedness and resilience while prioritising data protection and user consent, ensuring families can participate without compromising privacy.

BENEFITS

Empowerment of individuals, households and communities; enhanced climate resilience; promotion of sustainable practices; promotion of climate awareness.

RISKS

Inability to cope with climate events that are more aggressive than anticipated; incorrect or ineffective recommendations; increased anxiety; cybersecurity and safeguarding data privacy.

Individuals and households proactively adapt to climate shifts **through an integrated society-wide platform that enables individuals to personalise their climate resilience strategies**

What if long-term uncertainty became the greatest investment opportunity?

28

A Catalyst for Common Good

Within Reach | **Transitional** | Visionary

A global equity fund tackles humanity's greatest long-term challenges by combining decentralised governance for transparency with multilateral development bank capital to scale breakthrough innovations for climate, energy, food and water security.

UNCERTAINTIES

Collaboration, Systems

MEGATREND (Most significant)

Future Humanity

TRENDS

Community-Based Solutions
Cross-Sectoral Partnerships
ESG & Beyond GDP
International Collaboration
Mobilising Innovation

TECHNOLOGIES

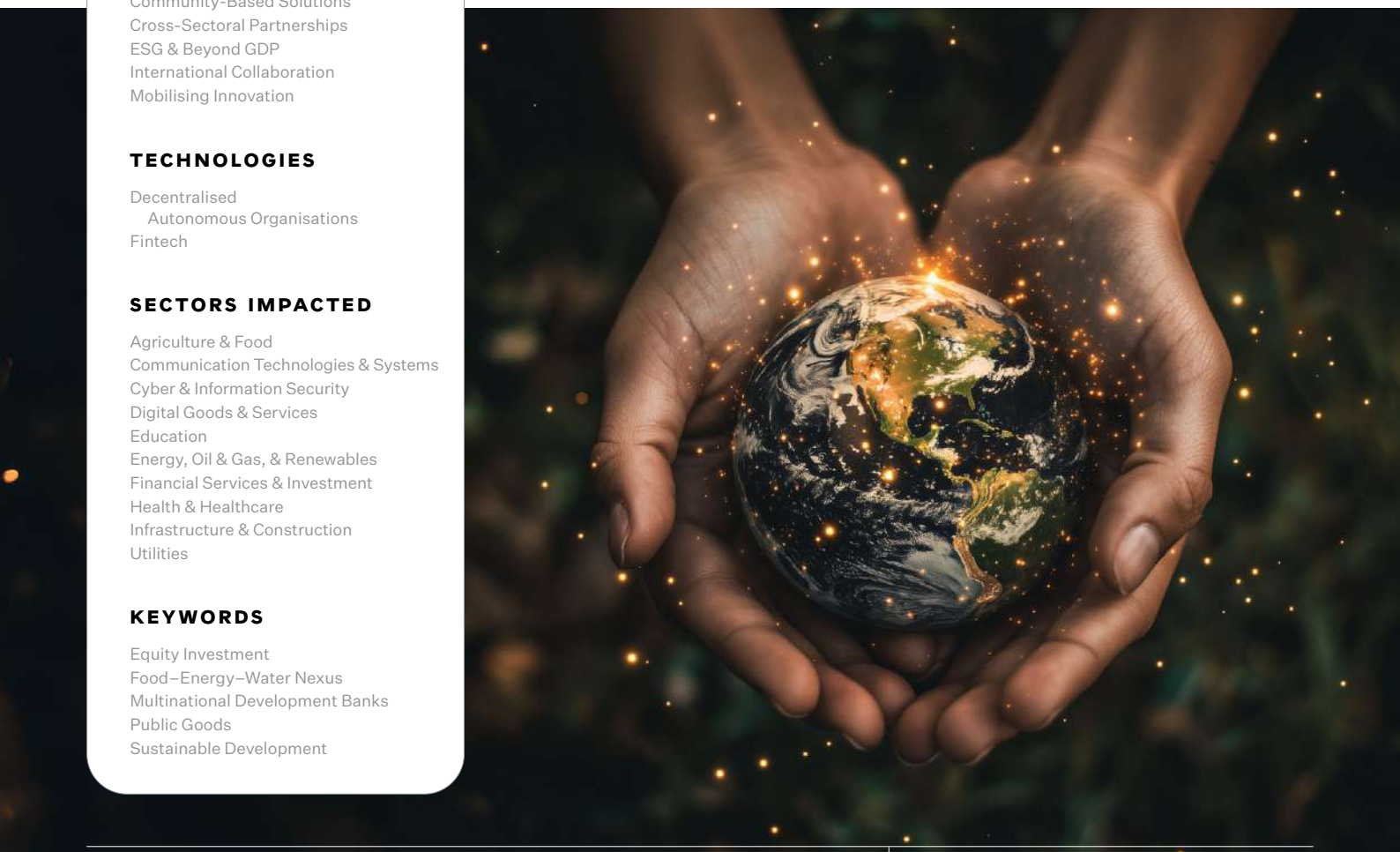
Decentralised Autonomous Organisations
Fintech

SECTORS IMPACTED

Agriculture & Food
Communication Technologies & Systems
Cyber & Information Security
Digital Goods & Services
Education
Energy, Oil & Gas, & Renewables
Financial Services & Investment
Health & Healthcare
Infrastructure & Construction
Utilities

KEYWORDS

Equity Investment
Food–Energy–Water Nexus
Multinational Development Banks
Public Goods
Sustainable Development



WHY IT MATTERS TODAY

Public goods represent

30%

of global GDP, with government spending per citizen rising from $2,500 to $5,000 between 1980 and 2022 (using purchasing power parity), driving

20%

of poverty reduction.

There is a gap in our ability to face global challenges. Meeting these challenges will require significant funding, with an estimated $2.5 trillion annual gap for energy transitions, climate resilience, and development in low- and middle-income countries.[948] This translates into a gap of between $100 trillion and $300 trillion between now and 2050.[949] While annual public spending has increased by $700 billion each year since 2019, international public finance (from sources such as multilateral development banks) still falls short, providing only 57% of the required amount.[950] Despite previous progress, over 700 million people still live in extreme poverty and the external debt of middle-income countries reached $8.8 trillion in 2023 with key data gaps.[951]

Taking the long view of global challenges matters. Global challenges, such as climate stability and food, water and energy, require sustained investments. Addressing these interconnected long-term crises is essential for global resilience. The Paris Agreement[952] the Sustainable Development Goals (SDGs),[953] and the UN Pact for the Future (which incorporates the UN Declaration on Future Generations and the UN Global Digital Compact)[954] are all designed to adopt a long-term lens.

Despite challenges, public goods are impactful. The notion of public goods is not new,[955] yet demand for them is increasing.[956] They are essential but their availability remains limited because of various challenges, including a lack of enforceable mechanisms[957] and difficulties balancing long-term benefit with short-term cost.[958] Public goods represent 30% of global GDP, with government spending per citizen rising from $2,500 to $5,000 between 1980 and 2022 (using purchasing power parity), driving 20% of poverty reduction.[959] As a step towards data sharing and transparency, the Digital Public Goods Alliance includes a registry, linked to the SDGs, of 177 digital public goods (e.g. AI systems, content, data and software) that meet its standards.[960]

Global challenges such as climate stability and food, water, and energy require **sustained investments.**

THE OPPORTUNITY

BENEFITS

Move towards addressing critical long-term uncertainties; mobilisation of global innovation; evolution of MDBs;[964] alignment with global goals and commitments.

RISKS

Perpetuating existing risks faced by public goods; complexities in managing the DAO; fund sustainability and continuity; challenges managing global investments and innovations.

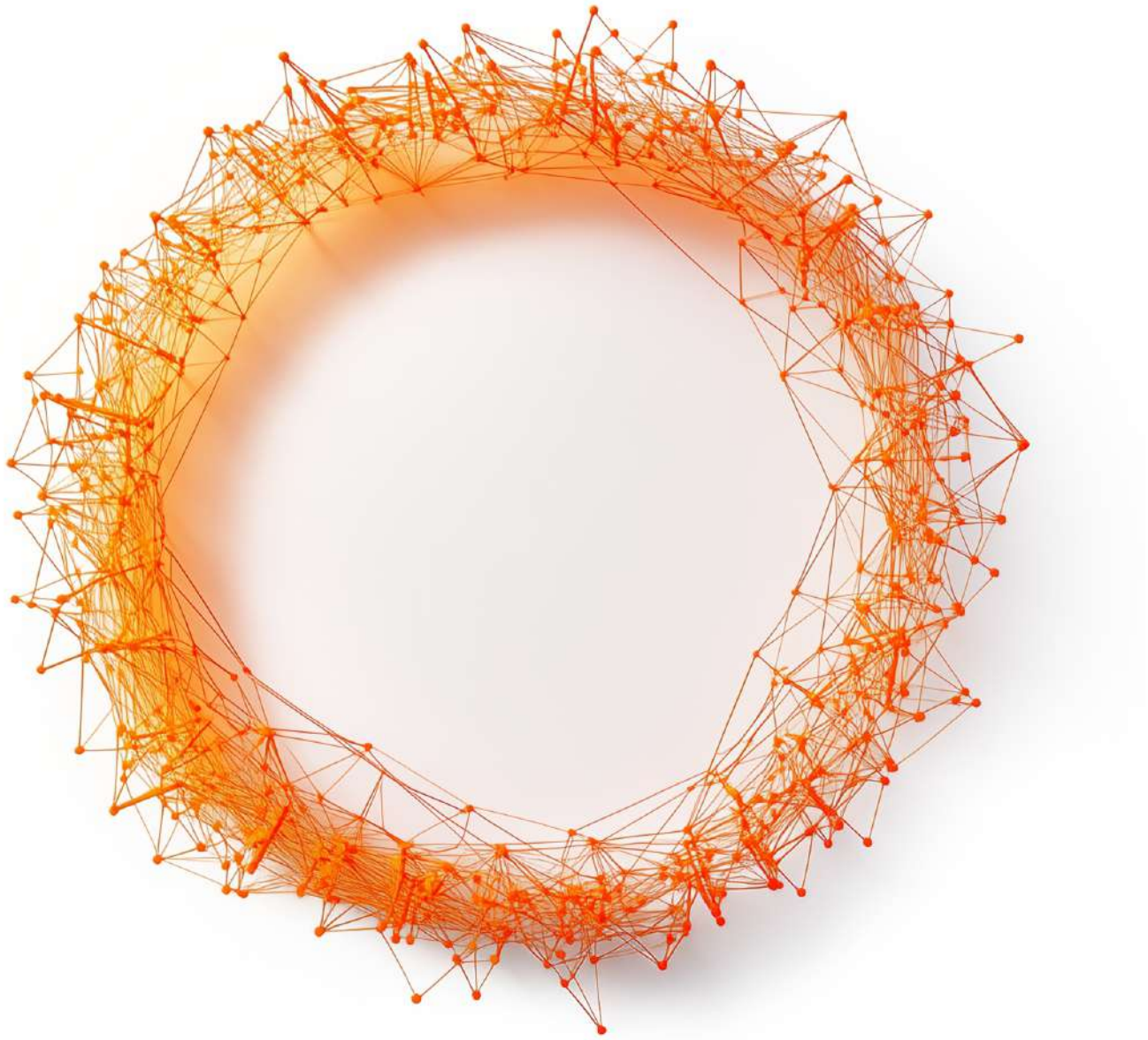
A global public equity fund designed to channel capital into innovations that address long-term uncertainties – often overlooked by traditional investors – focusing on climate and the nexus of energy, food and water while advancing public goods. The fund ensures that its investments meet commonly agreed criteria for public goods[961, 962] and by acquiring and managing relevant patents, the fund develops innovative licensing models to share critical technologies.

The fund is structured as a decentralised autonomous organisation (DAO) to ensure transparency, consistency and community oversight. Seeded by multilateral development banks (MDBs) seeking to diversify and grow their impact and outcomes,[963] the fund prioritises scalable solutions that advance public goods and solutions to long-term uncertainties.

There is an estimated

$2.5 trillion

annual funding gap for energy transitions, climate resilience, and development in low- and middle-income countries



Systems Optimised

Improve and build more effective and resilient systems underpinning advances in services and solutions at various levels of business, government and society.

What if new materials provided sustainable cooling solutions in a warming world?

29

Cool Materials

Within Reach | Transitional | **Visionary**

Advanced cooling systems with nanoengineered materials dynamically adapt to temperature changes, reducing air-conditioning needs and enhancing efficiency of cooling solutions.

UNCERTAINTIES

Technology, Systems

MEGATREND (Most significant)

Materials Revolution

TRENDS

ESG & Beyond GDP
Mobilising Innovation
Net Zero
New Materials
Urban Design

TECHNOLOGIES

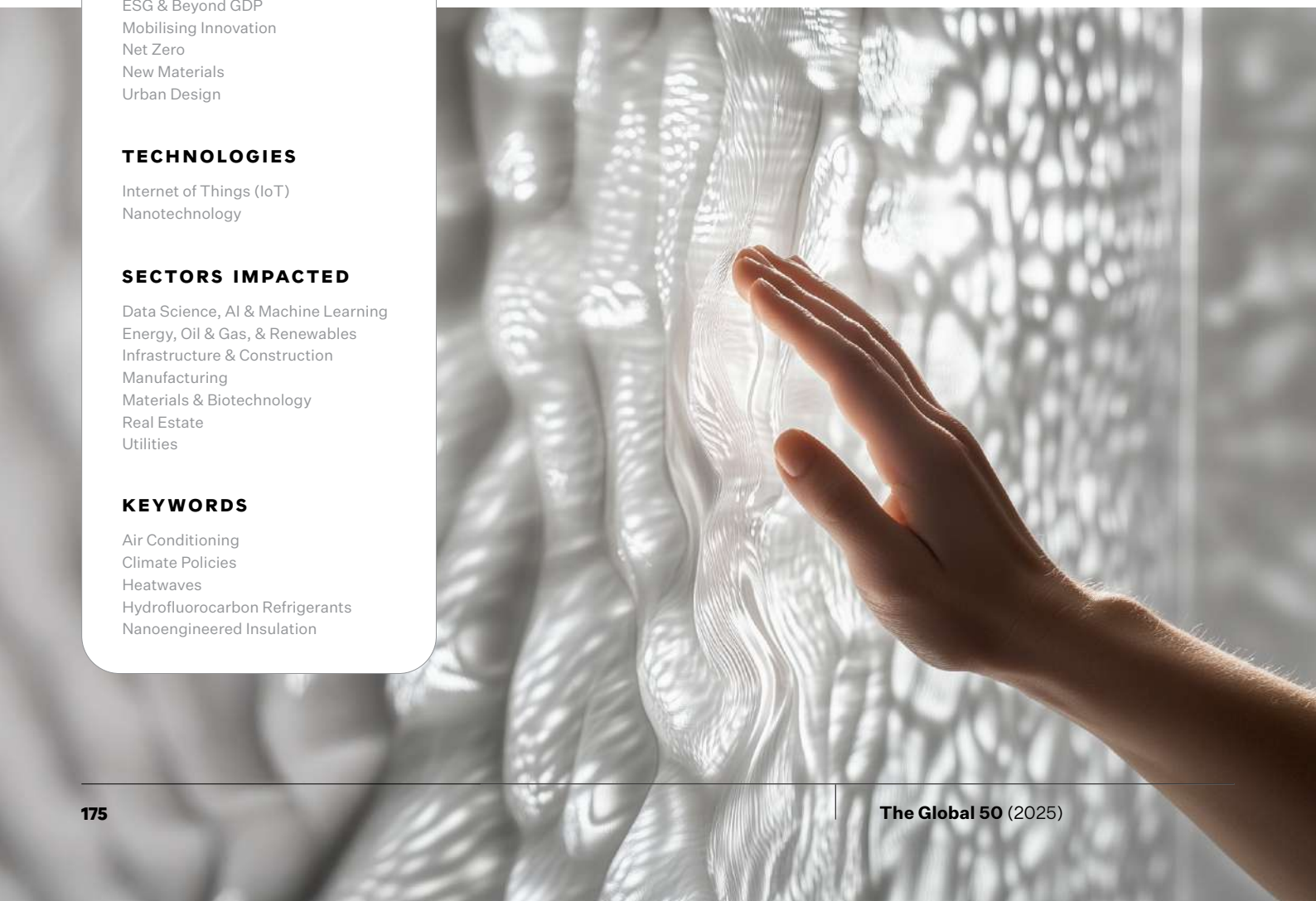
Internet of Things (IoT)
Nanotechnology

SECTORS IMPACTED

Data Science, AI & Machine Learning
Energy, Oil & Gas, & Renewables
Infrastructure & Construction
Manufacturing
Materials & Biotechnology
Real Estate
Utilities

KEYWORDS

Air Conditioning
Climate Policies
Heatwaves
Hydrofluorocarbon Refrigerants
Nanoengineered Insulation



WHY IT MATTERS TODAY

Heatwaves have intensified since the 1950s and, by 2030, 500 million people, mainly in South Asia and the Middle East, will face extreme heat for over 30 days annually, quadrupling current exposure.[965]

Global air conditioner sales continue to increase with rising temperatures and incomes. Use of air conditioning in households has tripled since 1990, exceeding 100 million units annually.[966] In 2016, 42 million units were sold in China, the most for any country,[967] and by the end of 2016, there were 1.6 billion air conditioners in use worldwide, including 570 million in China, 375 million in the United States, 50 million in the Middle East, and nearly 30 million in India.[968] By 2050, two-thirds of households could own air conditioners.[969]

International non-governmental organisations and governments around the world are looking at future climate scenarios to inform their cooling policies.[970] Many are testing approaches such as urban greenery, irrigation, and geoengineering.[971,972] Indoor cooling and heating using 30% of global energy[973] and cooling responsible for 4% of global greenhouse gas emissions.[974] Current refrigerants, such as hydrofluorocarbons (HFCs), contribute significantly to climate change.[975] Nature-based and alternative solutions will be key.[976]

There is unequal access to cooling globally, with impacts on health. Only 15% of households in the hottest regions have air conditioning, with adoption as low as 5% in sub-Saharan Africa and 24% in India, compared with over 85% in high-income countries such as Japan and the United States.[977] Heat-related deaths among seniors have risen by 61% over two decades, averaging 300,000 annually.[978]

By 2030,

500 million

people, mainly in South Asia and the Middle East, **will face extreme heat for over 30 days annually, quadrupling current exposure**

By 2050,

two-thirds of households

could own **air conditioners**

THE OPPORTUNITY

Cooling solutions evolve into comprehensive systems with advanced materials at their core. Nanoengineered insulation eliminates the need for air conditioners in regions with moderate climates and significantly enhances air-conditioning efficiency in warmer regions. These innovative materials dynamically adapt to temperature changes. Combined with innovations in ventilation,[979] radiant cooling,[980] and cooling roof technologies,[981] they enable the next generation of green air conditioners.[982] These systems integrate solar photovoltaics, efficient cooling, advanced coolants, temperature–sensing technologies, and next-generation batteries.

Using advanced machine intelligence, the structure, composition and arrangement of different nanoengineered insulation layers[983] are optimised for each type of climate. These multilayered nanomaterials incorporate phase-changing materials.[984]

BENEFITS

Accessible cooling; reduced energy consumption and carbon emissions; decrease in health risks; heating and cooling cost savings.

RISKS

High initial implementation costs; unforeseen health impacts from exposure to nanomaterials (e.g. nanoparticles in the air); long-term durability.

Combined with innovations in ventilation, radiant cooling, and cooling roof technologies, **advanced materials** enable the

next generation of green air conditioners

What if new economic classifications unlocked progress?

30

Beyond Classifications

Within Reach | Transitional | **Visionary**

Dynamic metrics replace traditional country development and income classifications, driving greater global cooperation, more effective trade flows, and innovation aligned with shared global goals and challenges and enabling progress beyond financial aid.

UNCERTAINTIES

Collaboration, Systems

MEGATREND (Most significant)

Future Humanity

TRENDS

Cross-Sectoral Partnerships
ESG & Beyond GDP
Government Agility
International Collaboration

TECHNOLOGIES

Artificial Intelligence
Real-Time Analytics

SECTORS IMPACTED

All Sectors

KEYWORDS

Development
Financial Aid
Global Cooperation
International Finance
National Income

WHY IT MATTERS TODAY

The UN Environment Programme-led Inclusive Wealth Index measures produced capital, natural capital, and human capital for

140
countries

Globally, the wealth growth rate as tracked by this index is **significantly lower than GDP growth.**

The world is facing complex, interconnected challenges that traditional metrics fail to capture. Climate change, social inequality, and technological disruption are reshaping our global landscape in ways that GDP alone cannot measure. The UN Environment Programme-led Inclusive Wealth Index measures produced capital, natural capital, and human capital for 140 countries.[985] Globally, the wealth growth rate as tracked by this index is significantly lower than GDP growth.[986]

Beyond the minimum resources required for health, education, and economic growth,[987] financial aid has not always resulted in greater development. Classifications have long guided decisions on financial aid, policy and resource allocation.[988] However, the main organisations responsible for a lot of the aid and development support – the International Monetary Fund, the World Bank, and the United Nations Development Programme – have different classifications,[989] agreeing on only 20–25% of countries[990] (most of which are 'developed'[991]), which affects how and when countries receive aid. While identifying that the economic impact of foreign aid is hindered by insufficient data, other challenges include unclear time frames necessary for achieving an impact and the complexity of mediating factors.[992]

THE OPPORTUNITY

Aided by advanced machine intelligence, development and income classifications are replaced with dynamic metrics that form the basis of global collaboration, allowing tracking of global cooperation patterns, trade flows, and progress towards shared local, regional and global goals. By matching country needs and capabilities with aid or other forms of support enables evidence-based partnerships that prioritise local needs and progress beyond financial aid.

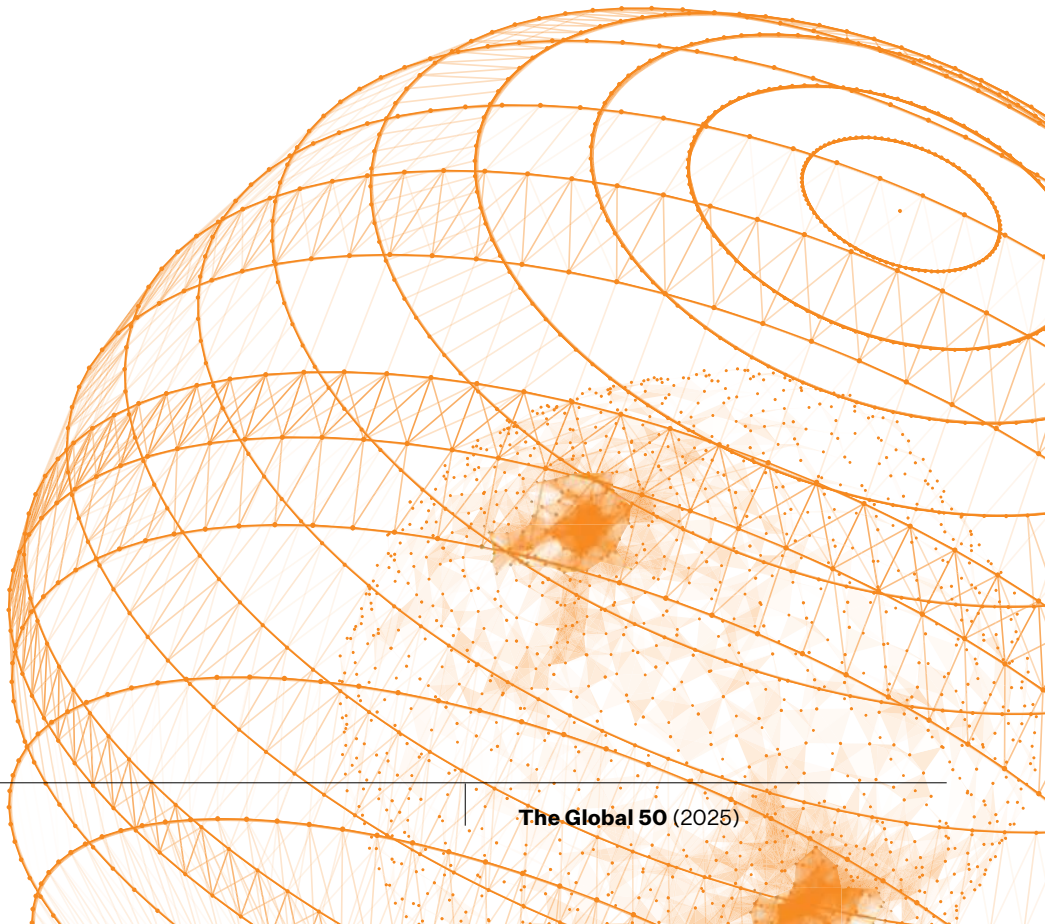
International cooperation shifts towards flexible networks and agreements addressing emerging challenges. Countries engage through partnerships that recognise their unique strengths and shared challenges[993] rather than historical economic metrics. As the basis of a dynamic form of cross-border collaboration,[994] innovation grows as nations focus on reporting their unique contributions to global progress. Increased cultural exchange fuels creative solutions to shared challenges, and development paths are as diverse as the needs and communities they represent.

BENEFITS

Enhanced global cooperation; progress beyond GDP; better resource allocation; accelerated progress towards shared global goals.

RISKS

Increased complexity in international relations and aid; difficulty achieving consensus on new metrics; shift away from the needs of local populations.



As a future opportunity, development and income classifications are replaced with dynamic metrics that form the basis of global collaboration, **allowing tracking of global cooperation patterns, trade flows, and progress towards shared goals**

What if academic publishing became truly open?

31

Public Publications

Within Reach | **Transitional** | Visionary

Academic publishing shifts to a centralised platform with universal access, advanced machine intelligence and blockchain, enhancing research quality, innovation, diversity, collaboration and global research.

UNCERTAINTIES

Collaboration, Systems

MEGATREND (Most significant)

Borderless World
– Fluid Economies

TRENDS

Cross-Sectoral Partnerships
Future of Education
International Collaboration
Mobilising Innovation
Open Data

TECHNOLOGIES

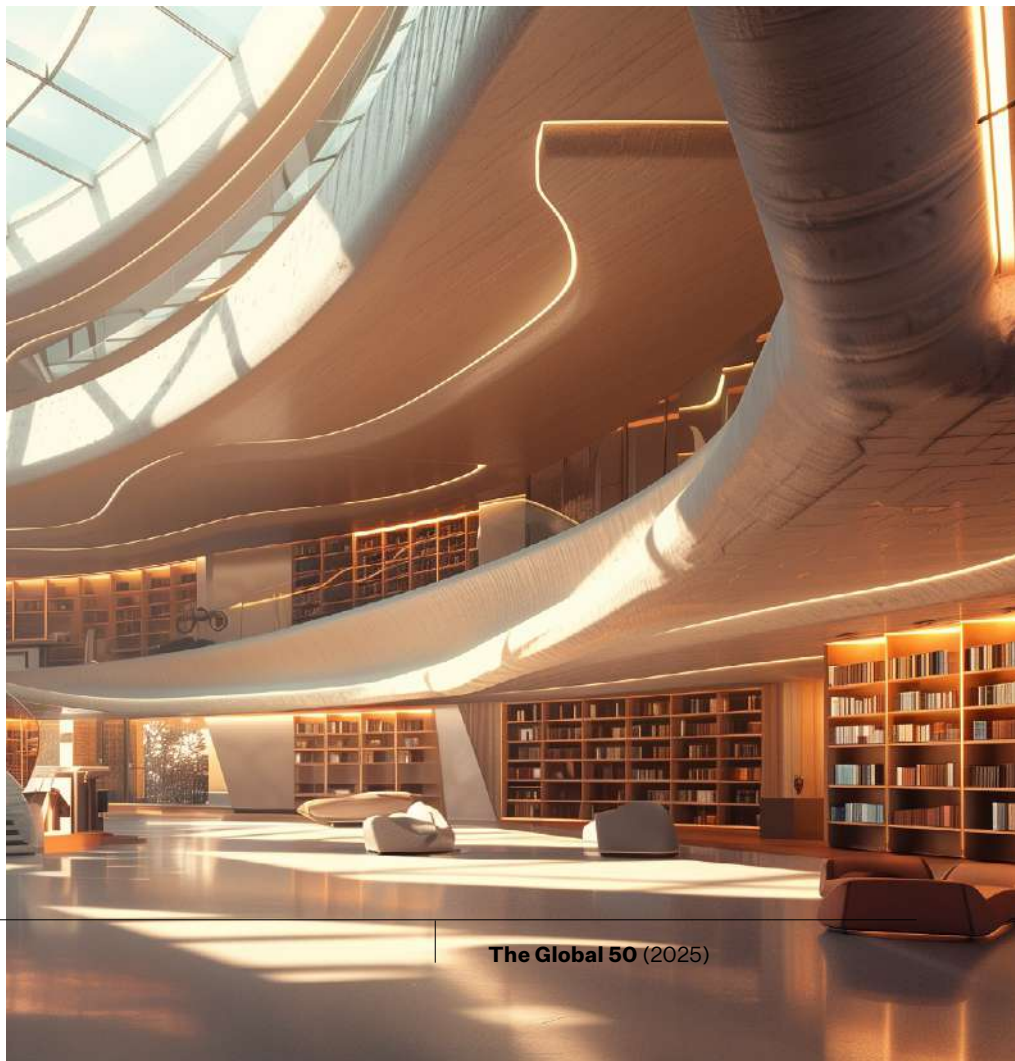
Artificial Intelligence
Data Protection & Privacy

SECTORS IMPACTED

All Sectors

KEYWORDS

Academic Publishing
Journal Impact Factor
Open Access
Plagiarism/Retraction
Research



WHY IT MATTERS TODAY

Despite a fragmented landscape, open access publishing continues to increase. It is estimated that just over

50%

of published articles are open access, and grant-making organisations are **increasingly stipulating that funded research must be published this way**

Despite a fragmented landscape,[995] open access publishing – where academic research is made freely available online for anyone to read and reuse – continues to increase. Globally, it is estimated that just over 50% of published articles are open access,[996, 997] and grant-making organisations (e.g. in Indonesia[998, 999] and Latin America[1000]) are increasingly stipulating that funded research must be published this way.[1001] Open Research Europe, provided by the European Commission, offers authors funded by the European Commission the option to publish their research as open access, with no charge to authors.[1002]

The focus on journal impact factors has led to exponential growth in misconduct and the prioritisation of quantity over quality. Despite a lack of evidence that it is a reliable metric,[1003] the impact factor rewards practices such as self-citation,[1004,1005] and citation data are often unrelated to the quality of papers.[1006] Paper mills and manipulated citations have also caused distortion, rewarding the mass production of fake papers.[1007] In 2024, the Retraction Watch Database had logged over 60,000 retractions, with the earliest dating back to 1927.[1008]

While it was designed for global access to knowledge, open access publishing remains in large part restricted. Globally, the average article processing charge (APC) – a fee authors pay for open access publication – is $1,626,[1009] yet the most significant nationwide grant for young researchers in Brazil (for example) is 30,000 reais (around $5,055)[I] for three years.[1010] At such high costs, many researchers – especially those from underfunded institutions or early in their careers – hesitate to make their work available for free. At the same time, the APC model unintentionally limits who gets published,[1011]especially when research is in a non-English language.[1012,1013] The big five academic publishers (Elsevier, Sage, Springer Nature, Taylor & Francis, and Wiley) earned approximately $1.06 billion in APC fees between 2015 and 2018,[1014] with Springer Nature recently reporting that its adjusted operating profit margin was 28%[1015] publishers have little reason to support free access.

[I] Based on REAIS:USD exchange rate as at 27 January 2025.

Globally, **the average article processing charge (APC) –** a fee authors pay for open access publication – is

$1,626

THE OPPORTUNITY

BENEFITS

Equal access to knowledge; accelerated research and innovation; enhanced global collaboration; improved research quality and diversity; broader global reach.

RISKS

Cultural resistance to change; poor quality despite efforts; unauthorised commercial use.

Academic publishing transitions from a diverse journal ecosystem to a centralised platform offering universal access to research. Operating under a non-commercial model with open licences like the Creative Commons, this platform enhances innovation, reduces plagiarism, and elevates research quality. Blockchain features improve transparency, provide decentralised storage, enable peer-to-peer collaborations, and reward research contributions, preventing unauthorised commercial use. Commercial applications, such as training large language models (LLMs), require separate licences to ensure fair compensation under relevant intellectual property frameworks.

Replacing journals, research outputs are dynamically grouped into themes using advanced machine intelligence, inspiring new research. Instant translation makes research accessible and diversified, while community peer reviews after publication enhance quality and relevance, moving away from traditional metrics.[1016] Meta-analysis research thrives with comprehensive datasets, automated tools for synthesis, and real-time updates, enabling deeper insights and researcher engagement where needed.

What if we could spray our way to personalised nutrition?

32

Nutrition Spray

Within Reach | **Transitional** | Visionary

Spray-based fortification uses nanoencapsulation and biomass for personalised nutrient delivery, addressing global micronutrient deficiencies and laying the foundation for 3D- and 4D printed food applications.

UNCERTAINTIES

Systems, Technology

MEGATREND (Most significant)

Advanced Health and Nutrition

TRENDS

Food–Water–Energy Nexus
Mobilising Innovation
New Materials
Precision/Personalised Medicine

TECHNOLOGIES

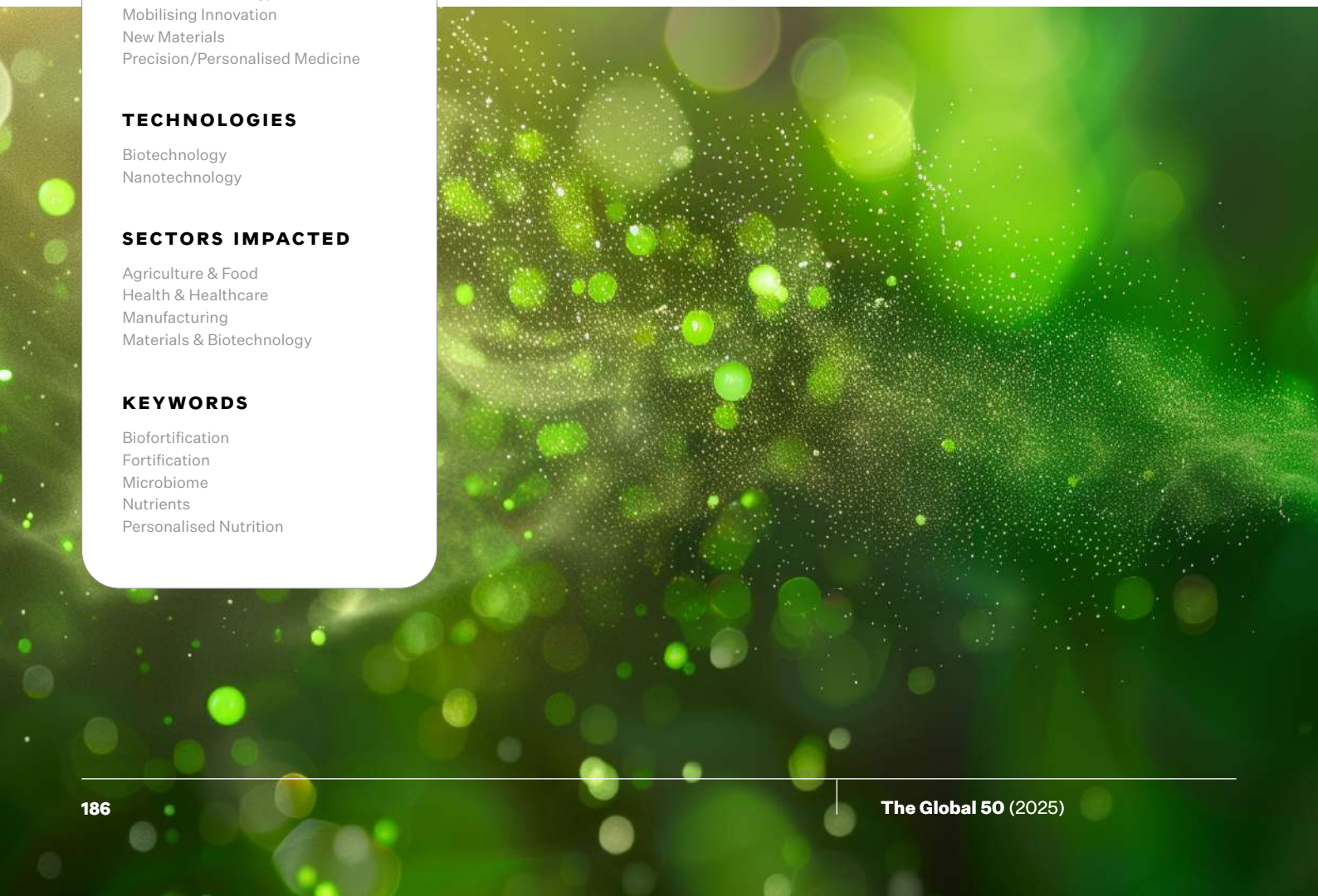
Biotechnology
Nanotechnology

SECTORS IMPACTED

Agriculture & Food
Health & Healthcare
Manufacturing
Materials & Biotechnology

KEYWORDS

Biofortification
Fortification
Microbiome
Nutrients
Personalised Nutrition



WHY IT MATTERS TODAY

Micronutrient deficiencies, also known as **'hidden hunger'**, affect **50% of preschool children** and **two-thirds of women** of reproductive age globally

Many around the world are deficient in vitamins and minerals needed for good health. Micronutrient deficiencies, also known as 'hidden hunger', affect 50% of preschool children and two-thirds of women of reproductive age globally.[1017] These deficiencies occur when people lack essential vitamins and minerals, even in individuals who consume adequate calories.[1018] Over 50% of the global population suffer from deficiencies in key nutrients such as iodine (5 billion) and iron (4 billion), severely impacting health and productivity.[1019]

Fortification – the addition of nutrients – has been proven an effective solution. Strategies include food fortification during processing and biofortification of crops.[1020] But the success stories (e.g. iodine fortification in salt and iron fortification in cereals) come with challenges, such as risk of thyrotoxicosis, high cost, and stability and absorption issues.[1021]

The market for minerals and vitamins is growing. The consumer health and wellness market was valued at $1.8 trillion in 2023, growing annually by 5–10%, and personalisation will be key.[1022] Over the past 20 years, supplement use has grown, with heightened demand during the COVID-19 pandemic for immune-boosting products. The market for these products surged by 50% between 2018 and 2020, reaching $220 billion in 2020, and is projected to reach just over $300 billion by 2028.[1023] The United States, Europe and Japan are the largest markets, but emerging markets such as the Middle East are also growing rapidly.[1024] While demand is expected to grow alongside the development of innovative forms and novel supplements, standardised regulations and scientific research will be critical to ensure safety and efficacy[1025] – the number of warning letters the US Food and Drug Administration sent to companies doubled between 2017 and 2022.[1026]

The consumer health and wellness market was valued at

$1.8 trillion

in 2023, growing annually by 5–10%, and personalisation will be key

THE OPPORTUNITY

Spray-based fortification targets micronutrient deficiencies, which harm health, cognitive development, and productivity, particularly in regions with limited access to nutrient-rich foods.[1027] These innovative sprays, applied directly into the mouth or added to food or drinks, use nanoencapsulation technology – used in drug delivery[1028] – combined with biomass to enhance nutrient stability and absorption.[1029]

Nanoencapsulation protects nutrients from degradation while enabling controlled release and targeted delivery.[1030] Sustainable biomass sources such as microalgae and safe-to-use agricultural waste (e.g. mango peel)[1031] provide eco-friendly nutrient sources. Customised sprays, with biosensors that analyse blood nutrient levels and the gut microbiome, enable personalised nutrition formulations distributed through kiosks in clinics, schools and remote areas supporting local health initiatives and opening the door to applications in 3D- and 4D-printed foods.[1032]

BENEFITS

Reduced reliance on mass biofortification; access to essential nutrients; tailored solutions for diverse populations.

RISKS

High production costs; limited scalability; logistical challenges; unintended toxicity and unwanted side effects.

While demand for supplements is expected to grow, **standardised regulations and scientific research will be critical to ensure safety and efficacy**

What if cities adjusted the energy mix in real time?

33 Dynamic Power

Within Reach | **Transitional** | Visionary

Citywide autonomous systems adjust energy generation and transmission in real time, optimising usage and extending asset life.

UNCERTAINTIES

Systems, Technology

MEGATREND (Most significant)

Energy Boundaries

TRENDS

Cross-Sectoral Partnerships
Food–Water–Energy Nexus
Government Agility
Air Pollution
Transforming Energy

TECHNOLOGIES

Artificial Intelligence
Internet of Things (IoT)
Real-Time Analytics

SECTORS IMPACTED

Communication Technologies & Systems
Cyber & Information Security
Energy, Oil & Gas, & Renewables
Government Services
Health & Healthcare
Infrastructure & Construction
Utilities

KEYWORDS

Energy Optimisation
Greenhouse Gas Emissions
Renewables
Smart Grids
Urbanisation

WHY IT MATTERS TODAY

Cities are responsible for approximately

75%

of **global energy consumption** and

70%

of global greenhouse gas emissions, values which are predicted to increase

Cities consume a lot of energy. Globally, they are responsible for approximately 75% of global energy consumption and 70% of global greenhouse gas emissions, values which are predicted to increase.[1033] Urbanisation accounts for around 10% of the increase in global emissions since 2015.[1034] Cities' need for diverse energy sources and smart grids will increase, and with renewables, they can reduce supply risks by up to 30%.[1035]

Population growth, and demand for energy, in cities is expected to increase. Globally, urban populations account for more than half of the 8 billion people on Earth today, a share that is increasing.[1036] The global urban population is expected to increase from approximately 56% today to around 70% by 2050.[1037] Cities already generate over 80% of global gross domestic product and are expected to continue to do so.[1038] Key to growth in artificial intelligence (AI), data centres will consume four (1,700 TWh) to nine (3,500 TWh) times more energy in 2050 compared with 2023 levels.[1039]

Renewable energy assets are a significant capital investment, and effectively managing them is critical for energy security. The costs of both solar photovoltaics (PV) and wind power technologies continue to decrease. Between 2010 and 2023, solar PV costs dropped 56% below fossil fuel and nuclear alternatives, reaching 4 cents per kWh,[1040] while wind turbine costs fell by an average of 53%.[1041] Driven by emission reduction targets, energy security, and strategic economic goals, demand will continue to increase. Subject to supply chain interruptions and financing, investment in energy are significant crossing $3 trillion in 2024, two-thirds of which is allocated to clean energy.[1042]

while wind turbine costs fell by an average of

↓53%

Between 2010 and 2023, solar PV costs dropped

↓56%

below fossil fuel and nuclear alterantives, eaching 4 cents per KWh

THE OPPORTUNITY

Citywide, fully integrated and autonomous systems optimise the energy mix in real time. The focus is no longer solely on what the energy mix is but on how it adjusts in real time to optimise energy generation and transmission. While advanced machine intelligence contributes to future energy demand, it also offers solutions for energy management and optimisation. With the Internet of Things (IoT) and advanced computing these systems reduce costs, enhance efficiency and extend asset life.

Beyond smart grids that optimise energy transmission, these systems adjust the energy mix to weather patterns, minimising conversion losses and reducing maintenance downtime. With quantum computing, it becomes possible to direct surplus renewable energy to storage or high-demand areas, ensuring a sustainable, reliable and cost-effective energy supply.

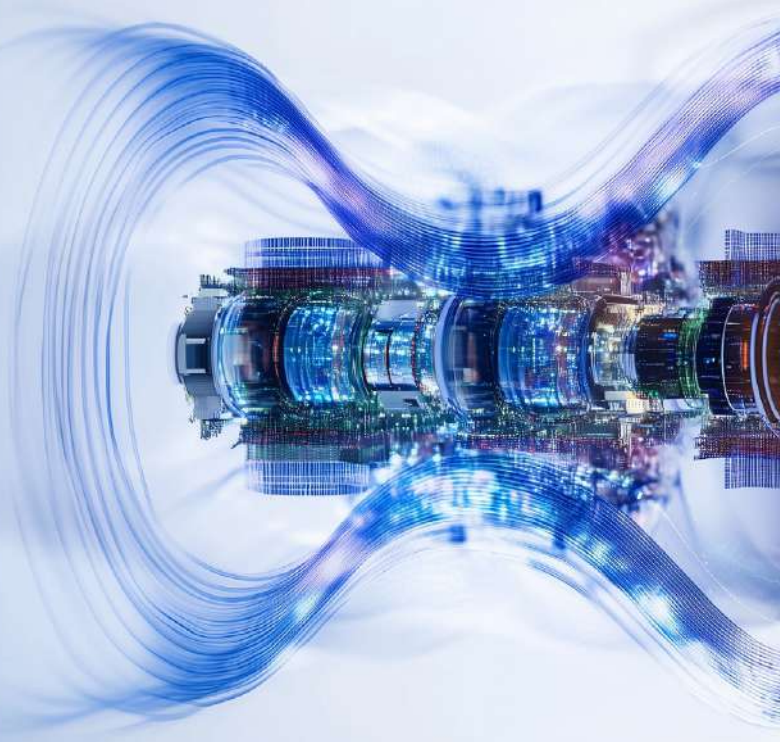
BENEFITS

Improved grid efficiency; enhanced energy storage; extended life of energy assets.

RISKS

Cybersecurity vulnerabilities; increased system complexity; high initial costs; technological complexity.

With quantum computing, it becomes possible to direct surplus renewable energy to storage or high-demand areas, **ensuring a sustainable, reliable, and cost-effective energy supply.**



What if patents were adaptive?

34

Adaptive Patent

Within Reach | Transitional | **Visionary**

An adaptive intellectual property (IP) system that ensures equitable access to essential technologies driving social-impact-focused innovation while enhancing transparency and supporting sustainable development for societal progress.

UNCERTAINTIES

Systems, Technology

MEGATREND (Most significant)

Borderless World – Fluid Economies

TRENDS

Cross-Sectoral Partnerships
Ideation, IP & Entrepreneurship
International Collaboration
Mobilising Innovation
Open Data

TECHNOLOGIES

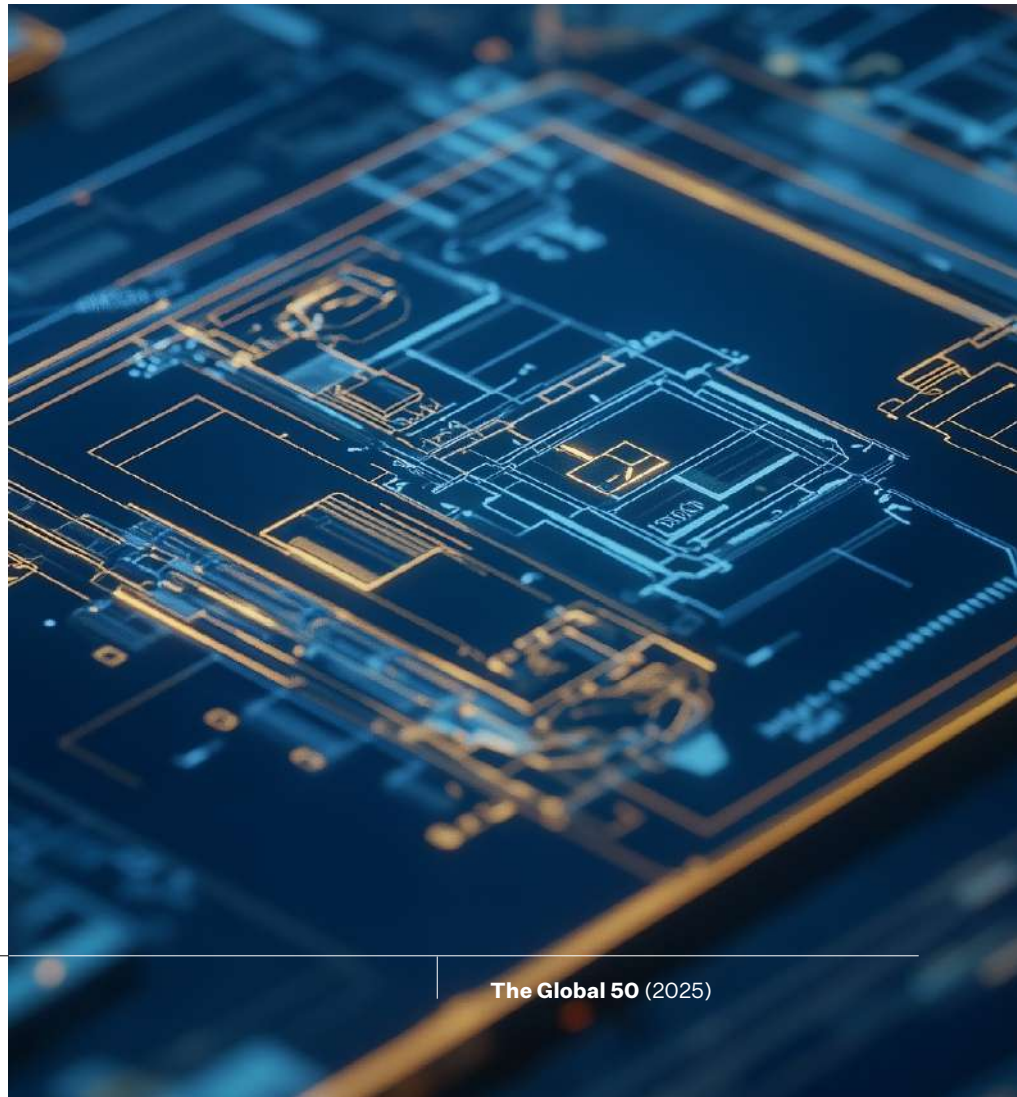
Advanced Computing
Artificial Intelligence
Blockchain

SECTORS IMPACTED

All Sectors

KEYWORDS

Blockchain
Cross-Border Data
Intellectual Property
Patents
Royalties



WHY IT MATTERS TODAY

Approximately

97%

of **patents never recover their filing costs,** and about

50%

expire prematurely because of unpaid maintenance fees.

Approximately 97% of patents never recover their filing costs, and about 50% expire prematurely because of unpaid maintenance fees.[1043] Even among university technology transfer offices, less than 20% break even on their patent investments.[1044] As a result, patents with limited commercial success are often abandoned despite filing costs and efforts.[1045]

Governments are trying to accelerate the patenting process. The United Kingdom's Green Channel, launched in 2009, expedites patent applications with environmental benefits.[1046] Similar programmes for green technologies are also being launched in Brazil,[1047] Canada,[1048] China,[1049] Japan[1050] and the United States,[1051] with China extending the scheme to other sectors, including biotechnology and advanced manufacturing.[1052] The Dubai Intellectual Property Hub was launched in October 2024 to make it easier for creators and/or innovators to understand what is required to protect their ideas and acquire the necessary resources to do so.[1053]

As AI evolves, its role in inventions and as a source of innovation is complex and may challenge current patent laws.[1054] When used as a general-purpose technology, AI raises fundamental questions about whether existing IP systems, designed for people and organisation-led innovation, require adaptation to account for AI-driven innovation and creation.[1055]

THE OPPORTUNITY

BENEFITS

Accelerated innovation; improved global societal outcomes; more equitable distribution of IP benefits.

RISKS

Increased complexity in IP management; cybersecurity vulnerabilities; challenges determining fair value; disruption of established industries.

An adaptive IP licensing system replaces static protections with a dynamic framework that triggers adjustments based on technological maturity, measurable public benefit and social impact priorities.[1056] Incorporating blockchain, advanced machine intelligence, and smart contracts,[1057] an adaptive patent system introduces 'explainable IP', enhancing transparency with interactive guidance, simplified language, and public engagement.

In addition to critical fields such as healthcare, environmental sustainability, and humanitarian aid, licensing terms adapt to country development indicators, such as the Human Development Index or progress on the Sustainable Development Goals, ensuring equitable access to essential technologies.[1058] By preventing patent hoarding and promoting active development, this approach creates a streamlined, equitable and future-ready global patent ecosystem.

What if synchronised robots perfected global supply chains?

35

Perfect Chains

Within Reach | **Transitional** | Visionary

Collaborative robots reshape industries and global supply chains through intelligent task-sharing, adaptive learning, real-time problem-solving, and continuous optimising and self-improvement across domains.

UNCERTAINTIES

Systems, Technology

MEGATREND (Most significant)

Life with Autonomous Robots and Automation

TRENDS

Automation
Cross-Sectoral Partnerships
Future of Purpose & Work

TECHNOLOGIES

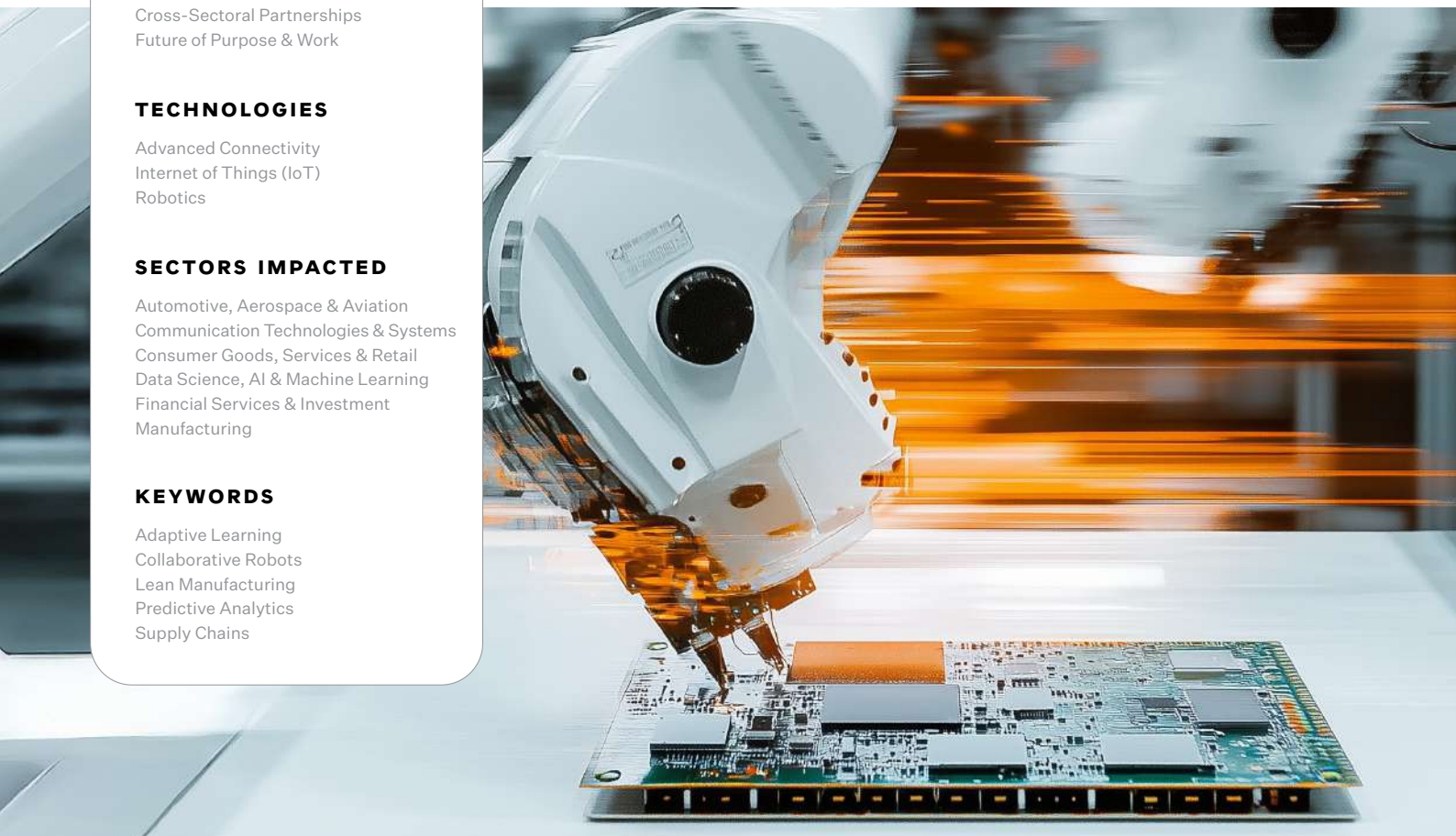
Advanced Connectivity
Internet of Things (IoT)
Robotics

SECTORS IMPACTED

Automotive, Aerospace & Aviation
Communication Technologies & Systems
Consumer Goods, Services & Retail
Data Science, AI & Machine Learning
Financial Services & Investment
Manufacturing

KEYWORDS

Adaptive Learning
Collaborative Robots
Lean Manufacturing
Predictive Analytics
Supply Chains



WHY IT MATTERS TODAY

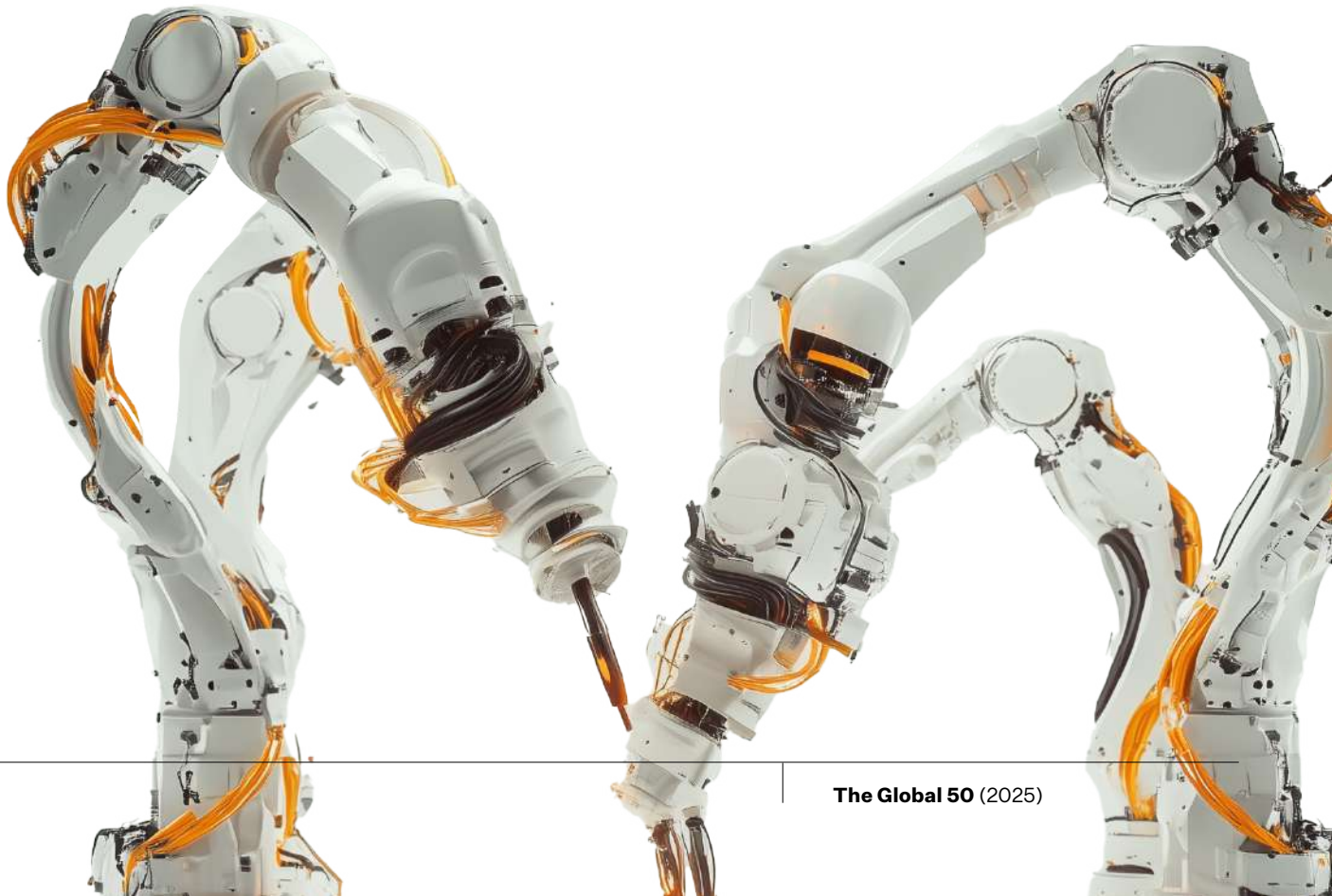
The manufacturing sector in the United States will require approximately

3.8 million

workers **between 2024 and 2033**

Both high- and low-income countries are dealing with labour shortages. Cultural perceptions prioritising academic degrees over vocational careers, persistent stereotypes about manufacturing jobs, and a growing mismatch between available skills and industry needs[1059] have had an impact on labour in the manufacturing sector. In the United States, this sector will require approximately 3.8 million workers between 2024 and 2033.[1060] Without effective strategies to bridge these skills and applicant gaps, around 1.9 million positions could remain unfilled, posing a significant challenge to the industry's growth and productivity.[1061]

Automation supports more resilient supply chains. It enables the optimisation of resources and enhances efficiency while aligning with Sustainable Development Goal 9, which focuses on infrastructure, technology, sustainability and societal well-being within a resilient global industrial framework.[1062] The Internet of Things (IoT) and AI can predict equipment failures by monitoring various parameters, reducing downtime and cutting maintenance costs by up to 15%.[1063] They can also reduce waste and improve product quality while cutting energy use by 20%, lowering operational costs and supporting sustainable manufacturing.[1064]



THE OPPORTUNITY

BENEFITS

Enhanced efficiency in global supply chains; optimised resource use; improved problem-solving.

RISKS

Job displacement; increased cyber-physical threats; overdependence on advanced technology; increased system complexity and ambiguity.

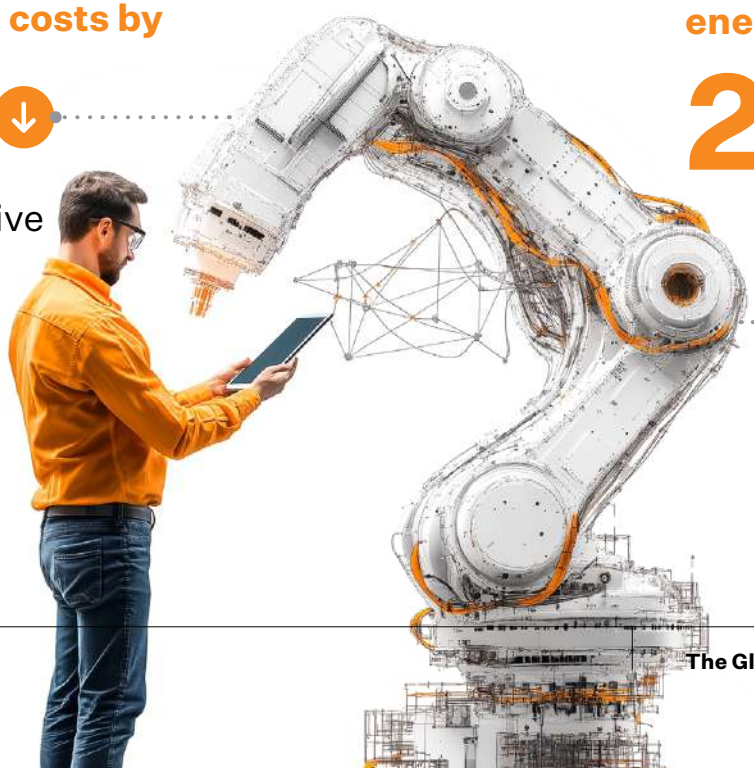
Ushering in a new era in industry,[1065] a network of collaborative robots reshapes value chains and industries to create a more interconnected global supply chain that functions as an ecosystem autonomously engaged in continuous self-improvement. They seamlessly work alongside humans, enhancing efficiency and productivity through intelligent task-sharing.[1066] Together, robots evolve into systems capable of learning, adapting, and collaborating across tasks and sectors.

Advanced machine intelligence (particularly quantum computing), edge computing, and neuroplastic AI algorithms[1067] enable them to process complex datasets in real time and dynamically share their performance and skill 'datasets' to enable adaptive learning and cross-domain problem-solving. Through predictive analytics, context-aware computing,[1068] and real-time anomaly detection, robots continuously refine their capabilities, adjust their performance, learn from collective experiences, and optimise operations across domains.

AI and the Internet of Things (IoT) **reduce manufacturing costs by**

15%

through predictive maintenance



while **cutting energy use by**

20%

What if a global sandbox streamlined cross-border innovation?

36

Global Sandbox

Within Reach | Transitional | Visionary

A global sandbox enables simultaneous testing of innovations across jurisdictions, advancing regulations and accelerating market entry while ensuring consumer protection through coordinated international oversight.

UNCERTAINTIES

Systems, Technology

MEGATREND (Most significant)

Borderless World – Fluid Economies

TRENDS

Cross-Sectoral Partnerships
Government Agility
Ideation, IP & Entrepreneurship
International Collaboration
Legal Transformation

TECHNOLOGIES

Artificial Intelligence
Data Protection & Privacy

SECTORS IMPACTED

Communication Technologies & Systems
Consumer Goods, Services & Retail
Cyber & Information Security
Data Science, AI & Machine Learning
Financial Services & Investment
Logistics, Shipping & Freight
Manufacturing

KEYWORDS

Cross-Border Consumer Safety
Digital Economy
E-Commerce
Market Entry
Regulatory Sandbox

WHY IT MATTERS TODAY

60%

of countries (especially in Africa) lack experience in cross-border consumer protection enforcement

Consumer product safety is important for society. According to the 2024 Report to the President and Congress, consumer products in the United States were associated with 14.1 million hospital visits and 3,595 deaths in 2023, involving appliances, home furnishings, personal use items, sports equipment, toys and more.[1069] In the European Union, preventable product-related accidents cost $12.8 billion annually, with financial losses from unsafe purchases reaching $21.6 billion per year.[1070] Globally, UN Trade and Development and the Intergovernmental Group of Experts on Consumer Protection Law and Policy are developing a model law to prevent cross-border distribution of unsafe products.[1071] While many high-income countries have established product safety laws, enforcement institutions, and recall mechanisms, 60% of countries (especially in Africa) lack experience in cross-border consumer protection enforcement, exposing them to unsafe products.[1072]

In parallel, the expanding digital economy is creating both economic opportunities and new safety challenges, particularly with the rise of AI-enabled products. The digital economy is projected to create 70% of new value in the coming decade[1073] and add $100 trillion to the global economy by 2025.[1074] The digital economy is expected to expand at a rate six times faster than the traditional economy, with the potential to account for 25% of global GDP in 2025.[1075] AI-enabled devices are rapidly becoming more common (e.g. the number of medical AI-enabled devices approved by the US Food and Drug Administration grew from 6 in 2015 to 950 in August 2024 alone).[1076] However, AI within these device is often unclear to both medical professionals and patients,[1077] increasing risks.

Attempts to address cross-border challenges are not new. While the Global Financial Innovation Network[1078] is not a sandbox, it does enable cross-border collaboration on financial innovation.[1079] Similarly, Mission Innovation[1080] is not a sandbox, but it does enable cross-border collaboration on energy solutions.[1081] In 2020, the world had 73 recognised fintech sandboxes in 57 countries (some general, some focusing on specific themes or jurisdictions).[1082,1083] While sandboxes may lack scalability and sometimes fail to transform testing into actual exit strategies, they are positively correlated with investments.[1084]

In 2020,
the world had

73

recognised **fintech sandboxes**

in

57

countries

THE OPPORTUNITY

Built on cooperation between different legal jurisdictions and regulatory authorities, and building on expertise in the financial sector,[1085,1086] a global sandbox focuses on testing a range of products, services, business models and technologies through a unified platform. Innovations are refined and tested simultaneously across multiple jurisdictions and markets, modelling their impact, and unintended consequences in diverse socio-economic landscapes. This approach significantly reduces the time and resources required for market entry in multiple countries.

In an interdependent and interconnected world, a global sandbox enables regulators to better understand the cross-border implications of new products, services and technologies and the testing in real-world scenarios under public sector oversight. This approach allows iterative development, real-time feedback, and collaborative engagement among diverse stakeholders.[1087]

BENEFITS

Simultaneous testing across jurisdictions; regulatory alignment; accelerated market entry; improved global consumer protection; enhanced knowledge sharing between jurisdictions.

RISKS

Complexity of cross-border supervision; lack of transparency in decision-making processes; challenges in maintaining consistent consumer protection across jurisdictions.

A global sandbox focuses on testing a range of products, services, business models and technologies through a unified platform, **modelling their impact in diverse socio-economic landscapes**

What if renewable wind and solar energy became fully circular?

37

Renewable Asset Loop

Within Reach | Transitional | **Visionary**

A global consortium advances circular standards for solar and wind assets, promoting sustainable design, recycling technologies and policies to maximise resource use and eliminate waste.

UNCERTAINTIES

Collaboration, Technology

MEGATREND (Most significant)

Evolving Ecosystems

TRENDS

Cross-Sectoral Partnerships
International Collaboration
New Materials
Sustainable Waste Management
Transforming Energy

TECHNOLOGIES

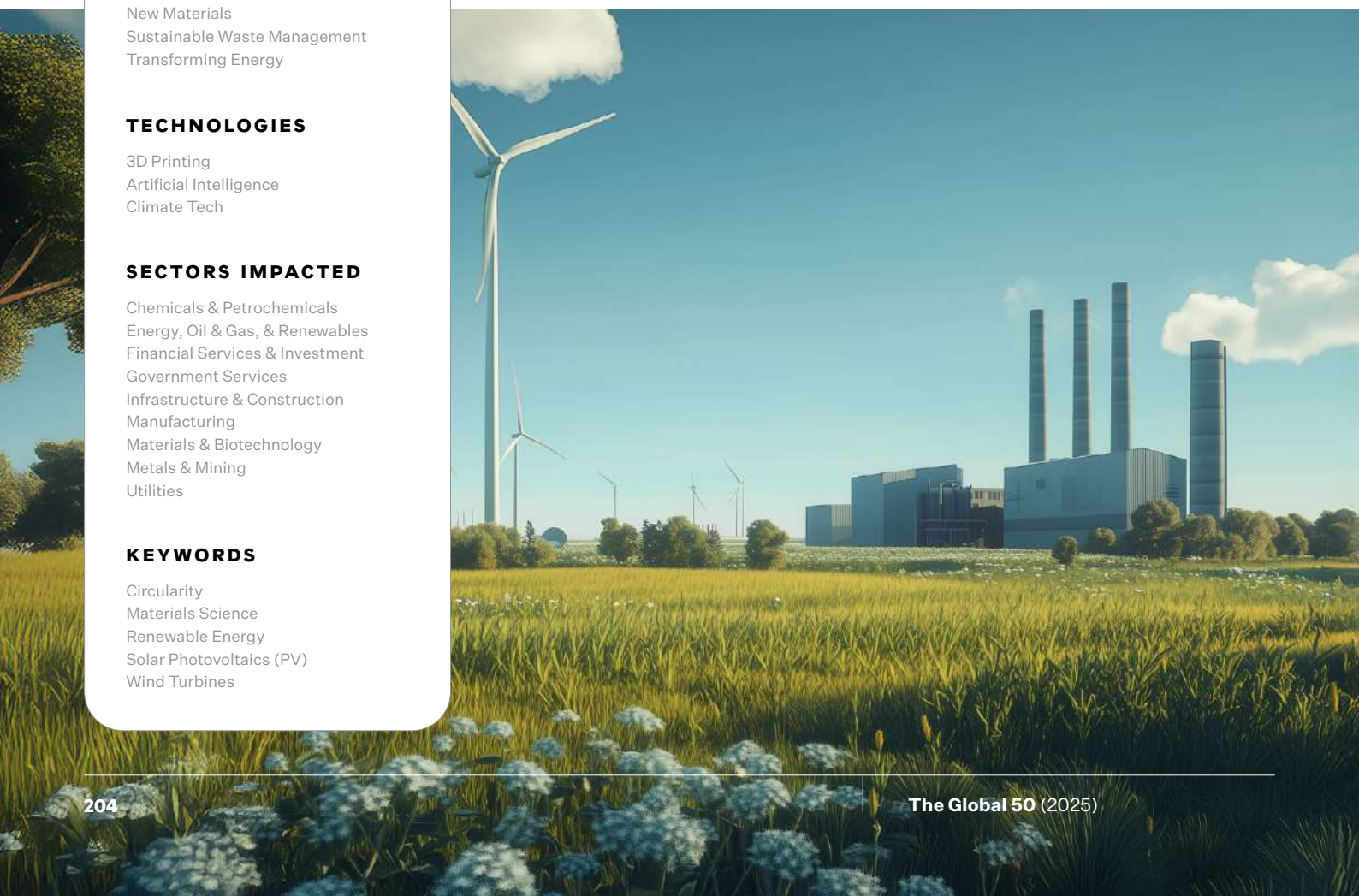
3D Printing
Artificial Intelligence
Climate Tech

SECTORS IMPACTED

Chemicals & Petrochemicals
Energy, Oil & Gas, & Renewables
Financial Services & Investment
Government Services
Infrastructure & Construction
Manufacturing
Materials & Biotechnology
Metals & Mining
Utilities

KEYWORDS

Circularity
Materials Science
Renewable Energy
Solar Photovoltaics (PV)
Wind Turbines



WHY IT MATTERS TODAY

The global energy transition will push **demands for renewable energy to**

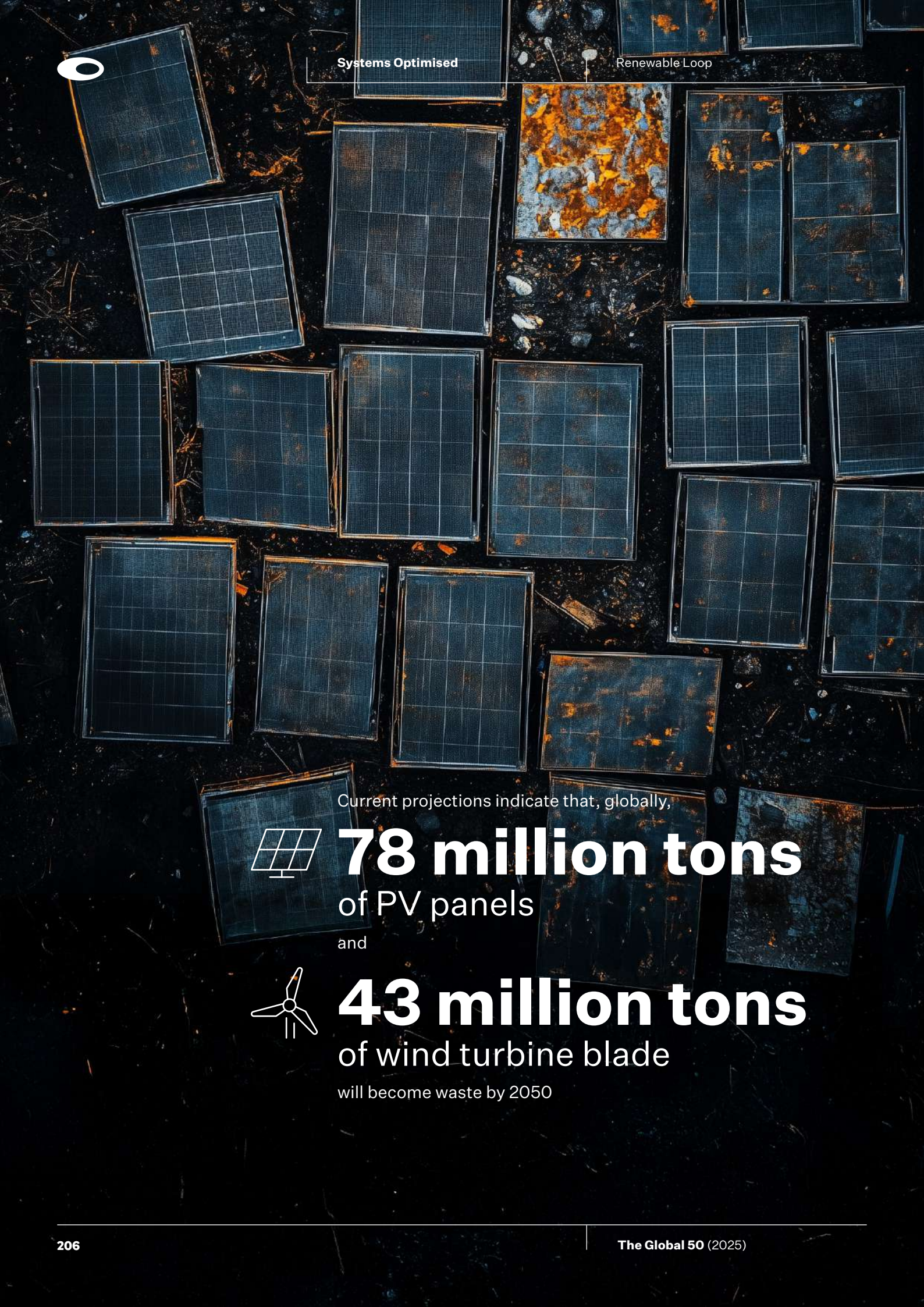
$150 trillion

in investment globally by 2050

The global energy transition will push demands for renewable energy, requiring $47 trillion in global investment by 2030, with $15.7 trillion allocated for renewable power generation and grid infrastructure.[1088] By 2050, the required investment will rise to $150 trillion globally, with $61 trillion needed for renewable power generation and grid infrastructure.[1089] While investment in offshore wind and other renewables (such as bioenergy and geothermal) is growing, these technologies remain underfunded.[1090] Renewable electricity's share of global power generation is expected to increase from 30% in 2023 to 46% in 2030, driven by solar and wind, which will account for the majority of growth.[1091] Solar photovoltaic (PV) panels are set to become the largest renewable electricity source by 2029.[1092]

Rapid expansion in renewable energy use will bring with it sustainability challenges. Wind turbines from the 1990s and 2000s are nearing the end of their life, and although much of a turbine can be recycled, components such as composite blades are typically sent to landfill or incinerated.[1093] Current projections indicate that, globally, 78 million tons of PV panels[1094] and 43 million tons of wind turbine blades[1095] will become waste by 2050.

Materials science and circularity may be key parts of the solution. Currently, 80–85% of wind turbine components[1096] and up to 95% of solar panel glass[1097] can be recycled. For example, the glass from solar panels can be reused in windows.[1098] Wind turbine blades can be used as supplementary building materials.[1099] Additionally, mobile grinding units would allow on-site recycling for the foundations for new turbines[1100] and blades have been used in rural applications, such as building walls and fences.[1101]



Current projections indicate that, globally,

78 million tons
of PV panels
and

43 million tons
of wind turbine blade
will become waste by 2050

THE OPPORTUNITY

A global consortium brings industry, governments and academia together to establish standards for recycling and circularity in renewable energy assets, beginning with solar and wind technologies. The focus of the consortium includes advancing materials science, integrating sustainable designs inspired by biomimicry, and deploying innovative recycling technologies powered by advanced machine intelligence to optimise designs[1102] and 3D printing of needed components on demand.[1103] By advocating policies to prohibit landfill disposal, mandate reuse, and encourage public–private partnerships, the consortium aims to create an all-encompassing framework for sustainable renewable energy asset management.

BENEFITS

Global alignment; new market opportunities and job creation; a more sustainable renewable energy sector.

RISKS

Implementation complexity; perceived lack of urgency regarding recyclability; limited suitable recycling technologies.

A global consortium brings industry, governments and academia together to **establish standards for recycling and circularity in renewable energy assets**

What if biomimicry made cybersecurity more resilient?

38

Nature Shield

UNCERTAINTIES

Systems, Technology

MEGATREND (Most significant)

Technological Vulnerabilities

TRENDS

Biomimicry
Cybersecurity
Government Agility
International Collaboration
Mobilising Innovation

TECHNOLOGIES

Artificial Intelligence
Internet of Things (IoT)
Real-Time Analytics

SECTORS IMPACTED

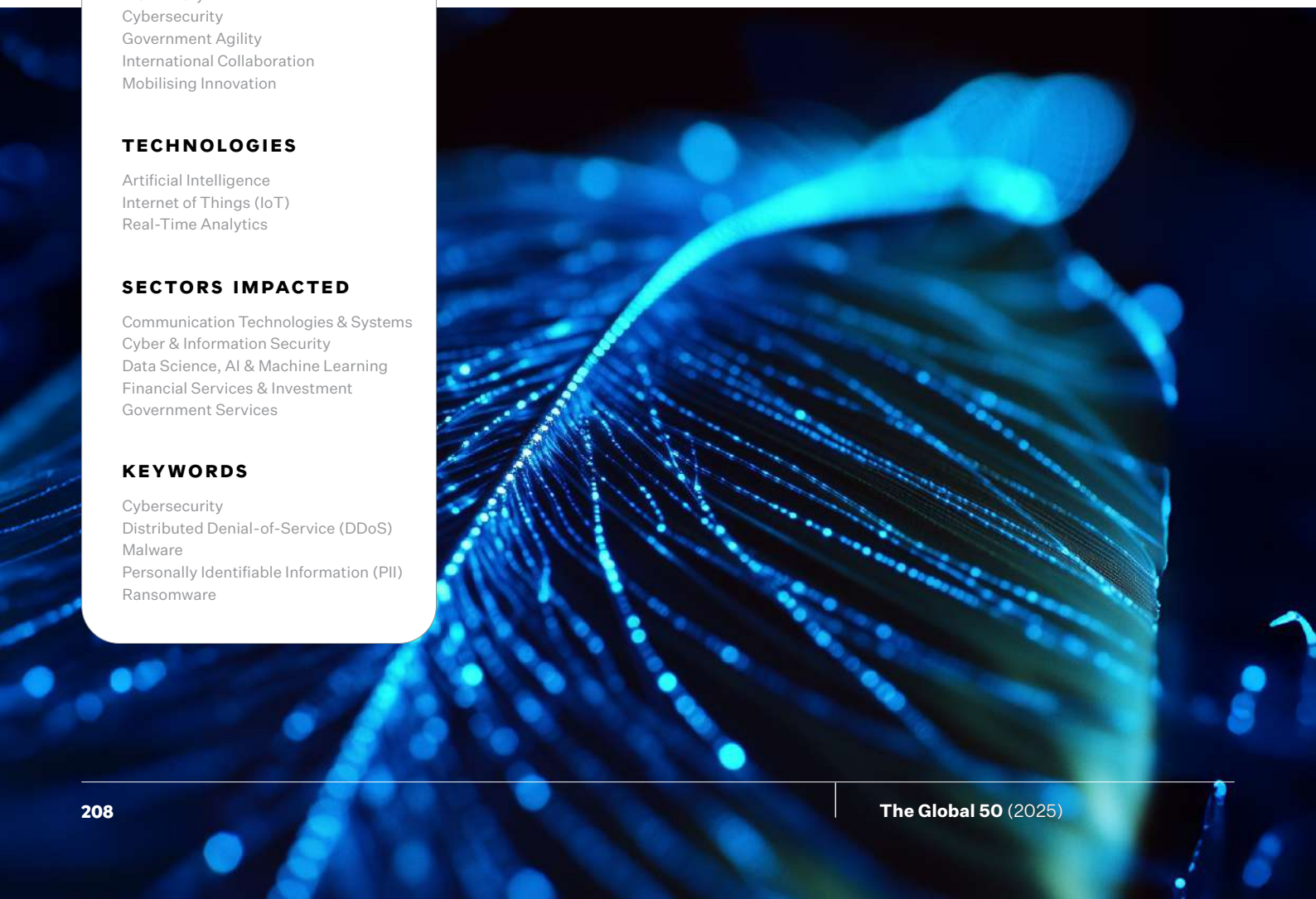
Communication Technologies & Systems
Cyber & Information Security
Data Science, AI & Machine Learning
Financial Services & Investment
Government Services

KEYWORDS

Cybersecurity
Distributed Denial-of-Service (DDoS)
Malware
Personally Identifiable Information (PII)
Ransomware

Within Reach | **Transitional** | Visionary

A biomimetic cybersecurity framework enhances digital ecosystems' ability to detect, respond to, and evolve against cyberthreats.



WHY IT MATTERS TODAY

The United States reported the highest average breach cost, at

$9.36 million

followed by the **Middle East**

$8.75 million

Seventy-two percent of those surveyed in the Global Cybersecurity Outlook (GCO) confirm that there was a rise in cyber risks.[1104] AI is increasingly used in cyberattacks, which are also becoming more large scale, automated, and intelligent. In a survey of more than 800 IT and security leaders around the globe, 95% agreed that cyberattacks are more sophisticated, with 51% having experienced AI-powered attacks, 36% deepfake and supply chain attacks, 35% cloud-jacking, and 34% Internet of Things (IoT) and 5G attacks.[1105]

Cybercrime costs and needs continue to rise. Globally, the average cost of a data breach increased by 10% in 2024, reaching $4.88 million.[1106] This increase is the largest since the COVID-19 pandemic, driven by business disruption and post-breach expenses, with nearly 46% of breaches involving personally identifiable information.[1107] The United States reported the highest average breach cost, at $9.36 million, followed by the Middle East ($8.75 million),[1108] while healthcare remains the costliest industry at $9.77 million per breach.[1109] Beyond the financial impact, cybercrime erodes trust, damages reputations,[1110] causes stress for victims, and polarises communities.[1111]

Globally, the average cost of a data breach increased by

10%

in 2023, reaching

$4.88 million

The average in the Middle East is nearly twice as high, $8.75 million, while healthcare is the costliest industry at $9.77 million per breach

THE OPPORTUNITY

A biomimetic cybersecurity framework mirrors nature's strategies to create resilient, adaptive systems capable of learning and evolving against cybersecurity threats. By leveraging principles such as self-organisation, decentralisation and rapid information sharing, it enhances detection and response using techniques such as particle swarm optimisation.[1112]

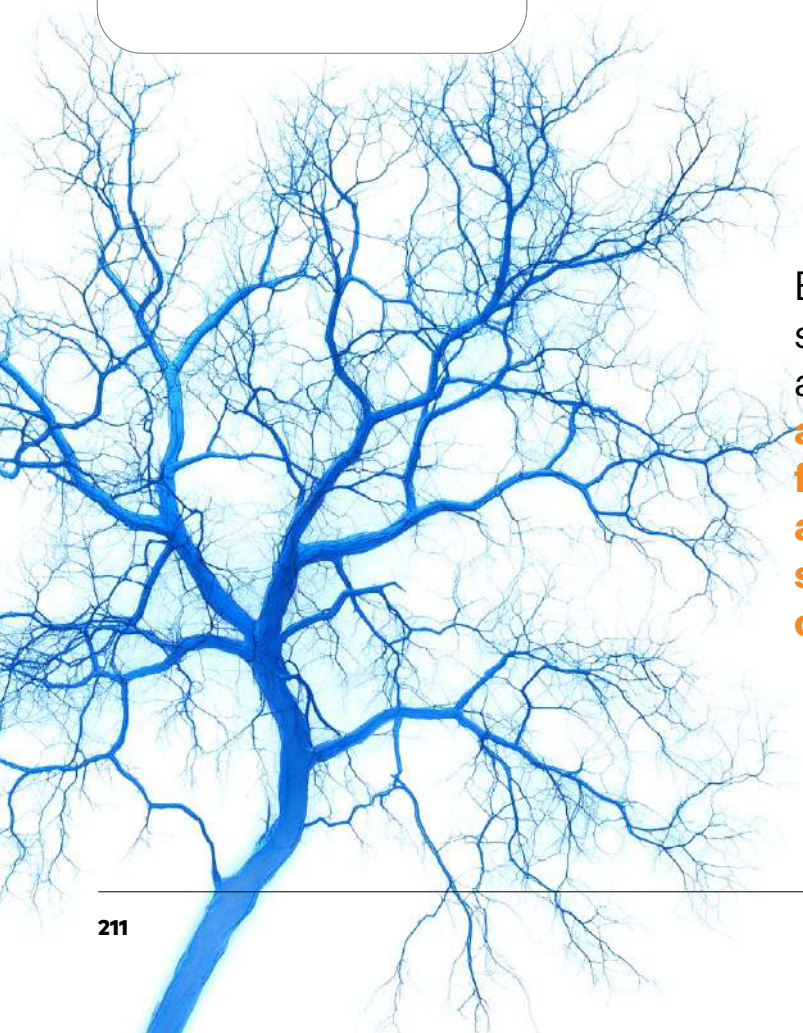
Integrating interdisciplinary insights from biology and environmental science, the framework sets global standards for dynamic, efficient cybersecurity,[1113] replacing static measures with evolving protocols that optimise resources and improve adaptability to an ever-changing threat landscape.

BENEFITS

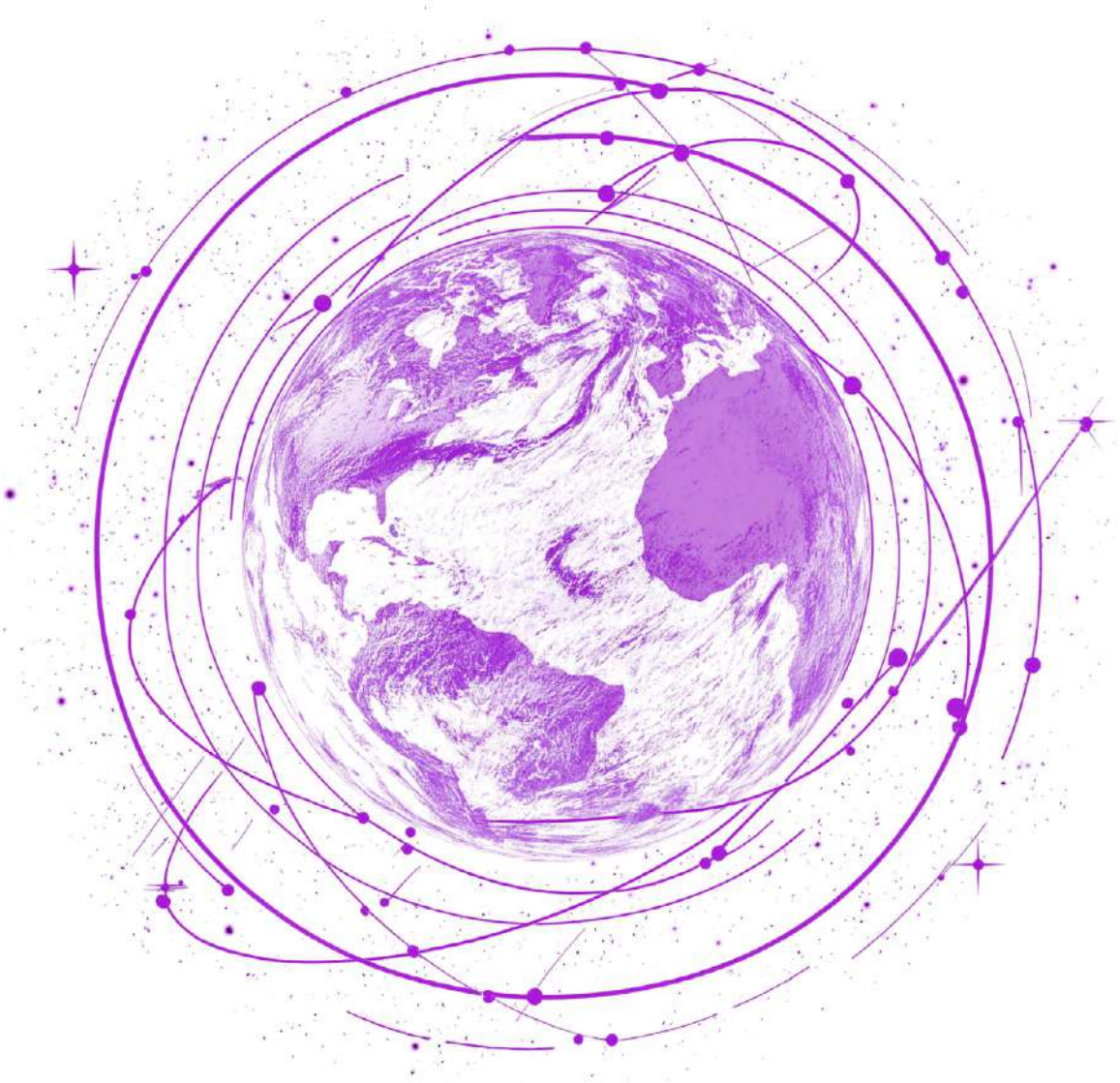
Enhanced digital security; autonomous optimisation and adaptation to novel threats; interdisciplinary application.

RISKS

Unforeseen vulnerabilities; outpacing of human oversight by rapid adaptation; increased complexity and ambiguity.



By leveraging principles such as self-organisation, decentralisation and rapid information sharing, **a biomimetic cybersecurity framework enhances detection and response using techniques suh as particle swarm optimisation.**



Transformational

The power to radically change ways of life by replacing the models that countries, communities and individuals live by. These new models enable individuals and communities to innovate and improve the transformation of humanity to new digital and non-digital realities.

What if strategic foresight guaranteed international cooperation success?

39

Future-Proof Agreements

Within Reach | **Transitional** | Visionary

Strategic foresight strengthens international agreements by embedding scenario planning, anticipating challenges, and developing adaptive responses, increasing the likelihood of successfully achieving shared goals.

UNCERTAINTIES

Systems, Technology

MEGATREND (Most significant)

Future Humanity

TRENDS

Cross-Sectoral Partnerships
Future of Purpose & Work
Government Agility
International Collaboration
Open Data

TECHNOLOGIES

Artificial Intelligence
Quantum Technologies
Real-Time Analytics

SECTORS IMPACTED

All Sectors

KEYWORDS

Climate Change
Complexity
Global Economy
Social Science
Uncertainty

WHY IT MATTERS TODAY

Only

17%

of the Sustainable Development Goal (SDG) targets are on track to be achieved by 2030, **and nearly half show moderate to severe deviations.**

Global interdependence is increasing, demanding collective solutions to global challenges. In our interconnected world, actions taken by one nation can have far-reaching consequences for others. The DHL Global Connectedness Index measures the world's depth of globalisation when it comes to trade on a scale ranging from 0% (nothing crosses national borders at all) to 100% (a 'frictionless' world where borders and distance have ceased to matter). The Index rose to a record high of 25% in 2022 and 2023 and currently available data suggest that it maintained a similar level in 2024 despite a series of global shocks.[1114]

Rapid technological advancements are reshaping society faster than ever before. AI, biotechnology and other emerging technologies are developing at an unprecedented pace, bringing both opportunities and risks. Across industries, 75% of organisations are planning to introduce AI over the next five years.[1115] With 22% of jobs expected to change in the next five years, according to the Future of Jobs Report, millions of people will need to move from declining to growing job sectors.[1116] Businesses predict that almost half (39%) of workers' core skills will be disrupted by 2027.[1117]

Progress on existing global goals is lagging behind. Only 17% of the Sustainable Development Goal (SDG) targets are on track to be achieved by 2030, and nearly half show moderate to severe deviations.[1118] Partnerships with civil society and local governments are emerging but need further expansion and formalisation to enhance SDG monitoring.[1119]

The DHL Global Connectedness Index measuring the world's depth of globalisation rose to

25%

in 2022, 2023 and is expected to be the same in 2024.

THE OPPORTUNITY

Strategic foresight, the ability to anticipate futures and take action, is embedded as a core element within international agreements and cooperation frameworks. Enabling parties strengthen agreements beyond legal protections by anticipating implementation challenges and developing responses to multiple possible scenarios. Through scenario planning, trend analysis and risk assessments, organisations can prepare for emerging situations, shifting mindsets from reactive crisis management to a commitment to proactive resilience building.

Scenario simulations empower decision-makers to anticipate and plan responses to challenges, while cross-border data sharing frameworks provide early-warning capabilities for complex multi-party agreements. Foresight integrated into agreements reshapes how nations and organisations address long-term challenges, strengthening partnerships and reducing the likelihood of implementation failure.

BENEFITS

Higher likelihood of achieving agreement goals; enhanced cooperation; better preparedness for crises; shift from reactive responses to long-term resilience.

RISKS

Disagreement over scenarios; misinterpretation or misuse of foresight to advance unrelated benefits; inability to address unanticipated events; institutional foresight gap.

Foresight can strengthen agreements beyond legal protections **by anticipating implementation challenges and developing responses to multiple possible scenarios**

40

What if energy was limitless, at room temperature?

Energy Without End 2.0[m]

GenAI

Within Reach | Transitional | **Visionary**

Breakthroughs in room-temperature fusion offer unlimited, sustainable and clean energy, transforming the global energy landscape.

UNCERTAINTIES

Systems, Technology

MEGATREND (Most significant)

Energy Boundaries

TRENDS

Cross-Sectoral Partnerships
Government Agility
Mobilising Innovation
New Materials
Transforming Energy

TECHNOLOGIES

Advanced Computing
Next-Gen Energy

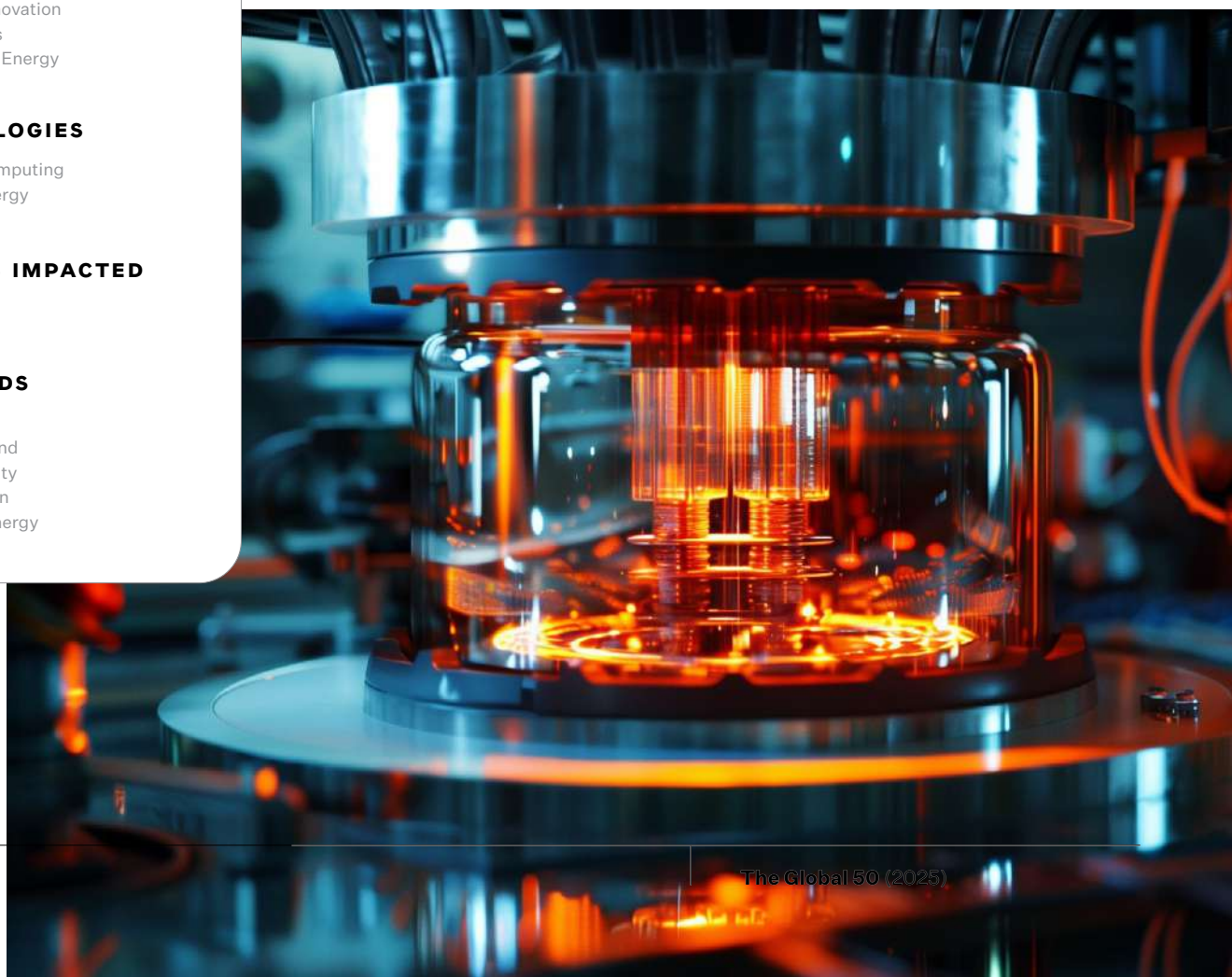
SECTORS IMPACTED

All Sectors

KEYWORDS

Deuterium
Energy Demand
Energy Security
Nuclear Fusion
Renewable Energy

[m] This opportunity builds on Opportunity 6 in the 2022 edition of The Global 50 report.



WHY IT MATTERS TODAY

In 2023,

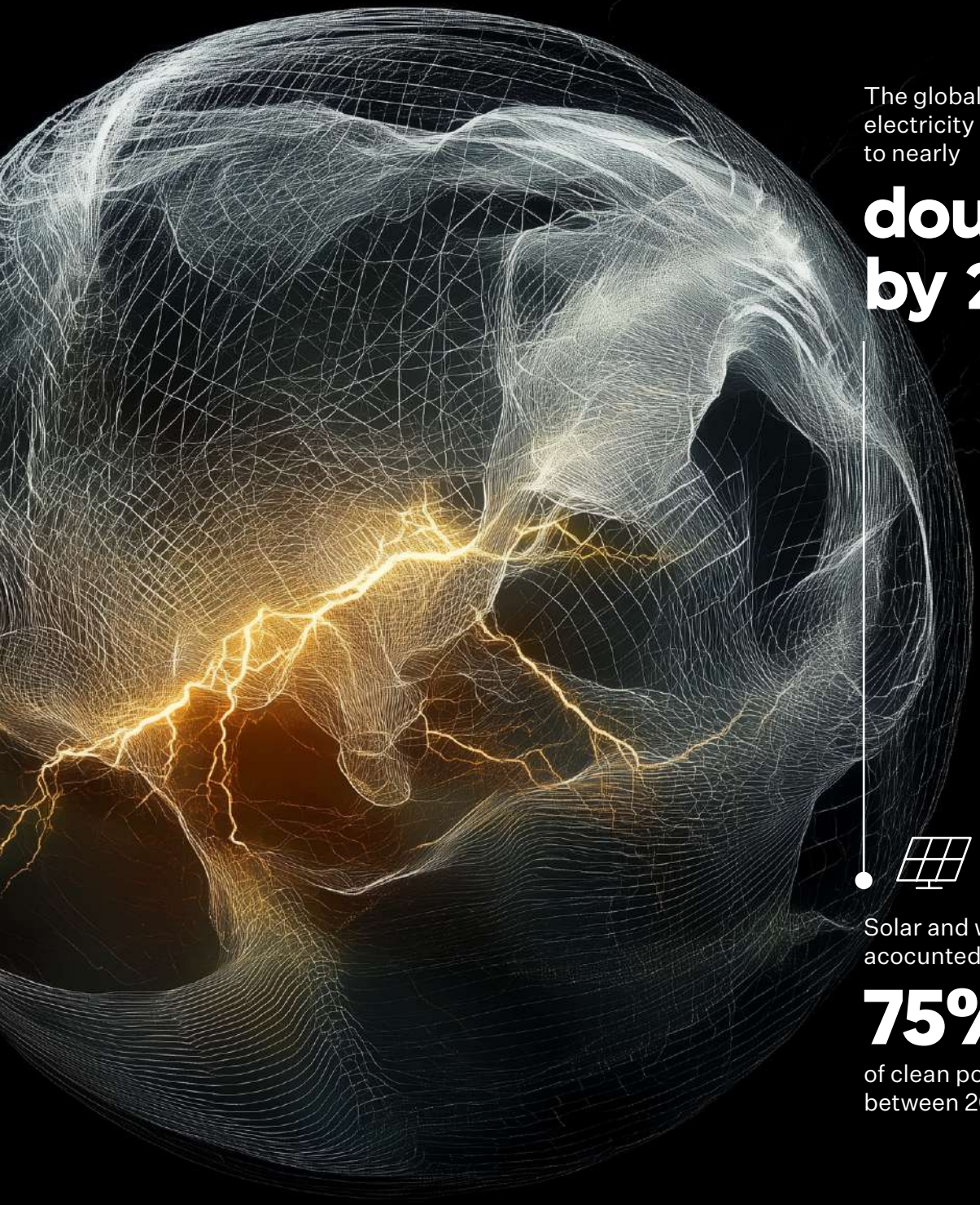
750 million

people still lacked access to electricity

Energy security – from diversified sources – is a global priority. The global demand for electricity is expected to nearly double by 2050, reaching 50,000 TWh (from 26,000 TWh in 2023).[1120] Between 2010 and 2030, solar photovoltaic and wind energy grew 40 times and 6 times respectively,[1121] wile renewables have increased by 3% per year since 2013 globally.[1122] Nuclear power currently provides 9% of global electricity supply, with more nuclear reactors also under construction.[1123] Additionally, small modular reactors are being considered, with the first projects outside China and Russia set to be implemented from 2030.[1124]

Global inequality is exacerbated by energy poverty. In 2023, 750 million people still lacked access to electricity.[1125] In Europe alone, between 50 million and 125 million people are living in energy poverty, highlighting the significant scale of this issue even in wealthy regions.[1126]

Technology is at the heart of the future of energy.[1127] From the Internet of Things (IoT) and big data to AI and renewable energy systems, technology is critical for improving energy infrastructure quality and sustainability.[1128] At the same time, while AI (for example) can optimise approaches to the sustainable energy transition, the computational power needed for AI doubles approximately every 100 days, with the energy demand expected to surpass Iceland's 2021 usage by 2028.[1129]



The global demand for electricity is expected to nearly

double by 2050

Solar and wind energy acocunted for

75%

of clean power growth between 2010 and 2023

THE OPPORTUNITY

BENEFITS

Decentralised energy production; abundant clean energy; off-grid energy availability; support for remote and disaster-affected areas; potential propulsion system for space exploration.

RISKS

Engineering feasibility and stability; complexity of safety mechanisms; economic scalability; unforeseen environmental impacts; inequitable global implementation.

In October 2024, the National Aeronautics and Space Administration (NASA) announced progress towards nuclear fusion at room temperature.[1130] Fusion – the bringing together of hydrogen atoms – has the potential to provide unlimited energy through reactions without hazardous materials such as plutonium or uranium. While fusion reactions are initiated at temperatures exceeding 100 million degrees Celsius,[1131] achieving this reaction at room temperature would be significant, eliminating barriers that currently make fusion a challenge to achieve.

Replicating the process found in the Sun, deuterium atoms – a special form of hydrogen that is abundantly found in seawater – fuse together to generate a massive amount of energy.[1132] NASA's recent achievement was through irradiating with gamma rays deuterium that was densely packed within a specially treated metal lattice.[1133] A single gram of deuterium–tritium fuel could generate energy equivalent to 2,400 gallons of oil,[1134] i.e. nearly 95 MW of power,[1135,n] roughly equivalent to the average annual capacity produced by nearly 28 wind turbines in the United States in 2023.[1136]

Replicating the process found in the Sun, fusion reactions initiated at room temperature have the potential to provide unlimited energy at room temperature instead of temperatures exceeding 100 million degrees Celsius

[n] 1 barrel of crude oil = 42 gallons = 5,689,000 Btu; 1 kW of electricity = 3,412 Btu; 1 MW = 1,000 kW.

What if national economies were centred around specific objectives?

41

Economies on a Mission

Within Reach | **Transitional** | Visionary

Mission-driven economies align public, private and civil society sectors to focus on specific objectives, replacing traditional economic models.

UNCERTAINTIES

Collaboration, Values

MEGATREND (Most significant)

Future Humanity

TRENDS

Community-Based Solutions
Cross-Sectoral Partnerships
ESG & Beyond GDP
Future of Purpose & Work
International Collaboration

TECHNOLOGIES

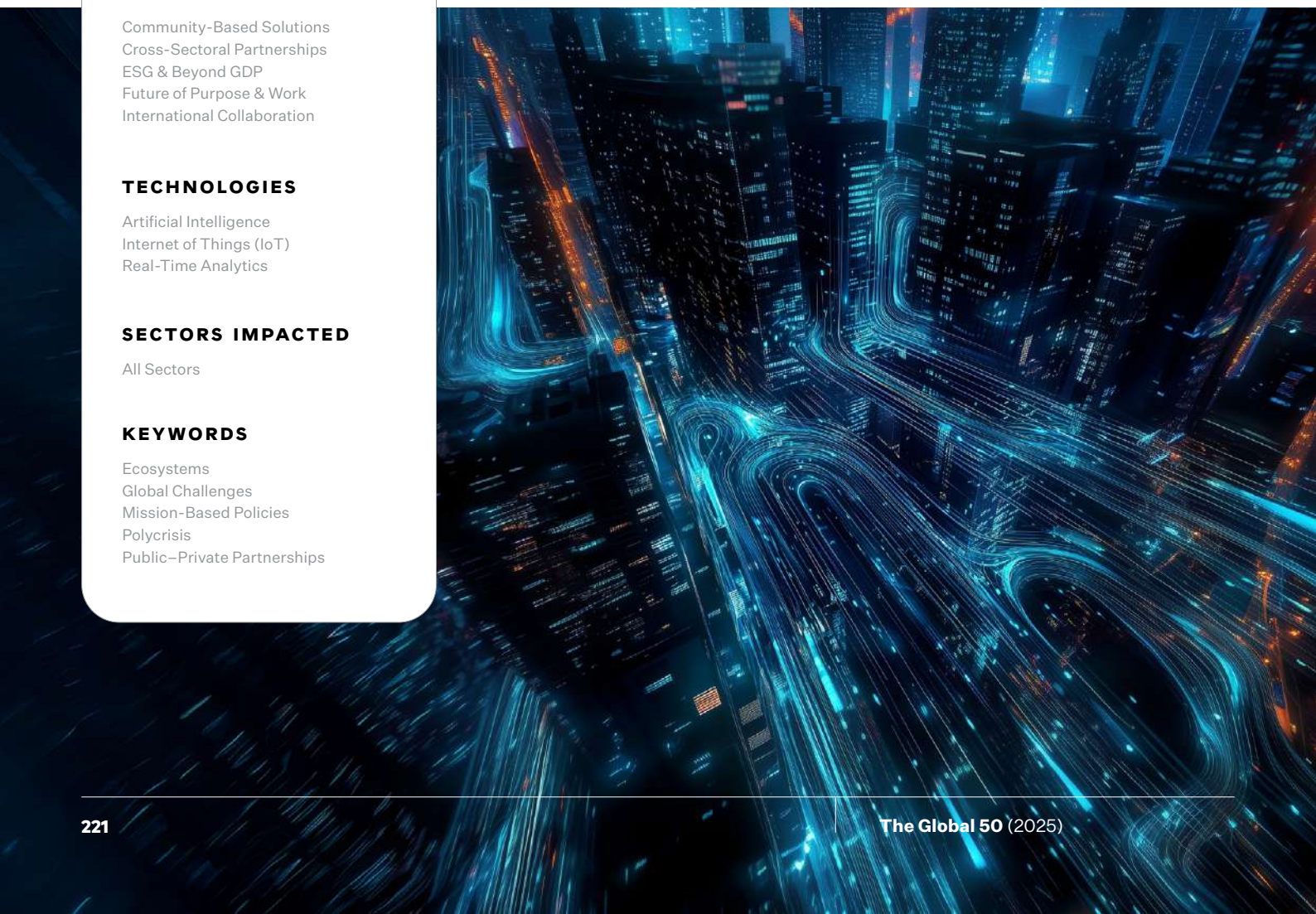
Artificial Intelligence
Internet of Things (IoT)
Real-Time Analytics

SECTORS IMPACTED

All Sectors

KEYWORDS

Ecosystems
Global Challenges
Mission-Based Policies
Polycrisis
Public–Private Partnerships



WHY IT MATTERS TODAY

The intensifying climate crisis highlights the need to redesign economies to **prioritise sustainability and inclusion, moving beyond traditional market fixes.**

We face several global challenges. The intensifying climate challenges highlights the need to redesign economies to prioritise sustainability and inclusion, moving beyond traditional market fixes.[1137] With public health challenges and slow progress towards the Sustainable Development Goals,[1138] the result is a 'polycrisis' – a convergence of interconnected global risks with compounding effects, where the cumulative impact far exceeds the effect of each individual issue.[1139]

Innovation, between business and government, in addition to economic concerns such as inflation and potential job losses, cause trust levels to vary particularly when it comes to regulation and governments' role in innovation. Approximately 60% of respondents to the 2024 Edelman Trust survey do not believe regulators understand how to effectively manage emerging technologies,[1140] highlighting the need for governments to work closely with business.

Mission-based policies offer a new approach to growth and innovation,[1141] translating challenges into achievable outcomes. Missions are measurable, ambitious, time-bound objectives tackling societal challenges like climate change and health inequities using purpose-driven, market-shaping strategies.[1142] Germany's High-Tech Strategy 2025, introduced in 2018, used a mission-oriented approach to combat cancer and carbon neutrality and to enhance living conditions, while also generating economic benefits through business development, job creation, cross-sector collaboration, investments and reduced barriers to further economic growth.[1143]

Nearly 60% of respondents

to the 2024 Edelman Trust survey do not believe regulators understand how to effectively manage emerging technologies, highlighting the need for governments to work closely with business

THE OPPORTUNITY

Mission-driven economies prioritise addressing local, regional and global challenges[1144] as opposed to only broader objectives of economic growth. Public, private and civil society sectors align their visions, missions and associated budgets and spending to specific objectives. Forging new partnerships through conditional funding mechanisms and purpose-driven contracts, governments serve as active collaborators rather than just regulators. Generating sustainable value over time, mission-focused economies are flexible in approach but rigid on outcomes.[1145] With clear priorities, cross-border agreements become achievable, enabling long-term impact.

BENEFITS

Focused and pragmatic solutions to challenges; increased drive towards purpose-driven industries and cooperation; shared goals across society; optimised resource allocation.

RISKS

Not suitable in all contexts; misallocation of resources; slow economic growth; failure to consider other stakeholders and important issues.

Mission-driven economies prioritise addressing local, regional and global challenges as oppposed to only broader objectives of economic growth

What if the world knew exactly how much water we use and could predict future water needs and shortages?

42

Better Water Meter

Within Reach | Transitional | **Visionary**

Industrial Internet of Things (IIoT) and satellite data form an automated and comprehensive water accounting system that provides insights into water usage and flows and a better understanding of how much water we really need to support more informed decisions on global water policies and conservation efforts.

UNCERTAINTIES

Collaboration, Technology

MEGATREND (Most significant)

Boundless
Multidimensional Data

TRENDS

ESG & Beyond GDP
Food–Water–Energy Nexus
International Collaboration
Open Data

TECHNOLOGIES

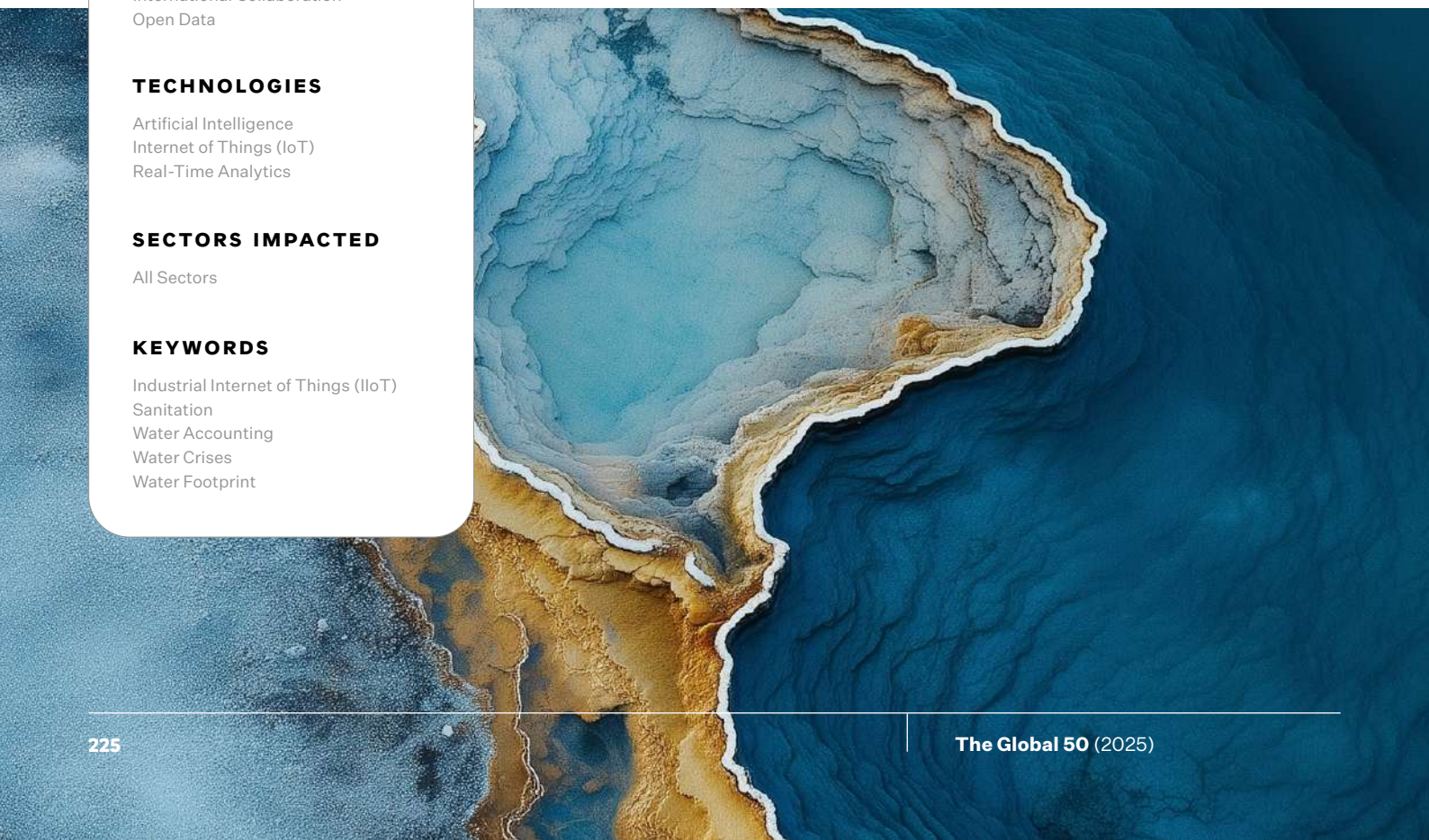
Artificial Intelligence
Internet of Things (IoT)
Real-Time Analytics

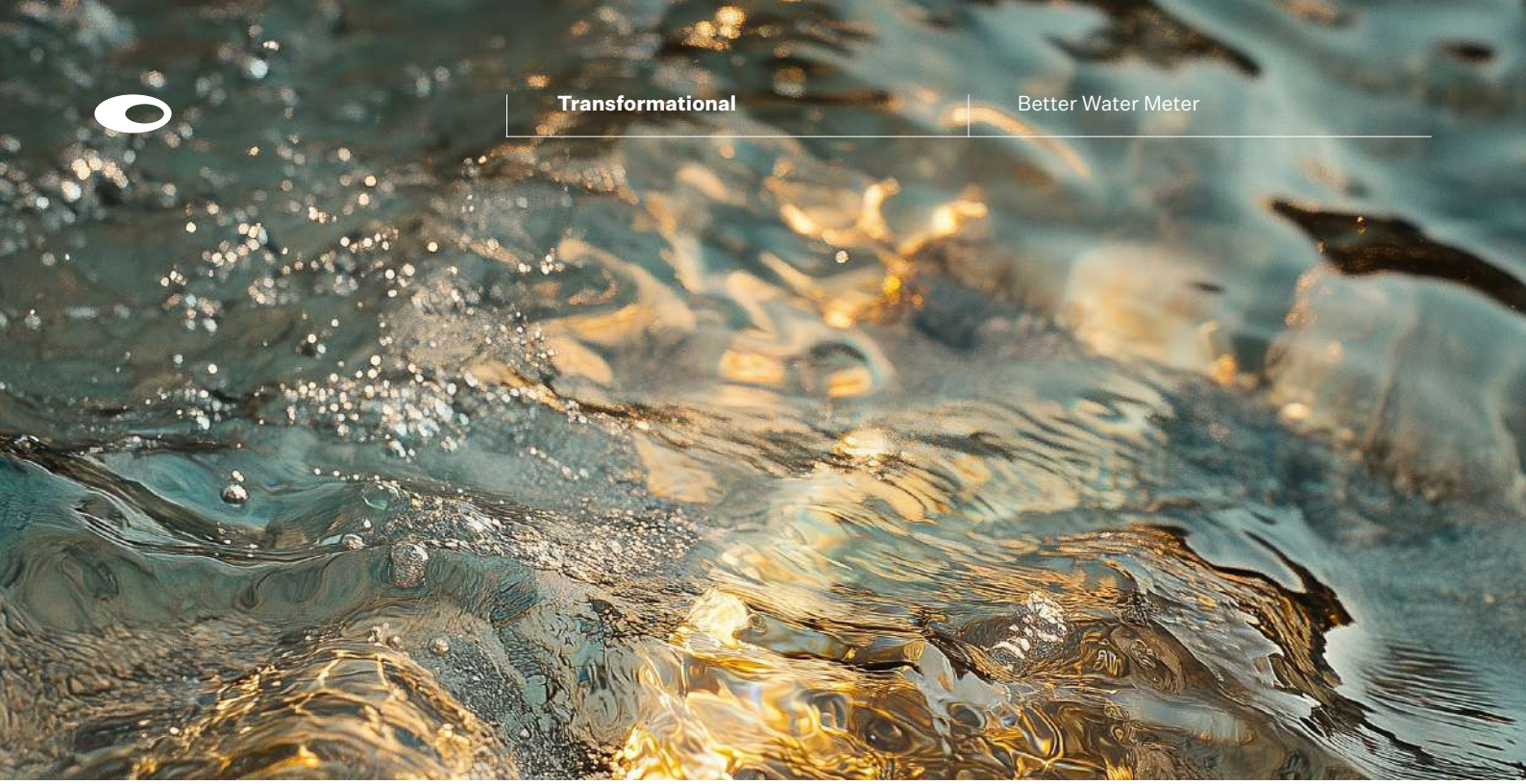
SECTORS IMPACTED

All Sectors

KEYWORDS

Industrial Internet of Things (IIoT)
Sanitation
Water Accounting
Water Crises
Water Footprint





WHY IT MATTERS TODAY

By 2030, **demand for water will likely exceed supply by**

40%

potentially reducing global GDP by 8% by 2050, **with low-income nations facing losses of up to 15%.**

The world faces an unprecedented water crisis affecting billions. Over 2 billion people lack access to safe drinking water, while nearly half the global population (3.6 billion people) cannot access proper sanitation.[1146] By 2030, demand for water will likely exceed supply by 40%, potentially reducing global GDP by 8% by 2050, with low-income nations facing losses of up to 15%.[1147] This crisis will threaten food security since more than half of global food production occurs in regions with unstable water availability.[1148]

Climate change and inefficient water use are jointly creating a cascading crisis in global water systems. In the Amazon, severe droughts are becoming more frequent, while Asia and Europe face unprecedented flooding.[1149] Mountain regions present a particularly stark example, where accelerated glacier melt is triggering chain reactions.[1150] Industrial use, particularly in food processing, wastes a significant proportion of water.[1151] For example, producing 1 kg of milk formula requires 4,700–7,430 litres of water.[1152]

Over 2 billion

people lack access to safe drinking water, while nearly half the global population (3.6 billion people) cannot access proper sanitation.

THE OPPORTUNITY

BENEFITS

Improved water accounting; forecasting droughts and floods; access to data that support scalable water management solutions; foundation for international cooperation and data sharing agreements.

RISKS

Extensive resource requirements; data and system interoperability; complex sensor networks; cybersecurity and potential misuse; data manipulation; incorrect predictions.

Together, data from the Internet of Things (IoT) – including the IIoT (secured by blockchain[1153]) – and satellite monitoring[1154] form a real-time digital twin of the Earth's entire water system.[1155] The automated water accounting system provides a comprehensive overview of water resources and movements, providing a better understanding of how much water we really need, better informing global policies, and optimising water use and conservation.

The system monitors all three water footprints[1156] – green (e.g. rain and soil moisture), blue (e.g. rivers, lakes and groundwater), and grey (e.g. from washing machines and showers) – while tracking water flows around the world. From underground aquifers and river systems to industrial and agricultural sites, sensors monitor groundwater levels, river flows, water quality, and consumption patterns. Satellites provide data on precipitation, soil moisture, and other key variables in the water cycle. Advanced machine intelligence helps predict droughts in advance to identify inefficiencies in water use in the global food trade, and equip local communities with information to manage their water needs and usage. As quantum computing handles complex calculations across the food–water–energy nexus, the system can provide early warnings on water quality, mitigating the risk of waterborne diseases.

This approach makes water accounting more accurate, transparent and clear, providing a comprehensive overview of water resources and movements worldwide and giving us a better understanding of how much water we really need

What if next-generation geothermal energy enabled universal energy access?

43

Next-Gen Geothermal

Within Reach | Transitional | **Visionary**

Innovative approaches to geothermal energy combined with advanced machine intelligence and materials make geothermal energy accessible, cost-effective and less dependent on location, promoting a sustainable source of renewable energy.

UNCERTAINTIES

Nature, Technology

MEGATREND (Most significant)

Pushing the Boundaries on Energy

TRENDS

Cross-Sectoral Partnerships
Net Zero
New Materials
Repurposing Assets
Transforming Energy

TECHNOLOGIES

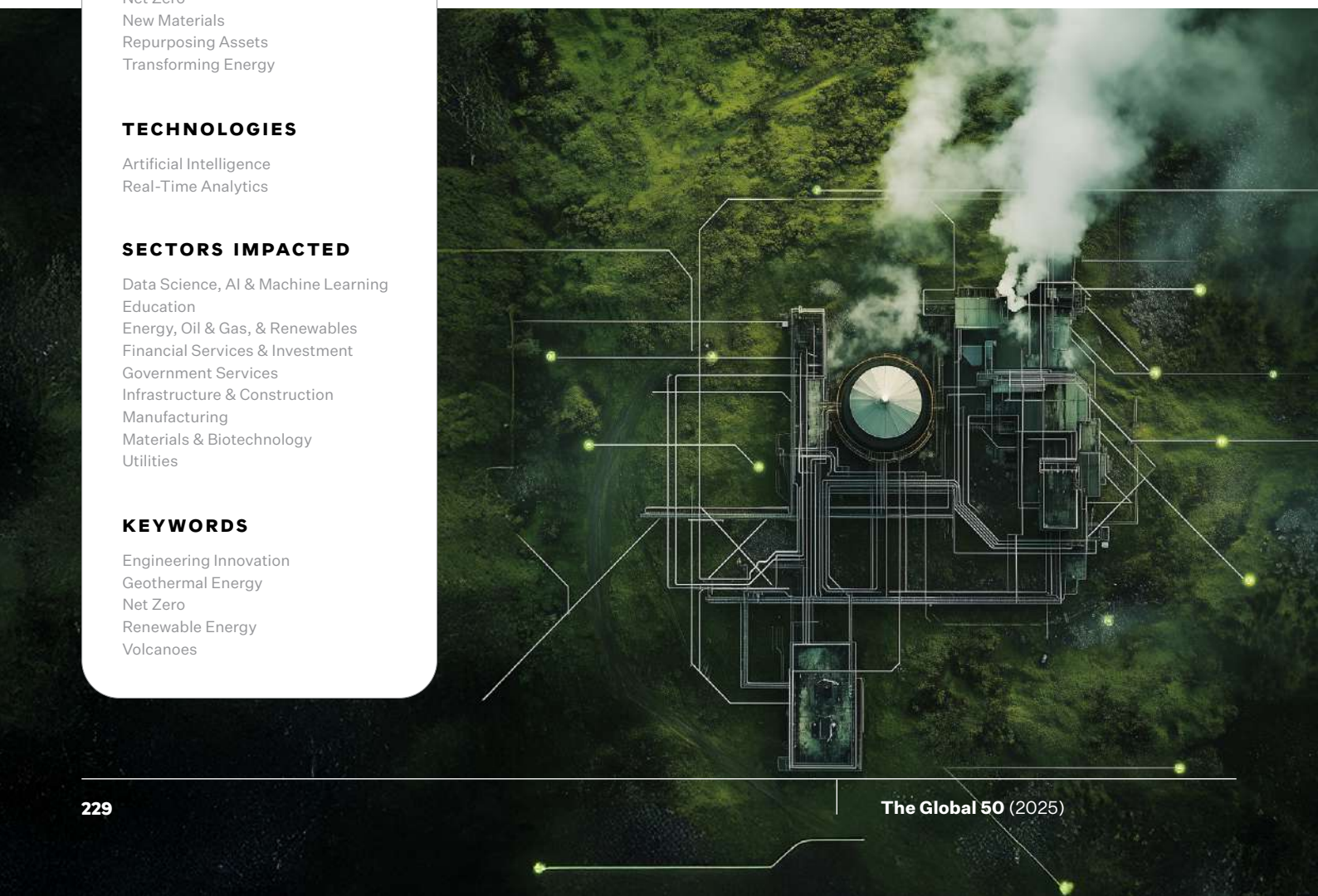
Artificial Intelligence
Real-Time Analytics

SECTORS IMPACTED

Data Science, AI & Machine Learning
Education
Energy, Oil & Gas, & Renewables
Financial Services & Investment
Government Services
Infrastructure & Construction
Manufacturing
Materials & Biotechnology
Utilities

KEYWORDS

Engineering Innovation
Geothermal Energy
Net Zero
Renewable Energy
Volcanoes



WHY IT MATTERS TODAY

With

60%

annual availability, **geothermal is the most reliable renewable energy source in the world, yet it is used the least**

With 60% annual availability, geothermal – heat from beneath the Earth's crust – is the most reliable renewable energy source in the world, yet it is used the least, lagging behind wind and solar due to limited investment and market share.[1157] Many East African countries could address energy poverty with their abundant geothermal reserves,[1158] and 15–22% of India shows high geothermal potential.[1159] Europe's geothermal energy is projected to supply 4–7% of electricity by 2050.[1160] As of 2022, 32 countries operated geothermal power plants, with a total capacity of 16,318 MW,[1161] accounting for 0.34% of worldwide electricity generation and 0.87% of clean energy production.[1162]

Traditional geothermal energy holds promise (especially for net zero) but is also a challenge. One study found that by repurposing oil wells to produce geothermal energy,[1163] carbon emissions can be reduced by 34% compared with conventional geothermal.[1164] At the same time, geothermal power would need to grow by 13% annually to meet net-zero emissions by 2050.[1165] Additionally, the capital costs of geothermal energy are high (despite the possibility of achieving over 90% savings on operations).[1166]

Moreover, traditional geothermal energy systems typically use convection methods, which requires either direct access to hot aquifers or fracking to increase the permeability of rock. While aquifers can be difficult to locate, fracking may induce seismic activity,[1167] limiting the possible locations for geothermal energy. The United States leads global production (followed by Indonesia, the Philippines, and Türkiye), and geothermal energy supplies over 30% of electricity in Iceland and 45% in Kenya.[1168]

By repurposing oil wells to produce geothermal energy, carbon emissions can be reduced by

34%

compared with conventional geothermal

THE OPPORTUNITY

BENEFITS

Scalable renewable energy; progress towards the Sustainable Development Goals; valuable by-products.

RISKS

High implementation costs; failure of materials in high heat conditions; unintended triggering of earthquakes.

Geothermal energy is not new, but innovative technologies, materials, and advanced machine intelligence make access to geothermal energy easier, less costly and not limited to any specific location.[1169,1170] Examples of approaches include using nuclear fusion for deeper and easier drilling to access thermal energy at depths of 20 km;[1171,1172] employing conduction, turning cold water into steam using hot rock instead of using aquifers or fracking;[1173,1174] repurposing decommissioned onshore oil rigs;[1175] and using magma's superheated steam to produce 10 times more energy than conventional geothermal wells.[1176]

Advanced materials, such as nickel–titanium alloys, can handle extreme heat[1177] and solid materials such as sand and ceramics address artificially created fractures in enhanced geothermal systems.[1178] Advanced machine intelligence can accelerate the development of next-generation geothermal energy by enhancing system design, including geothermal energy storage,[1179] optimising performance, and improving fault detection, particularly when coupled with real-time data.[1180] Geothermal energy can be integrated into energy grids and underground thermal storage systems and has hybrid applications with economically valuable by-products, such as boric acid[1181] and hydrogen.[1182]

Geothermal energy is not new and innovation may make access easier, less costly and not limited to any specific location

What if we could prevent bone loss and muscle atrophy in space?

44 Space Flex

Within Reach | **Transitional** | Visionary

Personalised bioengineered supplements prevent bone and muscle loss in space and on other planets, reducing limitations on humans' ability to spend extended periods beyond Earth while also offering a new solution for addressing bone and muscle mass decline on Earth.

UNCERTAINTIES

Systems, Technology

MEGATREND (Most significant)

Advanced Health and Nutrition

TRENDS

Future of Space
Mobilising Innovation

TECHNOLOGIES

Biotechnology
Genomics
Nanomedicine

SECTORS IMPACTED

Automotive, Aerospace & Aviation
Health & Healthcare
Materials & Biotechnology

KEYWORDS

Bone Density
Muscle Atrophy
Nanotechnology
Sarcopenia
Space Exploration

NASA is currently tracking over

6,000

asteroids

Astronauts on a six-month International Space Station mission lose up to

20%

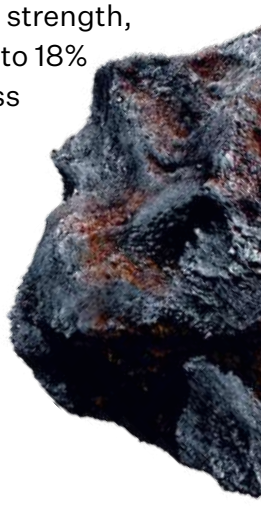
of their muscle mass

WHY IT MATTERS TODAY

Space exploration is entering a new era of ambition. Several national space agencies, including National Aeronautics and Space Administration's (NASA) Artemis programme, with private companies, are setting their sights on the Moon, Mars and beyond. In parallel, extraterrestrial resource mining holds opportunities.[1183] NASA is currently tracking over 6,000 asteroids.[1184] The top 10 most cost-effective asteroids alone could generate $1.5 trillion profit, and a single asteroid, 16 Psyche, may contain $700 quintillion worth of gold – enough to make every person on Earth a billionaire.[1185]

There are challenges to extended space exploration and residency. For example, microgravity significantly affects both muscle strength and bone density, severely impacting the prospect of long-duration missions to Mars and beyond.[1186] Astronauts on a six-month International Space Station mission lose up to 20% of their muscle mass.[1187] Interdisciplinary approaches are needed to address these and other challenges, such as team dynamics, conflict resolution, and ethical considerations in long-duration missions,[1188] along with environmental conditions and mental health.[1189]

Muscle atrophy also severely impacts ageing adults and hospitalised patients on Earth. Among the elderly, the condition manifests as sarcopenia, which affects up to o13% of adults over 60 and up to 50% over 80,[1190] increasing the risk of falls and reducing independence. For hospitalised patients, the deterioration is more rapid and severe, with muscle strength in the knee muscles declining up to 12% and thigh muscle strength, measured by the ability to climb stairs, declining by up to 18% in just 10 days of immobilisation.[1191] This accelerated loss not only extends hospital stays but also increases mortality rates and healthcare costs.[1192]



A single asteroid, 16 Psyche, may contain

$700 quintillion

worth of gold – enough to make every person on Earth a billionaire

THE OPPORTUNITY

BENEFITS

Longer space missions; better health in space settlements; muscle health longevity on Earth.

RISKS

Unknown long-term effects; cost of research and development.

A bioengineered supplement prevents bone and muscle loss (atrophy) in astronauts during long space missions, extended space travel, and planetary settlement. It also offers another possible solution for musculoskeletal decline on Earth. The supplement combines essential nutrients, anti-inflammatory agents, and metabolic boosters, all delivered through biodegradable nanoparticles designed for precise absorption and effectiveness. The formulation is personalised based on factors such as the individual's starting condition and atrophy risk.

Using nanotechnology and bio-based computing, the supplement targets the bones and muscles most affected by microgravity. The nanoparticles release their compounds gradually, ensuring long-lasting effects while minimising side effects,[1193] with release rates adapting to muscle changes over time. Use of the supplement reduces the reliance on intensive resistance training and exercise routines.

A bioengineered supplement prevents bone and muscle loss (atrophy) in astronauts during long space missions, extended space travel, and planetary settlement

What if frugal innovation from marginalised economies redefined global development?

45

Innovation Beyond Borders

Within Reach | Transitional | Visionary

Local innovation hubs connected to global networks scale innovations from economically marginalised communities worldwide, enabling local ingenuity to inspire worldwide sustainable development.

UNCERTAINTIES

Collaboration, Technology

MEGATREND (Most significant)

Borderless World
– Fluid Economies

TRENDS

Community-Based Solutions
Cross-Sectoral Partnerships
Mobilising Innovation

TECHNOLOGIES

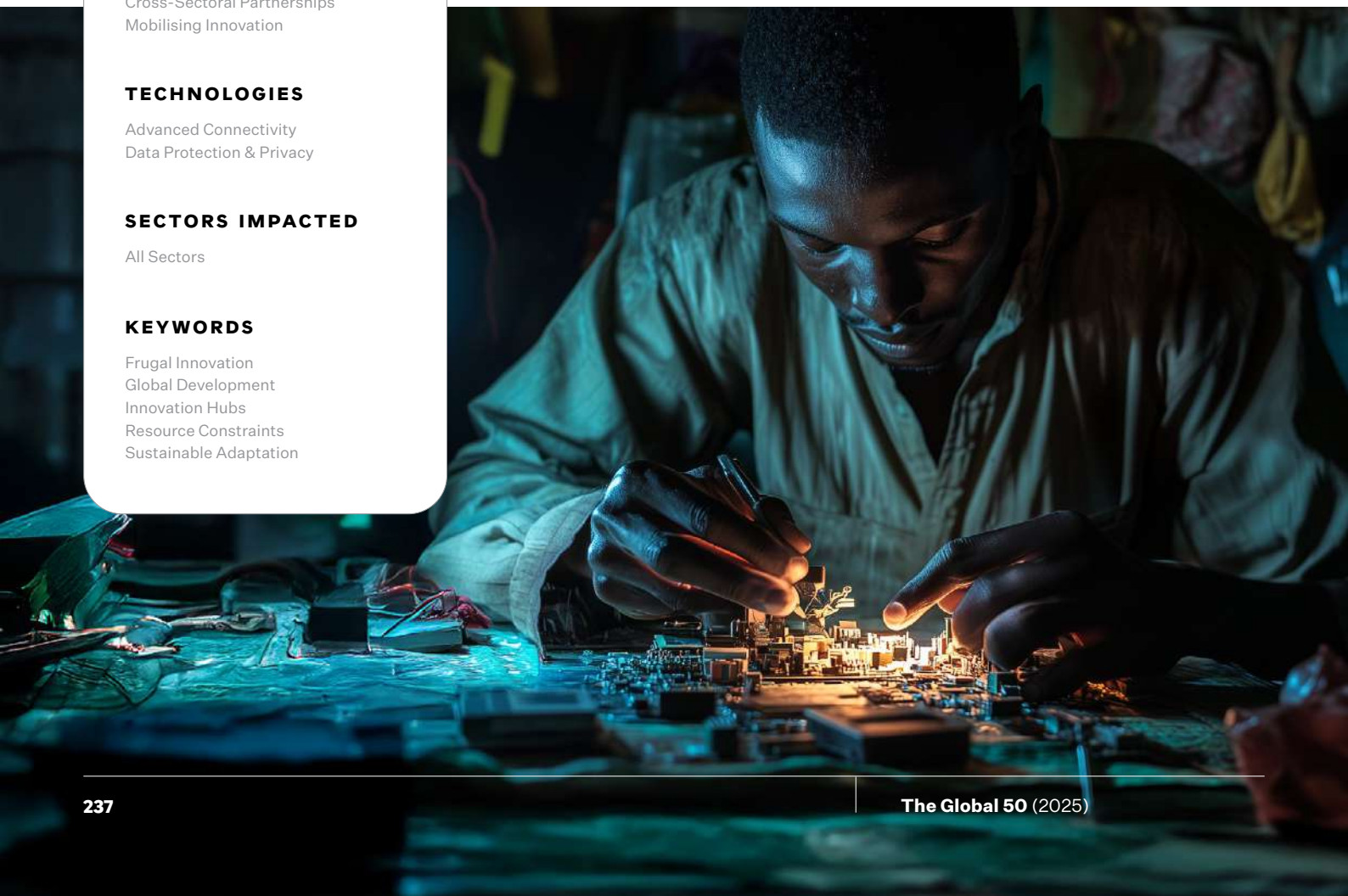
Advanced Connectivity
Data Protection & Privacy

SECTORS IMPACTED

All Sectors

KEYWORDS

Frugal Innovation
Global Development
Innovation Hubs
Resource Constraints
Sustainable Adaptation



WHY IT MATTERS TODAY

While traditional approaches to aid have contributed to global development, there are opportunities to enhance outcomes. Only 49% of World Bank development projects were rated as satisfactory or higher in achieving their development objectives.[1194] While calls to rethink economics, progress and innovations aim at addressing global challenges, they may overlook the resource constraints and infrastructural shortages of marginalised communities.[1195] The results may remain inaccessible to poorer nations and groups,[1196] risking them falling further behind.

Economically marginalised communities have a track record of generating sustainable and resource-efficient solutions. Faced with resource constraints, these communities often innovate within tight boundaries, showcasing their adaptability and inventiveness.[1197] For example, a clay fridge in India keeps food fresh for days using evaporative cooling, requiring no electricity.[1198] Low-income countries on the frontlines of climate impacts are generating locally led solutions that can empower communities to shape and drive responses.[1199]

Complex global challenges disproportionately affect poor communities, yet they are not part of the solution. Findings from the 160 countries covered by the Sendai Framework Monitor suggest that the lowest-income countries account for 26.6% of globally reported disaster mortality despite making up only 12.1% of the population.[1200] However, they are often excluded from key decision-making processes, with one study finding that only 22 of 374 climate adaptation projects featured a locally led approach.[1201] In addition, the recent (2023) growth in patent filings from Ethiopia (28.1%), India (17.2%) and Indonesia (5.9%)[1202] highlights untapped innovation potential.

Economically marginalised communities have **a track record of generating sustainable and resource-efficient solutions**

THE OPPORTUNITY

Local innovation hubs are connected to global networks through digital platforms, enabling people to share ideas, learn from one another, and collaboratively optimise solutions for scalability worldwide. These hubs identify frugal innovations from economically marginalised communities, bringing their solutions to the world and inspiring worldwide applications. Advanced communication technologies facilitate knowledge sharing, while unique collaborative patents are designed to generate income for marginalised communities.

Innovative partnerships with governments, international non-governmental organisations (NGOs), academia, and the private sector provide essential resources and networks. Locally governed hubs focus on local and regional challenges while contributing to global goals, ensuring that frugal innovation supports sustainable development and transforms how we address complex problems.

BENEFITS

Empowerment of marginalised communities; global collaboration; reduced inequality; increased diversity in problem-solving efforts; purpose-driven innovation; increased global resilience to challenges.

RISKS

Exploitation of local innovators; uneven community development; widening digital divides; intellectual property disputes.

Innovative partnerships with governments, international non-governmental organisations, academia, and the private sector **provide essential resources and networks**

What if the world agreed on a charter for brain–computer interfaces (BCIs)?

46

Neural Charter

Within Reach | Transitional | Visionary

A global brain–computer interface (BCI) charter and framework ensure global alignment through openness, safety standards, and responsible deployment, enabling ethical implementation and equitable access worldwide.

UNCERTAINTIES

Collaboration, Values

MEGATREND (Most significant)

Future Humanity

TRENDS

Cross-Sectoral Partnerships
Data Protection & Privacy
International Collaboration
Neuroscience
Open Data

TECHNOLOGIES

Advanced Connectivity
Brain–Computer Interfaces (BCI)
Human–Machine Interfaces

SECTORS IMPACTED

All Sectors

KEYWORDS

Cognitive Divide
Cybersecurity
Global Charters/MOUs
Neural Data Privacy
Regulations/Governance

WHY IT MATTERS TODAY

The global BCI market is projected to grow from

$1.74 billion

in 2022 to

$6.2 billion

by 2030, **with a compound annual growth rate of 17.5%**

There is increased interest in BCIs. The global BCI market is projected to grow from $1.74 billion in 2022 to $6.2 billion by 2030, with a compound annual growth rate of 17.5%.[1203] Applications of BCIs are growing[1204] and include gaming,[1205] integration with AI[1206] and the metaverse,[1207] and treatment of strokes,[1208] spinal cord injuries,[1209] brain injuries,[1210] and ALS (amyotrophic lateral sclerosis).[1211] The United States is leading advances in BCIs due to significant R&D funding, followed by Europe and emerging economies such as Brazil, India and South Africa.[1212]

With BCIs come critical challenges, including clarity in classification. While BCIs offer transformative benefits for healthcare and human enhancement, they present unique vulnerabilities in data security, with neural data requiring stringent privacy safeguards.[1213] At the same time, more organisations are facing shortages of critical cybersecurity professionals (42% of organisations in 2022 versus 53% in 2023).[1214] In terms of classification, while non-invasive (external) BCIs are currently more common, invasive (implanted) BCIs raise more concerns for society about their psychological and neurophysiological impacts.[1215] An alternative classification divides BCIs into those used for therapeutic purposes and those designed to augment humans' capabilities.[1216]

BCIs risk creating a new cognitive divide between the world's rich and poor. With just over a third of the global population – approximately 2.85 billion people[1217] – still lacking basic internet access, the introduction of sophisticated BCIs threatens to exacerbate existing digital divides. As these devices promise revolutionary medical treatments and cognitive enhancements, there is a real risk of creating an unprecedented gap between those who can access and pay for these technologies and those who cannot.[1218]

With just over a third of the global population – approximately

2.85 billion

people – still lacking basic internet access, the introduction of sophisticated BCIs threatens to exacerbate existing digital divides

THE OPPORTUNITY

Anticipating breakthroughs in BCI technology, a global charter and framework aligns implementation of BCIs across nations, focusing on three pillars: open research, safety standards, and responsible deployment.

The open research pillar includes a commitment to open access publications on BCI research and clinical trials, along with knowledge sharing and the registration of individuals equipped with BCIs. Algorithms, paired with robust privacy protocols for sensitive data, are shared solely with the signatories to ensure tamper-proof and fail-safe designs.

The safety standards pillar establishes rigorous hardware certification, software security, and ethical safeguards. It emphasises privacy protection, anti-discrimination measures, and cybersecurity to minimise risks such as brain tapping (uncovering confidential brain data), feedback manipulation, and adversarial attacks (manipulating the machine learning model in BCIs).[1219]

The responsible deployment pillar addresses diverse global contexts with guidelines for assessing risk, aligning local regulations, and monitoring societal impact. A global BCI governance body coordinates these efforts through regional committees, national regulatory bodies, and a technical advisory board comprising experts in neuroscience, ethics and cybersecurity.

BENEFITS

Clear regulatory guidelines for BCI; is supporting of equitable access; protection of individuals' rights; reduced risk of societal harm; minimised risk of exploitation; increased public awareness.

RISKS

Privacy breaches exposing neural data; global regulatory framework incompatibility; unintended harm of those who reject BCIs; uneven global adoption.

The framework focuses on three key pillars: openness, safety standards, and responsible deployment

What if the theoretical possibilities of dark energy inspired us to push our boundaries?

47 Dark Energy

GenAI

Within Reach | Transitional | **Visionary**

A deeper understanding of dark energy, the force pulling the universe's expansion, opens new doors to advance space travel, discover limitless energy for Earth, and inspire curiosity about science and humanity.

UNCERTAINTIES

Systems, Technology

MEGATREND (Most significant)

Borderless World – Fluid Economies

TRENDS

Future of Space
International Collaboration
Mobilising Innovation

TECHNOLOGIES

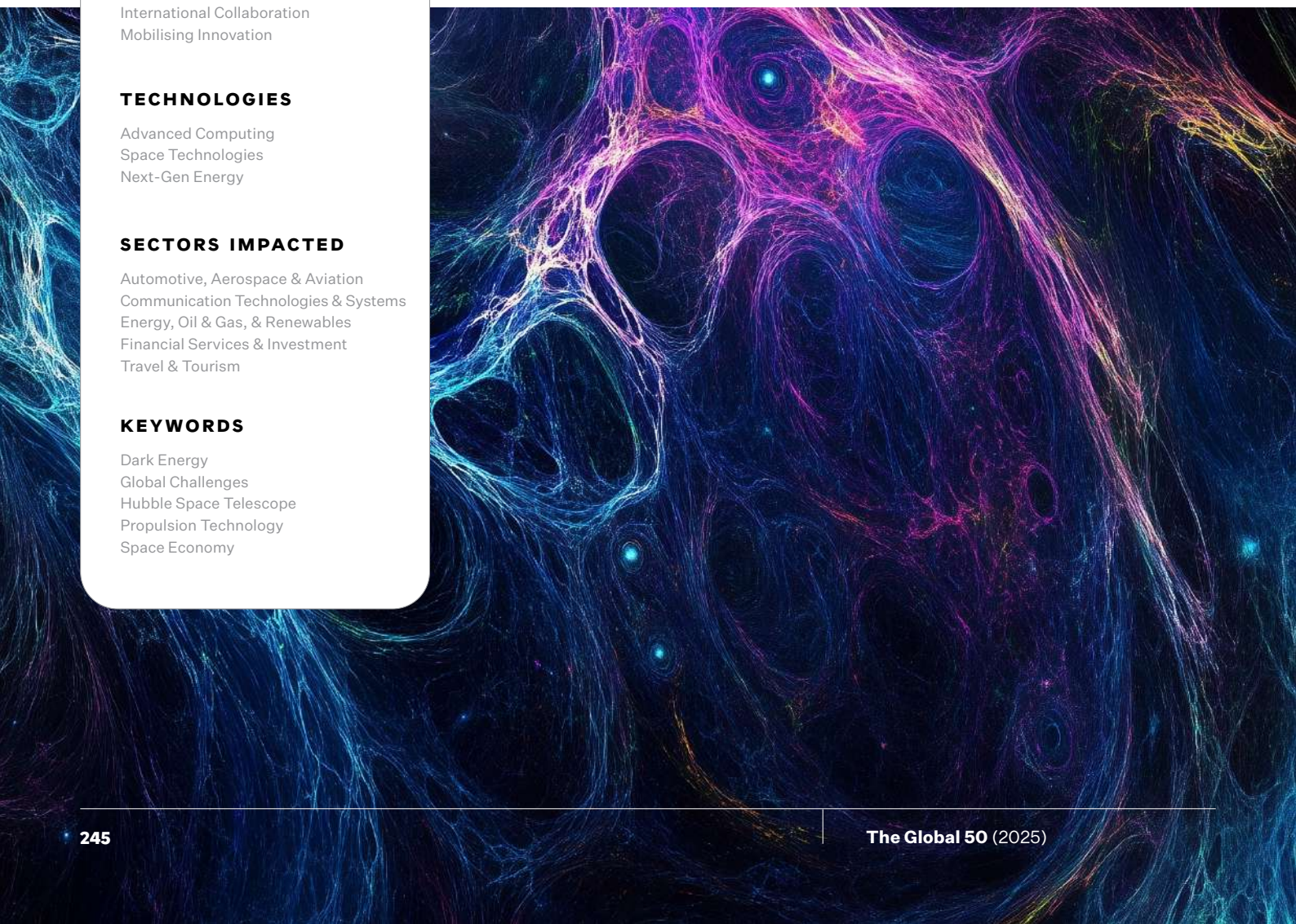
Advanced Computing
Space Technologies
Next-Gen Energy

SECTORS IMPACTED

Automotive, Aerospace & Aviation
Communication Technologies & Systems
Energy, Oil & Gas, & Renewables
Financial Services & Investment
Travel & Tourism

KEYWORDS

Dark Energy
Global Challenges
Hubble Space Telescope
Propulsion Technology
Space Economy



WHY IT MATTERS TODAY

By 2035, the space economy is expected to reach a value of

$1.8 trillion

up from $630 billion in 2023, growing annually by **9% and outpacing global GDP growth**

There is growing interest in the space economy. The National Aeronautics and Space Administration (NASA), along with other space agencies, are preparing for a return to the Moon with the Artemis programme, aiming for a long-term human presence there in the 2030s.[1220] By 2035, the space economy is expected to reach a value of $1.8 trillion, up from $630 billion in 2023, growing annually by 9% and outpacing global GDP growth.[1221] Through partnerships, innovation and robust business and science infrastructure, the UAE Space Agency aims to position the United Arab Emirates as a hub for space startups and a leader in the global space economy.[1222] Through the UAE's National Space Strategy 2030, over $6 billion has been invested in space-related industries, with ongoing funding through the $820 million National Space Fund.[1223]

Complex problems and increasing uncertainties, such as climate change, call for new solutions. Space has often inspired new approaches on Earth.[1224] As the world deals with the increasing impacts of climate change, there is a pressing need for clean, abundant energy sources. Despite record clean energy deployment,[1225] global energy-related carbon dioxide emissions grew by 1.1% in 2023, increasing by 410 million tonnes to reach a new record high of 37.4 billion tonnes.[1226] With experts estimating a 10–25% chance of climate change having catastrophic outcomes by 2100,[1227] space exploration offers a pathway to resilience, enabling humanity to adapt and thrive in an increasingly uncertain world.

Space has often inspired new approaches on **Earth.**

THE OPPORTUNITY

BENEFITS

Unlimited clean energy; shorter space travel times.

RISKS

Inability to move from theory to development.

While theoretical and with many unknowns, dark energy is currently thought to make up about 68% of the universe's total energy.[1228] While we cannot directly measure it, we assume it exists because of the accelerating expansion of the universe.[1229] Thanks to the launch of the Hubble Space Telescope,[1230] we are able to better estimate the age of our universe. The universe was estimated to be between 9.7 and 19.5 billion years old, based on the Hubble constant (an estimate of the universe's rate of expansion).[1231] However, with continued observations from the telescope, uncertainty in the Hubble constant has decreased from 10% in early 2000s to just 2% in 2019,[1232] refining the estimate of the universe's age to 13.8 billion years.[1233]

A potential application of dark energy could involve a spaceship tapping into the universe's expansion for propulsion. Although estimates of speed remain speculative, a recent simulation combined a neutral particle beam with a laser beam for a propulsion system to reach 7.5% of the speed of light with a 1 kg payload.[1234] Such a concept and technology alone could shrink the estimated duration of a journey to Mars (225 million km on average) from three years[1235] to just under three hours,[o] so imagine the possibilities with dark energy.

Still largely unknown,[1236] dark energy could inspire new technologies and open up new possibilities for humanity. Applications of dark energy on Earth could involve using the universe's expanding energy for limitless, emission-free power or inspiring new energy technologies.

Dark energy is currently thought to make up about **68% of the universe's total energy**

[o] Calculated based on a speed of light of just under 300,000,000 metres per second.

What if stem cell therapy was the answer to autoimmune disease?

48

Autoimmune Stem

Within Reach | **Transitional** | Visionary

Advanced machine intelligence enables precise stem cell therapy for autoimmune diseases, moving beyond variable results to establish treatments that achieve permanent disease remission.

UNCERTAINTIES

Systems, Technology

MEGATREND (Most significant)

Advanced Health and Nutrition

TRENDS

Communicable
& Non-Communicable Diseases
Longevity & Vitality
Precision/Personalised Medicine

TECHNOLOGIES

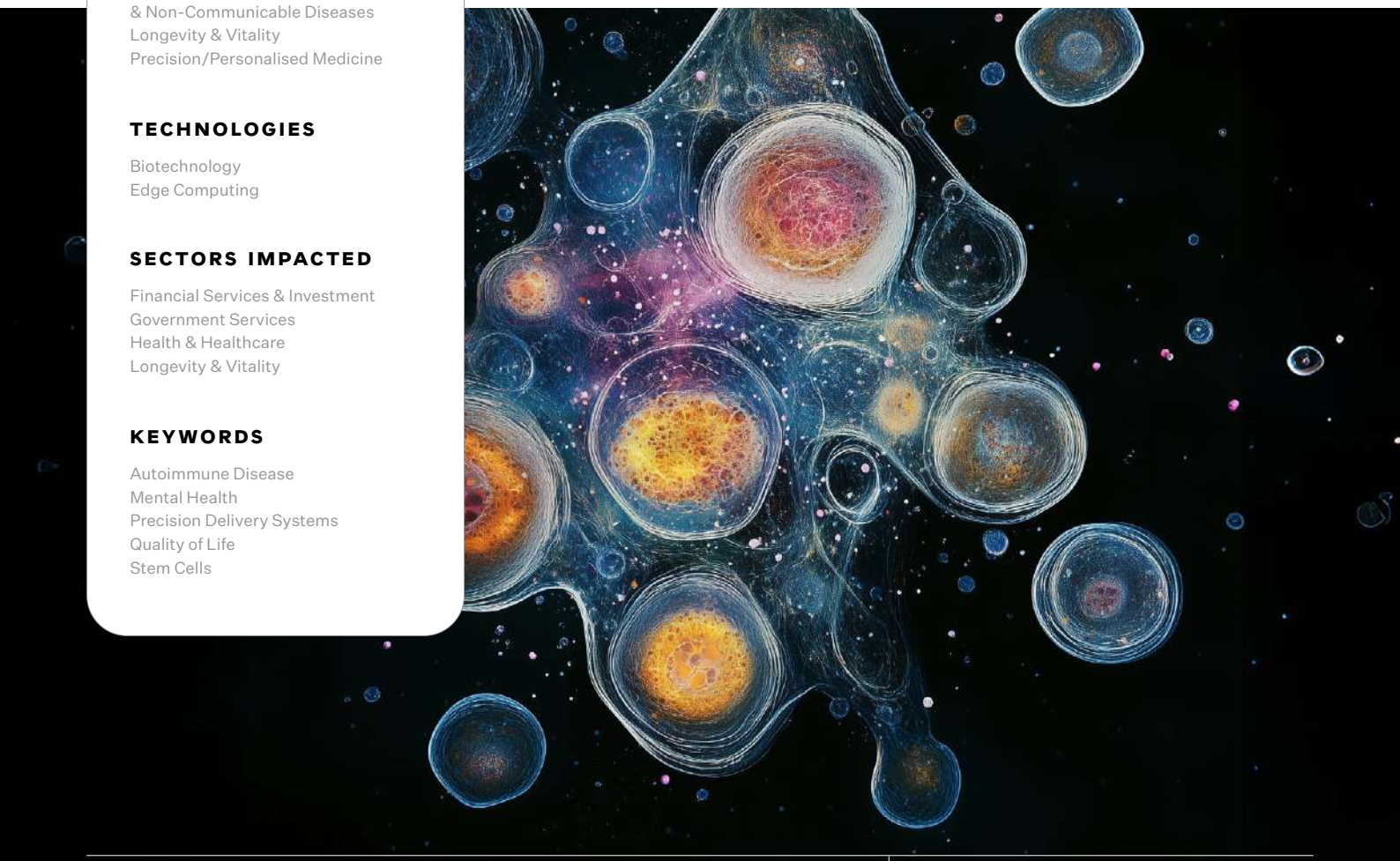
Biotechnology
Edge Computing

SECTORS IMPACTED

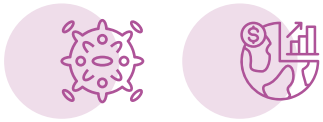
Financial Services & Investment
Government Services
Health & Healthcare
Longevity & Vitality

KEYWORDS

Autoimmune Disease
Mental Health
Precision Delivery Systems
Quality of Life
Stem Cells



WHY IT MATTERS TODAY



Currently, there is no cure for autoimmune disease, resulting in a significant socio-economic burden on society

Internationally, cases of autoimmune disease are **estimated to be rising by**

3–9%

annually, with environmental factors such as unhealthy diets potentially contributing

Autoimmune diseases affect approximately 1 in 10 individuals. A cohort study in the United Kingdom involving 22 million people found that nearly 1 million of them had been diagnosed with at least one autoimmune disease between 2000 and 2019.[1237] Internationally, cases of autoimmune disease are estimated to be rising by 3–9% annually, with environmental factors such as unhealthy diets potentially contributing.[1238]

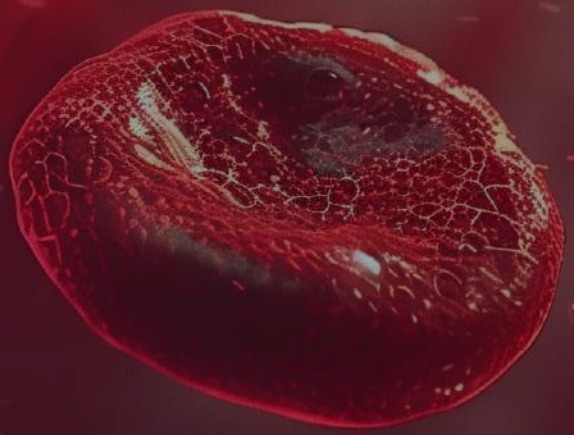
Autoimmune disease is often a lifelong condition. Diseases such as psoriatic arthritis, rheumatoid arthritis, multiple sclerosis, coeliac disease, type 1 diabetes, and inflammatory bowel disease affect millions globally, causing severe disability as the immune system attacks healthy tissue.[1239,1240] Traditional treatments often fall short, leading to chronic symptoms and progressive organ damage.[1241] Currently, there is no cure for autoimmune disease, resulting in a significant socio-economic burden on society.[1242,1243]

Autoimmune diseases impact people's quality of life. A nationwide survey of individuals affected by rheumatoid arthritis in the United States revealed that only 37% were working full time.[1244] Among those who were working, the majority experienced fatigue, pain and physical limitations.[1245] Respondents reported needing assistance with daily activities such as cleaning and household tasks, and 41% stated that a caregiver, typically a spouse, was actively involved in managing their arthritis.[1246] Additionally, over 50% of patients with autoimmune diseases, have been found to experience mental health conditions, such as depression or anxiety.[1247]

Autoimmune diseases affect approximately

1 in 10

individuals



THE OPPORTUNITY

BENEFITS

Enhanced treatment precision and efficiency; increased early detection of complications.

RISKS

Toxicity; AI-powered automation errors; over suppression of immune system by stem cells; development of treatment resistance; uneven access to stem cell therapy, widens health disparities across countries.

Advanced machine intelligence enables precise stem cell therapy to regenerate damaged tissue and, consistently, modulate overactive immune responses in autoimmune diseases.[1248] While clinical studies have demonstrated the effectiveness of stem cell therapy in treating conditions such as diabetic foot disease,[1249] skin ulcers,[1250] and spinal cord injuries,[1251] there are promising results in its potential in inducing autoimmune disease remission.[1252] Mesenchymal stem cells are particularly effective, causing immunomodulation,[1253] anti-inflammatory effects,[1254] and tissue regeneration.[1255]

With biosensors that enable real-time monitoring of patient responses, allowing rapid intervention when complications[1256] arise, advanced machine intelligence[1257] identifies and addresses key challenges, in stem cell therapy and autoimmune treatment[1258] including undesired cell differentiation and viral contamination risks.[1259]

Stem cells offer a groundbreaking solution through their **unique ability to regenerate tissue and, crucially, modulate overactive immune responses.**

What if products built themselves?

49 Self-Assembling Molecules

GenAI

Within Reach | Transitional | **Visionary**

Engineered through nanotechnology and computational design, self-assembling molecules represent the next generation of manufacturing, autonomously forming and transforming when triggered by chemicals or light.

UNCERTAINTIES

Systems, Technology

MEGATREND (Most significant)

Materials Revolution

TRENDS

Automation
Future of Raw Materials
New Materials

TECHNOLOGIES

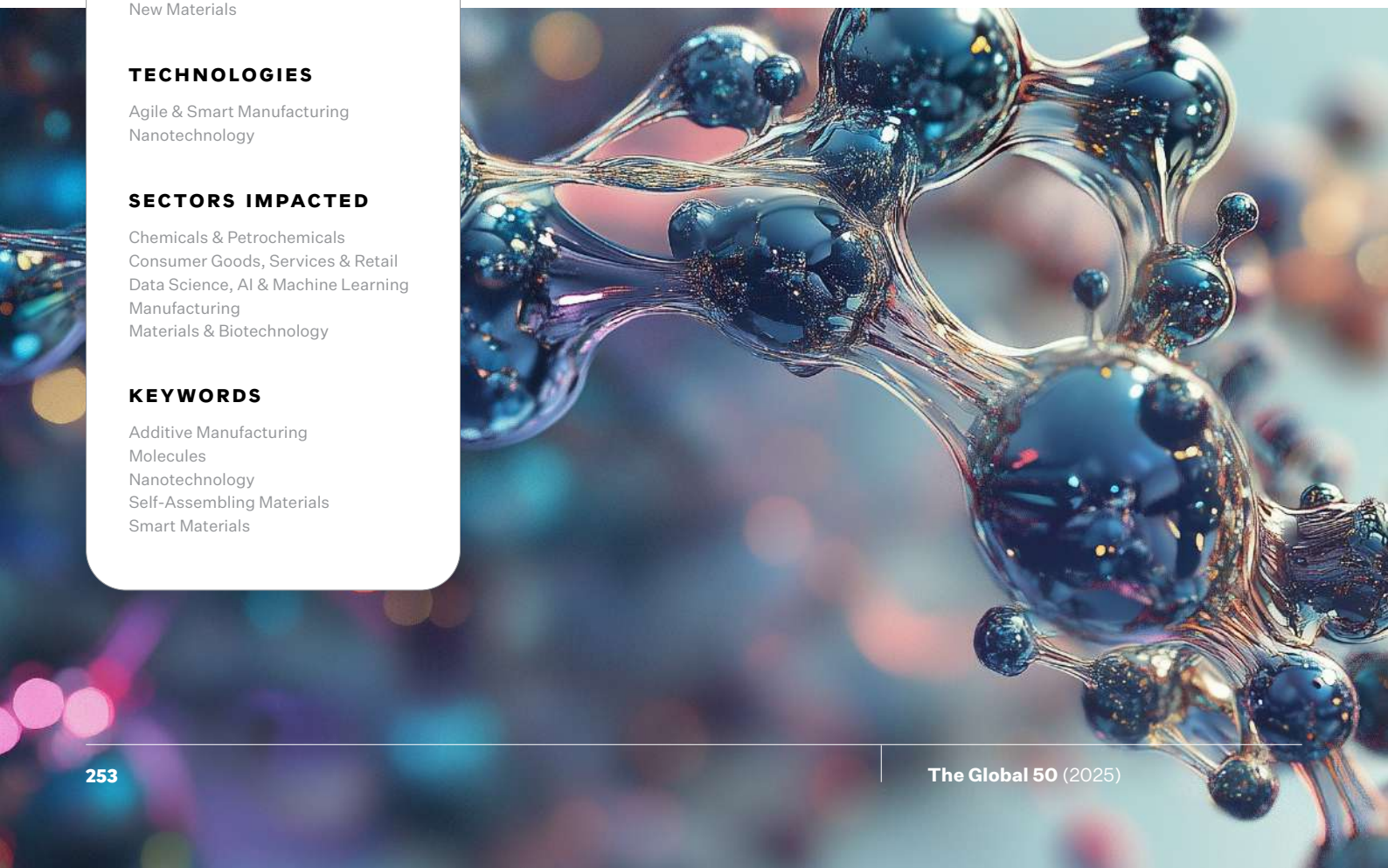
Agile & Smart Manufacturing
Nanotechnology

SECTORS IMPACTED

Chemicals & Petrochemicals
Consumer Goods, Services & Retail
Data Science, AI & Machine Learning
Manufacturing
Materials & Biotechnology

KEYWORDS

Additive Manufacturing
Molecules
Nanotechnology
Self-Assembling Materials
Smart Materials



WHY IT MATTERS TODAY

Globally, around

$163 billion

worth of inventory is discarded each year due to oversupply or damage, resulting in a substantial environmental impact, including increased air pollution and water contamination.

The global supply chain model is undergoing a major transformation. Over the past few decades, supply chains have become optimised for mass production and low costs, but they lack resilience.[1260] They are focused on efficiency but ignore environmental impacts and sustainability.[1261] However, companies are now shifting to more flexible, segmented supply networks that prioritise security, the sustainable energy transition, and agility.[1262] Globally, around $163 billion worth of inventory is discarded each year due to oversupply or damage, resulting in a substantial environmental impact, including increased air pollution and water contamination.[1263]

Over the past two decades, local material consumption has surged by 65%.[1264] Currently, overall, materials handling and use is responsible for 70% of global greenhouse gas (GHG) emissions,[1265] while only 7.2% of materials are recirculated.[1266] Research indicates that adopting circular economy strategies for four key industrial materials – cement, steel, plastics, and aluminium – could reduce global GHG emissions by up to 40% by 2050 through more efficient and sustainable material use.[1267]

Interest is growing in self-assembling materials, following early successes. Recently, researchers at Northwestern University in the United States developed soft, sustainable electroactive materials made from nanosized strips that mimic biological systems and are biodegradable. The material self-assembles when water is added, achieving stable ferroelectric properties previously unattainable with traditional plastics. Potential uses include smart fabrics and sticker-like implants.[1268] In another case, food proteins were hydrolysed to release self-assembling peptides, which serve as key components of hydrogels that can self-assemble for use as carriers for nutrients, solutions for wound-healing, and biosensors.[1269]

Adopting **circular economy strategies for four key industrial materials** – cement, steel, plastics and aluminium – could reduce global GHG emissions by up to

40%

by 2050

THE OPPORTUNITY

Through nanotechnology and computational design, molecules are engineered with capabilities that allow them to autonomously recognise and connect with one another in a manufacturing-like process. Energy – from chemicals or light – triggers the assembly process by providing the power needed to initiate and control self-assembly.[1270] Once a product has been assembled, modifications or disassembly can be triggered as needed by sending further instructions to the materials. Products can be dynamically reconfigured, repaired or completely transformed without traditional mechanical interventions.

Inspired by biological systems such as protein folding and cellular organisation, self-assembling molecules have the potential to create everything from advanced electronics to medical devices.

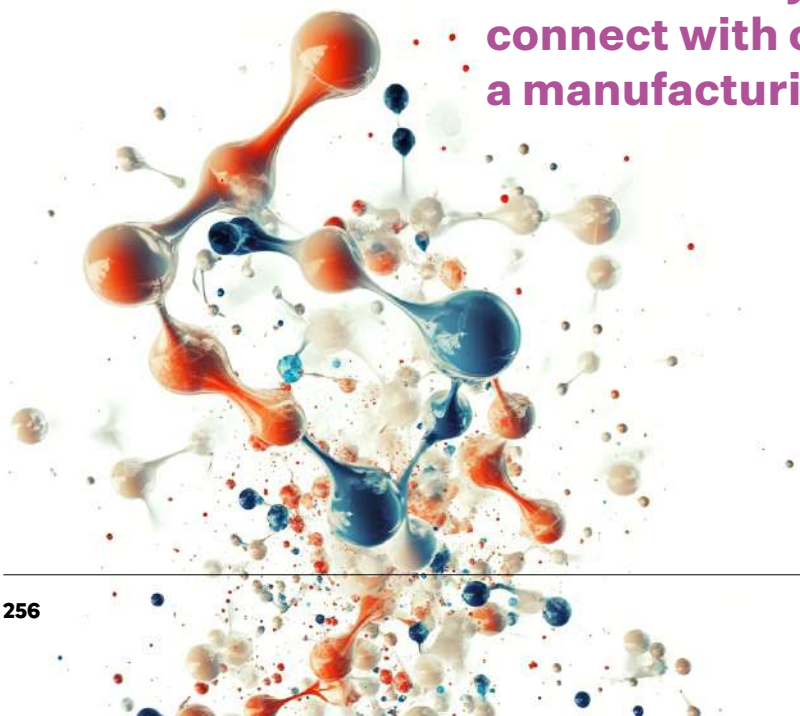
BENEFITS

Sustainable manufacturing; reduced waste and environmental impact; support for the circular economy; adaptive production.

RISKS

Job displacement; cybersecurity vulnerabilities in molecular assembly networks.

Self-assembling molecules are engineered with capabilities that allow them to **autonomously recognise and connect with one another in a manufacturing-like process**



What if higher education was no longer about the number of years but the quality of years? [p]

50

Higher Paths

UNCERTAINTIES

Collaboration, Values

MEGATREND (Most significant)

Future Humanity

TRENDS

Community-Based Solutions
Cross-Sectoral Partnerships
Future of Purpose & Work
Mobilising Innovation
Transforming Education

TECHNOLOGIES

Digital Communities
Digital Realities

SECTORS IMPACTED

All Sectors

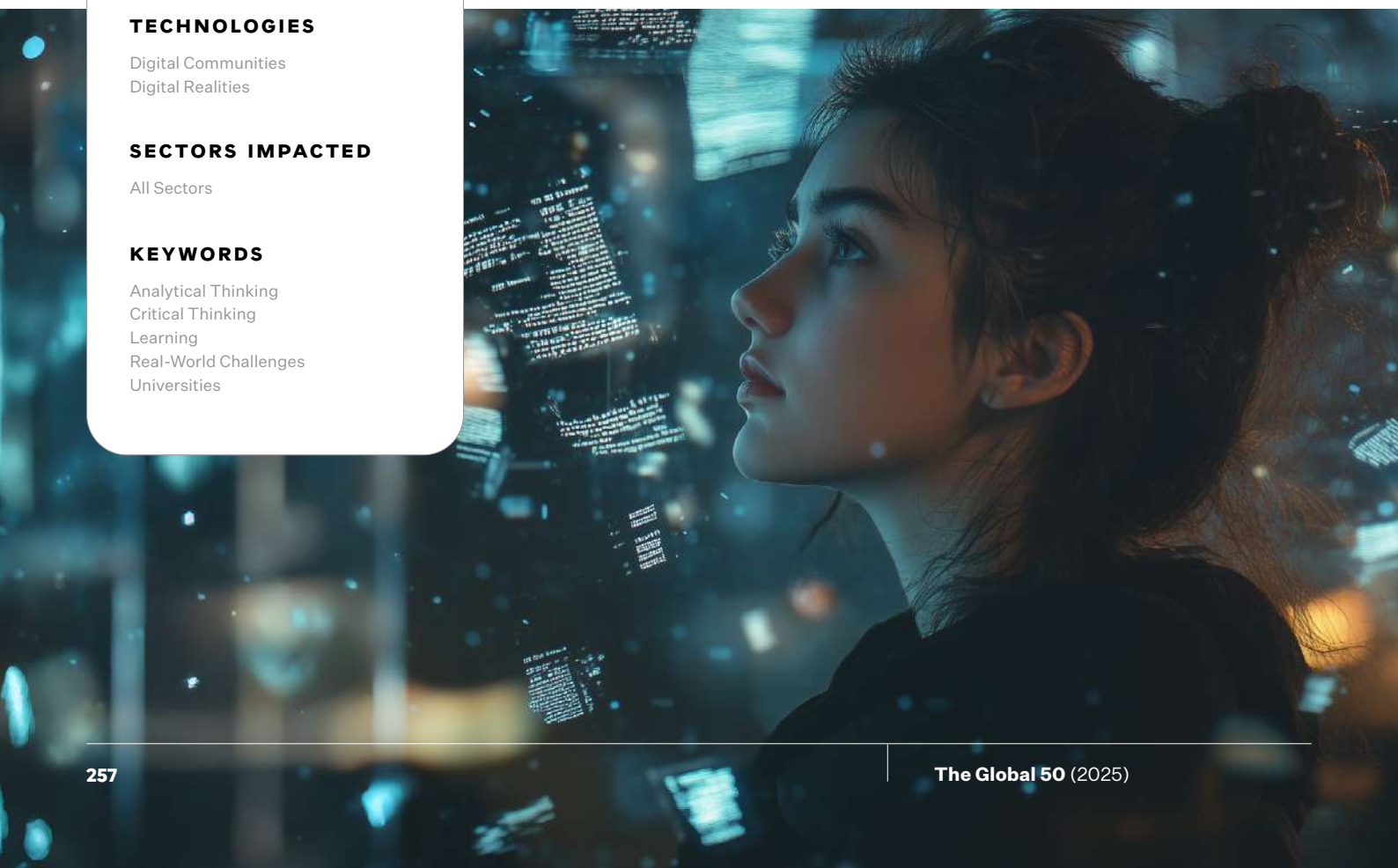
KEYWORDS

Analytical Thinking
Critical Thinking
Learning
Real-World Challenges
Universities

Within Reach | Transitional | **Visionary**

Higher education shifts to personalised and practical learning, prioritising critical thinking and real-world problem-solving. This shapes lifelong learners, with success measured through demonstrated competencies rather than fixed time periods.

[p] This opportunity, together with other education-related opportunities in the 2022, 2023 and 2024 editions of The Global 50, represents one of many models for transforming education to support future growth, prosperity and well-being.



WHY IT MATTERS TODAY

In 2024,

222 million

students were enrolled in university programs, more than **double the 100 million enrolled in 2000.**

From centres of learning to global institutions, universities evolved in the 11th century[1271] for knowledge, critical thinking, innovation, and societal progress. In 2024, 222 million students were enrolled in university programmes, more than double the 100 million enrolled in 2000.[1272] However, while enrolment has increased, especially in Latin America and Sub-Saharan Africa, maintaining quality remains a challenge.[1273]

Organisations are increasingly interested in hiring people with analytical thinking and creativity skills. According to the World Economic Forum, cognitive skills topped the list of those deemed to be of greatest importance for workers in 2023.[1274] Analytical thinking is considered to be a core skill by more companies than any other skill, making up, on average, 9.1% of the core skills reported by companies.[1275] Creative thinking comes second, as businesses believe demand for creative thinking will grow faster in the next five years – by 73% – than demand for analytical thinking.[1276] A five-year study of 93,743 students suggested that higher education institutions should embed authentic, hands-on learning and real-life projects into curricula.[1277]

The COVID-19 pandemic has shifted how students want to learn, with students showing diverse preferences for learning modes. Out of four learning mode preferences, 52% of students preferred traditional in-person learning and 51% least preferred online live learning.[1278] Before COVID-19, less than 1% of students used a computer to study for more than 10 hours per week.[1279] However, following COVID-19, most students use digital learning tools for between three and four hours per day.[1280]

Demand for creative thinking will grow

73%

faster than demand for analytical thinking over the next five years

THE OPPORTUNITY

Higher education shifts to personalised, flexible pathways streamlining their higher education journey. A universal foundation year[1281] in liberal arts and humanities builds critical thinking, self-awareness and understanding across all disciplines. As a robust base, learning pathways within traditional degrees are adaptable and no longer linear. Students combine different areas of expertise while engaging with real-world challenges, at any age. Success is measured through demonstrated competencies, and learning journeys adjust to individual needs rather than fixed time frames.

Universities evolve from traditional knowledge producers to active participants in an integrated ecosystem of industry, government and community partners.[1282] This integration bridges education and professional development, enabling students to address real-world challenges while learning.[1283] Educators take on expanded roles as both teachers and facilitators, developing new approaches to assessment. New funding models support a fluid and interconnected, yet sustainable, learning environment.

BENEFITS

Accelerated learning pathways; enhanced critical thinking skills; lifelong learning; increased global innovation; alignment of education with technological advances.

RISKS

Endless educational loops; misaligned standards across educational levels; lack of global alignment on credentials; high operational costs; conflicts with partnership goals.

Pathways are streamlined, adaptable and no longer linear, empowering students to shape their future while engaging in real-life opportunities and influencing industry and government policies for future generations

Methodology

Metareview Phase
Review Published Trends And Futures

Identify reputable global and regional organisations that publish trends- or future-oriented reports, seeking a balance across international governmental organisations, academia and government and private sources.

Extract publications between June 2023 and August 2024.

Review for completeness, credibility and authenticity.

Analyse the contents and extract key messages and data based on research template.

THIS YEAR
We conducted a detailed review of 57 reports (out of an initial total of 88) published by 43 organisations and, this year, including ones from the Middle East and North Africa (MENA) region (see Bibliography).

USE OF GENAI
This assessment was supported by the use of multiple GenAI models and platforms to extract information and supporting quotes from the reports examined, based on a template questionnaire with specific prompts. All outputs were fact-checked and extended by people.

Interview Phase
Conduct Expert Interviews

Identify experts for roundtable discussions, ensuring coverage across geographies, areas of expertise, and sectors as well as possible.

Ensure inclusion of experts who did not participate in the roundtables or interviews in other Global 50 editions and special editions.

Conduct virtual roundtables under the Chatham House Rule with a focus on growth, prosperity and well-being, seeking answers to open-ended questions such as ‘Irrespective of where the world is today, what might it look like 50 years from now?’, ‘What is your vision for the future?’, and ‘What do you hope will happen in the future?’

Carry out thematic coding of fully anonymised transcripts.

THIS YEAR
Six roundtables were conducted between 8 September and 10 October 2024, involving a total of 24 experts.

USE OF GENAI
The thematic coding of the fully anonymised transcripts was complemented by the use of multiple generative AI models and platforms to explore different ways to categorise, group, and build on the scenarios identified by the experts we engaged.

Ideation Phase

Validate the View of the Future and Generate Opportunities

Use the analysis from the metareview and interviews to validate the uncertainties, assumptions and megatrends that form our view of the future.

Use internal brainstorming and the analysis from the metareview and interviews to systematically capture a list of opportunities and questions about the future in a 'What if?' statement irrespective of present day trends, second order and third order impacts.

Apply an initial filter of a) negative implications on future growth, prosperity and well-being; b) understandability; c) benefit; and d) not included in previous Global 50 editions. Review opportunities with the selection committee for selection.

Apply research quality criteria to conduct research and analysis (some opportunities change as research is conducted) and assign scope and category (a posteriori).

THIS YEAR
An initial brainstorm generated a total of 492 opportunities.

USE OF GENAI
Multiple GenAI models and platforms were used as part of this exercise, providing prompts specific to The Global 50 research. Four of the opportunities in this edition were inspired by GenAI. While multiple generative AI models and platforms were used to assist in finding recent data on signals and trends, the team reverted back to manual searches to ensure high-quality sources and relevant data.

This research was undertaken by the Dubai Future Foundation's Dubai Future Institute. The Dubai Future Foundation produces insights and foresight reports using evidence-based analysis and imagination that enable stakeholders to anticipate and better navigate the future.

Our publications can be found at www.dubaifuture.ae/insights/

Acknowledgements

This report was led by Dr Heba Chehade, Dr Patrick Noack and Abdulaziz Al Jaziri. Design was led by Feras Sobh and the Arabic version was led by Ehab Khattab and Abdulla AlNuaimi. This report has also benefitted from valuable contributions made by colleagues throughout the Dubai Future Foundation: Alwud Alfalasi, Bilal Emad, Eman Alkadi, Fabio Araujo, Faisal Kazim, Farah AlHattab, Fatma Abulhoul, Isabella Pirolo, Jan Nutze, Lidia Kamleh, Mary Kaddah, Maryam Yousuf, Dr Mohamed Qasem, Nada AlTurifi, Rakesh Kumar, Sara Hussein, Shabin Parambath, Shaikha Al Tamimi, Shamma AlMurid, Tala Anshasi, Yahya Mohammed, and Yves Farhat.

We also wish to acknowledge the following external contributors and roundtable experts:

Agathe Acchiardo, Founder and Director, Think Next

Andreas Schmidt, Professor of Moral and Political Philosophy, University of Groningen

Balzhan Orazbayeva, Manager Strategic Initiatives, University Industry Innovation Network (UIIN)

Brian Head, Professor of Public Policy, University of Queensland

Cathryn Primrose-Mathisen, Editor

Craig Wills, Managing Director, Hi Mum! Said Dad

David McNair, Executive Director, The ONE Campaign

Graciela Selaimen, Founder and Executive Director, Instituto Toriba

Hazel Bird, Editor

Isabelle Hau, Executive Director, Stanford Accelerator for Learning, and Author of « Love to Learn »

Issam Yasin, Design Contractor

Jean-Dominique Coste, Head of Blue Sky, Airbus

Jonathan McCue, Managing Director, Sustainable Seas Ltd

Jugul Thachery, CEO, Hogr.app

Kelly Willis, Managing Director Malaria No More; Global Lead, Forecasting Healthy Futures

Kotchakorn Voraakhom, CEO, Porous City Network, Landprocess

Maria Ortiz Perez, Managing Director, Energy and Environment Program, Aspen Institute

Michael Silverman, Professor of Music, University of Minnesota

Morgan Lorio, Spine Surgeon (US, 2024-2025), President International Society for the Advancement of Spine Surgery, Orlando College of Osteopathic Medicine (OCOM)

Nick Walker, Co-founder and Managing Partner, OneBio

Nighat Akbar Shah, Founder & CEO, Adur Productions / Film

Richard James MacCowan, Founder, Biomimicry Innovation Lab

Roland Benedikter, Co-Head of the Center for Advanced Studies of Eurac Research Bolzano/Bozen, and UNESCO Chair in Interdisciplinary Anticipation and Global-Local Transformation

Szilvia Doczi, Senior Energy Economist, World Bank

Victor Anton, General Manager, Wildlife.ai

Wayne Holmes, Professor of Critical Studies of Artificial Intelligence and Education, University College London

Yoanna (Pepper) Okwesa, Founder and CEO, The Assembly

Desk-based research support was provided by the **Research Consulting Company,** UK

Design support was provided by **PrezLab,** UAE

Translation support was provided by **Tanwin Translation and Creative Writing,** UAE

Glossary

#

NEW **3D Printing**
Layer-by-layer printing of 3D structures.

NEW **4D Printing**
Layer-by-layer printing of 3D structures with designs, materials and properties that adjust over time.

A

Advanced Machine Intelligence
A product of algorithms, data, and processing power – including quantum computing – that enables computers to learn from data and to analyse and model vast datasets at speed in order to carry out advanced problem-solving and complex tasks.

NEW **Algal Bioreactors**
A unit that houses algal species that once exposed to sunlight or LED light absorbs carbon dioxide and other air pollutants to clean the air.

NEW **Algorithm**
Connected multiple lines of programming code that together provide instructions for autonomously carrying out tasks.

Antimicrobial Resistance (AMR)
When bacteria, viruses, fungi, or parasites no longer respond to antimicrobial medicines, making infections harder to treat and increasing the risk of disease spread, illness, and sepsis and possible death.

Augmented Reality
Augmented reality includes both wearable technology and the outputs of superimposing virtual reality or digital media, smells, sounds and other sensory perceptions onto the real world.

B

NEW **Beyond GDP**
Approach to progress that may or may not include gross domestic product (GDP) and that encompasses other measures related to people and planet.

NEW **Biodiversity**
The variety of species and living organisms on Earth.

NEW **Bioengineering**
Applying engineering principles to biological components.

NEW **Bioinformatics**
The field of analysing big biological data from health systems information, genomes and proteomes to uncover insights for further innovation and applications in medicine and therapeutics.

Biomarkers
A biomarker, irrespective of its type, measures what is happening in a cell or an organism at a given moment. Biomarkers can serve as early-warning systems for your health.

NEW **Biomass**
Any organic matter, including but not limited to plants, shrubs, trees, corn, by-products, waste streams or animal fats.

Biomaterials
Matter, surfaces, or constructs that interact with biological systems. They can be natural or synthetic, incorporating metal, polymer or ceramic components. Biomaterials are designed to have specific characteristics for use in, for example, medicine and healthcare, textiles, building materials or packaging.

Biomimicry
The imitation of natural biological forms, properties, or processes in engineering and design approaches to develop better products and processes.

NEW **Biosensors**
Sensors that are covered with, or entirely made of, biological substances that can detect changes in states, whether in air, water or land.

NEW **Blockchain**
A distributed ledger in which data are stored in connected nodes that are decentralised and mechanisms are managed by smart contracts and cryptography.

Brain–Computer Interfaces
Brain–computer or brain–machine interfaces are communication pathways that use wires connected to the brain or an external device to 'read' the brain's neural signals (electron activity) or send signals to the brain using electric currents.

C

NEW **Carbon Capture and Storage**
The process of capturing and storing atmospheric carbon dioxide (CO2). CO2 can be stored through geological capture by converting the CO2 gas into liquid under pressure and pumping it into porous rock or former oil-extraction sites. Alternatively, biological carbon capture is the natural absorption of CO2 by vegetation, soil and the oceans.

Circular Economy
In a circular economy, goods and services are used as long as possible and all forms of waste are either avoided or returned back into the value chain.

NEW **Cognitive Health**
A human's ability to use their brain to memorise, acquire knowledge and skills, imagines and analyse multiple types of content in a manner that is inline with a comparable population's speed and accuracy.

NEW **Cognitive Reserves**
A theoretical concept of cognitive health capacity accumulated through creativity, out-of-the-box activities, and so on, that maintain cognitive health.

Compound Annual Growth Rate (CAGR)
The average annual growth rate over a specific period of time greater than one year.

NEW **Cyberbiosecurity**
Frameworks, methods and controls to protect biological information and genomic samples from threats and, when threats occur, to respond effectively to minimise losses.

NEW **Cybersecurity**
Frameworks, methods and controls to protect technological systems and data from threats and, when threats occur, to respond effectively to minimise losses.

D

Decentralised Autonomous Organisations (DAO)
An organisation that is governed by code and not a CEO or board of directors. Governance tokens are held by various stakeholders who have an interest in a particular project or the organisation and who subsequently vote on decisions.

NEW **Deep Learning**
A machine learning technique that uses many layers of neural networks (see Neural Network) to learn patterns and extract insights.

NEW **Desalination**
The process of removing salt from saltwater through filtration, chemicals or any other method where the output is brine.

NEW **Digital Dementia**
First coined by Dr Manfred Spitzer, partial or full cognitive decline due to the overuse of screens and technology particularly in terms of memory.

Digital Literacy
The ability to use technology to read and write in order to acquire knowledge and engage in work and life, to critically assess and interpret digital content and to protect personal information through implementing cybersecurity practices.

NEW **Digital Twin**
A virtual blueprint of a physical system or body, which uses data to simulate and optimise related functions.

NEW **Disinformation**
Intentional spreading of misleading or false information online.

Distributed Ledger
A database of information that is simultaneously duplicated across a network of computers in different locations. In contrast to a centralised ledger, a distributed ledger is a decentralised database that processes, validates and records transactions that have been agreed upon by all parties involved. Validated transactions are timestamped with a unique encrypted signature. All participants in the distributed ledger can view all records.

E

NEW **Edge Computing**
The ability to capture, analyse and store data and transmit insights as close to source as possible, enabling real-time analytics and decision-making and minimising the need for cloud storage and other centralised storage solutions.

NEW **Electroencephalography (EEG)**
The ability to measure and analyse brain signals using non-invasive devices.

NEW **Epigenetics**
The branch of genomics research related to how internal and external factors influence – if at all – changes in gene expression without changing the DNA sequence.

NEW **ESG**
The concept of combining environmental, social and governance (ESG) aspects as part of organisational reporting and performance to illustrate corporate social responsibility.

Extended Reality
A general term that refers to augmented, mixed and virtual reality.

F

NEW **Fintech (financial technology)**
Technologies that automate, streamline and improve financial transactions and operations.

NEW **Foresight**
The process of exploring and analysing futures and translating them into decisions and action.

NEW **Fungal Fuel Cells (FFCs)**
Fuel cells that use fungi to produce electric current.

NEW **Fungi**
A family of organic organisms such as mushrooms, yeast and mould that do not have chlorophyll and can even grow in dead soil or medium.

G

NEW **Game Theory**
A social science theory that covers how individual decisions are influenced by others' decisions and how they affect final outcomes.

Gene Editing
Gene editing involves making highly precise changes to a DNA sequence using enzymes that have been engineered to target a specific sequence for removal and replacement.

Generative Artificial Intelligence
A machine learning model that can learn from a large amount of content to create other content including, but not limited to, code, images, data, music and videos.

NEW **Genomics**
The field of science concerned with the study of genomes in humans, animals and plants to advance knowledge and applications in medicine and agriculture.

Geothermal Energy
A type of renewable energy generated from heat stored in rocks and fluid at different depths beneath the Earth's crust.

H

Haptic Technology
Haptic technology enables the user to interface with a virtual environment via the sense of touch by applying forces, vibrations or motions to the user.

I

Immersive Technologies
Immersive technologies bridge reality and digital worlds by creating experiences in a simulated environment.

NEW **Industry 4.0**
The current industrial revolution involving artificial intelligence, automation and smart systems.

Internet of Things (IoT)
A concept referring to the many devices and sensors that are connected to the internet. In this way, captured data can be collected, shared and analysed for various purposes, such as health monitoring, improvement and delivery; managing smart cities; monitoring and improving manufacturing; and administering transportation.

NEW **Internet of Underwater Things (IoUT)**
A network of devices and sensors – similar to the IoT – that are designed for use underwater at various depths and pressures. This could one day evolve into the internet of submerged things (IoST) if other liquids are considered.

Interoperability
The capacity of different systems, devices, applications, and products to process and exchange data without delay, disruption, errors or inconvenience to the end user.

L

NEW **Lab-on-a-chip**
A fully functioning microchip (1mm) that uses microfluidics to analyse small blood or other biological samples to identify the presence of pathogens or disease.

Large Language Model (LLM)
A deep learning algorithm that can recognise, translate, and generate text from other text.

M

NEW **Mass Spectrometry**
A laboratory analytical system that analyses physical samples using electric charge and mass to uncover material properties and amounts.

NEW **Megatrends**
Thematic group of interrelated trends, drivers and signals that shape future economies, societies and everyday work and life.

Metacognition
The state of being aware of one's own thoughts and decision-making process.

NEW **Metamaterials**
Materials that are structurally modified, as opposed to chemically changed, for new applications.

NEW **Microbiome**
The group of fungi, bacteria, viruses and other microbes found in humans and other organisms.

NEW **Microhabitat**
A small, fully functioning ecosystem that supports biodiversity fit for purpose in a given space.

Microplastics
Minuscule plastic particles (under 5 mm in size) that emerge from various sources and processes, including friction of wheels on roads, textile wearing and washing, plastic goods, and industrial waste. Microplastics end up on the Earth's surface, in the atmosphere, or in the oceans and seas and are a health concern to both humans and animals when ingested.

NEW **Misinformation**
Unintentional spreading – due to errors or reasons out of one's control – of misleading or false information online.

NEW **Mycelium**
The root-like structure of fungi that can conduct electric charge.

N

NEW **Nanobiomaterials**
Nanoscale biomaterials.

NEW **Nanobiotechnology**
Technology that manipulates biological systems and living cells to develop nanoscale products and services.

NEW **Nanomedicine**
Field of medicine that is focused on materials, processes and innovations to diagnose, treat and prevent disease at the nanoscale level.

Nanobots
Autonomous robots that are of atomic size.

NEW **Neural Network**
A machine learning model that mimics the way the brain processes information instead of straightforward analytical processes.

NEW **Nuclear Fusion**
The opposite of nuclear fission.. Hydrogen atoms combine to produce massive amounts of heat that can be converted into energy. Fusion does not use uranium (radioactive) but uses deuterium from seawater instead.

O

Ocean Acidification
A process in which the ocean when it absorbs atmospheric carbon dioxide to a level that results in higher acidity (lower pH).

NEW **Open Data**
The availability of private data related to people and planet or the process of making the data open for public use or sharing with or without compensation.

P

Particulate Matter (PM)
Particulate matter consists of small particles found in the air. It may give rise to health concerns and may come from natural or synthetic sources. It includes dust, dirt, soot and smoke, and it may also be in liquid form. PM is sometimes reported as either PM2.5 or PM10, referring to the size of the particulate in micrometres.

NEW **Personalised Medicine**
An approach in medicine that offers personalised treatment for diseases. While personalised medicine may overlap with precision medicine, the two are not necessarily the same.

NEW **Photovoltaics (PV)**
Solar cells that use various semiconducting materials to convert light from the Sun into electric current.

NEW **Precision Medicine**
An approach in medicine that identifies, targets and treats diseases using genetic information. Precision medicine is a subset of personalised medicine.

NEW **Proteomics**
The study of proteomes – the set of proteins in an organism including humans – which are key to the functioning of cells.

Q

Quantum Computing
Quantum computing is based on the principles of quantum physics and exploits the ability of subatomic particles to exist in two states simultaneously (e.g. 1 and 0). This exponentially increases how much data can be encoded (as quantum bits, i.e. qubits) and thus enhances potential computational power.

NEW **Quantum Sensors**
Devices that use quantum mechanics for higher precision measurement.

NEW **Quantum Theory**
The physics theory that includes concepts such as entanglement and superposition to describe particles at the atomic level that can exist in multiple states at the same time as opposed to classical physics, in which objects have one state at a time.

NEW **Qubits or Quantum Bits**
The quantum computer's equivalent of a binary bit (0 or 1) used in computers today. Qubits can have more than one state at the same time at an atomic or subatomic level.

R

NEW **Regeneration**
The ability to renew and refill lost aspects in a particular ecosystem.

S

Signals
(Foresight) events, hypes, new technologies, products and services, or local and regional data and disruptions that have the potential to grow to become drivers or trends.

Smart Contracts
Smart contracts are written in code and stored on a blockchain to safeguard against theft and to protect the ownership of underlying real or digital assets.

Space Economy
The part of the economy that includes all activities related to progress in the areas of space exploration and interplanetary living.

NEW **Sports Analytics**
A field of statistical analysis that uses data captured through technologies, wearables, sensors, cameras and other devices to provide meaningful insights about sports including player performance, fan engagement, venue operations and refereeing.

NEW **Stablecoin**
A cryptocurrency that is backed by assets.

NEW **Stem Cells**
The red blood cells that are found in bone marrow or the placenta that are considered the root of all blood cells and that have clean DNA.

NEW **Sustainability**
The pursuit of a balanced and long-term state of equilibrium in financial, environmental, societal and operational systems with the aim to meet present and future needs.

T

NEW **Technology Readiness Level (TRL)**
A scale from 1 to 9, introduced by the National Aeronautics and Space Administration (NASA), that indicates how near a technology is to being ready for widespread adoption and scalability.

V

Virtual Reality
A computer-generated environment in which users can immerse themselves using wearable headsets or other accessories. In this way, they can interact with others and simulate real-life experiences and reactions within the fictitious environment.

About The Dubai Future Foundation

Dubai Future Foundation aims to realise the vision of His Highness Sheikh Mohammed bin Rashid Al Maktoum, Vice President and Prime Minister of the UAE and Ruler of Dubai, for the future of Dubai and consolidate its global status as a leading city of the future. In partnership with its partners from government entities, international companies, startups and entrepreneurs in the UAE and around the world, Dubai Future Foundation drives joint efforts to collectively imagine, design and execute the future of Dubai.

Under the supervision and with the support of His Highness Sheikh Hamdan bin Mohammed bin Rashid Al Maktoum, Crown Prince of Dubai, Chairman of the Executive Council of Dubai and Chairman of the Board of Trustees of Dubai Future Foundation, DFF works on a three-pronged strategy: to imagine, design and execute the future. It does this through the development and launch of national and global programmes and initiatives, preparing plans and strategies for the future, issuing foresight reports and supporting innovative and qualitative projects. These contribute to positioning Dubai as a global capital for the development and adoption of the latest innovative solutions and practices to serve humanity.

Dubai Future Foundation focuses on identifying the most prominent challenges facing cities, communities and sectors in the future and transforming them into promising growth opportunities by collecting and analysing data, studying global trends and keeping pace with and preparing for rapid changes. It is also looking at future sectors, their integration and the reshaping of current industries.

Dubai Future Foundation oversees many pioneering projects and initiatives, such as the Museum of the Future, Area 2071, The Centre for the Fourth Industrial Revolution UAE, Dubai Future Accelerators, One Million Arab Coders, Dubai Future District, Dubai Future Solutions, Dubai Future Forum, Dubai Metaverse Assembly. Its many knowledge initiatives

and future design centres contribute to building specialised local talents for future requirements and empowering them with the necessary skills to contribute to the sustainable development of Dubai.

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Any Arabic translation of The Global 50 is solely for convenience. While efforts have been made to ensure accuracy, the English version shall prevail in case of any discrepancies or inconsistencies between the two translations.

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2025